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COMMUNICATION

Does the size of the butterfly enhance detection? Factors influencing butterfly detection in species inventory surveys

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Abstract: Butterfly species' abundance and factors influencing butterfly detection in Chimmony Wildlife Sanctuary, Kerala was studied from April to June 2018. The survey was carried out on 15 tracks of 2-km lengths surveyed two times resulting in the sampling effort of 60km. A total of 141 species of butterflies belonging to two orders, six families and 103 genera were observed during the study, of which 15 species were recorded as endemic. The majority of butterfly species belonged to the families Nymphalidae and Lycanidae. The size of butterflies varies significantly among families with the largest butterflies recorded in Papilionidae and Nymphalidae and the smallest butterflies from Hesperidae and Lycanidae. The factors that determine butterfly detection during the count was determined using multiple regression. The number of detections had a linear relation with abundance, size, and activities of the butterflies. The model was highly significant and explained 86.9% of the variation in the detection of butterflies ($F=407.8$; $df=3$; $p<0.000$). Abundance had a primary influence on detection followed by the size and activities of the butterflies. Further studies on relative detectability of different species of butterflies in the diversity and abundance estimation would help in refining methods of assessment of butterflies.

Keywords: Abundance, Chimmony Wildlife Sanctuary, Hesperidae, Lepidoptera, Lycanidae, Nymphalidae

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Author contribution: MA developed the concept, formulated hypothesis and did data analysis. AV did the field data collection, conceived the idea and carried out the preliminary analysis. GC and BS supervised the work and preparation of the final manuscript.

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INTRODUCTION

Butterflies are universally popular among all fauna. They are very beautiful and come in various sizes, shapes, and colours. Different patterns on their body enhance their aesthetic value (Gupta & Majumdar 2012). The Western Ghats can be classified into three biogeographical parts based on the status and distribution of butterflies. They are the southern Western Ghats, central Western Ghats and the northern Western Ghats (Gaonkar 1996). Because of high levels of species endemism, the Western Ghats is listed under 34 global biodiversity hotspots. The region is prominent among all other biodiversity hotspots (Myers et al. 2000). The butterfly fauna of the Western Ghats consists of 346 species of butterflies under six families (Bhakre & Ogle 2018).

Most of the inventory surveys were carried out by sampling through forest paths and trails without any information on the sample area (Sudheendrakumar et al. 2000; Sreekumar & Balakrishnan 2001; Aneesh et al. 2013), hence it was not possible to estimate population density. The systematic surveys using fixed width transect or using pollard walk (Isaac et al. 2011) helps to estimate the population density of butterflies with the same sampling effort by recording additional information on length and width of the area sampled. It is essential to determine the different factors that determine the detection probability. Species-wise differences in the detection probability of butterflies were reported in the studies carried out in the United Kingdom (Isaac et al. 2011).

The family Nymphalidae is the most dominant family with a high number of species. A detailed diversity study of butterflies in Chimmony Wildlife Sanctuary (CWS) has not been done yet. Previous studies reported 24 species of butterflies in the study area (George 2012). We have investigated butterfly species size and abundance influence on the detection of butterflies in inventory surveys at CWS.

METHODS

Study area

The study was conducted in Chimmony Wildlife Sanctuary, which spreads geographically within 76.417N and 10.402E and 76.560N and 10.483E in Thrissur District of Kerala State (George 2012). The sanctuary was established in the year 1984. The sanctuary consists of parts of Kodassery Reserve with an extent of 85.07km^2. It is bounded by Nelliampathy Reserve Forest on the east, Peechi-Vazhani Wildlife Sanctuary on the north-west, and Sholayar Reserve Forest on the south (Fig. 1). The mean annual rainfall is 3,130mm. The sanctuary has a tropical humid climate, with three distinct seasons, dry season (December–March) followed by the south-west monsoon (April–July), and north-east monsoon (August–November). Temperature varies from 38.5°C to 15.6°C during different seasons. The minimum temperature falls below 15.6°C during December. The area is also vulnerable to forest fires during the dry season. The sanctuary has more than 250 streams and six man-made waterholes. Diverse vegetation and favourable climatic conditions in the sanctuary could support many species of butterflies.

