Towards an Understanding of Butterfly Diversity and Composition in an Artificial Habitat: A Case Study of the Ecology Education Park in the Endemic Species Research Institute

了解蝴蝶群聚於人工棲地的多樣性及組成：以特有生物研究保育中心之生態教育園區為例

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Abstract

Habitat destruction by human activity is a severe issue around the world. The growing number of semi-natural habitats and artificial habitats should be further studied owing to their potential functions in conservation and education. A one-year survey of butterflies in an artificial habitat, Ecology Education Park(EEP) in the Endemic Species Research Institute, was conducted to understand the composition and monthly variation of the butterfly community there. In total 96 butterfly species and 1754 individuals were recorded during 12 investigations. Among them, 9, 16, 13, 18, and 40 recorded species came from families Hesperiidae, Papilionidae, Pieridae, Lycaenidae, and Nymphalidae, respectively. Species richness peaked in July and October, and a similar pattern showed in all five butterfly families in EEP. During the 12-months period, large variation of butterfly abundance happened in Lycaenidae and Nymphalidae owing to one or two apparent peak(s); but no apparent peak resulted in relatively small abundance variation in Pieridae. For different families, the peak could have occurred due to outbreak of one or two species, or multiple species maintaining a certain level of population during the same period. Among the results from four diversity indices, a similar pattern was found when considering the number of individuals in the total sample. The apparent drop of values of indices occurred in December owing to a population outbreak of a small number of species. The preliminary results from this study can give light to the importance of monitoring community structure in artificial habitats by manipulating proper sampling methods and by adopting adequate diversity indices.

摘 要

人類活動造成的棲地破壞為全球性嚴重議題。隨之增加的半天然棲地和人工棲地因具備保育及教育的潛在功能，值得加以重視。特有生物研究保育中心的生態教育園區為人工營造的棲地，為了解棲息於該地之蝴蝶群聚的組成及月間變化，進行為期一年的蝶相調查。每月一次共計 12 次調查，

記錄到 96 種蝶類共計 1754 隻次，其中弄蝶科(Hesperiidae) 9 種、鳳蝶科(Papilionidae) 16 種、粉蝶科(Pieridae) 13 種、灰蝶科(Lycaenidae) 18 種、蛺蝶科(Nymphalidae) 40 種。分屬五科的蝶類在 7 月及 10 月達種數高峰。灰蝶科和蛺蝶科在數量分布上有較大的月間變異，肇因於一至二次的數量高峰；月間變異較小的粉蝶科在數量上則無明顯高峰。不同科別的蝶類，其數量高峰的複因可能為

一或二個物種的族群擴張，或是多個物種在同一期間維持一定的數量。採用四種多樣性指數計算的結果指出，在考量物種個體數於總個體數中比例時，數值於月間呈現出相似模式，均於 12 月驟降至最低數值，原因為該月份少數物種在個體數量上有族群擴張現象。本研究的初步結果旨在強調：透過適當的採樣方法及採用適當的多樣性指數，將有助於提供人工棲地中物種群聚組成監測上的重要訊息。

Key words : artificial habitat, Ecology Education Park, butterfly community structure, population outbreak, diversity index

關鍵詞：人工棲地、生態教育園區、蝴蝶群聚組成、族群擴張、多樣性指數

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Introduction

Almost all the habitats around the world have been influenced by human directly or indirectly in different scales and in many aspects (Bishop *et al.* 1981; Naeem *et al.* 1994; Vitousek *et al.* 1997; Chapin III *et al.* 2000). Since natural habitats are diminishing, semi-natural and artificial habitats, which are both increasing in number, have become important study plots as with natural ones (Hietala-Koivu *et al.* 2004). A well-designed management of those habitats can generate meaningful insights in conservation biology(e.g., protect and conserve plants and animals) or for educational purposes(Pratt 1994; Fernández-Juricic and Jokimäki 2001; Li 2005). Therefore, in addition to conserving natural habitats, it is critical to direct attention to the management of semi-natural or artificial habitats.

Previously a log-storage pool, Ecology Education Park(simplified as EEP thereafter) is an artificial habitat constructed in 1993 in the Endemic Species Research Institute(simplified as ESRI thereafter). After undergoing habitat reconstruction and systematical planting for several years, EEP is now composed of diverse microhabitats with abundant endemic plant species and has attracted many animals ever since. At least 697 plant species, 60 birds, 20 reptiles, 16 amphibians, 105 butterfly species, and 144 moths have been recorded in EEP. Previous studies have focused on the diversity of organisms inhabiting in natural sampling plots, and the correlation between the biodiversity and ecosystem functioning were also held(Chapin III *et al.* 2000; Loreau *et al.* 2001). However, little is known about the species diversity of artificial habitats, regardless of the benefits that monitoring changes in species composition in such habitats may provide useful information for improving the management protocols. The EEP, has been constructed and managed, thus becomes an ideal sampling plot for studying such important issues.

Butterflies are adequate indicators of habitat changes(Kunte 1997), especially when comparing to the other terrestrial insect groups with limited baseline knowledge(Thomas 2005). In this study, we underwent surveys of butterfly communities in EEP by recording the number of individuals in each species once every month. Assessment of species richness, evenness, and other diversity indices were conducted to understand the patterns of community composition and monthly variation. Based on the preliminary results, sampling methods and monitoring protocols for an artificial habitat are expected to be improved and reconstructed.

