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Note on range extension, local knowledge and conservation status of the Critically Endangered Anamalai gliding frog *Rhacophorus pseudomalabaricus* in the Cardamom Hills of Western Ghats, India

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ABSTRACT - *Rhacophorus pseudomalabaricus* is a Critically Endangered, range-restricted frog found in the southern Western Ghats of India. We report new distribution records outside the protected area network in the Cardamom Hills of Kerala State through direct sightings and local ecological knowledge. These records increase the distribution by 12 km to the south-east of its currently known range and increase the altitudinal range of the species to 1600 m asl. We present a preliminary call analysis of the species that is distinct from the call of its nearest congener *R. malabaricus*. Foam nests, tadpoles and metamorphs were sighted in agricultural land suggesting the importance of these landscapes for breeding. Breeding continues into the month of November extending the known length of its breeding season. Breeding occurred in highly disturbed areas and oviposition sites varied according to the vegetation around breeding sites and included the use of non-native plants. This suggests the need to exercise caution while conducting habitat restoration programs that involve a standard removal of non-native plants. The IUCN Red List status for this species could be revised from 'Critically Endangered' to 'Endangered' in light of our findings. Local ecological knowledge on amphibians could provide supplementary information on distinct species with local names and those that have short periods of activity, which may not be frequently encountered during field surveys.

INTRODUCTION

The Anamalai gliding frog *Rhacophorus pseudomalabaricus* Vasudevan and Dutta, 2000, is a Critically Endangered species associated with tropical moist evergreen forests of the southern Western Ghats between altitudes of 955–1430 m asl (Biju et al., 2004a; Biju et al., 2013). It is currently known from six locations in the states of Tamil Nadu and Kerala, both within and outside the protected area network (Fig. 1; Table 1). It is the only amphibian from the Indian subcontinent to adorn a postage stamp (Department of Posts - Government of India, 2012).

We report two new localities for this species in the Cardamom Hills of Kerala in the southern Western Ghats, specifically at Munnar and Mankulam (Fig. 1; Table 1). While the species was physically sighted at two sites in Munnar, at Mankulam species occurrence was only confirmed by the local ecological knowledge of indigenous and non-indigenous communities. The geographical coordinates of the locations are not provided here to safeguard the locations from collection for research purposes that is currently rampant outside the protected area network in the Western Ghats.

FIELD OBSERVATIONS AND DISCUSSION

R. pseudomalabaricus was sighted on multiple occasions at two sites in Munnar, a cardamom plantation and a tea

plantation. Individuals were sighted inside an active, shade-grown cardamom (*Elettaria cardamomum*) plantation, which had retained some of its primary vegetation in the form of mature trees, during the monsoon from 14th September to 10th November 2014 between 19:00–23:57 h (Munnar 1; Fig. 1; Table 1). A total of seven adult individuals (aggregation of three individuals on one occasion) were observed at the site around a concrete water tank (4.2 × 5.8 × 2.2 m) on different days. Foam nests, tadpoles and metamorphs were also observed (Figure 2a, b, d, e). The adults (identity

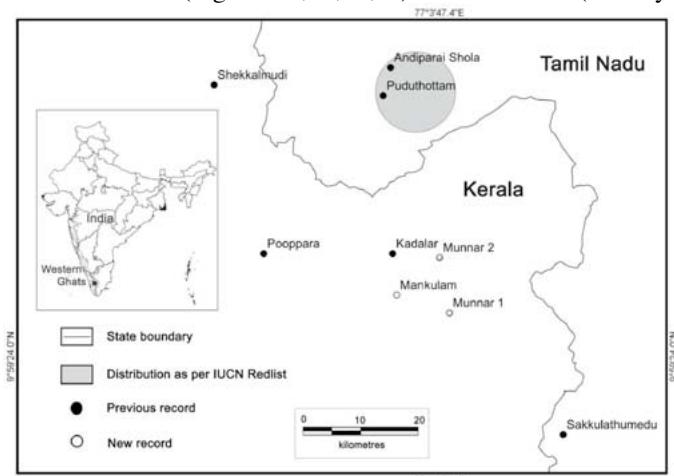


Figure 1. Distribution of *R. pseudomalabaricus* in the southern Western Ghats, India



