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COMMUNICATION

Range extension and larval habitat of *Lyriothemis tricolor* Ris, 1919 (Odonata: Anisoptera: Libellulidae) from southern Western Ghats, India

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Abstract: Worldwide many species of odonates are known to use phytotelmata as a breeding habitat. Hitherto, no species are known to breed in phytotelmata in India. However, field studies conducted in the southern Western Ghats revealed that *Lyriothemis tricolor* Ris, 1919 (Libellulidae) uses tree holes as a larval habitat. Here we report the range extension of *L. tricolor* to southern Western Ghats and describe morphology of the larva, exuvia, and adult female. Based on the present study, we describe the larval habitat of *L. tricolor* in the southern Western Ghats. Our findings reveal that *L. tricolor* breeds in the tree holes of evergreen and semi-evergreen forests in the southern Western Ghats.

Keywords: Evergreen forests, *Lyriothemis tricolor*, phytotelmata, Western Ghats.

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Author Details: K.S. Anoop Das works on ecology of tree hole insect communities and conservation biology of birds. K.A. Subramanian works on taxonomy, ecology and biogeography of aquatic insects. K.G. Emiliyamma works on taxonomy of Odonata and Dermaptera. Muhamed Jafer Palot works on taxonomy and ecology of butterflies, odonates, reptiles and birds. K.A. Nishadh is a research scholar.

Author Contribution: KSAD obtained funding and permissions, conducted field surveys in SVNP and NARF during 2009–2010, collected the larvae and documented physicochemical parameters of tree holes with KAN. KAS identified larvae collected from SVNP, compared the exuviae collected from SABS, analysed the data and wrote the manuscript. KGE identified the female species collected from SABS and described the female. MJP conducted field surveys in SABS, collected the female with exuviae. KAN conducted field surveys with KSAD.

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INTRODUCTION

Aquatic habitats in tree holes are one of the four broad categories of phytotelmata. They are known to support diverse insect orders including Odonata (Orr 1994; Kitching 2000). Worldwide 24 genera and 47 species of Odonata are known to make use of phytotelmata (Corbet 1999). The phytotelmata as a larval habitat has been reported from all major tropical biogeographic regions of the world except the Indian subcontinent (Corbet 1999). Here we report for the first time, the use of phytotelmata as a larval habitat in India by *Lyriothemis tricolor* Ris, 1919 and a range extension for this species from the Western Ghats.

STUDY AREA

The current discovery is based on field studies conducted at Silent Valley National Park (SVNP) in Palakkad District, New Amarambalam Reserved Forest (NARF), Malappuram District and Salim Ali Bird Sanctuary (SABS), Thattekkad in Ernakulam District of Kerala Western Ghats (Image 1). Studies at SVNP and NARF were conducted from December 2009 to September 2010 and at SABS in April 2013. The details of vegetation types and the bioclimatic features of the study area are provided in Table 1.

METHODS

The larvae from SVNP and NARF were collected by the first author and junior co-author in 2010 as part of a study which investigated the insect communities in tree holes (Nishadh & Das 2012). A total of 150 tree holes were sampled from three regions of the SVNP, namely, Sairandhri (n=68), Poochippara (n=34) and Walakkad (n=35) whereas in NARF tree holes were mostly sampled from Panapuzha (n=13) (Image 2).

The physical and structural characteristics of tree holes were documented as follows. For every tree hole sampled, the following were recorded: tree species, height of the tree hole from the ground, GBH of the tree, tree hole diameter measured as two longest hole opening measurements perpendicular to each other (Sota 1998), depth and water volume.

