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The status and conservation of Malabar River-lily (*Crinum malabaricum*) (Liliopsida: Amaryllidaceae)

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Abstract: The Malabar river-lily (*Crinum malabaricum* Lekhak & S.R.Yadav) is endemic to northern Kerala, south-western India, it was described new to science in 2012. It is native to seasonal rivers flowing over laterite at 80-100 m above sea level, in an area of approximately 5 x 10 km in Kannur and Kasaragod Districts. Populations are limited upstream by reaches involving steeper gradients with faster flow and downstream by deeper water over silt. It typically forms dense stands covering the entire channel with leaves forming a dense mat as water levels drop. Population counts suggest that the global population is more than 25,000 individuals. All known populations are abundantly fertile, flowering and setting seed abundantly from early September to late November. *C. malabaricum* is a major ecosystem architect, providing shelter for fish and invertebrate communities. Overall, known populations of *C. malabaricum* may be considered stable and relatively secure, although there is potential for local actions to affect all populations. The apparent absence of a mechanism for formal protection of sites supporting *C. malabaricum* highlights the need for surveys of potentially suitable habitat within the known range of the species, as well as for monitoring of all known populations to identify population trends.

Key words: Ecology, Conservation, Laterite Hills, Kerala

Introduction

The genus *Crinum* (Liliopsida, Amaryllidaceae) includes around 120 species worldwide (POWO, 2025) distributed throughout tropical regions, although new species are often described (Afroz *et al.*, 2018; Rasingam *et al.*, 2024), and the genus is described as needing taxonomic revision (Hewson, 2024). Many species are strongly associated with wetland habitats, although some occur in dry habitats or even deserts (POWO, 2025). *C. malabaricum* Lekhak & S.R.Yadav is one of two Asian species which are dependent upon flowing water, the other being *C. thaianum* J.Schulze which is endemic to Thailand. *C. malabaricum* was described new to science in 2012 (Lekhak & Yadav, 2012) from a seasonal river in the vicinity of Periya Village, Kasaragod District in northern Kerala, south-western India. *Crinum malabaricum* (Fig. 1) develops from large basal bulbs in clusters of 20-30, from which 8-19 leaves develop per bulb. The leaves are more or less parallel-sided and may be up to 4 m long and 2.5 cm wide, plants grow at a density sufficient that the leaves typically form a complete, closed canopy on the water (Fig. 1b) over distances of up to 2 km. Flowers are borne on a leafless stem up to 1.5 m long, bearing 6–13 flowers and each fruit produces 3–16 seeds (Lekhak & Yadav, 2016).

Surveys by Biju P. (Lansdown, 2023) revealed that native populations of *C. malabaricum* are restricted to a discrete area of northern Kerala. The topography of northern Kerala is characterised by the high mountains of the Western Ghats which run north to south, more or less parallel to the coast

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Fig. 1. *Crinum malabaricum* at Periya: **a**. Flower; **b**. Leaves covering the channel at Periya in 2017; **c**. Unripe fruits; **d**. Mature and dehiscent fruits (images R.V. Lansdown).

and reach heights of over 1300 m in places. To the west, there is a line of lower, more rolling hills, mainly composed of laterite, a soil and rock type produced by prolonged and intensive weathering of the parent rock, separated from the coast by low-lying plains, many of which are topped by extensive level plateaus. These plateaus often include areas with thin soils which are too shallow to support tall or woody vegetation (Sreejith *et al.*, 2016), however there are also extensive areas of more or less level ground which support woodland or forest crops. On areas with thin soils, the impermeable laterite means that during the monsoon, hollows hold water, creating large numbers of ephemeral pools which support a wide range of wetland-dependent plant species, many of which are endemic to the region. The poor suitability of the plateaus for agriculture means that they have historically been classed as "waste lands" (Pulparambil & Pradeep, 2023) and many are threatened by housing, as well as extraction of rock for building materials.

