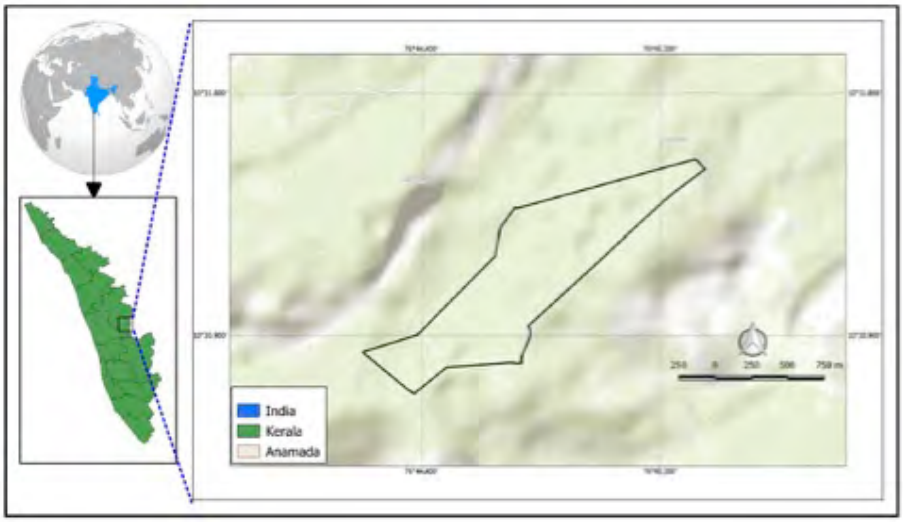
Preliminary checklist of anurans of Nelliampathy Hills, southern Western Ghats, Kerala, India

The most threatened taxa in the vertebrate world are constituted by the amphibians where in most of the members are on the brink of extinction (Stuart et al. 2004). Habitat loss and habitat fragmentation are the core cause for this. According to Baillie et al. (2004) & IUCN SSC Amphibian Specialist Group (2011a,b) threat for the 88% of the threatened amphibians of the world are due to habitat loss and habitat degradation. Among vertebrates of the world, declining rate of the amphibians is higher than any other taxa among vertebrates (Roelants et al. 2007). A total of 181 species of amphibians recorded in the Western Ghats, 87% are endemics (Subramanian et al. 2013). Western Ghats mountains that lie between river Tapti in the north to Kanyakumari in the south, is highly fragmented and surrounded with various land use systems, including plantations and settlements (Anonymous 2011). These fragments of the human-modified landscape that occur between the natural forests, act as corridors and they have the potential to conserve the native biodiversity, which is still untapped. The present study is to understand the conservation value and amphibian richness in a human-modified landscape located between the natural forests in the southern Western Ghats, in India.

Study area

The study was conducted at Anamada in the Nelliyampathy Hills of Palakkad District, Kerala. This area is contiguous with Parambikulam Tiger Reserve and Nemmara Forest Division. The total extent of the study site is 182ha (between 10.48–10.51^{0}N and 76.71–76.76^{0}E). The study site was the property of Maharaja of Kollenkode who leased vast tracts of dense jungle to the British for the cultivation of coffee, cardamom and oranges in the 18th century.



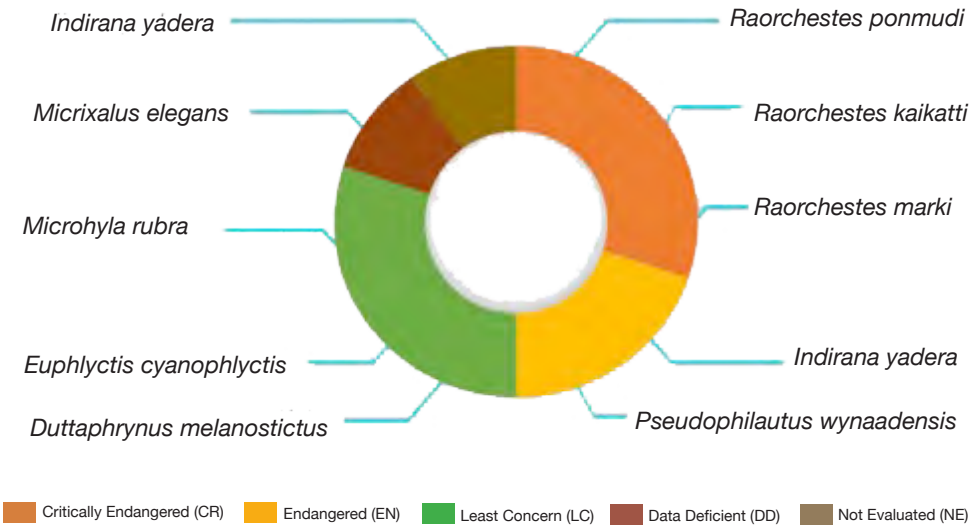
Anamada, Nelliampathy Hills, Southern Western Ghats, Kerala, India. Provide GPS coorinates

