Status of the rare and endangered *Lychnothamnus barbatus* in southeast Queensland, 2023

Report to Mohamed Bin Zayed Species Conservation Fund

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Cover photo: *Lychnothamnus barbatus in situ* in Wallace Creek, 2023 – Photo A.L.Gilmore & R.L.A.Casanova.

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Executive summary

The distribution and abundance of *Lychnothamnus barbatus,* the endangered 'Bearded Stonewort', was assessed via survey of suitable sites in south-east Queensland in November-December 2023. The species was found in only one site in 2023, reducing the Area of Occupancy and Extent of Occurrence since December 2022. Approximately 50 separate additional sites were surveyed, which adds to the 45 sites surveyed in 2022. *Lychnothamnus barbatus* continued to survive in Wallace Creek. However, in 2023, no other populations were discovered. The species was absent from Warrill Creek (original site from 1960 to 1996) and Wallaby Creek, despite searching the entire extent of Wallaby Creek (previously only found in that locality in 2022). The extent, condition and threats to the population in Wallace Creek were assessed along its entire distribution in Wallace Creek. The seed bank of the site in Wallaby Creek was sampled, but no oospores were detected. It is likely that the sequential flood and drought conditions experienced in the region from February to November 2023 removed the population of *L. barbatus* from Wallaby Creek and prevented reestablishment during 2023.

Under the advice provided for the listing of *Lychnothamnus barbatus* under the EPBC Act (2000) this study provides the results of: (i) survey work in suitable habitat and potential habitat to locate any additional populations/occurrences/remnants, and (ii) a more precise assessment of population size and distribution. Additionally, contact with members of the public, landowners, Landcare groups, local councils (Boonah and Somerset Regional Councils) and conservation organisations (Friends of the Forest, Friends of Yarraman Creek) during the survey work raised awareness about the species and its conservation. The work resulted in several posts to social media during the survey, highlighting the importance of the species and acknowledging the funding supplied by Mohamed bin Zayed Species Conservation Fund.

The evidence gathered so far demonstrates that this listed, Endangered species is on the brink of extinction in Australia. A single extreme weather event in its critical habitat could result in its extirpation. Further surveys to confirm reported populations and find new populations, along with ecological studies, are required to provide information about its habitat conditions, recovery potential and conservation actions.

Lychnothamnus barbatus

The species, its protection and aim of this study

Lychnothamnus is a genus in family Characeae (the stoneworts or *charophytes*), a group of green macroalgae that occur in fresh and brackish waters worldwide. This group of plants, charophytes, are important in freshwater ecosystem functioning. They provide food and habitat for invertebrates (which in turn are food for fish and birds), they stabilise the sediment, they help to remove turbidity from the water and overall, are indicators of good water quality (Schubert et al. 2018).

The genus *Lychnothamnus* has a single extant species: *L. barbatus* (the Bearded Stonewort), as well as several fossil species that were widespread and abundant from 93 to 40 million years ago (Vincente et al. 2020). *Lychnothamnus barbatus,* as a species, has a fossil history extending back to the Cretaceous (c. 70 million years ago; Musaccio 2010), with Australian fossils occurring in the Gulf of Carpentaria from the Pleistocene (14–40 thousand years ago; García and Chvias 2006). The species is thought to be a relict species (similar to the Wollemi Pine), having co-existed with dinosaurs, with a unique lineage in the tree of life (Karol et al. 2017). The charophytes as a group are living relatives of the ancestors of all the land plants (Karol et al. 2000).

Lychnothamnus is clearly distinguishable from other charophytes on the basis of the arrangement of its reproductive structures and its overall morphology. Its status and relationships are also well supported by genetic studies (McCourt et al. 1999; Karol et al. 2017). The species is known to occur in Europe, North America and Australasia, although it is considered rare throughout its distribution (Casanova et al. 2003; Karol et al. 2017). *Lychnothamnus barbatus* was listed under the Environmental Protection and Biodiversity Act (Commonwealth of Australia 2000) as *Endangered,* and under the Queensland Nature Conservation Act (1992) as *Threatened*. Under a State and Commonwealth agreement to use a common method of assessment for threatened species it is proposed that there be a standardised listing for the species in the future based on IUCN criteria (IUCN 2001). That threat-level (based on the Area of Occupancy, Extent of Occupancy and location-based threats) is likely to be *Critically Endangered*.

Conservation Adivce for *Lychnothamnus barbatus* was approved in 2008 (Commonwealth of Australia 2008) and consequently, under the EPBC Act, a referral should be sought if the species is likely to be significantly impacted by activities such as bridge-works or water extraction.

A survey was conducted in December 2022 with support from the Department of Transport and Main Roads Queensland, specifically for *L. barbatus*. Forty-five sites were surveyed, including the original location in Warrill Creek and the second location in Wallace Creek. At that time Warrill Creek was thoroughly surveyed but *L. barbatus* was not found. The population in Wallace Creek was surveyed upstream of C.Head Road, and found to have declined in abundance since 1996, although the population was distributed along at least 100 m of the creek line. The creek below C.Head Road was unable to be surveyed due to a lack of permission to enter the property. An additional site in Wallaby Creek was discovered, but not thoroughly surveyed due to a lack of permission to enter private properties along the creek.

As a result of funding by the Mohamed bin Zayed Species Conservation Fund this study aimed to 1) obtain permissions and contacts to survey where *Lychnothamnus barbatus* occurs in Queensland; 2) survey the known populations to determine habitat conditions, the status of the populations and threats; 3) undertake a more extensive survey of suitable habitat in south east Queensland to discover additional populations; and 4) inform the local land managers of the existence and importance of this species in an effort to conserve it in Australia.

Description

Like all charophytes *L. barbatus* (Fig. 1a) has a similar overall appearance to many water plants (e.g. *Ceratophyllum, Myriophyllum*), growing underwater with upright axes or stems, whorls of leaves or branchlets (Fig. 1c), and anchored in the soil by roots or rhizoids. *Lychnothamnus* is relatively easy to distinguish from other members of family Characeae, even when growing as part of a charophyte community (Fig. 1b).