Water in a tree hole was extracted using siphoning,

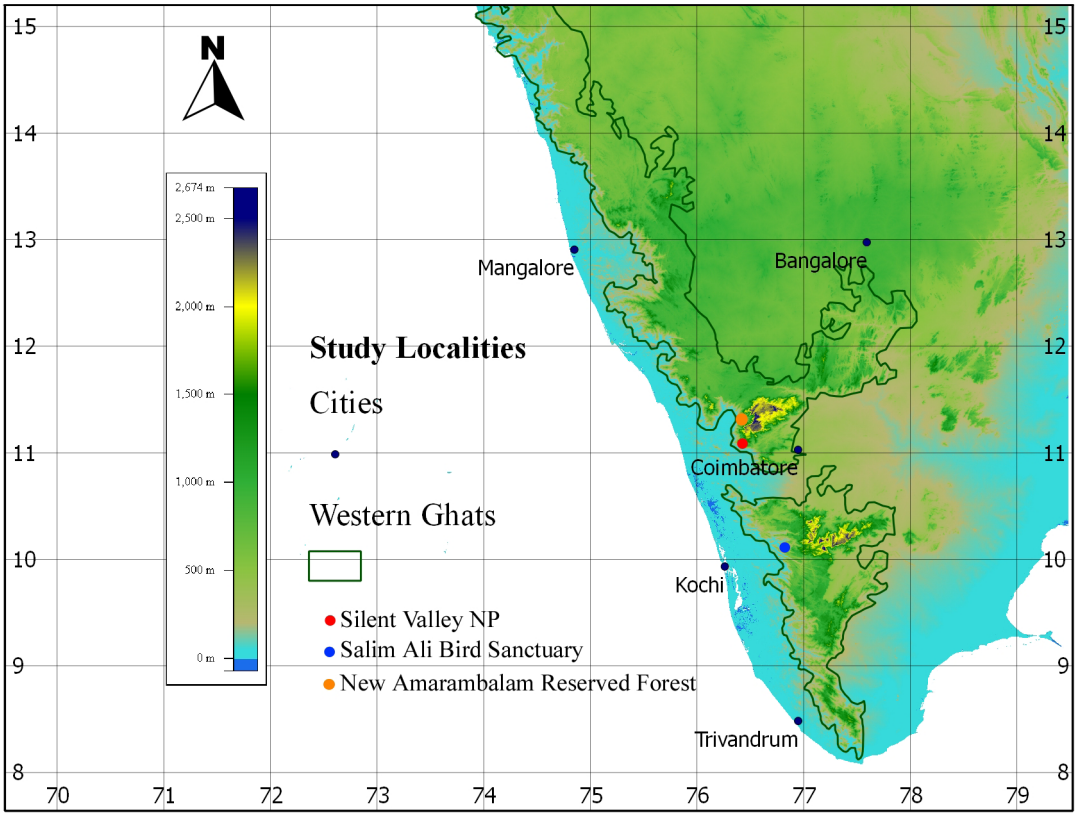


Image 1. Study area showing collection localities of the larvae and adult.

Image 2. The adult habitat at Thatekkad

Image 2. larval habitat at Silent Valley National Park

and volume was measured using a measuring cylinder. The contents of the tree hole such as leaf litter and detritus were transferred to a plastic tray and thoroughly checked for the presence of life forms. Thorough checks were made with the aid of a flashlight for elusive organisms in tree hole crevices. The water contents were then sieved with successive sieves from coarse to finer sieves (cc-500µm sieve size) by holding in a plastic tray. The organisms were counted and morpho-species preserved in 5% formalin (Yanoviak & Fincke 2005). The collected specimens were sorted out and identified to possible taxonomic level of family or genus referring to Edmondson (1959).

Physicochemical parameters of the water from the tree hole were studied based on Greenberg et al. (1992). Water samples from tree holes were collected using a suction rubber bulb, tube and stored in laboratory cleaned bottles. The samples were taken to the laboratory and analysed immediately. pH, electrical conductivity (EC, µS/cm), total dissolved solids (TDS, ppt), phosphate (mg/l), nitrate (mg/l), turbidity (FAU), sulphate (mg/l), and ammonia concentrations were analysed following standard methods (Greenberg et al. 1992).

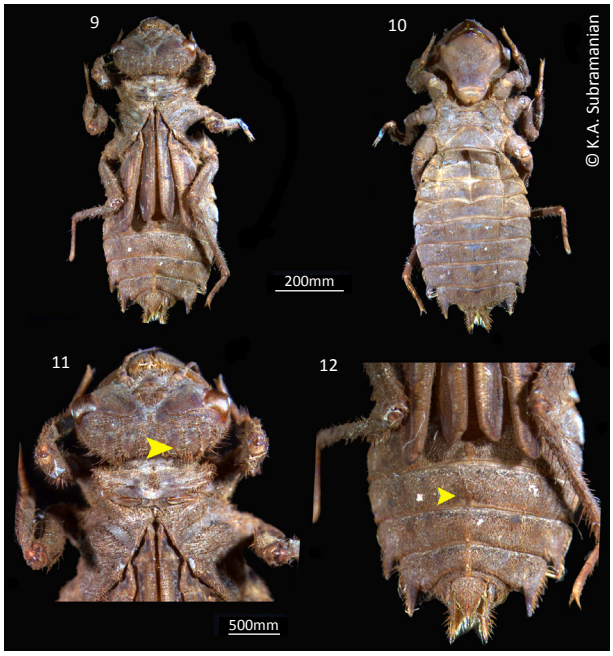
During a faunistic survey at SABS, on 03 April 2013, a female specimen was collected from Anachathapara area of the sanctuary. A freshly emerged female specimen with exuvia was sighted on the bark of a *Lannea coramandelica* (Houtt.) tree at a height of about 5m from the ground (Image 3). The collection locality is primarily a degraded semi-evergreen forest, interspersed with Mahogany and Teak plantations. The area is very close to the lake formed by the Boothathankettu Dam. We observed the specimen in a bottle for 10 days. Initially the specimen was pale yellow in colour with light brown markings on the head. After two days the colour drastically changed to darker and brighter.

