GOVERNMENT OF WESTERN AUSTRALIA

Department of **Biodiversity, Conservation and Attractions**

Section 1 – Eligibility for Listing

1. Name of the ecological community

Stromatolite-like freshwater microbialite community of coastal brackish lakes (Lake Clifton)

2. Listing Category for which the ecological community is nominated

	Current ranking under WA Minister ESA list in policy	EPBC Act (wholly or as a component)
Current listing category (Please check box)	☒ Critically endangered ☐ Endangered ☐ Vulnerable ☐ Priority 1-4 ☐ Data Deficient ☐ None – not listed	Name: Thrombolite (microbialite) Community of a Coastal Brackish Lake (Lake Clifton) ☒ Critically endangered ☐ Endangered ☐ Vulnerable ☐ None – not listed
	Recommended ranking under BC Act IUCN assessment	
Proposed listing category (Please check box)	☐ Collapsed ☒ CR: Critically endangered ☐ EN: Endangered ☐ VU: Vulnerable ☐ Priority 1-4	
Select one or more of the following criteria under which the community is to be nominated for BC Act listing. (Please check box). For further details on these criteria please refer to the Attachment to this form. The information you provide in Section 3 should support the criteria you select here.	☐ Criterion A – Reduction in geographic distribution ☒ Criterion B – Restricted geographic distribution ☐ Criterion C – Environmental degradation based on change in an abiotic variable ☐ Criterion D – Disruption of biotic processes or interactions based on change in a biotic variable ☐ Criterion E – Quantitative analysis that estimates the probability of ecosystem collapse	

Section 2 – Description, Condition, Threats & Recovery

Please answer all the questions, providing references where applicable. If no or insufficient information exists to answer a question, you must indicate this instead of leaving the question blank. The answers may be provided within this form or as attachments, ensuring that responses clearly indicate which question number they refer to.

Classification

3. What is the name of the ecological community?

Note any other names that have been used recently, including where different names apply within different jurisdictions. For example, is it known by separate names in different States or regions?

Stromatolite like freshwater microbialite community of coastal brackish lakes (Lake Clifton). Commonly referred to as Lake Clifton thrombolites or Lake Clifton microbialites.

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4. What authorities/surveys/studies support or use the name?

The community was originally described by Moore (1993). The community has been recognised since the publication of Moore's thesis, and was recommended for listing as endangered as the thrombolite community of Lake Clifton in 1996. Due to the increase in nutrient concentrations it was then reassessed and endorsed as a critically endangered TEC (under criteria CR Bi, ii) by the WA Minister for Environment in 2001. The ranking criteria developed in WA do not match those used in the International Union for the Conservation of Nature's Red List of Ecosystems Criteria (IUCN RLE) that is the internationally recognised standard. The community was then listed as CR under the name 'Thrombolite (microbialite) Community of a Coastal Brackish Lake (Lake Clifton)' under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) in 2010. The criteria used under that Act also differ from the ranking criteria used for the IUCN RLE.

5. How does the nominated ecological community relate to other ecological communities that occur nearby or that may be similar to it?

Does it intergrade with any other ecological communities and, if so, what are they and how wide are the intergradation zones?
Describe how you might distinguish the ecological community in areas where there is overlap (also see Description section below).

Other microbial structures occur in Western Australia at Hamelin Pool, Shark Bay. Living microbialites in the south west of the State that are not as well-known also occur at Pink Lake (Esperance), sea cliffs (Augusta), Lake Clifton, Pamelup Pond - Lake Preston (Yalgorup), Government House Lake and other lakes on Rottnest Island, Lake Thetis (Cervantes) and at Lake Richmond in Rockingham (Moore 1993). Each of these constitutes a distinct and significant community in terms of composition, history, structure, and morphology (Moore 1993). Lake Clifton supports the largest known examples of living non-marine microbialites in the southern hemisphere (Department of Conservation and Land Management 1995).

Upslope of the wetland vegetation that surrounds the lake edge is the Tuart (*Eucalyptus gomphocephala*) Woodlands and Forests of the Swan Coastal Plain, a critically endangered ecological community listed under the EPBC Act, and listed as a priority 3 ecological community (PEC) in Western Australia. Threats to that TEC include land clearing, weed invasion grazing, disease, altered fire regimes and hydrological change. The tuart woodlands and surrounding wetland vegetation acts as a buffer to the Lake Clifton system.

Description

6. List the main features that distinguish this ecological community from all other ecological communities.

Characteristic (or diagnostic) features can be biological (e.g. taxa or taxonomic groups of plants and animals characteristic to the community; a type of vegetation or other biotic structure) or associated non-biological landscape characteristics (e.g. soil type or substrate, habitat feature, hydrological feature). Please limit your answer to those features that are specific to the ecological community and can be used to distinguish it from other ecological communities.

The community occurs on a relict foredune plain on Holocene sands at Lake Clifton. It is a thrombolitic community comprising a distinctive complex assemblage of photosynthetic cyanobacteria and purple sulphur bacteria, eukaryotic microalgae and "true bacteria". The thrombolitic structures generally have an internal clotted structure as opposed to those that have a laminated organisation, that are stromatolitic. The Lake Clifton structures are formed through precipitation of calcium carbonate within the microenvironment of microbes as a result of photosynthetic and metabolic activity. The most abundant cyanobacterium in the early 1990s was *Scytonema*, as well as others including *Oscillatoria*, *Dichothrix*, *Chroococcus*, *Gloeocapsa*, *Johannesbaptista*, *Gomphosphaeria* and *Spirulina* (Moore 1993). More recent work by Warden *et al*. (2016) suggest there has been a dramatic shift in the cyanobacterial population toward coccoid, non-heterocystous forming taxa primarily from the order Chroococcales. The dominance of coccoid cyanobacteria is observed in microbialites of other hypersaline environments.

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7. Give a description of the biological components of the ecological community.

For instance, what species of plants and animals commonly occur in the community; what is the typical vegetation structure (if relevant).

The thrombolites of Lake Clifton are likely formed by precipitation of a particular form of calcium carbonate, termed aragonite, within the microenvironment of the community as a result of growth and metabolic activity (Moore 1993). They are formed by a distinctive complex assemblage of photosynthetic cyanobacteria and purple sulphur bacteria, eukaryotic microalgae and “true bacteria”. This assemblage of microbes forms the Benthic Microbial Community (BMC). Cyanobacteria (‘blue-green algae’) generally dominate microbial communities involved in the formation of thrombolites (Moore 1991). The thrombolites exhibit a range of external morphologies and vary in size up to 1.3m high. Their external morphology is controlled primarily by fluctuations in water depth, sedimentation rates and prevailing winds and currents (Moore 1991). The minimum net growth rate of the stromatolites at Lake Clifton is around 0.1mm per year (Moore 1993; Moore and Burne 1994). Changes to physical parameters, such as an increase or decrease in salinity, may cause a shift in the microbes that dominate the thrombolites possibly replacing these with a different microbial assemblage that does not facilitate carbonate deposition and thrombolite formation.

8. Give a description of the associated non-biological landscape characteristics or components of the ecological community.

For instance, what is the typical landscape in which the community occurs? Note if it is associated with a particular soil type or substrate; what major climatic variables drive the distribution of the ecological community (e.g. rainfall). Note particular altitudes, latitudes or geographic coordinates

Lake Clifton is part of the Yalgorup Lakes system in Yalgorup National Park as described in Commander (1988). Geologically it lies within the Perth Basin, separated from the Precambrian Yilgarn Craton by the Darling Fault to the east and the Indian Ocean to the west. The lake is a series of elongated depressions parallel to the coastline, separated by a sequence of stabilized Pleistocene dune ridges and Holocene dunes. Tamala Limestone outcrops occur along the eastern shoreline and contain marine and estuarine fossils (Commander 1988). The region experiences a “Mediterranean’ type climate with hot, dry summers and cool, wet winters, where up to 80% of annual rainfall falls in the winter half-year from May to October (Charles *et al*. 2010). The lake is replenished by winter rains or from underground water, with an extensive aquifer emptying into the lake along the eastern shoreline (Moore *et al*. 1984).

9. Provide information on the ecological processes by which the biological and non-biological components interact (where known).

A study in 1985-86 on Lake Clifton salinities (Knott *et al*. 2003) indicated that the lake varied seasonally and spatially between 10-45gL^{-1}. However, there has been a decrease in water levels and an increase in salinity in Lake Clifton over the last 30 years (Lane 2016) with the current data showing the lake is now hypersaline (seasonally varying between 60-200gL^{-1} during 2018/19). Lake Clifton is a groundwater sink, with a freshwater flow system (DWER WIN 1996: 0.8-2.0gL^{-1}) and an underlying body of hypersaline water (42gL^{-1} Commander 1988). There are no natural drainage channels into Lake Clifton. The lake is either replenished by winter rains or from underground water: either discharge from the fresh aquifer adjacent to the lake or from the hypersaline aquifer beneath the lake. This inflow of fresh groundwater probably provides calcium enriched water critical to the survival of the microorganisms and the growth of the thrombolites. The processes maintaining the balance between groundwater discharges from fresh and saline sources, groundwater abstraction, rainfall and evaporation are not well understood, but it is likely that a combination of anthropogenic influences combined with a drying climate is the primary driver behind low water levels and increased salinity.

10. Does the ecological community show any consistent regional or other variation across its extent, such as characteristic differences in species composition or structure?

If so, please describe these.

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Small isolated thrombolites were reported by Moore (1993) as occurring on the north-western shoreline of Lake Clifton but have not been investigated further.

11. Does the ecological community provide habitat for any listed threatened species and/or endemic species?

If so, please note the species and whether the species is listed on State and/or national lists and the nature of their dependence on the ecological community.