Instead of having multicellular organs (like flowers, leaves and roots), its stems and branchlets consist of single cells, joined end-on-end; and its reproductive structures are oogonia and antheridia instead of flowers (Fig. 3). *Lychnothamnus* is characterised by an incomplete stem cortex, ecorticate branchlets with long bract cells, oogonia and antheridia arranged side-by-side and gyrogonites on the oospores (Fig. 3).

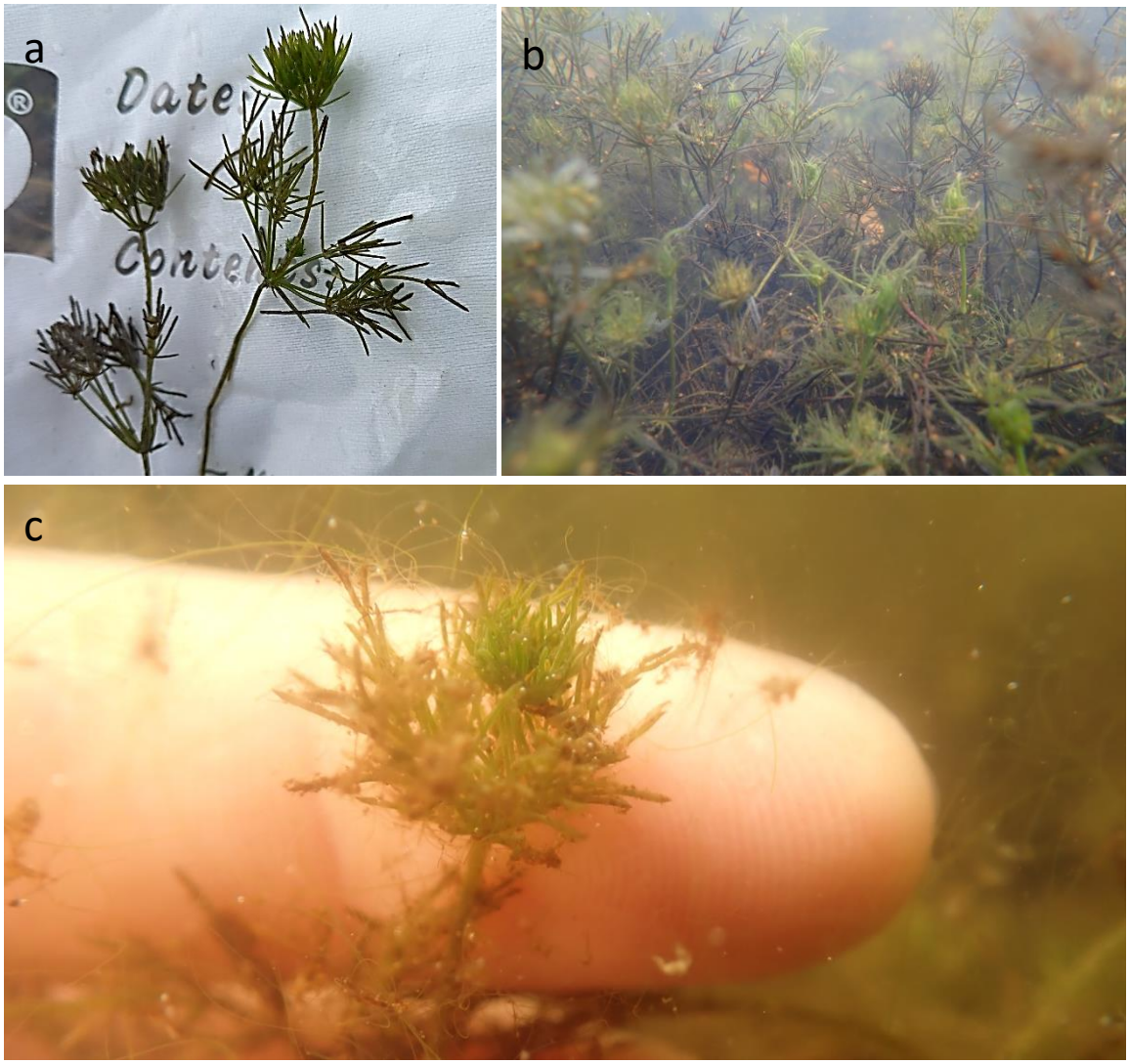

Figure 1. a) *Lychnothamnus barbatus* from Wallace Creek. Plants are characterised by whorls of naked branchlets with long bract cells and scarcely corticated axes. b) *Lychnothamnus barbatus* growing in Wallace Creek, 2023 in a mixed community of charophytes. c) Apex of *L. barbatus* shoot (with a finger for scale).

