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HIGH SPECIES RICHNESS AND ENDEMISM CHARACTERIZE THE BUTTERFLY FAUNA OF VIETNAM'S CENTRAL HIGHLANDS (LEPIDOPTERA, PAPILIONOIDEA)

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ABSTRACT. The temperature and habitat gradients of tropical mountains contribute to their high species diversity and endemism. Recent fieldwork in the Central Highlands of Vietnam has found many taxa new to science, but the area remains poorly explored. We surveyed the butterflies of Kon Ka Kinh National Park between 1999 to 2019 and noted the habitat, seasons, and freshwater availability for each transect in 2018–2019. We found a total of 368 butterfly species including 80 documented in that region for the first time in 2018–2019. Nymphalidae (41.8%) was the most abundant butterfly family, and Riodinidae was the least common. We recorded higher species richness in disturbed forests, but many of the species we document are endemic or have restricted ranges. The diverse fauna is at a biogeographic crossroads of mostly Indo-Malayan species from the south and some high elevation specialists from the north meeting along an elevational and climatic gradient. Correspondence analysis demonstrates that season and forest type are the most important environment covariates influencing butterfly abundance in this unique tropical forest. These results demonstrate that the Central Highlands of Vietnam are not only species rich, but also home to many rare and endemic species found nowhere else, making the area a conservation priority.

Additional key words: biogeography, endemic, Lepidoptera, species richness, tropical forest

Tropical forests are packed with more species per unit area than almost any other terrestrial habitat on earth, and many species are endemic to high elevations (Rahbek et al. 2019a). Montane species often have narrow thermal tolerances and low dispersal ability (Polato et al. 2018, Rahbek et al. 2019b), making them sensitive to climate change and habitat disturbance (Pardikes et al. 2015, Bhattacharjee et al. 2017). While much research effort has focused on the Andes in South America (Herzog et al. 2017), Mt. Kilimanjaro in Africa (Albrecht et al. 2018), and Mt. Kinabalu in Malaysian Borneo (Chen et al. 2009, Merckx et al. 2015), few studies have examined the biodiversity of Vietnam's Central Highlands. This mountainous area was so poorly explored that two new cloven-hoofed mammal species (*Pseudoryx nghetinhensis* and *Muntiacus vuquangensis*) hid from the view of biologists in the Central Highlands until their descriptions in the late 20th century (Vu et al. 1993, Tuoc et al. 1994)

The Central Highlands of Vietnam is a unique region with a climate and flora markedly different from other areas in the Southeast Asian mainland (Fig. 1a) (Averyanov et al. 2003). Between March and April 1999, BirdLife International and the Forest Inventory and Planning Institute (FIPI, Vietnam) conducted the first field survey in the K'Bang and Mang Yang districts of Gia Lai province, which is now part of the core zone of Kon Ka Kinh National Park (N.P.) (Le et al. 2000). During this survey, data were collected on the physical, biological, and socio-economic features of this protected area covering 41,710 ha. The National Park ranges in elevation from 570 to 1,748 m and supports a range of montane habitat types (Le et al. 2000). Analysis of vegetation data shows that an area of 8,247 ha, equivalent to 20% of the National Park, has been degraded by past commercial logging activities and continuing illegal timber extraction. A further 12,286 ha, or 29% of the national park, has been cleared by commercial logging or shifting cultivation and now supports a range of secondary vegetation types (Le et al. 2000). During the last survey implemented twenty years ago, 652 vascular plant species were recorded, including 16 globally threatened species and 10 species endemic to Vietnam. In total, 42 species of mammal, 160 species of birds, 51 species of reptiles and amphibians, and 209 species of butterflies were recorded at Kon Ka Kinh N.P. during this survey (Le et al. 2000).

Butterflies are a visible and species-rich component of tropical faunas, playing important roles as food for vertebrate and invertebrate predators, as pollinators, and as indicators of environmental change (Thomas 2005, Bonebrake et al. 2010). The butterfly fauna of Vietnam is affected by its biogeographic position, which extends from the seasonal tropics at its southern tip (8.5° N latitude) to high elevation subtropics in the north of the country (23° N), where it can snow in the winter. The tropical butterfly fauna from the south mingles with temperate species from the north in the Central

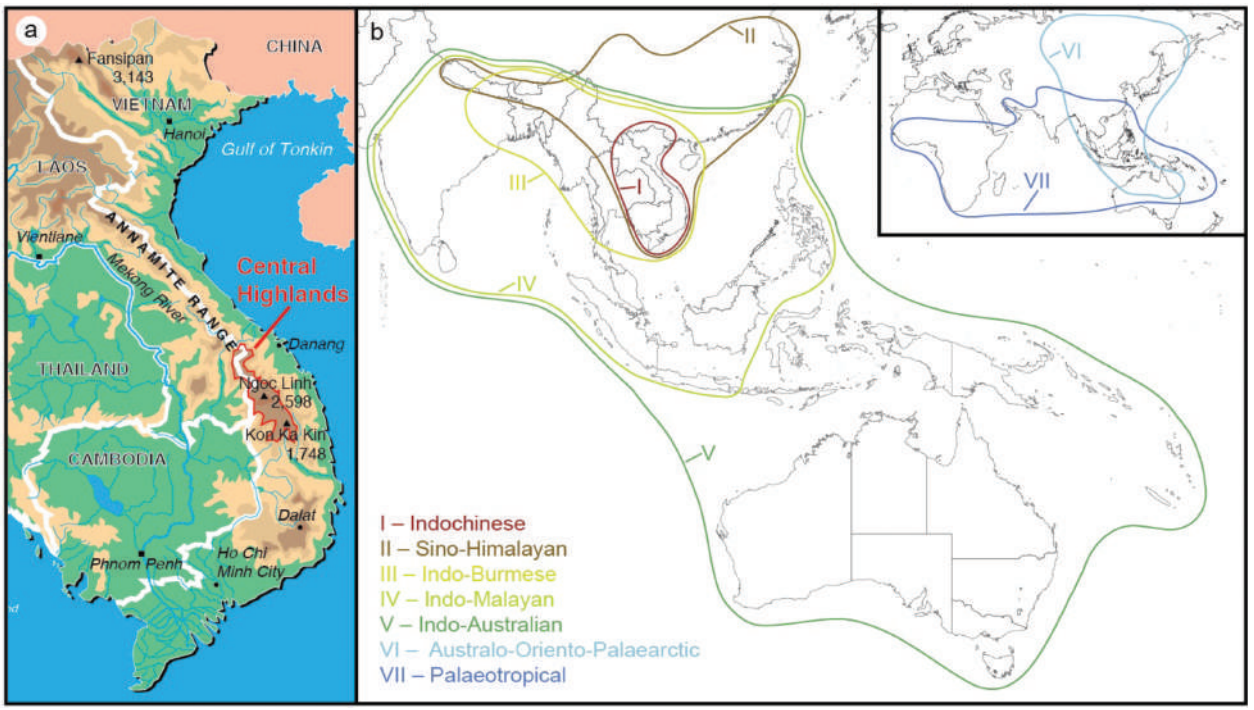

Fig. 1. **a)** Topographic map of Vietnam showing the Central Highlands and the country's highest peaks, including Kon Ka Kin. **b)** Categories of species distributions based on their geographic extent.

Highlands. The number of butterfly species documented in Vietnam increased from 455 species in 1957 to 1,181 species in 2015 (Metaye 1957, Monastyrskii & Devyatkin 2015). Since 2015, new genera, species, and subspecies have been described, bringing the total number of Papilionoidea to over 1,200 species (Monastyrskii & Uémura 2016, Saito & Inayoshi 2018, Hu et al. 2019). Previous studies suggest a relationship between butterfly diversity and environmental quality/habitat disturbance (Rod & Ken 1988, Ghazoul 2002, Hayes et al. 2009). Butterflies are sensitive to environmental changes, and they are excellent indicators of tropical forest disturbance (Hill et al. 1995, Hamer et al. 2003). At the same time, butterfly ecology is poorly studied in Vietnam, especially in the Central Highlands (Le et al. 2000, Tordoff et al. 2000, BirdLife International 2010).

Over the last twenty years, butterflies have been surveyed periodically within various areas of Vietnam's Central Highlands (BirdLife International 2010, Monastyrskii & Devyatkin 2015, Saito & Inayoshi 2018, Hu et al. 2019). Consequently, many new distribution records and taxa new to science have been recorded in the Central Highlands in and around Kon Ka Kinh N.P. (Monastyrskii & Devyatkin 2000, Monastyrskii 2012). More than twenty new taxa in the families Nymphalidae, Lycaenidae, and Hesperiidae were found in Ngoc Linh N.P., Kon Plong forest, Kon Chu Rang Nature Reserve (N.R)., Song Thanh N.P., and Ba Na N.R. and other sites in the Kon Tum Plateau and Central Truong Son Range (Monastyrskii & Devyatkin 2000, 2003, Monastyrskii 2005, 2012, Hu et al. 2019).

Kon Ka Kinh N.P. is part of the central Annamite Range extending from the northern border of Quang Nam Province at approximately 14° N latitude to the southern border of Gia Lai Province. The western boundary of Gia Lai runs along the Annamite Range in Laos, including the isolated Bolovens Plateau. The National Park supports some of the largest intact tropical forest ecosystems in the Central Truong Son Range, home to many globally threatened and vulnerable mammals, birds, reptiles, and amphibians (Le et al. 2000, Thinh et al. 2010, Monastyrskii 2012, Monastyrskii & Devyatkin 2015, Vislobokov et al. 2016). Kon Ka Kinh N.P. is also a globally important site for the conservation of insects, particularly butterflies. The park is home to a number of endemic species and three IUCN Red Listed species (Le et al. 2000, Tordoff et al. 2003).