Materials and Methods

Study area

Butterfly community survey took place during 2011 in EEP in ESRI, located in Jiji Township, Nantou County, Taiwan(N23° 49' 36", E120° 48' 4.56"). The altitude of the study location was 301 m. The 3.5-hectare area contains several habitat types, including forests, grasslands, and ponds. Around the park, plant species clustered in areas such as nectar plant area, evergreen to the 1st broad-leaf forest area, precious and rare plant area, special purpose plant area, and color- changing plant area(**Fig. 1**). Information about food plants of butterfly adults(i.e., nectar plants) and larvae(i.e., host plants) in EEP are listed in **Appendix 1**.

Sampling methods

The transect was a one-km route across each habitat type in EEP(**Fig. 1**). The investigation was made under good weather condition(except for raining) once every month from 09:00 to 12:00 when the highest species richness and the number of individuals could be observed during the day(Yan 2011). The recorders walked at a uniform pace forward and recorded the species name and number of individuals of butterflies found within a space formed by a 5-m range cube(i.e., a method which is similar to Pollard Walk by Pollard(1977,

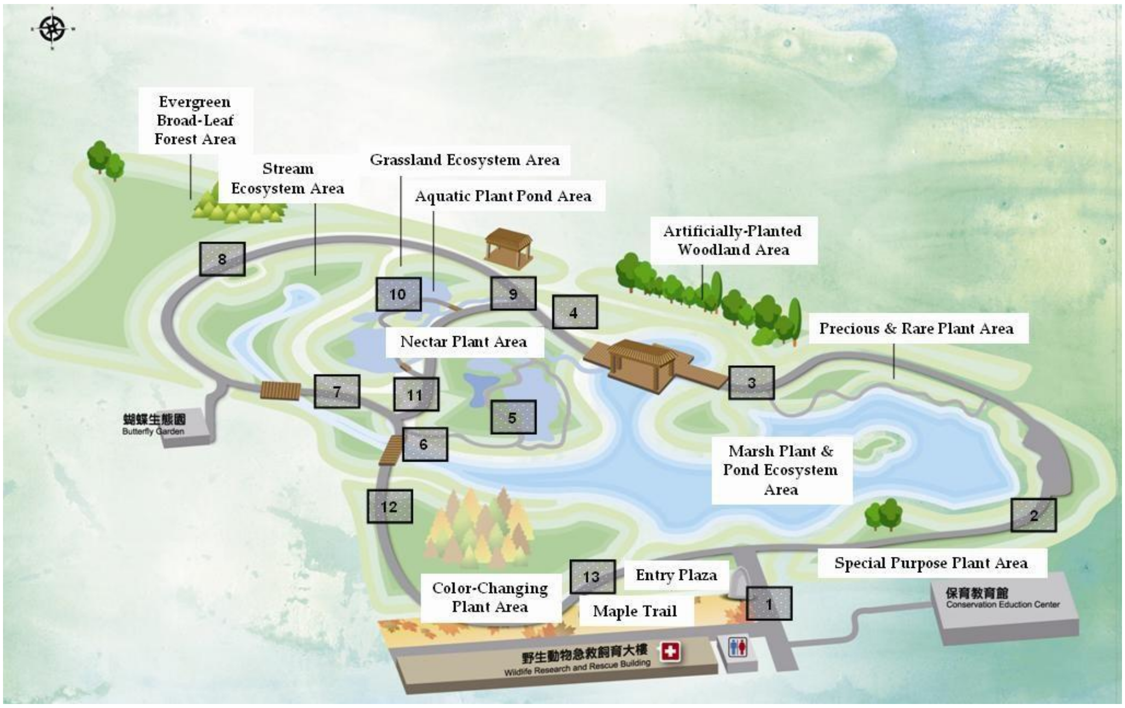

Fig.1. A map of EEP with distinctive areas. Shadowed squares with number represent the order of transect line from 1 to 13, formed as a circular route. That is, after passing the 13th spot, the recorder kept walking spot to finish the investigation.

1982), Pollard and Yates(1993), and descriptions by Pollard(1991); see **Fig. 2**). Most butterflies individuals(usually butterflies belonging to the family Hesperiidae) were captured by butterfly net for further identifications. Additional investigations during each month were made for were identifiable in flight, while some smaller and indistinguishable the supplement of butterfly species(asterisk symbol in **Table 1**), and data of which(both the number of species and individuals) were not included for further analyses.