Aerial distance (9.5km) between type locality of *Raorchestes kaikatti* and *R. marki* with present study area

However, for the past two decades, there were no major plantation activities taking place here and as a result, the use of pesticides was minimal for the past two decades. The major vegetation consists of the plantations of Coffee (*Coffea arabica*), Cardamom (*Elettaria cardamomum*) and Orange (*Citrus mandarin*). Apart from these the study site also has natural forest patches of IA/C4 west coast tropical evergreen forests and 2A/C2 west coast tropical semi evergreen forests interspersed with these plantations. The dominant tree species in the natural forest patches were *Bischofia javanica*, *Artocarpus hirsutus*, *Maesopsis eminii* etc. The altitude of the study site ranges from 1,000–1,100 m.

Methods

Visual encounter surveys were carried out in March - April 2018 from 16:00hr to 22:00hr. Efforts were made to cover all the representative habitats of the study site. We searched for anurans in suitable microhabitats including ponds, dried stream channels, rocky patches, leaf litters and dead logs. Standard morphological measurements were taken for all specimens as per Bossuyt & Dubois (2001). These include, snout-vent length (SVL), head width (HW),



IUCN status of encountered species

Table 1: Species diversity of anurans of Anamada, Nelliyampathy Hills

Common name	Scientific name	Family	IUCN status
Common Indian Toad	*Duttaphrynus melanostictus*	Bufonidae	LC
Warty Frog	*Minervarya* sp.	Dicroglossidae	** -
Common Skittering Frog	*Euphlyctis cyanophlyctis*	Dicroglossidae	LC
Narrow-mouthed Frog	*Microhyla* sp.	Microhylidae	** -
Reddish Narrow-mouthed Frog	*Microhyla rubra*	Microhylidae	LC
Elegant Dancing Frog*	*Micrixalus elegans*	Micrixalidae	DD
Gunther's Leaping Frog*	*Indirana brachytarsus*	Ranixalidae	EN
Yadera Leaping Frog*	*Indirana yadera*	Ranixalidae	NE
Jerdon's Bush Frog*	*Pseudophilautus wynaadensis*	Rhacophoridae	EN
Kaikatti Bush Frog*	*Raorchestes kaikatti*	Rhacophoridae	CR
Mark's Bush Frog*	*Raorchestes marki*	Rhacophoridae	CR
Ponmudi Bush Frog*	*Raorchestes ponmudi*	Rhacophoridae	CR

LC – Least Concern; DD – Data Deficient; EN – Endangered; CR – Critically Endangered; NE – Not Evaluated; * - endemic to the Western Ghats; ** - Identified at genus level.

head length (HL), mandible nostril (MN), eye length (EL), forelimb length (FLL), hand length (HL), thigh length (TL), shank length (ShL), foot length (FOL), total foot length (TFOL). The instrument used for taking measurement was Aerospace Digimatic Vernier Caliper (to the nearest 0.01mm).

Result and Discussion

A total of 12 species under six different families in which two could be identified only at the genus level were reported from the study site (Table 1). This include seven species that are endemic to Western Ghats such as *Micrixalus elegans*, *Indirana brachytarsus*, *Indirana yadera*, *Psuedophilautus wynaadensis*, *Raorchestes marki*, *Raorchestes ponmudi* and *Raorchestes kaikatti*. *Raorchestes kaikatti*, *Raorchestes marki* and *Raorchestes ponmudi* are Critically Endangered species (IUCN SSC Amphibian Specialist Group. 2011a, 2011b; Biju 2004a). While *Indirana brachytarsus* and *Pseudophilautus wynaadensis* are Endangered species according to IUCN (Biju et al. 2004a,b).