In this study, we test the hypothesis that high butterfly species richness and endemism in Vietnam's Central Highlands is related to the Highlands' climate and other environmental factors, which are unique within the region. The range size of butterfly species

found in the Highlands is also assessed to gauge the endemicity of the fauna. We further provide an updated checklist of butterflies in Kon Ka Kinh N.P., including many new records. These results will inform conservation efforts aimed at ending logging in this crucial region, creating green corridors between protected areas, and developing systems to manage the natural resources of this biodiversity hotspot in the face of global climate change.

MATERIAL AND METHODS

Study location

Kon Ka Kinh N.P. is 41,780 ha in size (14.15º to 14.6º N; 108.27º E to 108.47º E) situated on the Kon Tum Plateau in the central Annamite Range (Le et al. 2000, Averyanov et al. 2003). The elevation ranges from 570 m at the Ba River to 1,750 m at Kon Ka Kinh Peak. The geologic substrate of Kon Ka Kinh includes metamorphic rocks, principally gneiss (Le et al. 2000). More than 33,000 ha (80%) of Kon Ka Kinh N.P. is covered in natural forest. It supports a range of montane habit types. The most important is a mixed coniferous and broadleaf forest including the cypress *Fokienia hodginsii* (Le et al. 2000, Tordoff et al. 2003).

The region has a tropical monsoon climate with warm winters and summer rain. There are two regular seasons in Kon Ka Kinh: the dry season from December to April and the rainy season from May to November (Le et al. 2000, Averyanov et al. 2003). In the dry season, the average monthly rainfall is less than 100 mm, whereas all recorded precipitation values exceed 200 mm during the rainy season (General Statistics Office 2018). Both the northern and southern boundaries of the Annamite Range are clearly determined by natural and climatic parameters: most of its area lies in a monsoonal tropical climatic zone with warm winters, rainy summers, and high annual precipitation (3,500-4,000 mm) (Monastyrskii 2007b, 2010). There are two main types of vegetation: montane evergreen forest (1,000 – 2,500 m); and evergreen forest at low and medium altitudes on silicate soils. Besides Kon Ka Kinh N.P., this zone includes the Song Thanh, Ngoc Linh, Kon Plong, and Kon Chu Rang protected areas.

Transect selection

To estimate butterfly abundance, we designated four 3 m wide transects along existing paths. These transects were created by local people for ecotourism or harvest of non-timber forest products, which is now forbidden. These 2 km long transects were selected because they pass through the various different habitat types within the Central Highlands. Data from transects at the same site collected in the two seasons (wet and dry) of 2018 and 2019 were combined (Table 1 & Appendix 1).

Transect 1 was situated in the flat area of a valley with disturbed, riverine forest. The surveys were conducted along a pre-exiting trail. Transect 1 started from a forest edge adjacent to an agricultural area (14.21º N; 108.32º E) to Frankfurt Station (14.22º N; 108.32º E) and varies in elevation from 800 m to 1,000 m a.s.l. Streams were common along this trail, and many puddling butterflies were recorded (Molleman 2010).

Transect 2 was situated along a logging trail. From 1980 – 2002, the Mang Yang Forestry Company managed the forest in the region, ceasing when Kon Ka Kinh N.P. was established. The trail is now used by local people for non-logging purposes. There were no streams along this transect. The elevation varies from 1,000 m to 1,200 m a.s.l.

Transect 3 was situated along a trail inside the restricted forest area. This trail crosses many streams, and varies in elevation from 1,200 m to 1,500 m. The observation was started at primary forest, where agricultural activities is banned.

Transect 4 was located in K'Bang District in primary evergreen montane forest in the vicinity of Kon Ka Kinh Peak. The transect route started from (14.33º N, 108.41º E) to Kon Ka Kinh Peak, and varied in elevation from 1,500 m to 1,700 m.

Ecological observations

Butterfly assemblages were sampled using the Pollard Walk method (Pollard 1975) as modified to study the butterfly populations in tropical forest ecosystems (Spitzer et al. 1993, Basset et al. 2011). Two cycles of transects was performed each year: one in each of the two seasons. This cycle included walking each of the four transects three times. Sampling was only carried out on sunny days with one transect per day. Transect observations began in the morning, when the trail was walked at a speed of approximately 15-20 m per min in one direction from 9.00 to 12.00. In the afternoon of the same day, the same transect was traversed again in the opposite direction from 13.00 to 16.00. The order of transects and initial direction of travel was random. On each transect, all observed butterflies were recorded and subsequently identified from photographs or collected specimens. The following data were recorded for each transect: geographic coordinates, elevation, season, date, number of specimens of each species recorded, habitat, and weather.

Taxonomic study

Butterfly identification was carried out using dichotomous keys and color plates from a variety of references (Corbet & Pendlebury 1992, Osada et al. 1999, Monastyrskii 2005, 2007a, 2011) and existing

TABLE 1. Number of species recorded in each butterfly subfamily in Kon Ka Kinh N.P. over 20 years of sampling. Dry season: December–April; rainy season: May–November

Family/ Subfamily	Dry	Rainy	Dry	Rainy	Dry	Total
Hesperiidae						
Coeliadinae	8	2	0	2	1	**10**
Pyrginae	5	5	2	2	18	**25**
Hesperiinae	17	12	5	12	14	**39**
Total	**30**	**19**	**7**	**16**	**33**	**74**
Lycaenidae						
Poritiinae	0	2	0	0	0	**2**
Curetinae	1	0	1	0	1	**1**
Lycaeninae	1	2	2	1	2	**4**
Miletinae	3	2	2	4	5	**7**
Polyommatinae	13	12	14	17	21	**33**
Theclinae	9	8	5	3	8	**22**
Total	**27**	**26**	**24**	**25**	**37**	**69**
Nymphalidae						
Apaturinae	0	3	2	3	3	**6**
Biblidinae	2	2	0	1	1	**2**
Calinaginae	0	0	0	1	0	**1**
Charaxinae	0	2	0	1	1	**3**
Danainae	11	6	2	8	7	**15**
Heliconiinae	9	6	0	2	6	**10**
Limenitidinae	18	17	3	11	22	**39**
Cyrestinae	3	2	1	2	2	**5**
Pseudergolinae	2	2	1	1	1	**3**
Libytheinae	2	0	0	0	1	**2**
Nymphalinae	7	6	2	4	5	**12**
Satyrinae	34	17	12	23	29	**56**
Total	**88**	**63**	**23**	**57**	**78**	**154**
Papilionidae						
Papilioninae	13	6	3	9	8	**25**
Pieridae						
Coliadinae	9	8	2	7	7	**11**
Pierinae	20	6	2	7	11	**22**
Total	**29**	**14**	**4**	**14**	**18**	**33**
Riodinidae						
Riodininae	10	6	6	3	9	**13**
Number of species	**197**	**134**	**67**	**124**	**183**	**368**

reference collections of Indochinese butterflies in the natural history museums in London and Paris examined by ALM. The higher taxonomic classification system used in this report was taken from recent works on butterflies of Vietnam and elsewhere in the region (Ackery et al. 1999, Wahlberg et al. 2003, Monastyrskii & Devyatkin 2015).

Biogeographic provenance

Each butterfly species was classified on the basis of its geographic distribution, ordered here from most restricted range to the most widespread: I – Indochinese endemic; II – Sino-Himalayan; III – Indo-Burmese; IV – Indo-Malayan; V – Indo-Australian; VI – Australo-Oriento-Palaearctic; VII – Palaeotropical (Fig. 1b) (Holloway 1973, Monastyrskii 2007b, 2010, Monastyrskii & Holloway 2013)

Diversity indices

Diversity indices were calculated with Past v.3.15 (Hammer 2001) using count data from the 2018 – 2019 transects. These included the Shannon Index, Simpson's Index, Menhinick's Richness Index, Margalef's Richness Index, Evenness, and Equitability J (Magurran 1988). Margalef indices do not depend on assumptions of species abundance (Hamer et al. 1997), and values ranged from 0 (single taxon) to 5 (many taxa) (Hammer 2001). Dominants are defined as the minimum number of butterfly species with total abundance not less than 40-50% of the total abundance of the assemblage (Pesenko 1982).

Statistical analysis

Data collected prior to the 2018 – 2019 field season are useful for documenting species occurrences but were collected haphazardly (they were not replicated transects), weakening our ability to draw inferences statistically. Rather than exclude data from previous investigations, we used correspondence analysis (CA) to examine the effects of environmental covariates on the presence of butterfly species in each family. Count data were examined with Past (Hammer 2001, Greenacre 2010). We used three sets of paired covariates: available water (streams) in the habitat (WA) *vs*. no available water (NWA); rainy season (RS) *vs*. dry season (DS); primary forest at high elevation (PH) *vs*. secondary forest at low elevation (SL). Multivariate models illustrate the correlation of dependent environmental factors on species abundance in each of the six families.

RESULTS

Taxonomic composition of the butterfly fauna in Kon Ka Kinh N.P.

