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Research Article

Community Diversity And Fauna Analysis Of Butterflies In The Huboliao National Nature Reserve, Fujian Province.

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Abstract

As indicators of the ecological environment of insects, the distribution and variation of dynamic resources of butterflies are important for biodiversity conservation and research. Using the Shannon-Wiener index and relative abundance method, we analyzed the results and data from continuous surveys and observations of butterflies in the Huboliao National Nature Reserve (HNNR) from 2016 to 2018 to study the diversity and population dynamics of butterflies. The results showed that there are 176 species of butterflies belonging to 105 genera within five families in the HNNR. Of the six transect lines investigated, there were the largest number of butterfly genera and species in the Zijingshan line, with 71 species recorded. The dominant species, Pieris canidia, was stable for three years and may be closely related to the large areas of rape cultivation. The butterfly fauna of the HNNR is dominated by Oriental species, showing strong Oriental features. In addition, a wide range of species and a small number of Palaearctic species are present in the reserve, indicating the complexity of the nature conservation system composition in the HNNR.

Keywords : *Butterflies, Community diversity, Population dynamics, Environmental change, Conservation, Huboliao National Nature Reserve.*

INTRODUCTION

As butterflies are sensitive to environmental changes, they can indirectly reflect the degree of biodiversity shift[1,2,3] . With the increasing importance of protecting ecological environments and maintaining ecological balance, research and conservation of biodiversity, of which butterfly diversity is an essential component, is of particular importance. By studying the dynamic shift rule of butterfly population and its impact on the ecosystem, the role of butterflies as a regional biodiversity evaluation index can be given full play, which is of great research value[4]. In addition, identifying and studying butterflies, investigating their diversity, analyzing the causes of their dynamic changes, and aiming at their sustainable development are also of great significance for the protection and utilization of butterfly resources, prevention and control of harmful butterfly larvae, maintenance of ecological balance and beautification of the environment[5].

Huboliao National Nature Reserve (HNNR) is the only intact, contiguous and large-scale South Asian tropical rain forest ecosystem in low latitude and low altitude in China. It is a relatively primitive forest ecosystem with the characteristics of rain forest at the same latitude in the world, and has high protection and scientific research value[6,7]. The animal resources in the reserve have typical subtropical characteristics. There are 210 species in the Oriental kingdom, 29 in the Palearctic Kingdom and 58 in the widespread kingdom[8].

The study of butterfly diversity in the reserve aims to provide basic research data for the development of tourism, protection of butterfly diversity and sustainable development of the environment and the plantation industry in Nanjing County of Fujian Province. By understanding the status quo of butterfly diversity, we can learn the threat factors to butterfly diversity at HNNR. Through survey and studies, we can understand the extent of damage to butterfly diversity caused by different factors such as habitat change, environmental pollution, and human disturbance, assess the extent of butterfly diversity loss, and assess the effectiveness of conservation measures and policies in the observed areas. It also provides theoretical grounds and suggestions for the formulation of corresponding protective measures.

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MATERIALS AND METHODS

Study Area

Our study was conducted in the Huboliao National Nature Reserve (24°30 '05 "N ~ 24°56' 20" N, 117°12 '42 "E ~ 117°22' 45" E), Nanjing County, Fujian Province in China, during the calendar years 2016-2018. The area is dominated by medium and low mountain terrain (altitude 137.0 ~ 874.5 m), the water system is developed, and the stream flow is numerous and distributed in dendritic shape. The climate in the reserve is warm and humid, with an average annual temperature of 21.1°C. The coldest month is January (10.9°C on average), while the hottest month is July (26.7°C on average). The average annual rainfall ranges from 1,587.5 to 1,879.6 mm, and the relative humidity is 81.4%. The main research areas are subtropical evergreen broad-leaved forest, mixed forest and bamboo forest, which are abundant in plant and animal resources9.,

Sampling Of Butterflies

In this survey, we adopted the national unified line transect survey method10. According to different altitudes, vegetation and habitat types (such as forest, grassland, farmland, vegetable fields, etc.), in each 6 months from 2016 to 2018, six representative transect lines (Kezailin, E'xiandong, Jinshanchun, Louzai, Nankeng and Zijingshan) were selected for investigation in HNNR. Under the environmental conditions of no rain and no strong disturbance factors, we did the investigation on the same date (20th) in each month as possible. Six transect lines were set in the sample area of HNNR, and the specific observation method was the same as that described in Hong et al[11]. The butterfly specimens obtained from the HNNR were identified, classified and faunal divided, based on Wu and Xu[12] , Zhang and Zhao[13], Zhou[14], Xu[15] ,Huang[16] and other related books.