During the study, 20 individuals were sighted and morphological measurements were taken (Table 2). The most dominant family was the *Rhacophoridae*, which was represented by four species followed by *Dicroglossidae*, *Microhylidae*, and *Ranixalidae* with two species each (Table 1).

Table 2. Morphometric measurements (mm) of anurans from the study site

Species	Locality	SVL	HW	HL	MN	EL	FLL	HAL	TL	ShL	FOL	TFOL
Fejervarya sp.	Anamada	35.96	12.79	11.21	9.6	3.99	5.92	8.76	18.14	18.28	18.08	26.86
Euphlyctis cyanophlyctis	Anamada	34.31	12.12	11.23	9.67	3.82	7.09	9.44	17.62	17.61	17.53	24.88
Microhyla sp.	Anamada	15.03	5.11	4.24	3.68	1.78	3.09	4.05	7.62	7.96	7.28	11.59
Microhyla rubra	Anamada	10.96	4.14	3.28	2.4	1.2	2.24	2.86	6.11	6.19	5.9	8.5
Micrixalus elegans	Anamada	13.29	5.58	4.09	3.41	1.97	2.93	3.4	6.21	6.3	6.42	9.42
Indirana brachytarsus	Anamada	32.01	11.99	10.98	9.51	3.82	6.17	7.28	17.66	18.93	15.78	25.04
Indirana brachytarsus	Anamada	33.15	12.52	12.1	9.97	3.88	6.96	8.46	18.55	20.79	17.28	27.45
Indirana brachytarsus	Anamada	31.47	12.81	12.4	11.55	3.75	6.78	9	20.43	21.49	19.72	28.9
Indirana brachytarsus	Anamada	27.87	10.61	11.01	86.4	3.01	5	7.29	15.63	16.92	15.44	22.64
Indirana yadera	Anamada	22.45	9.71	8.96	7.47	3.27	4.88	6.05	12.82	13.64	11.58	17.75
Pseudophilautus wynaadensis	Anamada	18.82	7.52	6.32	5.68	2.45	4.02	5.64	9.33	10.05	7.27	12.59
Pseudophilautus wynaadensis	Anamada	28.8	9	8.12	6.88	3.04	5.19	6.5	12.23	12.58	10.45	16.17
Pseudophilautus wynaadensis	Anamada	19.74	8.24	6.64	5.72	2.61	4.62	5.26	10.53	11.14	9.19	14.84
Pseudophilautus wynaadensis	Anamada	20.22	7.74	7.11	6.04	2.82	4.1	6.28	10.68	10.8	8.7	14.27
Pseudophilautus wynaadensis	Anamada	22.06	8.76	8.41	6.61	2.7	4.6	6.94	11.97	12.31	9.6	16.02
Pseudophilautus wynaadensis	Anamada	20.8	7.89	7.22	6.24	2.5	4.25	5.53	10.21	10.92	8.69	13.95
Pseudophilautus wynaadensis	Anamada	18.84	8.15	7.1	5.84	2.86	5.04	6.17	11.44	11.14	8.58	14.67
Raorchestes kaikatti	Anamada	19.46	8.15	6.98	6.3	2.39	4.93	5.67	10.96	11.64	9.21	14.84
Raorchestes marki	Anamada	20.51	8.41	6.79	5.26	3.1	5.72	5.5	11.8	12.16	9.17	15.56
Raorchestes ponmudi	Anamada	35.04	14.44	11.77	9.85	4.25	8.09	11.32	18.14	18.08	15.09	23.59

SVL - snout vent length; HW - head width; HL - head length; MN - mandible nostril; EL - eye length; FLL - forelimb length; HL - hand length; TL - thigh length; ShL - shank length; FOL - foot length; TFOL - total foot length.

1. Common Indian Toad *Duttaphrynus melanostictus* (Schneider, 1799)

Duttaphrynus melanostictus is a cosmopolitan species, though during the study only two individuals were encountered. They were encountered along the drainage areas in the study site and were of two different color morph. Both the individuals were adult.

2. Common Skittering Frog *Euphlyctis cyanophlyctis* (Schneider, 1769)

It is a widely distributed species in the family Dicroglossidae. In this study, six individuals were encountered near a stagnant water body in a rocky patch. All were adults and one was calling from a water body.

3. *Minervarya* sp.