Crinum malabaricum contains several medicinally important alkaloids with analgesic, antiviral, and antitumor characteristics and is now the most promising treatment option for Alzheimer's disease under the trade names Reminyl® and Nivalin® (Pulparambil & Pradeep, 2023). The flowers of *C. malabaricum* are used by local people to prepare Pookkalam which is a circular decoration made on the floor for the Onam festival in Kerala (Figs. 2e &f).

Crinum malabaricum occurs in six seasonal rivers flowing over gentle gradients mainly through forest or forest crops. This article describes the results of surveys carried out between 2017 and 2025 to characterise ecology of *C. malabaricum*, assess the conservation condition of the different populations and monitor reproductive success. Each year, students of the second year Botany course at the Government College, Kasaragod have contributed to data collection (Fig. 2a).

Material and Methods

Crinum malabaricum is native to an area within 20 km of the coast in six seasonal rivers at around 100 m a.s.l. in northern Kerala: Periya and Cheemeni in Kasaragod District and Embate, Eramam, Aravanchal and Peringome in Kannur District. All known sites supporting native populations of *C. malabaricum* were visited in 2017 and 2022 (including the additional site found between these surveys) and most sites were visited in 2023–2025 (Table 1).

Surveys were carried out between September and November, during the growing period of the plant. The population at Peringome was found after completion of these surveys. At each site, an attempt was made to locate the upstream and downstream limits of the population, through field survey and discussion with local people. Surveys were carried out on the following dates: 25–27 September 2017; 3–5 October 2022; 27–

Table 1. Survey locations by year.

	2017	2022	2023	2024	2025
Aravanchal	26 September	4 October			
Cheemeni	26 September	4 October	27 October	27 October	6 November
Eramam		4 October			
Embate	26 September				
Periya	25 & 27 September	3 & 5 October	28 October	28 October	5 November
Peringome					3 September

28 October 2023; 27–28 October 2024; and 5 November 2025.

In addition to these surveys, at Periya a method was developed to obtain data for population monitoring, based on the UK River Corridor Survey method (NRA, 1992), complemented by data to inform an assessment of reproductive success. The protocol employed was designed to measure both the overall trend in the population and to assess reproductive capacity. Two types of data were collected:

1. A sketch map was prepared showing the main features of the river and adjacent habitat, as well as indicating areas where stands of *C. malabaricum* exceeded 80% cover in the channel (it was impractical to indicate the distribution of individual or scattered plants with any real accuracy). First, surveyors calculated the number of paces required to walk 10 m on the river channel or margin. Then each 100 m length of the river was walked using 10 m paced lengths to provide a reasonably accurate indication of the location of features.
2. Precise details were recorded on 100 m lengths of each stand of *C. malabaricum* which exceeded 80 % cover in the channel for the whole population, recording:

The total number of plants.

The number unopened inflorescences.

The number of buds.

The number of open flowers.

The number of immature fruit.

The number of mature fruit.

For the purposes of this project, the floristic characters were defined as follows:

Unopened inflorescence = Developing inflorescence, enclosed within the bracts at least to the extent that it is difficult to discern the number of floral parts within.

Buds = All unopened flowers from the stage when the bracts are sufficiently open to count the floral parts to (but not including) open flowers.

Flowers = Includes flowers from fully open to include bare ovaries which have yet to expand.

Unripe fruits = From the initial swelling of the ovaries to swollen but not reddish fruit (Fig. 1c).

Ripe fruit = Swollen, reddish to deep purple fruit (Fig.1d). At this stage, any other floral parts which are not developed are excluded.

