Appearance of *Anopheles jeyporiensis* James from Sri Lanka

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**Abstract:** Previous records of Sri Lankan *Anopheles* were most imperfect, and even the number and names of the species present were very doubtful. There was no systematic study conducted for Sri Lankan adult anophelines since 1990. Therefore, the objective of this study was to explore the species abundance and morphological variations of anopheline mosquitoes in Sri Lanka. Entomological surveys were conducted on a monthly basis from June 2010 to December 2013 in Trincomalee District, using five entomological techniques. Entomological surveys identified a total of 131,804 mosquito specimens belong to 18 anopheline species. One of which was *An. jeyporiensis*, a species that was not in the checklist in Sri Lanka. Its basic morphological features are similar to the members in *Myzomyia* series under the subgenus *Cellia*. Following characteristics were used to confirm the species as *An. jeyporiensis*; Centre of the scutum covered with short oblong white scales extending back to scutellum; Vein R₁ usually with accessory pale spot on preapical dark (PD) area; Foretarsomere 1 with apical pale band nearly 2.0 width of tarsomere diameter.

Key words: *Anopheles jeyporiensis*, Sri Lanka

**Introduction**

*Anopheles jeyporiensis* James has been recorded from many areas of the Oriental faunal region. This species was first recorded from Nagpur, Jeypur State (Central Provinces) in India by James in 1902. It has been detected from Bangladesh, Taiwan, Thailand, Laos, Viet Nam and Cambodia (Sadanandane, 1999). Previous records of Sri Lankan *Anopheles* were most imperfect, and even the number and names of the species present were very doubtful. An attempt to remedy the matter was made by the late Dr. A. J. Chalmers in 1905. Chalmers gave the results of investigations made in various parts of the island during the dry season, and also incorporated the records of previous observers—Green (1901), Manders (1903) and Marshall Philip (1904).

Chalmers recognized ten species of anopheline which included *An. jeyporiensis*. Further entomological studies conducted by Christophers in 1933 have indicated the presence of *An. jeyporiensis* in Sri Lanka. Thereafter no records or study reported *An. jeyporiensis*. Since there is no specimens of *An. jeyporiensis* from Sri Lanka and can find no substantial evidence it occurs there. Therefore, the records of *An. jeyporiensis* from Sri Lanka were considered as doubtful. The mosquito checklist of Sri Lanka was revised by Carter (1950) and subsequently by Jayasekera and Chelliah (1981). Carter (1950) mentioned that the record of Chalmers (1905) was probably misidentification of *An. aconitus*. This comment was also adopted by Harrison (1980) and Jayasekera and Chelliah (1981). In 1990, 22 anopheline species were recorded in Sri Lanka, but there was no *An. jeyporiensis* in the list (Amerasinghe, 1990).

Entomological studies in Eastern province have not been done over last 30 years due to the security situation existed in the county. Even the last taxonomical study conducted for the Sri Lankan adult anophelines in 1990 did not cover any survey in these areas. In 2010, proper entomological studies and systematical studies were initiated by the Tropical and Environmental Diseases and Health Associates Pvt. Ltd., under the malaria elimination program which is funded by the Global Fund against Aids, Tuberculosis & Malaria (GFATM) Round VIII. The main objective of this study was to explore the species abundance and morphological variations of anopheline mosquitoes in Sri Lanka. These collections have produced numerous specimens from several different areas in the Eastern province of Sri Lanka and reported here the presence of *An. jeyporiensis* in the Eastern Province of Sri Lanka.

**Materials and Methods**

**Site selection**

Five sentinel sites, namely; Gomarankadawala (E;
0494617, N; 0958609), Echchallampaththu (E; 0540791, N; 0918221), Mollipothana (E; 0506055, N; 0934096), Thoppur (E; 0534419, N; 0929257) and Padavisiripura (E; 0498928, N; 0988280) were selected in the District of Trincomalee (Eastern province of Sri Lanka) for surveillance in consultation with the TEDHA National Malaria Control Programme. The factors such as past malaria history, availability of breeding sites, an established agricultural community and feasibility of field operations to collect relevant data were also considered in selecting the study areas. The sentinel sites were over 20 km apart. In each sentinel site, 4 localities were selected within a 20 km radius of the sentinel site. Entomological surveillance was conducted in these 20 localities which, lasted 1 week every month (Figure 1).

Mosquito collection
Mosquitoes were collected at monthly intervals from June 2010 to December 2013 using five standard sampling methods namely; Larval Survey (LS), indoor Hand Collection (HC), Window Trap (WT), Cattle Baited Hut Trap (CBHT) and Cattle Baited Net Trap (CBNT) according to World Health Organization (WHO) standard techniques described for anopheline mosquitoes (WHO, 1992).