Butterfly abundance estimation

Butterfly species abundance was estimated using fixed-width transect method in CWS from April 2018 to August 2018. Totally, 15 strip transects of 2km were selected along paths with 2-m width on either side of the transect and sampled twice that resulted in the sampling effort of 60km. The surveys were conducted between 09.30h and 13.30h when the butterflies were most active. The butterflies observed in the field were photographed for further clarification and identification. Butterflies were identified using field guides (Kunte 2006; Palot 2015; Kehimkar 2016; Bhakre & Ogale 2018) and specialists were consulted in case of uncertainty in the identification of species. The butterflies were photographed using a Nikon 3100 DSLR camera with 18–50mm and 70–300 mm lens. The butterfly survey routes were marked with GPS (Fig.1).

Statistical analysis was performed by using Windows-based statistical package Microsoft Excel, PAST (Hammer et al. 2001) and SPSS. The diversity indices such as Simpson and Shannon-Wiener index of butterfly species from each habitat were analysed with the help of software PAST. Butterfly size difference among different families was tested using one-way analysis of variance (one-way ANOVA). The factors that determine the detection of butterflies, such as abundance, activities (0—resting; 1—foraging, flying, mud puddling, etc), size of butterflies were tested using multiple regression. Both response and independent variables were log-transformed due to positive skewness of data. Linearity was examined by plotting the relationship between the response variable (number of detections) and each predictor variable (abundance and size) using Lowess plot. To investigate multicollinearity between the environmental covariates, a correlation analysis was conducted before using

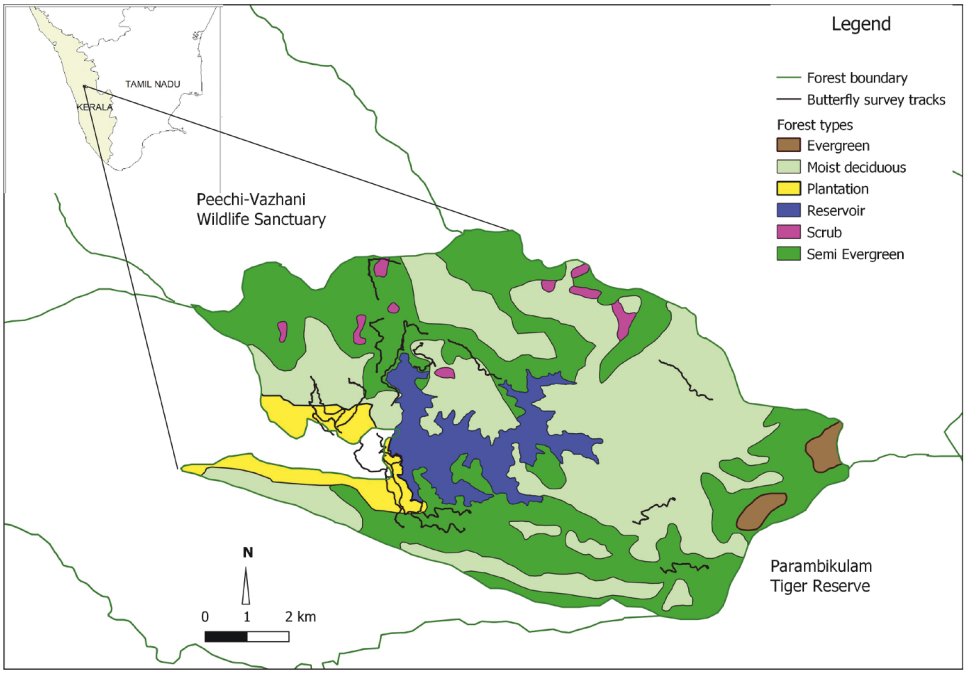

Figure 1. Chimmony Wildlife Sanctuary and butterfly survey routes in the study area.

multiple regressions to assess the relationships between the response variable and predictor variables, thereby providing valid parameter estimates and p values. The data were analyzed using SPSS Statistics 21 (IBM SPSS Inc., Chicago, Illinois, USA).

RESULTS

Totally, 141 butterfly species were documented in CWS from April to June 2020. Butterfly species composition varied among different families, with Nymphalidae and Lycanidae constituting 62%. Families such as Hesperidae, Papilionidae, and Pieridae were constituted 16.3%, 12.8%, and 8.5%, respectively. Only one species (Double-banded Judy) was recorded in the family of Riodinidae. Thus there is significant variation in the number of species recorded among different families (X^2=67.3; df=5; p<0.01). The majority of butterfly species belong to Nymphalidae and Lycanidae in Chimmony Wildlife Sanctuary.

