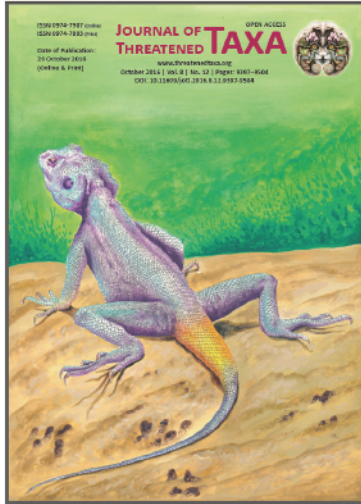


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COMMUNICATION

ON THE OCCURRENCE OF COMMON BARON (LEPIDOPTERA: NYMPHALIDAE: LIMENITIDINAE: *EUTHALIA ACONTHEA* CRAMER, 1777) IN THE DELHI AREA AND ANALYSIS OF ABIOTIC FACTORS AFFECTING ITS DISTRIBUTION IN INDIA

Rajiv K. Singh Bais

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ON THE OCCURRENCE OF COMMON BARON (LEPIDOPTERA: NYMPHALIDAE: LIMENITIDINAE: *EUTHALIA ACONTHEA* CRAMER, 1777) IN THE DELHI AREA AND ANALYSIS OF ABIOTIC FACTORS AFFECTING ITS DISTRIBUTION IN INDIA

OPEN ACCESS

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Abstract: This paper gives details of the occurrence of *Euthalia aconthea* from Delhi area situated in the Indo-Gangetic plains. Occurrence records of this species suggest that it is most frequent in five zones of India, despite the fact that its main larval food plant Mango *Mangifera indica* is abundantly available almost throughout India. Possible abiotic factors are hypothesized for this distribution.

Keywords: Common Baron, *Euthalia aconthea*, Indo-Gangetic plains, *Mangifera indica*, Mango.

Hindi Abstract: अभी तक ऐसा समझ जाता था कि एक तितली "कॉमन बैरन" (*Euthalia aconthea*) दिल्ली और आसपास के इलाकों में नहीं पाई जाती है. यह शोधपत्र गंगा-यमुना मैदानी भूभाग में वसे दिल्ली और उसके आसपास के क्षेत्रों में *Euthalia aconthea* की उपस्थिति का वर्णन प्रस्तुत करता है. भारत के विभिन्न भागों में इस तितली की उपस्थिति/ अदुपस्थिति के आधार पर ऐसा लगता है कि यह तितली भारत में सिर्फ पाँच हिस्सों में ज्यादा पाई जाती है हालांकि इसका लारवल फूड प्लांट (larval food plant) "आम" (mango) समस्त भारत में बहुतायत से मौजूद है. कौन से स्थानीय जलवायु से जुड़े वो आयाम हैं जो इस तितली को पूरे भारत में फैलने और स्थापित होने से रोकते हैं ? यह शोधपत्र जलवायु संबंधी कारकों के आधार पर इस तितली के भौगोलिक विस्तार की परिकल्पना प्रस्तुत करता है.

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INTRODUCTION

The distribution range of *Euthalia aconthea* covers India, Pakistan, Sri Lanka, Nepal, Bhutan, Bangladesh and Myanmar (Kehimkar 2008). Its range is alternatively described as all of south and south-east Asia, from Sri Lanka to the Sunda Island (Kunte 2000). This distribution however is not uniform and this butterfly appears to be practically absent from some parts of the Indo-Gangetic plains despite abundance of its larval food plant. Till date this butterfly has not been reported from Delhi area.

The most common and preferred larval host plant of this butterfly is Mango *Mangifera indica*. In coastal Maharashtra and perhaps in other states too, it also feeds on Cashew *Anacardium occidentale* (Kunte 2000). Mango and cashew both belong to the family Anacardiaceae. Mango occurs wild or semi-wild nearly throughout India, in tropical and sub-tropical hilly forests particularly near nullahs and ravines. It is common in the sub-tropical Himalaya, hills of Western and Eastern Ghats and the forests of central India, Bihar, Odisha, Assam and the Andaman Islands. It is grown in plantations and orchards, but more often in homegardens, field borders and roadside avenues (CSIR 1959).

There are three main papers on the butterflies of Delhi: Donahue (1966), Ashton (1973) and Larsen (2002). On the basis of the then available records from Lucknow, Lahore and Amritsar, Donahue kept this butterfly in the “hypothetical list” of butterflies for Delhi area at the end of the paper as *Euthalia garuda* (Moore, 1857); a synonym for *Euthalia aconthea* Cramer, 1777. Subsequent papers (Ashton 1973; Larsen 2002) did not mention this species as it was never recorded from Delhi area. In the first part of this paper (Part-A), I present the records of *Euthalia aconthea* from the Delhi area for the period 2003–2013. The second part of this paper (Part-B) examines the main abiotic factors (rainfall, temperature, insolation, soil moisture and topography) to understand the reasons as to why this butterfly is not common in Delhi despite an abundance of mango. The origin and native range of mango has also been analyzed to get an insight into the current distribution pattern of *Euthalia aconthea*.

PART-A

Euthalia aconthea – Delhi area records

I first spotted this butterfly on 10 September 2003 at 09:00hr in Sector 33, Noida and made a rough sketch of the butterfly in my pocket diary. As *Euthalia*

aconthea was not supposed to be a Delhi butterfly and Peter Smetacek’s booklet “Butterflies of Delhi” (which is based on Donahue 1966) did not include this butterfly, it took me some time to positively identify this butterfly. On 12 September 2003 one female landed in our front courtyard and was brought inside. I made a coloured pencil sketch of this brown butterfly with white spots in my diary and re-deposited the butterfly from where it was picked. This gave me an opportunity to closely examine the butterfly and positively identify it to be a *Euthalia aconthea*.

On 23 Sept 2003 I photographed one mud puddling at 13:30hr in Sector 33, Noida. On 21 Oct 2003 one male was spotted on the road at 09:30hr (Images 1 & 2). It was searching for the liquid nutrients on the edges of a fresh cow dung using its long green proboscis. At 13:30hr I found this butterfly dead on the same spot crushed by some vehicle. These are the records of the initial sightings of *Euthalia aconthea* from the Delhi area.

Study Area

Sector 33 and 24 of Noida (28.60N, 77.35E), a satellite town of Delhi. Sector 33 is a residential area with small home gardens and potted plants in almost all the houses. Sector 24 is an institutional area with numerous offices and educational institutes. A busy main road separates the two sectors. Karanj (*Pongania pinnata*), Gulmohar (*Delonix regia*), Kasod (*Cassia siamea*) and Ashoka (*Polyalthia longifolia*) are the main trees planted on both sides of the sector roads. In addition, Peepal, Jamun, Mango, Mulberry, Currypatta (*Murraya koenigii*), Lemon and Guava are also quite common in the area.

METHODS

After recording its initial presence in Noida in 2003, I kept a record of its sightings around my home in Sector 33, Noida for the period 2003–2013. Two trees are of special interest to these observations: first a Mango tree just across the road and the other a Guava tree that we have planted in front of our house. Both the trees are visible from our dining area and kitchen windows. Mango is the larval food plant. Rotting guava on the Guava tree (half-eaten by the fruit bats in the night) are a favourite with the adult butterflies. Both the trees remained under continuous observation by us for any bird, bat or butterfly activity. Every day between 09:00–09:30 hr, I came out of my house and scanned these trees for the presence of any butterfly. Again, while



Image 1. *Euthalia aconthea*, Sector 24, Noida



Image 2. *Euthalia aconthea*, Sector 33, Noida

taking lunch between 13:15–13:45 hr I kept a continuous watch on the birds and butterflies visiting these trees. At 13:45hr I once again came out and scanned the area for butterflies.

