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Distribution and habitat characteristics of the Troidine butterfly community in the Western Ghats, a biodiversity hotspot in India

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ABSTRACT: Investigation on the distribution patterns and habitat requirements of the butterfly tribe, Troidini was carried out in undisturbed forest habitats and disturbed, human-modiûed habitats in the Western Ghats, a biodiversity hotspot in south India. Compared various ecological and biological traits of the four species of this group which included a CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) listed species, *Troides minos* Cramer, an endemic species *Pachliopta pandiyana* Moore, a protected species, *Pachliopta hector* Fabricius and *Pachilopta aristolochiae* Linnaeus. Comparisons were based on transect counts conducted at 66 transects in 22 locations covering six types of habitat systems with a gradient of disturbance and management regimes during 2009 and 2010. Results indicated that *P. aristolochiae* was the most widely distributed species occurring in 90% of the transects sampled and *P. pandiyana* had a restricted distribution (36 %), while both *P. hector* and *T. minos* were observed in 73% of the transects. Sampling of the juveniles on the six species of host plants in the various habitats provided insights into host plant partitioning between these species in the different habitats. Life history traits and morphological characteristics of adult troidines, larval host plant characteristics and habitat characteristics were evaluated and characterized. © 2019 Association for Advancement of Entomology

KEY WORDS: Troidine butterflies, biological traits, Western Ghats, resource use, disturbance gradient

INTRODUCTION

The most rampant human exploitation of the environment in most parts of the world and especially in the tropics is the destruction and fragmentation of native vegetation. Although environmental disturbance affects the diversity and structure of ecological communities (Southwood, 1977; Spitzer *et al*., 1993; Huston, 1994), the presence of the diverse biota in complex ecosystems ensures higher stability and efficiency due to greater energy flow and nutrient cycling (Vitousek and Hooper, 1993; Tilman, 1997; Hooper *et al*., 2005). Human disturbance and habitat fragmentation in natural ecosystems as well as the effects of these impacts on the biota especially butterflies is well documented (Wood and Gillman, 1998; Steffan-Dewenter and Tscharntke, 2000; Ghazoul, 2002; Koh, 2007; Saikia, 2014). However, most studies are based on temperate butterflies (Blair and Launer, 1997; Kitahara and Sei, 2001; Krauss *et*

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al., 2003; Hogsden and Hutchinson, 2004) while tropical species have received less attention.

The Indian region includes parts of four hotspots (Western Ghats and Sri Lanka, Himalaya, Indo-Burma and Sundaland) out of the 35 global biodiversity hotspots (Mittermeier *et al*., 2011). The Western Ghats situated in south India like most biodiversity hotspots occurs in an area of high human density and rapid population growth (Cincotta *et al*., 2000). Currently only 9 million km^2 remain out of the approximately 16 million km^2 of original tropical rainforests worldwide (Whitmore, 1997; MEA, 2005). The last few decades have witnessed a drastic and rapid disappearance of the South East Asian tropical rainforests (Sodhi *et al*., 2004). Similarly, in the Western Ghats /Sri Lanka hotspot, primary forests have been decimated from the original extent of 182,500 km^2 to a meagre 12,450 km^2 **(Myers *et al*., 2000)**. Although the Kerala part of the Western Ghats has an established network of protected areas and managed forests under administrative control of the State Forest Department, most ecosystems are under strong anthropogenic pressure. Timber felling, extraction of firewood/ fodder and non-wood forest produce, livestock grazing and fire are the most proximate threats to biodiversity in this region.

The tribe Troidini of the family Papilionidae boasts of some of the most spectacular butterflies and consists of about 138 species coming under two subtribes, namely Battina having one genus and Battus Scopoli and Troidina containing the remaining genera (Munroe and Elhrich, 1960; Munroe, 1961; Hancock, 1983; Miller, 1987). This tribe contains many endemic genera and has a disjunct distribution. Two genera *Pachliopta* Reakirt and *Troides* Hubner are found in the Western Ghats region. The former genus has three species *Pachliopta hector* Fabricius, *P. aristolochiae* Linnaeus, *P. pandiyana* Moore and the latter a single species *Troides minos* Cramer. The larvae of this tribe feed exclusively on plants in the family Aristolochiaceae which contain toxic secondary chemicals which are in turn sequestered for defense against predators (Rothschild, 1972; Feeny, 1991; Silva -Brandão *et al*, 2005).

Due to their high sensitivity and swift responses to local temperature, humidity, rainfall and other parameters, butterflies are touted as the most appropriate indicators of environmental variations resulting from habitat disturbance and modification (Kremen, 1992). Different species have different habitat – linked ecological attributes such as life history traits, mobility and resource utilization. Therefore, whether a species can survive in a modified habitat is dictated by how it perceives the altered landscape vis-a-vis these crucial factors. Sawarkar (2005) observed that in the Indian context, the lack of baseline assessments of species and habitats across the various administrative units greatly impedes the integration of biodiversity and social issues in the management of protected areas. Hence attempts to detect patterns of change in structure and diversity of butterfly communities in response to human interference will give fresh insights and help to initiate the necessary conservation efforts.