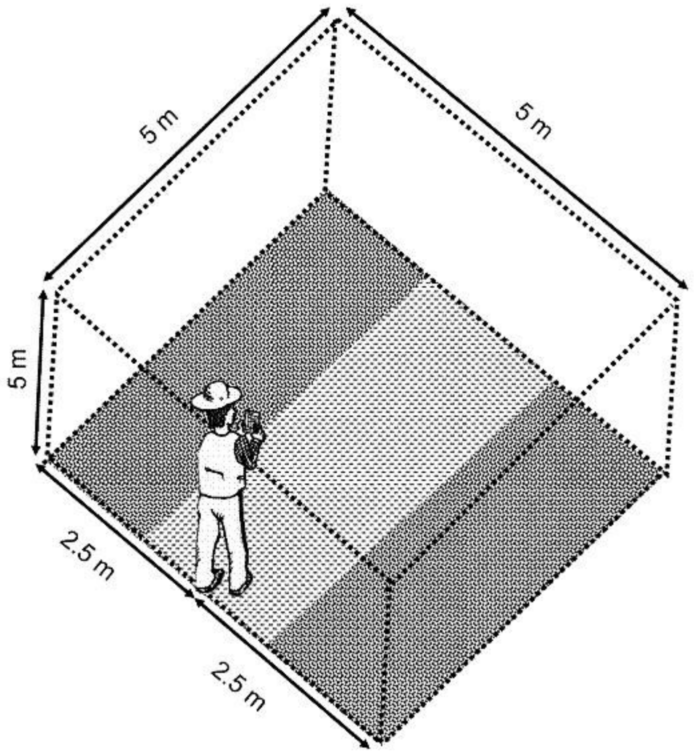

Fig. 2. The detection range when sampling in EEP. The space was formed as a 125 m^3 cube where the recorder kept track of the species and the number of butterflies passing by.

Diversity indices

We regarded EEP as a relatively small sampling plot, where the recording of butterfly species has been made for more than 3 years(i.e., assuming nearly all of butterfly species in the butterfly community were recorded and identified). The sampling frequency was also assumed to be enough in order to ensure the probability for each individual in each population being chosen is equal. With the above assumptions, the diversity indices can be adopted for interpretations. Four commonly used indices were adopted to make comparisons of the pattern of diversity and composition of butterflies.

(1) Species richness

Species richness indicates the number of species in the community(McIntosh 1967). In this study, we adopted the complete count of the number of butterfly species in order to make comparisons with other diversity indices considering the number of individuals.

(2) Evenness

Based on the Shannon index, which will be described in the next section, Pielou's evenness index(referred to as Pielou index thereafter) represents the ratio of observed diversity to the maximum possible diversity of a community with the same species richness(van Dyke 2008). The formula for calculating species evenness are

$$H_{max} = \ln S$$
$$J = H/H_{max}$$

(Pielou 1966)

where H_{max} is the Shannon index when all the species in the community had an equal number of individuals, S the species richness(i.e., the number of species), ln S the natural logarithm of S; J is the measure of species evenness(i.e., Pielou index), H the measure of species diversity (from Shannon index).

(3) Shannon index

The Shannon-Wiener index is a commonly used nonparametric measurement of heterogeneity (uncertainty) based on information theory(Margalef 1957, 1958). The name of the Shannon-Wiener index derived from Shannon's(1948) admiration for Norbert Wiener for his contribution of basic philosophy and theory to communication theory(also clarified by Spellerberg and Fedor (2002). The Shannon-Wiener index(as Shannon index thereafter) can be used with both large and small sample sizes(van Dyke 2008). The formula for the Shannon index is

$$H = -\sum_{i=1}^{S}(p_i)(\ln p_i)$$

(Shannon 1948)

where H is the measure of species diversity (i.e., Shannon index), S the species richness, p_i the proportion of individuals in the total sample which belongs to the ith species, and ln p_i the natural logarithm of p_i.

(4) Simpson's index

Simpson(1949) presented a nonparametric measurement of heterogeneity derived from the probability that two individuals chosen at random and independently from the population belonging to the same group(i.e., species). Since we regarded the sample as a finite collection(i.e., collection as a complete population, Pielou(1966, 1969), the complement of Simpson's diversity (simplified to Simpson's index thereafter) was used to estimate the heterogeneity of butterfly community in EEP. The formula for the Simpson's index is

$$1 - D = 1 - \sum_{i=1}^{S} \left[\frac{n_i(n_i - 1)}{N(N - 1)} \right] = 1 - \frac{\sum_{i=1}^{S} n_i(n_i - 1)}{N(N - 1)}$$

(Pielou 1969)

where $1-D$ is the Simpson's index of diversity for a finite population, S the species richness, n_i the number of individuals in the total sample which belongs to the ith species, N the number of individuals in the total sample.

Stastical Analyses

Chi-square goodness of fit test was used to check if the proportion of butterfly families in EEP fit the known proportion of butterfly families of Taiwan. Pearson's chi-squared test of independence was used to see if there was any correlation between total species number and species number in each family across months. Bartlett's test of homogeneity of variance was used to compare the pattern of butterfly abundance across months in the three families which took up the majority of total butterfly abundance.

Results

Composition of butterfly species

Scientific names of butterfly species being recorded during 2011 are listed in **Appendix 2**. As shown in **Table 1**, 104 butterfly species were found in EEP, accounting for 24.07% of the species in Taiwan. Among them, the family Papilionidae accounted for the largest proportion (41.46%) while the family Lycaenidae took up the smallest proportion(15.32%). The species distribution by families in EEP was different from the distribution of Taiwan(Chi-square goodness of fit test: $p = 0.013$). The butterfly family Nymphalidae contributed the most to all of butterfly species recorded during 2011(**Table 2**), and the similar pattern occurred in most of time periods(10 months during a year, **Fig. 3**). July and October were two peaks of the number of butterfly species during 2011(**Fig. 3**). The distribution of species number in each family was similar to an overall pattern regardless of the separation by butterfly families(Pearson's chi-squared test of independence: $p = 0.719$ in Hesperiidae; $p = 0.413$ in Papilionidae; $p = 0.321$ in Pieridae; $p = 0.87$ in Lycaenidae; $p = 0.994$ in Nymphalidae).