The lake and the vegetated buffer surrounding the lake provide valuable nesting and foraging habitat for many waterbirds, such as the black swan, musk duck and shelduck; as well as migratory wading birds (listed as migratory in WA and under EPBC Act) including the sharp-tailed sandpiper (*Calidris acuminata*), red-necked stint (*Calidris ruficollis*), curlew sandpiper (*Calidris ferruginea*) (CR in WA and EPBC Act), red knot (*Calidris canutus*) (EN in WA and EPBC Act), bar-tailed godwit (*Limosa lapponica*), whimbrel (*Numenius phaeopus*), marsh sandpiper (*Tringa stagnatilis*) and greenshank (*Tringa nebularia*). Several threatened fauna species, the chuditch (*Dasyurus geoffroii*) (VU in WA and EPBC Act), the western ringtail possum (*Pseudocheirus occidentalis*) (CR in WA and EPBC Act), and the Carnaby's cockatoo (*Calyptorhynchus latirostris*) (Endangered under WA and EPBC Act) have been recorded in the surrounding Yalgorup National Park (CALM 1995).

12. Identify major studies on the ecological community (authors, dates, title and publishing details where relevant).

Barr, A. (2003) Investigation of the Water Balance of Lake Clifton. A Client Report to the Western Australian Department of Conservation and Land Management. CSIRO, Western Australia.

Commander, D.P. (1988) Geology and hydrogeology of the superficial formations and coastal lakes between Harvey and Leschenault inlets (Lake Clifton Project). *Western Australian Geological Survey Professional Papers.* Report No 23: 37-50.

Davies, P.M. and Lane, J.A.K. (1996) The impact of vegetated buffer zones on water and nutrient flow into Lake Clifton, Western Australia. *Journal of the Royal Society of Western Australia*. 79: 155-160.

Department of Conservation and Land Management (1995) Yalgorup National Park Management Plan 1995 – 2005. Management Plan No 29, Department of Conservation and Land Management and National Parks and Nature Conservation Authority.

Forbes, M. and Vogwill, R. (2016) Hydrological change at Lake Clifton, Western Australia – Evidence from hydrographic time series and isotopic data. *Journal of the Royal Society of Western Australia* 99(2): 47-60.

Goater, S. (2003) Salinity concentrations and macroinvertebrate fauna of Lake Clifton, Western Australia. Honours Thesis, University of Western Australia.

John, J., Hay, M. and Paton, J. (2009) Cyanobacteria in benthic microbial communities in coastal salt lakes in Western Australia. *Algological Studies* 130: 125-135.

Knott, B., Bruce, L., Lane, J., Konishi, Y. and Burke, C. (2003) Is the salinity of Lake Clifton (Yalgorup National Park) increasing? Journal of the Royal Society of Western Australia.

Konishi, Y., Prince, J. and Knott, B. (2001) The fauna of thrombolitic microbialites, Lake Clifton, Western Australia. *Hydrobiologia* 457: 39-47.

Lane, J.A.K., Clarke, A.G. and Winchcombe, Y.C. (2017) South West Wetlands Monitoring Program (SWWMP) report.

Lindsay, R. (2002) Climate and land use impacts on groundwater levels in the Lake Clifton and Lake Preston Area. Unpublished Post Graduate Diploma thesis, Curtin University of Technology.

Moore, L. (1991) Lake Clifton - An internationally significant wetland in need of management. *Land and Water Research News* 8: 37-41.

Moore, L. (1993) The Modern Thrombolites of Lake Clifton South Western Australia. Unpublished PhD Thesis. University of Western Australia.

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Moore, L.S. and Burne, R.V. (1994) The modern thrombolites of Lake Clifton, Western Australia. In Bertrand, J. and Monty, C. (eds), Phanerozoic Stromatolites II, Kluwer Academic Publishers, Netherlands.

Moore, L., Knott, B., and Stanley, N. (1984) The Stromatolites of Lake Clifton, Western Australia. Living structures representing the origins of life. *Search* 14 (11-12): 309-313.

Neil, J. (1984) Microbiology of the Mats and Stromatolites of the Clifton/Preston Lake Complex, University of Western Australia.

Noble, C. (2010) The effects of surface water levels and salinity on groundwater movement between Lake Clifton and its neighbouring wetlands, Western Australia. Honours Thesis, The University of Western Australia.

Pache, M., Arp, G.and Reimer, A. (2002) Investigations on stromatolitic carbonates from Western Australian Lakes. Research Report for CALM Licence No. SF002571.

Rosen, M.R., Coshell, L., Turner, J.V. and Woodbury, R.J. (1996) Hydrochemistry and nutrient cycling in Yalgorup National Park, Western Australia. *Journal of Hydrology* 185: 241-274.

Shams, R. (1999) Assessment of Hydrogeology and water quality inputs to Yalgorup Lakes. Hydrogeology Report No. HR90. Water and Rivers Commission, East Perth.

Smith, M.D., Goater, S.E., Reichwaldt, E.S., Knott, B. and Ghadouani, A. (2010) Effects of recent increases in salinity and nutrient concentrations on the microbialite community of Lake Clifton (Western Australia): are the thrombolites at risk? *Hydrobiologia* 649: 207.

Warden, J. G., Casaburi, G., Omelon, C. R., Bennett, P. C., Breecker, D. O., and Foster, J. S. (2016) Characterization of microbial mat microbiomes in the modern thrombolite ecosystem of Lake Clifton, Western Australia using shotgun metagenomics. *Frontiers in Microbiology* 7: 1064.

Warden, J.G., Coshell, L., Rosen, M.R., Breecker, D.O., Ruthrof, K.X. and Omelon, C.R. (2019) The importance of groundwater flow to the formation of modern thrombolitic microbialites. *Geobiology* 0: 1-15.

Distribution

13. Describe the distribution across WA and nationally.

State the appropriate bioregions where the ecological community occurs. Attach or provide any maps showing its distribution with details of the source of the maps or explain how they were created and the datasets used.

This ecological community occurs at a single location. Lake Clifton is the second largest and the most northern lake in the Yalgorup National Park and is located southwest of Mandurah within the southern Swan Coastal Plain Bioregion. Lake Clifton measures approximately 21.5km long by 1.5km, with the waterbody covering about 17.8km^2 at its maximum extent (Commander 1988). Most of the lake is less than 1.5m deep, with certain areas up to 3.5m in depth. Both the deep basin and the mean annual water level are generally lower than sea level (Moore 1991). The thrombolite reef occurs in a zone about 15m wide on the eastern side of the lake and occupies a total area of ~5km^2 (Appendix 1). Small isolated thrombolites have also been reported by Moore (1993) as occurring on the north-western shoreline of Lake Clifton.

14. What is the area of distribution of the ecological community?

For answers to parts a, b, c & d: please identify whether any values represent extent of occurrence or area of occupancy (as described in the Attachment); provide details of the source(s) for the estimates and explain how they were calculated and the datasets used.

14 a. What is the current known area (in ha)?

~500ha

14 b. What is the pre-industrialisation extent or its former known extent (in ha)? An ecological community is considered to be naturally restricted if it has a pre-industrialisation area of occupancy that is less than 10 000 ha or a pre-industrialisation extent of occurrence that is less than 100 000 ha (refer to the Attachment A)

Unknown, but thought to be relatively stable at significantly less than 10,000ha. Partially eroded, fully lithified fossil microbialites occur on the outer margins of the lake, separated by the modern reef platform (Wacey 2010).

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14 c. What is the estimated percentage decline of the ecological community?

Available evidence indicates the Lake Clifton thrombolites occupy most of their former extent.

14 d. What data are there to indicate that future changes in distribution may occur?

Ongoing salinity measurements indicate significant increase since approximately 1985 (as shown in Lane *et al*. 2017).

Lake monitoring data indicate a slight decline in lake level from 1985 to 2016 (Lane *et al*. 2017).

Future climate change trends from National Climate Change Adaptation Research Facility (NCCARF) website (accessed 2019) are indicative of reduced rainfall and concomitant decline in fresh groundwater inflows. It is likely with increased salinity there will be a further reduction in the extent of active living thrombolites.

Patch size

15. What is the typical size (in ha) for a patch of the ecological community (if known)?

Explain how it was calculated and the datasets that are used. Relevant data includes the average patch size, the proportion of patches that are certain sizes, particularly proportions below 10 ha and below 100 ha, (but also below 1 ha and above 100 ha, for example). This could be presented as the range of patch sizes that comprise 90% of the occurrences.

There is only one location of this ecological community, and based on its extent around the lake shores, it is considered to cover approximately 500 hectares.

16. Quantify, if possible, the smallest percentage or area required for a patch of the ecological community to be considered viable.

This refers to the minimum size of a remnant that can remain viable without active management. It may be determined through the requirements for dominant native species, level of species diversity, or the nature of invasive weeds.

There is only one location known, in a single waterbody/lake, therefore this question is not relevant.

Functionality

17. Is the present distribution of the ecological community severely fragmented?

If so, what are likely causes of fragmentation?
If fragmentation is a natural or positive characteristic of this ecological community, please explain this and state the reason.
Severely fragmented refers to the situation in which increased extinction risk to the ecological community results from most remnants being found in small and relatively isolated patches.

NA

18. Has there been a loss or decline of functionally important species?

This refers to native species that are critically important in the processes that sustain or play a major role in the ecological community and whose removal has the potential to precipitate change in community structure or function sufficient to undermine the overall viability of the community.

Changes to physical parameters, such as an increase in salinity, has likely caused a shift in the microbes that dominate the assemblage possibly replacing these with a different microbial assemblage. The species currently present still produce large amounts of Extracellular Polymeric Substance (EPS) which is the site of carbonate deposition, and so significant accretion was still occurring when last monitored in 2015 (pers. comm. [redacted][1]). It is not known however, to what extent this is occurring and therefore the extent of the decline in the component species cannot be determined. Visual inspections indicate the appearance of the assemblage when the assemblage was actively accreting has changed considerably since the mid-1990s ([redacted] pers. obs[2]).

18 a. If yes, which species are affected?

[1] Independent ecologist.
[2] Principal Ecologist, DBCA Species and Communities Program

The specific species that are components of the current benthic microbial community that are affected is not known (see question 6 for genera recorded in the early 1990s and 2016).