MATERIALS AND METHODS

Study sites

For monitoring the butterfly species, 66 transects in 22 locations were selected along the Western Ghats covering six types of habitat systems with a gradient of disturbance and management regimes. Three habitats were relatively undisturbed habitats and the other three disturbed, man modified habitats (Fig. 1). The undisturbed habitats included three types of protected areas namely: i) national parks and biosphere reserves which are high priority conservation areas with minimum anthropogenic impacts, ii) wildlife sanctuaries which are protected conservation areas with restricted and sustainable extraction of non wood forest produce and iii) reserve forests which are managed forests with anthropogenic activities mainly timber felling and under the supervision of the State Forest Department. The disturbed habitats included three types of human impacted areas namely: i) reservoir/ dams which are areas located in the vicinity of reservoirs open to the public for sightseeing and tourism, ii) plantations which are privately owned, intensively managed agriculture systems with monoculture/polyculture crop management regimes and iii) gardens and parks which are public recreational areas with artificially recreated and managed landscapes/ vegetation. The habitat systems/ management types sampled in each location during January 2009 to December 2010 are given in the Table 1.

Butterfly sampling and characterization

Survey method: Butterflies in the selected sites were sampled using the Pollard line transect method (Pollard and Yates, 1993). The counts were taken between 10.00 and 15.30 local time only when the weather was sunny and the temperature was above 18°C. The transect routes were divided into sections of 500 m length, which as far as possible coincided with changes in the nature of the habitat being recorded. The length of transects in the different locations ranged between 800 m and 1000 m. The transect route was restricted to paths, the boundaries of which are easily located. Transect routes were walked at a constant pace of one km/h and all adult butterflies found within approximately 5 m on both sides and in front were recorded. The individuals that could not be identified by sight were either caught with an insect net for close examination and released or photographed. The sampling was done from January 2009 to December 2010 and 100 samples each were taken in undisturbed and disturbed sites.

Estimation of morphological characters of butterfly species: Morphological characters namely wing expanse, proboscis length and egg size were determined for the four troidine species. For obtaining wing expanse in each species, measurements of the distance between the wing tips in centimeters in fifteen well spread, preserved specimens were taken using a fine scale. The proboscis length was measured in fifteen laboratory bred and freshly emerged individuals of each species by carefully holding the butterfly sideways

Table 1. Habitat systems in the Western Ghats sampled for butterfly fauna

Habitat /Management types	Locations
National Park / Biosphere Reserve	Agasthyamalai Biosphere Reserve Eravikulam National Park Silent Valley National Park
Wildlife Sanctuary	Aralam Wildlife Sanctuary Chinmony Wildlife Sanctuary Parambikulam Wildlife Sanctuary Peechi-Vazhzani Wildlife Sanctuary Shenduruny Wildlife Sanctuary Waynadu Wildlife Sanctuary
Reserve Forest	Kalpetta Reserve Forest Periya Reserve Forest Puyankutty Reserve Forest Sholayar Reserve Forest Meppady Reserve Forest Nelliampathy Reserve Forest Vazhachal Reserve Forest
Dam/ Reservoir	Chinmony Dam Peechi Dam Vazhani Dam
Plantation	Chengalur (Monoculture plantation) Kiralur (Polyculture plantation)
Park / Garden	Kerala Forest Research Institute Butterfly Garden

and gently extending the proboscis with a fine needle and placing a thread along the length of the proboscis. The length of the thread was then measured in centimeters with a fine scale after releasing the butterfly. For determining the egg size, fifteen freshly field laid eggs of each species were brought to the laboratory. The eggs were examined under a microscope with a grid and the diameter was measured in mm.

Determination of life history traits: Life history traits namely larval development period, voltinism, phagy and susceptibility to predation and parasitism recorded. To obtain information on the larval development period, eggs collected from the field were placed in small glass tubes (2.0 cm diameter x 7.5 cm height), loosely plugged with cotton wool and containing a small piece of water-soaked tissue to maintain humidity. On hatching, larvae were transferred to sterilized glass containers (6.5 cm diameter x 13.0 cm height). The entrance of the containers were covered with a clean dry cloth and securely fastened with a rubber band. Frass and debris were removed daily and larvae removed to sterilized containers and provided with fresh leaves of the host plant. The 4th instar larvae were removed to larger containers (9.5 cm diameter x 19.0 cm height). Final instar larvae preparing for pupation were provided with a dry twig placed diagonally, leaning from the base of the container and resting against its wall. The duration of each instar was recorded. The voltinism of the four troidine species was evaluated and categorized as follows: univoltine - life cycle involves one generation per year; bivoltine - life cycle involves two generations per year and multivoltine – life cycle involves more than two generations per year. The host plant range of the four troidine species was evaluated and categorized as follows: monophagy- feeding on a single species of plants in one family, oligophagy- feeding on 10 or fewer species of plants in one family; polyphagy- feeding on 10 or more species of plants in one family and/ or on plants from two or more families. To obtain information on the susceptibility of the various stages of troidine butterflies to predation and parasitism, observations on these aspects in both field and laboratory conditions were recorded.

Larval host plant sampling and characterization

Survey method: Larval host plants of the troidines occurring in the different habitats were recorded. At each site, the area adjacent to the selected transects was thoroughly scanned to locate the host plants and record their numbers. The number of juveniles present on the located host plants were also recorded.

Determination of specific leaf area and leaf dry matter content of larval host plants: Specific leaf area and leaf dry matter content was estimated for each host plant species. For determining the specific leaf area (SLA) and leaf dry matter content (LDMC), three fully expanded leaves with attached stems were collected from robust, well-established host plants. Senescent or damaged leaves were avoided. Collected leaf-stem segments were immediately placed between wet papers, sealed in a plastic bag and placed in dark cooled containers. After being transported to the laboratory (usually within 1 hour after collection), leaf samples were placed in water in the dark at 5°C for 12 hours after the stem or petiole was removed under water (Garnier *et al*., 2001). This procedure ensured full leaf rehydration. Leaves were then dried with tissue paper to remove surface water and immediately weighed to determine their saturated fresh weight. Leaf area was then measured using grid paper. Samples were then oven-dried at 60°C for at least two days, and their dry weights were determined. Values of LDMC were calculated as the ratio between leaf dry mass and saturated fresh mass ($g\ g^{-1}$), and SLA was expressed as the ratio of leaf area to leaf dry mass ($cm^2\ g^{-1}$). Three replicates were done for each parameter and averaged to obtain the mean value.