Identification of Anopheles mosquitoes
All mosquitoes collected by HC, WT, CBNT, CBHT and adult emerging from larvae were identified using an achromatic magnifying lens (×10) and the taxonomic keys prepared by Amerasinghe (1990), Harrison (1980) and Rattanarithikul et al. (2006).

Calculation of mosquito abundance
The percentage of each mosquito species in the total number by each method was calculated.

Results
Number of units performed by each sampling technique is given in Table 1. Entomological surveys identified a total of 131,804 mosquito specimens belonging to 18 anopheline species. The list of anophelines collected and the density of anophelines recorded by each technique is given in Table 2.

An. peditaeniatus (26.8%, n = 35,329) was the most abundant Anopheles species followed by An. subpictus. Of the five techniques CBNT was denoted as productive, in which 46.6% (61,442/131,804) of total anopheline was encountered. Other species such as An. annularis (n = 5,405), An. pallidus (n = 5,107), An. vagus (n = 4,385), An. varuna (n = 1,132), An. tessellatus (n = 285) and An. aconitus (n = 90) were also noted as other potential vectors. Larval surveys were observed as the most productive technique for An. culicifacies (n = 1,681).

An adult Anopheles species belong to the Myzomyia series under the subgenus Cellia was recorded frequently from CBNT collections conducted at Gomarankadawala (n = 16) and Galkadawala (n = 11) localities of the Gomarankadawala sentinel site during November to December 2011. Morphological characters of this suspicious species were not compatible with any of the mosquito species in the morphological key for Sri Lankan anopheline fauna (Amerasinghe, 1990).

The basic morphological features are similar to the members in the Myzomyia series under the subgenus Cellia. The species was confirmed as An. jeyporiensis based on the following characteristics. Centre of the scutum covered with short oblong white scales extending back to scutellum (Figure 2). Vein R1 usually with accessory pale spot on preapical dark (PD) area.

| Table 1. Anopheles collected from June, 2010 to December, 2013. |
|------------------|----------------|
| Sampling technique | Total no. of units |
| LS | 691,465 dips |
| HC | 27,540 houses |
| WTC | 4,661 traps |
| CBHT | 1,727 traps |
| CBNT | 1,830 traps |

LS- Larval Survey, HC- Hand Collection (Indoor), WTC- Window Trap Collection, CBHT- Cattle Baited Hut Trap, CBNT- Cattle Baited Net Trap.
Foretarsomere 1 with apical pale band nearly 2.0 width of tarsomere diameter. The morphological characters used here were based on original observations and previous usage in the literature (Christophers, 1933; Reid, 1968; Harrison and Scanlon, 1975; Harrison, 1980; Amerasinghe, 1990; Rattanarithikul et al., 2006).

Table 2. The number of anophelines by sampling technique in the Trincomalee District.