A total of 368 butterfly species from 6 families were recorded during three rounds of surveys in Kon Ka Kinh N.P. in 1999, 2014–2016, and 2018–2019 (Appendix 1). Nymphalidae is the dominant family with 154 species (41.8% of total species recorded) of the total alpha diversity, followed by Hesperiidae (20.1%), Lycaenidae (18.8%), Pieridae (9.0%), Papilionidae (6.8%), and Riodinidae (3.5%). All 25 butterfly subfamilies found in Vietnam were recorded in Kon Ka Kinh N.P. There were 56 species in the subfamily Satyrinae, accounting for 15.2% of all species, making this the most species rich butterfly subfamily in the National Park. Hesperiinae (Hesperiidae) and Limenitidinae (Nymphalidae) were also species rich, accounting for more than 10% of the total. Seven subfamilies each accounted for less than 1% of the total butterfly richness: Poritiinae, Curetinae, Biblidinae, Calinaginae, Charaxinae, Pseudergolinae, Libytheinae (Table 1).

During the 2018–2019 survey, a total of 1001 individuals of 232 species were observed or sampled. The average number of observed individuals per species was 4.22 ± 0.47 (mean ± SE), Pieridae had the highest number of observed individuals per species (7.1 ± 2.12), followed by Nymphalidae (4.89 ± 0.95), Papilionidae, (3.93 ± 1.08), Lycaenidae (3.92 ± 0.65), Riodinidae (2.67 ± 0.5), and smallest in the Hesperiidae (2.22 ± 0.26).

New distribution records

The butterfly fauna in Kon Ka Kinh is remarkable for its diversity of co-existing congeners and for species newly recorded in Vietnam. Three species of *Faunis* and three *Stichophthalma* species co-occur in the park (Appendix 1). Our observations extend the distribution of *F. canens* into the southern part of the Central Vietnam to be sympatric with *F. bicoloratus*. This extends the southern extent of *F. canens'* distribution by at least 1.5 latitudinal degrees. Similarly, the range of *S. mathilda* was extended south by this study, and it co-occurs with *S. uemurai* and *S. eamesi*. This is similar to northern Vietnam where *S. mathilda* co-occurs with *S. suffusa* and *S. fruhstorferi*.

Two lycaenid species of the subfamily Miletinae, *Logania watsoniana* (900-1,000 m, 22 May 2018, female) and *Taraka mahanetra* (~1,300 m), were recorded in Vietnam for the first time. After our discovery of *T. mahanetra* on 6 April 2018, the species was recorded elsewhere in Gia Lai province and described as new subspecies, *T. m. miyagawai* (Saito & Inayoshi 2018). Two other lycaenids, *Miletus croton* (Miletinae) and *Leucantigius atayalicus* (Theclinae), were recorded in Gia Lai province for the first time. This is the first record of *Logania watsoniana* in Vietnam, and first record *Devyatkinia singularis* from Gia Lai province.

Table 2. The number of butterfly species recorded within different habitats at Kon Ka Kinh N.P. during surveys in 2018 -2019

Family	Transect 1 Secondary evergreen flat riverine forest at 800–1,000 m	Transect 2 Secondary forest at logging area at 1,000-1,200 m	Transect 3 Evergreen forest at 1,200–1,500m	Transect 4 Evergreen forest at 1,500–1,700m
Hesperiidae	26	19	6	11
Lycaenidae	37	18	9	8
Nymphalidae	65	48	23	31
Papilionidae	10	6	6	1
Pieridae	16	11	2	5
Riodinidae	5	4	1	3
Number of species	159	106	47	59
Percentage of species	68.5	45.7	20.3	25.4

In addition, *Coladenia indrani* (Hesperiidae, Pyrginae) (~1500 m, 18 May 2018, male), *Ethope diademoides* (Nymphalidae, Satyrinae) (~1500 m 6 April 2018), and *Pantoporia bieti* (Limenitidinae, Neptini) (~1500 m, 20 April 2016) were recorded in the Central Highlands of Vietnam for the first time during our surveys.

Butterfly ecology

Butterfly diversity and distribution

A total of 232 species from six families were recorded from surveys in 2018–2019 (Table 2). Many more species were sampled between 800–1200 m (190 species, Transects 1 and 2) than at higher elevations between 1,200–1,700 m (92 species, Transects 3 and 4). All butterfly families and subfamilies have few species at higher elevations, but this pattern was more distinct in the families Hesperiidae, Lycaenidae, Pieridae and some subfamilies of Nymphalidae.

Indices of the butterfly species diversity and dominance

Several indices of species richness, diversity, and dominance were calculated using samples from different elevations of tropical mountain evergreen forests (Table 3). The species richness and diversity of butterfly assemblages, as measured by indices including Shannon's H, Menhinick, and Margalef, were higher between 800–1200 m (transects 1, 2) than between 1200–1700 m (transects 3, 4). However, assemblages at both elevations were characterized by high and similar parameters of uniformity (Evenness, E and Equitability, J). The effects of recent logging near transect 2 apparently did not depress diversity or affect evenness, as the current evenness did not differ from evergreen forest as represented by transect 4 (Table 3). Indices of alpha diversity and dominance, based on data collected within forest habitats in both seasons, are shown in Table 2. A general pattern of decreasing dominance

Table 3. Indices of butterfly alpha diversity and dominance recorded at Kon Ka Kinh N.P.

	Transect 1	Transect 2	**T1+T2**	Transect 3	Transect 4	**T3+T4**
Species richness, S	159	106	190	47	58	92
Individuals	434	260	694	111	104	215
Dominance, D	0.01452	0.02571	0.01458	0.06193	0.04234	0.04264
Shannon's H	4.67	4.183	4.732	3.318	3.653	3.873
Evenness e^H/S	0.6708	0.6188	0.5975	0.5874	0.6653	0.5225
Menhinick	7.632	6.574	7.212	4.461	5.687	6.274
Margalef	26.02	18.88	28.89	9.767	12.27	16.94
Equitability, J	0.9212	0.8971	0.9018	0.8618	0.8996	0.8565
Fisher's alpha	90.48	66.73	86.29	30.76	54.06	60.89

TABLE 4. Relative abundance of dominant butterfly species observed (dominant species within a transect are marked with bold; endemic species is marked with *)

Dominant species	Transect 1	Transect 2	Transect 3	Transect 4
Notocrypta paralysos	**1.38**	0.38	0	0.96
Heliophorus ila	**2.07**	0.38	0	0.96
Allotinus drumila	**4.15**	1.54	0.90	0
Caleta roxus	**1.38**	0	0	0
Celastrina lavendularis	**1.61**	2	0	0
Lycaenopsis haraldus	**1.61**	**2.69**	0	0
Prosotas bhutea	**2.07**	1.15	0	0
Amblypodia anita	**1.38**	1.54	0	0
Yasoda tripunctata	**1.84**	0	0	2
Rohana parisatis	**1.38**	0.38	0	0.96
Cyrestis thyodamas	**1.38**	0	0	0
Euploea mulciber	**2.77**	1.15	**3.60**	0.96
Tanaecia lepidea	0	0	0	**2.88**
Lexias dirtea	0.92	0.38	0.90	**9.62**
Tanaecia julii	0.69	**4.62**	1.80	0.96
*Faunis bicoloratus**	0.69	0	**11.71**	**10.58**
Melanitis phedima	**1.38**	0.77	0	0
Mycalesis francisca	**1.38**	**1.92**	0	0.96
Mycalesis sangaica	1.15	**1.92**	0	0
Ragadia crisilda	**1.61**	**8.46**	**16.20**	**5.77**
Thaumantis diores	**5.53**	**3.08**	**8.11**	**9.62**
Meandrusa lachinus	0	0	**7.21**	0.96
Papilio helenus	0.46	**3.46**	0.90	0
Appias indra	0.92	**5.39**	**4.50**	0
Appias pandione	1.15	0.76	0	**3.85**
Leptosia nina	**4.15**	**6.15**	0	0
Talbotia naganum	0.46	**3.85**	0	0.96
Number of species	159	106	47	58
Number of individuals	434	260	111	104
Number of dominant species	17	10	6	6
Number of dominant individuals	161	108	57	44
Total richness (%)	37.07	41.54	51.33	42.32
Dominance_D	**0.01452**	**0.02571**	**0.06193**	**0.04234**
Simpson_1-D	**0.9855**	**0.9743**	**0.9381**	**0.9577**