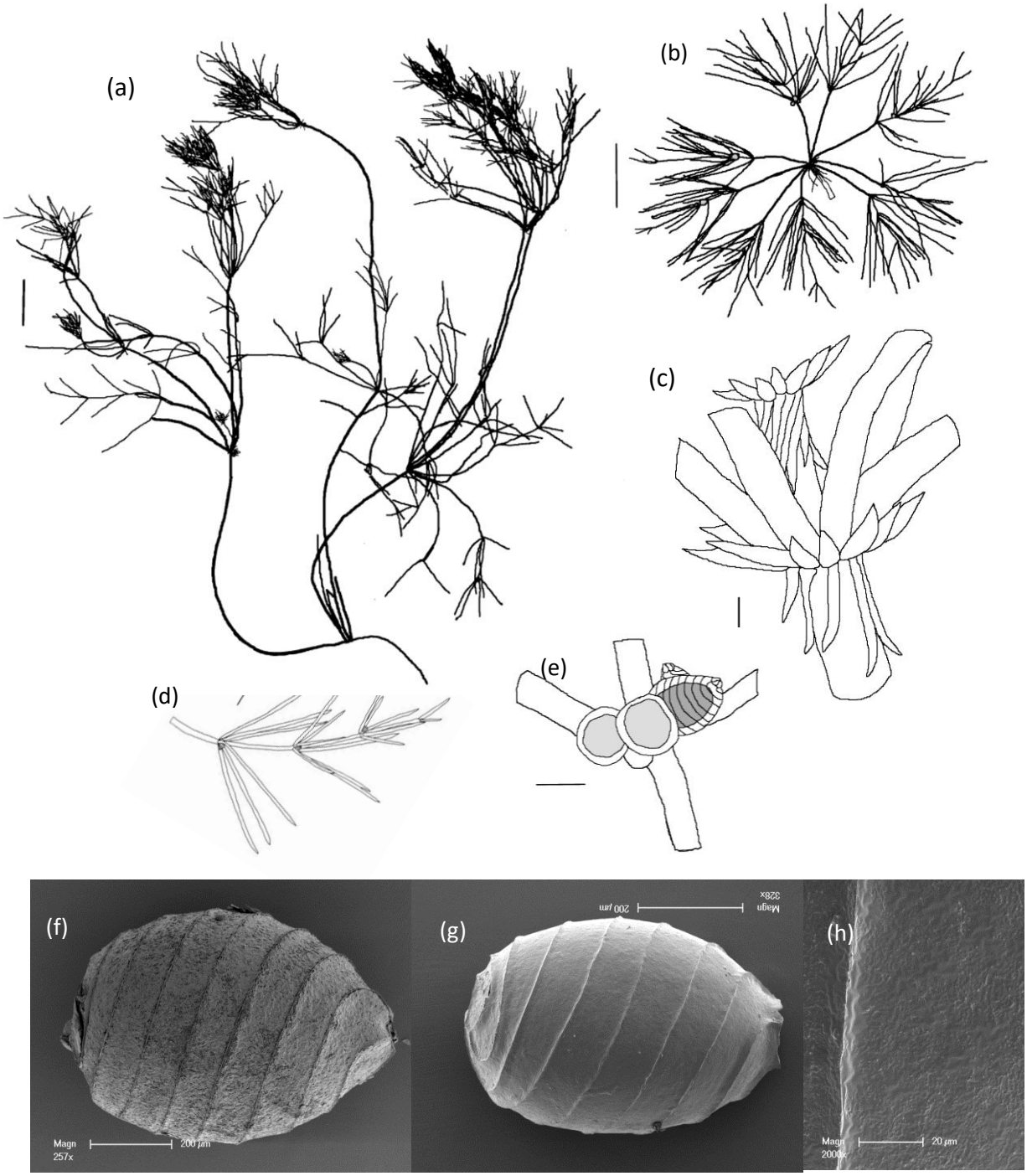

Figure 2. ***Lychnothamnus barbatus*****. a) Overall morphology of the plant. b) Whorl of branchlets seen from above. c) Morphology of nodes showing incomplete cortication and single row of stipulodes. d) A single branchlet showing whorls of long bract cells. e) Gametangia arranged side-by-side at a branchlet node, two antheridia and two oogonia. f) Gyrogonite (calcified oospore covering). g) Oospore in side-view. h) Detail of oospore wall (after Casanova and Karol in press).**

Methods

Charophyte specimens

Over the past several years all the available charophyte collections from Queensland that were deposited in various herbaria in Australia (AD, BRI, DNA, CANB, HO, MEL, NSW, PERTH) and overseas (BM, L, PC, LE, NY, W, LD, L) were examined. This amounted to 125 gatherings of species of *Chara, Nitella, Lamprothamnium* and *Lychnothamnus* collected between 1843 and 1996. Additional gatherings since 1996 by Casanova and associates added another 124 specimens. Between 22nd November and 11th December 2023, approximately 50 separate sites (Fig. 3) in south-east Queensland were surveyed specifically for *Lychnothamnus barbatus*. Sites were selected on the basis of locality (in the vicinity of previous collections; in areas with a similar geology and climate) or the occurrence of charophytes in the past (based on collections deposited in herbaria or recorded in the Atlas of Living Australia or iNaturalist), or general appearance and apparent water quality in a stream or wetland. The historical specimens were geolocated using Google Maps, based on the herbarium labels and information about the collectors. The recent specimens were geolocated *in situ* using a hald-held GPS device. Some of the locations are approximate (e.g. Bailey, s.n. *Brisbane*), but recent gatherings and those by Wood in 1960 are precise to within 10 m.

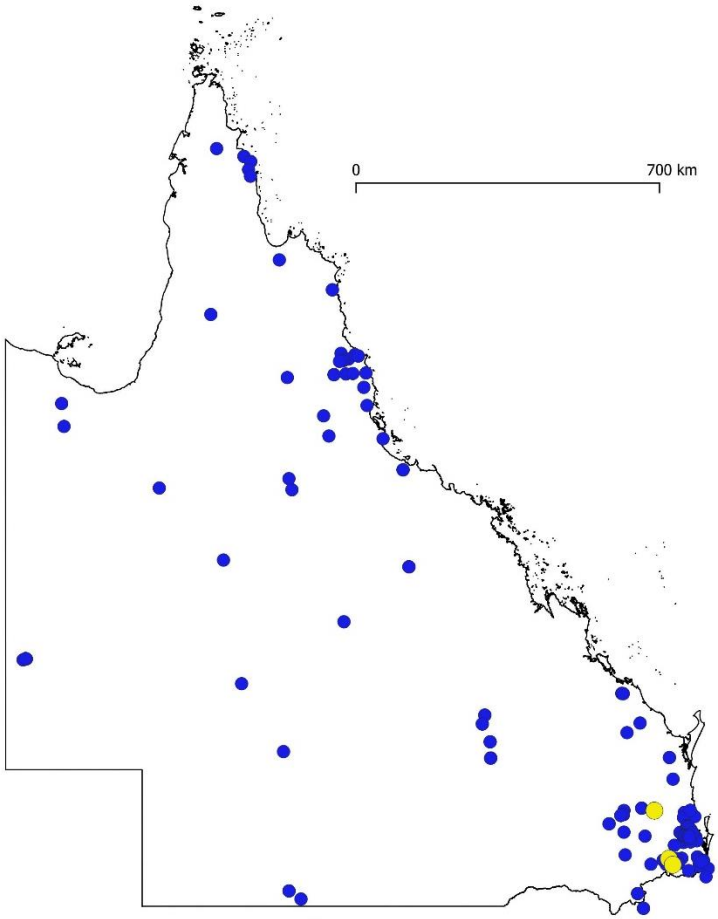

Figure 3. Sites where charophytes (blue dots) have been collected in Queensland between 1843 and 2023. Yellow dots indicate where *L. barbatus* has been collected (on the basis of vouchers seen).

