



Two new species of *Lagenandra* (Araceae) from the Wet Zone of Sri Lanka

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Abstract

Taxonomic revisions are the most reliable pathway in unfolding new species to the world. During such a revision of the genus *Lagenandra* in Sri Lanka, we came across two new species: *Lagenandra kalugalensis* and *Lagenandra srilankensis* from the Wet Zone of Sri Lanka. The two new species were studied in detail and compared with the morphology of the other species described in the genus, and based on field collected data conservation assessments were performed. A detailed description for the two new species and an updated taxonomic key to the Sri Lankan *Lagenandra* is presented here for easy identification. Recognizing two new endemic members enhances the number of Sri Lankan species of *Lagenandra* to eleven and global to nineteen. According to the IUCN red data category guidelines, *L. kalugalensis* qualifies for Critically Endangered category under Criterion B1ab (ii,iii,v) + B2ab (ii,iii,v) while *L. srilankensis* qualifies for Critically Endangered category under B1ab (iii, iv) + C2 (a) (i, ii). Hence, immediate conservation measures are imperative.

Keywords: Biodiversity conservation, Critically endangered, Endemic, Ornamental aquatic plants

Introduction

The global biodiversity is in verge of threat. As a result, concerns are raised as to how many species would get lost, even before they are been described to the world. This is something that needs to be taken seriously. At this juncture, taxonomists have an important role to play, by initiating taxonomic studies which could result in describing new species and revisions to the existing taxa. However, the existence of impediments to taxonomy is recognized as one of the key obstacles in the conservation and sustainable use of biodiversity (Dar *et al.*, 2012; Yakandawala, 2016). The Convention on Biological Diversity in 2002 recognizing the importance of taxonomic studies in the conservation of biodiversity established The Global Taxonomic Initiative (GTI) to remove or reduce the “taxonomic impediment”, first time in history that taxonomy has had recognition at such a high level in international policy (CBD, 2002). In this context, we have initiated the task of carrying out a detailed taxonomic study on the genus *Lagenandra* in Sri Lanka, as our conscious identifies the genus *Lagenandra* as a taxon that needs a revision with extensive field work.

Lagenandra Dalzell (1852: 289) is an evergreen perennial herb of the family Araceae, where the plants are semi-aquatic and occupying the amphibian region of rivers, streams, and marshy habitats. The genus shows a restricted distribution and are endemic to Sri Lanka, Bangladesh, and India. Globally up to date, 17 species have been recognized under the genus, which also includes the most recent addition, *L. wayambae* Madola *et al.* (2021: 217–220) that was described recently (Crusio and Graaf, 1986, Nicolson 1987, Sivadasan & Babu 1995, Sivadasan *et al.* 2001, Biju *et al.* 2018, Sasikala *et al.* 2019, Madola *et al.*, 2021). Eight species of *Lagenandra* have been described as occurring in the country; *L. bogneri* de Wit (1978: 33–34), *L. erosa* de Wit (1978: 36–38), *L. jacobsenii* de Wit (1983: 291), *L. koenigii* (Schott 1859: 81) Thwaites (1864: 334), *L. lancifolia* (Schott 1857: 221) Thwaites (1864: 334), *L. ovata* (Linnaeus 1753: 967) Thwaites (1864: 334), *L. praetermissa* de Wit (1983: 299), and *L. thwaitesii* Engler (1879: 621),

of which seven are endemic to the island (Nicolson 1987). With the recent recognition of *L. wayambae* the species number is now increased to nine while the endemics to eight. Crusio & Graaf (1986) recognized *L. dewitii* Crusio & de Graaf (1986: 56–59), as a species occurring in the country, however Nicolson (1987) discharge this but refers to the species as a variation of *L. praetermissa*. Many species of *Lagenandra* are popular as ornamental aquatic species due to their various leaf colours and attractive spathe. This has led to the extraction of these plants for the industry from their natural habitats (Yakandawala 2012, personal communication), leading to the decline in wild populations. On the other hand, habitat degradation due to anthropogenic activities is another threat we have noticed during the past few years. Subsequently, five endemics of the eight species recorded in Sri Lanka are now listed as endangered in the National Red list (MOE 2012), and the conservation status of the recently described *L. wayambae* has been determined as Critically Endangered (Madola *et al.*, 2021).

During the field explorations conducted for collecting specimens for the taxonomic revision of the genus, two unfamiliar *Lagenandra* populations, different from each other, were discovered; one from Kalugala Forest Reserve of Mathugama area and the other from Labugama Kalatuwawa Forest Reserve in the Wet Zone of Sri Lanka. A second population similar to the later population in Labugama Kalatuwawa Forest Reserve was also collected from Wewila along the Korala-ema-dola in the Udagama area of Sri Lanka. The leaf shape and the other associated leaf features of the individuals were different from each other and from the other *Lagenandra* species that have been described so far. With long term observations, we have observed that the inflorescence of the populations was also distinct from each other as well as the other described species. Therefore, a detailed study was carried out to record the morphological, vegetative, and reproductive features in order to evaluate if the two species are new additions for the genus.

