

DIVERSITY AND STRUCTURE OF THE BUTTERFLY ASSEMBLAGES IN TROPICAL FOREST ECOSYSTEMS

A. L. MONASTYRSKII

Vietnam-Russia Tropical Research Centre

Research of the general structural-functional patterns (SFP) of the tropical forest ecosystems includes a number of complex multilevel problems. Planning and implementation of these objectives are possible on a limit number of the tropical ecosystem inhabitants. Butterflies is a good model group for such studies (Tangah *et al.*, 2004; Cleary & Genner, 2006; New, 1998). They represent a convenient object for solving the problems related to the specific features of geographic, landscape, seasonal, and climatic distribution of species. Among many reasons that could be named to justify the use of this group as an object for solving the above problems, the following are most important: (1) Butterfly taxonomy is well-developed; (2) They are present in practically all the known tropical biotopes of Vietnam; (3) Their life cycle is associated with specific host plants; (4) Butterflies can be easily recorded and counted in nature, and can therefore be used for demonstrating temporal (seasonal) and spatial structures.

Studies demonstrate that the butterfly diversity within the natural ecosystems depends on some different factors most important of which are climatic and topographical (Cleary & Genner, 2006), characteristic of vegetation cover and botanical diversity (Koh, 2007).

Formerly measuring of the butterfly assemblage structure has been implemented using parameters of abundance and diversity counted to the ecosystem in whole. Much less attention has been paid to study the structure details in representatives of these insects within the concrete ecosystem. Most studies have focused on anthropogenic effects on animals including insects and particular butterflies (Hayes *et al.*, 2008). Another lack of previous works concerning spatial and temporal structures of butterfly assemblages in tropical ecosystems there was study mainly of their vertical distribution. There are a little researches have been carried out on horizontal butterfly distribution the main reasons of which are poor known local faunas and methods of study (Hayes *et al.*, 2008).

At the initial step of SFP study the main objective is to measure of some parameters of the butterfly assemblage structures in different habitats and seasons within a large forest massif. Absence of differences between diversities and structures of butterfly assemblages in some particular habitats confirms a null-hypothesis.

I. MATERIALS AND METHODS

The site and field observation. Current study was carried out at Cat Tien National Park (Nam Cat Tien sector) (S. Vietnam, Dong Nai province). Observations of butterflies were carried out from 20 February to 20 March 2009 (dry season) and from 20 June to 20 July 2009 (wet season). The data were collected by using the transect method described by Pollard *et al.* (1975) and modified by Spitzer *et al.* (1993). The butterfly assemblages were observed in four natural forest areas. Every approximately 1,000 m transect crossed the forest areas has been observed once a day in the morning from 9.00 to 12.00 am. One full observation included two passes back and forth. The observation was carried out along each transect at the speed of approximately 20 m per 1 min recorded all butterflies. Species that need identification has been

collected by butterfly net. Most butterflies have been recorded within three vertical levels (in metre): 1) 0-0.7 m - ground level; 2) 0.7-2 m - medium level and 3) 2.0-5.0 m - high level.

Characteristic of transect. The soil types and botanical communities of each area have been studied and described previously (Anichkin, 2008). **Transect 1** crosses the forest area situated along the right bank of Dong Nai river that dominated by representatives of Dipterocarpaceae: *Dipterocarpus alatus*, *D. obtusifolius*, *Hopea odorata*, *Shorea* sp. (25-40 m trees). Canopy, understorey and shrub layer are well developed; closing of leaf canopy is high; there are many lianas and palms. **Transect 2** crosses the semi-evergreen forest area characterised by the well drained clay soil. Canopy is dominated by *Lagerstroemia calyculata* and *Tetrameles nudiflora*. **Transect 3** is situated in the forest area characterised by poorly drained flooded soils. Canopy is dominated by *Lagerstroemia* spp. и *Dalbergia multiflora*. **Transect 4** is located about 2 km from transect 1 and crosses a raised forest area (~ 150 m) on seasonally flooded soils. The area is dominated by *Lagerstroemia* spp. and some representatives of families Moraceae, Fabaceae and Dipterocarpaceae.