An estimate of the potential maximum and minimum seed-set per 100 m of river for healthy *C. malabaricum* populations was calculated as follows;

1. The maximum and minimum number of potential fruit was calculated by multiplying the number of unopened inflorescences by 6 and 13 respectively, these being the range in number of flowers per inflorescence given by Lekhak and Yadav (2012). These totals were then added to the counts of numbers of buds, flowers, unripe and ripe fruit, giving a total maximum and minimum number of potential fruit. *C. malabaricum* has one ovary per flower as per Lekhak & Yadav (2012) and hence one flower is equivalent to a maximum of one fruit.
2. The total maximum and minimum number of potential fruit were each multiplied by 3 and 16 respectively, this being the range in number of seeds per fruit given by Lekhak & Yadav (2012). This provided maximum and minimum values for the potential number of seeds. The estimated maximum and minimum potential seed-set is then the maximum number of seeds

Fig. 2. a. Students of the Government College, Kasaragod with Biju P. and R.V. Lansdown, at Periya in 2022; **b**. Mature seeds of *C. malabaricum* on the bed of the river at Aravanchal in 2023 (image: R.V. Lansdown); **c**. Immature plants growing in gaps at Eramam in 2022; **d**. A caterpillar on a mature inflorescence of *C. malabaricum* at Cheemeni in 2024; **e** & **f**. Crinum flowers used for Pookkalam, Periya 2024 (images a, d, U. Ravindra; b, c, R.V. Lansdown; e& f. Praseedha).

for the maximum number of potential fruit and the minimum number of seeds for the minimum number of potential fruit.

3. The resulting figures were then divided by the length of the population surveyed in each year to provide a comparable measure per 100 m.

The results of the detailed recording were tabulated to provide average measures for each of the parameters recorded. In addition to mapping channel and bank features, notes were made at each site on features of the rivers supporting *C. malabaricum*, including notes on other wetland-dependent plant species occurring together with *C. malabaricum* or in upstream and downstream reaches.

Results

Habitat and distribution

All known populations of *Crinum malabaricum* are located on rivers within an area approximately 20 km long and 5 km wide, running parallel to the coast of Kerala at an altitude of 80-100 m above sea level, in a belt of relatively low-lying hills, characterised by extensive laterite exposures. These rivers are tributaries of more than one larger river and probably a total of three large rivers. All of the rivers supporting *C. malabaricum* arise from the laterite, and either initially descend rapidly before reaching a more or less level plateau or arise on plateaus. Laterite bedrock exposures dominate in the first stage of the rivers but typically occur only as discrete patches in the middle and lower stages. Downstream, as the water becomes deeper due to frequent inflowing streams, *C. malabaricum* declines and disappears. Subsequently, the rivers become broad and often slow-flowing before entering one of the larger rivers which take the water to the coast. The upstream and downstream limits of *C. malabaricum* populations appear to be dictated by steeper gradients with associated broken flow and by water deeper than approximately 50 cm at the peak flowering period, particularly where flow becomes sluggish and the water turbid. Where *C. malabaricum* occurs among these exposures, the leaves typically cover the entire channel for lengths of up to 2 km, it grows in gravel deposits on the rock or between outcrops. All of the rivers are seasonal, beginning to flow in May or June when the monsoon rains begin and flowing until January or February, when they dry out completely. As discharge declines at the end of the monsoon, flows are reduced and the water becomes shallower, eventually breaking up into ponded, still sections.

River sections supporting *Crinum malabaricum* are all 2-5 m wide, with crystal-clear, fast-flowing water approximately 0.5 m deep at the time of survey (i.e. during flowering and fruiting of *C. malabaricum*). They typically flow over a very shallow gradient dropping approximately 1m in nearly half a kilometre. *C. malabaricum* is absent from river reaches with steeper gradient, as well as from reaches which are disturbed by the activities of humans and wild animals. All the rivers which support populations of *C. malabaricum* have historically been extensively modified by man, mostly with a 2-3 m high wall of laterite blocks along one or both margins, other significant modifications are mainly associated with road crossings. These walls and their effects on the hydrology of the rivers do not appear to have affected *C. malabaricum*, however no data are available on the distribution or status of the species from before construction of the walls and so this cannot be confirmed. Where there are significant interventions, such as major crossings or sites where people regularly use the channel, this creates gaps in the stands of *C. malabaricum*. *C. malabaricum* is a major ecosystem architect, providing shelter for fish and invertebrate communities, dramatically modifying the hydrology of the rivers and almost certainly playing an important role in nutrient cycling.