18 b. How are the species functionally important and to what extent have they declined?

Photosynthetic and metabolic activity of the benthic microbial community facilitates carbonate deposition and thrombolite formation. The current level of decline is not known and difficult to measure.

Reduction in community integrity

19. Please describe any processes that have resulted in a reduction in integrity and the consequences of these processes, e.g. loss of understorey in a woodland. Include any available information on the rate of these changes.

This recognises that an ecological community can be threatened with extinction through on-going modifications that do not necessarily lead to total destruction of all elements of the community. Changes in integrity can be measured by comparison with a benchmark state that reflects as closely as possible the natural condition of the community with respect to the composition and arrangement of its abiotic and biotic elements and the processes that sustain them. Please provide a description of the benchmark state where available. For further information please refer to the Guidelines.

The microbialite community of Lake Clifton has been subject to historical disturbance by alterations to the levels of salinity and nutrients, lake level and other water quality and quantity parameters; physical crushing and disturbance due to extraction of marl in the bottom of the lake; and disturbance of the native vegetation buffer around the lake. The thrombolites are also likely to be subject to future threats, the most significant impact from hydrological changes.

An increase in salinity over 25 years resulted in a massive breakup of the benthic microbial mats from the bottom of the lake discolouring and adding nutrients into the lake, evident in 2002 and 2007. The thrombolites showed symptoms of eutrophication due to coverage by growth of Cladophora and Lamprothamnium (filamentous green algae) that smother the structure forming assemblages. The Scytonema that dominated the microbial mats had been replaced by another filamentous cyanobacterium. As salinity increases, a reduction in species diversity in Lake Clifton is expected and poses a serious threat to the thrombolites (John *et al*. 2009). A shift in composition away from dominance by structure forming assemblages is also likely based on the effects of nutrient enrichment and hydrological changes on microbialite assemblages in Lake Richmond (Vogwill and Whitehead 2018).

Survey and Monitoring

20. Has the ecological community been reasonably well surveyed?

Provide an overview of surveys to date, including coverage of different land tenure, and the likelihood of the ecological community's current known distribution and/or patch size being a true reflection of its actual distribution (consider area of occupancy and area of extent, including any data on number and size of patches).

An extensive survey of the microbialite assemblages in many areas of south Western Australia was undertaken by Dr Linda Moore for her PhD (Moore 1993). A small, isolated area of thrombolites occurring on the north-western shoreline was also identified in Moore (1993) but have not been investigated further.

21. Where possible, please indicate areas that haven't been surveyed but may add to the information required in determining the community's overall viability and quality.

Include commentary on issues to do with accessing different land tenures within the area of distribution, including private property, and the likelihood that these areas may include occurrences.

NA

22. Is there an ongoing monitoring program? If so, please describe the extent and length of the program.

A long-term monitoring program measuring water level, salinity and nutrient samples (nitrate, filterable reactive phosphate, total nitrogen and phosphorus) was completed annually in August and September at the boardwalk from 1985 to 2017 (Lane *et al*. 2017).

Peel Harvey Catchment Council (PHCC) has NLP2 funding to undertake hydrologic and heath monitoring of the Lake Clifton system, commencing 2019 with the detailed scope still being formulated. It does include water level and water quality monitoring of lake and bores.
A monitoring program for the physical condition and microbial assemblage of the thrombolites was established in 2003 but did not progress.

Sampling of the thrombolites was performed on three separate occasions in September 2006 and 2015.

The thrombolites attract significant scientific interest and studies of the ecology and hydrology by universities and other research bodies occur periodically.

Condition Classes and Thresholds

23. Do you think condition classes/thresholds apply to this ecological community? If not, give reasons.

The Committee recognises that ecological communities can exist in various condition states. In reaching its decision the Committee uses condition classes and/or thresholds to determine the patches that are included or excluded from the listed ecological community (see the Guidelines for details of the process of determining condition classes). Relevant here is recognition of different states following disturbance and the natural recovery of the occurrence towards a higher condition class.

While the thrombolite structures are persistent, it is not straight forward to determine whether the structure-building communities are active or inactive from visual cues. This requires use of specialist techniques and knowledge to establish the status of the microbial assemblage. Therefore, a condition class has been applied to the community as a whole based on:

- the presence/absence and species composition of the benthic microbial community and whether this will contribute to growth (accretion);
- hydrological changes within the lake;
- a visual survey of the physical condition of the thrombolite structures by people with expertise in determining if assemblages are active.

24. If so, how much of the community would you describe as in relatively <u>good condition</u>,
i.e. likely to persist into the long-term with minimal management?

Surveys of the benthic microbial community undertaken by Whitehead and Vogwill from 2013 to 2015 found that the original benthic community composition as described by Moore (1993) was present. However, there have been significant changes to the hydrological conditions to the lake. If species composition and lake ‘health’ are used as a baseline for ‘good condition’ then it can be applied that none of the community is in ‘good condition’. There is currently insufficient information about the processes involved however, and further systematic monitoring and research are required to provide quantifiable data to support inferences about condition of the community.

25. What features or variables do you consider to be most valuable for identifying a patch of the ecological community in relatively <u>good condition</u>?

Variables for establishing the highest condition class may include: patch size; connectivity; native plant species composition; diversity and cover (for example in overstorey; mid-shrub and/or understorey layers); recognised faunal values; and cover of weeds or other invasive species.

A ‘good’ condition class can be described as presence of a specific benthic microbial community that contributes to accretion, and specific hydrological conditions within the lake that support accretion (as recorded pre 1985).

26. How much of the community would you describe as in relatively <u>medium condition</u>, i.e. likely to persist into the long-term future with management?

Likely none (see above, question 24).

27. Please describe how you would identify areas in <u>medium condition</u> using one or a combination of indicators such as species diversity, structure, remnant size, cover of weeds or other invasive species, etc.

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A 'medium' condition class can be described as presence of a specific benthic microbial community that contributes to accretion, and minimal changes to the hydrological conditions within the lake.

28. How much of the community would you describe as in relatively <u>poor condition</u>, i.e. unlikely to be recoverable with active management?

It is inferred that 100% of the community is in poor to medium condition. Surveys of the benthic microbial community undertaken in 2015 found that species composition of the cyanobacteria communities that occur in the lake that support carbonate accretion has changed due to the increase in salinity levels. Despite these changes, the species currently present are producing large amounts of EPS and significant accretion was still occurring. It is not known however, to what extent accretion is occurring.

29. Please describe how you would identify areas in <u>poor condition</u> using one or a combination of indicators such as species diversity, structure, remnant size, cover of weeds or other invasive species, etc.

A 'poor' condition class can be described as the complete absence of specific benthic microbial communities that contribute to accretion; and permanent detrimental changes to physical and hydrological conditions within the lake so that accretion is no longer possible.

Threats

Note: If you plan to identify <u>climate change</u> as a threat to the ecological community, please refer to the IUCN Red List of Ecosystem Guidelines for information on how this should be addressed.

30. Identify <u>PAST</u> threats to the ecological community indicating whether they are *actual* or *potential*.

The microbialite community of Lake Clifton has been subject to actual historical disturbance by alteration to the levels of salinity and nutrients, lake level and other water quality parameters, physical crushing, extraction of substrate, and disturbance of the native vegetation buffer around the lake.

31. Identify <u>CURRENT</u> threats to the ecological community indicating whether they are *actual* or *potential*.

The microbialite community of Lake Clifton is subject to actual recent and ongoing disturbance by alterations to the levels of salinity and nutrients, lake level and other water quality and quantity parameters (caused by rainfall decline (drying climate), reduced groundwater inputs, physical crushing; and disturbance of the native vegetation buffer around the lake. An increase in population in the Mandurah area has resulted in an increase in use of off-road vehicles that encroach on the lakes edge and damage the microbialites.

32. Identify FUTURE threats to the ecological community indicating whether they are *actual* or *potential*.

It is predicted that in the future the microbialite assemblage of Lake Clifton will be increasingly threatened by alterations to the levels of salinity and nutrients, lake level and other water quality and quantity parameters (caused by rainfall decline (drying climate), changes to hydrological flows and groundwater abstraction); physical crushing; and disturbance of the native vegetation buffer around the lake. Increasing population in and around the Mandurah area resulting in higher visitation and usage of the lakes and surround communities and potentially increasing threats.

For <u>each</u> threat describe:

32 a. How the threat has impacted on this ecological community in the past.

Declining lake level

The level of the lake is likely to be crucial for maintaining the thrombolites, as they rely on sufficient water to cover the growing surface of the structures while still having adequate levels of light for photosynthetic and metabolic activity. Further, the fresh groundwater flowing into the lake on the eastern side is thought to be essential to the survival and growth of the thrombolites as it provides the ions for accretion. The water level at Lake Clifton fluctuates seasonally by up to 1m. It rises in winter through direct rainfall and increased groundwater input, and declines over summer as a result of evaporation, exposing most of the thrombolites (Moore 1991;

Moore and Burne 1994). The groundwater levels may vary yearly with climatic conditions and land uses (Lindsay 2002). However, if groundwater abstraction for agricultural, urban or other purposes in the groundwater catchment of Lake Clifton results in ongoing reduction of the lake water level, or reducing the inflow of fresh groundwater, this may expose the thrombolites and the BMC more frequently preventing growth of the structures. Reduced fresh groundwater inflows are also likely to alter the quality of lake water such that different assemblages of microbes are favoured. Monitoring data on water depth from 1985 to 2017 indicates a decline in overall lake depth (DOW 2015; Lane *et al*. 2017; Muirden 2019) (Figures 1, 2 and 3).