Other characteristics of the forest areas studied have been recorded during current survey time and include the canopy rarefaction (in %) and abundance of some tree markers. The canopy rarefaction has been recorded and calculated using the photographic method and the computer program Adobe Photoshop Elements 6.0. The number of marker trees *Lagerstroemia* spp. and representatives of Arecaceae family have been recorded during sequential observation of each transect.

Butterfly species diversity indexes (Shannon_H, Menhinick, Margalef indexes, Equitability_J and Fishers α) and dominance indexes (Dominance_D; Simpson_1-D; Berger-Parker) were calculated using the programme PAST version 1.93 (Hammer *et al.*, 2001). Data were analysed by means Correspondence Analysis (CA) ordination to calculate the relative significance of spatial and temporal variability in their compositions. Assemblages data were calculated by Correspondence Analysis that is a direct ordination method relating the composition of samples to variables (season, transect and vertical level) (Hammer *et al.*, 2001).

II. RESULTS AND DISCUSSION

1. Additional characteristics of the areas studied

Most lightened forest areas is dominated by *Lagerstroemia* (transects 2 and 4). In dry season the canopy rarefaction in these areas was 35-40%; in wet season the canopy openness decreased to 15-30%. Most thickened canopy was observed in inundated forest area (transect 1) and in area with poor drained flooded soils (transect 3). In wet season the canopy gaps within these areas has been changed insufficiently and it has mainly reduced in the deciduous and semi-deciduous parts of forest (transect 2 and 4).

Data on tree markers including abundance of *Lagerstroemia* (A) and palms (B) are shown in figure 1. Statistically the density of *Lagerstroemia* within the transect 2 is much higher than in other areas. Regarding palm trees there were significant differences between the riverine forest (transect 1), seasonally flooded transect 4 and the rest forest areas studied. These data demonstrate that studies of the butterfly assemblage structures including vertical and seasonal richness, abundance and distribution have been carried out on the forest areas that characterised by specific canopy rarefaction and density of some particular plants.

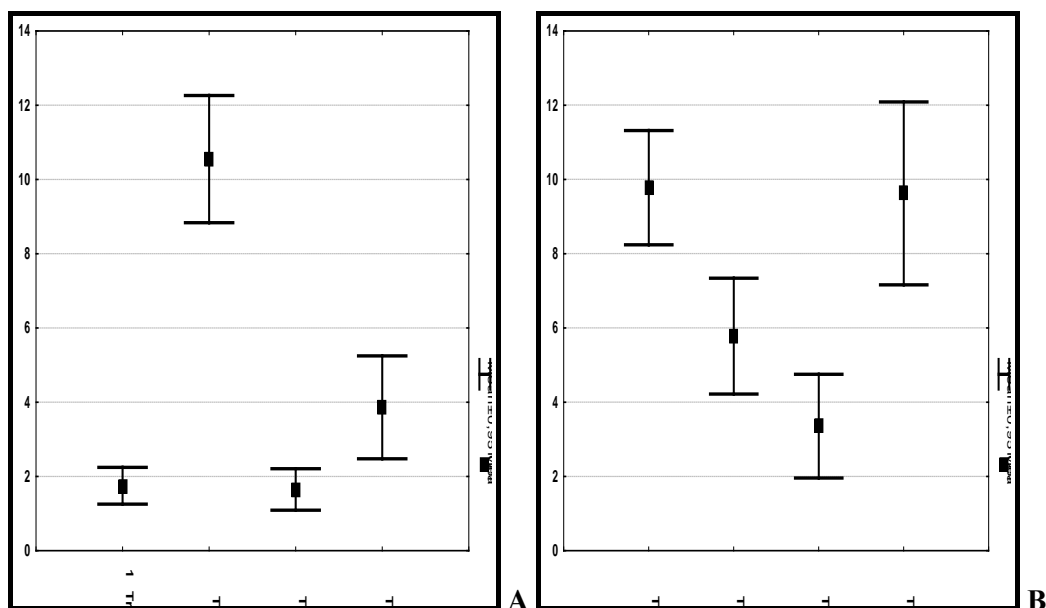


Figure 1: Number of Lagerstroemia (A) and palm (B) trees in forest area studied (Transects 1-4)

