Research Article

Diversity Pattern of Butterfly Communities (Lepidoptera, Papilionoidae) in Different Habitat Types in a Tropical Rain Forest of Southern Vietnam

Lien Van Vu¹ and Con Quang Vu²

¹ Department of Biology, Vietnam National Museum of Nature, 18 Hoang Quoc Viet, Nghia Do, Cau Giay, Hanoi, Vietnam

² Department of Insect Ecology, Institute of Ecology and Biological Resources, 18 Hoang Quoc Viet, Nghia Do, Cau Giay, Hanoi, Vietnam

Correspondence should be addressed to Lien Van Vu, vulien@gmail.com

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Diversity of butterfly communities of a tropical rain forest of Bu Gia Map National Park in South Vietnam was studied in four different habitat types (the natural forest, the disturbed forest, the bamboo forest, and the stream sides in the forest) in December 2008 and April 2009. A total of 112 species with 1703 individuals of Papilionoidae (except Lycaenidae) were recorded. The proportion of rare species tends to decrease from the natural forest to the stream sides, while the proportion of common species tends to increase from the natural forest to the stream sides. The stream sides have the greatest individual number, while the disturbed forest contains the greatest species number. The bamboo forest has the least species and individual numbers. The stream side environment in the forest plays an important role in conserving butterfly abundance while the bamboo shows the poorest butterfly diversity.

1. Introduction

In general, insect diversity is highest in habitats with the most plant diversity and is lowest in shrub, grass and open areas [1]. The diversity of beetle and some moth groups is high in natural forests and low in secondary forests [2, 3]. Butterfly diversity, however, is usually lower in natural forests, higher in disturbed forests, and highest in moderately disturbed forests [4–8], or forest edges [9, 10]. Other studies have also indicated that the numbers of butterfly species and individuals are high in disturbed and regenerating forests and low in natural forests [11, 12]. Warren [13] indicated that there were few butterfly species in the habitat with thick forest canopy and, vice versa, more butterfly species in the habitat with less forest canopy. Diversity of butterflies increases with increasing of habitat scale and vegetation structure complex [14]. This shows that a forest habitat with more forest canopy layers and high vegetation diversity supports more insect species

than a forest habitat with less forest canopy layers and less vegetation diversity.

The diversity of butterfly communities has been studied in different habitat types in different parts of the world including tropical forest of Southeast Asia. However, there have not been many studies on the diversity of butterfly communities in tropical forests within different habitat types including stream sides in the forest. Stream side habitats in the forest may play an important role in conserving a portion of tropical biodiversity, of which insects are a major part, but little data is available. The forest edge which has more exposure to the open also has the greatest diversity of butterflies [10]. The gaps in the forest have higher diversity of butterflies than the closed forest areas [15]. The stream sides with more open space should therefore have a high diversity of butterflies.

The hypothesis of this study is that the stream sides in the forest have the greatest butterfly diversity; the bamboo forest has the lowest community diversity.

2. Materials and Methods

2.1. Site Study. Research was carried out in Bu Gia Map National Park, Binh Phuoc province, southern Vietnam (12°08'–12°17' North and 107°03'–107°14' East). The Park has 26,032 ha of the protected area and 12,000 ha of buffer zone. The natural forest of the park is 21,376 ha, of which 388 ha of rich forest, 2,798 ha of medium forest, 1,692 ha of poor forest, 5,064 ha of mixed forest, and 11,434 ha of bamboo forest. The forest has two main forest types which are tropical moisture deciduous closed forest and tropical wet evergreen closed forest. The park was founded in 2002 and located in the north east of Binh Phuoc province, Dak Nong province in the east, frontier of Vietnam and Cambodia in the north west. The average altitude is 300–700 m with the highest peak of 738 m.

The study was conducted from 20 to 30 December 2008 and from 10 to 25 April 2009.

2.2. Sampling Method. A modification of the line transect count [16] was used to determine species richness and abundance of butterfly communities in different habitats. The transect method was used in Vietnam in previous works [10, 15, 17]. The method may pose some problems for assessing species richness and relative abundance of butterflies in tropical rain forests; however, this is a suitable method for surveying butterflies in a wide range of habitats including tropical rain forests [10, 18, 19].