In total, 15 species are found to be endemic to the Western Ghats region (Table 1). Butterfly species such as Indian Ace, Shiva Sunbeam, Blue Oakleaf, Danaid Eggfly, Gladeye Bushbrown, Malabar Tree Nymph, Tailed Palmfly, Tamil Catseye, and Southern Birdwing are endemic species (Images 1–45). There are four species of butterflies such as Orchid Tit, Malabar Banded Swallowtail, Crimson Rose, and Danaid Eggfly listed in the Schedule I of the Indian Wildlife Protection Act (1972). In total there are 20 species of butterflies that are catalogued in the Schedules of IWPA and provide protection to the butterflies. Common Lineblue is the most abundant butterfly followed by Common Crow and Common Emigrant in CWS. There were more than 100 individuals of all these butterflies that were recorded in the study area. There were 42 species that were recorded only once during the time of the survey.

Factors that determine detection of butterflies

The size of butterflies varies among families with the largest sized butterflies recorded from Papilionidae and Nymphalidae (102.8±23mm and 70.1±20.1mm). Hesperidae (37.5mm) and Lycanidae (30.6mm) are the smallest-sized butterflies. Pieridae and Riodinidae are the medium-sized butterflies (57.7mm and 45mm, respectively). There is a significant difference in the size of butterflies among different families (F= 118.20; df= 5; p< 0.001).

The relationship between the number of detection, abundance, and size of butterflies were tested using multiple regression. The number of detection had linear relation with abundance, size, and activities of the butterflies. The model was highly significant and explained 86.9% variation in the detection of butterflies (F= 407.76; df= 3; p< 0.00; Table 2). All the three predictors had positive abundance and size positively influenced number of detections. From the standardized

Table 1. Butterfly species and their abundance (data sorted in descending order) recorded in Chimmony Wildlife Sanctuary.

	Family/ Common name	Species	Abundance of butterflies	IWPA -Schedule		
				I	I,II	II,IV
	Hesperidae					
1	Demon sp.	*Notocrypta* sp.	10			
2	Dusky Partwing	*Psolos fuligo*	8			
3	Water Snow Flat	*Tagiades litigiosa*	7			
4	Chestnut Bob	*Iambrix salsala luteipalpis*	6			
5	Golden Angle	*Caprona ransonnettii*	6			
6	Common Banded Demon	*Notocrypta paralysos mangla*	5			
7	Chestnut Angle	*Odontoptilum angulata*	4			
8	Common Spotted Flat	*Celaenorrhinus leucocera*	3			
9	Bevan's Swift	*Pseudoborbo bevani*	1			
10	Brown Awl	*Badamia exclamationis*	1			
11	Common Red Eye	*Matapa aria*	1			
12	Common Small Flat	*Sarangesa dasahara dasahara*	1			
13	Dark Palm-dart	*Telicota bambusae bambusae*	1			
14	Grass Demon	*Udaspes folus*	1			
15	Indian Ace**	*Halpe homolea hindu*	1			1
16	Indian Dartlet	*Oriens goloides*	1			
17	Pygmy Scrub Hopper	*Aeromachus pygmaeus*	1			
18	Restricted Demon	*Notocrypta curvifascia*	1			
19	Spotted Small Flat	*Sarangesa purendra hopkinsi*	1			
20	Suffused Snow Flat	*Tagiades gana silvia*	1			
21	Tamil Grass Dart	*Taractrocera ceramas*	1			
22	Tricoloured Pied Flat	*Coladenia indrani indra*	1			
23	Wax Dart	*Cupitha purreea*	1			
	Lycaenidae					
24	Common Lineblue	*Prosotas nora*	240			
25	Tailless Lineblue	*Prosotas dubiosa*	60			
26	Tiny Grass Blue	*Zizula hylax*	44			
27	Common Pierrot	*Castalius rosimon*	29			
28	Quaker	*Neopithecops zalmora*	29			
29	Lesser Grass Blue	*Zizina otis*	26			
30	Angled Pierrot	*Caleta decidia*	21			
31	Monkey Puzzle	*Rathinda amor*	15			
32	Common Imperial	*Cheritra freja butleri*	12			
33	Yamfly	*Loxura atymnus atymnus*	12			
34	Plains Cupid	*Chilades pandava*	10			
35	Fluffy Tit	*Zeltus amasa*	9			
36	Common Cerulean	*Jamides celeno*	8			
37	Many-tailed Oakblue	*Thaduka multicaudata Kanara*	8			1
38	Metallic Cerulean	*Jamides alecto*	8			
39	Common Hedge Blue	*Acytolepis puspa felderi*	5			
40	Dark Cerulean	*Jamides bochus*	5			
41	Banded Blue Pierrot	*Discolampa ethion*	3			