2. The butterfly assemblage taxonomical structures

In total 3.346 individuals of 203 species of butterflies belonging to 6 families were recorded in the four forest areas. Representatives of three largest families Nymphalidae, Lycaenidae and Hesperidae included 72.5-85.7% of all species recorded. A total of butterfly species richness in dry season was much higher in comparison with this in wet season, 173 and 101 species respectively. Decreasing of species richness in wet season has been observed in all families however it was more prominent for local swallowtails, nymphalids, blues and skippers.

Another characteristic of the butterfly assemblage taxonomical structures is a number and composition of the unique species recorded either only in one transect or during only one season. The majority of unique butterfly species belong to stenotopic Nymphalidae (Satyrinae, Amathusiinae), Lycaenidae and Hesperidae families.

The parameter alternative to uniqueness is the number of common species recorded within all transects of the same season. In dry season there are 25 species (14.4 %) of total number have been recorded in all forest areas studied. In wet season the number of common species decreased to 13, however their proportion has been changed insignificantly (12.8%).

3. Diversity and dominance of the butterfly assemblages

Indexes of alpha-diversity and dominance calculated on data collected within forest habitats in both seasons are shown in table 1. Considering indexes calculated it is possible to see a general pattern that is decreasing of the majority values in wet season. Apparently, that the main reason of this is decreasing of species richness and species abundance. The second parameter demonstrates high evenness in forest areas and seasons studied which shows a poor dominance of particular species. The overwhelming species majority is characterised by the low abundance varied from 0.1 to 2.0% demonstrating high level of equitability. Considering such uniform patterns of species abundances, the groups of the species dominated have been chosen. Dominants are the minimal number of butterfly species a total abundance of which is not less than 50% of the total abundance of assemblage (determined by Pesenko, 1982).

Table 1

The butterfly diversity and dominance in forest habitats at Cat Tien National Park

	Transect 1		Transect 2		Transect 3		Transect 4	
	F/M	J/J	F/M	J/J	F/M	J/J	F/M	J/J
Total number of species	91	63	103	48	87	27	90	51
Abundance of all species	514	351	417	162	444	160	517	843
Dominance Indices								
Dominance_D	0.040	0.120	0.052	0.066	0.079	0.222	0.045	0.570
Simpson_1-D	0.959	0.880	0.948	0.934	0.921	0.778	0.955	0.429
Berger-Parker	0.142	0.239	0.151	0.179	0.250	0.413	0.118	0.751
Diversity Indices								
Shannon_H	3.874	2.894	3.664	3.243	3.559	2.121	3.703	1.338
Menhinick	4.323	3.256	4.113	3.693	4.319	2.135	4.09	1.791
Margalef	15.54	10.24	13.76	9.042	14.76	5.123	14.72	7.57
Equitability_J	0.845	0.704	0.826	0.842	0.789	0.644	0.817	0.339
Fisher_alpha	35.92	21.33	31.7	22.22	34.66	9.307	33.08	12.25
Canopy openness (rarefaction) (%)	6.37	5.29	16.24	11.26	8.14	5.43	10.57	5.72

Legends: F/M - February/March (dry season); J/J - June/July (wet season).

Assemblages of the butterfly species dominated

25 butterfly species of a total 203 species were found in all forest areas studied in both seasons. Main distinctiveness of these species is that their relative abundance in some forest areas was higher than 2% of the total community abundance (Table 2). The dominance level within each transect has been assessed by using the Dominance_D index which varies from 0 (all species have similar abundance = high evenness) to 1 (significant predominance of one species). Values of the Dominance_D index were higher in all forest areas of the wet season.