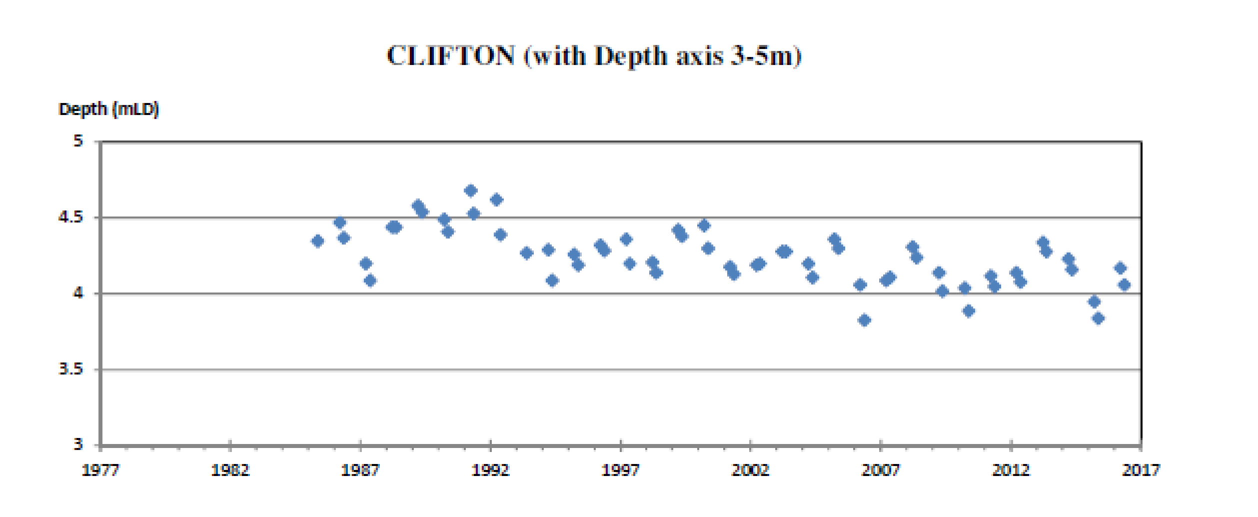

Figure 1. Depth (axis of 3-5 m) of Lake Clifton from 1985 to 2017 measured yearly in September and November (from Lane *et al*. 2017).

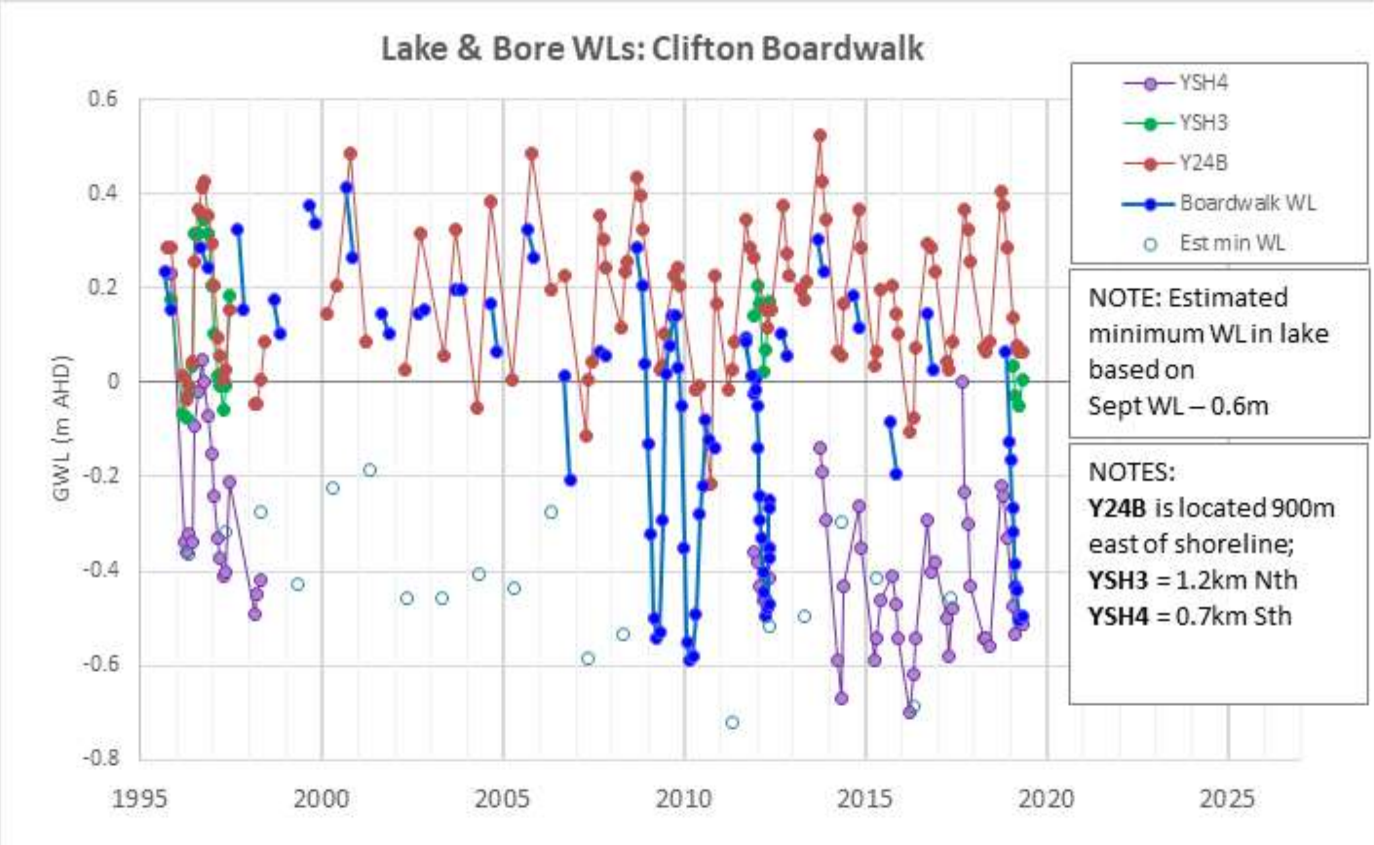

Figure 2. Lake Clifton water levels from 1995 to 2019 (data from DWER and DBCA via [redacted]).

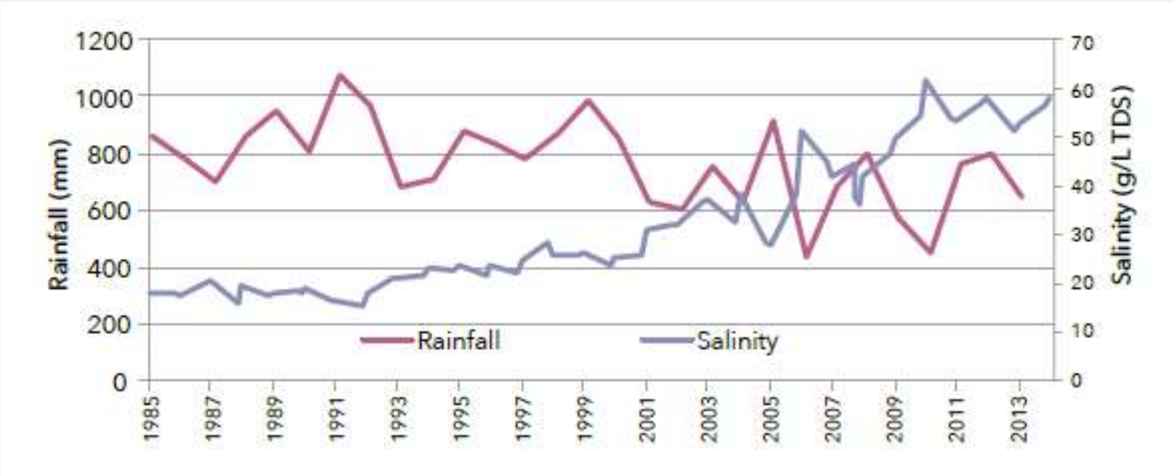

Figure 3. Annual rainfall and annual minimum salinity measured at Lake Clifton (from DOW 2015).

Increasing salinity

A decline in the lake volume has corresponded with an increase in the salinity and concentrated all other constituents of the lake water, as well being associated with a change in the dominant microbes. Salinity measurements taken in September and November from 1985 to 2017 indicate a steady increase in the salinity of the lake from 15gL^{-1} from 1985 to around 60gL^{-1} in 2017 (Lane *et al*. 2017). Other historic comparisons of salinity data show an increase in salinity from 17gL^{-1} in 1984 to 123gL^{-1} in 2014 (Whitehead and Vogwill 2013-2015) (see Figure 3 for BOM data).

An increase in salinity is linked with a reduction in Scytonema, from approximately 20% of the thrombolite microbial assemblage in 1984 (study by Neil 1984) to less than 1% in 2006 (Smith 2006). Other changes in the thrombolite assemblage include a dramatic increase in unicellular cyanobacteria (16% to 50%) and diatoms (8% in 1984 to 28% in 2006). It is likely that the increasing salinity is potentially favouring the diatoms and unicellular cyanobacteria over the filamentous cyanobacteria (Regan 2009; Smith *et al*. 2009). Sampling of the microbial assemblage from 2013 to 2015 indicate that although there was a change in the species composition of the cyanobacteria communities, the species present were still producing large amounts of EPS, which is the site of carbonate deposition. From this it was inferred that significant accretion was still occurring, despite the increasing salinity. Research undertaken in 2014 also found the thrombolites actively accreting and growing in limited areas of Lake Clifton (Warden *et al*. 2016). More recent research by Warden *et al*. (2019) indicates that conditions favourable to thrombolite formation still exist in certain locations of Lake Clifton despite increasing lake water salinity. As the salinity level increases the ionic composition of the lake water will interfere with the chemistry of the formation process with a corresponding reduction in carbonate accretion. Lake water chemistry will ultimately not support growth and accretion of the microbial assemblage (pers comm. [redacted]).