<table>
<thead>
<tr>
<th>Anopheles Species</th>
<th>LS</th>
<th>HC</th>
<th>WT</th>
<th>CBHT</th>
<th>CBNT</th>
</tr>
</thead>
<tbody>
<tr>
<td>An. culicifacies</td>
<td>1,681 (4.41)</td>
<td>2 (0.02)</td>
<td>4 (0.18)</td>
<td>324 (1.93)</td>
<td>9 (0.01)</td>
</tr>
<tr>
<td>An. subpictus</td>
<td>10,154 (26.65)</td>
<td>11,734 (88.65)</td>
<td>1,465 (66.53)</td>
<td>7,596 (45.23)</td>
<td>3,211 (5.22)</td>
</tr>
<tr>
<td>An. varuna</td>
<td>958 (2.51)</td>
<td>30 (0.23)</td>
<td>15 (0.68)</td>
<td>82 (0.49)</td>
<td>47 (0.08)</td>
</tr>
<tr>
<td>An. tesserullatus</td>
<td>56 (0.15)</td>
<td>5 (0.04)</td>
<td>1 (0.05)</td>
<td>63 (0.38)</td>
<td>160 (0.26)</td>
</tr>
<tr>
<td>An. annularis</td>
<td>1,704 (4.47)</td>
<td>19 (0.14)</td>
<td>21 (0.95)</td>
<td>1,026 (6.11)</td>
<td>2,635 (4.29)</td>
</tr>
<tr>
<td>An. nigerrimus</td>
<td>8,331 (21.87)</td>
<td>461 (3.48)</td>
<td>255 (11.58)</td>
<td>2,463 (14.66)</td>
<td>18,364 (29.88)</td>
</tr>
<tr>
<td>An. aconitus</td>
<td>58 (0.15)</td>
<td>1 (0.01)</td>
<td>5 (0.03)</td>
<td>26 (0.04)</td>
<td></td>
</tr>
<tr>
<td>An. voga</td>
<td>1,215 (3.19)</td>
<td>485 (3.66)</td>
<td>203 (0.92)</td>
<td>1,353 (8.06)</td>
<td>1,129 (1.84)</td>
</tr>
<tr>
<td>An. pallidus</td>
<td>2,677 (7.03)</td>
<td>66 (0.50)</td>
<td>32 (1.45)</td>
<td>986 (5.87)</td>
<td>1,346 (2.19)</td>
</tr>
<tr>
<td>An. peditaenius</td>
<td>6,410 (16.82)</td>
<td>214 (1.62)</td>
<td>120 (5.45)</td>
<td>1,760 (10.48)</td>
<td>26,825 (43.64)</td>
</tr>
<tr>
<td>An. jamesii</td>
<td>327 (0.86)</td>
<td>—</td>
<td>1 (0.05)</td>
<td>267 (1.59)</td>
<td>883 (1.44)</td>
</tr>
<tr>
<td>An. pseudojamesi</td>
<td>81 (0.21)</td>
<td>—</td>
<td>3 (0.14)</td>
<td>138 (0.82)</td>
<td>447 (0.73)</td>
</tr>
<tr>
<td>An. maculatus</td>
<td>15 (0.04)</td>
<td>—</td>
<td>—</td>
<td>2 (0.01)</td>
<td>1 (0.002)</td>
</tr>
<tr>
<td>An. karvari</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>4 (0.01)</td>
</tr>
<tr>
<td>An. barbrosiris</td>
<td>3,926 (10.3)</td>
<td>205 (1.55)</td>
<td>77 (3.50)</td>
<td>710 (4.23)</td>
<td>5,462 (8.89)</td>
</tr>
<tr>
<td>An. barbrosorus</td>
<td>507 (1.33)</td>
<td>15 (0.11)</td>
<td>5 (0.23)</td>
<td>17 (0.10)</td>
<td>893 (1.45)</td>
</tr>
<tr>
<td>An. aikeni</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>4 (0.02)</td>
<td>—</td>
</tr>
<tr>
<td>An. jeyporiensis</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>27 (0.04)</td>
</tr>
</tbody>
</table>

LS- Larval Survey, HC- Hand Collection (Indoor), WTC- Window Trap Collection, CBHT- Cattle Baited Hut Trap, CBNT- Cattle Baited Net Trap

Fig. 2. Illustration of the dorsal side of thorax indicating the centre of the scutum with white scales extending back to scutellum (Rattanarithikul et al., 2006).

Morphological description of *An. jeyporiensis* in Sri Lanka Adult female

Size small to medium (length of wing 2.5–3.5 mm). Head: scales of normal type, with a well-marked white vertical spot, chaetae forming short row ending in cluster of 5–6, mostly flattened, forming well-developed frontal tuft. Antennae: Antennae devoid of scales, some pale narrow scales on first flagellar segment. Palpi thin,

Fig. 3. Illustration of the wing of *An. jeyporiensis* showing the R₁ vein with accessory pale spot on preapical dark area (Rattanarithikul et al., 2006).
straight, cylindrical, and appearing very long; index 0.4; apical segment all white, with tip of preceding segment and narrow pale bands at 2–3, 3–4, dark area between apical and sub-apical pale bands usually 4–5 times length of sub-apical and about as long or slightly longer than apical pale band. Labium all dark.

Thorax: with chaetae only on anterior pronotal lobe; propleural hairs 1–2. Scutum with median area covered with narrow whitish scales, more numerous anteriorly, forming tuft in median area, lateral areas of mesopostnotum with usually a few dark flattish scales; fossae and lateral areas dark brown, contrasting with the lighter median area, without scales laterally anterior to root of wings, or, if scales present, these are few and narrow, not forming a definite line of overlapping scales. Pleurae devoid of scales; spiracular hairs 1; prealar about 3; upper mesepimeral about 5–7.

Wing: R₁ rather long, approaching twice length of petiole; cell-index 2. Base of costa usually with pale interruptions forming two long dark basal accessory spots of which the inner usually extends to root of wing; R₁ in this part of its extent entirely pale. Median dark costal spot with a distinct accessory sector or dark area on R₁ distinctly shortened an interruption towards outer end unusual. Preapical dark costal spot frequently with a pale interruption on vein 1, nearly always towards inner end of spot. Usually a pale interruption on R₂ often on R₃, M₁, and M₂. In some cases R₂ and R₃ are extensively pale on inner portions, with obliteration of spots. 1A most usually shows three dark areas, but the outer half may be continuously dark. A fringe-spot at 1A is usual; when no fringe-spot is present the border-scales are often pale. Border-scales towards base of wing pale almost to vein 1A.