RESULTS

Sight records for the period 2003–2013 are plotted in Fig. 1. It is evident from Fig. 1 that though not present every year, *Euthalia aconthea* is generally spotted in March and October in very low numbers. With this report presence of *Euthalia aconthea* from the Delhi area is confirmed and this butterfly may be added to the list of Delhi butterflies. Uttar Pradesh is the largest mango producing state of India. The main production centres are located in two clusters: first around the Lucknow - Faizabad axis, and the second around a line joining Saharanpur, Muzzafarnagar, Meerut and Bulandshahar. Delhi lies in the immediate vicinity to the west of this second cluster and therefore these records of *Euthalia aconthea* from Delhi may be the western most limit of the range of this butterfly at this latitude. Beyond Delhi, to the west, lies the desert of Rajasthan where this butterfly does not exist. Interestingly, even at the centre of the most prolific mango belt around Lucknow, this butterfly is not very common (de Rheapilipe 1902) and therefore on the fringes it is bound to exist at extremely low levels, making regular sightings in Delhi a matter of chance.

PART-B

***Euthalia aconthea* - Distribution pattern in India**

As per Evans there are five subspecies of this butterfly in India: subspecies *meridionalis* is distributed

Month Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003									3/1	2/1	3/1	
2004												
2005												
2006										1/1	4/2	
2007									1/1			
2008										1/1	4/2	
2009			3/1									
2010												
2011		1/1	1/1							1/1		
2012			1/1									
2013								1/2				1/1

Fig 1. Occurrence of *Euthalia aconthea* in the Study Area

Figures below the bar x/y under the month indicate:
 x = Number of days *Euthalia aconthea* was spotted in the month.
 y = Maximum number of individuals seen on any day in the month.

from southern India to northern Kanara, subspecies *anagama* is distributed from Bombay to Odisha and also Kangra to Kumaon, subspecies *suddhodana* in Bengal and Sikkim, subspecies *garuda* in Assam–Burma and a rare subspecies *acontius* is restricted to the Andamans (Evans 1927).

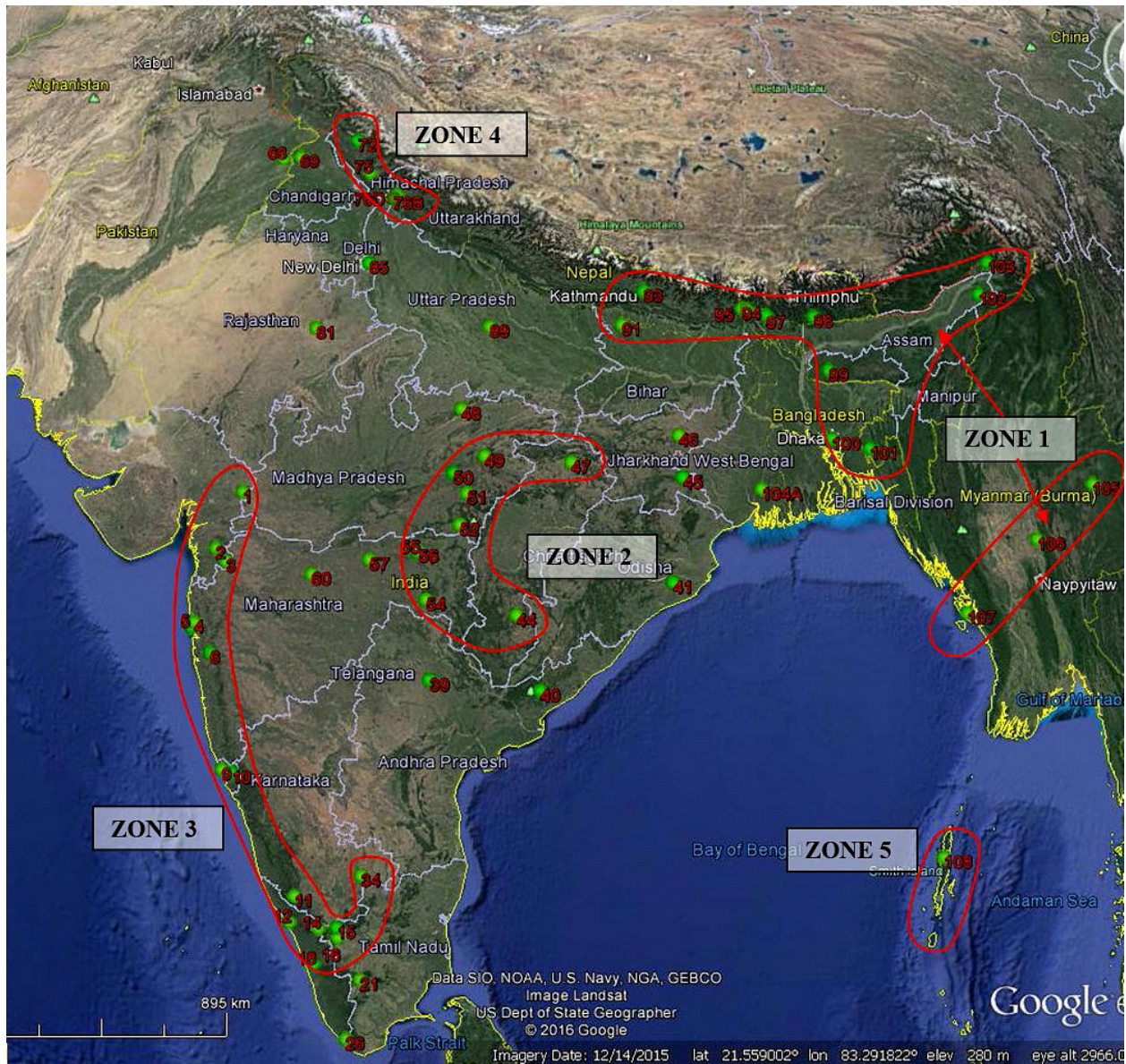


Figure 2a. Records of presence of *Euthalia aconthea*

In order to fully understand the distribution pattern of *Euthalia aconthea* in India past sighting records have been collected and compiled. In the present study subspecies level classification has not been used and all the sightings and published records have been considered at species level. These records are mostly for India but some records of Pakistan, Bangladesh, Bhutan and Myanmar have also been included using data from the Journal of Bombay Natural History Society, Journal of Threatened Taxa, Zoos' Print Journal other butterfly books and a few additional papers mentioned in the reference section. Compiled records are placed in Appendix 1. Based on the latitude and longitude of the

places these records have been transferred to Google Earth to get a visual feel of the distribution pattern. Fig. 2a shows the locations from where its presence has been reported. Fig. 2b shows the locations where it is reported to be not present. Fig. 2a reveals that *Euthalia aconthea* appears to be present most frequently in five zones in India roughly corresponding to northeastern hill regions of Sikkim-Assam-Tripura-Dhaka, central Indian hills of Madhya Pradesh and Chhattisgarh, Western Ghats, sub-tropical Himalayan forests of Himachal Pradesh-Uttarakhand, and Andaman Islands. Abundance levels at these locations have been judged by the descriptions given in the source and the same are