Observations demonstrate that every forest area studied is characterised by specific composition and abundance of butterfly species dominated. At the same time there were no species dominated in all forest areas in both seasons. For example, *Euthalia recta*, *Coelites nothis* and *Euploea tulliolus* (Nymphalidae) have prevailed in the majority forest areas of wet season (8-75%). Their dominance in dry season was not prominent. On the contrary, *Leptosia nina* (Pieridae), *Jamides celeno*, *Prosotas nora* (Lycaenidae) and also *Cirrochroa surya*, *Tanaecia julii* and *Euploea mulciber* (Nymphalidae) compose a group of dry season species prevailed (5-25%). In wet season these species either have a low abundance or they were absent.

Composition and abundance of butterfly species dominated have varied in forest areas at Nam Cat Tien. Danaine *Euploea mulciber*, satyrin *Mycalopsis mineus*, blues *Neomyrina nivea* and *Nacaduba* spp. were dominated in riverine forest in dry season demonstrating extremely low abundance in other forest areas. *Prosotas nora*, *Drina donina* (Lycaenidae) and *Lebadea martha* and *Cirrochroa surya* showed high abundance in transect 4 and were rare in other habitats.

In wet season the abundance of some species become very high demonstrating temporal over-dominance. In particular it concerns some representatives of family Nymphalidae (Danainae) belonging to the genus *Euploea* producing large patchy aggregations of many hundred specimens.

Table 2

Butterfly species dominated in tropical forest ecosystems at Cat Tien National Park

No.	Butterfly species dominated	February/March (dry season)				June/July (wet season)			
		Tr.1	Tr.2	Tr.3	Tr.4	Tr.1	Tr.2	Tr.3	Tr.4
1.	<i>Arhopala</i> sp.	3.6	1.6	1.1	0.8	0.0	0.0	0.0	0.0
2.	<i>Cheritra freja</i>	0.0	2.4	0.7	2.9	0.0	0.0	0.0	0.0
3.	<i>Cirrochroa surya</i>	1.6	0.6	2.3	10.2	0.0	0.0	0.0	0.0
4.	<i>Coelites nothis</i>	2.1	0.8	1.1	0.4	8.4	9.0	18.5	1.2
5.	<i>Drupadia ravindra</i>	3.6	2.4	2.7	1.3	5.9	2.2	0.0	0.4
6.	<i>Euploea modesta</i>	3.9	0.0	0.7	1.5	0.0	2.2	0.0	0.4
7.	<i>Euploea mulciber</i>	11.9	2.0	1.4	1.0	1.9	0.0	0.0	0.4
8.	<i>Euploea radamanthus</i>	3.4	0.8	1.6	0.2	0.3	0.6	0.0	0.1
9.	<i>Euploea tulliolus</i>	0.5	0.0	0.0	1.7	12.4	18.0	0.0	75.6
10.	<i>Euthalia recta</i>	0.8	6.0	2.3	7.1	26.3	2.8	40.7	7.9
11.	<i>Jamides celeno</i>	3.6	12.4	2.3	4.2	0.0	0.6	0.0	0.0
12.	<i>Lebadea martha</i>	1.0	0.2	0.9	3.7	0.0	1.7	0.0	0.2
13.	<i>Leptosia nina</i>	4.7	9.6	5.7	6.4	0.3	0.6	0.0	0.8
14.	<i>Lexias albopunctata</i>	0.3	1.0	2.9	1.9	2.8	8.4	9.3	0.5
15.	<i>Lexias dirtea</i>	0.0	0.4	0.2	1.2	1.5	2.2	4.9	0.4
16.	<i>Mycalesis perseoides</i>	2.8	2.0	0.9	0.2	0.9	1.1	0.6	0.1
17.	<i>Nacaduba</i> sp.	2.3	2.6	1.6	0.4	0.0	0.6	0.0	0.0
18.	<i>Neomyrina nivea</i>	3.6	0.0	0.0	0.0	1.9	0.0	0.0	0.0
19.	<i>Paralaxita telesia</i>	1.0	0.2	0.2	0.0	0.3	4.5	1.9	0.4
20.	<i>Parantica aglea</i>	2.6	1.8	2.0	0.4	0.6	0.6	0.0	0.0
21.	<i>Parthenos sylvia</i>	2.6	4.6	2.3	1.0	4.0	11.8	4.9	0.1
22.	<i>Prosotas nora</i>	1.0	0.4	25.2	12.5	0.0	0.0	0.0	0.0
23.	<i>Tanaecia julii</i>	1.0	4.0	7.0	5.2	3.4	4.5	3.1	1.1
24.	<i>Tanaecia lepidea</i>	2.3	0.6	0.5	1.2	1.2	2.8	0.6	0.4
25.	<i>Ypthima baldus</i>	1.8	3.6	0.0	0.0	0.0	0.0	0.0	0.0
Total No of dominating species		14	11	10	8	7	11	6	2
Percent of predominant species		15,4	10.7	11.5	8.9	11.1	22.3	22.2	3.9
Relative abundance of the dominating species		53,0	51.6	54.7	52.2	62.0	68.4	81.4	83.5
Dominance_D		0,041	0.052	0.078	0.045	0.120	0.066	0.222	0.570