The Anisopteran larvae collected from SVNP were identified up to the genus level following keys of, Xiufu (1994). Collected *Lyriothemis* larvae were compared with published descriptions of larval stages of *Lyriothemis* species (Lieftinck 1962; Lien & Matsuki 1979; Kitching 1986; van der Poorten 2009). The adult collected from SABS was identified based on keys of Fraser (1936) and van der Poorten (2009). The larvae were studied and compared with the exuvia collected from SABS. Body measurements and morphological characters of exuvia and larvae were studied under Leica EZ4HD and M205A microscopes.

Table 1. Details of the study area.

Locality	Major vegetation types	Altitude range (m)	Average annual rainfall (mm)	Annual temp-erature range (°C)
Silent Valley National Park, Palakkad District, Kerala.	West coast tropical wet evergreen forest	650–2330	3200–5000	18–23
New Amarambalam Reserved Forest, Malapuram District, Kerala	West coast tropical wet evergreen forests, semi-evergreen forests, moist deciduous forests and teak plantations.	40–2554	4000	23–45
Salim Ali Bird Sanctuary, Ernakulam District, Kerala	Moist deciduous forests, evergreen forests, teak and mahagony plantations.	30–523	4000	16–37

Images 4–8. Adult female (4–6) and exuvia (7–8).



Images 9–12. Morphology of larvae collected from Silent Valley National Park

RESULTS

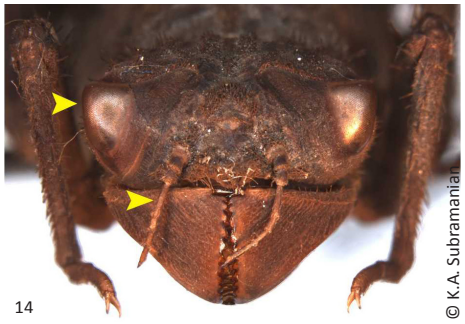
The adult female collected from SABS was identified as *Lyriothemis tricolor* Ris, 1919 based on descriptions of Fraser (1936). The morphological characters of the larvae matched the descriptions of *Lyriothemis tricolor* Ris, 1919 (Lien & Matsuki 1979). However, the larvae had nine palpal setae instead of eight as described by Lient & Matsuki 1979. The morphological characters of the exuvia also matched that of larvae collected from SVNP and NARF which were also identified as belonging to that of *Lyriothemis tricolor* Ris, 1919. The detailed description of the larvae, exuvia and adult are as follows.

Materials examined: Adult female with exuvia (1 pinned): ZSI/WGRC/IR-INV-2659, 3.iv.2013, (Images 4–6), (10.132256^{0}N & 76.685815^{0}E; 68m), Anachathapara, Salim Ali Bird Sanctuary, Thattekkad, Ernakulam District, Kerala, India, coll. Md. Jafer Palot.

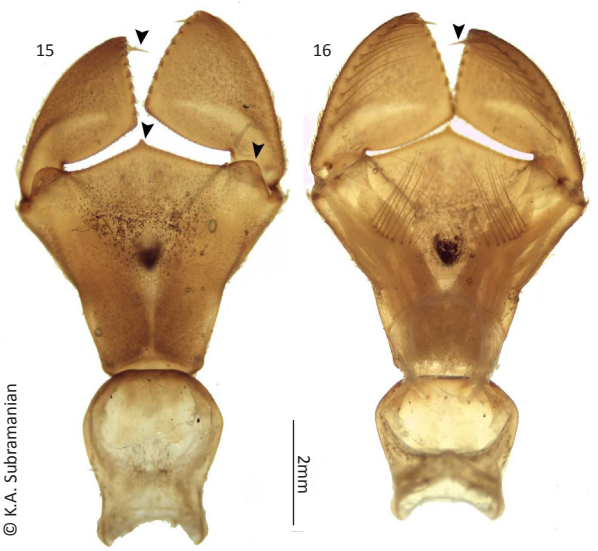
Exuvia (Images 7–8): Dark brown coloured and similar to the larvae in morphological characters. The measurement of exuvia is provided in Table 2. The palpal lobe was dissected out and digested in 10% KOH at room temperature for 24hr and photographed under the Leica microscope. The palpal lobe has nine palal setae, similar to that of larvae (Image 17).