Figure 2. a) Adult *R. pseudomalabaricus* b) Foam nest of *R. pseudomalabaricus* constructed at the corner of the tank. c) Nest of *R. pseudomalabaricus* on a shrub (*Eupatorium* sp) within a tea plantation d) Tadpole of *R. pseudomalabaricus* e) A metamorph of *R. pseudomalabaricus*. f) Male and female *R. pseudomalabaricus* in axillary amplexus.

confirmed from green dorsum with light yellowish-orange webbing between fingers and toes, flanks with white mottling; see Vasudevan & Dutta, 2000; Gururaja, 2012), were found resting or calling on the edges of the tank and on cardamom leaves, while some were seen floating inside the tank. Male individuals had a single vocal sac and the advertisement calls consisted of a series of notes (trrr tik tik tik tik trrrr). The call of a single, vocalising male was recorded with a Nikon Coolpix AW100 camera on 7th October, 2014 at 21:21 h (air temperature: 17.7 °C, substrate temperature: 21.5 °C, humidity: 71 %). Four consecutive calls of one individual were analysed using Raven Pro 1.4. Each call lasted for an average 2.5 s, which attained peak amplitude of 1059 kU at the beginning and 2727 kU towards the end (Fig. 3). The interval between two consecutive calls ranged from 4.2–14.1 s. Three foam nests were observed at the corners of the tank deriving support from herbaceous plants growing on the tank's edges and were not covered with leaves. No direct observations of breeding or foam nest construction were observed at this site. A fresh foam nest was observed on 3rd November, 2014. *R. pseudomalabaricus* tadpoles of varying sizes (Gosner stages 26–41; Gosner, 1960) were seen inside and around the tank, species identification was confirmed from their overall green colouration with black dorsal markings (see Vasudevan & Dutta, 2000). Metamorphs (Gosner stages 44–46; Gosner, 1960) had a green dorsum with leaf venation-like markings (see Vasudevan & Dutta, 2000) and were observed outside the tank clinging onto the cardamom and herbaceous plants.

R. pseudomalabaricus was sighted and opportunistically observed in an active tea (*Camellia sinensis*) plantation in Munnar on multiple occasions between the months of July and November during the years 2012 to 2014 (Munnar 2: Fig. 1; Table 1). The species were usually observed on eucalyptus trees and *Eupatorium* and *Lantana* shrubs growing alongside a small marsh (>0.5 ha) within the plantation after 19:00 h to as late as 01:30 h on days when moderate precipitation was recorded. The marsh is a common grazing ground for cattle owned by the plantation workers. It accumulates run off from the plantation and has standing water during the monsoon (June – November). A maximum of 42 adult *R. pseudomalabaricus* were observed during a single night at the marsh. A pair in axillary amplexus was observed on the night of 15th July, 2012 (Fig. 2f). A total of nine nests were observed during the three year period, from the water level where they were deposited on clumps of grass to 9 m above the ground on an eucalyptus tree with *Eupatorium* and *Lantana* bushes directly below, as well as on *Eupatorium* (Fig. 2c) and *Lantana* bushes overhanging the water in the marsh. These nests were on the sharp ecotone of the road and the marsh and ranged from having some form of leafy cover to being completely exposed. Tadpoles of *R. pseudomalabaricus*, as well as those of a *Zakerana* species were frequently observed in the marsh post September. As many as seven metamorphs were observed on the bushes on a single night. Tarred roads on either side of the swamp were used regularly by the tea-picking community. A road-kill of an adult individual was observed here in September, 2012 (Fig. 4).