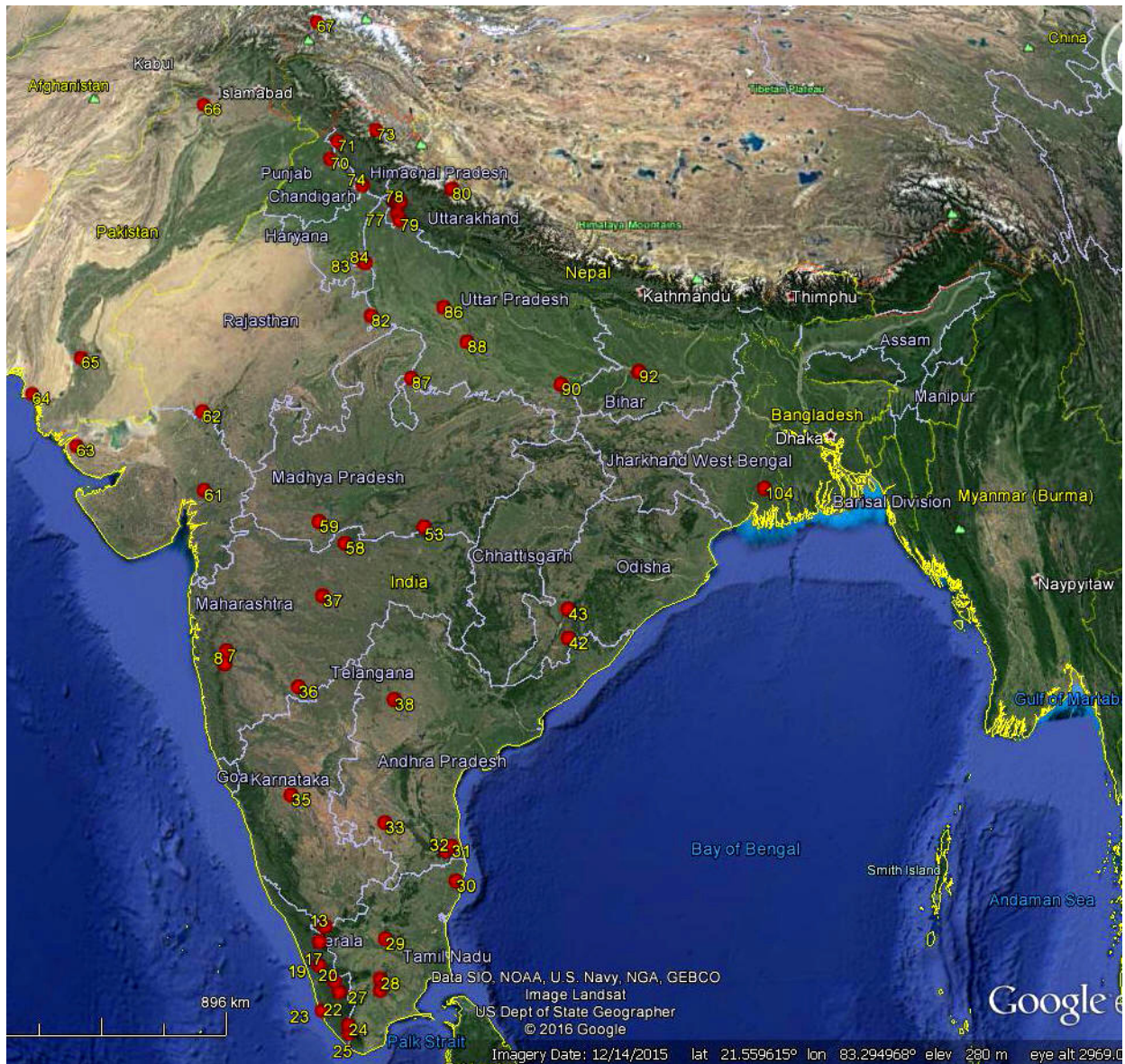


Figure 2b. Records of absence of *Euthalia aconthea*

briefly mentioned in Appendix 1. Butterfly records are however very incomplete in India and many areas have not been surveyed or surveyed very poorly, therefore these five zones remain speculative.

Presence of *Euthalia aconthea* in the five zones

Zone 1: The northeastern hill regions. In Sikkim it is common in the lower hot valleys of Rangpo, Rangeet and in Singtam. Also seen in cities and crowded markets, on rotten vegetables and fruits (Haribal 1992). In Bhutan it is a common butterfly (Wangdi 2012). It is present in Arunachal Pradesh (Gogoi 2012), Assam (Gogoi 2013) and Tripura (Majumder 2013). In Upper Neora Valley

National Park, West Bengal, it is present throughout the year (Singh 2012). In Dhaka, Bangladesh, it is not rare (Larsen 2004).

Zone 2: The hills of central India. One record describes this butterfly to be common and easily attracted to Mohwa refuse in the Central Provinces (Betham 1890). However a recent four year long fieldwork carried out in the five national parks of central India (Panna, Bandhavgarh, Kanha, Pench and Satpura) in the 1990s reveals *Euthalia aconthea* is “Not Rare” in central India (Shrivastava 2008). This means that even in the heart of the hilly jungles of central India receiving annual rainfall of 1,300–1,500 mm, this butterfly is no more abundant

Table 1. *Euthalia aconthea* butterfly habitat - rainfall and temperatures

Zone	SN	Weather Station	Lat. - Long. N-E	Rainfall (mm)				Temperature (°C)			
				Jan–Apr	May–Sep	Oct–Dec	Total	Avg. Annual Temp.	Max. of Monthly Avg. (a)	Min. of Monthly Avg. (b)	Annual Temp. Range (a–b)
I	1	Gangtok	27°20'–88°37'	488.2	2859	233.3	3580.5	15.5	19.8	11.3	8.5
	2	Passighat	28°06'–95°23'	270.3	3806.5	299.8	4376.6	23.2	27.7	18.9	8.8
	3	Dibrugarh	27°29'–95°01'	400.3	1987.7	200.7	2588.7	24	27.9	18.1	9.8
	4	Shillong	25°34'–91°53'	239.5	1914.4	261.4	2415.3	17.7	21.5	12.2	9.3
	5	Agartala	23°53'–91°15'	269.9	1695.1	213.6	2178.6	26.5	30.5	19.6	10.9
II	6	Jagdapur	19°05'–82°02'	90.2	1305.8	136.7	1532.9 [§]	28.0	31.4	19.2	12.2
	7	Ambikapur	23°10'–83°15'	69.1	1294.5	75.9	1439.5	27.4	30.3	17.6	12.7
	8	Jabalpur	27°20'–88°37'	57.6	1210.7	63.3	1331.6	29.6	32.6	18.9	13.7
III	9	Dang-Saputara	20°34'–73°44'	NA	NA	NA	2774 [@]	26.0 [#]	NA	NA	NA
	10	Mumbai	18°54'–72°49'	3.7	2064.5	78.4	2146.6	28.5	31.2	23.7	7.5
	11	Panjim	15°29'–73°49'	1.5	2758.1	172.4	2932	28.5	31.3	23.2	8.1
	12	Manglore	12°55'–74°53'	26.6	3641.5	273.1	3941.2 [§]	28.2	31.2	22.9	8.3
	13	Bangalore	12°58'–77°35'	14.3	688.7	267	970	26.5	29.0	8.6	10.4
IV	14	Dharmasala	32°16'–76°23'	362.6	2130.7	3035.1	3054.4 [§]	21.3	23.5	14.7	8.8
	15	Dehradun	30°19'–78°02'	168.3	1713.8	403.7	2315.4 [§]	25.1	28.0	15.4	12.6
V	16	Port Blair	11°40'–92°43'	155.2	1830.6	1183	3168.8	26.6	28.0	24.9	3.1
Rest of India	14	Delhi	28°35'–77°12'	51.1	697.1	49.1	797.3	29.3	31.4	18.8	12.6
	15	Lucknow	26°52'–80°56'	49.9	910.4	45.2	1021.5 [§]	29.1	31.8	19.0	12.8