Materials examined: Larvae (3 nos. in alcohol) : 4911/H13 (MIO Section, ZSI, Kolkata), 26.vii.2010, (Images 9–16), (11.111^{0}N & 76.422^{0}E; 1030m), Poochippara, Silent Valley National Park, Palakkad District, Kerala, India, coll. Anoop Das & Nishadh.

Description (Images 9–16): Larvae are uniformly rusty brown in colour and covered with short light brown hairs. Overall body texture is rough. Eyes are conical and pointed outwardly with metallic brown gloss under preserved condition. Antenna is eight segmented with 4th segment being the longest. Prementum of labium is an elongated pentagon with two anterio-lateral ovoid projections. Apex of the prementum ends in a tubercle-like projection. The inner side of the prementum has 11 premental setae on either side. Palpal lobe is shovel-



Images 13–14. Dorso-lateral view of the larva (13), anterior view of the head (14)



Images 15–16. Palpal lobes of larva

Image 17. palpal lobes of exuvia

Table 2. Measurements of larvae and exuvia (in mm).

Body part	Larva-01	Larva-02	Larva-03	Exuvia
Total length (excluding cerci and epiproct)	14.04	20.76	19.5	25.0
Inter ocular distance	2.36	3.86	4.12	4.28
Max. head width	4.18	5.97	6.04	6.32
Max. abdominal width	5.09	8.7	8.2	8.04

shaped with nine palpal setae. The anterior end of the palpal lobe has a thick spine. The occiput of the head has nine bald oval patches. In larva-01 the forewing pads extend to the 3rd abdominal segment and in larvae 02 and 03 it reaches up to the 6th abdominal segment. The legs are short and abdomen is ovoid. A single row of dorsal spines present from abdominal segments 3–9. The lateral spines of segment 9 reach half the length of paraproct. The cerci are shorter than epiproct and praproct is longer than epiproct. The measurements of larvae are provided in Table 2.

Adult female (Images 4–6)

Body measurements: Hind wing: 38mm. Abdomen: 31mm. Head: Labium yellow, middle lobe dull brown, lateral lobe yellow; mandible yellow with brown at centre; labrum brownish-black, a thin yellow stripe at base; labium and mandible with golden brown hairs along the border; anteclypeus dull yellow with brown shade medially; postclypeus bright yellow with median oval dark brown mark and dark brown edges; anterior surface of frons bright yellow, upper surface of frons and vesicle metallic green; occiput shining black; clypeus and frons with black hairs. Eyes: Reddish-brown above, bright yellow below and on sides. Prothorax: Yellow with pale brownish shade at the middle lobe. Thorax: dorsum with broad brownish shade; humeral suture with a broad black stripe; two short, oval antehumeral yellow spots as in male; laterally yellow with a thin brown stripe on mesepimeron and a similar stripe on posterolateral suture; tergum yellow; underneath thorax bright yellow with a brownish-black transverse stripe at the middle. Legs: black; all coxae yellow; trochanters yellowish brown. Wings: transparent, extreme base (anal field),

cubital space and subcostal up to first nervure bright amber yellow; pterostigma blackish-brown, covering 3 cells; membrane blackish-brown; discoidal cell traversed in all wings; 1 cubital nervure in forewings and 2 in hindwings; subtrigone in forewings traversed once, 2 celled; arc a bit proximal to second antenodal nervure; 3 rows of cells at beginning of discoidal field; nodal index:

12–18 / 17–11
12–16 / 13–11

Abdomen: Bright yellow with brownish-black median ridge from segments 2–7; lateral edges broad blackish-brown from segments 3–8; segments 3–7 with diffused brownish markings (not clear marking, irregular spots and stripes); segments 8–10 yellowish-brown. Anal appendage: brown, short, conical; vulvar scale very small, (not developed properly); segment 8 not dilated.