Data Analyses

The butterfly data from the above observational surveys were collated and counted, and the relative abundances and Shannon-Wiener indices of the recorded statistics were analyzed. Relative abundance: R = 100 Ni/N (Ni is the number of individuals of species i, N is the number of individuals of all species, the larger the value of R, the greater the proportion)[17]. Shannon-wiener index: H'= -∑Pi ln Pi (Pi is the proportion of the number of individuals of species i to the total number of individuals, the greater the H', the more uniform the distribution of species and the more stable the community)[3,18]. The observational data and results would be submitted to the butterfly diversity observation platform (China BON - Butterflies, https://58.213, 151.82:9966 /) after completion.

RESULTS

Species Composition

In total, 5,498 butterfly individuals were observed in the HNNR between 2016 and 2018. According to the international butterfly taxonomic system, based on Wu and Xu[12], a total of 176 species were recorded in HNNR, belonging to 105 genera of 5 families (**Supp Table 1**). Among them, there are 15 species in 5 genera of Papilionidae, 14 species in 9 genera of Pieridae, 92 species in 48 genera of Nymphalidae, 39 species in 29 genera of Pteronidae, and 16 species in 14 genera of Hesperiidae. According to the List of State Key Protected Wild Animals issued by the National Forestry and Grassland Administration (NFGA) and Ministry of Agriculture and Rural Affairs of the People's Republic of China (MARAPRC)[19] in Feb 2021 , *Sasakia funebris* in HNNR belongs to the national secondary key protected wild animals, accounting for 4.17% of the total number of butterflies (24 species) in the list. In addition, according to the List of Terrestrial Wildlife with Important Ecological, Scientific and Social Values [Abbreviated as List of the Three Categories of Wildlife Animals (LTCWA)] issued by the NFGA[20] in June 2023, there is one species of leopard eye butterfly (Nosea hainanensisi) in the nature reserve, accounting for 12.5% of the butterflies (8 species in total) in the LTCWA.

Annual Species Composition And The Dominant Butterfly Species

In the three years from 2016 to 2018, the results (**Table 1**) showed that the largest number of individual butterflies (2,243) observed was in 2018. Over three years from 2016 to 2018, we identified butterfly species with more than 100 individuals as the dominant species in each of the six observations. The dominant butterfly species in the HNNR is the white butterfly *Pieris canidia*, whose population has increased each year, from 114 in 2016 to 251 in 2017, and 575 in 2018. In 2016, 113 individuals of the *satyrid* butterfly *Ypthima baldus* were recorded, with *P. canidia* as the dominant species. In summary, P. canidia is the dominant butterfly species with the most stable activity at the HNNR. The reason for P. canidia becoming the dominant species is closely related to the extensive cultivation of rapeseed flowers in Nanjing County, where the reserve is located.

Table 1. Species composition of butterflies in the HNNR in each year

Year	Family	Genera	Species	Individual number
2016	5	68	116	1,330
2017	5	65	110	1,925
2018	5	75	111	2,243
Total	5	105	176	5,498

Butterfly Fauna

Based on reference publications[12,13], butterflies in the HNNR were divided into Palaearctic species, Oriental species and widespread species. The proportion of Palaearctic species, Oriental species and Widespread species and their distribution in each family are shown in **Table 2**.

Species found in the Palaearctic realm are known as Palaearctic species, and are mostly found in northwestern China, northern China, the Tibetan plateau, Europe, Siberia, northern Japan, Korea, and other regions. As the HNNR belongs to the tropical marine monsoon climate zone of South Asia, the distribution of the Palaearctic species is a few. Among the 176 species counted, only three species belong to Palaearctic species, accounting for only 1.70% of the total number, including two species (*Melanargia halimede* and *Neptis alwina*) of Nymphalidae and one species (*Albulina orbitula*) of Lycaenidae.The species wholly and chiefly distributed in the Oriental realm, including the southern provinces and districts within our eastern boundary, as well as Vietnam, Laos, Burma, Thailand, Sikkim, Bhutan, India, and the South Asiatic Islands, are called Oriental species. As the HNNR is located south of the eastern boundary, most of the butterflies belong to the eastern species. Among the 176 species identified, 146 belong to the Oriental family, accounting for 82.95% of the total, including 13 species of Papilionidae, 11 species of Pieridae, 77 species of Nymphalidae, 30 species of Lycaenidae, and 15 species of Hesperiidae.Species whose distribution spans two realms are called widespread species, and can be found from the southern provinces of China and South and Southeast Asia to the northern provinces of China and Korea, northern Japan, Siberia, Europe, etc. Of the 176 species, 27 belong to ubiquitous species, accounting for 15.34% of the total, including two species of Papilionidae, three species of Pieridae, 13 species of Nymphalidae, eight species of Lycaenidae, and one species of Hesperiidae.