Characterization of host plant growth form and phenology: The growth form of the host plants was characterized into the following three categories namely (i) tree/ shrub (ii) herb/ grass and (iii) climber/ liana. For scoring the phenology of the host plants, the flowering period of the different host plants was observed and recorded.

Distribution mapping: The location of transects

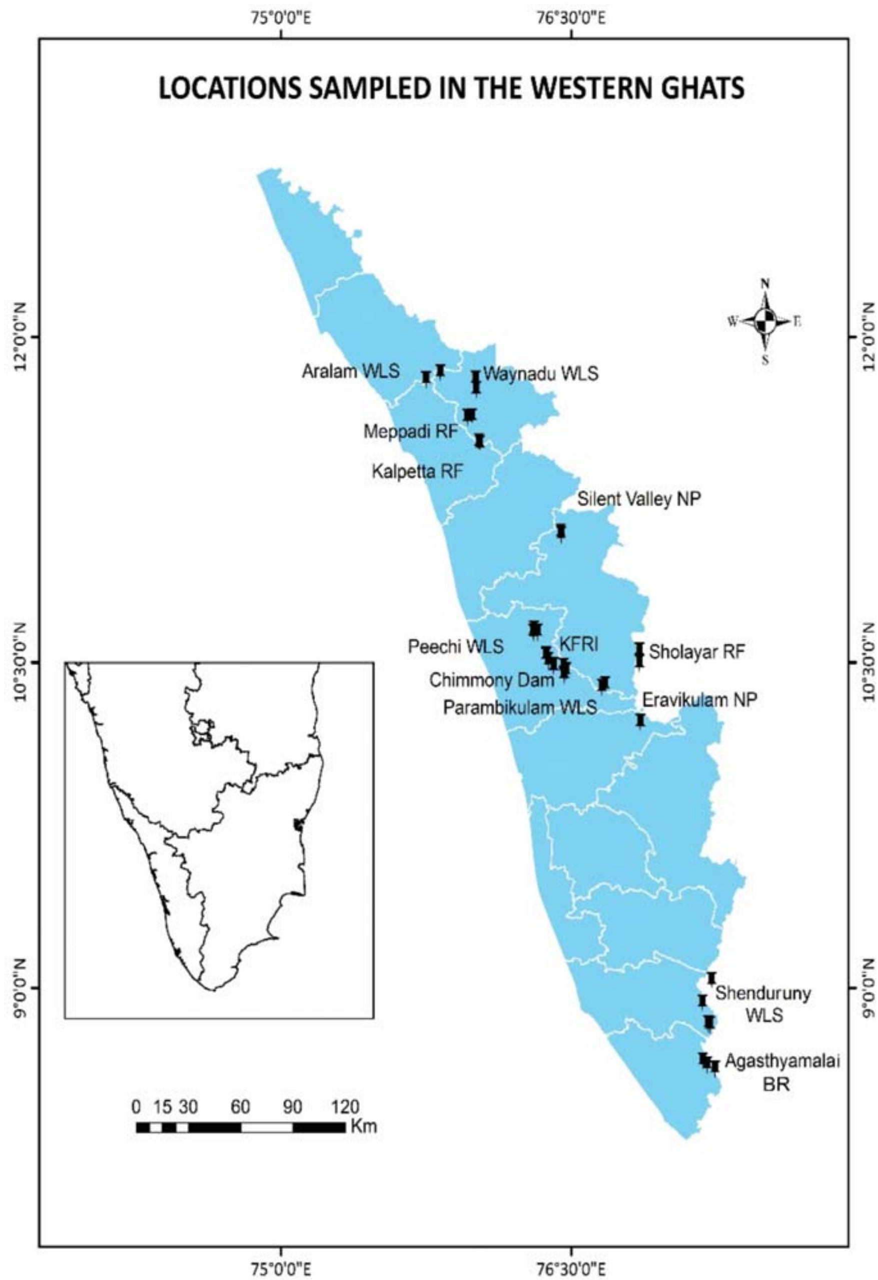

Fig. 1. Location of study sites in the Kerala part of the Western Ghats

with records of host plant occurrence was marked by using GPS (Global Positioning System) from the field. The GPS readings are plotted over geo-referenced Survey of India (SOI) by using open source GIS (Geographic Information System) software. The base layers such as water bodies, forest and boundaries were digitized from SOI topo sheets and updating of layers from latest satellite imageries using GIS and remote sensing software was done. The transects were classified according to forest/wildlife divisions of the State Forest Department and fifteen divisions were obtained of which mapping was done for the thirteen divisions where host plants were recorded. The final distribution map of troidine species in areas of host plant occurrence based on mean abundance of butterflies was prepared using GIS software (ESRI, 2011).

Habitat sampling and characterization: Environmental variables namely the weather parameters like relative humidity and mean temperature were recorded in the different habitats. The number of adult nectar plants utilized in the various habitats was scored for each species. Butterfly habitat variables like number of habitats occupied and flight period was obtained by sampling. Information on biogeographical range was obtained from literature and scored for each species. The geographical distribution ranges were categorized on a scale of 1-6 (smallest to largest) as follows: 1- Western Ghats, 2- South and Peninsular India, 3- Indian subcontinent, 4- Oriental (Indo-Malayan), 5- Paleotropics, 6- Cosmopolitan.