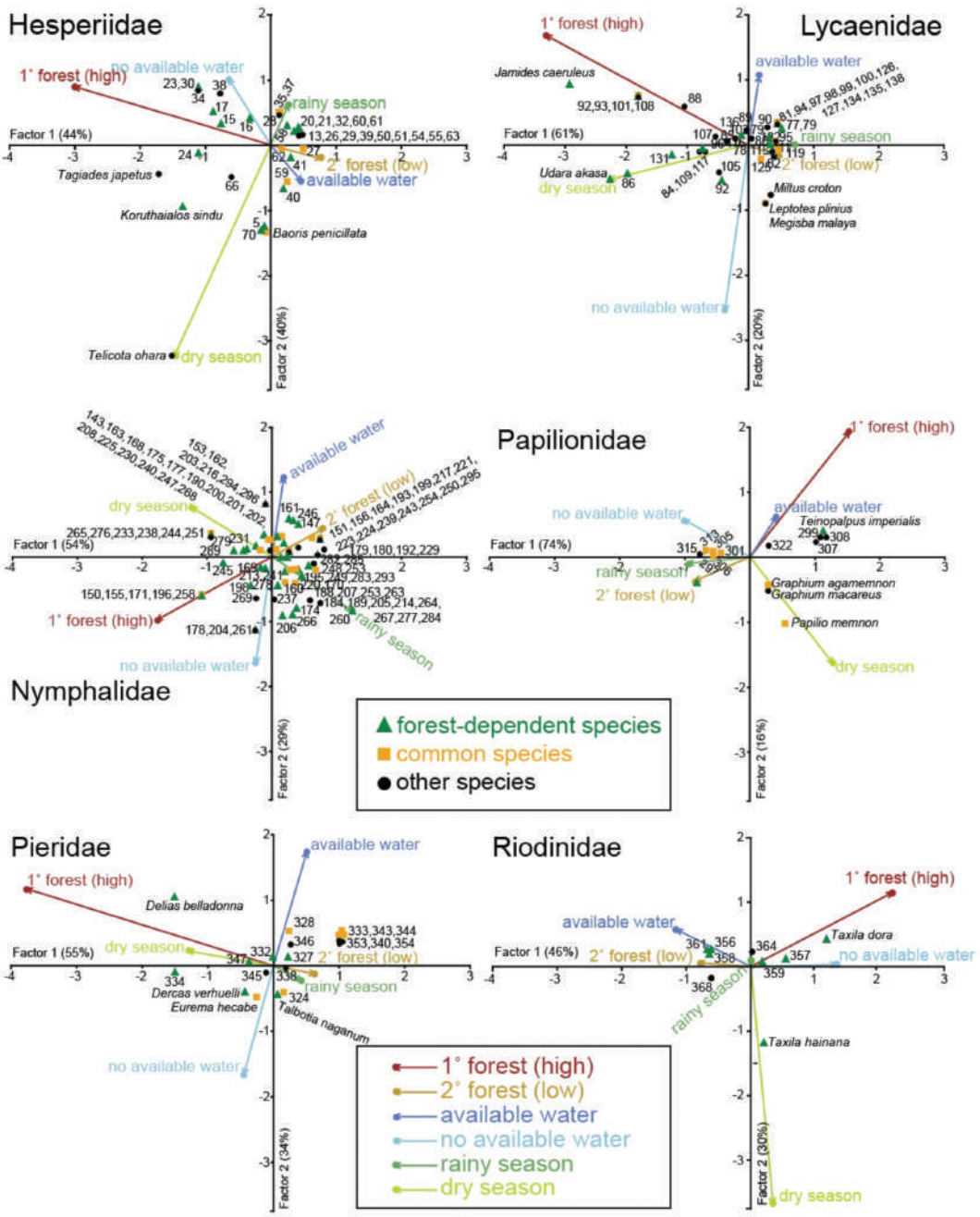

FIG. 2. Correspondence analysis between the occurrence of each species in relation to the environmental variables of its collection locality. The length of the lines connecting environmental variable points to the origin indicate the strength of the effect of the environmental factor on the abundance in each family. Arrows pointing in opposite directions indicate negatively correlated covariates, arrows pointing in the same direction are positively correlated, and arrows have no relation if they are at right angles (orthogonal). Colors of arrows indicate the type of environmental variable, and the color and shape of the points representing species indicate whether they were forest-dependent, common, or neither. The position of the species in relation to the environmental covariates indicates their dependance on them. Numbers refer to the species listed in Appendix 1. 1° forest – primary forest; 2° forest = secondary forest.

TABLE 5. Biogeographic composition of butterfly families at Kon Ka Kinh N.P.

Family	I	II	III	IV	V	VI	VII	Total
Papilionidae	0	4	5	12	4	1	0	26
Pieridae	2	0	10	12	4	1	3	32
Nymphalidae	12	23	40	62	10	3	5	155
Riodinidae	2	4	3	4	0	0	0	13
Lycaenidae	0	2	21	37	7	2	0	69
Hesperiidae	1	8	19	33	7	2	1	71
Total	**16**	**41**	**97**	**160**	**32**	**9**	**9**	**366**
Percentage	**4.3**	**11.3**	**26.6**	**44.0**	**8.8**	**2.5**	**2.5**	**100**

values in the wet season can be seen, attributable to a decrease in species richness and abundance. Simpson's parameter demonstrates high evenness in the forest areas and during the seasons studied, which shows low dominance of individual species. The majority of species are characterized by low abundance that varies from 0.1 to 2.0%, demonstrating a high level of equitability and evenness. Groups of dominant species were chosen based on these uniform patterns of abundance. Of 232 species observed within all transect during all seasons, only 27 species (11.6%) were characterized by percentage abundance exceeding 1.4% of the total number of specimens recorded. Dominant species represented between 1.4 and 16.2 % of the total number of specimens (Table 4).

Dependance on environmental factors

Species recorded in the 2018–2019 surveys were included in our ordination analyses, which demonstrated that microhabitat conditions influence the occurrence of species in different ways depending on the butterfly family (Fig. 2). In the species-rich families of Hesperiidae, Lycaenidae, and Nymphalidae, opposite environmental variables were strongly negatively correlated: dry *vs*. wet season, available water *vs*. no available water, primary *vs.* secondary forest. These environmental factors also affected species abundance in Pieridae, which is not a species rich family in Vietnam nor in Kon Ka Kinh N.P. However, in the Papilionidae and Riodinidae, the availability of water was orthogonal (or nearly so) to no available water. Primary forest strongly influenced both species richness and abundance of all families, and the dry season had a stronger effect than the wet season. While there were no clear patterns in the environmental preferences of forest dependent and common species, there was a tendency for forest-dependent species to be associated with primary forest (Fig. 2).

The two axes of each ordination plot explained 80 – 90% of variation in occurrence: Hesperiidae (84%; x: E_1: 0.29; y: E_2: 0.26) (Cumulative value; x: Eigenvalue of factor 1; y: Eigenvalue of factor 2), Lycaenidae (81%, 0.27; 0.09), Nymphalidae (83%, 0.21; 0.11), and Pieridae (89%, 0.16; 0.10). These values represent for 90% of Papilionidae species (E_1: 0.57; E_2: 0.12), but only 75% for Riodinidae species (E_1: 0.25; E_2: 0.17). Season and forest type were the principal factors influencing butterfly abundance. For instance, *Astictopterus jama, Hypolycaena amasa, Cirrochroa tyche, Lamproptera curius, Leptosia nina*, and *Zemeros flegyas* were commonly observed in the rainy season when streams were flowing (available freshwater), and in lowland secondary forest habitats, but they were less abundant or not recorded in high elevation primary forest in the absence of streams, nor in the dry season.

Biogeographic structure

Endemic and restricted-range species comprised a higher proportion of the diversity at higher elevations (> 1,200 m) than at mid-elevations (800–1,200 m) (Fig. 3). The proportion of restricted-range species (categories I and II) at high elevations and mid-elevations representatively occupied 32.7% and 11.6% of the sampled specimens, respectively. The biogeographic composition of butterfly families found at Kon Ka Kinh N.P. is shown in Table 5. Details of the range type of each species are given in Appendix I, but note that ranges of four Hesperiidae species have not yet been clarified. Details on of species in the first five biogeographic categories (Fig. 1) are described below:

I. (Indochinese distribution) We sampled nine species endemic to Vietnam (all Nymphalidae: Satyrinae): *Aemona kontumei*; *A. simulatrix*; *A. tonkinensis*; *Stichophthalma mathilda*; *S. uemurai*; *Faunis bicoloratus*; *Lethe melisana*; *L. konkakini*; and *Devyatkinia singularis*. The first six species listed above are in the tribe Amathusiini, and are found only in the Central Highlands of Vietnam; they have not been recorded elsewhere. We also sampled several species

endemic species to Indochina: *Oriens goloides* (Hesperiidae); *Stichophthalma eamesi*, *Ragadia critias* (Nymphalidae: Satyrinae); *Eurema novapallida* and *Delias vietnamensis* (Pieridae); and *Dodona katerina* and *Taxila dora* (Riodindae).

II. (Sino-Himalayan distribution) In Vietnam, species in this group comprise more than 10% of the montane butterfly fauna and comprise 11.3% of Kon Ka Kinh's butterflies. Around 60% species of this group are nymphalids, most of which are Satyrinae (11) or Limenitidinae (8). There are eight skipper genera (Hesperiidae) in this category, seven of which belong to subfamilies Pyrginae (*Capila*, *Celaenorrhinus* and *Seseria*) and Coeliadinae (*Hasora* and *Choaspes*).

III. (Indo-Burmese distribution) Species characteristic of the Indo-Burmese faunistic element are spatially distributed uniformly in Vietnam, but are perhaps better represented in the central and southern areas of the country, where their contacts with Sino-Himalayan species are less extensive (Monastyrskii, 2007). In Kon Ka Kinh, 26.7% of the species are Indo-Burmese (category III, which is similar to the percentage throughout the Central Annamite Range (25.6%). Of the 97 Indo-Burmese species in category III, 61.3% are Nymphalidae (41.2% of the total) and Lycaenidae (20.1%).

IV. (Indo-Malayan distribution) These species in category IV include many of the dominant species in Kon Ka Kinh (43%) (Table 4). At mid-elevations (transects 1 and 2) species in this category comprised 46% of the total, which is 20% higher than at high elevations (transects 3 and 4). Species in this category found in Vietnam are in genera that are most species-rich in the Indo-Australian Archipelago or Philippine Islands (*e.g.*, *Delias georgina*-group).

V. (Indo-Australian distribution) and **VI.** (Australo-Oriento-Palaearctic distribution) include 32 and 9 species, respectively, in Kon Ka Kinh. Neither groups include Riodinidae nor species in the nymphalid subfamilies Biblidinae, Cyrestinae, Charaxinae, Apaturinae or Satyrinae. The subfamilies Heliconiinae and Limenitidinae in Kon Ka Kinh include in single species of group V and VI respectively. The highest number of species in both groups consists of danaines, nymphalines, papilionids and pierids.