Overall, the butterfly fauna of the HNNR is dominated by Oriental species, showing strong oriental features. In addition, a wide range of species and a few Palaearctic species were also present in this reserve, indicating the complexity of the nature conservation system composition in the HNNR.

Table 2. Fauna composition of butterflies in the HNNR

Family	Palaearctic species	Oriental species	Widespread species
Papilionidae	0	13	2
Pieridae	0	11	3
Nymphalidae	2	77	13
Lycaenidae	1	30	8
Hesperiidae	0	15	1
The total	3	146	27
Rate/%	1.70	82.95	15.34

Composition Of Butterfly Species In Various Lines

Among the 6 transect lines in HNNR, the number of species (71) and genera (50) of Zijingshan transect was the largest, which should be related to the better protection of ecological environment in this transect area (**Table 3**).The numbers of Jinshanchun transect lines (57 species, 39 genera) were the fewest, which was also related to the frequent human activities and the relatively simple vegetation species in the transect area. Composition of butterfly species in various lines is shown in **Supp Table 2**.

Table 3. The number of species and genus of various line butterflies in the HNNR

Family	Kezailin		E'xiandong		Jinshanchun		Louzai		Nankeng		Zijingshan	
	Genera	Species	Genera	Species	Genera	Species	Genera	Species	Genera	Species	Genera	Species
Papilionidae	4	9	2	5	3	7	4	10	3	9	3	8
Pieridae	3	6	2	3	3	5	4	7	4	6	7	9
Nymphalidae	21	36	23	37	17	27	25	43	19	32	22	33
Lycaenidae	12	13	8	10	14	16	6	6	8	8	12	15
Hesperiidae	5	5	4	4	2	2	3	3	5	5	76	6
Total	45	69	39	59	39	57	42	69	39	60	50	71

Butterfly Diversity Index

Not only does the HNNR have a large number of butterfly species, it has also increased its butterfly population year by year, from 1,330 individuals in 2016 to 1,925 individuals in 2017 and 2,243 in 2018. This is due to the fact that the reserve has paid attention to nature conservation over the years and developed relevant conservation measures to avoid man-made damage. And strengthening the protection of the environment in the reserve (such as strictly controlling the entry and exit of tourists and vehicles) has a certain relationship. Shannon-wiener index calculated results showed that butterfly diversity was higher in HNNR (**Table 4**).

Table 4. Species diversity index of butterflies in the HNNR

Year	Family	Genera	Species	Individuals	Shannon-Wiener index
2016	5	68	116	1,330	3.8796
2017	5	65	110	1,925	4.2902
2018	5	75	111	2,243	3.286

In terms of the annual variation of the diversity index, the HNNR had the highest species diversity index (4.2902) in 2017, and the lower species diversity index in 2018, mainly because the whole Fujian Province was greatly affected by the typhoon and rainstorm in June that year. According to the analysis of butterfly population dynamics in each month,we found that in each of the three years, the number of butterfly species and individuals in October was the highest (**Table 5**).

Table 5. Species and individual numbers of butterflies in the HNNR in six months each year

Year	April		May		June		July		Augest		September		October		October	
	Species	Inds.	Species	Inds.	Species	Inds.	Species	Inds.	Species	Inds.	Species	Inds.	Species	Inds.	Species	Inds
2016	-	-	35	186	55	179	44	209	55	268	-	-	44	239	41	249
2017	34	325	39	258	-	-	51	222	54	288	64	466	46	366	-	-
2018	33	472	35	426	48	377	51	160	-	-	62	412	58	396	-	-

-: Lack of data (cannot be observed due to typhoons, torrential rains or other extreme weather).

DISCUSSION

Butterflies are particularly abundant at the HNNR. According to the current international butterfly classification system, there are five families, the Papilionidae, Pieridae, Nymphalidae, Lycaenidae, and Hesperiidae. Based on the results of six lineages, there were 5,498 individuals of 176 species belonging to 105 genera in five families. In the HNNR, the Nymphalidae are particularly rich in resources, with a total of 48 genera, accounting for 59.3% of the species in the Fujian Nymphalidae. Longqishan National Nature Reserve (LNNR, at E 117^{0}13′–117^{0}21′, N 26^{0}28′–26^{0}37′) is the nature reserve in Fujian during the same period of investigation, and HNNR is not far away. There are 193 species of butterflies (belonging to 107 genera of 5 families) in LNNR, which is slightly more than 176 species in HNNR.