Transect surveys took place between 9:00 am and 4:00 pm on fine days. It took about an hour for each transect. Transects were counted once to twice daily. The sample times for each transect were alternated from day to day, to reduce the effect of different monitoring times on the data recorded. The surveyors walked at a uniform pace and recorded all butterflies of Papilionoidae (except Lycaenidae family) seen within an imaginary 10 m × 10 m × 10 m box. The transects were restricted to the road, the stream sides in the forest and the forest path. Total 100 counts were taken for 4 transects.

Four 500-m transects were set up in four different habitat types. The vegetation of each habitat type is summarized, with the vegetation identification and nomenclature following Pham [20].

Natural forest (NF): there are a variety of plant species with diameter from 30 to 45 cm, the canopy height of 30–35 m. The forest canopy is 70%. The main plant species are *Metadina trichotoma* (Rubiaceae), *Lagerstroemia calyculata*, *Lagerstroemia angustifolia* (Lythraceae), *Albizia chinensis* (Mimosaceae), *Combretum quadragulare* (Combretaceae), *Dalbergia mammosa* (Fabaceae), *Horsfieldia amygdalina* (Myristicaceae), *Irvingia malayana* (Ionanthaceae), *Balakata baccata*, *Mallotus tetracoccus* (Euphorbiaceae), *Tetrameles nudiflora* (Datisceae), *Sandoricum koetjape*, *Swietenia* sp. (Meliaceae), *Hopea odorata*, *Anisoptera* spp., *Dipterocarpus alatus* (Dipterocarpaceae), and others.

Disturbed forest (SF): there are a variety of plants from plants of natural forest to light-preferred quick growing plants, shrubs and grasses, and some bamboos. The forest canopy height ranges 20–35 m, and forest canopy is 50%.

The main plant species are *quadragulare* (Combretaceae), *Dalbergia mammosa* (Fabaceae), *Horsfieldia amygdalina* (Myristicaceae), *Irvingia malayana* (Ionanthaceae), *Bombax aceps* (Bombacaceae), *Balakata baccata* (Euphorbiaceae), *Tetrameles nudiflora* (Datisceae), *Dipterocarpus alatus* (Dipterocarpaceae), and others.

Stream sides (SS): two sides along the “Dac O” stream with the wideness of 20–25 m. The vegetation is broad leaf evergreen plants with diameter of 15–40 cm, the canopy height of 15–30 m. The main plant species are *Anisoptera* spp. (Dipterocarpaceae), *Dalbergia* (Fabaceae), plants of Anonaceae, Euphorbiaceae and other families, and shrubs and grasses along the stream sides. The forest canopy is 30%.

Bamboo forest (BF): the bamboo forest consists of 80–90% bamboos with the canopy height of 10–25 m. The bamboo forest canopy is 60%. The main bamboo species is *Bambusa balcoa*.

2.3. Data Analysis. Indices of diversity, evenness, and species richness of butterfly communities were assessed for each habitat type, and calculated using Primer v5 software [21] running in Window Vista. The similarity of species composition between habitat types (Bray-Curtis similarity with square root transformation) was analyzed with Cluster Analysis using Similarity Tree software [21].

Identification and nomenclature of butterfly species were followed, Chou [22], D'Abrera [23], and Monastyrskii and Devyatkin [24].

3. Results

A total of 112 different species with 1703 individuals of butterflies were recorded in four different habitat types in the studied period in 2008–2009. The butterfly list and their abundance are presented in Table 1. The major number of species contain the lowest individual numbers with 61 species (54% of all species) showing individuals less than 5 for all 4 transects. The two most abundant species are *Catopsilia pomona* (231 individuals) and *Ypthima baldus* (273 individuals). The greatest number of individuals of *Catopsilia pomona* occurred in the stream sides with 170 individuals, while most of the individuals of *Ypthima baldus* are found in the disturbed forest and bamboo forest with 145 and 122 individuals, respectively.

Figure 1 indicates that the proportion of rare species (R) tends to decrease from the natural forest to the stream side environment or from the thickest forest canopy to the least forest canopy. The proportion of common species (C) tends to increase from the natural forest to the stream sides. The proportion of common species of the stream sides and the bamboo forest is similar. The proportion of uncommon species (UC) does not appear to be significantly different among habitats.