VII. (Paleotropical distribution) Species in category VII were not recorded at high elevations. Among the few butterfly species in Vietnam with ranges spread throughout tropical and subtropical zones of the Old World, some are common: *Catopsilia pomona*, *Eurema hecabe* (Pieridae), *Melanitis leda* (Nymphalidae: Satyrinae), *Argynnis hyperbius*, and *Phalanta phalantha* (Nymphalidae: Heliconiinae).

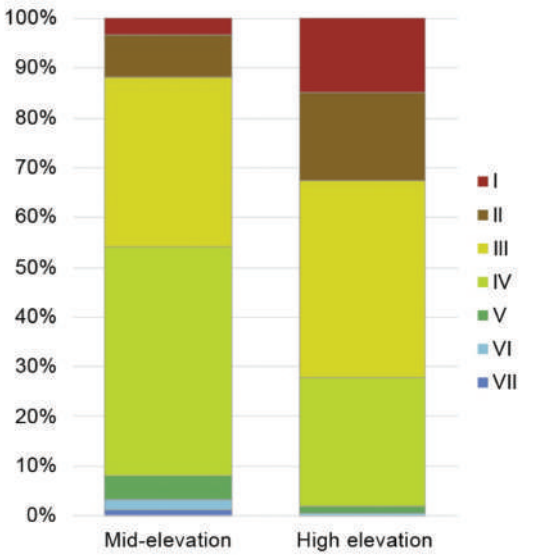

Fig.3. Range-restricted species are proportionally more abundant at higher elevations. Stacked bars indicate the proportion of species in each of 7 biogeographic categories at mid elevations (Transects 1 and 2; 800-1200 m) and high elevations (Transects 3 and 4; 1200-1700 m). The categories indicate endemism and range size; category I is the most range-restricted (Indochinese endemics) and VII is the most widespread (Paleotropical distribution); see Fig. 1.

Discussion

Diversity of butterfly fauna in Kon Ka Kinh National Park

The species diversity of tropical butterflies is much higher than temperate regions; for example, the number of butterfly species recorded from Vietnam is ten times greater than butterfly fauna of the British Isles. The richness of Kon Ka Kinh is unusually high: 368 species in 6 families. This is more than four times greater than the entire butterfly fauna of the United Kingdom, which comprises ca. 80 native species (Riley 2007). It is also higher than other protected areas in Indochina, such as Hoang Lien N.P (302 species), Tam Dao N.P (363 species) in the north (Vu & Dang 2002), Ngoc Linh N.P (236 species) in central Vietnam (Le et al. 1999), Doi Inthanon N.P Chiang Mai province, (296 species) (Tasen et al. 2007), and Namnao N.P, Petchabun province (323 species) (Choldumrongkul & Chumnarnkid 1998) in Thailand. Interestingly, aside from our study site, only two other areas in Vietnam are known to support all 25 subfamilies: Hoang Lien Mountain Range and Kon Tum Plateau. High evenness and equitability (J) among species are another indication of the paucity of truly dominant species in

our surveys. Evenness is sometimes considered the most important index of community structure (Magurran 2003). Our surveys indicate that the forests of the Central Highlands harbor a unique and distinctive fauna with many geographically restricted species.

Long-term studies of butterfly communities at different sites in Vietnam have identified a set of 105 common butterfly species (Monastyrskii & Devyatkin 2002, Monastyrskii 2010). The proportion of these common butterfly species differs among habitats. In primary and virgin tropical forest habitats they rarely exceed 20–25% of the total number of species. In lightly disturbed and secondary forest habitats, the percentage may vary between 25–45%. In poor quality forest, bamboo and mixed secondary forests, common butterflies comprise ca. 45–50% of species, and in secondary vegetation in the vicinity of roads and cultivated areas the ratio of common butterfly is higher than 60% (Monastyrskii 2007b). The low proportion of common species in Kon Ka Kinh National Park suggests that the butterfly fauna is intact and currently protected (Vu & Yuan 2003, Monastyrskii 2007b, Hayes et al. 2009).

Butterfly extensions of distribution records

Logania watsoniana (Lycaenidae: Miletinae) has been recorded from India, Myanmar, Thailand, Laos (Eliot 1986, New 1993), and now Vietnam. Two *Logania* species have been recorded from Lam Dong province on the Dalat Plateau (Monastyrskii & Devyatkin 2015). All species in the lycaenid subfamily Miletinae are aphytophagous (Pierce 1995), meaning that the larvae do not feed on plants. In Malaysia, *Logania malayica* larvae eat aphids that live with ants (Fiedler 1993) on ginger plants, but the biology of *L. watsoniana* is unknown. Prior to this study, *Coladenia indrani* and *Ethope diademoides* were recorded in Vietnam only in Binh Thuan (Monastyrskii & Devyatkin 2003, Miyazaki & Saito 2010, Monastyrskii & Devyatkin 2015). Furthermore, our surveys recorded three co-occurring *Faunis* species in Kon Ka Kinh N.P.: *F. bicoloratus*, *F. canens*, and *F. eumeus*. Of these species, *F. eumeus* is a common butterfly and has a wide distribution in Vietnam (Vu & Yuan 2003, Larsen et al. 2005, Monastyrskii 2011). Within Vietnam, *F. canens* was previously known from northern Vietnam south to Quang Tri province (Monastyrskii 2011, Monastyrskii & Devyatkin 2015), and *F. bicoloratus* was recorded from Quang Ngai province to southern Vietnam.

Other taxa newly recorded from Kon Ka Kinh N.P. during our surveys include *Euthalia bunzoi danangensis*, *Neptis sankara sugimotoi*, *N. cartica teshirogii*, *N. zaida inayoshii*, (Limenitidinae); *Kallima alicia kishii* and *K. incognita* (Nymphalinae); and *Faunis bicoloratus*, *Ethope diademoides metayei*, *Lethe melisana*, *Devyatkinia singularis* (Satyrinae). Most of these species had been previously documented in adjacent areas of the Central Highlands including Ba Na N.P. (Da Nang Province), Bao Loc (Lam Dong Province), and Ngoc Linh N.P. (Kon Tum Province) (Monastyrskii & Devyatkin 2003, Monastyrskii 2005, 2010, Nakamura 2014, Monastyrskii & Uémura 2016, Saito & Inayoshi 2018). Most of these species and subspecies are endemic to the Central Highlands and other montane areas of Indochina. Some of them have not been recorded yet outside the Kon Tum plateau, which includes Kon Ka Kinh N.P.: *L. konkakini*; *L. melisana*, *A. kontumei*.

Butterfly biogeography

The butterfly fauna of Vietnam includes species with different ranges and range sizes. These distributions vary from strict endemics to cosmopolitan species (Monastyrskii 2010, Monastyrskii & Holloway 2013). For ease of analysis, species with different ranges can be classified into discrete categories. Most of the butterflies of in Vietnam's Central Highlands are found elsewhere in the Indo-Malayan region. Nearly half of recorded species are restricted to the Indo-Malayan Region including montane taxa found in southeast China. In a previous study, Hamer et al. (1997) demonstrated a correlation between an index of biogeographic distinctiveness and forest disturbance. We failed to replicate this result. We found no Holarctic or cosmopolitan species (Monastyrskii & Holloway's [2013] categories VIII and IX). These widespread butterflies, *Lampides boeticus* and *Vanessa cardui*, were recorded in nearby regions, both Central Truong Son and Dalat Plateaus, but the species were not observed during our surveys. We assume that these widespread species will eventually be recorded, which would further increase the number of butterflies in Kon Ka Kinh N.P. Most of the six species in category I (Indochina endemics) are recorded only from the Central Highlands of Vietnam and are in the tribe Amathusiini (Nymphalidae: Satyrinae). In this study, species with Indo-Burmese distributions (category III) in Vietnam are better represented in the central and southern areas of the country, where their contacts with Sino-Himalayan species are less extensive (Monastyrskii 2007b).

Environmental covariates strongly influence the community composition of tropical montane butterflies

In tropical rain forests, seasons can influence butterfly diversity and abundance because of varying temperature, humidity, and day length (Jones & Rienks 1987, Pollard 1991, Dover 1996, Checa 2016). Butterfly abundance generally increases with increasing

temperatures and non-monsoonal precipitation, and temperature affects courtship and feeding behavior (Beck et al. 1999, Boonvanno et al. 2000, Checa 2016). Our observations were confined to sunny days with low precipitation in both seasons. The main difference between rainy season and dry seasons is the temperature and number of rainy days. Therefore, the apparent abundance of tropical butterflies increases in the rainy season and decreases in the dry season (Leps & Spitzer 1990, Spitzer et al. 1993, Bonebrake et al. 2010), similar to other investigations in Vietnam: Cuc Phuong (Larsen et al. 2005) and Tam Dao (Spitzer et al. 1993). While some studies report higher species richness in tropical primary forests, others report more species in disturbed forests (Koh et al. 2004, Koh 2007). We demonstrate that species abundance is higher in secondary than in primary forest (Table 2). Butterflies are attracted to streamside areas where they can imbibe water, salts, and perhaps other nutrients from mud puddles and other wet spots (Oostermeijer & Van Swaay 1998, Larsen et al. 2005). Thus, adult butterflies are often highly concentrated along riverine forests (Oostermeijer & Van Swaay 1998, Vu & Dang 2002, Hayes et al. 2009). However, our correspondence analysis demonstrates that season and habitat type are more powerful predictors of butterfly diversity than the presence of freshwater (Fig. 2). This could be because female butterflies prefer to remain near their species' host plants, and only males fly around seeking sodium to pass to females during mating (Hamer et al. 2006, Molleman 2010).

