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A note on spatial and temporal distribution of Anopheline mosquitoes in Western Ghats, Southern India

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ABSTRACT
Mosquito faunal surveys were carried out in different habitats of 11 hill ranges of the Western Ghats between 2000 and 2012. Thirty three anopheline species were examined and recorded out of 8730 specimens belonging to subgenera *Anopheles* (12) and *Cellia* (21). Very low densities of malaria vectors *Anopheles* (*Cellia*) *fluviatilis* (0.7%) and *An.* (*Cel.*) *culicifacies* (3.04%) were also recorded.

Keywords: *Anopheles*, *Cellia*, Western Ghats, mosquito fauna.

1. Introduction
The Western Ghats are one of the richest hot spots for mosquito fauna in the world. Earlier surveys made in this first quarter of the 20th Century resulted in a huge number of species which, were published in a monograph on the Indian anophelines [1]. Subsequently, studies were carried out by many entomologists like, Brooke Worth [2], Covell and Harbhagwan [3], Das [4], Jaswant Singh and Jacob [5], Kalra and Wattal [6], Measham and Chowdhuri [7], Nagpal and Sharma [8], Ramachandra Rao [9], Russell and Jacob [10], Tewari [11], Tyagi [12-14], Vedamanikkam [15-16], and Wattal and Kalra [17].
Over the past four decades the ecology of Western Ghats has greatly altered. There has been extensive deforestation due to the construction of dams, roads, industries and rehabilitation camps. The natural forest has been replaced over large areas by new social foresting. No long-term systematic surveys of anopheline fauna had been carried out in the post-DDT era, therefore, virtually nothing is known about changes in mosquito fauna belonging to *Anopheles*. The present study was taken up to update knowledge on distribution and prevalence of anopheline species, many of which are potential vectors of malaria.

2. Material and methods
2.1. Study area
The Western Ghats occupy the western and southern portions of the Indian peninsular plateau. There is considerable variation in annual rainfall but the whole area receives good rains from both monsoons (Southwest and Northeast; >2000 mm), and rise to the height of 2600 m in some places. Altogether, twenty four surveys were carried out by CRME between 2000 and 2012 in 11 hill ranges, *viz*., Agastya hills, Anamalai hills, Andipatti hills, Bodi hills, Nilgiri hills, Palani hills, Varusanad hills (Tamil Nadu State), Wynad & Malapuram hills, Parambikulam hills, Silent Valley (Kerala State) and Coorg (Karnataka State) (Fig.1). These surveys were confined to three Southern States, and the Eastern and Western slopes of Western Ghats. Studies were repeated at least once in a different season for each hill range with seven surveys made in the Nilgiri hills alone for its vast richness.

Altitude was measured by a portable altimeter. Immatures were collected from respective habitats such as slow flowing streams, springs, rivers, pools, tree holes, paddy fields, elephant foot prints etc., and reared individually up to the adult stage. Identification was based mainly on adult characters, however larval and pupal chaetotaxy was also examined wherever necessary. Generic and subgeneric abbreviations used were after Reinert [18].

3. Results & Discussion

Thirty three species of Anopheles were recorded from out of 8730 specimens belonging to subgenus *Anopheles* (12) and subgenus *Cellia* (21) (Table1). Nilgiri hills had the richest anopheline fauna, which became apparent on the first survey (February 1986). For this reason the area was visited twice in each season (7 times), so that comparisons could be made with the earlier studies of Russell and Jacob [10]. *An.* (*Cel.*) *maculatus* (#1418) was numerically the most abundant species and was found everywhere except in the Agastya hills in the far down south, followed by *An.* (*Ano.*) *aitkenii* (#1232) and *An.* (*Cel.*) *mirans* (#991). The latter species had been reported as a vector of simian malaria from foothills of Western Ghats in southern India [11]. Most of the species were found up to 1250 m above sea level, although above 2000 m only four species occurred (Table1).