Habitat ecology

A total of 18 larvae of *L. tricolor* were collected from 15 tree holes of Sairandhri (n=8), Poochippara (n=3), Walakkad (n=0), Aruvanpara (n=4) and Panapuzha (n=3). Due to logistic reasons in the field, no attempt was made to raise the larvae to adulthood. Out of 150 tree holes sampled at an altitude range of 40–1175 m, only 10% of tree holes were occupied by the larvae of *L. tricolor*. No larvae were found in tree holes from Walakkad, SVNP.

Table 3. Details of *L. tricolor* larvae collection

Locality	Tree Hole Name	Tree Hole Code	Tree Species	Date of collection	No. of larvae
Aruvanpapra (SVNP)	A13	01	Unidentified	26.vii.2010	4
Panappuzha (NARF)	PA11	02	*Albizia lebbeck*	15.v.2010	1
Panappuzha ARF)	PA2	03	*Tetrameles nudiflora*	13.v.2010	1
Panappuzha (NARF)	PA4	04	*Tetrameles nudiflora*	13.v.2010	1
Poochippara (SVNP)	Po18	05	*Holigarna arnottiana*	18.viii.2010	1
Poochippara (SVNP)	Po7	06	*Myristica dactyloides*	15.viii.2010	1
Poochippara (SVNP)	PoA12	07	*Holigarna arnottiana*	18.viii.2010	1
Sairandhri (SVNP)	E4	08	*Syzygium cumini*	23.vii.2010	1
Sairandhri (SVNP)	P1	09	Unidentified	01.ix.2010	1
Sairandhri (SVNP)	p15+p15	10	*Elaeocarpus tuberculatus*	05.iii.2010	1
Sairandhri (SVNP)	S2-K8	11	Unidentified	31.viii.2010	2
Sairandhri (SVNP)	S2-MP4	12	Unidentified	01.ix.2010	1
Sairandhri (SVNP)	S2-TH4	13	Unidentified	01.ix.2010	1
Sairandhri (SVNP)	WLB14	14	*Syzygium cumini*	20.vii.2010	1
Sairandhri (SVNP)	WS1	15	*Elaeocarpus tuberculatus*	30-08-2010	1

Table 4. Structural characteristics of the tree holes

	Tree hole structural chracteristics																
Tree Hole Code	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
01	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
02	158	12	6	15	600	35	0	75	n/a	0	N	28.2	32.4	86	Linear	Morphological	1.73
03	180	55	12	70	6670	75	70	50	n/a	0	E	27	35	73	Cylinder	Morphological	n/a
04	196	16	17	12	420	19	0	100	n/a	0	N	26.8	30.3	95	Cylinder	Morphological	1.86
05	400	37.5	15	11.25	300	n/a	n/a	n/a	n/a	1	E	19.7	21.5	n/a	Triangular	Morphological	n/a
06	250	14	13	5	400	72	n/a	n/a	n/a	4	S	19.5	22.6	n/a	Cylinder	Wreckage	n/a
07	250	13	9	6.5	250	90	n/a	n/a	n/a	2	S	19.7	21.5	n/a	Cylinder	Morphological	n/a
08	320	18	6.5	8.5	300	n/a	n/a	n/a	n/a	n/a	n/a	19.7	19.7	100	Cylinder	Morphological	0.4
09	39	5	8	4	110	148	n/a	n/a	n/a	n/a	NW	n/a	n/a	n/a	Cylinder	Wreckage	n/a
10	400	15	5	29	2250	45	<50	n/a	>75	1	n/a	20.2	25.1	67	Cylinder	Morphological	n/a
11	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
12	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
13	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
14	158	25	34	30	2000	350	50	0	n/a	1	n/a	19.7	21.5	n/a	Cylinder	Wreckage	15.67
15	250	16	6.5	8	225	140	n/a	n/a	n/a	0	n/a	n/a	n/a	n/a	Cylinder	Morphological	n/a

Legend: (1) GBH in cm; (2) Tree hole diameter-1 in cm; (3) Tree hole diameter-2 in cm; (4) Tree hole depth in cm; (5) Water volume (ml); (6) Tree Hole height from ground (cm); (7) % Ground cover vegetation; (8) % Herb around tree hole; (9) % Rock cover around tree hole; (10) No. of trees within 5m radius; (11) Aspect (12) Temperature inside tree hole C; (13) Ambient temperature C; (14) Relative Humidity; (15) Shape; (16) Cause of formation; (17) Litter mass in g; (18) n/a: data not available