Contact with land-owners

In Australia it is trespass to enter private property without permission. Therefore, in each region where *L. barbatus* had been discovered in the past, the local shire council was contacted, and contact was made with the Environmental Officer appointed by the council. Environmental Officers contacted the land-owners directly to obtain permission for the botanists to enter their property.

Once the land-owners were contacted and met, they were able to provide additional contacts via their community groups (Friends of the Forest; Friends of Yarraman Creek, Landcare groups, neighbours) in the local area. Additionally, the botanists made casual enquiries of the general public where they stopped to eat and stay, and in this way were informed of other potential localities where *L. barbatus* might occur.

General survey methods (1996 – 2023)

On arrival at survey sites the investigators undertook a safety assessment (hazards: snakes, falls, drowning, traffic hazards) and then, if safe, proceeded to survey for water plants. Most of the survey work was undertaken via wading/swimming in the water (Fig. 4a), but where the water was too deep, a grapnel was used to collect charophytes (Fig. 4b). If charophytes were detected a numbered collection was made, retained in water from the site in a plastic zip-loc bag. The locality was recorded, along with depth of collection. If a charophyte was suspected to be *L. barbatus* photos were sent to the senior author for on-the-spot confirmation (Fig. 5a, b). Collected charophytes were rinsed, pressed on paper (3 replicates). Some of the remaining material was placed in bags with water from the site for longer-term culture, and/or also preserved in 70% alcohol in a vial or jar. All samples were labelled with the collection number.

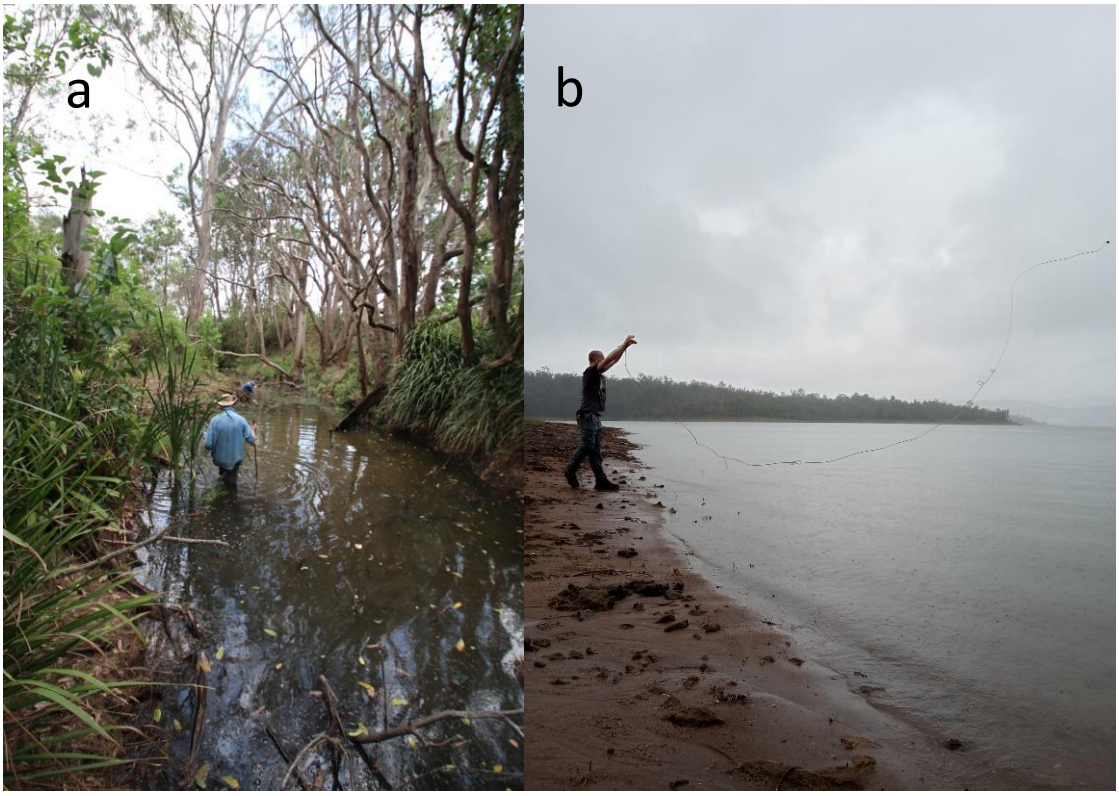

Figure 4. a) Collecting charophytes in a shallow creek. b) Collecting charophytes in a deep reservoir via grapnel. If charophytes were detected via grapnel the botanists swam to collect (when safe).

Pressed material was thoroughly dried, inserted into acid-free plastic sleeves and duplicates will be deposited at Queensland Herbarium (BRI), the National Herbarium of Victoria (MEL) or the William and Lynda Steere Herbarium of the New York Botanical Garden (NY). Cultured and spirit preserved material are retained by the author pending further study.