	Family/ Common name	Species	Abundance of butterflies	IWPA -Schedule		
				I	I,II	II,IV
42	Dark Pierrot	*Tarucus ananda*	3			1(IV)
43	Gram Blue	*Euchrysops cnejus*	3			1
44	Shiva Sunbeam**	*Curetis siva*	3			
45	Dingy Lineblue	*Petrelaea dana*	2			
46	Indian Sunbeam	*Curetis thetis*	2			
47	Large Oakblue	*Arhopala amantes*	2			
48	Apefly	*Spalgis epeus*	1			
49	Common Silverline	*Spindasis vulcanus*	1			
50	Cornelian	*Deudorix epijarbas*	1			
51	Forget-me-not	*Catochrysops Strabo*	1			
52	Indigo Flash	*Rapala varuna*	1			1
53	Lime Blue	*Chilades lajus*	1			1
54	Malayan	*Megisba malaya*	1			
55	Orchid Tit	*Chliaria othona*	1	1		
56	Plain Hedge Blue	*Celastrina lavendularis lavendularis*	1			
57	Pointed Lineblue	*Ionolyce helicon viola*	1			1
58	Redspot	*Zesius chrysomallus*	1			
59	Slate Flash	*Rapala manea*	1			
	Nymphalidae					
60	Common Crow	*Euploea core*	168			
61	Chocolate Pansy	*Junonia iphita*	71			
62	Tamil Yeoman	*Cirrochroa thais*	46			
63	Clipper	*Parthenos Sylvia*	45			1
64	Common Four-ring	*Ypthima huebneri*	45			
65	Common Castor	*Ariadne merione*	24			
66	Rustic	*Cupha erymanthis*	21			
67	Bushbrown Sp.	*Mycalesis sp.*	18			
68	Common Evening Brown	*Melanitis leda*	18			
69	Great Eggfly	*Hypolimnas bolina*	13			
70	Striped Tiger	*Danaus genutia*	12			
71	Blue Tiger	*Tirumala limniace*	10			
72	Plain Tiger	*Danaus chrysippus*	10			
73	Tamil Lacewing**	*Cethosia nietneri*	10			
74	Angled Castor	*Ariadne Ariadne*	9			
75	Blue Oakleaf**	*Kallima horsfieldii*	8			
76	Common Nawab	*Polyura athamas*	8			
77	Dark Blue Tiger	*Tirumala septentrionis*	8			
78	Common Sailer	*Neptis hylas*	7			
79	Cruiser	*Vindula erota*	7			
80	Glassy Tiger	*Parantica aglea*	7			
81	Lemon Pansy	*Junonia lemonias*	7			
82	Autumn Leaf	*Doleschallia bisaltide*	6			1
83	Extra Lascar	*Pantoporia sandaka*	6			
84	Tailed Palmfly**	*Elymnia caudata*	5			