The geographical location and climatic conditions of the two nature reserves are similar. There are 128 species of butterflies (77 genera of 5 families) and all distributed in the two nature reserves. The common dominant species are P. canidia and Y. baldus. In terms of the numbers of butterfly species in each family, the two nature reserves were similar in the numbers of Papilionidae, Pieridae and Nymphalidae (**Table 6**). However, the numbers of Lycaenidae in the HNNR (39 species, 22.16%) were more than those in the LNNR (30 species, 15.54%). But there were fewer species of Hesperiidae in the HNNR (16 species, 9.09%) than in the LNNR (29 species, 15.03%), which was related to the large distribution of bamboo forest in the LNNR, and the distribution area of bamboo forest accounted for about 1/3 of the forest area21.

Although there are six butterfly species under national protection in each of the two national nature reserves, the remaining four species are distinct, except for the Jungle Queens *Stichophthalma howqua* and *Yamamotozephyrus kwangtungensis*, which are common species. In the LNNR, there are the Golden Birdwing *Troides aeacus*, *Papilio elwesi*, *Stichophthalma suffusa* and the Orange Oakleaf butterfly *Kallima inachus*, while in the HNNR, there are *Atrophaneura horishanus*, the white dragontail butterfly *Lamproptera curius*, Nosea harnesses and the empress butterfly Sasakia funebris. As can be seen from the comparison of the two national nature reserves, which are close in geographical location and ecological environment and have the same period of investigation, the distribution of butterflies are relatively similar, but there are some differences, this is mainly reflected in the slight differences in the distribution types and numbers of Lycaenidae and Hesperiidae. This is because butterflies have diverse ecological characteristics and habitat requirements, and are highly sensitive to changes in habitat vegetation and microenvironment. As a result, butterflies have a wide range of biogeographic and ecological probe functions and can be used to detect trends in environmental change as an effective indicator species for environmental detection. This is because butterflies have diverse ecological characteristics and habitat requirements, and are extremely sensitive to changes in habitat vegetation and microenvironment[22,23]. Therefore, butterflies have extensive biogeography and ecological probe functions, and can be used to detect the trend of environmental change as an effective indicator species for environmental detection.

The dominant species, P. *canidia*, accounted for the highest proportion over the three-year period, with a total of 940 butterfly individuals and a relative abundance of 47.2, as rapeseed flowers were planted in a large area of Nanjing County, where the HNNR is located..In order to promote the balanced development of butterfly diversity and avoid the destruction of vegetation, it is suggested to correctly return farmland to forest, control the use of pesticides, and reduce

human interference such as logging and tourism, so as to expect better improvement and enhancement of biodiversity in HNNR in the future.

Table 6. Comparison of the numbers of species and genera of butterflies between LNNR and HNNR

Nature Reserve	Papilionidae		Pieridae		Nymphalidae		Lycaenidae		Hesperiidae	
	Genus (%)	Species (%)	Genus (%)	Species (%)	Genus (%)	Species (%)	Genus (%)	Species (%)	Genus (%)	Species (%)
Longqishan	4	18	7	10	53	106	24	30	19	19
	(3.74)	(9.33)	(6.54)	(5.18)	(49.53)	(54.92)	(22.43)	(15.54)	(17.76)	(15.03)
Huboliao	5	15	9	14	48	92	29	39	14	16
	(4.76)	(8.52)	(8.57)	(7.95)	(45.71)	(52.27)	(27.62)	(22.16)	(13.33)	(9.09)

Data availability

Data is provided within the manuscript or supplementary information files.

Acknowledgments

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Authors' contributions

F.H. was the first author and analyzed the research data, performed the statistical analysis, and wrote the manuscript. S.Q.P. C.H.Z. and W.B.L. participated in the manuscript writing. G.F.J. designed and organized and led a three-year butterfly survey and participated in the manuscript writing and interpretation of the results.

Competing interests

F.H., S.Q.P., C.H.Z., W.B.L., and G.F.J. declare no competing interests.

Availability of data and materials

All the data are provided within this manuscript (see supplementary materials).

Consent for publication

Not applicable.