The diversity of butterfly community in four different habitat types in Bu Gia Map National Park is presented in Table 2. The disturbed forest has the greatest species number (80 species) and the bamboo forest has the least (40 species). The stream sides have the greatest individual number (644 individuals); the natural forest has the least

TABLE 1: Species list and abundance of butterflies in different habitats.

No.	Species	Habitats			
		NF	DF	SS	BR
	Papilionidae				
1	<i>Atrophaneura aidoneus</i> (Doubleday)	2	1		
2	<i>Graphium doson</i> (Felder)	4	1	41	4
3	<i>Graphium sarpedon</i> (Linnaeus)	3		16	
4	<i>Graphium agamemnon</i> (Linnaeus)	3	4	7	
5	<i>Graphium xenocles</i> (Doubleday)		1		
6	<i>Lamprotera meges</i> (Zinken)			2	
7	<i>Losaria coon</i> (Fabricius)	5	1		1
8	<i>Papilio demoleus</i> (Linnaeus)		2	1	
9	<i>Papilio demolion</i> (Cramer)	3		1	1
10	<i>Papilio mahadeva</i> (Moore)			2	
11	<i>Papilio memnon</i> (Linnaeus)	2	3	3	
12	<i>Papilio helenus</i> (Linnaeus)	14	24	24	6
13	<i>Papilio nephenus</i> (Boisduval)	6	2	13	1
14	<i>Papilio paris</i> (Linnaeus)		1	3	
15	<i>Papilio polytes</i> (Linnaeus)	5	5	13	
16	<i>Papilio protenor</i> (Cramer)	3	1		
17	<i>Troides helena</i> (Linnaeus)	2	1		
	Pieridae				
18	<i>Appias albina</i> (Boisduval)	7	11	20	7
19	<i>Appias lyncida</i> (Cramer)	2	6	6	18
20	<i>Appias nero</i> (Fabricius)	1		1	
21	<i>Catopsilia pomona</i> (Fabricius)	2	49	170	10
22	<i>Cepora nadina</i> Lucus	3	4	9	11
23	<i>Cepora nerissa</i> (Fabricius)			5	3
24	<i>Delias hyparete</i> (Linnaeus)		1	1	
25	<i>Dercas verhuelli</i> (van de Hoeven)		12	2	5
26	<i>Hebomoia glaucippe</i> (Linnaeus)	5	2	17	3
27	<i>Eurema andersoni</i> (Moore)	2	11	8	35
28	<i>Eurema blanda</i> (Boisduval)		17	45	12
29	<i>Eurema hecabe</i> (Linnaeus)		6	23	
30	<i>Ixias pyrene</i> (Linnaeus)	4	2	8	6
31	<i>Leptosia nina</i> (Fabricius)	8	12	1	13
32	<i>Pareronia anais</i> (Lesson)		15	12	5
	Danaidae				
33	<i>Danaus genutia</i> (Cramer)		1		
34	<i>Euploea camaralzeman</i> (Butler)		3	1	
35	<i>Euploea core</i> (Cramer)		1	1	
36	<i>Euploea doubledayi</i> (C. & R. Felder)	2	5	2	
37	<i>Euploea mulciber</i> (Cramer)	5	10	2	6
38	<i>Euploea radamanthus</i> (Fabricius)	10	4	16	1
39	<i>Ideopsis vulgaris</i> (Butler)	1		1	
40	<i>Parantica aglea</i> (Stoll)			1	
41	<i>Parantica melaneus</i> (Cramer)		1		
42	<i>Tirumala septentrionis</i> (Butler)			3	
	Amathusiidae				
43	<i>Amathuxidia amythron annamensis</i> (Talbot)	2	1		
44	<i>Discophora sondaica</i> (Boisduval)	2		1	1
45	<i>Thaumantis diores</i> (Doubleday)	2	1		

TABLE 1: Continued.