Population survey 2023

Where *Lychnothamnus barbatus* had been found in 2022 (Wallace Creek in Boonah Regional Council area, and Wallaby Creek in Somerset Regional Council area) comprehensive assessments of the

distribution, abundance and habitat conditions were made. The botanists walked to the head of each creek then assessed the composition of the charophyte community while walking/wading downstream. When *L. barbatus* was found we recorded the extent of the population coverage (m^2), health or appearance (1 = encumbered by epiphytes, broken branchlets to 5 = clean, actively growing with reproductive organs and many new shoots). The depth range and boundaries were measured (tape measure). The water pH, conductivity ($mScm^{-1}$), temperature (˚C) and turbidity (NTU) were measured using a hand-held water quality meter. The substrate type (qualitative assessment) and riparian characteristics (shading, species, evidence of grazing) were recorded, along with associated charophyte species. Photos were taken at each site, along with underwater photographs and motion pictures of *L. barbatus* using an Olympus TG-6 digital underwater camera. In sites where *L. barbatus* had occurred in the past but was no longer present seed bank samples were collected by obtaining c. 10 x 30g of material from a diversity of places within the creek-line where oospores might have been deposited. The samples were mixed, subsampled and then sieved through 500 µ and 250 µ mesh Endcot sieves and the retained material examined with the use of a Zeiss binocular microscope following the methods of Casanova et al. (2003).

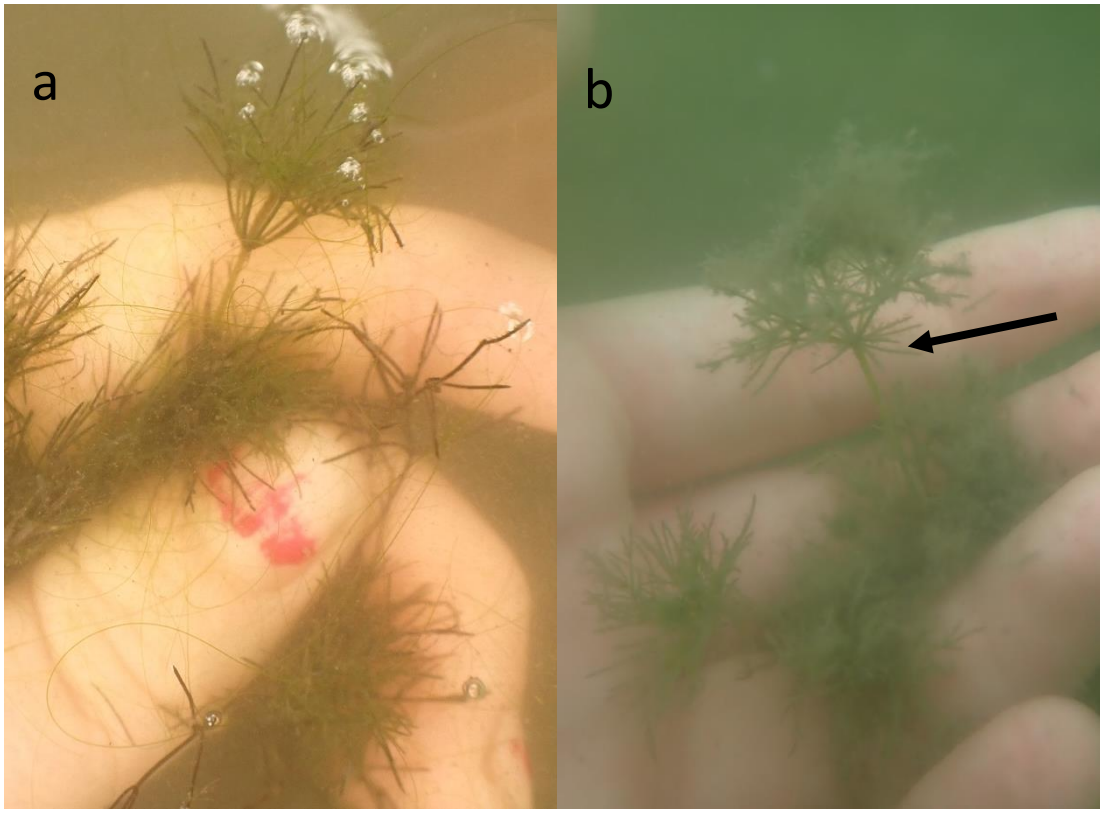

Figure 5. Photos of specimens taken for confirmation of species. a) *Nitella sp.* characterised by a lack of stipulodes and lack of cortication. b) *Lychnothamnus barbatus* showing whorled bract cells and stipulodes (arrowed).

Results

Charophyte specimens and general survey

A total of 178 gatherings of charophytes from Queensland were examined before this study, (Fig. 3). This survey added an additional 50 sites and 34 separate gatherings of charophytes (Fig. 6). Of all the sites in Queensland where charophytes have been collected, *Lychnothamnus barbatus* has been recorded from only three sites (c. 1% of sites) historically: Warrill Creek (1960–1996), Wallace Creek (1996–2023) and Wallaby Creek (2022) (Fig. 3). The populations in Warrill and Wallaby Creeks were not detected in 2023, and we did not find oospores in the seed bank of those sites (in 1996 for Warrill Creek, and in 2023 for Wallaby Creek). A number of species of *Chara* and *Nitella* were collected, some of which are likely to be new or poorly know species.