Soil sampling and characterization: In order to obtain information on the soil characteristics in the different habitats where the host plants of the troidines were recorded, soil was sampled at 48 locations. Within the selected sites, soil samples were collected at 3 random locations at 0-20 cm depth. These samples were pooled and the following edaphic variables were estimated: pH, total soluble solutes (TSS), organic carbon (OC), phosphorus (P) and potassium (K). Eight replicates were obtained in each habitat and averaged to obtain the mean.

Data analysis: The correlation between the habitats based of the abundances of the four troidine species in the different habitats was sought. The correlation analysis of the troidine butterfly abundance and the habitat variables namely soil properties, temperature and humidity was also done.

RESULTS AND DISCUSSION

Butterfly sampling and characterization: When considering the abundance of the troidines in the various habitats (Fig. 2) it was observed that *P. aristolochiae* was the most widely distributed species occurring in 90% of the transects sampled and having the highest abundance in the reserve forests and wildlife sanctuaries. *P. pandiyana* had a restricted distribution occurring in only 36% of the sampled transects with main populations in the national parks, wildlife sanctuaries and garden habitats. Both *P. hector* and *T. minos* were observed in 73% of the transects. *P. hector* showed maximum numbers in the reserve forests while *T. minos* numbers peaked in wildlife sanctuary habitats. There are varied morphological characters and life history traits (Table 2). *T. minos* had two generations in a year, *P. pandiyana* had one generation while both *P. hector* and *P. aristolochiae* had several generations. When

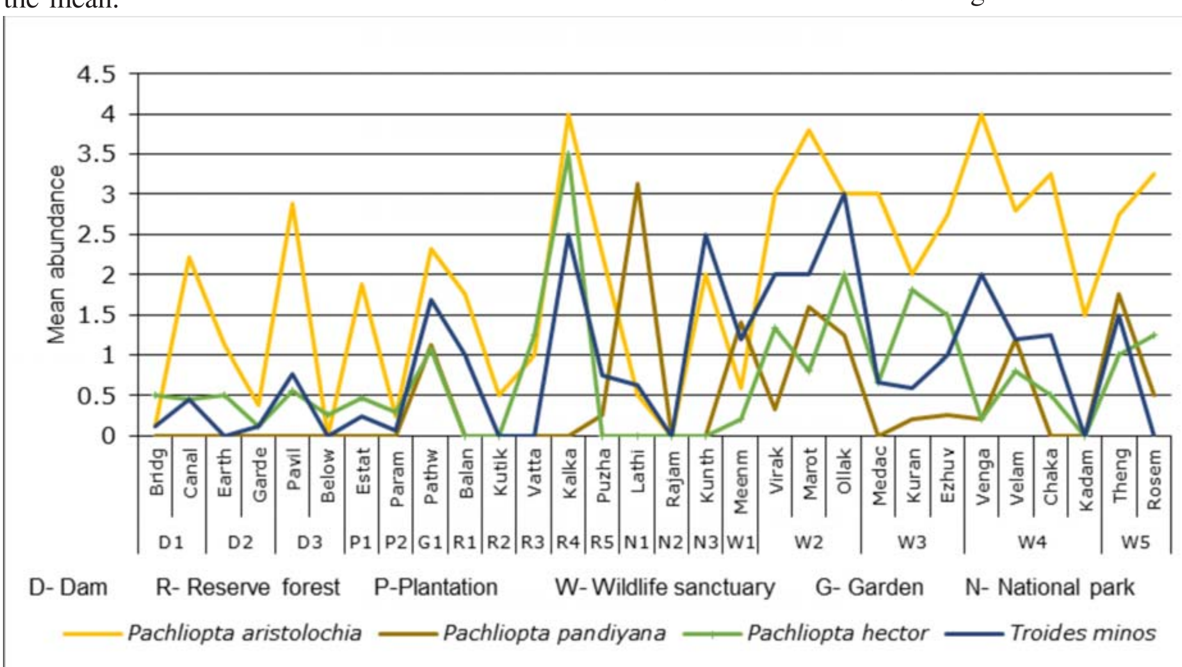

Fig. 2. Mean abundance of troidines in the different habitats sampled during 2009 and 2010