	Family/ Common name	Species	Abundance of butterflies	IWPA -Schedule		
				I	I,II	II,IV
85	Commander	*Moduza procris*	4			
86	Gladeye Bushbrown**	*Mycalesis patnia*	4			
87	Grey Pansy	*Junonia atlites*	4			
88	Chestnut-streaked Sailer	*Neptis jumbah*	3			
89	Dark Evening Brown	*Melanitis phedima*	3			
90	Dark-branded Bushbrown	*Mycalesis mineus*	3			
91	Grey Count	*Tanaecia lepidea*	3			1
92	Yellow Pansy	*Junonia hierta*	3			
93	Black Prince	*Rohana parisatis*	2			
94	Blackvein Sergeant	*Athyma ranga*	2			1
95	Common Lascar	*Pantoporia hordonia*	2			
96	Danaid Eggfly**	*Hypolimnas misippus*	2		1	
97	Medus Bushbrown	*Orsotriaena medus*	2			
98	Tamil Catseye**	*Zipaetis saitis*	2			1
99	Black Rajah	*Charaxes solon*	1			
100	Blue Admiral	*Kaniska canace*	1			
101	Brown King Crow	*Euploea klugii*	1			
102	Common Five-ring	*Ypthima baldus*	1			
103	Common Three-ring	*Ypthima asterope*	1			
104	Double-branded Crow	*Euploea Sylvester*	1			
105	Great Evening Brown	*Melanitis zitenius*	1			1
106	Malabar Tree Nymph**	*Idea malabarica*	1			
107	Peacock Pansy	*Junonia almana*	1			
108	Plain Tawny Rajah	*Charaxes psaphon*	1			
109	Red-spot Duke	*Dophla evelina*	1			1
110	Tawny Coster	*Acraea terpsicore*	1			
	Papilionidae					
111	Common Mormon	*Papilio polytes*	73			
112	Narrow-banded Bluebottle	*Graphium teredon*	65			
113	Blue Mormon	*Papilio polymnestor*	64			
114	Southern Birdwing**	*Troides minos*	20			
115	Tailed Jay	*Graphium Agamemnon*	19			
116	Common Jay	*Graphium doson*	16			
117	Red Helen	*Papilio helenus*	15			
118	Five-bar Swordtail	*Graphium antiphates*	11			
119	Paris Peacock	*Papilio paris*	11			
120	Malabar Raven**	*Papilio dravidarum*	10			
121	Lime	*Papilio demoleus*	5			
122	Malabar Rose**	*Pachliopta pandiyana*	5			
123	Common Rose	*Pachliopta aristolochiae*	4			
124	Malabar Banded Swallowtail**	*Papilio liomedon*	4	1		
125	Common Mime	*Papilio clytia*	2			
126	Spot Swordtail	*Graphium nomius*	2			
127	Common Banded Peacock	*Papilio crino*	1			

	Family/ Common name	Species	Abundance of butterflies	IWPA -Schedule		
				I	I,II	II,IV
128	Crimson Rose	*Pachliopta hector*	1	1		
	Pieridae					
129	Common Emigrant	*Catopsilia Pomona*	112			
130	Three-spot Grass Yellow	*Eurema blanda*	55			
131	Common Grass Yellow	*Eurema hecabe*	53			
132	Great Orange Tip	*Hebomoia glaucippe*	50			
133	Nilgiri Grass Yellow**	*Eurema nilgiriensis*	28			
134	Common Wanderer	*Pareronia hippia*	24			
135	Common Albatross	*Appias albina*	22			
136	One-spot Grass Yellow	*Eurema andersonii*	18			1
137	Lesser Gull	*Cepora nadina*	11			1
138	Mottled Emigrant	*Catopsilia pyranthe*	3			
139	Psyche	*Leptosia nina*	3			
140	Spotless Grass Yellow	*Eurema laeta*	1			
	Riodinidae					
141	Double-banded Judy	*Abisara bifasciata*	3			

**- Endemic species

Table 2. Multiple regression to investigate the effect of factors that influence detection of butterflies in Chimmony Wildlife Sanctuary.

Independent Variable	Predictor	Coefficients ± SEM		SPRC	t	p	Model (r^2)	model (p)
Number of detections	(Constant)	-0.476	0.185		-2.572	0.011	0.869	F= 407.76; df= 3; p< 0.00
	Activity	0.017	0.05	0.01	0.346	0.729		
	Abundance (log)	0.738	0.023	0.908	32.295	0.000		
	Size of butterflies (log)	0.190	0.048	0.108	3.978	0.000		

SEM—Standard error of mean | SPRC—Standardized Partial Regression Coefficient

partial regression, it was inferred that abundance (b_1= 0.74) had the primary influence on the detections, followed by size (b_2= 0.19), and activity of the butterflies (b_3= 0.02; Fig. 2).