Material and methods

Field explorations were conducted in the Wet Zone of the country between 2018–2021 with repeated field visits to monitor the flowering and fruiting.

The species were denoted as *Lagenandra* sp. 1 and 2 respectively. The morphological characters of the field collected samples were studied in detail in the laboratory, at the Department of Botany, University of Peradeniya. Both quantitative and qualitative morphological characters were studied in detail. A minimum five mature individuals from each population were selected to collect data for characters, and five measurements were taken from each individual plant for a particular character. The mean of the measurements was taken as the particular character value. Macroscopic parts were observed under a dissecting microscope and a stereomicroscope (LEICA L2). All character measurements were obtained using a ruler (smallest measurement 1 mm) or an eyepiece graticule (smallest measurement 0.1 mm) where applicable.

The morphological features recorded for the two species were separately compared with herbarium specimens of *Lagenandra* species that have already been described from Sri Lanka, deposited at the National Herbarium, Royal Botanic Gardens, Peradeniya, Sri Lanka and on-line herbaria and resources (JSTOR Global Plants 2019, Smithsonian National Museum of Natural History 2019, Bastmeijer 2018). In parallel, all published literature (de Wit 1978, Graaf & Arends 1986, Nicolson 1987, Sivadasan & Babu 1995, Sivadasan *et al.* 2001, Biju *et al.* 2018, Sasikala *et al.* 2019) were also referred to compare the morphological features.

Employing the GPS location data, distribution maps were compiled for the two species, *Lagenandra* sp. 1 and 2 using ArcGIS version 10.4 software (ESRI 2017) and the Area Of Occupancy (AOO), the area of suitable habitat currently occupied by the taxon and Extent Of Occurrence (EOO), the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy. Conservation assessments of the newly described two *Lagenandra* spp. were carried out following IUCN (2019) recommendations.

Results

Detailed morphological studies of the specimens of *Lagenandra* sp. 1 and 2, and comparison with the previously described species using both published literature and herbarium specimens, provided convincing evidence that the two species are undeniably two new *Lagenandra* species. The two species were named as *Lagenandra kalugalensis* and

Lagenandra srilankensis, and a key for the accurate identification of all the *Lagenandra* species described in Sri Lanka to date was constructed.

Additional location for *L. srilankensis*: extensive field visits discovered a third location for *L. srilankensis*, along a stream outside the Labugama Kalatuwawa Forest Reserve. The distribution map of *L. kalugalensis* and *L. srilankensis* is given in Figure 1.