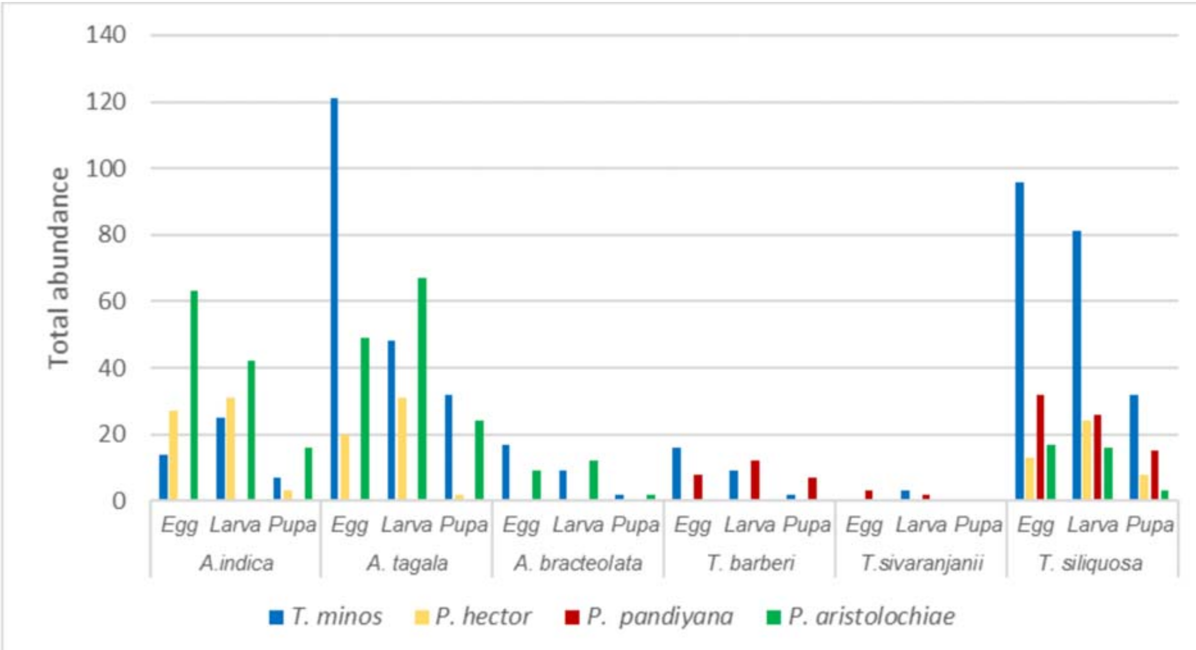

Fig. 3. Total abundance of juveniles of troidines recorded on different host plants in all habitats during 2009 and 2010

considering feeding preferences, *P. pandiyana* was observed to only feed on *Thottea* species while the other three troidine species were oligophagous feeding on both *Aristolochia* as well as *Thottea* species. A hymenopteran egg parasitoid, *Telenomus dilates* sp.n. was reported for the first time in the eggs of *T. minos* and *P. aristolochiae* (Rajamohana and Anto, 2014). A dipteran larval parasite and a hymenopteran pupal predator were also recorded in *T. minos*.

Larval host plant sampling and characterization: Six species of the family Aristolochiaceae were recorded as the larval host plants of the four species of troidine butterflies in the different habitats that were sampled in the study. The data obtained from the sampling of juveniles on the six species of host plants in the various habitats (Fig. 3) provide some insights into host plant partitioning between the conspecific species of butterflies in the different habitats. *T. minos* was the only troidine which utilized all six of the recorded host plant species. *A. tagala* recorded the highest count of juveniles of *T. minos* while *T. sivarajanii* had the lowest count. *P. aristolochiae* utilized four species of host plants with *A. tagala* recording the highest count of juveniles followed by *A. indica. P. hector* also utilized four species of host plants and the highest count of juveniles was obtained on *A. indica* followed by *T. siliquosa. P. pandiyana* utilized three species of host plants all belonging to the *Thottea* species with *T. siliquosa* recording the highest count of juveniles followed by *T. sivarajanii.* Observations indicate that *A. tagala* was the host plant species which recorded highest count of troidine juveniles followed by *T. siliquosa*. Hence the observed pattern of host plant utilization of *T. minos* which uses all of the six recorded *Aristolochia* species hints of an ancestral host plant use characteristic of basal taxa for this species (Silva Brandão *et al*., 2005). On the other hand, *P. pandiyana* has a restricted host range using fewer species thereby showing features of a more specialized terminal taxa (Kelly and Farrel, 1998). The highest specific leaf area (SLA) as well as leaf dry matter content (LDMC) was recorded in *A. tagala* followed by the endemic *T. sivarajanii* (Table 3). When considering the distribution of the host plant species across habitats, it was observed that the wildlife sanctuaries and gardens supported more larval host plant species followed by national parks and reserve forests. The plantations and