Habitat-wise and hill-wise distribution of various species are illustrated in Figs. 2 and 3. Forest streams were the most favourable habitat, from which 28 species were collected. Pools and springs were also productive next to streams (25 species), whereas paddy fields contributed 21 species. Ten species were recorded from larvae collected from tree holes, log holes and bamboo stumps. These were *An. (Ano.) aitkenii, An. (Ano.) culiciformis, An. (Ano.) insulaeflorum, An. (Ano.) interruptus, An. (Ano.) sintoni, An. (Cel.) culicifacies, An. (Cel.) elegans, An. (Cel.) mirans, An. (Cel.) jeyporiensis, An. (Cel.) maculatus.* Of this *An.* (*Cel.*) *culicifacies* was collected from typical wide open holes (25-50 cm diam.) near the base of felled tree trunks. Elephant foot prints contributed six species. *Anopheles* (*Cel.*) *mirans* breeds in >10 habitats, followed by *An.* (*Ano.*) *barbirostris* and *An.* (*Cel.*) *jeyporiensis. Anopheles* (*Cel.*) *dravidicus* and *An.* (*Cel.*) *willmori* whose breeding was restricted only to slow flowing streams. Similarly *An.* (*Ano.*) *interruptus* larvae were collected in tree holes only.

Table 1: *Anopheles* species collected as immature in Western Ghats -South India (2000-12)

S. No.	Species	Total	Altitude(m)
1	*Anopheles* (*Anopheles*) *aitkenii* James, 1903	1232	300-2050
2	*Anopheles* (*Anopheles*) *barbirostris* Van der Wulp, 1884	532	350-1300
3	*Anopheles* (*Anopheles*) *barbumbrosus* Strickland and Chowdhury, 1927	113	350-1200
4	*Anopheles* (*Anopheles*) *crawfordi* Reid, 1953	12	900-1200
5	*Anopheles* (*Anopheles*) *culiciformis* Cogill, 1903	11	900-1200
6	*Anopheles* (*Anopheles*) *gigas* Giles, 1901	153	800-2250
7	*Anopheles* (*Anopheles*) *insulaeflorum* (Swellengrebel and Swellengrebel de Graaf, 1919)	190	500-900
8	*Anopheles* (*Anopheles*) *interruptus* Puri, 1929	28	900-1200
9	*Anopheles* (*Anopheles*) *nigerrimus* Giles, 1900	8	850-1300
10	*Anopheles* (*Anopheles*) *nilgiricus* Christophers, 1924	133	1800-2050
11	*Anopheles* (*Anopheles*) *peditaeniatus* (Leicester, 1908)	147	300-1200
12	*Anopheles* (*Anopheles*) *sintoni* Puri, 1929	149	500-900
13	*Anopheles* (*Cellia*) *aconitus* Doenitz, 1902	16	850-1200
14	*Anopheles* (*Cellia*) *annularis* Van der Wulp, 1884	10	850-1000
15	*Anopheles* (*Cellia*) *culicifacies s.l.* Giles, 1901	265	400-1200
16	*Anopheles* (*Cellia*) *dravidicus* Christophers, 1924	26	900-1200
17	*Anopheles* (*Cellia*) *elegans* (James, 1903)	109	350-1000
18	*Anopheles* (*Cellia*) *fluviatilis s.l.* James, 1902	57	300-1200
19	*Anopheles* (*Cellia*) *jamesii* Theobald, 1901	414	300-1200
20	*Anopheles* (*Cellia*) *jeyporiensis* James, 1902	839	300-1250
21	*Anopheles* (*Cellia*) *karwari* (James, 1902)	69	350-1250
22	*Anopheles* (*Cellia*) *maculatus* Theobald, 1901	1418	400-1000
23	*Anopheles* (*Cellia*) *majidi* Young and Majid, 1928	140	350-2050
24	*Anopheles* (*Cellia*) *mirans s.l.* Sallum and Peyton, 2005	991	400-850
25	*Anopheles* (*Cellia*) *moghulensis* Christophers, 1924	126	300-400
26	*Anopheles* (*Cellia*) *pallidus* Theobald, 1901	4	300-1000
27	*Anopheles* (*Cellia*) *splendidus* Koidzumi, 1920	214	850-1250
28	*Anopheles* (*Cellia*) *subpictus* Grassi, 1899	52	300-1200
29	*Anopheles* (*Cellia*) *tessellatus* Theobald, 1901	119	850-1200
30	*Anopheles* (*Cellia*) *theobaldi* Giles, 1901	829	300-650
31	*Anopheles* (*Cellia*) *vagus* Doenitz, 1902	91	300-1200
32	*Anopheles* (*Cellia*) *varuna* Iyengar, 1924	228	350-650
33	*Anopheles*(*Cellia*) *willmori* (James, 1903)	5	900-1200

4. Distribution and bio-economics notes on few species

Anopheles (*Anopheles*) *barbirostris* Group: This group consists of 11 species reported from Southeast Asia [19]. However, in the present study only two species were collected, viz., *An. barbirostris* (538 specimens) and *An. barbumbrosus* (113 specimens).