No.	Species	Habitats			
		NF	DF	SS	BR
46	<i>Thauria lathyi</i> (Fruhstorfer)	2	1		
47	<i>Stichphthalma eumurai eumurai</i> (Nishimura)	7	10	5	10
Satyridae					
48	<i>Coelites nothis</i> (Westwood)	5			
49	<i>Elymnias hypermnestra</i> (Linnaeus)	1	1		
50	<i>Erites medura rotundata</i> (de Niceville)	8			1
51	<i>Lethe confusa</i> (Aurivillies)	1	3	2	
52	<i>Lethe kansa</i> (Moore)	2	1		
53	<i>Lethe mekara</i> (Moore)	2	1		
54	<i>Lethe minerva tritogeneia</i> (Fruhstorfer)	2	1		
55	<i>Lethe verma</i> (Kollar)		1		
56	<i>Melanitis leda</i> (Linnaeus)	4		1	
57	<i>Mycalesis anaxias</i> (Fruhstorfer)	4	2	3	
58	<i>Mycalesis mineus</i> (Moore)		24	5	20
59	<i>Mycalesis sangaica tunicula</i> (Fruhstorfer)		3		7
60	<i>Mycalesis mnasicle perma</i> (Fruhstorfer)		4		3
61	<i>Ragadia critias</i> (Riley & Godfrey)	2			
62	<i>Ypthima baldus</i> (Fabricius)	2	145	4	122
63	<i>Ypthima savara savara</i> (Uemura & Monastyrskii)	2	2	1	
Nymphalidae					
64	<i>Ariadne merione</i> (Cramer)		15	5	13
65	<i>Athyma cama</i> (Moore)			2	
66	<i>Athyma nefte</i> (Cramer)				
67	<i>Athyma ranga</i> (Moore)			2	
68	<i>Athyma selenophora</i> (Kollar)		7	16	
69	<i>Cethosia biblis</i> (Drury)			3	
70	<i>Chersonesia intermedia</i> (Martin)		11		2
71	<i>Cirrochroa tyche</i> (Felder)		1		
72	<i>Cupha erymanthis</i> (Drury)	2	7	1	1
73	<i>Cyrestis themire</i> (Honrath)		7	10	
74	<i>Cyrestis thyodamas</i> (Doyere)		1	2	1
75	<i>Doleschalia bisaltide</i> (Cramer)		1		1
76	<i>Cynitia cocytus</i> (Fabricius)	3	2	7	1
77	<i>Cynitia lepidea</i> (Butler)			1	
78	<i>Euthalia monina</i> (Fabricius)	3	3	2	1
79	<i>Euthalia recta</i> (de Niceville)	4	1	2	1
80	<i>Moduza procris</i> (Cramer)	6		15	
81	<i>Junonia atlites</i> (Linnaeus)			4	
82	<i>Junonia almana</i> (Linnaeus)		2	3	
83	<i>Junonia iphita</i> (Cramer)		1	15	
84	<i>Junonia lemonias</i> (Fabricius)		1		
85	<i>Laringa horfieldi glaucescens</i> (de Niceville)		1		
86	<i>Lasippa tiga</i> (Moore)		1		
87	<i>Lebadea martha</i> (Fabricius)	2			
88	<i>Lexias dirtea</i> (Fabricius)	4		2	
89	<i>Lexias pardalis</i> (Moore)	8		15	
90	<i>Neptis clinia</i> (Moore)		1		
91	<i>Neptis harita</i> (Moore)	1			
92	<i>Neptis hylas</i> (Linnaeus)		5		2

TABLE 1: Continued.

No.	Species	Habitats			
		NF	DF	SS	BR
93	<i>Neptis nata</i> (Moore)	2	4	2	
94	<i>Pantoporia hordinia</i> (Stoll)	1	1		
95	<i>Pantoporia aurelia</i> (Staudinger)			1	
96	<i>Parasarpa dudu</i> (Westwood)		1		
97	<i>Parthenos sylvia</i> (Cramer)		1	1	
98	<i>Polyura athamas</i> (Drury)			2	
99	<i>Polyura eudamippus</i> (Doubleday)	3		9	
100	<i>Polyura delphis</i> (Doubleday)	2		1	
101	<i>Rhinopalpa polynice</i> (Cramer)			1	
102	<i>Rohana nakuba</i> (Moore)		1		1
103	<i>Terinos terpander</i> (Hewitson)		1		1
104	<i>Vagrans egista</i> (Cramer)	2	2	5	
105	<i>Vindula erota</i> (Fabricius)	4	1	8	
106	<i>Libythea myrrha</i> (Godart)		1		
Riodinidae					
107	<i>Abisara abnormis</i> (Moore)	2			
108	<i>Abisara bifasciata</i> (Moore)	2		1	
109	<i>Abisara echerius</i> (Stoll)		1		1
110	<i>Abisara neophron</i> (Hewitson)		1		
111	<i>Paralaxita telesia</i> (Hewitson)	4	2	1	
112	<i>Zemeros flegyas</i> (Cramer)		2		2

Note: Habitats as Figure 1; order of species list of each family by alphabet.