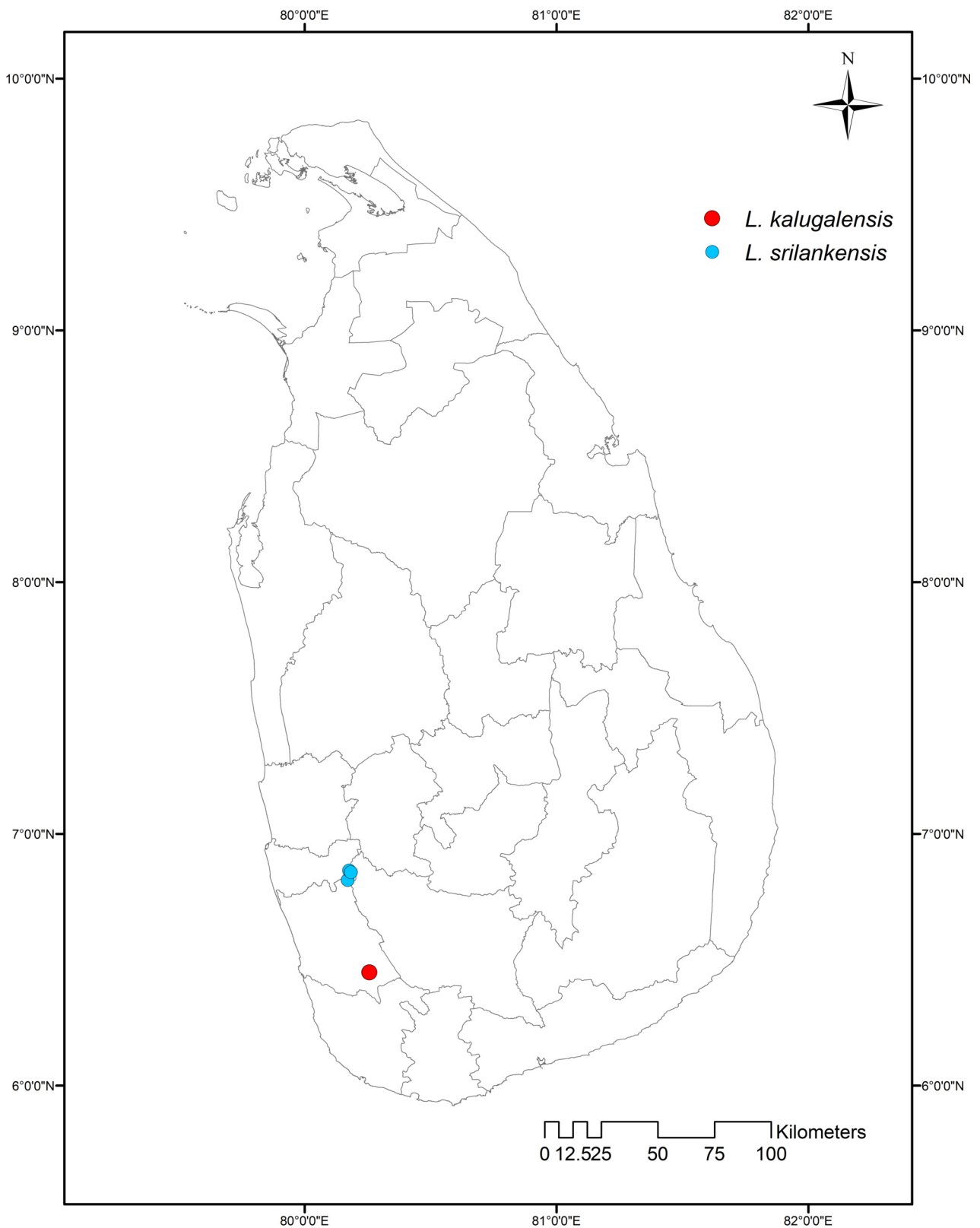


FIGURE 1. Map of Sri Lanka indicating the locations of *L. kalugalensis* and *L. srilankensis*, in the Wet Zone of Sri Lanka.

Taxonomy

Lagenandra kalugalensis Madola, D.Yakandawala & K.Yakandawala, sp. nov. (Figs. 2–4)

The habit of *L. kalugalensis* differs from all other species described to date, both from the leaf shape and orientation of the limb in relation to the kettle. The large, more or less oblong/linear leaf blades with parallel margins are distinct from other species. All other species possess either elliptic, elliptic-ovate, ovate-narrowly ovate, narrowly lanceolate or linear leaves with no parallel margins. The light maroon-violet spathe with un-twisted limb that opens up widely and is placed 45° to the kettle are other distinct features of *L. kalugalensis*. Even though limb of *L. koenigii* is occasionally placed approximately 45° to the kettle, the peduncle of *L. koenigii* is much shorter than of *L. kalugalensis* and the limb is always less open. The limb of both *L. srilankensis* and *L. koenigii* are untwisted but can be easily separated from *L. kalugalensis* as the limb of the latter is widely opened.

Type:—SRI LANKA, Western Province, Kalutara District, Kalugala in the periphery of the Kalugala Forest Reserve of Sri Lanka, 47 m asl. Collected 1 February 2020, Madola, Yakandawala & Yakandawala L69 (holotype PDA!, isotypes PDA!, K!).



FIGURE 2. *Lagenandra kalugalensis*; A. Habitat. B and C. Habit.