The bed material associated with each population was dominated by laterite gravel with material ranging from fine grit to small or even medium-sized stones, all of the rivers include local silt

deposits where flow slows, but these deposits do not generally support *C. malabaricum*. All six populations are in river sections which flow mainly either through natural riparian woodland or tree crop plantations which are often mixed and include areca, cashew and coconuts, bananas, bread and jack fruit, rubber and teak. Whilst *C. malabaricum* appears able to tolerate direct sunshine (e.g. at Eramam and Aravanchal), the healthiest populations with the largest numbers of flowers and ripe fruit were under a closed canopy of tall trees with a dense shrub layer.

In general, *Crinum malabaricum* occurs directly with a few or no other species, at least in part because it tends to cover the entire channel and may preclude growth of other vegetation. Only where some factor such as silt banks, bedrock exposures, deeper water or human intervention breaks up populations of *C. malabaricum* do other species occur within the river channel. *Cryptocoryne spiralis* (Retz.) Fisch. ex Wydler var. *caudigera* Bogner and *Lagenandra toxicaria* Dalzell occur among stands of *C. malabaricum* at Periya, with the former also at Aravanchal, while sections of rivers which do not support *C. malabaricum*, but in areas where it occurs, typically support a range of aquatic species such as *Blyxa aubertii* Rich. var. *echinosperma* (C.B.Clarke) C.D.K.Cook & Lüönd, *Eriocaulon dalzellii Körn., E. heterolepis* Steud., *E. setaceum* L., *Limnophila repens* (Benth.) Benth. and *L. aquatica* Alston, with *Isachne globosa* (Thunb.) Kuntze, *Sacciolepis interrupta* Stapf and *Oryza rufipogon* Griff. in the margins or occasionally forming stands in the channel.

Population dynamics

C. malabaricum typically occurs at >80% cover in the channel, to the extent that it impedes flow, except for five situations:

- Among bedrock outcrops which limit the channel such that flow is narrow and fast, it occurs only as scattered plants.
- Where local people enter the channel to wash clothes or cross the river, this creates gaps in the population, partly apparently as a consequence of the direct disturbance but also partly by cutting plants.
- At a point, c 200 m upstream of the road bridge at Periya, where the banks have been completely replaced by concrete and a partial dam installed beneath a foot-bridge, the water is deep and flow slow and *C. malabaricum* is absent. There is also point c 100 m downstream of the road bridge where flow is deep and slow and *C. malabaricum* largely absent. It is likely that the change in flow and consequent absence of *C. malabaricum* are due to artificial modification of the channel.
- Immediately upstream, downstream and beneath bridges, *C. malabaricum* is absent.

All populations included flowering plants in each year of survey and a fairly high proportion of these produce fruit which develop and appear to ripen (Table 2). All populations showed successive stages of flowering, from inflorescences in which the buds had yet to develop, through open flowers to fully mature fruit (although at Eramam, most flowers appeared to have aborted before fruit developed). From the different stages of development of the flowering parts seen during surveys, it would appear likely that the process from initiation of the inflorescence through to ripening of the fruit takes at least a few weeks and probably more than a month. Thus, it is reasonable to conclude that *C. malabaricum* flowers at least from mid- to late-August until the end of November. Ripe seeds sink immediately and in 2022 many were apparent on the bed of the rivers, following fruit dehiscence (Fig. 2b). There is no information available on vegetative reproduction in *Crinum malabaricum*.