Supp Table 1. List of butterflies species recorded in the Huboliao National Nature Reserve

Species	Number of individuals	Fauna composition
1 Papilionidae		
1) Atrophaneura horishanus (Matsumura)	3	O
2) Byasa alcinous (Klug)	69	O
3) Papilio polytes Linnaeus	122	O
4) Papilio helenus Linnaeus	150	O
5) Papilio protenor Cramer	35	O
6) Papilio memnon Linnaeus	18	O
7) Papilio bianor Cramer	32	W
8) Papilio dialis (Leech)	4	O
9) Papilio paris Linnaeus	120	O
10) Papilio xuthus Linnaeus	3	W
11) Lamproptera curius (Frabricius)	75	O
12) Graphium cloanthus (Westwood)	14	O
13) Graphium sarpedon (Linnaeus)	44	O
14) Graphium chironides (Honrath)	2	O

15) Graphium doson (C.&R.Felder)	1	O
2 Pieridae		
1) Catopsilia pyranthe (Linnaeus)	6	O
2) Eurema laeta (Boisduval)	16	O
3) Eurema hecabe (Linnaeus)	184	W
4) Eurema blanda (Boisduval)	1	O
5) Ixias pyrene (Linnaeus)	15	O
6) Delias pasithoe (Linnaeus)	350	O
7) Delias acalis (Godart)	13	O
8) Delias belladonna (Fabricius)	1	O
9) Prioneris thestylis (Doubleday)	5	O
10) Cepora nerissa (Fabricius)	2	O
11) Pieris rapae (Linnaeus)	195	W
12) Pieris canidia (Sparrman)	940	W
13) Talbotia naganum (Moore)	7	O
14) Hebomoia glaucippe (Linnaeus)	4	O
3 Nymphalidae		
1) Melanitis leda (Linnaeus)	37	O
2) Melanitis phedima (Cramer)	7	O
3) Lethe dura (Marshall)	56	O
4) Lethe syrcis Hewitson	40	W
5) Lethe helena Leech	4	O
6) Lethe christophi Leech	4	O
7) Lethe hyrania (Kollar)	1	O
8) Lethe confuse Aurivillius	102	O
9) Lethe verma (Kollar)	12	O
10) Lethe sinorix (Hewitson)	6	O
11) Lethe butleri leech	1	O
12) Lethe europa (Fabricius)	13	O
13) Lethe chandica Moore	45	O
14) Lethe mekara Moore	2	O
15) Lethe siderea Marshall	5	O
16) Neope armandii (Oberthür)	7	O
17) Neope bremeri (C.&R.Felder)	1	O
18) Neope muirheadii (C.&R.Felder)	60	O
19) Mandarinia regalis (Leech)	3	O
20) Nosea hainanensisi Koiwaya	1	O
21) Mycalesis mineus (Linnaeus)	117	O
22) Mycalesis mucianus Fruhstorfer	38	O
23) Mycalesis gotama Moore	48	W
24) Mycalesis francisca (Stoll)	7	O
25) Penthema adelma (C.&R.Felder)	21	O
26) Neorina patria Leech	1	O
27) Melanargia halimede (Ménétriès)	2	P
28) Ypthima baldus (Fabricius)	438	O
29) Ypthima motschulskyi (Bremer et Gray)	17	O
30) Ypthima praenubila Leech	6	O
31) Ypthima multistriata Butler	214	W
32) Ypthima lisandra (Cramer)	1	O

33) Palaeonympha opalina Butler	2	O
34) Danaus genutia (Cramer)	45	O
35) Tirumala limniace (Cramer)	159	O
36) Parantica sita Kollar	3	O
37) Parantica melaneus (Cramer)	8	O
38) Parantica agles (Stoll)	4	O
39) Ideopsis similis (Linnaeus)	3	O
40) Euploea midamus (Linnaeus)	32	O
41) Euploea core (Cramer)	14	O
42) Aemona amathusia (Hewitson)	37	O
43) Stichophthalma Howqua (Westwood)	4	O
44) Faunis aerope (Leech)	1	O
45) Acraea violae (Fabricius)	3	O
46) Argynnis paphia (Linnaeus)	3	W
47) Argyreus hyperbius (Linnaeus)	42	W
48) Argyronome laodice Pallas	6	W
49) Damora sagana Doubledag	5	W
50) Childrena children (Gray)	2	O
51) Hypolimnas bolina (Linnaeus)	5	O
52) Kaniska canace (Linnaeus)	10	O
53) Polygonia c-aureum (Linnaeus)	6	W
54) Vanessa cardui (Linnaeus)	5	W
55) Junonia almanac (Linnaeus)	12	O
56) Junonia iphita (Cramer)	1	O
57) Symbrenthia lilaea Hewitson	3	O
58) Symbrenthia hypselis (Godart)	4	O
59) Polyura nepenthes (Grose-Smith)	2	O
60) Charaxes bernardus (Fabricius)	5	O
61) Mimathyma chevana (Moore)	1	O
62) Rohana parisatis (Westwood)	11	O
63) Helcyra superba Leech	17	O
64) Sephisa chandra (Moore)	1	O
65) Sephisa princeps (Fixsen)	1	W
66) Sasakia funebris (Leech)	1	O
67) Hestina assimilis (Linnaeus)	1	W
68) Stibochiona nicea (Gray)	3	O
69) Cyrestis thyodamas Boisduval	15	O
70) Ariadne ariadne (Linnaeus)	1	O
71) Euthalia niepelti Strand	18	O
72) Euthalia kosempona Fruhstorfer	1	O
73) Euthalia bunzoi Sugiyama	1	O
74) Limenitis cleophas Oberthür	2	O
75) Limenitis sulpitia (Cramer)	39	O
76) Athyma cama Moore	9	O
77) Athyma perius (Linnaeus)	1	O
78) Athyma selenophora (Kollar)	9	O
79) Athyma nefte (Cramer)	5	O
80) Athyma jina Moore	16	O
81) Parasarpa dudu (Doubledag)	4	O