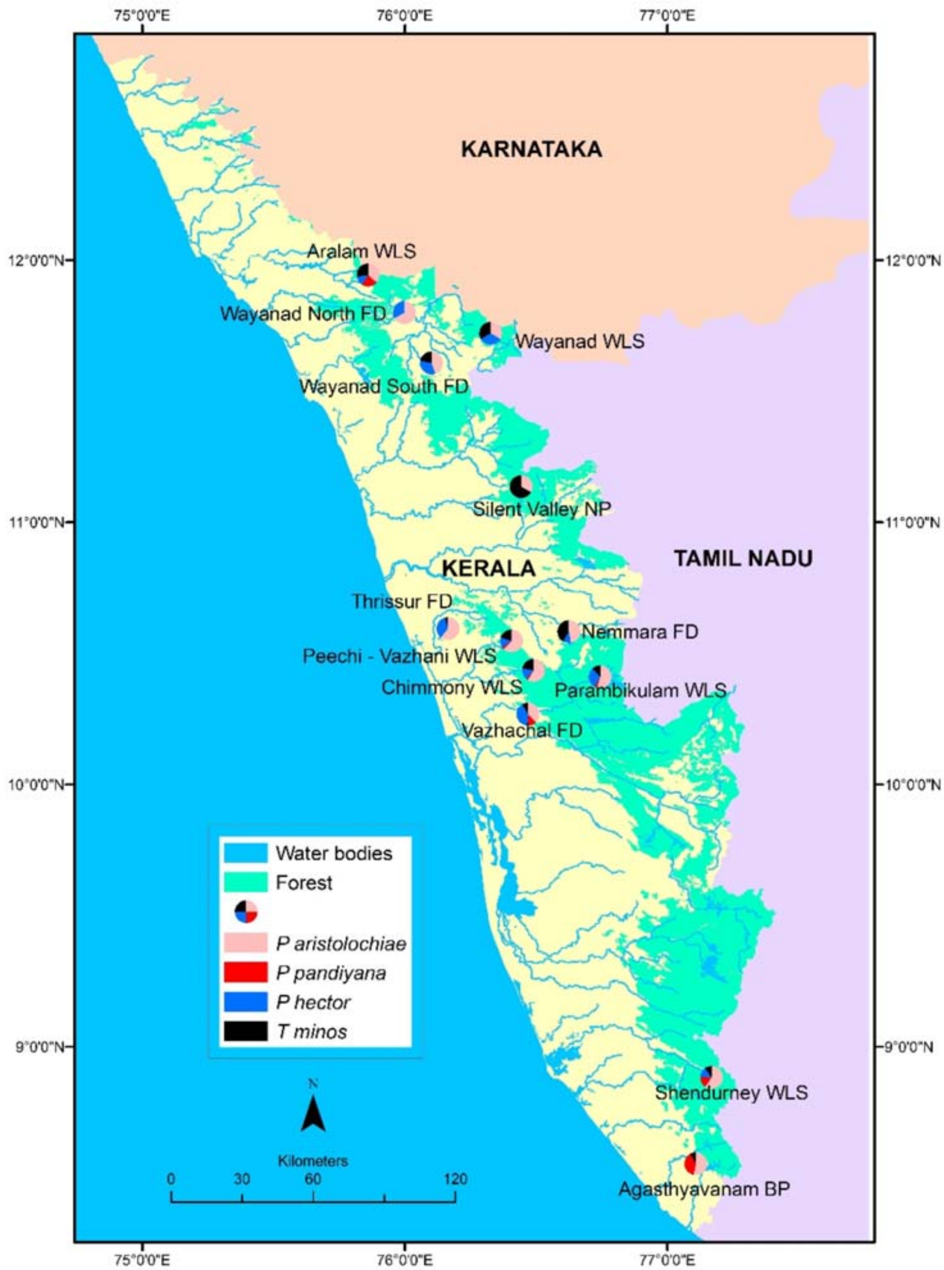

Fig. 4. Distribution map of troidines based on mean abundance of adults in transects with host plant occurrence in the habitats sampled during 2009 and 2010

dams were comparatively poorer in host plant species.

Distribution mapping of Troidines: The distribution of the troidine species based on occurrence of larval resource plants in the sampled sites was mapped (Fig. 4). The mapping of the resource plants for this group of butterflies across the various habitats was attempted keeping a species-centered view of the landscape (Fischer *et al*., 2004). In tropical regions, the distribution of a species across landscapes and its persistence depends on many factors of which mobility through modified "countryside" habitats (Gascon *et al*., 1999) is critical. Among the troidines, *P. aristolochiae* and *T. minos* having the broadest host plant ranges occurred in 86% and 80% of the divisions respectively. *P. hector* was sighted in 73%

Table 2. Morphological characters and life history traits of the troidine species

Traits/Characters	min	pan	hec	ari
Larval period (mean± SE in days)	28.2±0.698	30.3±0.987	27.8±0.578	25.4±0.532
Wing span (mean± SE in cm)	13.84±0.252	10.64±0.183	9.94±0.119	8.85±0.077
Proboscis length (mean± SE in cm)	2.99±0.051	2.15±0.037	1.48±0.036	1.28±0.020
Egg size (mean± SE in mm)	1.842±0.052	1.506±0.021	1.358±0.011	1.230±0.012
Voltinism	bivoltine	univoltine	multivoltine	multivoltine
Phagy	oligophagy	monophagy	oligophagy	oligophagy
Predators	pupal	none recorded	none recorded	none recorded
Parasites	egg, larval	egg	none recorded	egg

SE = Standard error.
Butterfly species codes = min - *Troides minos*, pan - *Pachliopta pandiyana*,
hec - *Pachliopta hector*, ari - *Pachliopta aristolochiae*.

Table 3. Specific leaf area (SLA), leaf dry matter content (LCDM), growth form, phenology, butterfly hosts and occurrence of larval host plants.

Host plant species	SLA (cm^2g^1)	LDMC $(g\,g^{-1})$	Growth form	Phenology	Butterfly host species	Habitat systems
Aristolochia indica	0.087	0.44	climber/ liana	June-Oct	min, hec, ari	P, D, G
Aristolochia tagala	0.271	1.36	climber/ liana	Oct-Feb	min, hec, ari	WS, G
Aristolochia bracteolata	0.130	0.65	climber/ liana	Jun-Sep	min, hec, ari	WS, G
Thottea siliquosa	0.243	1.22	tree/ shrub	May-Dec	min, pan, hec, ari	WS, G, RF
Thottea barberi		0.097	0.49	tree/ shrub	Jun-Sep	min, pan NP, WS, G
Thottea sivarajanii	0.263	1.32	tree/ shrub	Oct-Jan	min, pan	NP, WS, RF

Habitat codes = NP-National park/ Biosphere reserve, WS-Wildlife sanctuary, RF-Reserve forest, D-Dam, P-Plantation, G-Garden.
Butterfly species codes = min-*Troides minos*, pan- *Pachliopta pandiyana*, hec - *Pachliopta hector*, ari - *Pachliopta aristolochiae*

Table 4. List of habitats occupied, flight period and biogeographical distribution range of troidine species