Table 5. Physicochemical properties of tree hole water

Tree hole code	pH	ORP	CON	TDS	Phosphate (mg/l)	Nitrate (mg/l)	Turbidity (FAU)	Sulphate (mg/l)	Ammonia (NH3)
1	5.87	72	1	0	0.446	0.687	382.8	58.561	1.637
2	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
3	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4	6.48	12	245	113	7.682	1.442	9.4	22.773	2.699
5	5.06	120	17	8	1.686	n/a	148	52.455	12.349
6	5.11	119	255	127	1.087	n/a	27.4	80.379	2.432
7	3.56	215	2	1	0.458	n/a	19.8	50.758	3.062
8	5.46	96	5	2	0.769	3.362	204.2	70.909	1.390
9	5.06	120	7.7	3.8	0.431	n/a	705.4	12.348	2.596
10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
11	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
12	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
13	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
14	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
15	3.99	189	5.4	2.6	0.208	n/a	259.4	17.576	2.486

Legend: ORP - Oxidation reduction potential; CON - Electrical Conductivity; TDS - Total dissolved solids; n/a - data not available

Table 6. Number of Individuals of invertebrates and vertebrates in tree holes.

Taxa		Tree hole code														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Annelida	Oligochaeta (Earthworm)	0	1	0	0	0	0	0	0	10	0	0	0	0	1	0
Nematoda	Nematoda	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0
Crustacea	Gecarcinidae (Crab)	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Arachnida	Acari (Mites)	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Insecta	Odonata: Libellulidae: *L .tricolor*	4	1	1	1	1	1	1	1	1	1	2	1	1	1	1
	Hemiptera: Velidae: *Baptista* sp.	0	0	0	1	0	5	0	0	0	0	0	0	0	0	0
	Thysanoptera	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Coleoptera: Scritidae	0	17	20	0	0	0	7	2	220	32	2	15	41	234	80
	Coleoptera: Hydrophilidae: *Helocharus* sp.	1	2	1	0	0	0	0	0	22	1	0	2	3	2	0
	Coleoptera: Ptilodactylidae	0	0	0	0	10	5	0	0	0	0	0	0	0	0	0
	Diptera: Tipulidae	2	0	1	0	1	0	0	0	18	0	0	0	0	1	1
	Diptera: Culicidae: *Culex*	160	0	3	6	0	0	0	0	0	0	1	0	0	0	1
	Diptera: Culicidae: *Aedes*	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
	Diptera: Chrinomidae	0	0	2	0	0	0	0	2	0	0	1	0	0	0	2
	Diptera: Syrphidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
	Trichoptera: Lepidostomatidae: *Goerodes* sp.	320	79	9	7	0	0	0	21	7	35	6	10	27	10	7
	Hymenoptera	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Amphibia	Microhylidae: *Ramanella* sp.	13	0	0	0	4	0	0	0	3	0	0	0	0	0	0

The tree holes with Odonata larvae were distributed from 600m to 1056m. The structural, water quality and associated biotic communities of the tree holes with the Odonata larvae are provided in Tables 3–6. Since many of the tree holes were remotely located in the forests or samples collected during the rainy days, it

was not possible to take back the water sample to the laboratory for analysis. Hence these water samples were not analysed for physical and chemical properties. Tree holes without water quality data are indicated in the tables. All the larvae were collected between March and September 2010 from host trees such as *Tetrameles nudiflora* R. Br. (Tetramelaceae), *Elaeocarpus tuberculatus* Roxb. (Elaeocarpaceae), *Albizia lebbeck* (L.) Benth. (Fabaceae), *Myristica dactyloides* Gaertn. (Myristicaceae), *Holigarna arnottiana* J. Hk. (Anacardiaceae) and a few unidentified tree species.

Physicochemical parameters of water collected from the tree holes show that the water is generally acidic with high levels of total dissolved solids, phosphates, sulphates and nitrates. The pH varied from extremly acidic to (pH 3.56) to near neutral (pH 6.48).

A diverse community of invertebrates and vertebrates coexist with *L. tricolor* larvae (table 6). Larvae and adults of Coleoptera and Diptera were very common in the tree holes. Three tree holes had frogs (Microhylidae: *Ramanella* sp.) and earthworms. Nematodes, and crabs were found only in one tree hole. It is not known how the different taxa interact in the community. However, the presence of predatory larvae of *L. tricolor* may significantly influence the community structure of tree holes.