Legs: with femora slightly swollen in basal half. Foretarsomere 1 with apical pale band nearly 2.0 width of tarsomere diameter. Tarsus of fore and mid-legs with segments 1 and 2, and sometimes 3, with narrow pale white apical bands, hind legs with segments 1–4 similarly banded. Coxae dark, devoid of scales except for a few dark scales anteriorly on coxae 1 and a few pale scales on coxae 3.

Abdomen: entirely devoid of scales even on cerci.

**Discussion**

*An. jeyporiensis* has been reported only from the oriental region. Its distribution extends from the Indo-China peninsula in the north to Kerala (India) in south and from Taiwan in the east to Maharasstra (India) in west (Nandi et al., 1993). *An. jeyporiensis* is an unique and well differentiated species that exhibit characters similar to several diverse members of the Myzomia series. It can be separated from other species by the presence of gray–brown scales on the remigium—R base of wings in female specimen as described by Harrison (1980) and Center of scutum covered with short oblong white scales extending back to scutellum (Rattanarithikul et al., 2006).

The adults of *An. jeyporiensis* have the general Culicine like habitus of most of the other members in the Myzomia series. However, the species is rather variable, especially in the wing markings. The proportion of dark and pale on the female palpi is also rather variable (Christophers, 1933). Therefore, there can be some slight differences in palpi and wing markings of the specimens observed in different geographical locations. But, the specimens recorded from this study denoted identical morphological features as described by the previous researches (Christophers, 1933; Rattanarithikul et al., 2006). These features can be express as the wing with 4 or more dark margins involving both costa and vein R–R₂, accessory sector pale (ASP) spot, vein R₃ usually with accessory pale spot on preapical dark (PD) area. The maxillary palpi with 3 pale bands. However, the presence of white oblong white scales on the centre of the scutum extending back to scutellum can be easily used as a unique feature to confirm the species identification (Rattanarithikul et al., 2006; Gunathilaka et al., 2013).

The seasonal abundance of *An. jeyporiensis* is mainly influenced by the quantum of rainfall that occurs in a particular region. *An. jeyporiensis* is more abundant during post-monsoon and cold (November to March) seasons and either disappeared or the abundance reduced during the monsoon months in India (Perry, 1914; Young and Abdul, 1929; Senior White, 1938; Singh and Jacob, 1944; Kulkarni, 1990; Misra et al., 1993; Nandi et al., 1993). However, the present study reveals that the abundance of the species was observed with the high rainfall recorded in November and December which contributed nearly 50–53% of the total annual rainfall in the Trincomalee District. The distribution of anophelines may vary temporally and specially depending upon environmental conditions and availability of breeding habitats (Bouma and van der Kaay, 1996). Therefore, the abundance of *An. jeyporiensis* with high rainfall may be due to the fact that the increasing rainfall tends to create temporary breeding habitats which may resulted more habitats for oviposition.

According to the literature, immature stages of *An. jeyporiensis* breeds in ground habitats with clear, cool, fresh water, slow moving or nearly stagnant with abundant emergent vegetation (Harrison, 1980). In addition, larvae of *An. jeyporiensis* also present in pools, ponds, swamps, tanks and terraced rice fields where water replacement took place (Sadanandane, 1999).

The current study was not able to detect larval specimens of *An. jeyporiensis* through larval collections. However, following breeding habitats were observed predominantly in the study areas such as tank margins, channels with vegetations, paddy fields, ponds, earth wells, built wells and marshy lands. Therefore, these breeding habitats might be the origin for the adult *An.
jeyporiensis species collected from CBNT collections.

However, it is necessary to emphasize that taxonomic characters are only a rapid and convenient guide to identification, based on the examination of a few important characters at each step. In case of doubt, it is essential to consult published literature with detailed descriptions.

An. jeyporiensis is a confirmed vector of malaria parasites in Vietnam and China, causing serious malaria problems in Vietnam as late as the early 1960s’ (Chow, 1970). This species is also recognized in southern China as a vector of periodic Wuchereria bancrofti and periodic Brugia malayi (Hawking, 1973). Therefore, it is very important to study the vectorial capacity of this species to explore whether this can be a good candidate to transmit malaria or other potential diseases in Sri Lanka. Hence, more entomological studies are essential to update the species composition of Anopheles in the country and attention should be given to revise existing morphological identification keys in order to strengthen and support current malaria elimination program.

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References