Our findings should be interpreted in the context of several potential limitations. Other studies have documented similar relationships between butterfly diversity and environmental variables including temperature, precipitation, and season, (Hill et al. 1995, Boonvanno et al. 2000, Hamer et al. 2005). One limitation of this study was that we could not measure precipitation; however, our observations occurred on rain-free days during both two seasons, so results from the two seasons are likely comparable with each other. The effects of increased rainfall during the rainy season include great available freshwater and increased production of tender, new plant growth preferred as food by most butterfly larvae (Floater 1997). Thus, measured differences in rainfall between the seasons is unlikely to explain much of the variance in our data.

In conclusion, our analyses demonstrate high diversity and high endemism of butterflies in Kon Ka Kinh, a previously poorly studied site in the Central Highlands of Vietnam. Variation in species composition is influenced primarily by differences in season and forest type rather than the availability of freshwater, and there were family-specific differences in microhabitat conditions that affected species occurrences. These results, in concert with the new species occurrence records we document, demonstrate the high conservation value of Vietnam's Central Highlands and the need to prevent future habitat loss or land use change within its protected areas.

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Appendix 1. Checklist of species found in Kon Ka Kin N.P. indicating presence/absence in different seasons and category of each species' distribution. Numbers correspond to species in Fig. 2. *forest-dependent species; (N) new taxa (species or subspecies) first discovered in Kon Ka Kinh N.P.; (V) new records for Vietnam. The taxonomy of butterflies recorded in 1999 (Le et al. 2000) has been updated, and taxa with "sp." are unidentified species

No.	Taxon	Distribution Category	Dry (4/1999)	Rainy (2014-16)	Dry (2014-16)	Dry (2018-19)	Rainy (2018-19)
	Hesperiidae: Coeliadinae						
1	*Burara vasutana*	III	0	1	0	0	0
2	*Burara harisa*	IV	0	1	0	0	0
3	*Burara amara*	III	0	1	0	0	0
4	*Bibasis sena*	IV	0	1	0	0	0
5	*Hasora vitta*	V	1	0	0	1	0
6	*Hasora chromus*	V	1	0	0	0	0
7	*Hasora schoenherr**	IV	1	0	0	0	0
8	*Hasora salanga*	IV	0	1	0	0	0
9	*Hasora malayana*	IV	1	1	0	0	0
10	*Hasora taminatus*	II	1	0	0	0	0
11	*Badamia exclamationis*	V	1	0	0	0	0
12	*Choaspes subcaudata**	IV	0	0	0	1	0
13	*Choaspes stigmata**	IV	1	0	0	0	1
14	*Choaspes furcata**	II	1	0	0	0	0
	Hesperiidae: Pyrginae						
15	*Capila lidderdali**	II	0	0	0	0	1
16	*Capila pauripunetata**	II	0	0	0	0	1
17	*Capila pennicillatum**	III	0	0	0	0	1
18	*Capila jayadeva**	III	0	0	1	0	1
19	*Celaenorrhinus asmara**	IV	1	0	0	0	0
20	*Celaenorrhinus aspersa**	II	0	0	0	0	1
21	*Celaenorrhinus leucocera**	III	0	0	0	0	1
22	*Celaenorrhinus pyrrha*	III	0	1	0	0	0
23	*Celaenorrhinus patula**	II	0	0	0	0	1
24	*Celaenorrhinus putra**	IV	1	1	0	1	1
25	*Darpa striata*	IV	1	0	0	0	0
26	*Darpa pteria*	IV	1	0	0	0	1
27	*Pseudocoladenia dan*	IV	0	0	0	0	1
28	*Coladenia agni*	IV	0	0	0	0	1
29	*Coladenia indrani*	III	0	0	0	0	1
30	*Satarupa gopala**	IV	0	1	0	0	1
31	*Seseria sambara*	II	1	0	0	0	0
32	*Gerosis tristis**	III	0	0	0	0	1
33	*Gerosis sinica*	III	0	1	0	0	0
34	*Tagiades cohaerens*	III	0	0	0	0	1
35	*Tagiades gana*	III	0	0	1	0	1
36	*Tagiades japetus*	V	0	0	0	1	0
37	*Tagiades litigiosa*	III	0	0	0	0	1
38	*Tagiades menaka*	IV	0	1	0	0	1
39	*Mooreana trichoneura*	IV	0	0	0	0	1

Appendix 1. Page 2

No.	Taxon	Distribution Category	Dry (4/1999)	Rainy (2014-16)	Dry (2014-16)	Dry (2018-19)	Rainy (2018-19)
	Hesperiidae: Hesperiinae						
40	*Ancistroides nigrita*	IV	0	1	0	1	1
41	*Astictopterus jama*	IV	1	0	0	1	1
42	*Arnetta atkinsoni*	III	1	0	0	0	0
43	*Baoris penicillata*	IV	0	0	0	1	0
44	*Baoris farri*	IV	0	1	1	0	0
45	*Borbo cinnara*	V	1	0	0	0	0
46	*Caltoris sirius*	III	1	0	0	0	0
47	*Caltoris tenuis*	III	1	0	0	0	0
48	*Caltoris cormasa*	IV	1	0	0	0	0
49	*Caltoris confusa*	III	1	0	0	0	0
50	*Halpe clara*	III	0	1	0	0	1
51	*Halpe pelethronix*	IV	1	0	0	0	0
52	*Hyarotis adrastus*	IV	1	0	0	0	0
53	*Iambrix salsala*	IV	1	1	0	0	1
54	*Iton semamora*	IV	0	0	0	0	1
55	*Koruthaialos rubecula* *	IV	0	1	0	0	1
56	*Koruthaialos sindu**	IV	0	0	0	1	0
57	*Lotongus calathus*	IV	1	0	0	0	0
58	*Matapa sasivarna**	IV	0	0	1	0	1
59	*Notocrypta clavata*	IV	0	1	0	1	1
60	*Notocrypta curvifascia**	VI	0	0	0	0	1
61	*Notocrypta feisthamelii**	IV	1	0	1	1	1
62	*Notocrypta paralysos*	IV	0	1	0	1	1
63	*Oriens goloides*	I	0	0	0	0	1
64	*Parnara* sp.	¬--	0	0	0	1	0
65	*Parnara bada*	VII	1	0	0	0	0
66	*Polytremis eltola*	III	0	0	1	1	1
67	*Polytremis lubricans*	VI	1	0	0	1	0
68	*Potanthus* sp.	--	1	0	1	0	1
69	*Pyroneura margherita*	III	1	0	0	0	0
70	*Sebastonyma dolopia**	II	0	0	0	1	0
71	*Suada swerga**	IV	1	0	0	0	0
72	*Telicota colon*	V	0	1	0	0	0
73	*Telicota ohara*	V	0	0	0	1	0
74	*Thoressa* sp.	--	0	0	0	0	1
	Lycaenidae: Poritiinae						
75	*Poritia erycinoides*	IV	0	1	0	0	0
76	*Poritia hewitsoni*	III	0	1	0	0	0
	Lycaenidae: Curetinae						
77	*Curetis bulis*	III	1	0	1	0	1
	Lycaenidae: Lycaeninae						
78	*Heliophorus epicles*	IV	0	0	0	0	1
79	*Heliophorus ila*	IV	1	1	0	1	1

Appendix 1. Page 3

No.	Taxon	Distribution Category	Dry (4/1999)	Rainy (2014-16)	Dry (2014-16)	Dry (2018-19)	Rainy (2018-19)
	Lycaenidae: Miletinae						
80	*Allotinus drumila**	III	1	1	1	1	1
81	*Logania watsoniana** (V)	III	0	0	0	0	1
82	*Miletus chinensis*	III	1	0	0	0	1
83	*Miletus croton*	III	0	1	1	0	1
84	*Miletus mallus*	III	1	0	0	1	1
85	*Taraka hamada*	IV	0	0	0	1	0
86	*Taraka mahanetra** (V)	IV	0	0	0	1	0
	Lycaenidae: Polyommatinae						
87	*Una usta**	IV	0	1	1	0	0
88	*Acytolepis puspa*	IV	1	1	1	1	1
89	*Caleta elna*	IV	0	1	1	1	1
90	*Caleta roxus*	IV	1	1	1	1	1
91	*Cupido lacturnus*	V	0	1	0	0	0
92	*Callenya melaena**	III	1	0	1	1	1
93	*Castalius rosimon*	IV	0	0	0	1	0
94	*Catochrysops panormus*	V	0	1	1	0	1
95	*Celastrina lavendularis*	V	0	0	1	0	1
96	*Celatoxia marginata*	III	1	0	0	1	1
97	*Discolampa ethion*	IV	1	0	1	0	1
98	*Ionolyce helicon*	V	0	1	0	0	1
99	*Jamides alecto**	IV	0	1	0	0	1
100	*Jamides bochus*	IV	0	1	0	0	1
101	*Jamides caerulea**	IV	0	0	0	1	0
102	*Jamides celeno*	IV	1	0	1	1	0
103	*Jamides pura*	IV	1	0	0	0	0
104	*Leptotes plinius*	V	0	0	0	0	1
105	*Lycaenopsis haraldus*	IV	0	1	1	1	1
106	*Megisba malaya*	IV	1	0	1	0	1
107	*Nacaduba beroe*	IV	0	0	1	1	1
108	*Niphanda tessellata*	IV	0	0	0	1	0
109	*Pithecops corvus*	IV	1	0	0	1	1
110	*Pithecops fulgens*	IV	0	1	0	0	0
111	*Prosotas bhutea**	III	0	0	0	1	1
112	*Prosotas dubiosa*	IV	0	0	1	0	0
113	*Udara akasa**	III	0	0	0	1	0
114	*Udara selma*	III	0	1	0	0	0
115	*Udara albocaeruleus**	III	1	0	1	0	1
116	*Udara dilectus*	V	1	0	1	1	1
117	*Udara placidula**	III	1	0	0	1	1
118	*Zizina otis*	IV	1	0	0	0	0
119	*Pseudozizeeria maha*	VI	0	1	0	0	1