Anopheles hyrcanus Group: In India, this is represented by three species, *viz*., *An. peditaeniatus* (147 specimens), *An. nigerrimus* (8) and *An. crawfordi* (12) were recorded in our

survey. *An.* (*Ano.*) *crawfordi* (5) was recorded first time in Nilgiri hills, southern India [11], and now it is extended to Wynad hills (Kerala) and Coorg (Karnataka).

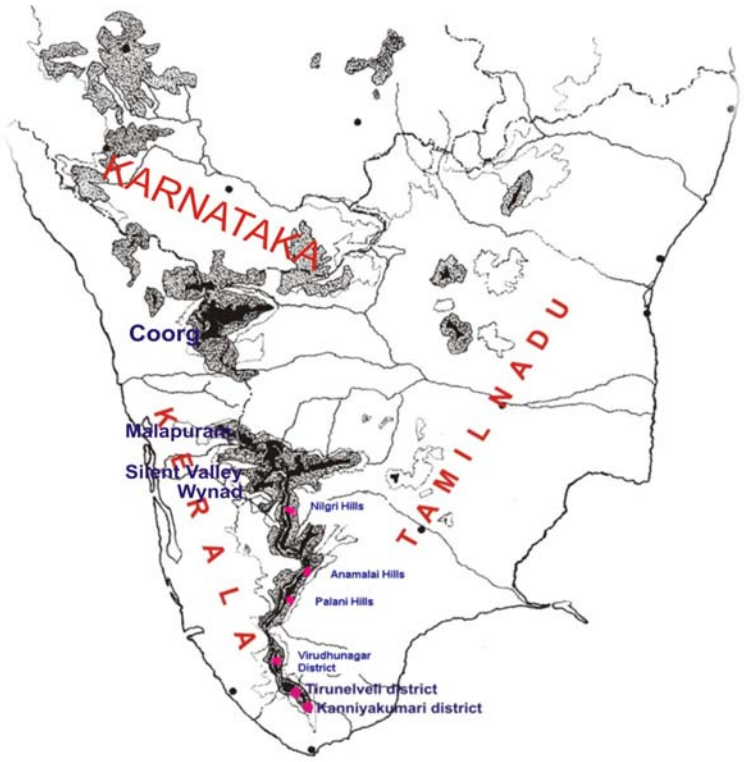

Fig 1: Map of study area

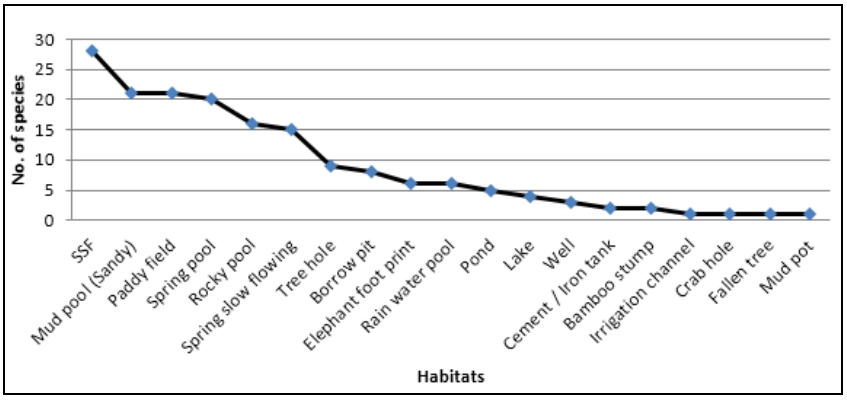

Fig 2: Habitat wise distribution of *Anopheline* species in Western Ghats

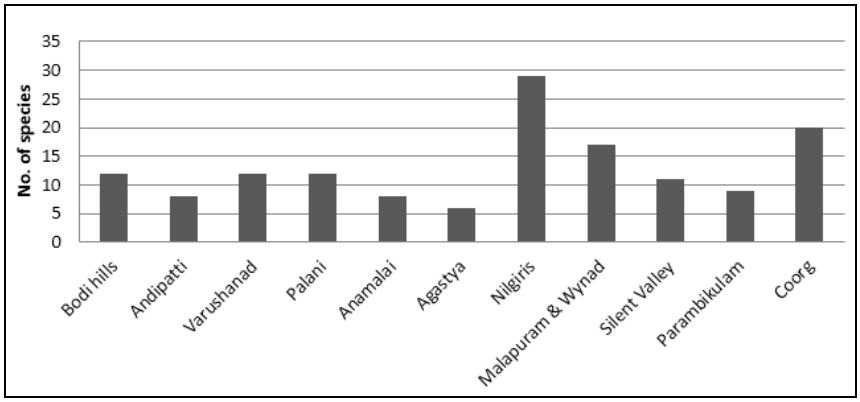

Fig 3: Hill-wise distribution of *Anopheline* species in Western Ghats

Anopheles (*Anopheles*) *insulaeflorum* (Swellengrebel and Swellengrebel de Graaf, 1919): This species belongs to *Aitkenii* species group and very similar to *An. peytoni* which was recently described from Sri Lanka by Kulasekara [20].

Altogether 1422 specimens were collected, reared individually and identified on the basis of adult and larval characters. Only 190 specimens of *An. insulaeflorum* and 1232 specimens of *An. aitkenii* were recorded. No specimen of *An. peytoni* could be recorded.

Anopheles (*Anopheles*) *nilgiricus* Christophers, 1924: This was earlier one of the subspecies of *An. lindesayi s.l.* Giles. Harrison, while reviewing the records of Culicidae of Thailand and neighbouring countries [21], elevated it to species status and stated that *An. lindesayi* occurred in Northern India and *An. nilgiricus* in South India. The present study recorded this species (133 specimens) from Nilgiri hills and its neighbouring hill ranges of Western Ghats (Palani and Anamalai hills).

Anopheles (*Anopheles*) *sintoni* Puri, 1929: It belongs to the *Culiciformis* species group. It was collected (149 specimens) from three hill ranges of the Western Ghats.