Nutrient enrichment and increases in other pollutants

There is a wide range of land uses surrounding Lake Clifton, some of which have potential to contribute to input of nutrients and other pollutants. Land uses include national park which occupies the majority of the northern and western periphery of Lake Clifton, periodical harvesting of pines in State Forest, quarries for extraction of limestone, irrigated horticulture, and pasture and rural residential properties that mostly occupy the entire eastern shoreline. With increasing subdivision and use of land for agriculture on the eastern side of Lake Clifton, the concomitant rise in runoff of nutrients and other pollutants from adjacent properties impacts the growth and survival of the thrombolites. Excessive irrigation and fertiliser application in the catchment, for example on agricultural land, private lawns and market gardens, results in pollution of the lake due to leaching of contaminants to groundwater or through surface runoff from heavy rains in winter flushing large amounts of nutrients from urban and agricultural areas into wetlands (Davies and Lane 1996). Over the last 20 years the nutrient levels in Lake Clifton have increased to above recommended levels (total phosphorus 0.048mgL^{-1} in 1979 to 0.186mgL^{-1} in August 1988 (Moore 1993)). Blooms of the blue green alga Cladophora is an indicator of eutrophication. At that time Cladophora was also found growing profusely on the thrombolites. This alga effectively competes for light with the microbes forming the thrombolites. It can lead to decreased light penetration that reduces or prevents photosynthesis of the thrombolite forming benthic microbial community and has the potential to prevent thrombolite formation and growth. Nutrient concentrations have not been regularly monitored in the Yalgorup Lakes and the most recent available data were collected from Lake Clifton between 2005-2006 (John *et al*. 2009; Smith *et al*. 2010). Total nitrogen was 2 to 4mg/L, and total phosphorus was 0.13mg/L, indicating a trend towards increasing nutrient concentrations.

The lack of surface water outflow channels results in dissolved constituents in groundwater and rainfall being retained in the wetlands and becoming concentrated over time, with the only source of flushing through loss of groundwater to the ocean (Coote 2015).

Physical crushing

The thrombolites have been subject to physical crushing underfoot by visitors to Lake Clifton in localised areas with easy public access in recent decades. Visitors may not be aware of the significance of the thrombolites unless they have noted the interpretive information that occurs at the site of easiest access. Active recreation such as 4WD activity, fishing and canoeing would have significant impact on the thrombolites through crushing. Evidence of motor bike tracks along the lakes edge has been recorded and physical signs of crushed microbialites occur. Cattle from adjacent properties have also been observed on the lake crushing the thrombolites. As the population increases in the area, the impact of crushing is also likely to increase unless actions are taken to ameliorate all these impacts.

Mineral extraction

The lime rich marl that lines the bottom of Lake Clifton was harvested in the 1920s through the pumping of sediment from the bottom of the lake via a pipeline to lime kilns located on the eastern side of the lake. This is a land use that is very unlikely to occur in the future as the lake’s values are now well recognised.

Land use impacts

The vegetation buffer has been impacted historically by clearing for agricultural use, and more recently by crushing by visitors. Vegetation near the lake shore can be important in areas of surface and groundwater intrusion as a buffer can significantly reduce the level of nutrients entering the lake from surface flow. Major weeds occur among the sedges at the edges of the lake and displace native plants, requiring constant control. These include *Carduus pycnocephalus* (thistle), *Avena fatua* (oats), *Stenotaphrum secundatum* (buffalo grass), *Aster subulatus* (bushy starwort), *Polypogon monspeliensis* (annual barbgrass) and *Gomphocarpus fruticosus* (narrowleaf cotton bush). The risk of fire is increased by the presence of grassy weeds in the understorey, as they are likely to be more flammable than the original native species in the herb layer. Fire in the vegetation buffer would also result in a short-term flush of nutrients being washed into the lake, both because of the removal of the retentive plant barrier, and due to release of nutrients from the burnt vegetation. Thrombolites are likely to be impacted by the release of nutrients into the lake, the loss of the dense sedges as a physical barrier to walkers trampling on the structures, and by the release of sediment immediately following fire in the remnant buffer near the lake. If used immediately adjacent to the structure’s chemicals used for weed control may impact on the thrombolites through impacting on the photosynthetic capability of the microbial assemblages.

Introduced fauna

The introduction of fauna, such as black bream (*Acanthopagrus butcheri*) and snails to the lake may have a had a significant impact on the original lake fauna and may also threaten the thrombolites. Bream and snails are thought to graze on the microbial layer that forms the thrombolites, as do numerous other species of metazoan (Konishi *et*

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al. 2001). Nutrients from the faecal material of bream may also alter the nutrient levels within the lake. Bream were introduced to Lake Clifton in 1947 (Dortch 2008) and were caught from the boardwalk by local anglers when it was completed in 1996. The bream were dated at up to 18 years old, and morphological changes also indicate that there is more than one generation (Sarre *et al*. 1999). A large fish kill occurred in the lake in 2007 from lack of dissolved oxygen, but since then smaller sized bream have still been observed.

32 b. What its expected effects are in the future. Include or reference supporting research or information.

Hydrological changes

Using historical rainfall data from 1961 to 1990 from Mandurah Park (BOM 9572, ~21km to the north of Lake Clifton), DOW (2015) predicted future dry, median and wet climate scenarios (Figure 4). The projections indicate that by 2020 the long-term average annual rainfall for Mandurah (average of 845mm per year for the baseline period of 1961 to 1990) will decline by 2.5, 5.8 and 8.9% under a wet, mid or dry scenario respectively, and by 2030 by 3.4, 9.0 and 13.6%. It is expected that future changes to the hydrology of the lake from groundwater abstraction for agricultural, urban or other purposes, as well as from a drying climate, will result in lower lake levels, higher water temperatures, and an increase in salinity and nutrients, thereby exposing the thrombolites and changing the BMC potentially eventually preventing accretion (growth) of the structures.

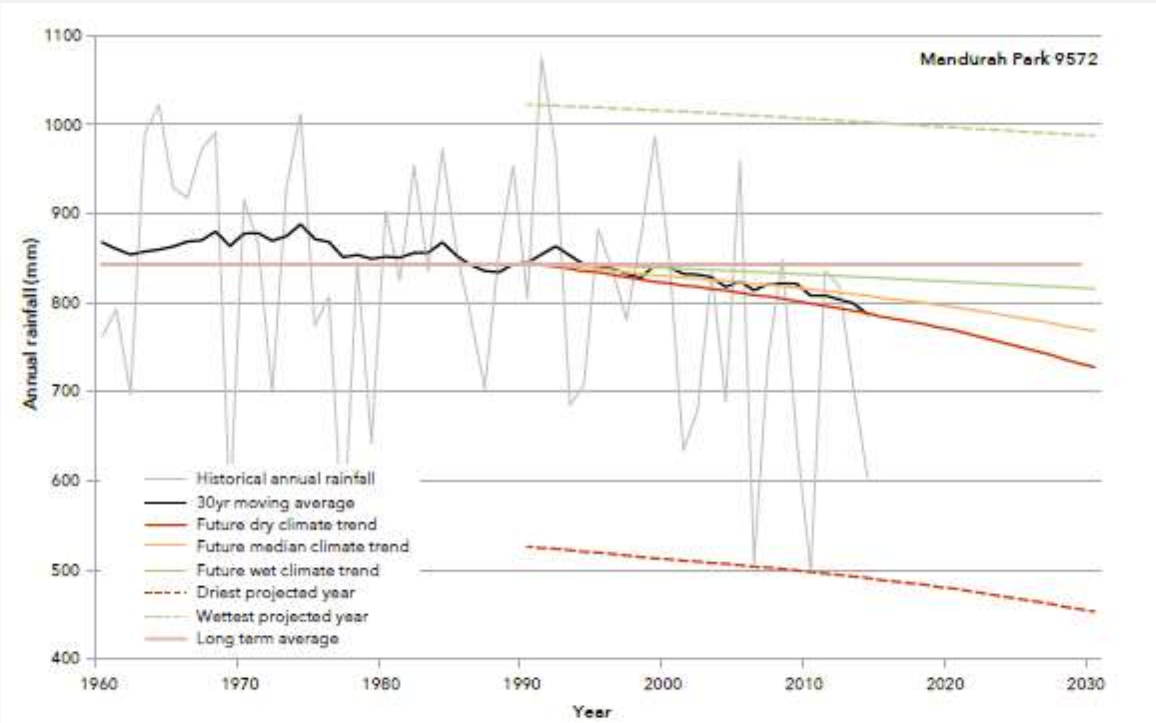

Figure 4. Future predicted scenarios for climate trends at BOM site Mandurah Park 9572 using a 1961-1990 baseline (from DOW 2015).

Groundwater allocation limits for future public water supply in the area of Lake Clifton have been capped by DWER at 661,440kL/year. Should monitoring indicate a decline in groundwater levels, the options to manage this are limited because of minimal groundwater use up-gradient of the lake and the lack of alternative water sources (DOW 2015).

Weeds

Weed control in the buffer vegetation area is ongoing, however the control of some dominant species such as *Gomphocarpus fruticosus* (narrowleaf cotton bush) is yet to be achieved.

Physical crushing

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Interpretation shelter panels and a boardwalk were constructed with the purpose of providing visitors information on the conservation values of Lake Clifton and surrounds and reducing the direct impacts to the thrombolite structures. However, management of physical crushing of the thrombolites from recreational users of the lake is difficult to manage. This threat will likely continue and may increase as the population increases.

Land development

DBCA continues to attain, as the opportunity arises, suitable parcels of land for addition to Yalgorup National Park. However, further potential impacts may occur if land use planning decisions support subdivision and development of the adjacent buffer area.

Introduced fauna

As bream are an estuarine species, the increasing level of salinity in the lake may favour them and lead to increases in their numbers.

32c. Identify whether the threat only affects certain portions or occurrences. Give Details.

The threats listed above have and are likely to continue to impact on the lake, the thrombolites and the microbial assemblage, as well as the surrounding vegetation buffer.

33. Identify any natural catastrophic event/s

Explain its likely impact and indicate the likelihood of it occurring (e.g. a drought/fire in the area every 100 years). Catastrophic events are those with a low predictability that are likely to severely affect the ecological community.