82) Neptis sappho (Pallas)	15	W
83) Neptis hylas (Linnaeus)	15	O
84) Neptis clinia Moore	157	O
85) Neptis soma Moore	9	O
86) Neptis nata Moore	1	O
87) Neptis miah Moore	59	O
88) Neptis cartica Moore	5	O
89) Neptis ananta Moore	4	O
90) Neptis alwina (Bremer & Grey)	1	P
91) Neptis pryeri Butler	1	W
92) Pantoporia hordonia (Stoll)	5	O
4 Lycaenidae		
1) Abisara fylloides (Westwood)	11	O
2) Abisara echerius (Stoll)	3	O
3) Abisara neophron (Hewitson)	5	O
4) Stiboges nymphidia Butler	41	O
5) Zemeros flegyas (Cramer)	110	O
6) Allotinus drumila (Moore)	4	O
7) Miletus chinensis C.Felder	9	O
8) Taraka Hamada Druce	66	W
9) Curetis acuta Moore	76	O
10) Thecla betula (Linnaeus)	2	W
11) Yamamotozephyrus kwangtungensis(Forster)	4	O
12) Arhopala bazalus (Hewitson)	25	O
13) Arhopala rama (Kollar)	70	O
14) Arhopala paramuta (deNicéville)	36	O
15) Mahathala ameria Hewitson	4	O
16) Spindasis syama (Horsfield)	1	O
17) Deudorix epijarbas Moore	2	O
18) Rapala varuna Horsfield	2	O
19) Sinthusa chandrana (Moore)	4	O
20) Heliophorus ila (de Nicéville & Martin)	10	O
21) Heliophorus epicles (Godart)	1	O
22) Heliophorus saphir (Blanchard)	1	O
23) Nacaduba kurava (Moore)	4	O
24) Prosotas nora (Felder)	1	O
25) Prosotas aluta (Druce)	9	O
26) Jamides bochus (Stoll)	1	O
27) Lampides boeticus Linnaeus	9	W
28) Euchrysops cnejus (Fabricius)	2	O
29) Zizeeria maha (Kollar)	164	W
30) Zizeeria karsandra (Moore)	5	O
31) Zizina otis (Fabricius)	3	
32) Everes argiades (Pallas)	77	W
33) Tongeia filicaudis (Pryer)	15	W
34) Tongeia fischeri (Eversmann)	4	W
35) Neopithecops zalmora (Butler)	1	O
36) Albulina orbitula (de Prunner)	1	P
37) Chilades lajus (Stoll)	2	O

38) Chilades pandava (Horsfield)	4	O
39) Polyommatus eros (Ochsenheimer)	2	W
5 Hesperiidae		
1) Choaspes benjaminii (Guérin—Méneville)	3	O
2) Tagiades litigiosa Möschler	3	O
3) Abraximorpha davidii (Mabille)	26	O
4) Ampittia dioscorides (Fabricius)	19	O
5) Isoteinon lamprospilus C.& R.Felder	2	O
6) Astictopterus jama C.& R.Felder	11	O
7) Iambrix salsala (Moore)	4	O
8) Erionota torus Evans	4	O
9) Matapa aria (Moore)	4	O
10) Suastus gremius (Fabricius)	1	O
11) Taractrocera flavoides Leech	1	O
12) Telicota colon (Fabricius)	1	O
13) Telicota besta Evans	5	O
14) Parnara guttata (Bremer & Grey)	13	W
15) Parnara ganga Evans	6	O
16) Baoris farri (Moore)	1	O
The total	5,498	O

Note: P:The Palaearctic species, O:The Oriental species, W:The widespread species