DISCUSSION

Composition of butterflies varied among different families. A total of 141 species of 1,986 individuals were observed from CWS. Though the study was carried out in a limited period, the number of species reported was higher than earlier reports of the study area (George 2012). The number of species recorded in the study area was more than other protected areas in Kerala; Sudheendrakumar et al. (2000) recorded 124 species at adjacent Parambikulam Tiger Reserve. A total of 71 species from Aralam WS (Sreekumar & Balakrishnan 2001) have been recorded. The results, however, are not directly comparable outside the protected areas. The number of species recorded in Kerala Agricultural University was 139 species of butterflies (Aneesh et al. 2013). The reason for comparison is the geographical proximity of KAU compass to the study area. The study area is part of the network of protected areas such as Peechi-Vazhani towards north, Sholayar Reserve Forest in the south and Parambikulam Tiger Reserve in the east. The major habitat of the study area is evergreen and moist deciduous forest. Earlier studies recorded higher species diversity and richness in the similar habitats (Sudheendrakumar et al. 2000). Thus, the contiguous forest and evergreen habitat supports higher species diversity and endemism in the study area.

Family Nymphalidae and Lycanidae represented 62% of the total. Families such as Hesperidae, Papilionidae, and Pieridae were comparatively less. They are, 16.3%,

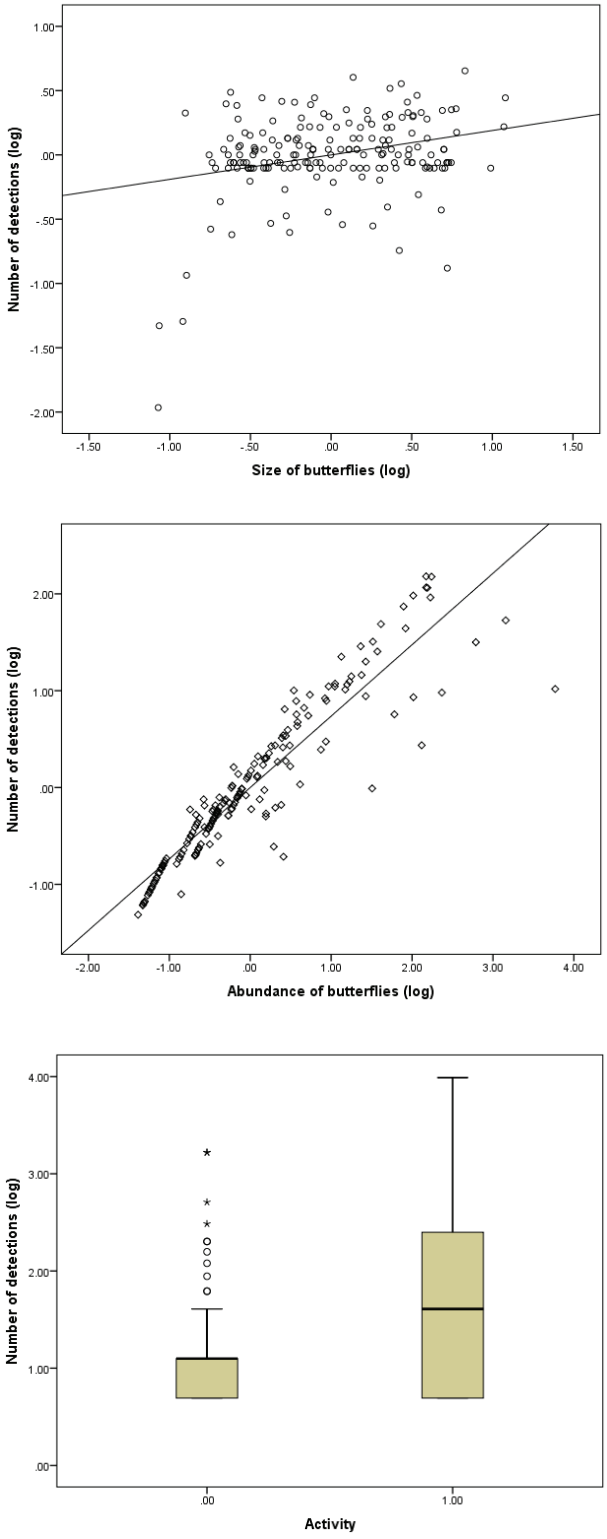

Figure 2. Relation between mean size of butterflies, abundance, activities: 0—Inactive-resting | 1—active-foraging, mud puddling, flying | and number of detections at Chimmony Wildlife Sanctuary.