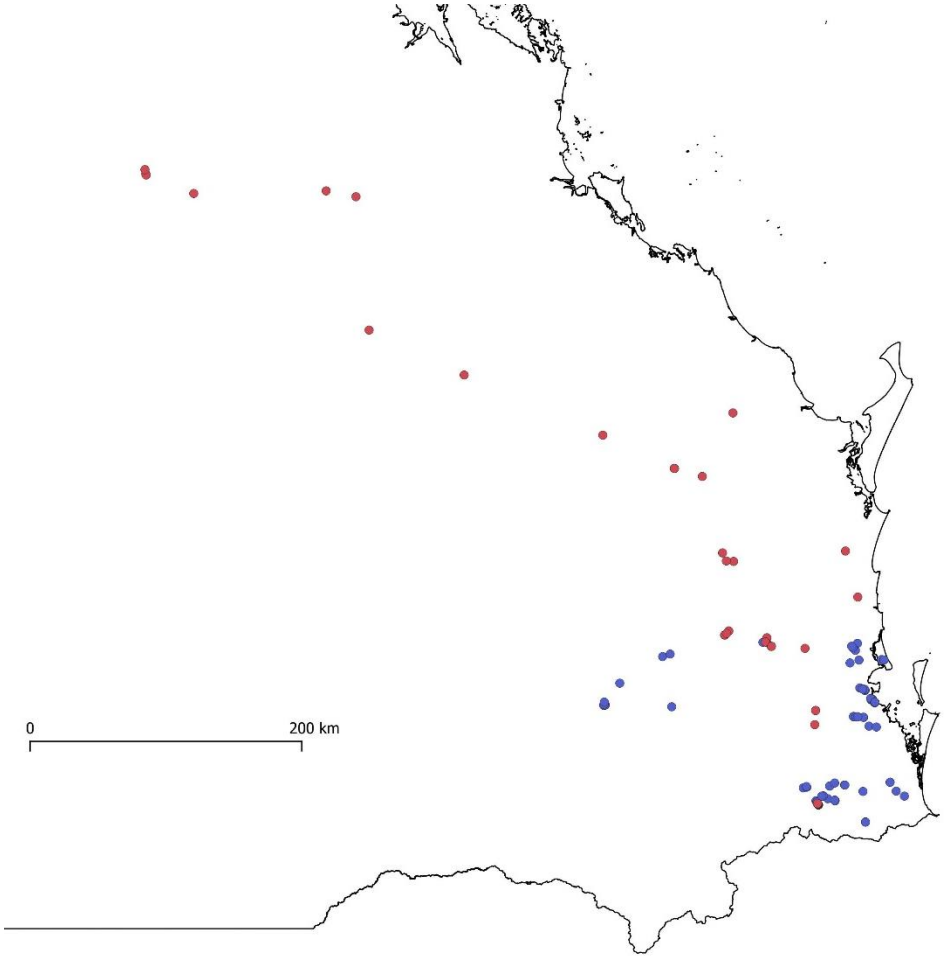

Figure 6. Sites in the Australian state of Queensland that were surveyed for *Lychnothamnus barbatus* in 2022 (blue dots) and 2023 (red dots).

Population survey

Wallaby Creek was traversed from the headwaters to where it met the Brisbane River. The waterway was largely dry in the upper reaches and consisted of well-separated still, shallow pools in the lower reaches. The prevailing land use along the creek was cattle-grazing. *Lychnothamnus barbatus* was not found in any part of the creek in 2023. The Brisbane River was also sampled, along with similar waterways in the vicinity of Wallaby Creek (Emu Creek, Yarraman Creek) and although charophytes were collected, *L. barbatus* was absent in 2023. No oospores of *L. barbatus* were detected in the seed bank samples taken from Wallaby Creek.

Wallace Creek was traversed from the headwaters to where it met Warrill Creek. The waterway consisted of a series of relatively stagnant pools, separated by shallow, or dry, riffles, except in the

lower reaches where some flow was apparent. The prevailing land use in the catchment was cattle-grazing, with open access to the creek. Many sites had evidence of use by cattle (pugging, erosion). There were scattered riparian trees along the creek, specifically *Casuarina cunninghammii*, *Melaleuca lanceolata* and *Eucalyptus tereticornis* and stands of reeds within the creek. Below the intersection with C.Head Road the abundance of riparian vegetation and shading in the creek increased and became dominated by *Lantana camara* (a weed species in Queensland that produces impenetrable thickets).

Lychnothamnus barbatus was found in 14 separate in Wallace Creek sites along a length of approximately 1 km of creek line (Fig. 7). The first charophytes (beds of *Nitella hyalina*) were detected c. 200 m upstream of the first occurrence of *L. barbatus*. Populations of charophytes (*Chara* spp and *N. hyalina*) were also detected in several sites downstream of the last site for *L. barbatus*, as far as the crossing at Gillet Court. No populations were detected downstream of Gillet Court crossing.

Sites where *L. barbatus* occurred were from 0.03 to 1.27 m deep (Figs 8, 9), with a pH of between 7.73 and 8.58. The water was described as 'clear to green to brown or oily', and at the lowest site was occupied by iron-bacteria. Sites were reasonably fresh (conductivity of 2.41–4.94 $mScm^{-1}$) and the water was relatively clear with turbidity ranging from 40.16–314 NTU (Table 1). The sites where the abundance and condition of *L. barbatus* was ranked to be best (5 out of 5 on the condition score and >20 m^2 in area) had deeper maximum depths than the average site (up to 1.27m deep), a lower temperature and higher water clarity (lower turbidity) than the average of the other sites (Table 1) although the differences were not statistically significant ($p>0.05$).