DISCUSSION

The genus *Lyriothemis* with 15 species are exclusively found in Asia from Western Ghats to Japan (75–127 ^{0}E) (Schorr & Paulson 2013). The habitat of five species of *Lyriothemis* has been reported as marshy forested habitat across its geographic range (van der Poorten 2009). Four species of *Lyriothemis* i.e., *L. bivittata* (Thailand), *L. cleis* (Borneo, Sulwesi), *L. magnificata* (Malaysia) *L. tricolor* (Taiwan) are known to use phytotelmata as larval habitat (Corbet 1999). In Taiwan, *L. tricolor* has been reported using phytotelmata (Lein & Matsuki 1979). Within the Indian subcontinent, four species of *Lyriothemis,* viz., *L. acigastra* (Selys, 1878), *L. bivittata* (Rambur, 1842), *L. cleis* Brauer, 1868, *L. tricolor* Ris, 1919 were reported earlier (Fraser 1936; Mitra 2002). Recently a new species *Lyriothemis defonsekai* was reported from Sri Lanka (van der Poorten 2009) and the range of *L. acigastra* was extended to the Western Ghats (Emiliyamma et al. 2013). Within its geographical range in Asia, *L. tricolor* was known to occur only up to 26^{0}N & 89^{0}E in Rajabhatkhawa in Buxa Tiger Reserve, West Bengal (Fraser 1936). Our discovery of this species from the southern Western Ghats extends the eastern range of the species to 11^{0}N & 76^{0}E in the Indian subcontinent.

The larvae and exuvia of *L. tricolor* collected from Western Ghats has nine palpal setae and 11 premental setae similar to that of *L. elegantissima* Selys, 1883 (Lien & Matsuki 1979). However, the final instar larvae of *L. elegantissima* is much smaller (17.6–19 mm) than the *L. tricolor* larvae (21.5–24 mm) (Lien & Matsuki 1979). Moreover, the characters of adult female match that of *L. tricolor* and *L. elegantissima* is not distributed in the oriental region. Hence, *L. elegantissima* is excluded and the variation observed in premental and palpal setae of *L. tricolor* from Western Ghats may be due to intraspecific variation of different disjunct populations of the Indian subcontinent. Long isolation of populations may have favoured some genetic changes such as changes in the number of premental and palpal setae. Genetic studies are required to ascertain taxonomic status of Western Ghats populations of *L. tricolor*.

These recent discoveries highlight the disjunct distribution of the genus within the Indian subcontinent. It has been proposed that the disjunct distribution of the genus in the southern part of the subcontinent is caused by passive or active wind dispersals (Laidlaw 1951; Dijkstra 2007) or movement along corridors along the east coast of India during the Pleistocene (Laidlaw 1951). In the Western Ghats, in addition to *Lyriothemis*, libellulids such as *Hylaeothemis indica* Fraser, 1946, *Epithemis mariae* (Laidlaw, 1915) and the recently discovered *Lyriothemis acigastra* (Selys, 1878) (Emiliyamma et al. 2013) are found exclusively in lowland forest swamps. Zygopteran species such as *Phylloneura westermanni* (Selys, 1860), *Melanoneura bilineata* Fraser, 1922 and *Calocypha laidlawi* (Fraser, 1924) are also restricted to such forest swamps. Currently, these forest swamps and associated odonates are found in small patches in the north and south of the Palakkad gap. Lowland forest swamps once existed extensively throughout the southern Western Ghats. They were drained, deforested and converted for agriculture during early human colonization (Chandran 1997). The extent of lowland forest swamps and associated odonate species are highly fragmented in the Western Ghats.

Recent palynological studies provide evidence that species-rich rain forests and swamps were once widespread in the Indian subcontinent during early palaeogene times (Prasad et al. 2009). After India-Asia collision during the quaternary and recent times, climate changed dramatically and the subcontinent became much drier climatically, leading to the disappearence of wet forests in most parts of peninsular India.