Troidine Species	Habitatsoccupied	Flight period (months/year)	Biogeographical range
Troides minos	NP,WS,RF,D,P,G	10	2
Pachliopta pandiyana	NP,WS,R,G	5	1
Pachliopta hector	WS,RF,D,P,G	8	3
Pachliopta aristolochiae	WS,RF,D,P,G	12	4

Habitat codes = NP-National park/ Biosphere reserve, WS-Wildlife sanctuary,
RF-Reserve forest, D-Dam, P-Plantation, G-Garden.
Geographical distribution range codes = 1-Western Ghats, 2- South and Peninsular India,
3-Indian subcontinent, 4-Oriental, 5- Paleotropics, 6- Cosmopolitan

Table 5. Soil properties, troidine mean abundance and environmental conditions at selected sites in the various habitats

Habitat systems	Soil properties					Troidine abundance (Mean±SE)				Environmental conditions (Mean±SE)	
	pH	TSS	OC	P (kg/ha)	K (kg/ha)	min	pan	hec	ari	Temp (°C)	RH (%)
National park	5.21	0.13	1.06	7.17	155.37	0.87± 0.56	1.5± 0.92	0	0.12± 0.17	20.28± 0.95	81.13± 2.62
WL sanctuary	5.9	0.12	1.10	24.07	246.75	1.12± 0.56	0.7± 0.44	0.25± 0.23	0.87± 0.62	31.23± 1.54	61.88± 4.81
Reserve forest	5.47	0.20	1.11	16.2	189.75	0.75± 0.74	0.12± 0.17	0.87± 0.62	0.87± 0.49	31.19± 0.71	69.75± 2.61
Dam	5.91	0.1	0.91	27.35	224.25	0.37± 0.37	0	0.5± 0.37	1.12± 0.56	38.25± 1.46	60.74± 4.09
Plantation	5.52	0.1	0.88	5.37	170.87	0	0	0.37± 0.37	1.12± 0.49	38.96± 1.85	58.50± 3.24
Garden	6.15	0.1	0.72	12.82	198.62	1.5± 0.59	1.2± 0.79	0.75± 0.79	2.12± 0.72	37.11± 1.88	64.25± 4.29

Table 6. Correlation matrix of troidine abundance in different habitats

	NP	WS	RF	D	P	G
NP	1					
WS	0.44501	1				
RF	-0.91222	-0.11826	1			
D	-0.79576	0.06052	**0.77540**	1		
P	-0.71583	-0.08006	0.57442	**0.94491**	1	
G	-0.05208	**0.71796**	0.17128	**0.64281**	**0.61844**	1

Table 7. Pearson correlation coefficients (r^2) between troidine abundance and soil properties, temperature and humidity

Troidine Species	pH	TSS	OC	P (kg/ha)	K (kg/ha)	Temp (°C)	RH (%)
Troides minos	**0.5432**	-0.0495	-0.3371	0.0497	0.1991	-0.1114	0.2763
Pachliopta pandiyana	-0.1858	-0.0351	0.1017	-0.3098	-0.2595	**-0.7708**	**0.9219**
Pachliopta hector	0.3684	0.3111	-0.3189	0.1247	0.1153	0.1153	**-0.7974**
Pachliopta aristolochiae	**0.7667**	-0.3903	**-0.8517**	-0.0195	0.1517	**0.5963**	-0.4250

Bold numbers indicate significant correlation (pe” 0.05). Soil properties= pH-ion concentration, TSS-Total soluble solutes, OC-Organic carbon, P-Phosphorus, K- Potassium, Temp (°C)-Temperature in degrees centigrade, RH (%)- Relative humidity expressed as a percentage, (kg/ha)-kilogram per hectare

Table 8. List of nectar plants of Troidine butterflies recorded in the various habitat systems

Troidine species	Nectar plant species	Habitat systems
min, pan, hec, ari	*Clerodendrum paniculatum*	RF, P, D, G
min, hec, ari	*Clerodendrum viscosum*	RF, P, D, G
min, pan, hec, ari	*Ixora coccinea*	D, G
min, pan, ari	*Ixora nigrans*	WS, RF, D, G
min, pan	*Ixora malabarica*	NP, WS
min, hec, ari	*Mussaenda glabra*	D, G
min, pan	*Mussaenda parviflora*	NP, WS
min, pan, hec, ari	*Mussaenda frondosa*	D, G
min, pan, hec, ari	*Mussaenda ethryophyllum*	D, G
hec, ari	*Nerium odorum*	D, G
hec, ari	*Carissa carandus*	D, G
hec	*Albizzia lebbeck*	P, D
min, pan, hec, ari	*Lantana camara*	RF, P, D, G
min, hec, ari	*Pentas sp.*	D, G

Habitat codes = NP-National park/ Biosphere reserve, WS-Wildlife sanctuary, RF-Reserve forest, D-Dam, P-Plantation, G-Garden. Butterfly species codes = min-*Troides minos*, pan- *Pachliopta pandiyana*, hec - *Pachliopta hector*, ari - *Pachliopta aristolochiae*

and the monophagous *P. pandiyana* in only 46% of the divisions. All the wildlife sanctuaries with the exception of the Wayanad Wildlife Sanctuary sustained populations of all the four troidine species. Similarly among the forest divisions, Vazhachal Forest Division had populations of the four species. The Agasthyavanam Biological Park had the largest population of the endemic species, *P. pandiyana*.