Drought may reduce the lake water level and groundwater inflows, and result in other impacts to water quality that may affect the microbial assemblages and hence thrombolite growth/accretion. Reduced rainfall and potentially drought are predicted outcomes of a drying climate.

Major fires can occur any time and have potential for major impacts to the vegetation buffer and increased nutrients and sediment in the lake.

34. Additional biological characteristics

Identify and explain any additional biological characteristics particular to the community or species within it that are threatening to its survival (e.g. low genetic diversity). Identify and explain any models addressing survival or particular features.

34 a. How does it respond to disturbance?

Physical disturbance, such as by vehicles, walkers and cattle, can damage the thrombolites through crushing.

Fire in the vegetated buffer increases weed levels and produces a short-term flush of nutrients into the lake, both because of the removal of the retentive vegetation barrier, and due to nutrients and sediment from the burnt vegetation. Thrombolite growth is likely to be negatively impacted by the release of nutrients into the lake, the loss of the dense sedges as a physical barrier to walkers trampling on the structures, and by the release of sediment immediately following fire in the remnant buffer near the lake. Chemicals used for weed control can impact on the thrombolites if used immediately adjacent to the structures as they are photosynthetic.

34 b. How long does it take to regenerate and/or recover?

The minimum net growth rate of the stromatolites at Lake Clifton is around 0.1mm per year (Moore 1993; Moore and Burne 1994). Based on this low growth rate, recovery of microbialites following physical damage would take many years.

The surrounding vegetation buffer will recover from occasional fire, but too frequent fire could potentially result in loss of fire-sensitive species.

There is no information available to indicate how quickly the microbial assemblage might recovery if the salinity, nutrient and other hydrological factors improve.

Threat Abatement and Recovery

35. Identify key management documentation available for the ecological community, e.g. recovery plans, biodiversity management programmes, or site-specific management plans (e.g. for a reserve).
Luu, R., Mitchell, D. and Blyth, J. (2004) Thrombolite (Stromatolite-like Microbialite) community of a coastal brackish lake (Lake Clifton). Interim Recovery Plan 2004-2009. Department of Conservation and Land Management, Western Australia. Peel-Harvey Catchment Council 2009, Peel-Yalgorup Ramsar Site Management Plan, Peel-Harvey Catchment Council, Mandurah. Department of Conservation and Land Management (1995) Yalgorup National Park Management Plan 1995-2005. Management Plan No. 29. Department of Conservation and Land Management, Western Australia.
36. Give an overview of how threats are being/potentially abated and other recovery actions underway and/or proposed. Identify who is undertaking these activities and how successful the activities have been to date.
Application of environmental impact assessment processes that control development, including the WA *Environmental Protection Act 1986* and planning legislation, have placed limits on clearing in the surrounding vegetation. Other key measures required to mitigate risks to the ecological community include ensuring adjacent landowners are aware of the significance of the thrombolite community and the importance of keeping cattle out of the area, the construction of a boardwalk on the eastern edge of the lake to allow visitors to view the thrombolites without crushing them, the development of a visitor education centre to inform the public about the importance of the thrombolites, and control of weeds in the rehabilitation areas on the east side of the lake.
37. What portion of the current extent of the ecological community is protected in a reserve set aside for conservation purposes, and what proportions are private land, or other tenure? Give details including the name of the reserves, and the extent the ecological community is protected within these reserves.
The entire Lake Clifton thrombolites community occurs within the Yalgorup National Park that is vested in the Conservation Parks Commission (CPC) and is managed by the Department of Biodiversity, Conservation and Attractions for the purposes of national park.
37 a. Which of the reserves are actively managed? Note which, if any, reserves have management plans and if they are being implemented.
Lake Clifton occurs on lands managed by Parks and Wildlife Service, Swan Region, Department of Biodiversity, Conservation and Attractions. Management of Yalgorup National Park is outlined in the Yalgorup National Park Management Plan No 29, 1995-2005.
37 b. Give details of any other forms of protection, such as conservation covenants, and whether the protection mechanisms are permanent.
Tenure: A Class Crown reserve. Lake Clifton is listed as a Ramsar Convention Wetland in the Australian Nature Conservation Agency (ANCA) Directory of Important Wetlands in Australia and on the Register of the National Estate.
37 c. Indigenous interests **Is the nominated ecological community or parts thereof known to occur on any culturally significant sites?** If so, comment on any issues with respect to aboriginal interests, in particular with regard to management of the ecological community.
Noorook Yalgorup is the Nyoongar name for Lake Clifton. Some artefacts have been discovered within the Yalgorup National Park (Novak 1975). However, according to the Department of Planning, Lands and Heritage Sites Register, there are currently no recognised archaeological sites listed for the Yalgorup National Park. As the

area has not been examined in detail it is possible that sites exist (Department of Conservation and Land Management 1995). The Winjan Aboriginal Corporation and Bibbulum groups represent Aboriginal people in the Peel Region but no groups are actively involved in relation to the management of Yalgorup National Park. The Yalgorup National Park Management Plan recommends a number of actions related to the protection and conservation of the park's Aboriginal cultural values.

37 d. Native Title

Do Native Title or Indigenous Protected Areas apply to any parts of the community? If so, comment on any issues with respect to exclusive possession and rights to plants and animals, in particular with regard to management of the ecological community.

NA

38. Give details of recovery actions that are or could be carried out at the local and regional level, e.g. develop and implement management plan for the control of specific weed species (regional), undertake weeding of known sites (local).

The recovery plan (Luu *et al*. 2004) refers to biological research to better understand the community's management requirements, access control, education, monitoring, managing water quality, rehabilitation of adjacent vegetation and managing fire. Most of the recommended actions have been implemented to some degree. Many actions are ongoing, including monitoring, research, weed control and fire management.

39. Is there an existing support network for the ecological community that facilitates recovery? e.g. an active Landcare group, Conservation Management Network.

There is a recovery team that covers the Lake Clifton thrombolites. The recovery team is largely responsible for initiating and guiding actions and securing funds, and consists of representatives from DBCA, the City of Mandurah, University of Western Australia, CSIRO, Lake Clifton Landcare Group and Agriculture WA. The Recovery Team will continue to coordinate recovery actions for the Lake Clifton thrombolite community. Reports are prepared by the department annually and include review of progress of the recovery plan, implementation of recovery actions and results of analysis of monitoring within an adaptive management framework.

The Peel Harvey Catchment Council is also involved in recovery of the catchment area and has a leading role in working with representatives of many of the above-mentioned organisations to support the management of the Peel-Yalgorup System Ramsar Site, that includes Lake Clifton.

40. Describe methods for identifying the ecological community including when to conduct surveys.

For example, season, time of day, weather conditions; length, intensity and pattern of search effort; and limitations and expert acceptance; recommended methods; survey-effort guide. Include references.

The thrombolite community was originally described by Moore (1993). Thrombolitic structures can be identified by their internal clotted structure as opposed to those that have a laminated organisation that are stromatolitic. They are formed through precipitation of calcium carbonate within the microenvironment of microbes, a complex association of photosynthetic cyanobacteria and purple sulphur bacteria, eukaryotic microalgae and what are known as 'true bacteria', as a result of photosynthetic and metabolic activity.

Microbialite formation is favoured in warmer temperatures in sunny conditions, and when the local hydrological processes (including water level) are most favourable for the delivery of the chemicals that are required to build microbialites. Survey and identification of the microbialite assemblage should occur when likelihood of detection is maximised.

A specific method for monitoring of the health of the microbial community is described in Regan (2009). Samples of both the thrombolites and microbial mats were taken sporadically, a metre apart, in October. The samples under the microscope were examined to identify some of the different microorganisms identified in the thrombolites and microbial mat microbial assemblages. Both light and fluorescence microscopy were used to examine the thrombolite and microbial mat samples (Regan 2009).

41. Are there other any aspects relating to the survival of this ecological community that you would like to address?
No

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Section 3 - Justification for this nomination

In order for the nomination to be considered further, one or preferably more of the following criteria need to be fulfilled and substantiated. A clear case for why the ecological community is eligible for listing under the criteria is required, including evidence as to how it meets the requirements for listing under a particular listing category, e.g. 'David *et al*. (1999) finding of 95% decline in geographic distribution suggests it should be listed as critically endangered'. The type of data available will determine which criteria will be used to justify the application of a listing category.
At least one criterion must trigger the thresholds of a listing category as indicated in the Attachment. Criteria may be of different levels of listing category e.g. Criterion 1 = CR and Criterion 3 = VU.

42. Provide data that demonstrates why the ecological community meets at least one of the following criteria for the nominated listing category.

Please use data provided in previous sections to demonstrate how it specifically meets at least one of the following criteria. Advice on how to interpret the listing criteria is in Attachment A. Provide a response for every sub-criterion.

Criterion A: Reduction in geographic distribution.

Criterion A ☐ CR ☐ EN ☐ VU ☒ not eligible	☐ **A1** ☐ **A2a** ☐ **A2b** ☐ **A3**

Justification for assessment under Criterion A:

For criteria A and B, the ecosystem was assumed to collapse when the mapped distribution declines to zero.

The Lake Clifton thrombolite community has not incurred the required minimum 30% reduction in geographic distribution over any 50-year period, or a 50% reduction since 1750 (ie. the minimum requirements to meet the category VU under criterion A).

Criterion B: Restricted geographic distribution.