Our records extend the range of the species by 12.4 km

Site Name	State	Elevation (m asl)	Habitat	Land Status	Literature
1 Andiparai	Tamil Nadu	1190	Artificial pond in rainforest	Protected Area - Anamalai Wildlife Sanctuary and Tiger Reserve	Vasudevan & Dutta, 2000
2 Puduthottam	Tamil Nadu	1000	Degraded rainforest fragment	Private forest fragment under the jurisdiction of Anamalai Wildlife Sanctuary and Tiger Reserve	Vasudevan & Dutta, 2000
3 Sakku-lathumedu+	Tamil Nadu & Kerala	1080	Close to plantation and rainforest fragment	Outside protected area network	Srinivas et al., 2009, G. Srinivas, pers. comm.
4 Shekkalmudi	Kerala	1118	Artificial water hole between evergreen forest and tea estate	Protected Area -Parambikulam Wildlife Sanctuary and Tiger Reserve	Jobin & Nameer, 2012
5 Kadalar	Kerala	1429	Marsh beside perennial stream outside cardamom plantation	Outside protected area network	Biju et al., 2013
6 Pooppara	Kerala	955	Secondary forests on the fringe of abandoned cardamom plantation	Outside protected area network	Biju et al., 2013
7 Munnar 1	Kerala	1350	Artificial water tank within cardamom plantation and on surrounding vegetation	Outside protected area network	Current Study
8 Munnar 2	Kerala	1573	Vegetation surrounding a marsh within a tea plantation	Outside protected area network	Current Study
9 Mankulam*	Kerala	1640	Forests, cardamom plantations, streams	Outside protected area network	Current Study

Table 1. Current and new distribution records of the Anamalai gliding frog *R. pseudomalabaricus*

+Srinivas et al (2009) state that Sakkulathumedu occurs in Kerala, however the GPS co-ordinates they have provided points to a location in Tamil Nadu. This site borders the two States and the species is known to occur around this site across both the States (G. Srinivas, pers. comm.)

**R. pseudomalabaricus* has not been physically sighted here but this record is the result of ecological knowledge surveys with local communities.

to the south-east of its closest known locality in Kerala and 34.4 km south of the reported range according to the IUCN Red List (Biju et al., 2004). We also extend its altitudinal range to 1600m asl. Biju et al., (2013) and Jobin and Nameer (2012) had also encountered *R. pseudomalabaricus* in and around cardamom and tea plantations. The vocalisation of the morphologically similar *R. malabaricus* has been formerly described (Hampson & Bennet, 2002) and its call is distinct and can be used to differentiate it from *R. pseudomalabaricus*. *R. pseudomalabaricus* has been known to breed and build foam nests in artificial ponds (Vasudevan & Dutta, 2000). Our observations suggest that breeding continues into November and is not restricted to June – October as reported by Biju et al., (2013) and may occur throughout the year with peaks during monsoon and winter (Vasudevan & Dutta, 2000).

Previously, mating individuals/foam nests have been observed at a height of 2-6 m only on understorey vegetation overhanging pools of water (Vasudevan & Dutta, 2000; Biju, 2009; Biju et al., 2013). Our observations show that foam nesting can take place from the ground level up to 9 m suggesting that foam nest construction is adjusted according to the vegetation or substrate available around the breeding site as observed in *R. malabaricus* (Kadadevaru & Kanamadi, 2000). Not all foam nests were wrapped in leaves as reported by Biju (2009) and

Biju et al. (2013), but were constructed in clumps of grass or on the sides of cement water tanks. The use of invasive plants, such as *Eupatorium sp.* and *Lantana sp.* for building nests is also an encouraging sign. Habitat restoration programs are undertaken in the species range and usually involve the complete removal of invasive plants as a standard. We urge that such programs be undertaken only after understanding the current habitat use and as well as, ideally only when the frogs are not breeding. Invasive species should also be ideally replaced with native ones, which provide similar habitat structure for the species. The species appears to utilise the same water-holes/sources as breeding sites over multiple years suggesting strong site fidelity. While the protection of breeding sites is important, it is also critical to protect non-breeding sites and home ranges of breeding populations. At present, the home range and habitat utilisation of *R. pseudomalabaricus* outside of the breeding season is unknown and requires further research. The IUCN Red List status for this species may need to be re-evaluated and the species down-listed from ‘Critically Endangered B1ab(iii)’ to ‘Endangered B1ab(i,ii,iii)+2ab(i,ii,iii)’ since the extent of occurrence (EOO) integrating all currently known locations is 1282km² and area of occurrence is 36km² (Appendix 1). Moreover, it is now known from nine locations across a highly fragmented region including at degraded habitats in agricultural