Analysis of the potential maximum and minimum seed-set per 100 m of the Periya population (Table 3) shows wide variation. It is possible that there is significant inter-annual variation, as the number of plants per 100 m varies around the average by ±250 between 2022 and 2024. However, from

Table 2. Population and reproductive characters at Periya, upstream and downstream of the main road bridge

Section	River length surveyed (m)	No. Plants	No. unopened inflorescences	No. buds	No. flowers	No. unripe fruit	No. ripe fruit
2017							
Upstream	300	1598	NR	47	36	67	84
2022							
Upstream	1000	4050	34	457	1019	766	657
Downstream	500	573	5	38	107	392	400
Total	**1500**	**4623**	**39**	**495**	**1126**	**1158**	**1057**
2023							
Upstream	730	5515	55	98	151	158	139
Downstream	370	3316	7	3	29	24	22
Total	**1090**	**8831**	**62**	**101**	**180**	**182**	**161**
2024							
Upstream	650	3916	62	116	90	132	181
Downstream	440	3148	0	40	32	22	102
Total	**1100**	**7064**	**62**	**156**	**122**	**154**	**283**
2025							
Upstream	750	3750	79	233	274	138	223
Downstream	400	2263	8	58	76	26	59
Total	**1150**	**6013**	**87**	**291**	**350**	**164**	**282**

the similarity of counts of flowering plants in 2023 and 2024 and the potential seed-set range also being similar for these two years, it appears logical that the variation in potential seed-set is a phenological factor. It appears likely that in late September, flowering is in its early stages (shown by data for 2017), reaches a peak in early October (shown by data for 2022) and then declines in late October (shown by data from 2023 and 2024), at which point many ripe fruits have sunk below the surface or dehisced and were not counted. The flowering plants being almost double in the second week of November (shown by data from 2025) compared to late October 2023 & 2024 survey data suggests that *C. malabaricum* may experience a secondary, lower-amplitude flowering peak

Table 3. Potential maximum and minimum seed-set per 100 m at Periya

	2017	**2022**	**2023**	**2024**	**2025**
min/100 m	234	814	272	299	420
max/100 m	234	4633	2080	2233	3086
Number of plants/100 m	533	308	803	648	523

following the main peak in early October (shown by data from 2022). Further surveys are needed to confirm this pattern. Thus, it is likely that surveys to-date have provided an indication of the amplitude of variation in numbers of flowers and fruit through the flowering season, rather than a measure of population trends.

It is likely that *Crinum malabaricum* is a long-lived perennial, as suggested by the large bulbs which persist through the dry season buried in the river bed. It is significant that the only young plants recorded during surveys have been in and around an area from which plants had been lost through human activity (Fig. 2c). It appears likely that populations are mainly stable and composed of mature individuals, whilst seeds serve to enable re-colonisation of areas from which plants are lost and any new habitat which becomes available. Thus, sexual reproduction may be necessary to replace plants which are lost and to colonise new habitat which becomes available, but the annual harvest of flowers for Pookkalam is unlikely to compromise the long-term survival of the species.

The occurrence of a large plant such as *Crinum malabaricum* in small water courses where its own growth significantly modifies the hydrology progressively as water levels decline and the rivers dry out, is unusual. It is echoed only by species such as *C. thaianum* in Thailand (Pradissan and Pipatcharoenchai 2008) together with the larger *Ranunculus* Sect. *Batrachium* taxa and some *Potamogeton* species in Europe (Lansdown, 2007) and North America, although these typically occur in larger, perennial water courses. It is possible that this high density is important for the survival of *C. malabaricum* populations and almost certain that *C. malabaricum* can be considered an ecosystem architect and keystone species where it occurs. Pradissan and Pipatcharoenchai (2008) note the importance of *C. thaianum* for fish and anecdotal observations suggest that there is also a strong association between *C. malabaricum* and fish communities.

The sheer size of the plants and the density at which they occur means that as the water levels drop and the rivers ultimately dry out, the plants initially force flow into narrower pathways within the channel and then represent a massive quantity of degrading vegetation which must have implications for the nutrient status of the bed material. The process of degradation of the plants is aided by grazing caterpillars (Fig. 2d), tentatively identified as the larvae of the Indian lily-moth (*Polytela gloriosae*) which can occur in very large numbers and are reported to completely graze out large populations before the rivers dry out completely, although they were mainly seen eating inflorescences in 2022.