§ Errors in monthly sum of rainfall data retained as in the original source; @ Gujarat Water Yearbook 2010. Govt of Gujarat; # Ecoregions of Gujarat 1997. Gujarat Ecology Commission, Vadodara, India. (Source: Climatological Tables of observatories in India 1951–1980, Fifth Edition, 1999, India Meteorological Department, Government of India, New Delhi)

or common. As more and more hills are demolished in Madhya Pradesh, Chhattisgarh, Jharkhand and Odisha by massive mining operations for extracting limestone, coal, iron, bauxite and other minerals from this mineral rich area of India, it is likely to become even more scarce.

Zone 3: The Western Ghats. *Euthalia aconthea* is common throughout the year in Dangs forests (Shull 1963), plentiful in Goa (Larsen 1987), occurs throughout the year in Bondla Wildlife Sanctuary, Goa (Borkar 2004). It is found all over Coorg (Yates 1931). It occurs throughout the year in Bangalore and becomes abundant in September (Yates 1933). It is sometimes very common in places like Bangalore (Larsen 1987). The book "Some South Indian Butterflies" (Gunathilagaraj 1998) informs that as mango, its principal host plant is cultivated everywhere, it is now very common even in cities and crowded markets, on rotten vegetables and fruits, toddy, plant sap and damp patches. Though exact location for this description is not mentioned in the book, this appears to be a description for areas around Bangalore. However it is rare in the Nilgiris (Larsen 1987).

Zone 4: The Sub-Himalayan Tract. *Euthalia aconthea* is common in Bir-Billing area of Dhauladhar range in the Joginder Nagar Valley of Kangra, Himachal Pradesh, in northwestern Himalaya. Arora (2009) reports its presence in Kangra and Shimla districts of Himachal Pradesh. It was once very common in Dehradun (Mackinnon 1898) and is still reported to be common (Singh 2016). It is also reported from Mussoorie (Ollenbach 1931).

Zone 5: The Andaman Islands. Subspecies *acontius* is a rare species confined to the Andaman Islands.

Factors Affecting Distribution

As the distribution range as marked in Fig. 2a, is much smaller as compared to the distribution range of its main larval food plant mango, climatic factors are perhaps the range limiting constraints for this butterfly. Rainfall, temperature, insolation (incoming solar radiation), soil moisture and topography of these zones have been examined as these are believed to be the main abiotic factors influencing the survival, growth and range limits of insects. Rainfall and temperatures have been taken

Table 2. *Euthalia aconthea* butterfly habitat - topography, insolation and soil moisture

Zone	SN	Weather Station	Height above MSL (m)	Geography - Area located in / or in the vicinity of	Insolation * kWh/(m ² .day)	Soil Moisture	
						Soil Moisture Index (%) #	Agroclimate #
I	1	Gangtok	1812	Eastern Himalaya	5.0–5.2	100 and above	Perhumid
	2	Passighat	157		4.6	100 and above	Perhumid
	3	Dibrugarh	111		5.2–5.4	100 and above	Perhumid
	4	Shillong	1500		4.8–5.0	100 and above	Perhumid
	5	Agartala	16		5.0–5.2	100 and above	Perhumid
II	6	Jagdapur	553	Central Highlands	5.4	0 to 20	Moist subhumid
	7	Ambikapur	611		5.4	0 to 20	Moist subhumid
	8	Jabalpur	393		5.4–5.6	0 to 20	Moist subhumid
III	9	Dang-Saputara	1100	Western Ghats	5.4–5.6	20 to 100	Humid
	10	Mumbai	11		5.4–5.6	20 to 100	Humid
	11	Panjim	60		5.4–5.6	20 to 100	Humid
	12	Manglore	102		5.4	20 to 100	Humid / Perhumid
	13	Bangalore	921		5.4–5.6	-66.7 to -33.3	Semi arid
IV	14	Dharmasala (Kangra)	1211	Sub-tropical Himalaya	5.4–5.6	20 to 100	Humid / Perhumid
	15	Dehradun	682		5.4–5.6	20 to 100	Humid
V	16	Port Blair	79	Andaman Islands	4.7	20 to 100	Humid / Perhumid
Rest of India	17	Delhi	216	Northern Plains	5.4–5.6	-66.7 to -33.3	Semi arid
	18	Lucknow	111	Northern Plains	5.4–5.6	-33.3 to 0	Dry subhumid

* based on <http://www.tnsea.in/solar-energy-in-india.html> . Accessed on 08 April 2014

based on <http://www.imdagrimet.gov.in/node/287> accessed on 02 April 2014

from Climatological Tables of India Meteorological Department (IMD), Government of India. Insolation data are not available for all the locations from IMD and therefore the same has been taken from the website <http://www.tnsea.in/solar-energy-in-india.html> . Accessed 08 April 2014.

Soil Moisture Index is expressed in % using following formula (Thornthwaite):

$$\text{Soil Moisture Index} = \{(P - \text{PET}) / \text{PET}\} \times 100$$

Where

P = Total annual Precipitation in mm

PET = Potential Evapotranspiration

Table 1 summarizes the temperature and rainfall data pertaining to these five zones and Table 2 shows data related to topography, insolation and soil moisture.

Fig. 3 showing Normal Distribution of Monsoon Rainfall in India reveals that five zones (Fig. 2a) where *Euthalia aconthea* appears to be most frequent correspond to the areas of high rainfall receiving more than 1,250mm of rainfall during the monsoon season. Figs. 4 and 5 show that these are also areas of moderate insolation and positive soil moisture index.

Soil Moisture Index

100 and above

20 to 100

0 to 20

-33.3 to 0

-100 to -66.7

Based on <http://www.imdagrimet.gov.in/node/287> accessed on 02 April 2014

Agroclimate

Perhumid

Humid

Moist Sub-humid

Dry Sub-humid

Arid

Preferred Habitat

After examining Table 1 and Table 2 and also relative abundance levels (Appendix 1), climatic conditions of the preferred habitat of *Euthalia aconthea* may be defined as below:

1. Total Annual Rainfall: More than 1,600mm.
2. Average Annual Temperature: < 28.5°C, Average Annual Temp Range of 10°C.
3. Insolation: 4.6–5.6 kWh/(m².day)
4. Soil Moisture Index: 20–100 or more (i.e., Humid or Perhumid).
5. Topography: Hilly terrain with valleys and gorges.