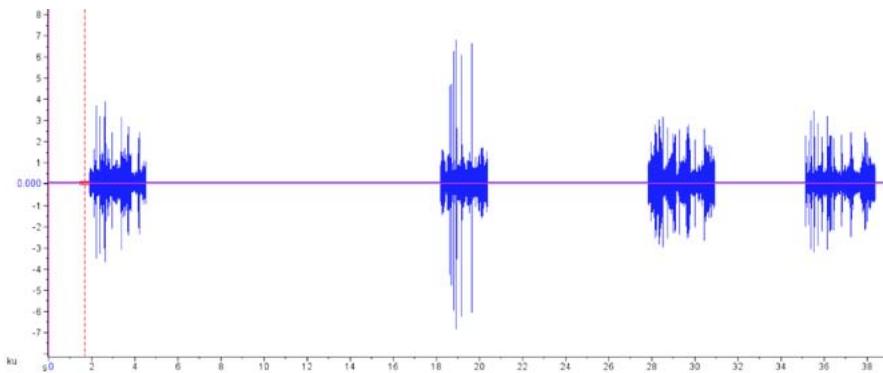


Figure 3. An oscillogram of four consecutive calls of a single, male *R. pseudomalabaricus*.



Figure 4. Road kill of *R. pseudomalabaricus* in a tea plantation in Munnar.

areas (Table 1, Appendix 1) unlike previously indicated (Biju et al., 2004), where it is also able to breed.

LOCAL ECOLOGICAL KNOWLEDGE AND DISCUSSION

Preliminary local ecological knowledge on *R. pseudomalabaricus* was gathered from the indigenous (Muduvar, Mannan) and non-indigenous local communities of Mankulam Forest Division in the Idukki District of Kerala in the Cardamom Hills. Morphologically, this species is similar to the widely distributed *R. malabaricus* (Biju et al., 2013) and local communities may not be able to distinguish between the two species. However, the distribution of the two species is not known to overlap and *R. malabaricus* is found at lower elevations (Vasudevan & Dutta, 2000; Biju et al., 2013). We have also not encountered *R. malabaricus* during our three years of field surveys at Munnar and to our knowledge, there are no published records of the species occurring at this site. The only other large Rhacophorid frog in the region is *R. calcadensis*, which is stark greyish-brown in colour and easily distinguishable from *R. pseudomalabaricus* (Biju et al., 2013). A total of 27 face-to-face questionnaires were conducted in the local languages (Tamil and Malayalam) with respondents being selected opportunistically from three settlements in Mankulam (Companykudi (n=10), Kandattikudi (n=6) and Viripara (n=11)) in January 2014. Most of the respondents either worked in cardamom plantations or as daily-wage labourers and were most likely to encounter frogs during their work, which involved de-weeding, digging, spraying pesticides/fertilizers, collecting cardamom or monitoring the estate. An unnamed colour photograph of *R. pseudomalabaricus* was shown and the respondents were asked whether they had seen the frog, the local name for the species and the habitat they had seen it in.

All the respondents confirmed the occurrence of *R. pseudomalabaricus* at the indicated habitats around their settlements at Mankulam. The respondents identified *R. pseudomalabaricus* with six names of which, Pacha tavala, Pacha tovaka and Pacha tera mean 'green frog', Mara tavala means 'tree frog', Ela thovaka means 'leaf frog' and Totturu whose meaning is not understood. The local names, which mean 'green frog' and 'leaf frog' were also used for bush frogs *Raorchestes jayarami* and *R. beddomii*. Only the indigenous individuals used the names Ela thovaka, Mara tavala and

Totturu. Most of the respondents had seen the frog on leaves or trees (n=13), followed by cardamom plantations (n=11) and forest, bamboo and streams (n=5). Three respondents stated that they most often saw *R. pseudomalabaricus* during the monsoon while another had seen it inside his house. One respondent also stated that it 'flies' from one plant to another and that it vocalises all night during the monsoon. *R. pseudomalabaricus* was not consumed by the local communities and one individual from the Mannan community stated that pregnant woman should not touch it. One respondent also mentioned that the species consumed cardamom.