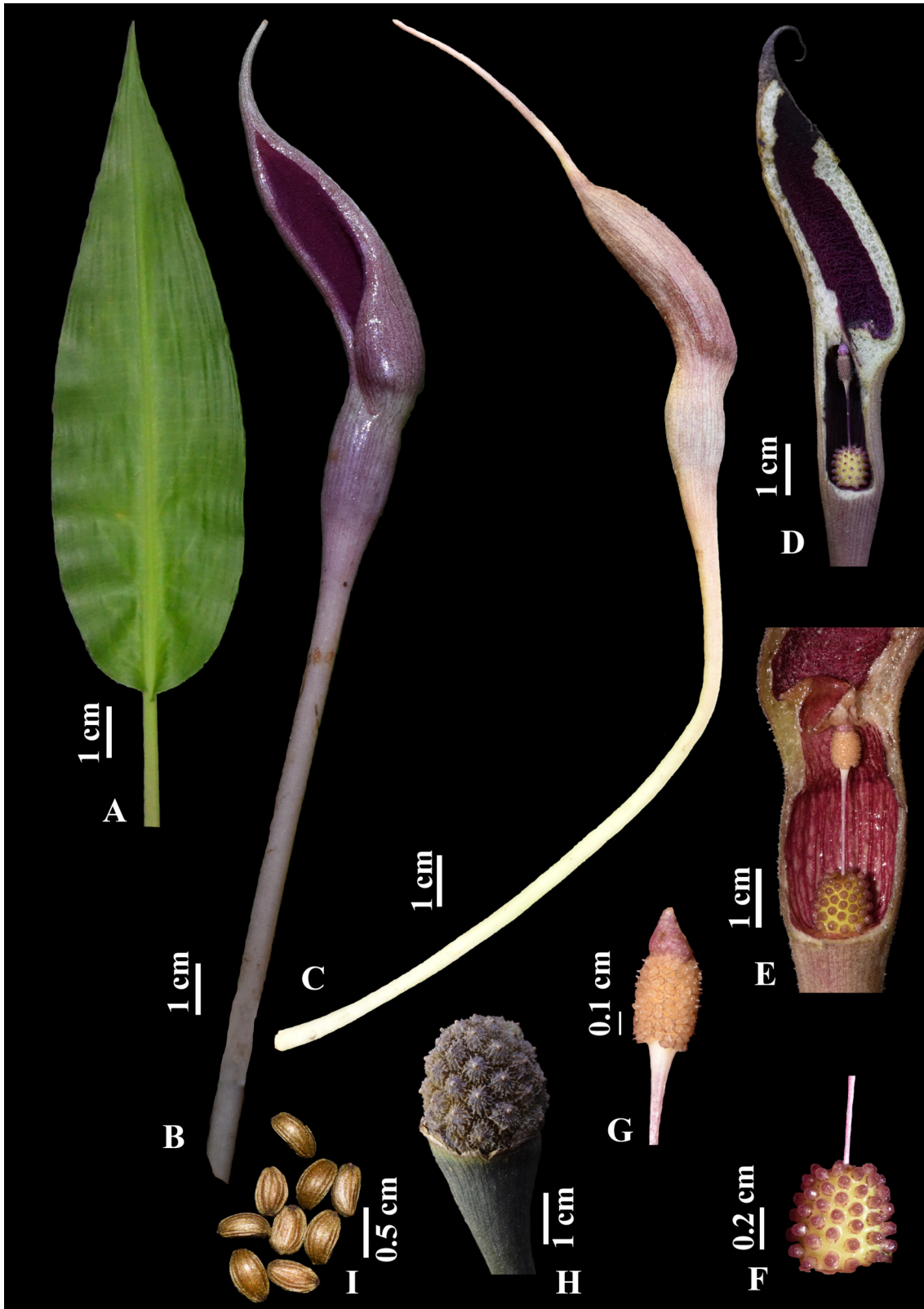


FIGURE 3. *Lagenandra kalugalensis*; A. Leaf, B. and C. Spathe from different angles showing the opening in the limb; note the untwisted spathe and the limb placed 45° angled to the kettle and opening up widely. D. Spathe dissected and opened. E. Kettle with the spadix; note the light maroon/violet smooth longitudinal striations. F. Pistillate flower zone. G. Appendix and staminate flower zone. H. Infructescence and I. Seeds.



FIGURE 4. *Lagenandra kalugalensis*; A. Habit. B. Spathe. C. Infructescence and D. Seeds.

Evergreen large herb with creeping to erect rhizome ca. 1.0–1.5 cm in diam. Cataphylls ca. 6.5–15.0 cm. Petiole ca. 17–45 cm long, ca. 0.5–0.7 cm wide, sheath ca. 3.5–9.5 cm long, unequal. Leaf blades green, blade more or less oblong/linear with parallel margins, apex acuminate, base gradually tapering/acute, margin entire, blade ca. 19.0–28.5 × 5.0–10.5 cm; midrib visible on both surfaces and prominent on the lower surface. Peduncle ca. 14.0–29.5 cm long, 0.5–0.6 cm width, terete. Spathe light maroon/violet, slightly rugose with no distinct warts, ca. 9.5–15.0 cm long, kettle ca. 1.5–3.5 × 1.0–1.5 cm, light maroon/violet with smooth longitudinal striations inside; limb ca. 4.0–6.5 × 1.3–2.5 cm, un-twisted, placed 45° angled to the kettle and opens up widely, light maroon/pink and horizontally irregularly roughened inside; tail ca. 3.0–6.5 × 0.1–0.3 cm. Spadix ca. 2.0–2.7 cm long; pistillate flower zone ca. 0.5–0.7 × 0.6–0.7 cm; sterile zone ca. 0.8–1.5 cm long (whitish pink); staminate flower zone ca. 0.3–0.5 × 0.2–0.3 cm, cream; appendix ca. 0.2–0.3 × 0.1–0.2 cm long, whitish maroon. Pistils ca. 55–60, upright. Style clearly visible. Staminate flowers ca. 80–84. Inflorescence up to 21 cm long, oblate with few fruitlets, fleshy capsule up to 38–40, with warty out-growths. Seeds 4–5, size ca. 0.4–0.6 × 0.2–0.3 cm and longitudinally ridged.

Distribution, phenology and conservation status:—To date distribution of *L. kalugalensis* appears to be restricted to one locality in Sri Lanka, in the stream-let, that originates from the Kalugala Forest Reserve, which joins the Kaluganga (River). The population is scattered and spread over a stretch of about 150 m. The population consists of about 35 mature individuals. The streamlet where the plant populations are occurring is bordering the Kalugala Forest Reserve and not within the protected area. Therefore, the plants are exposed to anthropogenic activities. According to personal communication with the villagers, a few years back there had been a person who visited the area regularly and collected plants in large scale with the help of the villagers for export. The plants inhabit the bank of the stream and is exposed to strong water currents during the rainy season where the rains are severe in the Wet Zone.