TABLE 2: Diversity of butterfly (Papilionoidea, except Lycaenidae) communities in four different habitat types in Bu Gia Map National Park.

Habitat types	Species number (<i>S</i>)	Individual number (<i>N</i>)	Species richness index (<i>d</i>)	Evenness index (<i>J</i>)	Diversity index (<i>H'</i>)
NF	60	209	11.04	0.95	3.89
DF	80	508	12.68	0.74	3.23
SS	73	644	11.13	0.77	3.29
BF	40	342	6.68	0.72	2.65

Note: The habitats as Figure 1.

individual number (209 individuals). For all butterfly species (Papilionoidea and Hesperoidea) in the area during the studied period, 193 species were recorded (personal information). The result is similar concerning the species number of Papilionoidea (except Lycaenidae) in each habitat. The natural forest has 105 species, the stream sides have 114 species, the disturbed forest has the most species number (134 species), and the bamboo forest has the least species number (54 species). Species richness index is highest in the disturbed forest and lowest in the bamboo forest. This index is similar when comparing the natural forest and the stream sides. The evenness index is very high in the natural forest where there is not any prominent species with high individual number. The high evenness index of the natural forest leads the high diversity index although it has the least individual number and the lowest species number. The disturbed forest and the stream sides have the greatest species

number and individuals, respectively, but not the highest diversity indices. The bamboo forest has the lowest diversity index of butterfly community.

The natural forest has few species but all species of the family Amathusiidae and many species of the family Satyridae (75% species of the family) (Table 3). The result of this study corresponds with previous work that shows the natural forest supports many species of the families Amathusiidae and Satyridae [10, 17]. Table 3 shows that the stream sides have all species of the family Pieridae and many species of the family Danaidae (80% species of the family). The bamboo forest has the fewest species of all families with the exception of the family Pieridae.

The similarity of butterfly communities between habitats is displayed in Figure 2. The similarity of butterfly communities among habitats is divided into two groups. One group is the stream sides and the natural forest (50%), and the other

FIGURE 1: Proportion of species abundance (rare, uncommon, common) in each habitat. *Note:* NF: natural forest; DF: disturbed forest; SS: stream sides in the forest; BF: bamboo forest; R: rare species with individuals less than 5; U: uncommon species with individuals from 6 to 10; C: the common species with individuals more than 10. This is used as *ad hoc* for this study only.

FIGURE 2: The similarity of butterfly communities between habitats. *Note:* Habitats as Figure 1.

group is the disturbed forest and the bamboo forest (62%). The disturbed forest and the bamboo forest have similar species composition.

4. Discussion

The natural forest has fewer butterfly species than the disturbed forest. Disturbed forests have more species than the stream sides. Bamboo forests have the least species number. This is similar to other studies showing that the disturbed forest has more butterfly species than shrub and grass habitats and agricultural lands [9, 10, 12]. The agricultural lands have the least species number similar to the bamboo forest. Living environment of disturbed forests is nonhomogeneous with a variety of vegetation in the intermediate procession. This consists of opening preferred growing plant species and shrubs. The disturbed forests have more diversity of plants of different processions than the natural forests and the stream sides. The more diverse plants are, the more diverse insects are [14, 25]. In additional, the disturbed forests have more openings that provide more light and spaces to attract more butterfly species than the natural forests [15, 26]. The disturbed forests also have more flowering plants that obviously support more butterfly species than

TABLE 3: The percentage of species of families in habitats.