Criterion B ☒ CR ☐ EN ☐ VU ☐ not eligible	☒ **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)

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Justification for assessment under Criterion B:

B1: The extent of a minimum convex polygon enclosing the Lake Clifton thrombolites community is 22km^2 (≤2,000km^2, which is significantly less than the threshold for CR).
B2: The Lake Clifton thrombolites community is estimated to occupy three 10 × 10km square grid cells (threshold for EN is 20 and for CR is 2 grid cells). As for criterion B1, there is evidence of continuing decline in the microbial assemblage inferred from changes to the hydrological regime, and decline in biological processes associated with microbialite formation, therefore the status under criterion B2 is Endangered.

a): Data are available to measure decline in environmental quality (ii) or disruption to biotic interactions (iii). The Lake Clifton thrombolite community is dependent on a specific hydrologic regime including fresh calcium rich groundwater for survival of the micro-organisms and the growth of the thrombolites. Surveys of the benthic microbial community undertaken in 2015 indicate that species composition of the cyanobacteria assemblages that occur in the lake that support carbonate accretion has changed, likely due to the increase in salinity levels and other changes to lake chemistry. A massive reduction in Scytonema from approximately 20% of the thrombolite microbial community in 1984 (study by Neil 1984) to less than 1% in 2006 (Smith 2006). The genus was critical to the formation of the thrombolites. Other changes in the thrombolite community include a dramatic increase in unicellular cyanobacteria (16% to 50%) and diatoms (8% in 1984 to 28% in 2006). It is likely that the increasing salinity is potentially favouring the diatoms and unicellular cyanobacteria over the filamentous cyanobacteria (Regan 2009; Smith *et al*. 2009).
b): Decline observed from the impacts of recreational activities; and detrimental changes to the hydrologic regime (increasing salinity and nutrients).
c): Ecosystem exists at one threat-defined location (threshold for CR is one and for EN is 5 threat-defined locations).

B3: The Lake Clifton thrombolite community is dependent on an inflow of fresh calcium rich groundwater for survival of the micro-organisms and the growth of the thrombolites. The effects of human activities or stochastic events may cause the ecosystem to collapse within a very short period of time, given its highly restricted distribution, and ongoing threats posed by hydrological changes. The ecosystem therefore meets Vulnerable status under criterion B3.

Criterion C: Environmental degradation based on change in an abiotic variable.

Criterion C	
☐ CR ☐ EN ☐ VU ☒ not eligible	☐ **C1** ☐ **C2** ☐ **C3**

Justification for assessment under Criterion C:

The most significant abiotic variable affecting the community is hydrological change. The community is considered in medium to poor condition due to changes in lake hydrology that have occurred at least since 1985, and water quality (salinity levels) is considered to be indicative of the level of degradation of the community. Collapse of the community is defined under criterion C as a change in salinity levels in the lake such that net carbonate accretion of the microbialites is no longer supported and is unlikely to be supported in future. The salinity level that would result in collapse is not known however. Monitoring in 2015 showed that at specified sample sites the microbial assemblages present were producing large amounts of extracellular polymeric substances (EPS), and so significant accretion was still occurring (pers. comm. [redacted]). The proportion of the total extent of the community in which accretion was occurring is not known, however. Due to lack of the required data it is not possible to determine the proportional extent of decline or the relative severity of decline in relation to the specified collapse state. It is not known if the minimum threshold for proportion of the extent

(≥30%) of the community or relative severity of degradation (≥30%) over the past 50 years, or any 50-year period, has been met, to meet Vulnerable (VU) under criteria C1 and C2.

C1: Increasing salinity of Lake Clifton has resulted from a reduction in direct rainfall, reduced freshwater recharge from groundwater, increased abstraction of fresh water from the superficial aquifer, and upwelling of more dense saltier groundwater from deeper aquifer systems. Salinity measurements taken in spring over a 34-year period from 1985 to 2017 have shown a 300% increase in the salinity of the lake (15gL^{-1} from 1985 to around 60gL^{-1} in 2017; from Lane *et al*. 2017). Other historic comparisons of salinity data show a 623% increase (from 17gL^{-1} in 1984 to 123.02gL^{-1} in 2014; Whitehead and Vogwill 2013-2015). It is assumed that the increase in salinity affects 100% of the extent of the microbial community across the lake and has resulted in changes to the microbial assemblage.

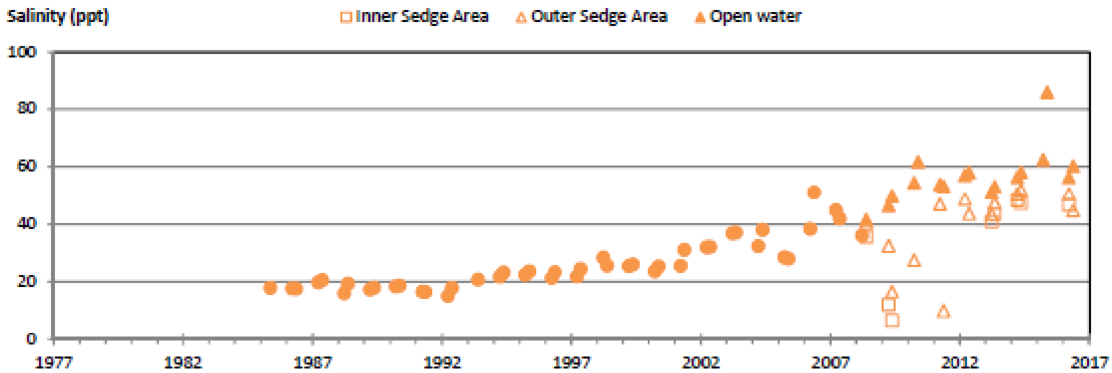

Figure 5. Salinity of Lake Clifton from 1985 to 2017 measured yearly in September and November (from Lane *et al*. 2017).

Moore (1987)	17g/L	26g/L	1984 - 1985
Commander (1988)	15g/L	26g/L	1984 - 1985
			7 years
Rosen et, *al,* (1996)	14.45g/L	27.79g/L	1991 - 1992
			23 years
Whitehead & Vogwill	52.14g/L	123.02g/L	2013 - 2014

Figure 6. Comparison of historic salinity levels from 1984 to 2014 (Whitehead and Vogwill 2013-2015).

C2: Climate modelling projections by DOW (2015) indicate that by 2020 the long-term average annual rainfall for Mandurah (which is 845mm per year for the baseline period of 1961 to 1990) will decline by 2.5, 5.8 and 8.9% under a wet, mid or dry scenario respectively, and by 2030 by 3.4, 9.0 and 13.6% (Figure 7). This means further significant reductions in direct rainfall and fresh groundwater discharge into the lake. Reduced lake water levels are likely to force upconing of hypersaline water in aquifers beneath the lakes, reducing water quality and increasing salinity further. As the salinity level increases a point will be reached where the ionic composition of the lake water will interfere with the chemistry of the formation process with a corresponding reduction in carbonate accretion. At some point, accretion is predicted to cease (pers comm. [redacted]).

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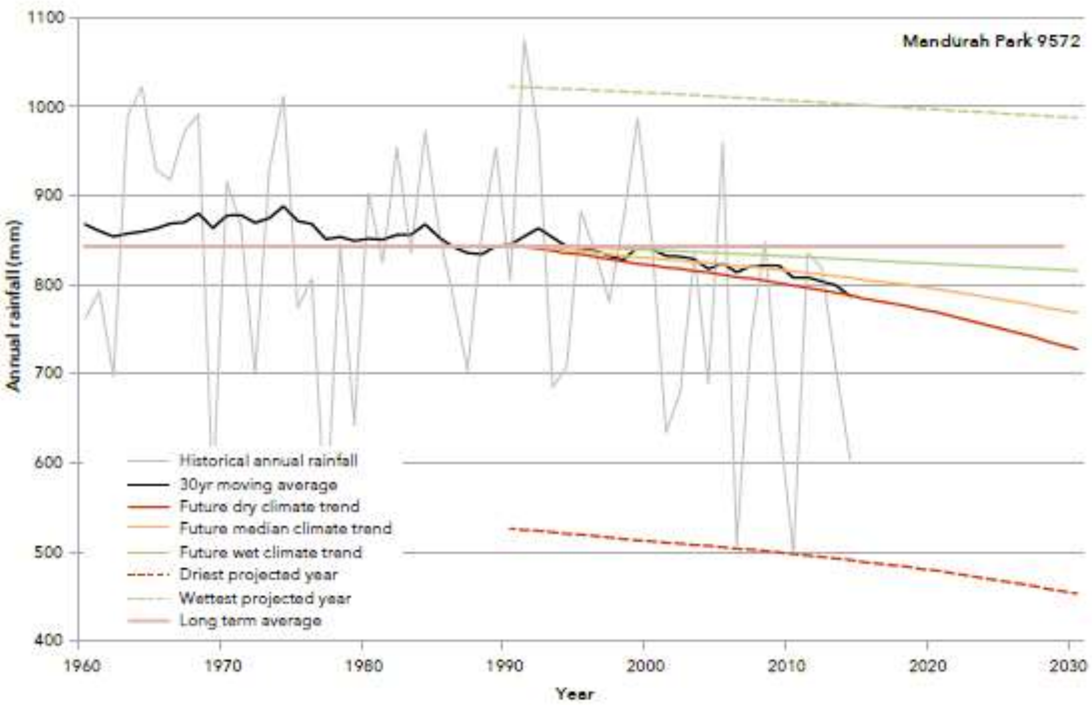

Figure 7. Future predicted scenarios for climate trends at BOM site Mandurah Park 9572 (~21km to the north of Lake Clifton) using a 1961-1990 baseline (from DOW 2015).

C3: Radiocarbon dating indicates that the age of the thrombolites in Lake Clifton is likely to be approximately 1,950 years BP, to modern (Moore and Burne 1994), forming after the isolation of the lake from the sea that occurred between 4,670 and 3,890 years BP (Coshell and Rosen 1994). It is estimated that the hydrological conditions of Lake Clifton prior to 1750 are similar to those recorded in 1985 when conditions were apparently more suitable for accretion of the microbial assemblages. As noted above, the proportion of the total extent of the community in which accretion is currently occurring and the relative severity of decline of accretion is not known, however, in relation to the likely impact of changes in salinity. Therefore, there is insufficient evidence to indicate if the community meets the minimum threshold for proportion of the extent (≥50%) of the community or relative severity of degradation (≥50%) since ~1750, to meet VU under criterion C3.