Table 1. Number of butterfly species in EEP and in Taiwan

Family	Number of species		Percentage(%)
	EEP*	Taiwan**	
Hesperiidae	13	69	18.84
Papilionidae	17	41	41.46
Pieridae	14	38	36.84
Lycaenidae	19	124	15.32
Nymphalidae	41	160	25.63
Total	104	432	24.07

* represent the number of species including the supplied records

** The number of species in Taiwan is the most recent record from TaiBNET(Catalogue of Life in Taiwan: http://taibnet.sinica.edu.tw/)

Table 2. Records of the number of butterfly species and individuals in EEP during 2011

Family	Species		Individuals	
	Number	Percentage(%)	Number	Percentage(%)
Hesperiidae	9	9.37	34	1.94
Papilionidae	16	16.67	149	8.49
Pieridae	13	13.54	456	26.00
Lycaenidae	18	18.75	534	30.45
Nymphalidae	40	41.67	581	33.12
Total	96	100.00	1754	100.00

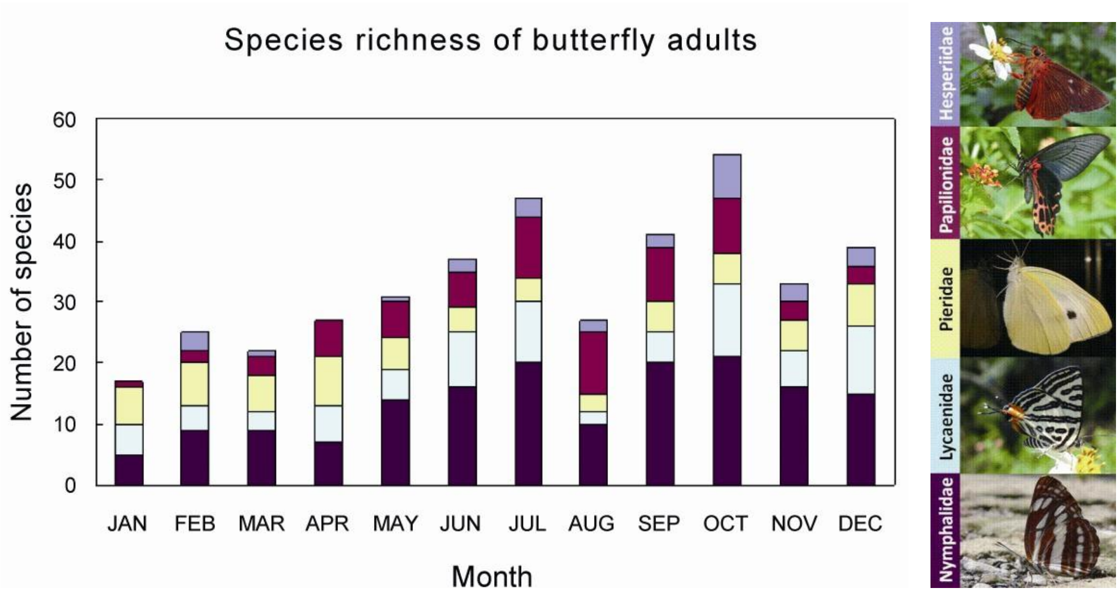

Fig. 3. Number of butterfly species in EEP during 2011(see **Appendix 3** for details).

Composition of individual butterflies

The combination of individual butterflies (populations of different species) recorded in every survey was considered as a butterfly community in EEP. The family Nymphalidae contributed the most to all of the individuals recorded during 2011, and the families Pieridae and Lycaenidae also took up relatively large proportions(**Table 2**). However, the distribution of individual butterflies during a year in each of the