On the basis of these five parameters, Lucknow offers a better habitat as compared to Delhi. Lucknow

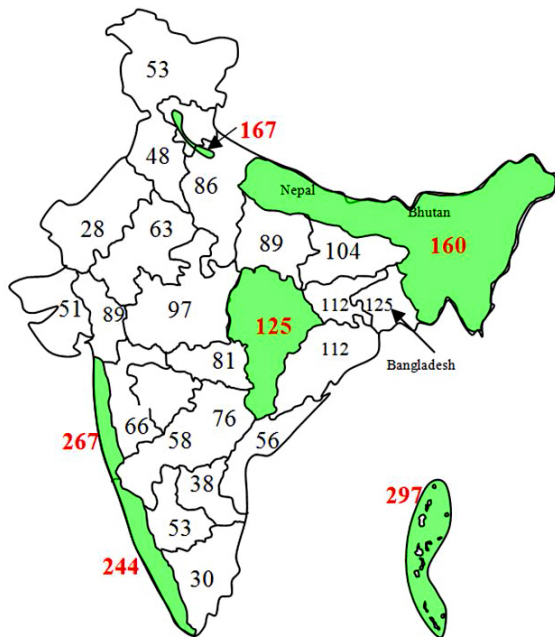


Figure. 3 Normal distribution of monsoon in India in cm (after K.N. Rao), based on Hawkins 1986 and additional inputs from <http://www.rainwaterharvesting.org/urban/rainfall.htm> Green areas show rainfall more than 125cm; preferred habitat of *Euthalia aconthea*.

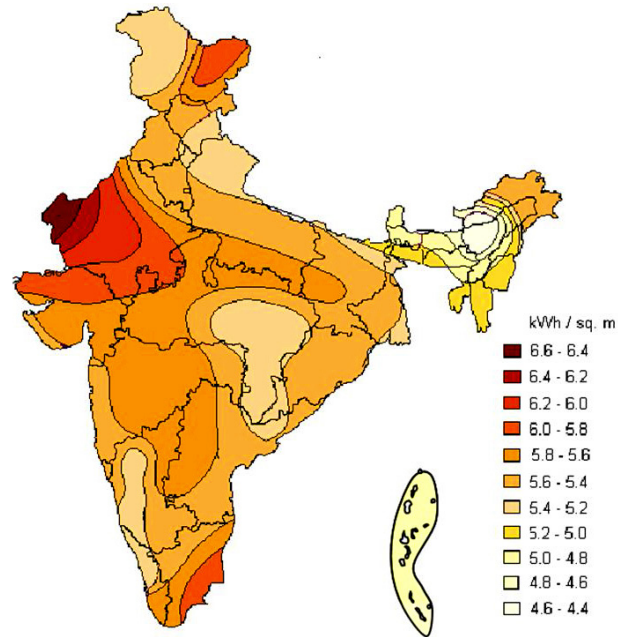


Figure. 4 Insolation map of India Average Daily Solar Radiation in units of kWh/m².day Source: <http://www.cercind.gov.in/> Lighter areas with insolation of 5.4 kWh/m².day or less are the preferred habitat of *Euthalia aconthea*.

receives more rainfall, has better soil moisture and is a bit cooler than Delhi. However Lucknow and Delhi both are far from being the preferred habitat despite an abundance of mango. It is also observed that there is something special about Bangalore's proximity to the high rainfall area and presence of a hilly corridor right up to the Western Ghats making it a good habitat despite relatively lower rainfall and Delhi like semi-arid conditions, although temperature and insolation are favourable.

Areas where *Euthalia aconthea* appears to be more abundant support some of the finest tropical wet evergreen, semi-evergreen and moist deciduous forests of India and presence of trees appears to be one of the requirements of its habitat. As per my experience at Gonda, Uttar Pradesh (27.1340N & 81.9619E), Pipariya, Madhya Pradesh (22.7622N & 78.3487E) and Noida, Uttar Pradesh, this butterfly is generally seen on or under large shady mango or other trees; more often on rotten fruits under the trees, and avoids large open areas.

Larval food plants

This part examines the original native range of wild mango and the extended range of cultivated varieties of mango to show that five zones of very high rainfall where *Euthalia aconthea* appears to be most abundant

are also the centres of origin and evolution of wild mango.

Origin of Mango

Although its precise centre of origin is not known, mango is probably indigenous to the lower montane forests of eastern India, Bhutan, Bangladesh and Myanmar between latitudes 16°N and 28°N. (Parrotta 1993). Truly wild mango trees have been recorded in Bangladesh (Chittagong Hills), northeastern India (Assam valley) and Myanmar (ICAR 2014). The evergreen mango tree is indigenous to Assam, Western Ghats, Satpuras and parts of the sub-Himalayan tract (Sagriya 1994).

Climate for Mango

The native range of mango is characterized by an annual rainfall of between 1,500–2,600 mm, with a dry season of 4–5 months between November and March. In its native range, mean annual temperatures range from 24–27 °C, with mean minimum temperatures of 11–17 °C and mean maximum temperatures of 32–34 °C during the coldest and warmest months, respectively (Parrotta 1993).

The Indo-Burma range

In its native Indo-Burma range, mango grows in secondary moist deciduous forests in a codominant

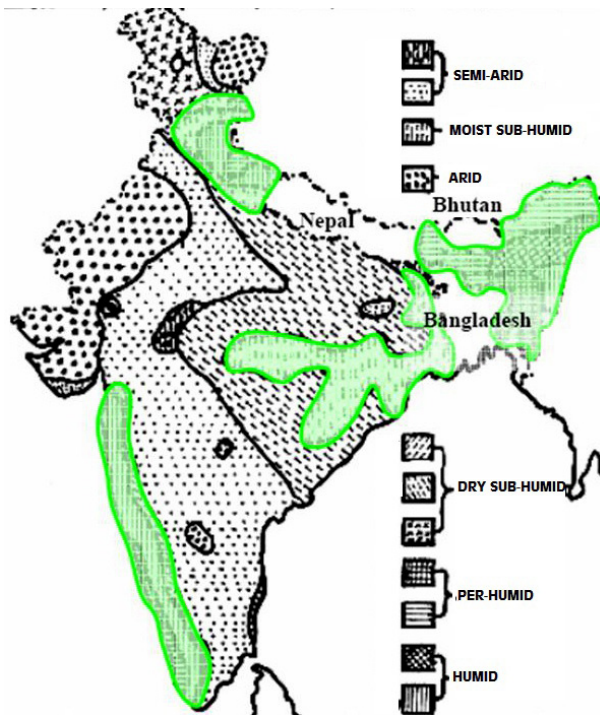


Figure 5. Agroclimatic classification of India
Areas marked Green indicate Soil Moisture Index of (0 to 100) and above

canopy position with *Anthocephalus cadamba*, *Schleichera trijuga*, *Terminalia tomentosa*, *Bursera serrata*, *Melia composite*, and *Bridelia retusa*. In West Bengal (India) it grows in association with *Butea monosperma*, *Madhuca latifolia*, *Pterocarpus macrocarpus* and *Shorea robusta* (Parrotta 1993).

Hills of central India

"The Central Provinces is generally a mountainous country, with plateaux, plains, hills and valleys. At the entrance of the glen are magnificent old mango trees, their roots entwined amongst the rocks, their boughs o'ershadowing the stream" (Betham 1890). The Sal forest dominated by *Shorea robusta* cover the top of the hills. The mixed evergreen forest are in the middle zones of the hills and around the Pachmarhi plateau dominated by *Mangifera indica*, *Terminalia tomentosa*, *Terminalia bellerica*, *Sygygium cumini* and *Anogeissus latifolia*. It is one of the areas where natural forests support large sized wild mango trees. Along streams and water courses fine riparian forests are encountered with rich mango, Jamun, Arjun and Manilkara tree. Topographical changes and hill directions have different micro-climatic conditions. The hill not facing the sun has always more moisture and humidity compared to the side facing the sun and on these faces there is a

dominance of mixed evergreen forest, dominated by Sal and mango (Singh 2001).