Dispersal

It appears likely that within a river that is on suitable habitat, *Crinum malabaricum* is capable of colonising areas where flow is relatively smooth and the depth does not exceed 50 cm. It is not obvious how seed might travel upstream or between catchments. The most likely dispersal vector would be large herbivores which might enter rivers to eat either the leaves or developing fruit. However large herbivores are no longer present in the area and there is no other obvious dispersal vector available. It appears likely that dispersal may be the main constraint on the range and abundance of *C. malabaricum* populations.

Conservation

The conservation condition of known populations of *Crinum malabaricum* can be summarised as follows:

1. Aravanchal: Adjacent laterite grassland has been allocated to housing and although the *C. malabaricum* population is protected by the status of the sacred grove, it is vulnerable to secondary effects of housing development such as pollution, mobilisation of sediment and increased domestic use of the river.
2. Cheemeni: There is no evidence of a decline in the population, but in 2022 most inflorescences

appeared to be aborting before fruit began to develop. There is no immediately obvious cause for this sterility, but if it continues, it could compromise the resilience of the population. It is possible that the lack of a shrub layer in the rubber plantation, compared to forest and tree-crop plantations at other sites, makes plants more vulnerable to direct heat and the drying effect of wind.

3. Eramam: The upstream part of this population appears fairly stable, but may be vulnerable to short-term changes in use of the site by local people. The downstream part appears to be stable and relatively secure.
4. Embate: It has been reported that this population has already been affected by modification of adjacent habitats and that the decline is continuing. It was not possible to confirm this decline or document the condition of this population in 2022.
5. Periya: This population appears able to tolerate the effects of the use of the river by local people and appears to be in a similar condition from 2017 to 2025. It can therefore be considered to be stable and relatively secure.
6. Peringome: A site located in 2025 where scattered populations occur over approximately 1 km of river. It is vulnerable to short-term changes in use of the site by local people.

Population estimates based on detailed recording of the population at Periya suggest that the global population is at least 25,500 individuals as follows: Aravanchal 500, Cheemeni 5,000, Embate 12,000 and Periya 8,000 individuals. In 2016 on the basis of available information, *C. malabaricum* was classed as Critically Endangered under the IUCN Criteria (version 3.1) (Lansdown, 2016). Subsequent data collection suggests that populations are healthy and largely stable, but vulnerable to anthropic activities affecting the rivers where populations occur. *C. malabaricum* is also now known from six sites, with new populations being discovered every few years. There is therefore a need to revise and update the Red List assessment for this species. A number of attempts have been made to establish populations of *C. malabaricum* outside its native range:

- Plants grown permanently submerged in flowing water in large tanks survived for nearly ten years, going dormant for several months per year and only once producing a single flower, but they were not as vigorous as wild plants (C. Kasselmann pers. comm.).
- Plants introduced to relatively deep standing water tanks at the Malabar Botanical Garden & Institute for Plant Sciences in Kozhikode persisted for a short while but eventually died (S.N. Pradeep pers. comm.).
- A bulb was introduced by B. Punnakot to a river originating from but not flowing over laterite, near the native range of the species. A few fresh leaves developed following translocation, but the flow was too strong and the bulb was washed away.
- A bulb (with an inflorescence of 5 buds) which was not rooted into the laterite gravel of the river bed, was found growing on a log stranded on the river bed. This was planted into a small aquarium by Shyam Kumar P, it grew fresh leaves and the buds all developed into flowers, but it then died.
- The Malabar Botanic Garden and Institute for Plant Science has carried out introductions to a number of sites in lateritic seasonal rivers in Maharashtra, Karnataka and Kerala, with some degree of success (Pulparambil & Pradeep, 2023), with the aim of reducing the dependence of *C. malabaricum* on such a small number of unprotected sites in a very restricted region.