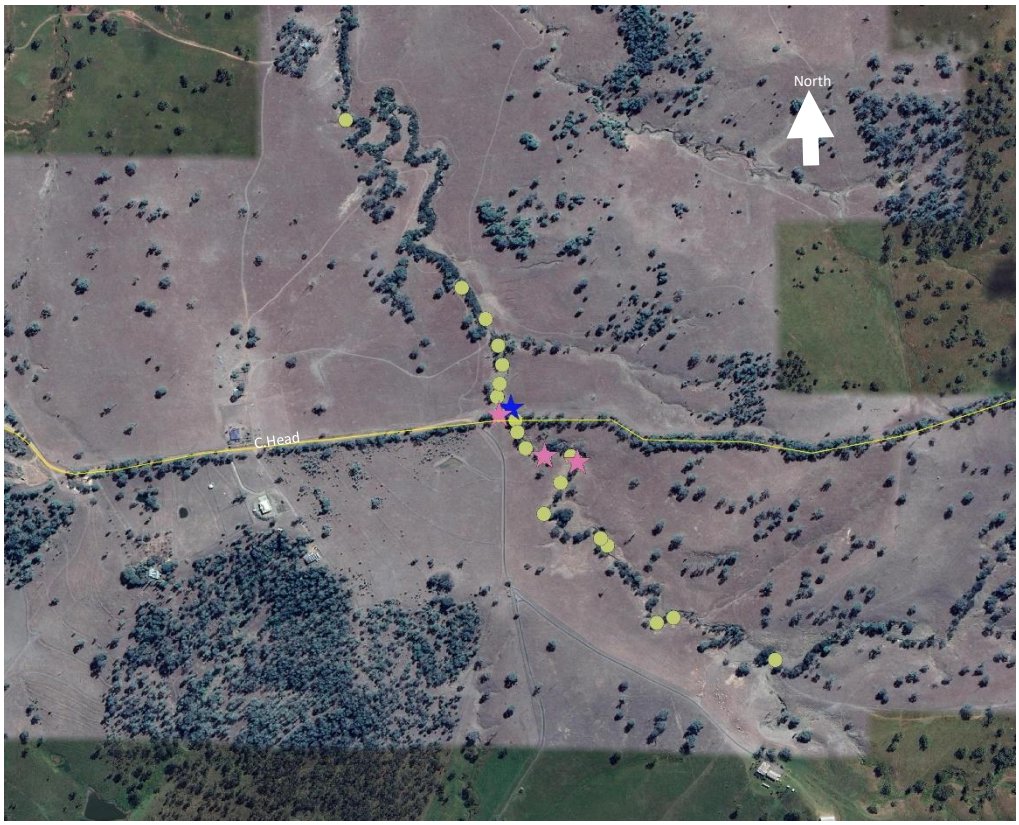

Figure 7. Sites where L. barbatus occurred in Wallace Creek. The creek flows from the south-east to the north on the map. The blue star indicates the site of the original discovery in 1996, pink stars are collection points from 2022 and yellow circles are where the species was found and detailed assessments were undertaken in 2023.

Table 1. Site and condition characteristics for *Lychnothamnus barbatus* in Wallace Creek in 2023. *Average depth at each site was not recorded.

Site code	Estimated area (m^2)	Condition of plants (1=bad-5=good)	Depth range (m)	Water quality description	Substrate	pH	Conductivity ($mScm^{-1}$)	Turbidity (NTU)
1	1.5	4	0.75– 0.8	Clear-green	Black silt mud	7.86	3.08	40.16
2	1.5	4	0.5– 1.0	Green	Black silt mud	7.86	3.08	40.16
3	0.4	3	0.3– 0.45	Clear-green	Black silt mud	8.02	4.77	71.50
4	1	3	0.8	Clear-green	Clay-sand-silt	8.02	4.77	71.50
5	0.5	3	0.07– 0.26	Clear-green-oily	Clay-sand-silt	8.41	2.41	152.23
6	20	5	0.15– 1.27	Clear-oily	Clay-sand-silt	7.9	3.2	15.40
7	3	5	0.2– 0.85	Clear-brown-green	Clay-sand-silt	8.58	2.69	107.70
8	0.5	4	0.33	Clear-green	Black silt mud	8.74	2.69	162.0
9	6.5	5	0.44– 0.63	Green-oily	Black silt mud	8.1	3.01	94.30
10	3	4	0.21– 0.81	Green	Black silt mud	8.27	3.09	92.35
11	30	5	0.35– 1.15	Clear-green	Black silt mud	8.31	2.85	41.00
12	10	5	0.15– 0.42	Clear-green	Gravel-sand	7.86	3.96	314.66
13	0.05	2	0.15– 1.27	Clear-oily	Black silt mud	7.86	3.94	314.66
14	0.05	2	0.03	Flocculent-iron bacteria-oily	Pebbles	7.73	4.94	67.80
average	**5.57**	**3.8**	*			**8.18**	**3.33**	**105.37**
range	**0.05–30**	**2–5**	**0.03–1.27**			**7.73–8.58**	**2.41–4.94**	**40.16–314.66**

Figure 8. Sites in the lower parts of Wallace Creek

Figure 9. Sites in the upper catchment of Wallace Creek

Discussion

This study provides evidence for a change in the listing of *Lychnothamnus barbatus* from *Endangered* to *Critically Endangered* in Australia. Actions are needed to prevent its extinction. We found what appeared to be a healthy population in Wallaby Creek in 2022 had been removed by extreme flooding with scouring flows, followed by the driest Spring ever recorded in Australia (BOM 2024). The population appears to have been removed from the lower reaches of Wallaby Creek via scouring

flows, and in the upper reaches by having the habitat dry completely. These events are in line with past predictions of more extreme weather events for eastern Australia. The original population in Warrill Creek appears to have been driven to extinction by changed water regime and increased nutrients as a consequence of irrigated agriculture in its catchment. Since this survey was undertaken there have been intense storms and flooding in south-east Queensland, in the vicinity of the only remaining population in Wallace Creek and the current condition of that population (in January 2024) is not known.

The results of this study support reassessment of the prioritisation, likelihood and severity of threats to *Lychnothamnus barbatus*. The greatest threat appears to be an increased likelihood of severe weather events due to climate change, because this can have the greatest consequence (i.e. complete removal of a population, including its seed bank). The consequences are likely to be exacerbated by removal of water from the system for agricultural purposes.

Disturbance by cattle grazing was listed as a threat by Casanova (2023). However, the population survey results from Wallace Creek do not currently support a high threat category. The stocking rate is apparently low in the catchment of Wallace Creek and healthy populations of *L. barbatus* were found even where disturbance from cattle was obvious (i.e. near cattle crossings, where there was pugging). It is possible that some disturbance actually facilitates *Lychnothamnus* persistence by exposing the seed bank to light and allowing oospores to germinate. It is quite likely that cattle grazing, while not markedly detrimental to *Lychnothamnus*, is not necessary for its survival. The ideal stocking rate is not known, but high stocking rates could be detrimental to *Lychnothamnus*, and natural disturbance from variable flow might be enough to facilitate *Lychnothamnus* persistence in the absence of cattle.