Supp Table 2. Distribution information of butterflies in each sample line

Lines	Code	Altitude (m)	Startingpoint	Endpoint	Species
Kezailin	3500261001	229-413	24.7778°N 117.3261°E	24.7821°N 117.3348°E	Atrophaneura horishanus, Byasa alcinous, Papilio polytes, Papilio helenus, Papilio protenor, Papilio memnon, Papilio bianor, Papilio paris, Graphium sarpedon, Eurema laeta, Eurema hecabe, Delias pasithoe, Delias belladonna, Pieris rapae, Pieris canidia, Melanitis leda, Lethe dura, Lethe confuse, Lethe verma, Lethe chandica, Lethe sidereal, Mycalesis mineus, Mycalesis gotama, Penthema adelma, Neorina patria, Ypthima baldus, Ypthima praenubila, Ypthima multistriata, Ypthima lisandra, Danaus genutia, Parantica melaneus, Parantica agles, Ideopsis similis, Euploea core, Euploea midamus, Argynnis paphia, Argyreus hyperbius, Argyronome laodice, Hypolimnas bolina, Kaniska canace, Charaxes bernardus, Helcyra superba, Cyrestis thyodamas, Limenitis cleophas, Limenitis sulpitia, Athyma perius, Athyma nefte, Neptis hylas, Neptis clinia, Neptis soma, Neptis miah, Zemeros flegyas, Taraka Hamada, Curetis acuta, Arhopala paramuta, Deudorix epijarbas, Prosotas aluta, Jamides bochus, Zizeeria maha, Everes argiades, Tongeia filicaudis, Tongeia fischeri, Albulina orbitula, Chilades pandava, Abraximorpha davidii, Ampittia dioscorides, Astictopterus jama, Matapa aria, Telicota colon

E'xiandong	3500261002	596-639	24.7944°N 117.3321°E	24.8014°N 117.3380°E	Atrophaneura horishanus, Papilio helenus, Papilio protenor, Papilio Memnon, Papilio bianor, Eurema hecabe, Pieris rapae, Pieris canidia, Melanitis leda, Melanitis phedima, Lethe dura, Lethe syrcis, Lethe confuse, Lethe verma, Lethe chandica, Lethe sidereal, Neope bremeri, Neope muirheadii, Nosea hainanensisi, Mycalesis mucianus, Mycalesis gotama, Mycalesis francisca, Melanargia halimede, Ypthima baldus, Ypthima multistriata, Danaus genutia, Parantica sita, Parantica agles, Euploea core, Euploea midamus, Aemona amathusia, Stichophthalma howqua, Acraea violae, Argynnis paphia, Argyreus hyperbius, Argyronome laodice, Junonia iphita, Charaxes bernardus, Helcyra superba, Cyrestis thyodamas, Euthalia bunzoi, Limenitis sulpitia, Neptis Sappho, Neptis clinia, Neptis soma, Zemeros flegyas, Miletus chinensis, Taraka Hamada, Curetis acuta, Thecla betula, Arhopala paramuta, Heliophorus ila, Heliophorus saphir, Zizeeria maha, Everes argiades, Abraximorpha davidii, Ampittia dioscorides, Astictopterus jama, Taractrocera flavoides
Jinshanchun	3500261003	67-73	24.7552°N 117.3348°E	24.7492°N 117.3257°E	Byasa alcinous, Papilio polytes, Papilio helenus, Papilio protenor, Papilio bianor, Papilio paris, Graphium sarpedon, Catopsilia pyranthe, Eurema laeta, Eurema hecabe, Pieris rapae, Pieris canidia, Melanitis leda, Lethe dura, Lethe syrcis, Lethe helena, Lethe confuse, Lethe europa, Neope muirheadii, Mycalesis francisca, Melanargia halimede, Ypthima baldus, Ypthima praenubila, Ypthima multistriata, Danaus genutia, Parantica sita, Parantica melaneus, Parantica agles, Ideopsis similis, Euploea core, Acraea violae, Argyreus hyperbius, Junonia almanac, Symbrenthia hypselis, Sephisa chandra, Limenitis cleophas, Limenitis sulpitia, Neptis sappho, Neptis clinia, Zemeros flegyas, Allotinus drumila, Taraka hamada, Curetis acuta, Thecla betula, Deudorix epijarbas, Heliophorus epicles, Prosotas nora, Prosotas aluta, Euchrysops cnejus, Zizeeria maha, Everes argiades, Tongeia filicaudis, Tongeia fischeri, Chilades pandava, Polyommatus eros, Choaspes benjaminii, Parnara guttata
Louzai	3500261004	354-475	24.5252°N 117.2395°E	24.5261°N 117.2405°E	Byasa alcinous, Papilio polytes, Papilio helenus, Papilio protenor, Papilio bianor, Papilio dialis, Papilio paris, Papilio xuthus, Lamproptera curius, Graphium sarpedon, Eurema laeta, Eurema hecabe, Eurema blanda, Ixias pyrene, Pieris rapae, Pieris canidia, Talbotia naganum, Melanitis leda, Lethe christophi, Lethe hyrania, Lethe confuse, Lethe verma, Lethe sinorix, Lethe butleri, Lethe europa, Lethe chandica, Neope armandii, Neope muirheadii, Mandarinia regalis, Mycalesis mineus, Mycalesis gotama, Mycalesis francisca, Ypthima baldus, Danaus genutia, Tirumala limniace, Euploea core, Aemona amathusia, Stichophthalma howqua, Faunis aerope, Argyreus hyperbius, Childrena children, Kaniska canace, Symbrenthia lilaea, Mimathyma chevana, Rohana parisatis, Helcyra superba, Stibochiona nicea, Cyrestis thyodamas, Euthalia niepelti, Limenitis sulpitia, Athyma cama, Athyma selenophora, Neptis Sappho, Neptis hylas, Neptis clinia, Neptis soma, Neptis miah, Neptis cartica, Neptis ananta, Neptis alwina, Stiboges nymphidia, Zemeros flegyas, Taraka hamada, Arhopala bazalus, Mahathala ameria, Zizeeria maha, Abraximorpha davidii, Parnara guttata, Baoris farri