The Western Ghats

In wet evergreen forests of Western Ghats mango occupies a codominant position in association with jamun and jack fruit tree (Hawkins 1986). In 1837 Col. Sykes noticed a huge mango tree, at Bhimashankar on the crest of the Sahyadris, which was stated to be 80ft (24m) high (Dixon 1895). In the recent exploration mission carried out by the Indian Institute of Horticultural Research (IIHR), Bangalore, 34 unique types of wild mango were collected from the Western Ghats which is the hotspot for the pickle mangoes. These indigenous types are specific to the humid, tropical rainforests and are carried away by the rainwater and propagated through the seeds, resulting in rich diversity (Vasugi 2012).

Sub-Himalayan tract

In the outer hills of the western Himalaya (Himachal Pradesh and Uttarakhand) there is a narrow belt of high rainfall area that supports wild *Mangifera indica*. Records of the Botanical Survey of India for the area mention that "*Mangifera indica*, Linn, is not seen in Chamba, but there are many fine trees in the Kangra Valley" (Gammie 1898). A giant mango tree; over 100 year old is reported from Chandigarh with a trunk girth of 9.6m and crown area of 2,250m² (CSIR 1959). Chandigarh is located in the foothills of Shivalik, the outer most Himalayan range, about 90km from Joginder Nagar.

In Uttarakhand, as per Flora of British India (Hooker 1879), *Mangifera indica* occurs in tropical Himalaya; alt 1–3,000 ft (1–914 m) from Kumaon to Bhotan Hills. In *Forest Flora for Kumaon*, Osmaston writes: *Mangifera indica* occurs wild and is apparently indigenous, in shady moist ravines in the outer hills up to 3,000ft (914m). It is also abundantly planted throughout the area up to 914m (Osmaston 1927). These descriptions appear valid for Dehradun valley also which lies in the neighbouring Garhwal Himalaya as mango is reported to be "cultivated and almost wild in Saharanpur and Dun" (Kanjilal 1928). Western Himalayan region provided germplasm of the wild relatives of *Mangifera indica* collected under National Agricultural Technology Project (NATP) on Sustainable Management of Plant Diversity (Pandey 2005).

In Himachal Pradesh heaviest rainfall of over 2,500mm is observed in a 13km wide strip along the southern slopes of Dhauladhar for 72km right from

Dharamsala to Joginder Nagar in Kangra District. A gradual decrease in rainfall is recorded in every direction from the centre of this belt. First a ring of 1,250–2,500 mm of rainfall is formed followed by 750–1,250 mm which then further gets reduced to 600–350 mm in the inner areas between Dhauladhar and Pangri range (Joshi 1984). District Chamba lies between Dhauladhar and Pangri range in the rainshadow of Dhauladhar.

Dehra Dun is a gently sloping valley, 45 miles long and 15–20 miles broad between the Himalaya in the north and the Shiwalik Hills in the south. It is divided in two parts by a connecting ridge from which eastern Dun slopes down to the Ganga and the western Dun to Yamuna. On the north the outer range of the Himalaya rises abruptly to a height of 7,000–8,000 ft (2,134–2,439 m), with the hill stations of Mussoorie, Landour and Chakrata (The Imperial Gazetteer of India 1908). Dehradun and adjoining areas receive an annual rainfall of more than 2,000mm. Dehradun is capital of Uttarakhand.

The Andaman Islands

The Andaman Islands are a mass of hills running north to south and enclosing narrow valleys and the whole area is covered by dense tropical forest. The highest point is Mount Saddle Peak, 732m. The average annual rainfall is about 3,048cm (Padalia 2004). True wild mango is distributed in India, Burma, Andamans etc. (Mukherjee 1972).

So it is seen that the 5 Zones where *Euthalia aconthea* appears to be most abundant are also the centres of origin / evolution of the mango.

Mango range extension: Cultivated varieties of Mango in India

Mango has been cultivated in India for 4,000 years (Hawkins 1986). Owing to its cultivation and dissemination for thousands of years, in India semi-wild trees can be found in the forests throughout the subcontinent. Total number of distinct mango varieties named and maintained in India has been estimated to be over one thousand. About 30 varieties are commercially grown in India (ICAR 2014). Under the Moghul emperor Akbar (1556–1605), the best selection of seedling mangoes were planted in large orchards. The 'Lakh Bagh', a mango orchard of 1,00,000 trees was planted near Darbhanga in Bihar (Mukherjee 2009). All the cultivars of mango belong to the single species *mangifera indica* L (Mukherjee 1972).

Currently major mango growing states in India are Uttar Pradesh, Gujarat, Andhra Pradesh, Maharashtra,

Odisha, West Bengal, Karnataka, Goa, Haryana, Madhya Pradesh, Punjab and Tamil Nadu. Area wise, Andhra Pradesh occupies 21.55% of the total area under mango cultivation in India, followed by Maharashtra (19.79%), Uttar Pradesh (11.74%), Bihar (6.2%), and Karnataka (6.1%) (Banerjee 2011).

Cashew (new larval host plant) in India

Cashew (*Anacardium occidentale*), a native of Eastern Brazil was introduced to India by the Portuguese about 500 years back. It was first introduced in Goa and now it is grown in the coastal regions of Kerala, Karnataka, Goa and Maharashtra in the west and Tamil Nadu, Andhra Pradesh, Odisha and West Bengal along the eastern coast. To a limited extent it is also being cultivated in Chhattisgarh, northeastern states (Assam, Manipur, Tripura, Meghalaya and Nagaland), and the Andaman & Nicobar Islands (Salam 1999).

CONCLUSION

There are five distinct high rainfall zones in India that receive an average annual rainfall of more than 1,250mm. These zones are northeastern India, hills of central India, Western Ghats, sub-tropical Himalayan forests and Andaman Islands. These five zones are also the centres of origin and evolution of mango. Ignoring its recent association with cashew, *Euthalia aconthea* is largely a monophagous butterfly on mango and it appears to be most frequent to these very same distinct zones of high rainfall and wild mango. *Euthalia aconthea* appears to have refused to follow the expanding range of the cultivated varieties of mango to relatively drier areas, away from hills and mountains. Cashew (new introduced plant) has been accepted in the existing range but the original host plant (mango) has failed to sufficiently attract it to the new territories beyond its native range. How hills and valleys of the native range and associated climatic factors affect the growth and survival of this butterfly during different stages of its lifecycle is yet to be fully understood. Fig. 6 summarizes the distribution pattern of *Euthalia aconthea* in India based on the findings of this study. However as Part-B of this paper is based on the published occurrence records of *Euthalia aconthea*, more research on the ground is required in different zones to prove the proposed hypothesis.