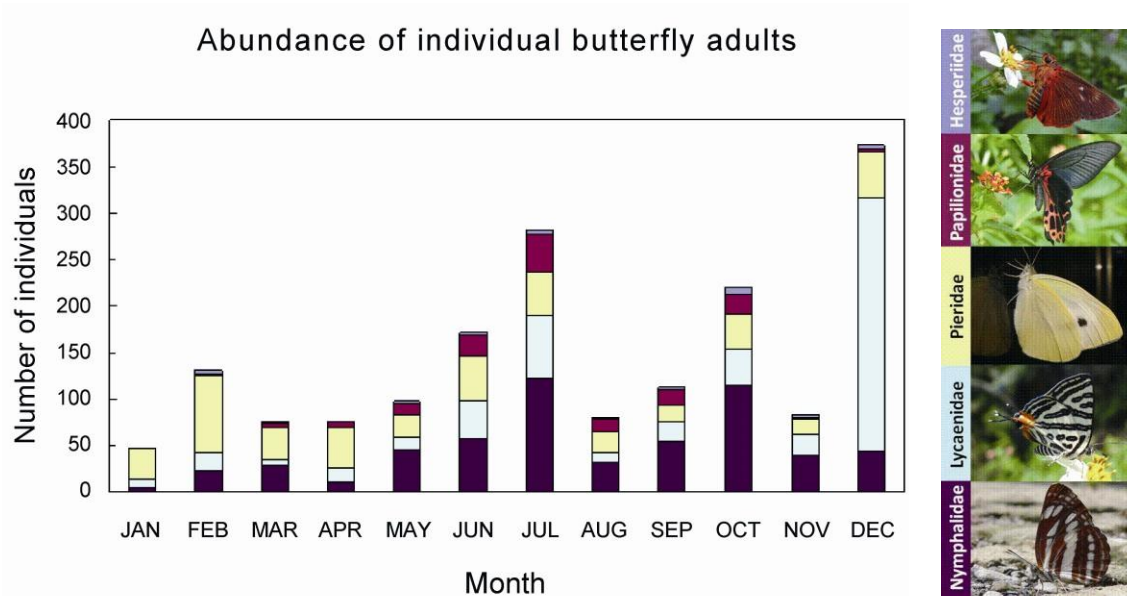

Fig. 4. Number of individual butterflies in EEP during 2011(see **Appendix 4** for details).

three families was different significantly(Bartlett's test of homogeneity of variance: $p < 0.001$)(**Fig.4**). The family Lycaenidae had the largest variance 5476.6, followed by Nymphalidae at 1346.4 and Pieridae at 339.3. Outbreaks occurred once in Lycaenidae in December and twice in Nymphalidae in July and October, respectively; the abundance of Pieridae was highest in February while in the families which contributed less to total abundance: Hesperiidae peaked in October and Papilionidae peaked in July(**Fig. 4**).

Information from diversity indices

Species richness increased from January to the first peak in July, and the second peak occurred in October after a sudden drop in August(**Fig. 5**). The maximum and minimum values of species richness were 54 and 17 in October and January, respectively. Once considering the number of individuals, the distribution pattern during 2011 changed obviously. Values from the Pielou index showed that species evenness was relatively stable until the smallest value occurred in December (**Fig. 5**). Results of the Shannon index and the Simpson's index shared a similar pattern to species evenness (**Fig. 5** and **6**). The maximum and minimum values of the three indices across months were both found in September and December, respectively(Pielou index = 0.926 and 0.607; Shannon index = 3.440 and 2.223; Simpson's index = 0.968 and 0.788).

Discussion

Composition of butterfly species

Slightly less than quarter of the butterfly species in Taiwan were found in EEP(**Table 1**). However, nearly half of Papilionidae species of Taiwan were found in EEP during 2011. Besides various nectar plants and host plants(**Appendix 1**), shoals and small ponds are scattered in EEP. Adults of Papilionidae species, for example, *Graphium sarpedon connectens*, *Papilio bianor thrasymedes*, and *Papilio thaiwanus*, used to have water in such microhabitats(Hsu 1999). By studying the life history strategies and behaviors of butterfly species, the connection of habitat diversity to their growth, survival, and reproduction, might be informed. On

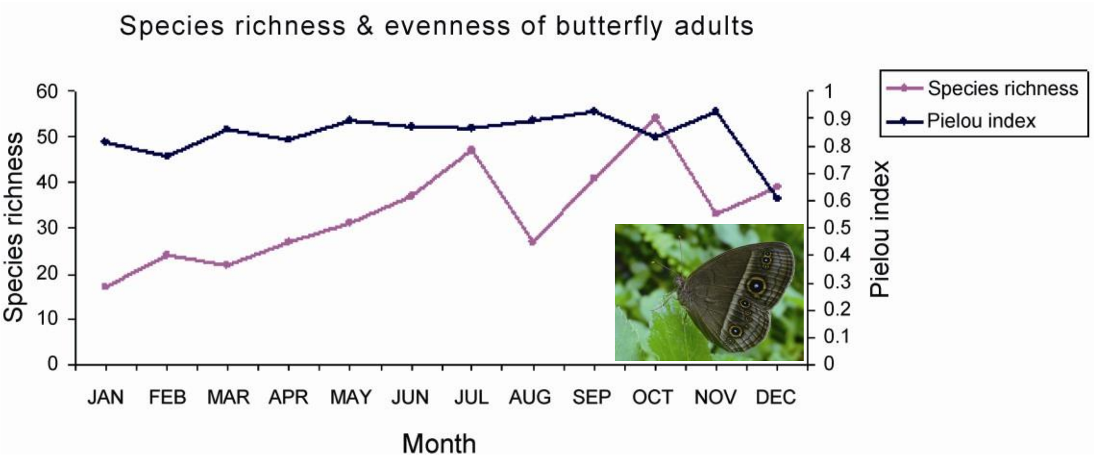

Fig. 5. Species richness and evenness of butterfly adults in EEP during 2011.