We found this individual from a stagnant water body in a rocky patch. Morphological characters of the specimen are distinct tympanum and supra tympanic fold, pointed fingers lack webbing and toes with moderate webbing and small but prominent sub articular tubercles. *Fejervarya* species in the Western Ghats are now under *Minervarya* (Sanchez et al. 2018). Further molecular analysis is needed for the species level confirmation.

4. Reddish Narrow-mouthed Frog *Microhyla rubra* (Jerdon, 1854)

It was sighted among the leaf litters in a coffee plantation. There is dark stripe which runs from the snout through its eyes back to hind legs. The legs have a banded pattern with a black spot on groin and thigh. Its belly is creamy white with some markings on the throat. The tympanum was indistinct.

5. *Microhyla* sp.

It was encountered near flowing water body during 19:00–21:00 at 1,069m. It seems like *Microhyla sholigari* due to the presence of discs on fingers with circum marginal groove cover notched distally and on toes with circum marginal groove cover bifurcate distally. The present study area is in the south of Palghat gap, but all the specimen in Seshadri et al. (2016) is from north of Palghat gap. So, it could be a range extension of *M. sholigari*. However, DNA analysis of the species will be needed to confirm the taxonomy. Total three individuals were encountered during the study period.

6. Elegant Dancing Frog *Micrixalus elegans* (Rao, 1937)

Only one individual was encountered from leaf litter near a flowing stream during the

study period. It has restricted distribution between Palghat gap and Goa gap. It is a Data Deficient (Biju 2004b) species by IUCN. The snout is round in both lateral and dorsal view with round canthus rostralis.

7. Gunther's Leaping Frog *Indirana brachytarsus* (Gunther, 1876)

Total four individuals were encountered during the study time. One individual was encountered from stagnant water in a rocky patch and the remaining were encountered from flowing waterbodies in cardamom and coffee plantations. This species has been reported from Idukki Wildlife Sanctuary, Ponmudi Reserve Forest, Neyyar Wildlife Sanctuary, Anamalai Tiger Reserve, Peechi-Vazhani Wildlife Sanctuary and Chimmony Wildlife Sanctuary (Dahanukar et al. 2016). The present study shows its distribution in Nelliampathy Hills.

8. Yadera Leaping Frog *Indirana yadera*

This species was encountered from stagnant waterbody in a valley. Only one individual was sighted at an altitude of 1,075m. The first finger is longer than second, double outer palmer tubercle. The tympanum is well distinct. The encountered specimens were reddish brown in colour.

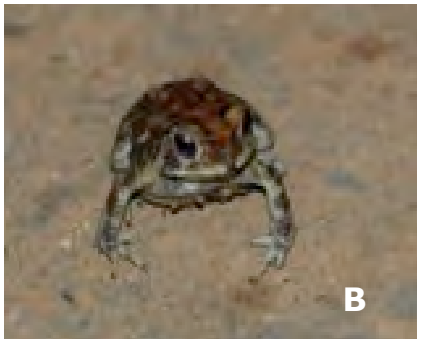
9. Jerdon's Bush Frog *Pseudophilautus wynaadensis* (Jerdon 1853).

It is the most abundant anuran found in our study site. Total eight individuals were encountered with different color morphs. Most of the individuals were encountered from coffee and cardamom plantation at an altitude of 1,100m.

10. Kaikatti Bush Frog *Raorchestes kaikatti* (Biju & Bossuyt, 2009)

It was encountered from coffee plantation inside the hollow fallen tree. Its holotype was collected from Kaikatti, which is 13km (Ground Distance) away from the present study area. The aerial distance between the type locality and present study area is about 9.5km. The GPS coordinates of the type locality were 10.583^{0}N & 76.733^{0}E (Biju & Bossuyt 2009). The present encountered coordinates are 10.50^{0}N & 76.75^{0}E. The GPS used for recording was Garmin etrex 30x (Accuracy 5m). Only one individual was encountered during the study, which was a sub-adult. It is interesting to note that this is the first sighting of the *Raorchestes kaikatti* from outside the type locality. *Raorchestes kaikatti* is a single-location, Critically Endangered species, thus belonging to the Alliance of Zero Extinction (AZE) category of species.