For a quick hypothesis test, occurrence records of *Euthalia aconthea* were examined from two internet based Citizen Science resources: Indian Foundation for

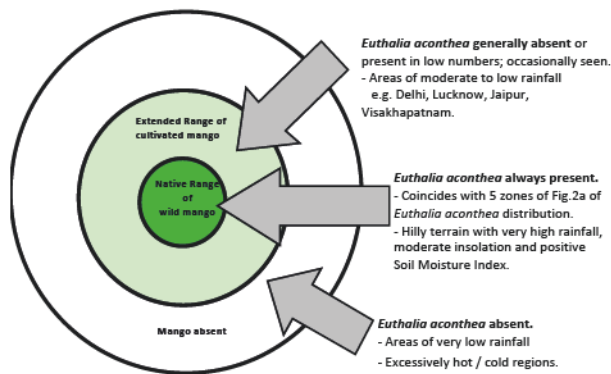


Figure 6. Distribution pattern of *Euthalia aconthea* vis-à-vis *Mangifera indica* range in India.

Butterflies (<http://www.ifoundbutterflies.org/sp/586/Euthalia-aconthea>) and India Biodiversity Portal (<http://indiabiodiversity.org/species/show/256463>), accessed on 11 August 2016. These internet resources provided two independent datasets (point records) in the form of geo-tagged photographs; however there was no information about the abundance levels at various locations. Distribution patterns on these websites closely resemble the distribution pattern of *Euthalia aconthea* hypothesized by this paper (Fig. 2a), with dots more closely packed in and around zone 3 (the Western Ghats) and Zone 1 (north east hill regions). Citizen Science datasets are based on photographs submitted by the volunteers for the period (2009–2016) whereas Fig. 2a of this paper is based on the published papers and books for the period (1887–2016).

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Appendix 1. Sighting records of Common Baron *Euthalia aconthea*

Sno	Place	State	Lat /Long (N/E)	Y/N	Additional Remarks in the source	Source
1	Ratan Mahal WS	Gujarat	22.5583 / 74.1167	Y	Not present in March. Present in October.	Bhalodia 2002a
2	Vansda NP	Gujarat	21.1053 / 73.4319	Y	Common.	Bhalodia 2002b
3	Dangs	Gujarat	20.7838 / 73.7478	Y	Common throughout the year in Dangs forests with its mountain streams, hills, valleys and plateaux.	Shull 1963
4	Lulsi Lake and Kanheri. Bombay	Maharashtra	19.2013 / 72.9125	Y	Not common.	Best 1951
5	Mumbai	Maharashtra	19.0667 / 72.85	Y	-	Raut 2010
6	Tamhini	Maharashtra	18.45 / 73.4167	Y	Present in Summer. This place is a part of northern Western Ghats.	Padhey 2006
7	Pune	Maharashtra	18.5 / 73.8833	N	-	Kunte 1997
8	Bhor - Pune	Maharashtra	18.1646 / 73.8468	N	-	Nimbalkar 2011
9	Goa	Goa	15.4936 / 73.8183	Y	Plentiful in Goa in 1986	Larsen 1987
10	Bondla WS	Goa	15.4325 / 74.1063	Y	Occurs throughout the year but shows a peak in the cooler months.	Borkar 2004
11	Coorg	Karnataka	12.3376 / 75.8068	Y	All over Coorg, as elsewhere.	Yates 1931
12	Madappally	Kerala	11.633 / 75.65	Y	College situated on a small hill.	Nair 2002
13	Nilgiri Biosphere Reserve	Kerala	11.55 / 76.625	N	-	Mathew 2011
14	Nilgiri District	Tamil Nadu	11.5149 / 76.4277	Y	Rare	Larsen 1987
15	Thengumarahada (Nilgiri)	Tamil Nadu	11.5682 / 76.9265	Y	Here Western Ghats and Eastern Ghats meet	Rufus 2007
16	Mettupalaiyam (Nilgiri)	Tamil Nadu	11.2993 / 76.9354	Y	Very Rare.	Wynter-Blyth 1944
17	Silent Valley NP	Kerala	11.1333 / 76.4667	N	-	Mathew 1999
18	Thrissur	Kerala	10.5417 / 76.275	Y	Western Ghats. Occasional (observed 40-60 % times)	Aneesh 2013
19	Peechi-Vazhani WS	Kerala	10.4865 / 76.4329	N	-	Mathew 2005
20	Puyankutty (Idukki)	Kerala	10.0833 / 76.8333	N	-	Arun 2003
21	Palni Hills	Tamil Nadu	10.1996 / 77.4988	Y	Area between Nilgiris and Travancore.	Evans 1910
22	Idukki WS	Kerala	9.7917 / 76.9583	N	-	Pulikkal 2012
23	Alappuzha	Kerala	9.2369 / 76.4738	N	Krishna Puram Gram Panchayat	Babjan 1998
24	Shendurny WS	Kerala	8.8833 / 77.1083	N	-	Shamsudeen 2010
25	Peppara WS	Kerala	8.6333 / 77.175	N	-	Mathew 2004
26	Travancore	Kerala	8.5160 / 77.0641	Y	Very common in plains and hills.	Ferguson 1891
27	Madurai City	Tamil Nadu	9.90 / 78.05	N	-	Baskaran 2002
28	Sirumalai Hills	Tamil Nadu	10.2167 / 78.0583	N	Part of Western Ghats	Amala 2011
29	Anaikatty Hills	Tamil Nadu	11.30 / 78.2167	N	Nilgiri	Eswaran 2005
30	Chennai	Tamil Nadu	12.8782 / 80.0859	N	Arignar Anna Zoological Park	Rajagopal 2011
31	Nalapattu BS	Andhra Pradesh	13.7715 / 79.9780	N	-	Guptha 2013
32	Nagalapuram	Andhra Pradesh	13.6506 / 79.8312	N	Outer spur of Eastern Ghats	Best 1954
33	Seshachalam Hills	Andhra Pradesh	14.3333 / 78.25	N	Southern Eastern Ghats	Guptha 2012
34	Bangalore	Karnataka	12.9732 / 77.5946	Y	Throughout the year. Abundant in September.	Yates 1933
35	Shimoga	Andhra Pradesh	14.9333 / 75.75	N	-	Kumar 2007
36	Solapur	Maharashtra	17.68 / 75.92	N	-	Narvade 2012
37	Lonar Crater	Maharashtra	19.9768 / 76.5240	N	Near Aurangabad	Palot 2003
38	Secunderabad	Andhra Pradesh	17.4407 / 78.4993	N	-	Home 1935
39	Warangal	Andhra Pradesh	17.9583 / 79.4083	Y	-	Samatha 2012