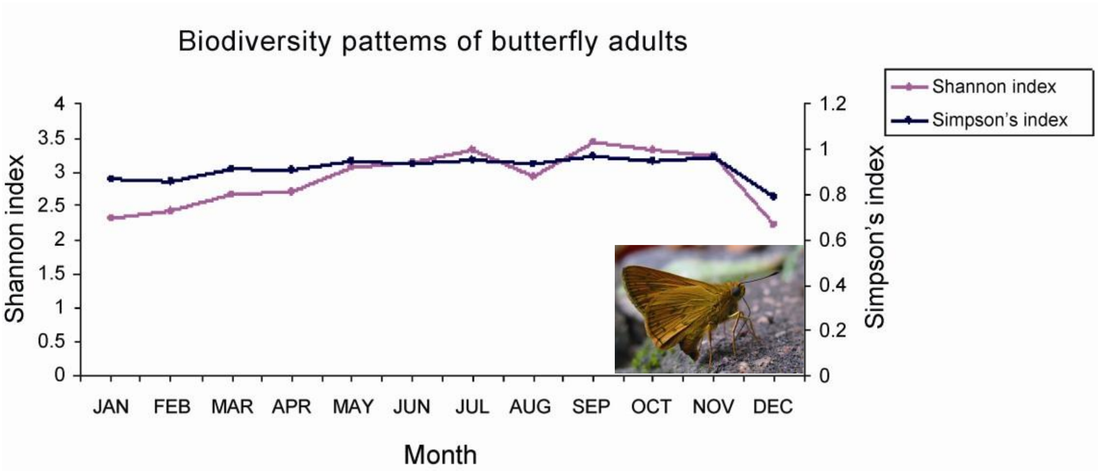

Fig. 6. Biodiversity patterns of butterfly adults indicated by two diversity indices in EEP during 2011.

the other hand, since the surveys were always held from 09:00 to 12:00, some butterfly species, such as *Ravenna nivea* (belonging to the family Lycaenidae) that is usually active at dawn and dusk(Hsu 1999), were possibly neglected when counting. In addition, many species were active inside the bush or the forest, making them hard to discover if surveying along the transect route. In addition, the Pollard Walk method(mainly followed in this study) was constructed and advocated in countries in the temperate zone, thus the investigation method was suggested to be modified according to regional characters in countries that lie in the subtropics and the torrid zones(Lyu 2011). In conclusion, additional investigations in different time periods, by various routes, and with adjustment based on regional difference can increase the relevance of specie richness monitoring in an artificial plot.

Species composition by family in EEP did not coincide with species composition in Taiwan, although the family Nymphalidae made up the largest proportion in both cases(**Table 2** and **Fig. 3**). However, the checklist from TaiBNET may possibly overestimate the number of butterfly species in Taiwan, since some species were rarely discovered and even considered as "vagrant" butterfly species. As a result, the comparison of species number between EEP and Taiwan will only be more meaningful if integrated with checklists of butterfly species made by as many other survey groups as possible. The pattern of species number in each family across months was similar; Papilionidae, Lycaenidae, and Nymphalidae butterflies mainly peaked in July and October(**Table 2** and **Fig. 3**). In our records, monthly rainfall in July and October differed significantly(July: 309 mm; October: 74 mm; unpublished data); however, with limited environmental information, no convincible explanation could be made. Species abundance can correlate closely with the weather(Roy and Sparks 2000), the growth of nectar plants (Warren 1987; Peterson 1997), and many other extrinsic or intrinsic factors(e.g., Cushman *et al.* 1994). Therefore, studies on life history characters of butterfly species and their interactions with plants, combining with long-term environmental factors, should all help to explain the occurrence of the population outbreak.

Composition of individual butterflies

The abundance peak(i.e., the highest number of individual butterflies) in each butterfly family during 2011 was February in Pieridae, July in Papilionidae and Nymphalidae, October in Hesperiidae, and December in Lycaenidae(**Fig. 4**). In February, *Pieris rapae crucivora* and *P. canidia* contributed the most to Pieridae's abundance(unpublished data). Similar to the description from previous investigation, these two Pieridae species were active from December to February even when cold currents came(Li 2011). In July, *Cupha erymanthis*, *Euploea tulliolus koxinga*, *Tirumala limniace limniace*, and *E. mulciber barsine* were frequently seen in the Nectar Plant area, visiting plants such as *Bidens pilosa radiata, Lantana camara*, *Asclepias curassavica*, and *Eupatorium clematideum gracillimum*. The abundance peak of Nymphalidae did not owe to the outbreak of certain species but was influenced by different species(**Fig. 3** and **4**). Many Papilionidae species were active in July as well(**Fig. 3**). Among them, *Graphium sarpedon connectens* and *Papilio protenor protenor* usually flew near shoals, drinking water occasionally. Records of Hesperiidae were scarce in both number of species and individuals(**Fig. 3** and **4**). In October, there were only 8 Hesperiidae individuals belonging to 7 species(unpublished data). Owing to not only the relatively small size but high flying speed of Hesperiidae butterflies, more efforts should be made for discovering them and counting their number. In December, outbreaks of the two Lycaenidae species, *Jamides bochus formosanus* and *Zizula hylax*(the smallest butterflies in size in Taiwan indicated by Li(2011)) resulted in the abundance peak of the family(unpublished data). In sum, large variance in abundance across months indicated that there was one apparent peak of abundance in the family(e.g., Lycaenidae); on the other hand, small variance represented no clear abundance peak during a year. Among the peak in certain family, there may be outbreaks of one or two species(e.g., Lycaenidae), or relatively equal individuals contributed from several species(e.g., Papilionidae). The above scenarios will be more apparent after incorporating diversity indices.