Legends: The species marked with bold are members of the dominating complexes.

4. Vertical structure of the butterfly assemblages

Overall 175 butterfly species have been recorded within three vertical levels. The maximal number of species (145 spp.) were recorded at medium level between 0.7 and 2.0 m. In ground level (0-0.7 m) and in high level (2.0-5.0 m) there were recorded 89 and 85 butterfly species respectively. To demonstrate equality of species abundance in each vertical level studied the Dominance_D index has been calculated (Table 3). Correspondence between the forest area locations (transects 1-4) and representatives of predominant species found at vertical levels in dry and wet seasons are shown in Figures 2-4.

Vertical ground level 0-0.7 m (Fig. 2)

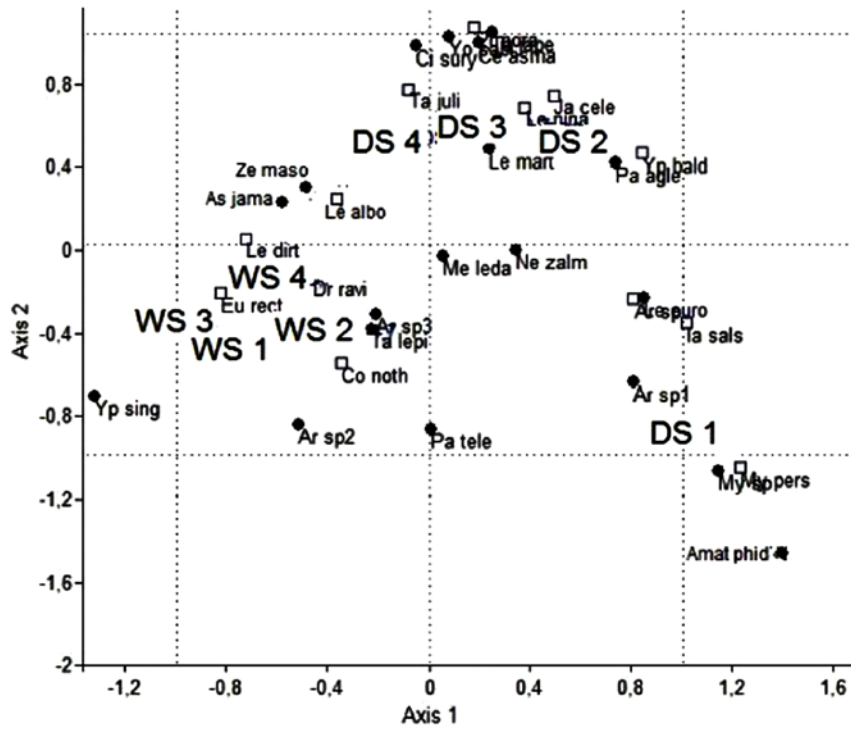


Figure 2: Correspondence analysis ordination of butterfly species with forest areas