Peak flowering of *L. kalugalensis* was observed from January–April, occasional flowering from July–October. Fruiting from February to May and July–November. The open inflorescence persists for 3–4 days.

The calculated AOO accounted to 4 km² while we were unable to calculate the EOO due to the presence of only one data point. Therefore, the EOO was also taken as equal to AOO. Considering the facts that *L. kalugalensis* being restricted to only one locality in the country, and the number of healthy individuals in the population is restricted to less than 35 mature individuals, scattered along the bank of a streamlet bordering the protected area and is subjected to anthropogenic activities, the population could be considered as under threat. Following the present IUCN guidelines (2019); based on geographic range, with only 4 km² of EOO and AOO, this species qualifies for Critically Endangered category (CR) under the thresholds for both B1 and B2. Considering the anthropogenic activities at the border of the protected area, number of locations is considered as 1 (a). Further, considering the conditions, the large healthy population of *L. kalugalensis* located in the broader of the protected area exhibited a continuing decline in the EOO (bi) and AOO (bii) which is evident from the personal communication with the villagers, where large scale collections have been made few years back. Further, a continuing decline is observed in the quality of the habitat (biii) as well as the number of mature individuals (bv). Considering all these facts, *L. kalugalensis* qualifies for Critically Endangered category under Criterion B1ab (ii,iii,v) + B2ab (ii,iii,v).

Habitat:—The plants inhabit the bank of the streams.

Eponymy:—The new species is named after the Kalugala Forest Reserve that was recently declared as a forest reserve, where the type locality falls in the boundary of the reserve.

Other specimens examined (paratypes):—Kalugala Forest Reserve, 47 m asl. Collected 16 January 2021, Madola, Yakandawala & Yakandawala L220 (PDA!)

***Lagenandra srilankensis* Madola, D.Yakandawala & K.Yakandawala, sp. nov. (Figs. 5–7)**

The habit of L. srilankensis resembles L. bogneri and L. jacobsenii in vegetative state but can be easily separated by the presence of the faint silver line in leaf margin. The occurrence of a faint silver margin relates the species with L. thwaitesii, the only other species in the genus with this feature. However, the silver margin in L. srilankensis appears faint against the light green colour of the leaf blade oppose to the dark green leaves of L. thwaitesii. The silver margin appears conspicuous while the leaf is wet. The size and the shape of the leaves of the two species also differ; the leaves are large and ovate in L. srilankensis, while in L. thwaitesii the blade sublinear, 10 × longer than broad. However, during the flowering they can be easily separated by their distinctive spathes; L. thwaitesii with a shorter peduncle and a more than half twisted spathe opposed to the longer peduncle and less than or untwisted spathe of L. srilankensis.

Type:—SRI LANKA, Western Province, Colombo District, Labugama Kalatuwawa Forest Reserve, 165 m asl, Collected 28 March 2018, Madola, Yakandawala & Yakandawala L33 (holotype PDA!, isotype PDA!)



FIGURE 5. *Lagenandra srilankensis*; A Habitat, B and C Habit.

Large evergreen herb with creeping to erect rhizome ca. 0.8–2.0 cm in diam. Cataphylls ca. 6–13 cm. Petiole ca. 17–32 cm long, ca. 0.3–0.7 cm wide, green-maroon and rugose; with protuberances (multicellular hairs), sheath ca. 3–8 cm long, unequal. Leaf blades green with a faint silver margin that is very conspicuous while wet; ovate to narrowly ovate, apex acute, base round, unequal/oblique, margin entire, blade ca. 16–24 × 4.5–9.0 cm; midrib visible on both surfaces and prominent on the lower surface; lower leaf surface rugose and with protuberances. Peduncle ca. 1.0–10.5 cm long, 0.3–0.6 cm width, light maroon, terete. Spathe light maroon, slightly rugose with no distinct warts, ca. 6.5–8.8 cm long, kettle ca. 1.3–2.0 × 0.9–1.5 cm, dark maroon with smooth longitudinal striations inside; limb ca. 2.7–4.0 × 1.0–2.5 cm, opening by a slight twist, dark maroon and horizontally ribbed inside; tail ca. 1.5–3.5 cm. Spadix ca. 1.0–1.6 cm long; pistillate flower zone ca. 0.3–0.5 × 0.4–0.6 cm; sterile zone ca. 0.3–0.7 cm long (light pink); staminate flower zone ca. 0.2–0.4 × 0.2–0.3 cm; appendix ca. 0.1–0.2 × 0.1–0.2 cm long (dark maroon). Pistils ca. 28–32, cream brown with pink stigma, oriented upright. Staminate flowers ca. 65–70. Infructescence up to 9 cm long, prolate with 28–32 fruitlets, peduncle 2.5–6.5 cm long, fleshy capsules up to 10, with warty outgrowths. Seeds 2–4, size ca. 0.5–0.6 × 0.1–0.3 cm and longitudinally ridged.