Information from diversity indices

When the pattern comparison was made between species richness and species evenness across 12 months, fluctuations were more obvious in species richness than evenness(**Fig. 5**). Results of species richness indicated that there were numerous butterfly species coming out in specific months while results of species evenness showed that there was only one odd event occurring in December. From November to December, species richness of butterflies in EEP was increasing while outbreaks of certain species(in family Lycaenidae) caused species evenness to decrease. The Shannon index and the Simpson's index both consider the number of individual butterflies when estimating the heterogeneity of butterfly community. Though underlying mechanisms of the two indices are different, the patterns were similar in this case. Many diversity indices have been proposed based on different concepts and for different applications; each diversity index has its derived characters as well. For example, the sensitivity is different between the two indices we adopted in this study.

The Simpson's index is more sensitive to changes in dominant species in the community while the Shannon index is more sensitive to changes in rare species(Peet 1974). To choose diversity indices for biological applications, the following considerations should be made. First, diversity indices should be conducted in adequate spatial scales(i.e., α, β, or γ diversity by Whittaker(1960); local, landscape, or macro-scale by Whittaker *et al.*(2001). Second, the adoption of adequate indices depends on the understanding of studying organisms' life history strategies, of the sampling methods we design, and of concepts underlying the indices(summarized by Krebs(1989). Without thorough consideration, many interpretations and further examinations based on diversity indices would be inconvincible(see examples reviewed by Chi *et al.*(2003).Were species recorded in EEP close to completeness? Was the sampling frequency enough to ensure the equal probability for each individual in each chosen population? Only if the above assumptions can be confirmed by more evidence would the results from diversity indices be reliable.

Future studies

For the improvement of sampling methods and monitoring protocols, butterfly diversity and composition in an artificial habitat was examined. However, data gathered once a month over a year provided limited information because of the lack of long-term monitoring and comparative studies across years. By long-term monitoring of butterfly populations or communities, more information can be obtained. For example, records of butterfly populations or communities by years can reflect the butterflies' phenology(Brakefield 1987; Pollard 1988; Kunte 1997), the effects of habitat changes(Krauss *et al.* 2010; Krämer *et al.* 2012), climate changes(Parmesan *et al.* 1999; Roy and Sparks 2000; van Swaay *et al.* 2010), and human disturbances(Kitahara and Fujii 1994; Blair and Launer 1997; Kitahara *et al.* 2000; Tiple *et al.* 2007; White and Kerr 2007; Chen *et al.* 2009).

In EEP, park managers prune and renew vegetation routinely to prevent possible danger and for the convenience of guided tours offered to tourists. As indicated by previous studies just mentioned above, there are some directions for future studies in EEP. A comparison of the butterfly community's structure before and after vegetation changes, or under different degree of human disturbances(e.g., mowing, pruning, and plantation), may help us measure the impact of artificial managements. In addition, though the transect route across microhabitats in EEP was set to avoid nonrandom sampling from observations in certain habitat types, the comparison of butterfly communities' structures between different microhabitats may provide information about butterflies' life history characteristics(Lyu 2011). Since EEP is an artificial park planted with various plant species, the comparison of community compositions of animal species and abundance between this artificial-planted environment and other natural or semi-natural environments may help us examine the relationship between the characters of habitats and organisms biodiversity. In addition, the relationships of community compositions between plants and animals may also be informed. The butterfly is a good model for examining the relationship between plants and animals, since previous studies have examined the coevolution between food plants and butterflies(Ehrlich and Raven 1964; Janz *et al.* 2001). In our case, the plantation of food plants for butterflies(see **Appendix I**), including the control of their quality(Culin 1997) and quantity(Tiple *et al.* 2011), their distribution(Grossmueller and Lederhouse 1987) and further interactions with butterflies should all help to improve the managing protocol in an artificial park.

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Appendix 1. List of food plant species of adults(nectar plants) and larvae(host plants) of butterflies in EEP.

Nectar Plants	
Species name	**Endemic species**
Family Acanthaceae	
Strobilanthes formosanus Moore	
Family Asteraceae	
Ageratum houstonianum Mill.	
Bidens pilosa L. var. *radiata* Sch.	
Eupatorium clematideum(Wall. ex DC.) Sch. Bip. var. *gracillimum*(Hayata) C. I Peng & S. W. Chung	Y
Family Capparidaceae	
Crateva adansonii DC. subsp. *formosensis* Jacobs	Y
Family Iridaceae	
Belamcanda chinensis(L.) DC.	Y
Family Leeaceae	
Leea guineensis G. Don	
Family Plumbaginaceae *Plumbago zeylanica* L.	
Family Verbenaceae	
Callicarpa japonica Thunb. var. *luxurians* Rehder	
Clerodendrum cyrtophyllum Turcz.	
Clerodendrum inerme(L.) Gaertn.	
Clerodendrum kaempferi(Jacq.) Siebold ex Steud.	
Clerodendrum trichotomum Thunb.	
Duranta repens L.	
Lantana camara L.	
Premna hengchunensis Lu & Yang	Y
Premna serratifolia Linn.	
Stachytarpheta urticaefolia(Salisb.) Sims.	
Tectona grandis L. f.	
Vitex negundo L.	
Vitex trifolia L.	