Discovery of the six populations currently known has enabled development of a relatively precise characterisation of the ecology of *C. malabaricum*. Based on this, it is possible to define parameters which should enable a search of potentially suitable

sites for this species which should then enable a more rigorous assessment of the conservation status of the species. Searches should focus on rivers flowing over laterite between Kasaragod and Kannur, with at least part of their length flowing over relatively level ground at between 80-100 m altitude. This work should be carried out as soon as possible and any additional populations incorporated into the monitoring programme described here.

All flowing waters in India are owned by the state and this is taken to include the bed of the watercourse. In contrast, the banks are owned privately and can apparently be modified without any form of planning control. Clearly, although the actions which appear to have had the greatest effect on existing populations have involved large-scale modification of the rivers such as works associated with the track bridge at Periya which completely altered the vegetation, there is also potential for small-scale local works to damage *C. malabaricum* populations. The most effective way to avoid such damage is to ensure that local residents are aware of the species and its conservation importance, as well as understanding that their actions could have a dramatic adverse effect on it. The first steps toward informing local people about the species have been achieved, initially through visits by foreign botanists such as Karen Randall and Christel Kasselmann and more recently through the involvement of the students from Government College, Kasaragod with Zoo Outreach Organisation in the monitoring. The lecturers and students from the college have the best potential to communicate the conservation message to local people and this should become part of the annual monitoring work.

In the absence of a mechanism for formal protection of sites supporting *Crinum malabaricum*, it is difficult to see what conservation action could be taken to enhance the conservation condition of *C. malabaricum* populations, apart from discussion with local people to raise awareness of their significance. In spite of recognised potential threats, it is also clear that the species is relatively secure, at least for the next ten years and it is therefore difficult to justify conservation action for this species alone. However, there is justification for conservation action for this species as part of wider conservation of wetland-dependent plants in the region.

Over the last ten years B. Punnakot has documented the vegetation of more than 600 seasonal ponds on the laterite toward submission of a PhD thesis in 2018, while S.P. Purayil has documented the vegetation of a number of laterite plateaus as part of a study of the conservation status of *Rotala malabarica*. The IUCN SSC Western Ghats Plant Specialist Group has achieved a number of notable successes in conservation of the vegetation of laterite plateaus in Karnataka State. This work has therefore already provided much of the information necessary to inform conservation of these sites and habitats. One of the most important actions needed to enable protection of wetland-dependent sites, habitats and species in the region is to establish a sound scientific baseline toward designation of sites of conservation importance. The conservation status of more than 600 freshwater wetland-dependent plant species occurring in the Western Ghats has been assessed using the IUCN Red List Criteria. Most of the Red List assessments were completed in 2010 and there is a need for these to be repeated to include new data collected since the first assessments, as well as newly described species. Site and habitat-specific data need to be compiled into a document which provides explicit and detailed recommendations for formal recognition of priority areas for conservation of wetland-dependent plants in the region, to inform local and regional administrative organisations. This work should involve collaboration between Zoo Outreach Organisation, the IUCN SSC Western Ghats Plant Specialist Group, the IUCN SSC Freshwater Plant Specialist Group, Malabar Botanical Garden and Institute for Plant Sciences, the University of Calicut and the Government College Kasaragod and should be supported by IUCN.

Action to protect specific sites in the short term, to ensure that they are not lost whilst the long-term conservation work is developed could include purchase of priority areas when they become available. This is particularly relevant to the site at Aravanchal which is threatened by conversions of adjacent laterite grassland to housing. Purchase of the site would effectively prevent any development of the habitats and ensure long-term protection. The aim of this purchase would be to establish a field research centre in the area on the purchased land, thereby maintaining a presence of conservation-oriented work in the area, promoting conservation of seasonal wetlands and the rivers by direct local action and potentially involving local people in conservation of these habitats.