Family	Habitats			
	NF	DF	SS	BF
Papilionidae	70.59	76.47	70.59	29.41
Pieridae	60.00	86.67	100.00	80.00
Danaidae	40.00	70.00	80.00	20.00
Amathusiidae	100.00	80.00	40.00	40.00
Satyridae	75.00	75.00	37.50	31.25
Nymphalidae	34.88	60.46	66.11	25.58
Riodinidae	50.00	66.67	33.33	33.33

Note: Habitats as Figure 1.

the natural forest. Other studies also concluded that diversity of species and individuals of butterfly communities increases when natural forests are disturbed; the diversity reaches the highest in moderately disturbed forests but decreases rapidly in urbanized forests [4, 6].

The stream sides of the forest have the greatest abundance of butterflies but lower species number than the disturbed forest. The living environment of the stream sides is diversified with vegetation, rocks, sand, and mud and water that attract more butterflies as they land taking water and nutrients from wet rocks, sand, and mud along the stream sides. The wet area supports more butterflies as concluded by Janzen and Schoener than in the tropical forest in the dry season as the study result of Janzen and Schoener [27] that in the tropical forest in dry season. There is greater insect diversity in the wet sites than in the dry sites. In addition, the stream sides in the forest have openings which supports more butterflies. Gaps in the forest have higher butterfly diversity than closed forests [15]. Along the stream, shrub and grass with flowering plants also support more butterflies. The environment of the stream sides is less diverse than the living environment of the disturbed forest. The stream sides have less vegetation layers and simpler vegetation than the disturbed forest, thus the stream sides have less species number than the disturbed forest does. In the disturbed forest, species do not gather in big numbers as they do in the stream side environment. Thus the stream sides have more individuals than the disturbed forest.

The shrub and grass habitat has a high proportion of common butterfly species with a wide geographical distribution range [10]. The stream side habitat is similar to the shrub and grass habitat in which the stream sides have a high proportion of common species with a wide geographical distribution range. This is especially true concerning species of the families Pieridae and Danaidae. Some species prefer wet sand, rocks, and mud along the stream sides. The most abundant species in the stream sides are *Catopsilia pomona*, *Graphium doson*, *Eurema blanda*, and *E. hecabe*. However, many species of the families Satyridae and Amathusiidae are absent from the stream sides. They are forest species with small geographical distribution ranges [10, 17].

The bamboo forest consists of very simple vegetation, mostly bamboo. The less diversity of vegetation results with less diversity of butterflies. Studies show that the more divers

plants are, the more diverse butterflies and insects are [1, 25]. The bamboo forest has more individuals than the natural forest due to the fact that the bamboo forest has more individuals than the natural forest due to abundance of some species such as *Ypthima baldus*, *Mycalesis mineus*, and *Eurema* spp. *Ypthima baldus* is very abundant in the bamboo forest (122 individuals).

Natural forests are richer in abundance of rare species and this metric decreases with increasing habitat opening levels (from natural forest to the stream sides). Conversely, common species increase with increasing forest opening level.

Species composition was dissimilar among habitats, but rather similar between the disturbed forest and bamboo forest, and between the natural forest and the stream sides in the forest. In the study, the stream sides are located in the natural forest and just differ from the natural forest in which the stream sides have openings. Along the stream sides are forest canopies which harbor many species found both in the stream sides and the natural forest. Habitats of the disturbed forest and the bamboo forest are not much similar but many species found in the bamboo forest are also found in the disturbed forest (e.g., species of the families Pieridae and Satyridae). These butterflies fly near the ground. "Thus, the species composition of the disturbed forest and the bamboo forest is similar; the species composition of the natural forest and the stream sides is also rather similar. The butterfly species composition differed between habitat types. This result is similar with Steffan-Dewenter and Tscharnkte [28] and Vu [10].

The result of this study supports the hypothesis that the stream side environment possesses a high abundance of butterflies but not the highest species number and diversity index. The bamboo forest has the least species and diversity index of butterfly community. The stream sides consisting of a mosaic habitat type (natural forest with different layers along the stream sides, openings, and wet sand and rocks) are important environment for the conserving of large abundance of butterflies. However, undisturbed habitats such as the natural forests are important to conserve forest restricted butterfly species (specialist species) [9]. Swengel and Swengel [29] also indicated that long-term vegetative consistency is advised for conservation management of specialist butterflies.

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