Legends: (Transects 1-4) in dry (DS) and wet (WS) seasons at the ground level (0-0.7 m); open square marks - species dominated: **Eu rec** - *Euthalia recta*; **Le dirt** - *Lexias dirtea*; **Le albo** - *Lexias albopunctata*; **Co noth** - *Coelites nothis*; **Ta juli** - *Tanaecia julii*; **Le nina** - *Leptosia nina*; **Yp bald** - *Ypthima baldus*; **Ia sals** - *Iambrix salsala*; **My pers** - *Mycalesis perseoides*.

Table 3

Vertical structures of butterfly assemblages within tropical forest ecosystems

Level of habitation	Species richness and dominance	Dry season				Wet season			
		Tr. 1	Tr. 2	Tr. 3	Tr. 4	Tr. 1	Tr. 2	Tr. 3	Tr. 4
0-0.7 m	Total number of species	40	31	34	39	26	17	10	21
	Total species abundance	118	140	104	122	101	34	59	56
	Dominance_D	0.051	0.128	0.087	0.083	0.217	0.102	0.327	0.153
0.7-2.0m	Total number of species	82	66	57	63	43	31	16	36
	Total species abundance	235	188	187	238	152	63	78	113
	Dominance_D	0.035	0.038	0.101	0.048	0.094	0.055	0.217	0.139
2.0-5.0m	Total number of species	34	37	41	45	20	17	8	21
	Total species abundance	94	76	48	145	94	51	17	478
	Dominance_D	0.081	0.044	0.145	0.099	0.235	0.296	0.190	0.855

In butterfly assemblages occupied the ground level (0-0.7 m) 3-8 species were dominated. Their abundance was higher than 50% of total number of individuals at all forest areas studied. In dry season the taxonomical composition of dominants in most dense riverine forest fragment (DS1) was characterised by high distinctiveness.

Stenotopic species of genera *Mycalesis* (Nymphalidae) and *Arhopala* (Lycaenidae) were prevailed here. In other forest areas the group of dominants include the white *Leptosia nina*, nymphalids *Euthalia recta* and *Lexias albopunctata*. In the wet season structures of butterfly assemblages were changed: evenness of species abundance reduced while a dominance of some species became more prominent (Table 3).

Vertical middle level 0.7-2.0 m (Fig. 3)

A number of species found in this level have also been recorded in the ground layer. Seasonal dynamic of species richness and abundance at the middle level reveals a similarity to the butterfly diversity pattern at the ground level. In the wet season compositions of dominated species were significantly changed within transects 1, 3 and 4. In particular abundances of nymphalids *Coelites nothis*, *Euthalia recta*, *Lexias albopunctata* became much higher. At the same time abundances of such dry season dominants as blues *Cheritra freja* and *Prosotas nora*, nymphalids *Tanaecia julii* and *Cirrohroa surya* were considerably decreased.