Although competition with exotic species was not flagged as a threat by Casanova (2022), the survey results indicate that where there is deep shade from riparian species (particularly exotic *Lantana camara*) *Lychnothamnus* was not found. The healthiest and most extensive populations were exposed to dappled sunlight through moderately sparse riparian vegetation.

Habitat critical to survival in Australia

At the present time, the habitat critical to the survival of *Lychnothamnus barbatus* in Australia, based on vouchered specimens and repeated surveys, is Wallace Creek, upstream and downstream of C.Head Road on private property. Cattle grazing occurs in the riparian zone and the sites where *L. barbatus* was most healthy were in dappled shade of riparian trees. The stream appears to exist perennially, consisting of pools up to 1.5 m deep, interspersed with shallow, stony riffles. *Lychnothamnus* occurs in the pools, primarily. Flow rates vary from time to time (as demonstrated by debris in the surrounding vegetation and erosion of the banks), but the range of variation is not quantified. Water appears to be mesotrophic (although we did not measure nutrients), fresh and flowing, with a pH of 7.7–8.5, conductivity of 2.41–4.94 μScm^{-1}, and turbidity ranging from 40 to 314 NTU. Terrestrial vegetation consists of several tree species (*Casuarina cunninghammii*, *Melaleuca lanceolata* and *Eucalyptus tereticornis*) and Grass trees (*Xanthorrhoea johnsonii*), with a grassy understory.
Further study documenting the light regime within the habitat, photosynthetic rates, along with co-occurring flowering plant, vertebrate and invertebrate species would enhance our understanding of habitat parameters.

Threats

Based on assessment by the survey data and observations in 2022 and 2023 the following threats are documented (Table 2). A risk matrix is provided in Table 3.

Table 2. Threats are noted in approximate order of highest to lowest impact, based on available evidence from the 2023 habitat survey. There are two additional sites on Cape York reported (García and Chivas 2006) for which vouchers have not been seen, and these are not included in the assessment.

Threat	Status	Evidence
Climate change and severe weather	• Timing: current • Confidence: observed • Likelihood: likely • Consequence: catastrophic • Trend: increasing • Extent: across the entire known range	The incidence of severe floods causing scouring flows has increased in south-east Queensland (NSW EPA). The incidence of extremely low rainfall causing drought and no-flow events has increased in south-east Queensland (NSW EPA). High flows have been observed to remove populations including seed bank material. Drought that results in drying of habitat has been seen to completely remove populations in Wallaby Creek.
Cattle grazing and erosion of banks by cattle	• Timing: current/future • Confidence: observed • Likelihood: almost certain • Consequence: moderate • Trend: stable • Extent: 100% of populations.	The site where *L. barbatus* occurs at C.Head Road is largely on private property and open to cattle grazing. There appears to be significant erosion of the banks where cattle drink and cross the creek (as well as natural erosion from variable flows).
Habitat loss, disturbance and modification	• Timing: current/future • Confidence: observed • Likelihood: almost certain • Consequence: major • Trend: increasing • Extent: throughout the known range of the population.	Where *L. barbatus* occurs at Wallace Creek there appears to be little retention of native vegetation in the riparian zone, and almost no reestablishment. Wallaby Creek is also in cattle country, but has more established riparian vegetation. However, water extraction occurs from Wallaby Creek on a regular basis, even during periods of no-flow.
Altered water quality caused by anthropogenic activities	• Timing: current/future • Confidence: observed • Likelihood: likely	The catchment of all stream sites is in highly utilised agricultural landscape. There is

	• Consequence: major • Trend: increasing • Extent: across the entire range	evidence of runoff from agricultural land along Warrill Creek, potentially leading to eutrophication. Some patches of *L. barbatus* were invested with filamentous and other algal growth.
Invasion of and shading by exotic species	• Timing: future • Confidence: observed • Likelihood: likely • Consequence: moderate • Trend: not determined • Extent: not known	Sites downstream of the occurrence of *L. barbatus* are heavily shaded by the exotic *Lantana camara* which could be influencing the occurrence and abundance of *L. barbatus.*
Altered water regimes	• Timing: past • Confidence: inferred • Likelihood: possible • Consequence: moderate • Trend: stable • Extent: Warrill Creek	Development of onstream weirs or dams has occurred or been proposed in the past for Warrill Creek, and occurs in other rivers that could provide potential habitat for *L. barbatus.*
Road works and bridge works	• Timing: current/future • Confidence: observed • Likelihood: likely • Consequence: moderate • Trend: stable • Extent: across the entire known range	Repair or creation of bridge works has occurred at two sites, and will occur in the future due to those sites being on highway crossings. The site on Wallace creek has a number of small fords where erosion can occur.

Timing—identifies the temporal nature of the threat
Confidence—identifies the nature of the evidence about the impact of the threat on the species
Likelihood—identifies the likelihood of the threat impacting on the whole population or extent of the species
Consequence—identifies the severity of the threat
Trend—identifies the extent to which it will continue to operate on the species
Extent—identifies its spatial context in terms of the range of the species

Categories for likelihood are defined as follows:
Almost certain – expected to occur every year
Likely – expected to occur at least once every five years
Possible – might occur at some time
Unlikely –known to have occurred only a few times
Unknown – currently unknown how often the threat will occur

Categories for consequences are defined as follows:
Minor – individuals are adversely affected but no effect at population level
Moderate – population recovery stable or declining
Major – population decline is ongoing
Catastrophic – population trajectory close to extinction

Table 3 Risk Matrix

Likelyhood	Consequences				
	Not significant	Minor	Moderate	Major	Catastrophic
Almost certain			Cattle grazing and erosion	Habitat loss	
Likely			Exotic species; Road works and bridge works	Altered water quality	Climate change and severe weather
Possible			Altered water regime		
Unlikely					
Unknown					

Risk Matrix legend/Risk rating:

Low Risk	Moderate RIsk	High Risk	Very High Risk

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