Wet forests with a dominance of Dipterocarpaceae disappeared from most parts of peninsular India during the cenozoic period (Shukla et al. 2013). However, the southern Western Ghats, with its unique topographic features, high precipitation and shorter periods of dry months provided refugia to sustain lineages of ancient tropical vegetation (Prasad et al. 2009). The existence of many ancient lineages of amphibians, fishes, reptiles and odonates in the southern Western Ghats also support the palynological evidence that this part of the Western Ghats was a rainforest refugia during the drier Pleistocene period when most of the tropical rainforests from other parts of the subcontinent disappeared (Abraham et al. 2013). Extant species of *Lyriothemis* in the southern Western Ghats and Sri Lanka may in fact be the relict populations of Palaeogene times when tropical rainforests and forest swamps extensively covered the subcontinent and not wind dispersals or migration through land corridors as suggested earlier (Laidlaw 1951; Dijkstra 2007). However, detailed molecular phylogenetic studies are required to further investigate this hypothesis.

Larvae of *Lyriothemis tricolor* being a predator in the tree hole community, may play a significant role in structuring the community composition of tree hole breeding insects. Studies on *L. cleis* at Sulawesi (Kitching, 1986); *L. tricolor* and *L. elegantissima* at Taiwan (Lien & Matsuki 1979) suggest that they act as top level predators within treehole food web (Kitching 1986). Similarly, *L. cleis* larvae were observed in Bornean rain forest tree hole aquatic habitat (Orr 1994). The breeding habitat of *L. tricolor* is very different from the other species of the Western Ghats. The larvae live in extreme conditions where the pH is as low as 3.6 and with high levels of total dissolved solids, phosphates, sulphates and nitrates (Paradise 1997). High levels of nutrients and low pH is also reported from other tree hole aquatic medium such as in North America (Paradise & Kuhn 1999), Panama (Yanoviak 1999) and Germany (Schmidl et al. 2008). This is due to degradation of litter and and woody debris. Studies have shown that tree hole inhabiting larval species, especially the Odonata have a broad range of chemical tolerance (Fincke 1999; Yanoviak 1999).

This indicates the specialization of larvae to survive in extreme water quality conditions. The low pH also might influence the growth of certain key inhabitants and impact community interactions by affecting the processing chain commensalisms that occur in tree hole aquatic habitats. Therefore, the usability of tree hole habitats can be considered as a bio-indicator of forest ecosystem towards acidic deposition (Paradise & Dunson 1997). The limited availability of suitable tree holes with the right microhabitat and climatic conditions may significantly influence the distribution of *L. tricolor* within the Western Ghats. The discovery of a tree hole breeding dragonfly highlights the importance of tropical forests in conserving Odonata fauna of the Western Ghats and also emphasises the need to consider the larval habitats in conservation action plans.

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Malayalam Abstract:

സാരാംശം: മരപൊത്തുകളിൽ കെട്ടിനിൽക്കുന്ന വെള്ളത്തിൽ മുട്ടയിട്ടു പ്രജനനം നടത്തുന്ന തുമ്പികൾ ലോകത്തിൽ വളരെ വിരളമാണ്. ഇത്തരം തുമ്പികൾ ലോകത്തിൻറെ വിവിധ ഉഷ്ണമേഖല വനപ്രദേശങ്ങളിൽ കണ്ടുവരുന്നു. എന്നാൽ ഇതുവരെ ഇന്ത്യൻ ഉപഭൂഖണ്ഡത്തിൽ മരപൊത്തുകളിൽ പ്രജനനം നടത്തുന്ന തുമ്പികൾ ഉള്ളതായി അറിവില്ല. അടുത്തിടെ കേരളത്തിലെ പശ്ചിമഘട്ട വനങ്ങളിൽ നടത്തിയ ഗവേഷണം *ലിരിഒതെമിസ് ത്രികൊലോർ* എന്ന ഇനം തുമ്പി ന്യൂ അമരമ്പലം, സൈലന്റ് വാലി, തട്ടേക്കാട് എന്നി വനമേഖലകളിലെ മരപൊത്തുകളിൽ പ്രജനനം നടത്തുന്നതായി കണ്ടെത്തി. ഈ തുമ്പിയുടെ ലാർവയെകുറിച്ചും അതിന്റെ ആവാസവ്യവസ്ഥയെ കുറിച്ചും ഈ ഗവേഷണ പ്രബന്ധം പ്രതിപാദികുന്നു. ഇന്ത്യൻ ഉപഭൂഖണ്ഡത്തിൽ മരപൊത്തുകളിൽ പ്രജനനം നടത്തുന്ന തുമ്പിയെ ആദ്യമായാണ് പശ്ചിമഘട്ട വനങ്ങളിൽ നിന്നും കണ്ടെത്തുന്നത്.