Indigenous communities may have a greater association with the species since they related it more with its habitat. The species may be considered as a bad omen among the Mannan community and could reflect the general dislike towards frogs among local communities, which was especially high among women (A. Kanagavel, unpublished data). The perception that *R. pseudomalabaricus* consumes cardamom has been documented in the region previously (Kanagavel & Parvathy, 2014) and whether they consume it in reality is not known. Local ecological knowledge surveys should be used prudently and in combination with other habitat/species characteristics for further surveys of *R. pseudomalabaricus* due to identical local names for smaller-sized bush frogs in the region. Since the size classes of these species are quite distinct we strongly suspect that the respondents did not make erroneous identifications, however, this cannot be completely ruled out. Local ecological knowledge surveys are not usually undertaken for amphibians and our preliminary findings suggest that such surveys would be beneficial for distinctive frogs with local names like *Nasikabatrachus sahyadrensis*, *Melanobatrachus indicus* and *Rhacophorus lateralis*, which are all threatened species (Biju, 2004; Biju et al., 2004b, c). These surveys would also be appropriate for amphibians that may not be encountered during routine herpetological surveys due to extremely seasonal or limited activity patterns. A case in point is *N. sahyadrensis*, a species with very seasonal activity period that was unknown to science until 2004 but was well known among indigenous communities (Aggarwal, 2004).

CONCLUSION

This report highlights the importance of agricultural habitats including cardamom and tea plantations for rare and threatened frogs and the role *R. pseudomalabaricus* may perform as a flagship for amphibian conservation in the region (Kanagavel et al., 2014). The species is easily identified by local communities and emblematic, including being featured on a postage stamp and similar to the culturally significant Mountain chicken frog *Leptodactylus fallax* in Dominica (Tapley et al., 2014), is a good candidate for conservation. The IUCN Red List status for this species would need to be re-evaluated and may need to be down-listed from ‘Critically Endangered’ to ‘Endangered’ based on the new distribution records and an increase in their range. A systematic field-based study supplemented by local ecological knowledge surveys needs to be undertaken to determine the actual distribution of this species. Home ranges should be determined to improve our understanding of breeding and non-breeding habitats so that appropriate conservation action can be implemented.

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Appendix 1. Proposed Red List Status for *Rhacophorus pseudomalabaricus*

Current Status: Critically Endangered B1ab(iii)

Proposed Status: Endangered (B1ab(i,ii,iii)+2ab(i,ii,iii))

Taxonomy

Scientific name: *Rhacophorus pseudomalabaricus* Vasudevan and Dutta, 2000

Common names: False Malabar tree frog, Anamalai flying frog, Parachuting frog, Anamalai gliding frog

Synonyms: None

Taxonomic notes: *Rhacophorus pseudomalabaricus* was described by Vasudevan and Dutta (2000) from the rainforests of Andiparai Shola in Anamalai Wildlife Sanctuary and Tiger Reserve, Valparai, Tamil Nadu State, India.

Assessment Information

Red List category and criteria:

Endangered (B1ab(i,ii,iii)+2ab(i,ii,iii))

Justification: *Rhacophorus pseudomalabaricus* is assessed as Endangered (B1ab(i,ii,iii)+2ab(i,ii,iii)) since it has a restricted distribution with an estimated extent of occurrence (EOO) of 1282 km² and area of occupancy (AOO) of 36 km² both of which are projected to decline due to increased anthropogenic stressors. The species is currently known from nine severely fragmented locations, where the area, extent and quality of species habitat is declining, due to development of large-scale tourism infrastructure and runoff of chemical effluents from plantations.