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No.	Taxon	Distribution Category	Dry (4/1999)	Rainy (2014-16)	Dry (2014-16)	Dry (2018-19)	Rainy (2018-19)
	Lycaenidae: Theclinae						
120	*Cigaritis syama*	IV	0	1	0	0	0
121	*Cigaritis lohita*	IV	0	1	0	0	0
122	*Deudorix epijarbas*	V	0	1	0	0	0
123	*Leucantigius atayalica*	II	0	0	1	0	0
124	*Ravenna niveus** (N) (ssp. *miyagawai*)	III	1	0	0	0	0
125	*Amblypodia anita*	III	0	1	0	1	1
126	*Arhopala atosia**	IV	0	0	0	0	1
127	*Arhopala aurelia**	III	0	0	0	0	1
128	*Arhopala arvina*	IV	0	0	1	0	0
129	*Arhopala birmana**	II	1	0	0	0	0
130	*Arhopala eumolphus**	VI	1	0	0	0	0
131	*Bindahara phocides**	IV	0	0	0	1	0
132	*Hypolycaena amasa*	IV	0	1	1	0	1
133	*Hypolycaena kina*	III	0	0	1	0	0
134	*Hypolycaena erylus*	IV	1	0	0	0	1
135	*Surendra quercetorum*	III	1	1	1	0	1
136	*Yasoda tripunctata**	III	1	1	0	1	1
137	*Sinthusa chandrana*	II	0	1	0	0	0
138	*Rapala rhoecus**	IV	0	0	0	0	1
139	*Rapala iarbus**	IV	0	0	1	0	0
140	*Rapala manea**	IV	1	0	0	0	0
141	*Rapala pheretima*	IV	1	0	0	0	0
142	*Rapala nissa**	IV	1	0	0	0	0
	Nymphalidae: Biblidinae						
143	*Ariadne merione**	IV	1	1	0	1	1
144	*Laringa horsfieldii**	IV	1	1	0	0	0
	Nymphalidae: Cyrestinae						
145	*Chersonesia risa**	IV	1	1	0	0	1
146	*Chersonesia intermedia**	IV	0	0	0	1	0
147	*Cyrestis thyodamas**	III	1	0	1	1	1
148	*Cyrestis nivea**	IV	0	1	0	0	0
149	*Cyrestis themire**	IV	1	0	0	0	0
	Nymphalidae: Pseudergolinae						
150	*Dichorragia nesimachus**	V	1	0	0	1	0
151	*Stibochiona nicea**	III	1	1	1	0	1
152	*Pseudergolis wedah*	II	0	1	0	0	0
	Nymphalidae: Calinaginae						
153	*Calinaga bedoci** (N) (ssp. *distans*)	II	0	0	0	1	0
	Nymphalidae: Charaxinae						
154	*Charaxes bernardus*	IV	0	1	0	0	0
155	*Charaxes kahruba**	III	0	0	0	1	0
156	*Polyura athamas*	IV	0	1	0	0	1

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No.	Taxon	Distribution Category	Dry (4/1999)	Rainy (2014-16)	Dry (2014-16)	Dry (2018-19)	Rainy (2018-19)
	Nymphalidae: Danainae						
157	*Danaus genutia*	V	1	0	0	0	0
158	*Danaus chrysippus*	VII	0	1	0	0	0
159	*Ideopsis vulgaris*	IV	1	1	0	0	0
160	*Euploea algea*	V	1	0	0	1	1
161	*Euploea doubledayi**	IV	1	0	0	1	1
162	*Euploea eunice**	V	0	0	0	1	0
163	*Euploea mulciber*	IV	1	1	0	1	1
164	*Euploea radamanthus**	IV	1	1	0	1	1
165	*Euploea core*	V	1	1	0	0	0
166	*Euploea tulliolus**	V	1	0	0	0	0
167	*Euploea eyndhovii*	IV	0	0	1	0	0
168	*Parantica aglea*	III	1	1	0	1	1
169	*Parantica melaneus**	III	1	0	1	1	1
170	*Parantica sita**	IV	1	0	0	0	1
171	*Parantica swinhoei**	II	0	0	0	1	0
	Nymphalidae: Heliconiinae						
172	*Argynnis hyperbius*	VII	1	0	0	0	0
173	*Phalanta phalantha*	VII	1	1	0	0	0
174	*Cirrochroa chione**	IV	1	0	0	0	1
175	*Cirrochroa tyche*	IV	1	1	0	1	1
176	*Algia fasciata**	IV	1	0	0	0	0
177	*Cupha erymanthis*	IV	1	1	0	1	1
178	*Terinos clarissa**	IV	1	0	0	0	1
179	*Vagrans egista*	V	1	1	0	0	1
180	*Vindula erota*	IV	0	1	0	0	1
181	*Cethosia biblis*	IV	1	1	0	0	0
	Nymphalidae: Limenitidinae						
182	*Euthalia aconthea*	IV	0	1	0	0	0
183	*Euthalia alpheda*	IV	0	1	0	0	0
184	*Euthalia monina*	IV	0	1	0	0	1
185	*Euthalia lengba* (N) (ssp. *lei*)	II	0	1	0	0	0
186	*Euthalia bunzoi* (N) (ssp. *danangensis*)	II	0	0	0	0	1
187	*Euthalia teuta*	IV	0	1	0	0	0
188	*Athyma asura*	IV	0	1	0	0	1
189	*Athyma cama**	IV	0	0	0	0	1
190	*Athyma kanwa**	IV	0	0	0	1	1
191	*Athyma ranga*	III	0	1	0	0	0
192	*Athyma nefte**	IV	0	0	0	0	1
193	*Athyma selenophora*	IV	1	1	1	0	1
194	*Athyma zeroca*	III	0	1	0	0	0
195	*Bhagadatta austenia**	II	0	0	0	0	1
196	*Tanaecia lepidea*	III	1	1	0	1	0
197	*Lebadea martha**	IV	1	1	0	0	0

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No.	Taxon	Distribution Category	Dry (4/1999)	Rainy (2014-16)	Dry (2014-16)	Dry (2018-19)	Rainy (2018-19)
	Nymphalidae: Limenitidinae (continued)						
198	*Lexias dirtea**	IV	1	1	0	1	1
199	*Moduza procris**	IV	0	0	0	0	1
200	*Neptis ananta**	II	1	0	0	1	1
201	*Neptis clinia*	IV	0	1	0	1	1
202	*Neptis hylas*	VI	1	1	0	1	1
203	*Neptis leucoporos**	IV	1	0	0	1	0
204	*Neptis miah**	III	1	0	0	0	1
205	*Neptis namba**	II	0	0	0	0	1
206	*Neptis nata**	IV	0	0	0	0	1
207	*Neptis soma**	III	0	0	0	0	1
208	*Neptis zaida** (N) (ssp. *inayoshii*)	II	1	0	0	1	1
209	*Neptis yerburii**	III	1	0	0	0	0
210	*Neptis sankara* (N) (ssp. *sugimotoi*)	IV	1	0	0	0	0
211	*Neptis cartica** (N) (ssp. *teshirogii*)	III	1	0	0	0	0
212	*Neptis radha**	III	1	0	0	0	0
213	*Neurosigma siva**	II	1	0	0	1	1
214	*Pantoporia aurelia**	IV	1	1	1	0	1
215	*Pantoporia bieti* (N) (ssp. *aurantina*)	II	0	0	1	0	0
216	*Pantoporia sandaka*	IV	0	0	0	1	0
217	*Phaedyma columella*	IV	1	0	0	0	1
218	*Parasarpa daraxa**	IV	1	0	0	0	0
219	*Tanaecia jahnu*	III	0	1	0	0	0
220	*Tanaecia julii*	IV	1	1	0	1	1
	Nymphalidae: Libytheinae						
221	*Libythea myrrha*	IV	1	0	0	0	1
222	*Libythea geoffroyi*	V	1	0	0	0	0
	Nymphalidae: Nymphalinae						
223	*Doleschallia bisaltide*	V	0	0	0	0	1
224	*Symbrenthia hypselis*	IV	0	0	0	0	1
225	*Symbrenthia lilaea*	IV	1	1	0	1	0
226	*Hypolimnas bolina*	VII	1	0	1	0	0
227	*Junonia almana*	VI	1	1	0	0	0
228	*Junonia atlites*	IV	1	0	0	0	0
229	*Junonia iphita*	V	0	1	0	0	1
230	*Junonia lemonias*	IV	1	0	0	1	1
231	*Kallima alicia** (N) (ssp. *kishii*)	II	1	1	1	1	0
232	*Kallima incognita** (N)	III	0	0	0	0	1
233	*Kaniska canace*	VI	1	1	0	1	0
234	*Rhinopalpa polynice*	IV	0	1	0	0	0
	Nymphalidae: Apaturinae						
235	*Herona marathus*	III	0	1	0	0	0
236	*Mimathyma ambica*	IV	0	1	1	0	0
237	*Eulaceura osteria*	IV	0	0	0	1	1
238	*Hestinalis nama*	IV	0	0	0	1	0
239	*Rohana nakula**	IV	0	0	0	0	1
240	*Rohana parisatis**	IV	0	1	1	1	1