Anopheles (Cellia) culicifacies s.l. Giles, 1901: This is one of the primary vectors of malaria in south Asia, and in India, mainly the rural plains. A total of 265 specimens of this species from 5 hill ranges of Western Ghats were collected.

Anopheles (*Cellia*) *fluviatilis s.l.* James, 1902: This species was reported highly abundant during the pre-DDT era and was the major vector of the foothills of the Western Ghats in south India. At present prevalent at low densities (0.7%), not sufficient to play role as a vector.

Anopheles leucosphyrus Group: Taxonomy of *leucosphyrus* group was reviewed repeatedly in past 5 decades. The notable changes with reference to India are as follow: the former *An. dirus* 'D' named as *An. baimaii* (found in Assam and Andaman & Nicobar Islands, West Bengal – vector of forest malaria), *An. dirus* 'E' of Western Ghats [11] will referred as *An. elegans* James whereas a new species, *viz*., *An. mirans* was described by placing it in Hackeri subgroup. According to Sallum, *An. mirans* was previously misidentified as *An. elegans*, which was reported as vector of simian malaria from foothills of Western Ghats, Southern India [22]. A total of 109 specimens of *An. elegans* (non-vector) and 991 specimens of *An. mirans* (vector of simian malaria) were recorded.

Anopheles maculatus Group: Christophers (1931) described *An. maculatus* (Theobald), keeping *pseudowillmori* Theobald, *dravidicus* Christopher and *willmori* James as synonyms/varieties. Rattanarithikul and Green, reviewed the whole group from India and elevated to species status, *viz*., *pseudowillmori*, *willmori* and *dravidicus* [23]. Two species *willmori* (5) and *dravidicus* (26) were also recorded in the present surveys.

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