Geographic range

Range description: The species is endemic to the southern Western Ghats of India where it is currently known from the Anamalai Hills and Cardamom Hills in the states of Tamil Nadu and Kerala (Vasudevan & Dutta, 2000; Srinivas et al., 2009; Jobin & Nameer, 2012; Biju et al., 2013). Its occurrence in the Meghamalai Wildlife Sanctuary needs confirmation. It has an altitudinal range of 955–1640 m asl. The approximate current extent of occurrence (EOO) is 1282 km² (see Figure 1).

Countries: India (states of Kerala and Tamil Nadu)

Range Map: see Figure 1

Habitat and Ecology

It is an arboreal species, occurring in the understorey of high elevation tropical moist evergreen forests (Vasudevan & Dutta, 2000; Biju et al., 2013; current study). It is also present in highly degraded and disturbed secondary forests and habitats inside tea and cardamom plantations (Biju et al., 2013; current study). The species aggregate during the breeding season at stationary artificial and natural pools of water and on vegetation overhanging marshes, streams and ponds (Vasudevan & Dutta, 2000; Biju et al., 2013; current study). The species constructs foam nests in which eggs are deposited. These foam nests are constructed according to the vegetation or substrate available around the breeding site (current study). The eggs begin to develop into tadpoles in the foam nest and drop into the pools after attaining Gosner Stage 11, where they develop further (S. Varma, unpublished data; Gosner, 1960).

Systems: Terrestrial; Freshwater

Threats

Major Threat(s): The habitat of the species is greatly affected by

fragmentation due to which ‘potential habitat’ has been reduced to small rainforest fragments among tea, coffee, cardamom, teak and eucalyptus plantations (Raman & Mudappa, 2003). Potential runoff of fertilisers, pesticides and other chemical effluents from the surrounding plantations degrades species habitats (Daniels, 2005). However, the species continues to occur in such landscapes and the actual effects of these threats are not well understood. The area and extent of habitat is also reducing due to development of large-scale tourism infrastructure in the species range. Road-kills of *R. pseudomalabaricus* have also been encountered (Vasudevan & Dutta, 2000; current study). The species used to be culled at cardamom plantations due to the perception that they consumed cardamom (Kanagavel & Parvathy, 2014), which is a highly valuable cash crop and one of the major livelihood sources in the region. *R. pseudomalabaricus*’ range also coincides with the area where the probability of chytrid presence is high (Molur et al., 2015) but whether populations of this species are affected by the fungus is currently not known. Natural predators of foam nests and adults include Lion-tailed macaques *Macaca silenus* (Vasudevan & Dutta, 2000).

Population

Population: No reliable estimates of the status or trends in populations are available. The species is known to be common within its range (Vasudevan & Dutta, 2000; current study).

Population trend: Unknown

Conservation

Conservation action: No species specific conservation actions are currently in place. Except for the populations inside the Anamalai Wildlife Sanctuary and Tiger Reserve in Tamil Nadu and Parambikulam Wildlife Sanctuary and Tiger Reserve in Kerala, much of the range of this species (especially in the Cardamom Hills) is outside formal protected areas. The species is known to occur in privately-owned plantations including at areas owned by the Kanan Devan Hills Plantations Company Private Limited (KDHP), which have considerably high levels of protection. This plantation company has also recently been certified by Rainforest Alliance, which suggests that such certification could serve as a suitable incentive for integrating biodiversity conservation in cultivated landscapes. The project ‘Cardamom plantations in the Western Ghats: Are these killing fields for amphibians justified?’ implemented by Conservation Research Group, St. Albert’s College, Kochi, India aims to understand the issue of amphibian (including *R. pseudomalabaricus*) culling in cardamom plantations and reduce culling through raising awareness among local communities. The species also has a high flagship potential (Kanagavel et al., 2014) and could be used as a symbol for promoting nature-friendly farming practices in the region. *R. pseudomalabaricus* use invasive plants such as *Eupatorium* and *Lantana* bushes for building nests and, caution needs to be exercised while removing them as a part of habitat restoration programs. A systematic field-based study supplemented by local ecological knowledge surveys needs to be undertaken to determine the actual distribution of this species including at Meghamalai Wildlife Sanctuary. The home range of the species should be determined to improve our understanding of breeding and non-breeding habitats, so that appropriate conservation action can be implemented.

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