Images



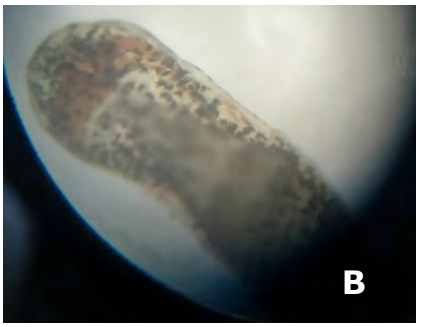
Common Indian Toad *Duttaphrynus melanostictus* (A & B are different colour morphs) A - © U.S. Amal, B - © M. Abin

Reddish Narrow-mouthed Frog *Microhyla rubra* © U.S Amal

Common Skittering Frog *Euphlyctis cyanophlyctis* © Afthab Faisal

Elegant Dancing Frog *Micrixalus elegans* © U.S Amal

Yadera Leaping Frog *Indirana yadera* © U.S Amal



Narrow-mouthed Frog *Microhyla* sp. A - © U.S. Amal, B - ©Afthab Faisal

Warty Frog *Minervarya* sp. © Afthab Faisal

Mark's Bush Frog *Raorchestes marki* © Afthab Faisal

Kaikatti Bush Frog *Raorchestes kaikatti* © Afthab Faisal

Ponmudi Bush Frog *Raorchestes ponmudi* © Afthab Faisal

Jerdon's Bush Frog *Pseudophilautus wynaadensis* © (A, B, C & D are different colour morphs). A, B, C - © Afthab Faisal, D - © U. S Amal

11. Mark's Bush Frog *Raorchestes marki* (Biju & Bossuyt, 2009)

It was encountered from coffee plantation after a rain. Its holotype was also collected from Kaikatti which is 13 km (Ground Distance) away from the present study area. The aerial distance between the type locality and present study area is about 9.5km. The GPS coordinates of the type locality were 10.583^{0}N & 76.733^{0}E (Biju & Bossuyt 2009). The present encountered coordinates are 10.50^{0}N & 76.75^{0}E. The GPS used for recording was Garmin etrex 30x (Accuracy 5m). Only one individual was encountered during the study. It is interesting to note that this is the first sighting of the *Raorchestes marki* from outside the type locality. *Raorchestes marki* is a single-location, Critically Endangered species, thus belonging to the Alliance of Zero Extinction (AZE) category of species.

12. Ponmudi Bush Frog *Raorchestes ponmudi* (Biju & Bossuyt, 2005)

It was encountered from the coffee tree of 1m height during a heavy rain

Gunther's Leaping Frog *Indirana brachytarsus* © Afthab Faisal

while it was calling. It was encountered at 19:00–21:00 hr. It was previously recorded by Biju & Bossuyt (2009) from places Ponmudi, Vagamon, Gavi, Kalpetta, Mananthavady and Sulthan's Battery of Kerala. It is also recorded from Parambikulam Tiger Reserve by Jobin & Nameer (2012). The present location is from Nelliampathy hills which is bordering Parambikulam Tiger Reserve. Only one individual was encountered during the study.

Dolia et al. (2008) have stated that agroforestry systems or plantations are resilient for biodiversity conservation than other land modifications because of the arboreal vegetation they incorporate. In the present study, four species (Table 1) belong to Rhacophoridae,

which shows that the arboreal vegetation in the study area acted as a suitable microhabitat for tree frogs. Majority of the encounter in the present study was from the leaf litters along with dead logs in the plantation which supported the anuran diversity of the study area. Habitat heterogeneity and structural complexity of this human-modified production landscape of Western Ghats may be the reason behind the presence of a large number of endemic species in the current work. Anand et al. (2010) emphasized that protected areas alone are inadequate to conserve the native tropical biodiversity in the long term. Conservation of the area outside Protected Areas (PA's) is needed for prevention of extinction of globally threatened species and there by achieving Aichi Biodiversity Target 12 (Raghavan et al. 2016). Syamili & Nameer (2018) also highlighted the significance of the human-modified landscape in the conservation of anurans in the Western Ghats.

Conclusion

The present study highlights the significance of this human-modified landscape, sandwiched between natural forests, such as Parambikulam Tiger Reserve and Nemmara Reserved Forests. We report seven species of anurans that are endemic to the Western Ghats from the study area. This includes three Critically Endangered and two Endangered species. One of the major highlights of the study was the sighting of the two globally threatened species such as *Raorchestes kaikatti* and *R.marki*. These species until now were known only from the type locality. All these findings show the significance of conservation of this tropical human-modified productive landscape and to achieve the Aichi Biodiversity Target 12.

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