Criterion D: Disruption of biotic processes or interactions based on change in a biotic variable.

Criterion D	
☐ CR ☐ EN ☐ VU ☒ not eligible	☐ **D1** ☐ **D2** ☐ **D3**

Justification for assessment under Criterion D:

The most significant biotic variable affecting the community is considered to be competition with macrophytes. An increase in nutrients entering the lake since 1988 has resulted in growth of the filamentous green alga Cladophora that can 'smother' the thrombolites and is considered to be indicative of the level of biotic degradation of the community. The collapse state is considered to be the level of competition with green alga (for example Cladophora) such that biotic processes in the microbialite assemblage do not support carbonate accretion.

D1, D2: Since 1988, nutrient levels in Lake Clifton have been increasing to above recommended levels (total phosphorus 0.048mgL^{-1} in 1979 to 0.186mgL^{-1} in August 1988 (Moore 1993)). Blooms of the green alga, Cladophora were also found at the time growing profusely on the thrombolites, at five sampling sites (40m transect), a sign of eutrophication across much of the range of the thrombolites. This alga effectively competes for light with the microbes forming the thrombolites. It can lead to decreased light penetration that reduces or prevents photosynthesis of the thrombolite forming benthic microbial community and has the potential to prevent thrombolite formation and growth. Nutrient concentrations have not been regularly monitored in the Yalgorup Lakes and the most recent available data was collected from Lake Clifton between 2005 to 2006 (John *et al*. 2009; Smith *et al*. 2010). Total nitrogen was between 2 to 4mg/L, and total phosphorus was 0.13mg/L, indicating a trend towards increasing nutrient concentrations. The lack of surface water outflow channels results in dissolved constituents in groundwater and rainfall being retained in the wetlands and becoming concentrated over time, with the only source of flushing through loss of groundwater to the ocean (Coote 2015). From the sampling method used (see below) it can be inferred that the blooms of Cladophora cover approximately 100% of the thrombolites. However, monitoring in 2015 showed that at specified sample sites the microbial assemblages present were producing large amounts of EPS, and so significant accretion was still occurring (pers. comm. [redacted]). Due to lack of the required data it is not possible to determine the relative severity of decline in relation to the specified collapse state. It is not known if the community meets the minimum threshold for proportion of the extent (≥30%) of the community or relative severity of degradation (≥30%) over the past 50 years, or any 50-year period, to meet vulnerable (VU) under criteria D1 and D2.

D3: The local geology indicates that age of the thrombolites in Lake Clifton is likely to be approximately 3,000 to 6,000 years (Moore 1991). It is inferred that the conditions of Lake Clifton prior to 1750 are similar to those recorded in 1985 when conditions were apparently more suitable for growth to occur. Therefore, in relation to criterion D3 it is estimated that 100% of the extent of the community is impacted by the invasive filamentous alga - Cladophora, based on evident nutrient level rises in the lake and apparent blooms of Cladophora indicating eutrophic conditions (John *et al*. 2009). However, it is not possible to determine the relative severity of decline in relation to the specified collapse state and it is not known if the community meets the minimum thresholds for proportion of the extent (50%) or proportional severity of disruption of abiotic processes (50%) since 1750 to meet the criteria for CR under D3.

Criterion E: Quantitative analysis that estimates the probability of ecosystem collapse.

Criterion E	
☐ CR ☐ EN ☐ VU ☒ not eligible	

Justification for assessment under Criterion E:

The ecosystem could not be assessed under Criterion E as there were no quantitative estimates of the risk of ecosystem collapse.

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Summary assessment against IUCN RLE Criteria

Criterion	Rank indicated	Overall conclusion
A1	-	• Available data do not indicate community meets criterion
A2a	-	• Available data do not indicate community meets criterion
A2b	-	• Available data do not indicate community meets criterion
A3	-	• Available data do not indicate community meets criterion
B1a	CR	• EOO is ≤2,000km^2 • An observed decline in environmental quality (ii) and biotic interactions (iii) has occurred due to the change in the specific hydrologic regime that supports the process of accretion in the microbial assemblage. • Meets criterion for CR
B1b	CR	• EOO is ≤2,000km^2 • Observed and inferred continuing decline in the microbial assemblage inferred from changes to the hydrological regime. • Meets criterion for CR
B1c	CR	• EOO is ≤2,000km^2 • Ecosystem exists at one threat-defined location • Meets criterion for CR
B2a	EN	• AOO is three grid cells • An observed decline in environmental quality (ii) and biotic interactions (iii) has occurred due to the change in the specific hydrologic regime that is required to support the process of accretion in the microbial assemblage. • Meets criterion for EN
B2b	EN	• AOO is three grid cells • Observed and inferred continuing decline in the microbial assemblage inferred from changes to the hydrologic regime. • Meets criterion for EN
B2c	EN	• AOO is three grid cells • Ecosystem exists at one threat-defined location • Meets criterion for EN
B3	VU	• Known from one threat-defined location • Prone to the effects of hydrological change, recreational activities • Meets criterion for VU
C1	-	• Insufficient evidence to indicate the community meets the minimum threshold for proportion of the extent (≥30%) of the community or relative severity of degradation (≥30%) over the past 50 years, or any 50-year period, to meet VU.
C2	-	• Insufficient evidence to indicate if the community meets the minimum threshold for proportion of the extent (≥30%) of the community or relative severity of degradation (≥30%) over the past 50 years, or any 50-year period, to meet VU.
C3	-	• Insufficient evidence to indicate if the community meets the minimum threshold for proportion of the extent (≥50%) of the community or relative severity of degradation (≥50%) since ~1750, to meet VU.
D1	-	• Insufficient 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	-	• Insufficient evidence to indicate the community meets the minimum thresholds for proportion of the extent (≥30%) or proportional severity

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		of disruption of biotic processes (≥30%) over any 50-year period to meet VU.
D3	-	• Insufficient evidence available to indicate community meets the 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 under B1a(ii,iii),b,c

Section 4 – References/Standard of Scientific Evidence/Critical habitat

Note: The opinion of appropriate scientific experts may be cited (with their approval) in support of a nomination. If this is done the names of the experts, their qualifications and full contact details must also be provided in the reference list below. Harvard style of referencing is preferred.

43. Please provide copies of key documentation/references used in the nomination.

Barr, A. (2003) Investigation of the Water Balance of Lake Clifton. A Client Report to the Western Australian Department of Conservation and Land Management. CSIRO, Western Australia.

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Lindsay, R. (2002) Climate and land use impacts on groundwater levels in the Lake Clifton and Lake Preston Area. Unpublished Post Graduate Diploma thesis, Curtin University of Technology.

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44. Statement on the Standard of Scientific Evidence

Published data on the Lake Clifton thrombolite community was sufficient to apply the Red List of Ecosystem criteria. There are likely to be inaccuracies in various aspects of the assessment, particularly with distinguishing historical decline estimations. However, the outcomes of the assessment are robust.

45. Has this document been reviewed and/or have relevant experts been consulted?
If so, indicate by whom and provide their contact details.

The document was reviewed by the following people:

Conservation Officer (wetlands), DBCA Swan Coastal District; Parks and Wildlife Service

DBCA Environmental Officer, Wetlands Conservation, Biodiversity and Conservation Science

DBCA Regional Leader Nature Conservation, Swan Region;

University of Western Australia, Crawley.

Director and Principal Hydrogeologist, Hydro Geo Enviro

DBCA PVS Manager South, Parks and Wildlife Service

Ecologist, DBCA Species and Communities Program

District Manager, DBCA Swan Coastal District; Parks and Wildlife Service

Regional Ecologist, DBCA Swan Region

46. Do you wish to propose any areas of habitat for consideration as Critical Habitat for the nominated community?
If so, refer to Ministerial Guideline No 5 and attached a separate nomination proposal addressing the matters required under that guideline. Indicate location/s including a map and attached shapefiles.

Identifying a reasonable buffer along the eastern shore may assist to provide greater protection from landuse practices if this area were well vegetated with native species.

Section 5 - Nominator Details & Declaration

47. Contact Details

Note: Nominator details are subject to the provision of the *Privacy Act 1988*

Title/Full Name	[redacted]
Organisation or Company name	Department of Biodiversity, Conservation and Attractions
Postal address	17 Dick Perry Avenue, Kensington Post: Locked Bag 104, Bentley Delivery Centre, WA 6983.
Email	[redacted]

Department of Biodiversity, Conservation and Attractions

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Phone	[redacted]
Fax	
48. Declaration	
Signature (Or insert electronic signature)	***I declare that the information in this nomination form and any attachments is true and correct to the best of my knowledge.***
Date signed	

Section 6 – Completed nomination form checklist

Please check all items on this list have been completed or are included with your nomination.

- ☐ I have read and applied the further information and guidelines for completing this nomination form in Attachment A
- ☐ Nominator details including name, address contact phone number included
- ☐ Name of the EC
- ☐ Any other names it is known by
- ☐ Map included or attached
- ☐ References cited
- ☐ If questions are left unanswered, a statement indicating that insufficient information is available

A description of:

- ☐ Biological components of the ecological community
- ☐ Non biological components of the ecological community
- ☐ Key interactions and functional processes
- ☐ Characters distinguishing it from other ecological communities
- ☐ Key species (dominant, characteristic or diagnostic, threatened etc)
- ☐ Known or estimated current extent of the ecological community
- ☐ Past/current/future threats including actual/potential, how/ where, how being/how could be abated
- ☐ Which listing category/categories it should be listed under and why

How to lodge your nomination

Completed nominations may be lodged either:

1. by email to: **communities.data@dbca.wa.gov.au**

If submitting by email, please also mail hard copies of attachments that cannot be emailed.

OR

2. by mail to: Species and Communities Branch
Department of Biodiversity, Conservation and Attractions, WA Government
Locked Bag 104, BENTLEY DELIVERY CENTRE WA 6983

If submitting by mail, please include an electronic copy on memory stick or CD.

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Appendix 1.

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Lake Clifton Thrombolites TEC