Whilst there is a sound logic to trying to increase the resilience of *Crinum malabaricum* populations, the capacity of the species to dominate extensive reaches of rivers suggests that a cautious approach should be taken to introducing plants to natural watercourses because of the risk of establishing a new invasive non-native species.

Monitoring and further surveys

The only means by which to measure population trends and therefore the true conservation status of each population is through replicable monitoring. The aim of the monitoring protocol described here is to measure changes in the populations of *C. malabaricum* which can be interpreted as trends for the purpose of assessing population trends. The extent to which *C. malabaricum* may depend upon sexual reproduction is not yet clear and cannot be dismissed, particularly as populations appear to be quite mobile. There is therefore a need to measure both the persistence of each population and the reproductive potential. The monitoring protocol is therefore based on two complementary strands:

1. Measurement of reproductive parameters to provide an indication of potential for this species to colonise of new areas and to recover following loss.
2. Measurement of the extent to which vegetative cover persists between years, as an indication of survival of individual plants or re-colonisation of areas following loss.

The aim is for survey data to be collected each year by staff of Zoo Outreach Organisation in collaboration with staff and students of the Government College Kasaragod. This will thereby not only enable acquisition of the desired quantitative data on reproductive potential but will provide an element of training in field survey techniques for botany students. Mapping by hand should be replaced by use of drones to monitor both the upstream and downstream limits of populations, as well as the distribution and extent of any gaps in populations. The main method by which to document both the extent of the population which is represented by different densities as well as the upstream and downstream limits of each population should be by use of a drone to fly over the length of river occupied by each population. Images obtained should be analysed both to establish the up- and downstream limits of the population and to derive a simplistic index of population density based on whether plants are at 80-100 % cover or less than 80 % cover. Where areas are inaccessible to the drone, information gaps should be completed by eye.

Conclusion

Crinum malabaricum is native to an area within 20 km of the coast in six seasonal rivers at around 100 m a.s.l. in northern Kerala: Periya and Cheemeni in Kasaragod District and Embate, Eramam, Aravanchal and Peringome in Kannur District. Population estimates based on detailed recording of the population at Periya suggest that the global population is at least 25,500 individuals as follows: Aravanchal 500, Cheemeni 5,000, Embate 12,000 and Periya 8,000 individuals. There are no obvious threats to the populations of *C. malabaricum* at Cheemeni, Embate and Periya, although there are anecdotal accounts of a decline at Embate. The monitoring baseline established at Periya

should, if extended to cover the other populations, enable measurement of population trends and a response should a decline become apparent. The population at Aravanchal and Peringome are threatened by destruction of adjacent laterite grassland for housing. The Red List Assessment for *C. malabaricum* needs to be revised as most populations appear to be stable and relatively secure, at least for the immediate future.

The river reaches where *C. malabaricum* occurs flow over a very gentle gradient, they are 2–5 m wide and <1 m deep in the wet season, with a laterite gravel bed and fairly fast flow. *C. malabaricum* is a major ecosystem architect, providing shelter for fish and invertebrate communities, dramatically modifying the hydrology of the rivers and almost certainly playing an important role in nutrient cycling. The rivers all arise on the laterite, *C. malabaricum* typically forms dense stands covering the entire channel with leaves which form a dense mat as water levels drop and occurs where the rivers flow over the laterite and flow through a range of habitats from relatively open gardens, through areca (betel) nut, coconut and rubber plantations to dense scrub and woodland. *C. malabaricum* thrives in relatively fast-flowing water but appears unable to survive in standing water, it flowers and appears to set seed abundantly from early September to late November. All rivers supporting *C. malabaricum* have been extensively modified by man, mostly with a 2–3 m high wall of laterite blocks along one or both margins, other significant modifications are mainly associated with road crossings. Where there are significant interventions, such as major crossings or sites where people regularly use the channel, this creates gaps in the stands of *C. malabaricum*.

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