Sno	Place	State	Lat /Long (N/E)	Y/N	Additional Remarks in the source	Source
40	Visakhapatnam	Andhra Pradesh	17.7 / 82.3	Y	Uncommon	Raju 2003
41	Bhubaneswar	Odisha	20.2981 / 85.8333	Y	-	Mohapatra 2013
42	Mahendragiri Hills	Odisha	18.9744 / 84.3681	N	-	Mohapatra 2009
43	Krishnmali Hills	Odisha	19.6868 / 83.0747	N	-	Mohapatra 2009
44	Bastar	Chhattisgarh	19.5657 / 81.6945	Y	Compilation of past records	Chandra 2007
45	Dalma WS	Jharkhanda	22.8963 / 86.2061	Y	-	Verma 2009
46	Parashnath Hills	Jharkhanda	23.9655 / 86.1446	Y	Very Rare	Morrison-Godfrey 1948
47	Sarguja	Chhattisgarh	23.3437 / 83.1882	Y	Compilation of past records	Chandra 2007
48	Panna	Madhya Pradesh	24.7224 / 80.1874	Y	Compilation of past records	Chandra 2007
49	Umaria	Madhya Pradesh	23.5255 / 80.8431	Y	Compilation of past records	Chandra 2007
50	Jabalpur	Madhya Pradesh	23.0989 / 79.9894	Y	Very Rare. Tropical Forest Research Institute	Tiple 2012
51	Mandla	Madhya Pradesh	22.5979 / 80.3714	Y	Compilation of past records	Chandra 2007
52	Balaghat	Madhya Pradesh	21.8126 / 80.1849	Y	Compilation of past records	Chandra 2007
53	Pench	Madhya Pradesh	21.7375 / 79.2417	N	-	Chandra 2002
54	Chandrapur	Maharashtra	19.9500 / 79.3000	Y	Compilation of past records.	Tiple 2011
55	Nagpur	Maharashtra	21.1 / 79.05	Y	-	Kasambe 2008
56	Nagpur	Maharashtra	21.1458 / 79.0881	Y	Compilation of past records.	Tiple 2011
57	Amravati	Maharashtra	20.9307 / 77.7588	Y	Compilation of past records.	Tiple 2011
58	Melghat	Maharashtra	21.3084 / 77.0917	N	-	Chandrakar 2007
59	Nimar	Madhya Pradesh	21.8399 / 76.3431	N	-	Witt 1909
60	Buldana	Maharashtra	20.5330 / 76.1843	Y	Compilation of past records.	Tiple 2011
61	Kaira	Gujarat	22.5514 / 72.9716	N	-	Aldrich 1946
62	Mount Abu	Rajasthan	24.5926 / 72.7156	N	-	Macpherson 1926
63	Narayan Sarovar WS (Kutch)	Gujarat	23.5667 / 68.8167	N	-	Bhalodia 2002c
64	Karachi	Pakistan #	24.9138 / 67.0507	N	-	Swinhoe 1887
65	Sind	Pakistan #	25.9444 / 68.5706	N	-	Menesse 1950
66	Kohat	Pakistan #	33.3167 / 71.25	N	-	Perveen 2012
67	Chitral	Pakistan #	35.8395 / 71.7800	N	-	Leslie 1903
68	Lahore	Pakistan #	31.5910 / 74.3309	Y	Very Rare. Only a single specimen - a female - seen in September.	De Rhe-Philippe 1917
69	Amritsar	Punjab	31.6353 / 74.8752	Y	Common at Amritsar	Sevastopulo 1948
70	Dholbaha	Punjab	31.5602 / 75.8613	N	-	Sharma 2009
71	Khajjiar	Himachal Pradesh	32.0667 / 76.0417	N	-	Thakur 2002
72	Bir-Billing	Himachal Pradesh	32.05 / 76.70	Y	Common	Chandel 2013
73	Manali	Himachal Pradesh	32.35 / 77.275	N	-	Bhardwaj 2009
74	Bir-Shikargah	Haryana	30.7621 / 76.9774	N	-	Uniyal 2007
75	Simla / Shimla	Himachal Pradesh	31.1023 / 77.1775	Y	Caught sparingly	Wynter-Blyth 1940
76	Dehradun	Uttarakhand	30.2826 / 77.9715	N	-	Bhardwaj 2012
76B	Dehradun	Uttarakhand	30.3556/77.9588	Y	New Forest, Common	Singh 2016
76C	Dehradun	Uttarakhand	30.3137/78.0333	Y	Very Common	Mackinnon 1898
76D	Mussoorei	Uttarakhand	30.459/78.066	Y	-	Ollenbach 1931

Sno	Place	State	Lat /Long (N/E)	Y/N	Additional Remarks in the source	Source
77	Haridwar	Uttarakhand	29.9222 / 78.1276	Y	Present in 2009. Absent in 2010. Gurukul Kangri.	Kumar 2013
78	Haridwar	Uttarakhand	30.25 / 78.2	N	Jhilmil Jheel area.	Tewari 2013
79	Rajaji NP	Uttarakhand	29.75 / 78.2083	N	-	Joshi 2007
80	Nanda Devi NP	Uttarakhand	30.5833 / 79.7583	N	-	Uniyal 2004
81	Jaipur	Rajasthan	26.8333 / 75.9167	Y	Not Common	Trigunayat 1998
82	Bharatpur NP	Rajasthan	27.1571 / 77.5238	N	Keoladeo National Park	Palot 2000
83	Delhi	Delhi	28.6283 / 77.1673	N	-	Larsen 2002
84	Delhi	Delhi	28.5932 / 77.2508	N	-	Donahue 1966
85	Delhi	Delhi	28.5886 / 77.3543	Y	At Noida, a satellite town of Delhi.	This Paper
86	Fatehgarh	Uttar Pradesh	27.37 / 79.63	N	-	Peile 1910
87	Jhansi	Uttar Pradesh	25.5137 / 78.7759	N	Paricha Dam area.	Kumar 2012
88	Kanpur	Uttar Pradesh	26.4527 / 80.3308	N	-	Sevastopulo 1948
89	Lucknow	Uttar Pradesh	26.8539 / 80.9425	Y	Not common, it may be taken occasionally in August and September in mango groves.	De Rhe-Philippe 1902
90	Benaras	Uttar Pradesh	25.3194 / 82.9762	N	-	Allen 1919
91	Champaran	Bihar	26.8441 / 84.6826	Y	Common most of the year. Himalayan foothills start.	Harman 1950
92	Patna	Bihar	25.6121 / 85.1460	N	-	Varshney 1976
93	Kathmandu	Nepal	27.7000 / 85.3335	Y	Quite common.	Wangdi 2012
94	Rangpo	Sikkim	27.1762 / 88.5288	Y	Common	Haribal 1992
95	Rangeet	Sikkim	27.1329 / 88.2801	Y	Common	Haribal 1992
96	Singtam	Sikkim	27.1367 / 88.3936	Y	Common	Haribal 1992
97	Upper Neora Valley NP	West Bengal	26.9917 / 88.8333	Y	Baron present through out the year.	Sengupta 2014
98	Sankosh River Catchment	Bhutan #	26.9167 / 90.2083	Y	Present in March and November	Singh 2012
99	Garo Hills	Meghalaya	90.5 / 25.5	Y	-	Kunte 2012
100	Dhaka	BanglaDesh#	23.7258 / 90.4010	Y	Not Rare	Larsen 2004
101	Trishna WS	Tripura	23.4356 / 91.4697	Y	Only two individual sightings.	Majumder 2013
102	Jeypore RF	Assam	27.3667 / 95.4167	Y	-	Gogoi 2013
103	Mishmi Hills	Arunachal	28.2417 / 95.9	Y	-	Gogoi 2012
104	East Calcutta Wetlands	West Bengal	22.5417 / 88.4583	N	-	Chowdhury 2011
104A	Kolkata	West Bengal	22.5378/88.3325	Y	Relative abundance 7 (Clench Scale)	Ghosh 2005
105	Shan State	Burma #	22.0871 / 98.1300	Y	Common all over the country	Carrott 1940
106	Rangoon	Burma #	16.8005 / 96.1499	Y	Fairly Common	Best 1957
107	Arakan Coast	Burma #	19.0889 / 93.8584	Y	Common in Ramree Island	Gladman 1946
108	Andaman	Andaman & Nicobar	12.8742 / 92.8408	Y	-	Ferrar 1948

Neighbouring countries; Y = Yes (present); N = No (not present).





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