12.8%, and 8.5%, respectively. Out of two butterflies in the family Riodinidae of Kerala and Western Ghats, one species (Double-banded Judy) was recorded from the study area during the period of study. There is a significant variation in the species composition among different families. Family Nymphalidae dominated over other families. In almost all the studies conducted in butterflies of Western Ghats (Sudheendrakumar et al. 2000; Sreekumar & Balakrishnan 2001; Aneesh et al. 2013) Nymphalidae is the family showing the maximum number of species because this is the family representing more number of species in the Western Ghats. The study area harbours 40.7% of butterfly species of Western Ghats (Bhakre & Ogle 2018).

In total there are 20 species of butterflies that are listed in various schedules of Indian Wildlife Protection Act (1972) that provide protection to these butterflies. Only 14.2% of butterflies of recorded species are protected under IWPA. Hence it is important to include all the endemic species in the IWPA and butterflies which are more charismatic, and rapidly declining species need to be listed under the schedules. Common Lineblue is the most abundant butterfly followed by Common Crow and Common Emigrant in CWS. The other species such as Common Mormon, Chocolate Pansy, Narrow-banded Blue Bottle, Blue Mormon, Tailless Lineblue, Three-spot Grass Yellow, and Great Orange Tip were recorded. Similar species composition was recorded in Parambikulam TR (Sudheendrakumar et al. 2000) and Aralam WS (Sreekumar & Balakrishnan 2001).

Factors that determine detection of butterflies

The study highlights the differences in the species detection based on size and abundance and importance of differences in detection probability of butterfly species inventory surveys. Butterfly species such as Common Lineblue, Common Crow, Common Emigrant, Common Mormon, Three-spot Grass Yellow, Narrow-banded Bluebottle, and Blue Mormon were more frequently sighted. All these species are conspicuous, larger in size, active flyers, and some species show mud-puddling behaviour as well. This could have resulted in higher abundance and detectability. Studies on butterflies have shown that detection of same species tends to vary according to habitats (Pellet et al. 2012). Further, survey technique could also influence the abundance and density estimation. Thus our preliminary examination on butterfly detectability showed the influence of size, abundance, and activities. The number of detection had a direct relation with the abundance, size, and activities of the butterflies.

Image 1. *Troides minos*

Image 2. *Papilio polymnestor*

Image 3. *Pachliopta aristolochiae*

Image 4. *Papilio paris*

Image 5. *Graphium teredon*

Image 6. *Papilio demoleus*

Image 7. *Papilio liomedon*

Image 8. *Graphium antiphates*

Image 9. *Eurema blanda*

Image 10. *Eurema nilgiriensis*

Image 11. *Catopsilia pomona*

Image 12. *Appias albina*

Image 13. *Hebomoia glaucippe*

Image 14. *Cepora nadina*

Image 15. *Cethosia nietneri*

Image 16. *Idea malabarica*

Image 17. *Dophla evelina*

Image 18. *Junonia atlites*

Image 19. *Parthenos sylvia*

Image 20. *Kaniska canace*

Image 21. *Kallima horsfieldii*

Image 22. *Doleschallia bisaltide*

Image 23. *Elymnias caudata*

Image 24. *Tanaecia lepidea*

Image 25. *Euploea klugii*

Image 26. *Rohana parisatis*

Image 27. *Vindula erota*

Image 28. *Polyura athamas*

Image 29. *Tirumala limniace*

Image 30. *Ypthima huebneri*

Image 31. *Abisara bifasciata*

Image 32. *Caprona ransonnettii*

Image 33. *Odontoptilum angulata*

Image 34. *Tagiades litigiosa*

Image 35. *Tagiades gana silvia*

Image 36. *Halpe homelea hindu*

Image 37. *Cupitha purreea*

Image 38. *Cheritra freja butleri*

Image 39. *Thaduka multicaudata Kanara*

Image 40. *Loxura atymnus atymnus*

Image 41. *Zesius chrysomallus*

Image 42. *Chliaria othona*

Image 43. *Curetis siva*

Image 44. *Megisba malaya*

Image 45. *Deudorix epijarbas*

The model was highly significant and explained 86.9% variation in the detection of butterflies. Both abundance and size positively influenced the number of detections. From the standardized partial regression, abundance (b_1= 0.74) had the primary influence on the detection of butterflies, followed by size (b_2= 0.19) and activity (b_3= 0.02). Similar species-wise differences in the detection of butterflies were reported in the studies carried out in the United Kingdom (Isaac et al. 2011; Pellet et al. 2012). Further investigation on the detectability of butterflies based on size, colouration, and habitats will help to estimate population size rather than species abundance.

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