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No.	Taxon	Distribution Category	Dry (4/1999)	Rainy (2014-16)	Dry (2014-16)	Dry (2018-19)	Rainy (2018-19)
	Nymphalidae: Satyrinae: Amathusiini						
241	*Aemona simulatrix** (N)	I	1	1	0	0	1
242	*Aemona kontumei** (N)	I	1	0	1	1	1
243	*Aemona gialaica**	I	0	0	0	1	1
244	*Enispe cycnus** (N)	II	1	0	1	1	0
245	*Faunis bicoloratus* * (N)	I	0	1	0	1	1
246	*Faunis canens**	III	0	0	0	1	1
247	*Faunis eumeus*	III	1	0	1	1	1
248	*Stichophthalma eamesi** (N)	I	1	1	0	0	1
249	*Stichophthalma mathilda**	I	0	0	0	0	1
250	*Stichophthalma uemurai* (N)	I	0	0	0	0	1
251	*Thaumantis diores**	II	1	1	1	1	1
252	*Discophora sondaica**	IV	0	1	0	0	0
	Melanitini						
253	*Melanitis leda*	VII	1	0	0	0	1
254	*Melanitis phedima**	IV	0	1	0	0	1
255	*Melanitis zitenius**	III	1	0	0	0	0
	Elymniini						
256	*Elymnias patna**	III	1	0	0	0	0
	Satyrini						
257	*Neorina neosinica*	II	0	0	1	0	0
258	*Ethope diademoides** (N) (ssp. *metayei*)	III	0	0	0	1	0
259	*Penthema darlisa**	III	1	0	0	0	0
260	*Neope bhadra**	II	0	0	0	0	1
261	*Lethe dura**	III	0	0	0	0	1
262	*Lethe europa*	IV	0	1	0	0	0
263	*Lethe insana*	II	1	0	1	1	1
264	*Lethe latiaris*	II	1	0	0	0	1
265	*Lethe mekara*	IV	0	0	0	1	0
266	*Lethe melisana** (N)	I	0	0	0	0	1
267	*Lethe naga*	III	0	0	0	0	1
268	*Lethe verma*	III	1	1	1	1	1
269	*Lethe vindhya*	III	1	1	1	1	1
270	*Lethe confusa*	IV	1	0	0	0	0
271	*Lethe distans**	II	1	0	0	0	0
272	*Lethe kansa*	II	1	0	0	0	0
273	*Lethe rohria*	IV	1	0	0	0	0
274	*Lethe sinorix**	III	1	0	0	0	0
275	*Lethe konkakini** (N)	I	1	0	0	0	0
276	*Mandarinia regalis**	II	0	0	0	1	0
277	*Coelites nothis**	III	1	0	0	0	1
278	*Erites falcipennis**	III	1	1	0	1	1

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No.	Taxon	Distribution Category	Dry (4/1999)	Rainy (2014-16)	Dry (2014-16)	Dry (2018-19)	Rainy (2018-19)
	Satyrini						
279	*Mycalesis anaxias**	III	1	1	0	1	0
280	*Mycalesis adamsonii*	III	0	1	0	0	0
281	*Mycalesis gotama*	III	0	1	0	0	0
282	*Mycalesis francisca**	III	1	1	1	1	1
283	*Mycalesis mineus*	IV	1	0	0	1	1
284	*Mycalesis perseoides*	III	1	1	0	0	1
285	*Mycalesis sangaica*	III	0	1	0	1	1
286	*Mycalesis mucianus*	II	1	0	0	0	0
287	*Culapa mnasicles**	IV	1	0	0	0	0
288	*Devyatkinia singularis** (N)	I	0	0	0	0	1
289	*Ragadia crisilda**	III	0	1	1	1	1
290	*Ragadia latifasciata crystallina**	I	1	0	0	0	0
291	*Ypthima huebneri*	III	1	1	0	0	0
292	*Ypthima tappana**	II	1	0	0	0	0
293	*Ypthima baldus*	IV	1	0	0	1	1
294	*Ypthima dohertyi**	III	1	0	1	1	0
295	*Ypthima nebulosa*	IV	0	0	0	0	1
296	*Ypthima savara**	III	1	0	0	1	0
	Papilionidae: Papilioninae						
297	*Atrophaneura varuna **	III	0	0	0	0	1
298	*Atrophaneura dasarada**	III	1	0	0	0	0
299	*Graphium macareus*	IV	0	0	0	1	0
300	*Graphium agamemnon*	V	1	1	0	1	0
301	*Graphium antiphates*	IV	0	0	0	0	1
302	*Graphium agetes*	IV	0	0	1	1	0
303	*Graphium eurypylus*	V	1	0	0	0	0
304	*Graphium doson*	IV	1	1	0	0	0
305	*Lamproptera curius*	IV	0	1	0	0	1
306	*Lamproptera meges*	IV	0	0	0	0	1
307	*Meandrusa lachinus*	III	0	1	0	1	0
308	*Pachliopta aristolochiae*	IV	0	0	1	0	0
309	*Papilio arcturus**	II	0	0	0	1	0
310	*Papilio protenor*	VI	1	0	0	0	0
311	*Papilio alcmenor**	II	1	0	0	0	0
312	*Papilio polytes*	IV	1	1	0	0	0
313	*Papilio demoleus*	V	1	0	0	0	0
314	*Papilio helenus*	IV	1	0	0	1	1
315	*Papilio memnon*	V	1	0	0	1	1
316	*Papilio nephelus*	III	1	0	0	0	1
317	*Papilio epycides*	II	1	0	0	0	0
318	*Papilio slateri*	IV	0	0	1	0	0
319	*Papilio clytia*	IV	0	1	0	0	0
320	*Teinopalpus imperialis**	II	0	0	0	1	0
321	*Troides aeacus*	III	1	0	0	0	0
322	*Troides helena*	IV	1	0	0	1	1
	Pieridae: Coliadinae						
323	*Dercas verhuelli**	III	1	1	1	1	1
324	*Catopsilia pomona*	VII	1	0	0	1	1
325	*Catopsilia scylla*	V	1	0	0	0	0
326	*Catopsilia pyranthe*	V	1	0	0	0	0

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No.	Taxon	Distribution Category	Dry (4/1999)	Rainy (2014-16)	Dry (2014-16)	Dry (2018-19)	Rainy (2018-19)
	Pieridae: Coliadinae						
327	*Eurema andersoni**	IV	1	1	0	1	1
328	*Eurema blanda*	V	1	1	0	1	1
329	*Eurema hecabe*	VII	1	1	0	1	1
330	*Eurema ada**	IV	1	1	1	1	0
331	*Eurema brigitta*	VII	1	1	0	0	0
332	*Eurema novapallida**	I	0	1	0	1	1
333	*Eurema simulatrix*	IV	0	1	0	0	1
	Pieridae: Pierinae						
334	*Delias vietnamensis** (N)	I	1	0	0	1	1
335	*Delias belladonna**	III	1	0	0	1	0
336	*Delias agostina**	III	1	0	0	0	0
337	*Delias pasithoe*	IV	1	0	0	0	0
338	*Leptosia nina*	IV	1	1	0	1	1
339	*Prioneris philonome*	IV	1	0	0	0	0
340	*Prioneris thestylis*	III	1	1	0	0	1
341	*Pieris canidia*	VI	1	0	0	0	0
342	*Talbotia naganum* (ssp. *aurelia*)*	III	1	1	1	1	1
343	*Cepora nadina*	IV	0	1	0	0	1
344	*Appias albina*	V	1	0	0	0	1
345	*Appias indra*	III	1	1	0	1	1
346	*Appias lalassis*	III	0	0	0	1	1
347	*Appias pandione**	IV	1	0	1	1	1
348	*Appias galba*	IV	1	0	0	0	0
349	*Appias lyncida*	IV	1	0	0	0	0
350	*Appias lalage*	III	1	0	0	0	0
351	*Appias libythea*	IV	1	0	0	0	0
352	*Ixias pyrene*	III	1	0	0	0	0
353	*Hebomoia glaucippe*	IV	1	1	0	0	1
354	*Pareronia anais*	III	1	0	0	0	1
355	*Pareronia avatar*	III	1	0	0	0	0
	Riodinidae: Riodininae						
356	*Abisara burnii**	III	0	1	1	1	1
357	*Abisara fylla**	II	1	0	1	0	1
358	*Abisara echerius**	IV	1	0	1	0	0
359	*Archigenes attenuata**	IV	1	1	0	0	1
360	*Archigenes neophron**	III	1	1	0	0	1
361	*Dodona ouida**	II	1	0	1	0	1
362	*Dodona egeon*	III	1	0	0	0	0
363	*Dodona katerina** (N)	I	1	0	0	0	0
364	*Stiboges nymphidia*	IV	0	1	0	0	0
365	*Stiboges elodinia**	II	1	0	1	0	1
366	*Taxila dora**	I	1	0	1	0	1
367	*Taxila hainana**	II	0	1	0	1	1
368	*Zemeros flegyas*	IV	1	1	0	1	1