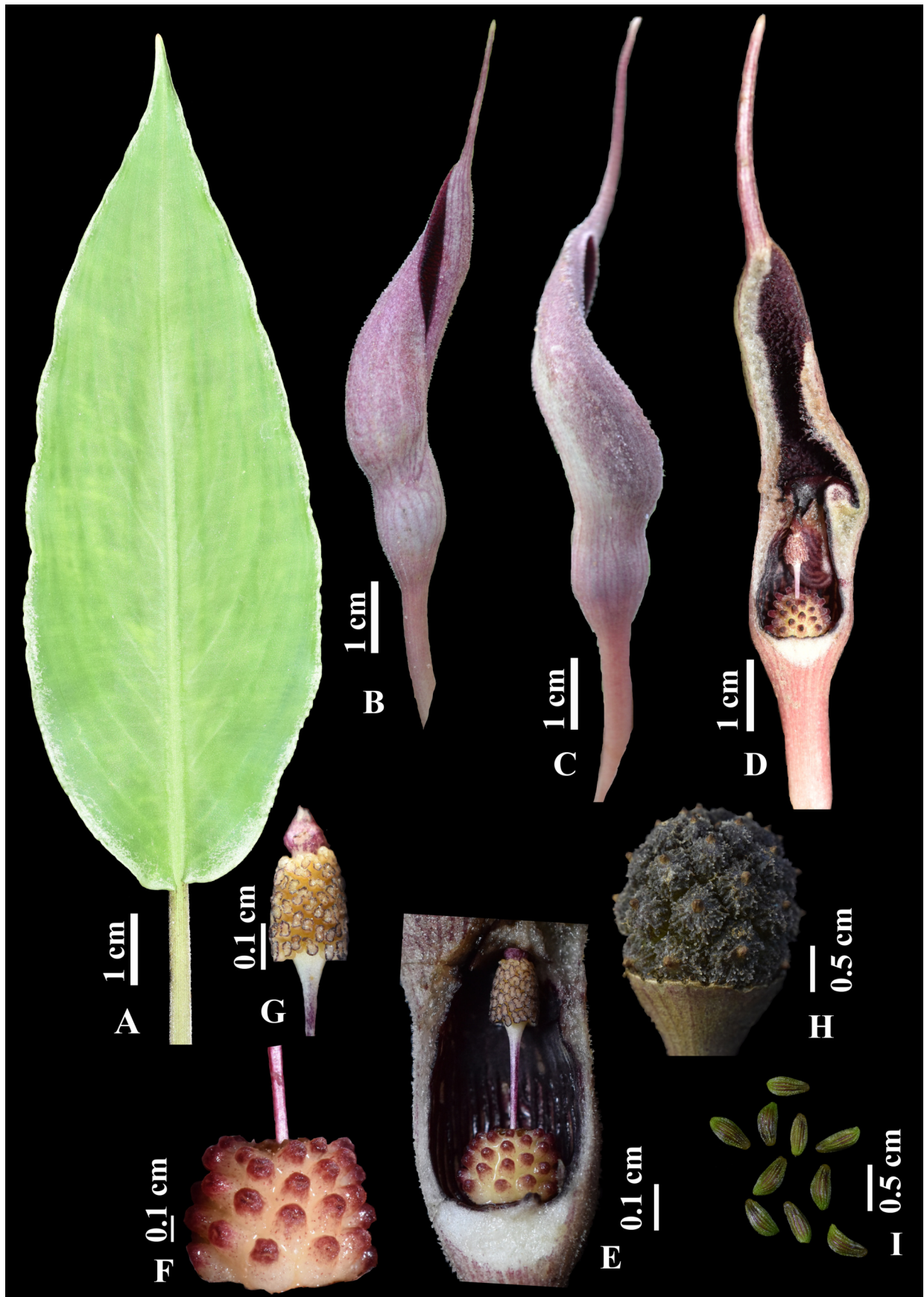


FIGURE 6. *Lagenandra srilankensis*; A. Leaf, note the silver margin. B. and C. Spathe from different angles showing the opening in the limb of the spathe giving access to the reproductive organs. D. Spathe dissected and opened. E. Kettle with the spadix; note the dark maroon wall with smooth longitudinal striations. F. Pistillate flower zone with cream brown pistils and pink stigma that are oriented upright. G. Appendix and staminate flower zone. H. Infructescence and I. Seeds.