Habitat sampling and characterization: Butterfly habitat variables include number of habitats occupied, flight period and biogeographical range (Table 4). The lowest ranked species, *P. pandiyana* with score 1 was endemic to the Western Ghats and the highest ranked species, *P. aristolochiae* with a score 4 was the most widely distributed species with an Oriental distribution. *T. minos* has a peninsular distribution and *Pacliopta hector* is found in the Indian subcontinent. No species with geographic range scores of 5 and 6 were recorded among the troidine species in our study. *T. minos* occurs in all the habitat types, *P. aristolochiae* and *P. hector* were not recorded in biological reserves and *P. pandiyana* was absent in dams and plantations. The values obtained for the various soil parameters, mean troidine abundance and the temperature and humidity conditions are given in Table 5.

Correlation: The correlation between habitats based on the butterfly abundance of the four troidine species evaluated (Table 6) indicated that while all three different disturbed habitats were significantly correlated to one another, none of these had a significant correlation to undisturbed habitats. This further emphasizes the well documented fact that relatively undisturbed habitats namely national parks, wildlife sanctuaries and reserve forests are the key areas to be targeted for conservation management. Among the man-modified habitats, the gardens were significantly correlated to wildlife sanctuaries and the dam sites to the reserve forests. This finding is significant as it further supports previous studies (Mathew and Anto, 2007, Mathew *et al*., 2011) which demonstrate that artificially created parks and gardens with diverse larval and adult resources and managed with respect to the ecological needs of butterfly species can attract and sustain viable populations in the area.

The correlation analysis of the troidine butterfly abundance and the habitat variables namely soil properties, temperature and humidity (Table 7) show that some of these factors are strongly correlated to the occurrence of species in the various habitats. The occurrence of *P. pandiyana* was limited by humidity and temperature levels of the habitats. It was observed only at humidity levels of 85% and above and low temperatures (negative correlation). *P. hector* on the other hand was found in areas of low humidity levels and higher temperatures. *P. aristolochiae* showed positive correlation to temperature. Among the soil edaphic factors only pH and organic carbon appeared to be significant.

Since the host plants in a habitat are utilized only when sufficient adult resources (nectar) are also available, optimal butterfly habitat must include sufficient larval and adult food resources. In the present study, the maximum number of troidine species and individuals were observed in wildlife sanctuaries and garden habitats (Table 8) where availability of diverse plants and access to host plants promoted the butterfly richness and density. Most of these plants provide rich nectar sources to adult butterflies. Comparatively, the other habitats especially plantations and dam sites have lesser density of vegetation. The vegetation in national parks is highly specialized and that of the reserve forests are less species rich in character. The dams and plantations being subject to anthropogenic activities have lower butterfly colonization.

Among the biodiversity hotspots, Western Ghats has the highest human population living in close proximity to the forests resulting in human disturbance being the single most important factor in the deterioration of habitat quality and loss of biodiversity. In the case of forest landscapes in the Western Ghats, the disturbance regime in terms of timber and other forest produce extraction has evolved along with the livelihood practices of native as well as settler populations over the past centuries. Protected areas like national parks, biological reserves and reserve forests are undoubtedly strategic conservation areas for rare species and their protected status help maintaining human impacts at minimal levels. However, the proportion of these areas is clearly not sufficient to support the rich and diverse fauna of the region. Hence, managed habitats like bio parks and butterfly gardens incorporating a wide range of artificially created conditions have the potential to provide refuge to a diverse assemblage of butterfly species. Therefore, sustainably and ecologically managed areas providing economic benefits may complement the “large protected area” concept which is becoming increasingly impractical in our resource crunched world. Ultimately, the future of many species will be determined by how well they adapt life history strategies in a mosaic of urban, agricultural, semi natural and natural habitats. Thus, equipped with a better understanding of ecological processes of selected species in natural and human modified landscapes, the sustainability of traditional land use patterns can be reassessed with greater clarity.

The troidine species of butterflies are a group of distinctly patterned butterflies which are easily detectable in field surveys and has been proposed as an ideal group for monitoring by forest guards on a routine basis along forest tracks (Anto and Mathew, 2014). The selection of taxa for conservation has always been a dilemma as sampling of entire faunas is practically impossible. Endemicity of plants and animals is considered a very important criteria for conservation purposes. Moreover, taxa that are endemic to a single geographic area are singularly relevant as their conservation will be policy-based and local. This study is significant as it focuses on the four troidine species of the Western Ghats area namely:- *Pachliopta pandiyana* (Western Ghats endemic); *Troides minos* (Peninsular India endemic and CITES listed species); *Pachliopta hector* (listed in Schedule I of Indian Wildlife Protection Act) and *Pachliopta aristolochia*. The larval host host plants of these butterflies also include endemic and RET species namely *Aristolochia indica, Aristolochia tagala, Aristolochia bracteolata* and *Thottea siliquosa*. Thus information generated on their utilization within the Kerala part of the Western Ghats is particularly relevant as *Aristolochia indica* is widely used in traditional medicine and regularly extracted from the forest areas. Further studies on troidines and other threatened invertebrate/plant taxa will probably provide more robust correlations and definitely demands further investigations.

As human impacts on ecological systems escalate, it is important to understand the complex dynamics and interactions in natural ecosystems. The distribution mapping has helped understand the patterns of larval resource use in the selected habitats. Further, interactions such as predation, competition and parasitism and their influence on the structure of butterfly communities needs further research and analysis. In the Kerala part of the Western Ghats where a sizeable proportion of the population live near forests and many activities are forest-dependent, an ideal sustainable conservation model would be one which balances the future of biodiversity with the livelihood of the people. Once this crucial equation is computed, it will definitely show the way forward in this ecologically fragile and politically sensitive region.

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