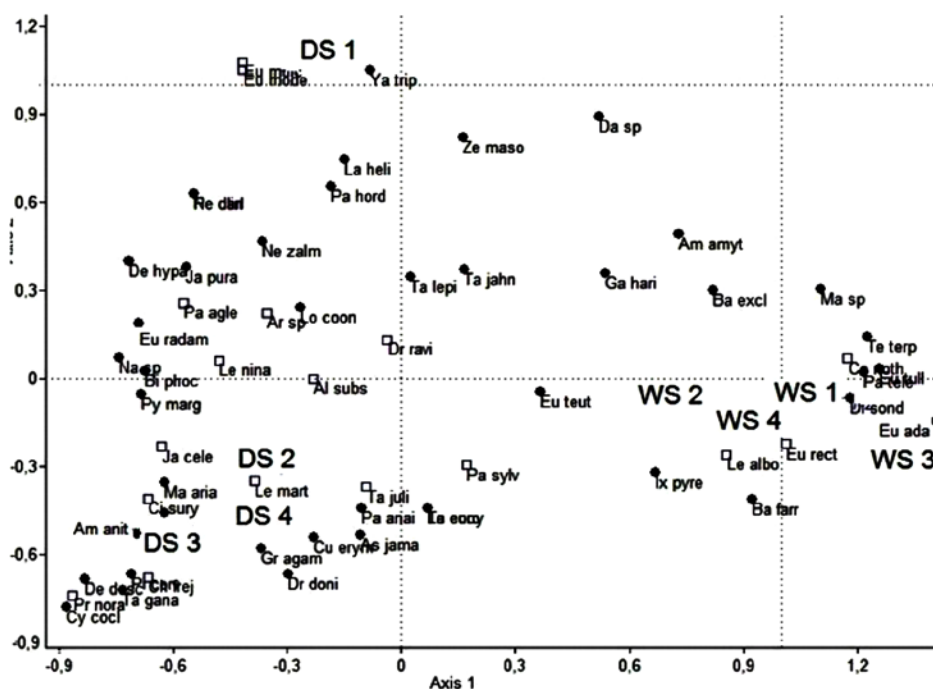


Figure 3: Correspondence analysis ordination of butterfly species with forest areas

Legends: (Transects 1-4) in dry (DS) and wet (WS) seasons at the ground level (0.7-2.0 m); open square marks - species dominated: **Eu rec** - *Euthalia recta*; **Le albo** - *Lexias albopunctata*; **Co noth** - *Coelites nothis*; **Ta juli** - *Tanaecia julii*; **Le nina** - *Leptosia nina*; **Eu mulc** - *Euploea mulciber*; **Eu mode** - *Euploea modesta*; **Pa agle** - *Parantica aglea*; **Al subs** - *Allotinus substrigosus*; **Ja cele** - *Jamides celeno*; **Pr nora** - *Prosotas nora*; **Ci sury** - *Cirrohroa surya*; **Le mart** - *Lebadea martha*; **Dr ravi** - *Drupadia ravindra*; **Pa sylv** - *Parthenos sylvia*.

Vertical high level 2,0-5,0 m (Fig. 4)

Taxonomical compositions of butterfly assemblages at this vertical level include a group of species that were either absent or not such abundant as at the lower ground and medium levels. Many of them are opportunistic and were represented by the oviparous females, for example,

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SỰ ĐA DẠNG VÀ CẤU TRÚC CÁC QUẦN THỂ BƯỚM NGÀY TRONG NHỮNG HỆ SINH THÁI RỪNG NHIỆT ĐỚI

MONARSTYRSKII A. L.

TÓM TẮT

Tổ chức và đa dạng quần xã loài bướm ngày trong hệ sinh thái rừng nhiệt đới đã được nghiên cứu tại Vườn Quốc gia Cát Tiên (tỉnh Đồng Nai). Bài báo này trình bày phương pháp phân loại học và cấu trúc tầng đứng của quần xã. Quần xã bướm mùa khô có số lượng nhiều hơn và đa dạng hơn so với quần xã bướm mùa mưa. Ngược lại các nhóm loại và số lượng loài thì đa dạng hơn trong mùa mưa. Đa số các loài được tập trung theo tầng tầng đứng cách mặt đất 0,7 - 2 m. Sự phong phú về loài và sinh sống của các loài bướm đã được phát hiện ở mỗi tầng tầng đứng trong 4 phân đo ạn rừng nhiệt đới phụ thuộc vào mùa mưa và đặc trưng sinh cảnh.