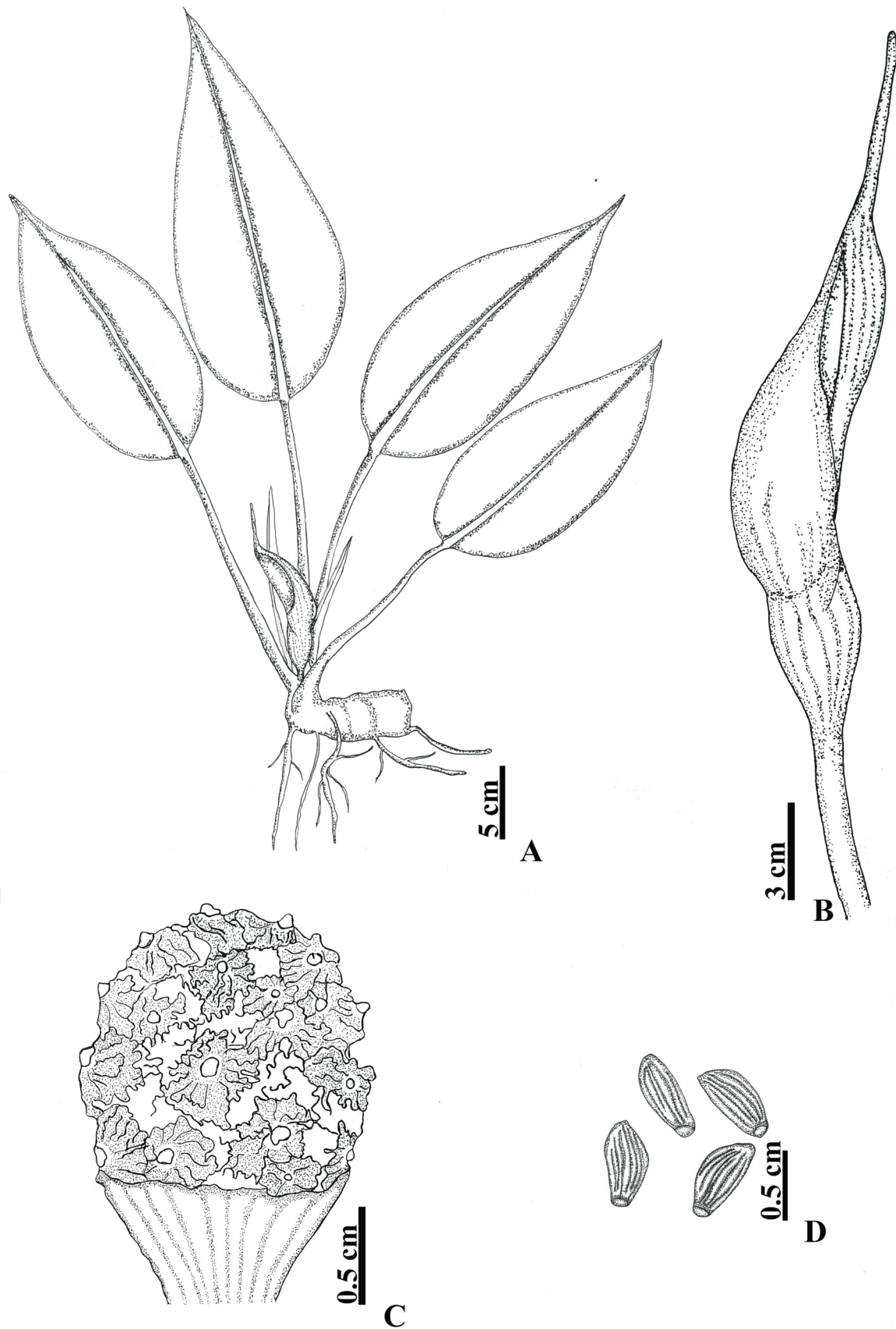


FIGURE 7. *Lagenandra srilankensis*; A. Habit. B. Spathe. C. Infructescence and D. Seeds.

Distribution, phenology and conservation status:—To date, the distribution of *L. srilankensis* has been recorded from three localities in the Western Province of Sri Lanka. The population within the Labugama Kalatuwawa Forest Reserve harboured only 10 mature individuals along a stream. The other population that occurred just outside the forest reserve, along a stream, contained only 6 mature individuals. It was noted that both populations did not contain any young individuals. The aerial distance between the two populations is approximately 1.3 km. The healthier population in Wewila occurred along the Korala-ema-dola. The Korala-ema-dola is a stream that serves as the demarcation between Colombo and Kaluthara districts, Western Province, of an elevation of 157 m asl. This population is spread along the border of privately owned lands on both banks. The plants are concentrated in to two places, with a distance of 50 m in between, each patch spreading about 2–6 m. Since the populations are outside a protected area or forest reserve, they are exposed to anthropogenic activities. They inhabit the banks of the stream and are vulnerable to strong water current during the rainy season. One patch harboured 10 mature individuals with few young plants, while the other had 15 individuals.

Peak flowering in *L. srilankensis* was observed from January–April and occasional flowering in June–July. Fruiting from February–August. The open inflorescence persists for 3–4 days.

The calculated AOO accounted to 12 km² while the EOO was 1.8972 km². Since the EOO was less than AOO, the EOO was also taken as equal to AOO. According to the field data *L. srilankensis* is restricted to three localities in Sri Lanka. The number of healthy individuals in the protected area, Labugama Kalatuwawa Forest Reserve is limited to few individuals (10) and are scattered while the population outside also harboured a few (6) mature individuals. The healthier larger population (25) occurs in Wewila area in a stream that runs across a village. Due to this reason, the population is subjected to anthropogenetic activities, which is a direct threat to the population. The plants occupy the bank of the stream, and as the Wet Zone experience very heavy rains, there is a possibility that heavy water currents would remove individuals from the bank. Further, the observation made during the past three years, we have noticed the deposition of silt and debris over the young individuals after the rains. Therefore, the two populations could be considered as exposed to anthropogenic threats.