Nankeng	3500261005	282-359	24.5209°N 117.2389°E	24.5285°N 117.2252°E	Byasa alcinous, Papilio polytes, Papilio helenus, Papilio bianor, Papilio dialis, Papilio paris, Graphium cloanthus, Graphium sarpedon, Graphium chironides, Eurema laeta, Eurema hecabe, Prioneris thestylis, Pieris rapae, Pieris canidia, Talbotia naganum, Melanitis leda, Melanitis phedima, Lethe syrcis, Lethe confuse, Lethe europa, Lethe chandica, Lethe mekara, Neope armandii, Neope muirheadii, Mycalesis mineus, Mycalesis gotama, Ypthima baldus, Ypthima motschulskyi, Palaeonympha opalina, Tirumala limniace, Aemona amathusia, Argyreus hyperbius, Polygonia c-aureum, Junonia almanac, Rohana parisatis, Helcyra superba, Sasakia funebris, Cyrestis thyodamas, Euthalia niepelti, Athyma cama, Athyma selenophora, Athyma jina, Neptis hylas, Neptis clinia, Neptis nata, Neptis miah, Neptis ananta, Pantoporia hordonia, Stiboges nymphidia, Zemeros flegyas, Taraka Hamada, Curetis acuta, Arhopala paramuta, Mahathala ameria, Rapala varuna, Zizeeria maha, Abraximorpha davidii, Erionota torus, Iambrix salsala, Suastus gremius, Parnara ganga
Zijingshan	3500261006	257-503	24.4896°N 117.3598°E	24.4844°N 117.3631°E	Byasa alcinous, Papilio polytes, Papilio helenus, Papilio protenor, Papilio bianor, Papilio paris, Papilio xuthus, Graphium sarpedon, Eurema hecabe, Ixias pyrene, Delias pasithoe, Delias acalis, Prioneris thestylis, Cepora nerissa, Pieris rapae, Pieris canidia, Talbotia naganum, Melanitis leda, Melanitis phedima, Lethe syrcis, Lethe helena, Lethe confuse, Lethe verma, Lethe chandica, Neope muirheadii, Mandarinia regalis, Mycalesis mineus, Mycalesis mucianus, Mycalesis gotama, Penthema adelma, Ypthima baldus, Ypthima motschulskyi, Danaus genutia, Tirumala limniace, Euploea midamus, Aemona amathusia, Argyreus hyperbius, Kaniska canace, Polygonia c-aureum, Vanessa cardui, Helcyra superba, Stibochiona nicea, Euthalia niepelti, Euthalia kosempona, Limenitis sulpitia, Athyma jina, Parasarpa dudu, Neptis hylas, Neptis clinia, Neptis cartica, Abisara fylloides, Abisara neophron, Stiboges nymphidia, Zemeros flegyas, Taraka Hamada, Curetis acuta, Arhopala bazalus, Arhopala rama, Sinthusa chandrana, Heliophorus ila, Nacaduba kurava, Zizeeria maha, Zizeeria karsandra, Zizina Otis, Chilades lajus, Abraximorpha davidii, Ampittia dioscorides, Isoteinon lamprospilus, Astictopterus jama, Iambrix salsala, Parnara guttata

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