Following the present IUCN (2019) guidelines, based on Criteria B- the geographic range, with only 12 km² EOO, the species qualifies for the Critically Endangered category (CR) under the thresholds for B1. However, as the AOO exceeds 10 km² the species cannot be considered as qualifies as CR but as Endangered (EN) under Criteria B2. According to our field experiences, *L. srilankensis* exhibits a linear distribution along streams. In addition, these plants are herbs where their maximum height does not exceed 40 cm and therefore calculating the AOO with a 2 km × 2 km grid provides an over-estimated AOO value. This scenario is highlighted by Manawaduge *et al.* (2020), where the smaller aquatic plants with high habitat specificity are at a disadvantage when securing their conservation statuses, when a 2 km × 2 km grid is employed and thereby lose the protection they deserve through legislations. If the AOO was calculated by using a 1 km × 1 km grid, *L. srilankensis* would secure only a AOO of 3 km² which would be a more reasonable estimation. Considering the conditions of Criteria B, the species fulfills, (a) severely fragmented; (b) Continuing decline observed, estimated, inferred or projected in (iii) quality of habitat and (v) number of mature individuals. Therefore, *L. srilankensis* could be considered as Critically Endangered under B1ab (iii, iv). In addition, taking Criteria C into account, with the number of mature individuals been less than 250 and with an estimated, projected or inferred continuing decline in the mature individuals where (a) (i) number of mature individuals in each subpopulation less than 50, and (ii) % of mature individuals in one subpopulation is 90–100%, *L. srilankensis* qualifies for CR under C2 (a) (i, ii). Therefore, *L. srilankensis* Qualifies for Critically Endangered category under B1ab (iii, iv) + C2 (a) (i, ii).

Habitat:—The plants occupy the banks of small water courses, streams and streamlets.

Eponymy:—The new species is named after Sri Lanka, an island that is rich in biodiversity, that also harbors 11 species of *Lagenandra* of the totally described 19 species of the world, with 10 endemics.

Other specimens examined (paratypes):—SRI LANKA. Colombo and Kaluthara District boarder, Wewila along the Korala-ema-dola, Udagama area of Sri Lanka, 157 m asl, Collected 12 February 2019, *Madola, Yakandawala & Yakandawala L70* (PDA!, K!). Colombo District, outside Labugama Kalatuwawa Forest Reserve, 90 m asl, Collected 19 February 2021, *Madola, Yakandawala & Yakandawala L239* (PDA!).

Key for the identification of *Lagenandra* species in Sri Lanka

Modified from Nicolson (1987) and Madola *et al.* (2021).

1. Spathe distinctly warty outside.....2
- Spathe smooth or merely roughened outside by papillae.....5
- 2 Warts large (1.5–3.0 mm long); spathe limb abruptly globular-inflated above the kettle.....*L. ovata*
- Warts small (to 1.0 mm); spathe limb subcylindric.....3
3. Spathe large (more than 10 cm long); pistillate flowers more than 60.....*L. praetermissa*
- Spathe small (up to 10 cm); pistillate flowers less than 40.....4
4. Spathe outside with few distinct irregular warts; leaves linear lanceolate to linear ovate.....*L. wayambae*
- Spathe outside, rugose, not with distinct warts; leaves broadly elliptic or broadly lance-ovate.....*L. lancifolia*
5. Leaf-blade sublinear, c. 10 × longer than broad.....6
- Leaf-blade ovate-lanceolate, to 5 × longer than broad.....7
6. Leaf-blade to 50 cm long, margins smooth; inside of spathe limb strongly laterally ribbed, outside dark purple.....*L. koenigii*
- Leaf-blade to 20 cm long, margins erose; inside of spathe limb rugose spongy, outside green.....*L. erosa*
7. Spathe limb strongly twisted to one side, inflated and opening subhorizontally.....*L. jacobsenii*
- Spathe limb sub-erect, cylindrical and opening subvertically.....8
8. Leaf blades often silver margined; Peduncle short.....9
- Leaf blades not silver margined; Peduncle long.....10
9. Leaf blade small (upto 20 × 4 cm); narrowly ovate to lanceolate; dark green, abaxial surface smooth; silver margin conspicuous; peduncle c. 2 cm.....*L. thwaitesii*
- Leaf blade large (upto 28 × 5.0–10.5 cm); ovate to narrowly ovate; light green; with a faint silver margin, abaxial surface rugose; peduncle c. 11 cm.....*L. srilankensis*
10. Leaf base round; spathe yellow-green; limb inside surface yellowish white; tail length 9–16 cm; twisted.....*L. bogneri*
- Leaf base tapering, acute; spathe light maroon/violet; limb inside surface maroon; tail length 3.0–6.5; un-twisted.....*L. kalugaleensis*

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