Host Plants		
Species name	Endemic **species**	**Species recorded**
Family Acanthaceae		

		Junonia almana(Linnaeus, 1758)
Hygrophila pogonocalyx Hayata	Y	
		Zizula hylax(Fabricius, 1775)
Lepidagathis formosensis Clarke ex Hayata		*Kallima inachus formosana*(Fruhstorfer, 1912)
Strobilanthes formosanus Moore		*Kallima inachus formosana*(Fruhstorfer, 1912)
Family Annonaceae		
Goniothalamus amuyon(Blanco) Merr.		*Graphium agamemnon*(Linnaeus, 1758)
Family Aristolochiaceae		
Aristolochia zollingeriana Miq.		*Byasa polyeuctes termessus*(Fruhstorfer, 1908)
		Pachliopta aristolochiae interposita(Fruhstorfer, 1904)
Aristolochia heterophylla Hemsl.		*Byasa polyeuctes termessus*(Fruhstorfer, 1908)
		Pachliopta aristolochiae interposita(Fruhstorfer, 1904)
Aristolochia cucurbitifolia Hayata	Y	*Byasa polyeuctes termessus*(Fruhstorfer, 1908)
		Pachliopta aristolochiae interposita(Fruhstorfer, 1904)
Family Asclepiadaceae		
Asclepias curassavica L.		*Danaus chrysippus*(Linnaeus, 1758)
Tylophora ovata(Lindl.) Hook. ex Steud.		*Parantica aglea maghaba*(Fruhstorfer, 1909)
		Parantica sita niphonica(Moore, 1883)
Dregea volubilis(L. f.) Benth.		*Tirumala limniace limniace*(Cramer, 1775)
Hoya carnosa(L. f.) R. Br.		*Parantica sita niphonica*(Moore, 1883)
Family Cycadaceae		
Cycas taitungensis C. F. Shen, K. D. Hill, C. H. Tsou & C. J. Chen	Y	*Chilades pandava peripatria*(Hsu, 1989)
Family Fabaceae		
Archideneron lucidum (Benth.) I.Nielse		*Eurema blanda arsakia*(Fruhstorfer, 1910)
Cassia fistula L.		*Eurema blanda arsakia*(Fruhstorfer, 1910)
		Catopsilia pomona(Fabricius, 1755)
Senna siamea(Lamarck) Irwin & Barneby		*Catopsilia pomona*(Fabricius, 1755)
Indigofera spicata Forsk.		*Freyeria putli formosanus*(Matsumura, 1919)
Family Flacourtiaceae		
Scolopia oldhamii Hance		*Cupha erymanthis*(Drury, 1773)
Family Lauraceae		
Cinnamomum camphora(L.) Presl.		*Graphium sarpedon connectens*(Fruhstorfer, 1906)
Cinnamomum verum J. S. Presl.		*Graphium sarpedon connectens*(Fruhstorfer, 1906)
Machilus japonica Sieb. & Zucc. var. *kusanoi*(Hayata) Liao	Y	*Graphium sarpedon connectens*(Fruhstorfer, 1906)
Machilus thunbergii Sieb. & Zucc.		*Graphium sarpedon connectens*(Fruhstorfer, 1906)
Family Magnoliaceae		
Michelia compressa(Maxim.) Sargent	Y	*Graphium doson postianus*(Fruhstorfer, 1908)
Family Moraceae		
Malaisia scandens(Lour.) Planch.		*Euploea tulliolus koxinga*(Fruhstorfer, 1908)

Ficus microcarpa L. f. var. *microcarpa.*	*Euploea mulciber barsine*(Fruhstorfer, 1904)
	Euploea eunice hobsoni(Butler, 1877)
Ficus virgata Reinw. ex Blume	*Euploea mulciber barsine*(Fruhstorfer, 1904)
	Euploea eunice hobsoni(Butler, 1877)
Ficus formosana Maxim.	*Euploea mulciber barsine*(Fruhstorfer, 1904)
	Euploea eunice hobsoni(Butler, 1877)

Family Oxalidaceae

Oxalis corniculata L. *Zizeeria maha okinawana*(Matsumura, 1929)

Family Piperaceae

Piper betle L. *Graphium agamemnon*(Linnaeus, 1758)

Family Plantaginaceae

Plantago major L. *Junonia almana*(Linnaeus, 1758)

Family Poaceae

Miscanthus floridulus(Labill.) Warb. ex Schum. & Laut. *Parnara bada*(Moore, 1878)

Setaria palmifolia(J. Konig) Stapf *Melanitis leda*(Linnaeus, 1758)

Telicota bambusae horisha(Evans, 1934)

Family Rutaceae

Genus *Citrus* *Papilio demoleus*(Linnaeus, 1758)

Family Salicaceae

Salix babylonica L. *Cupha erymanthis*(Drury, 1773) *Salix warburgii* O. Seem Y

Cupha erymanthis(Drury, 1773)

Family Scrophulariaceae

Lindernia ciliata(Colsm.) Pennel *Junonia almana*(Linnaeus, 1758) *Lindernia anagallis*(Burm. f.)

Junonia almana(Linnaeus, 1758)

Family Zingiberaceae

Hedychium coronarium Koenig *Jamides alecto dromicus*(Fruhstorfer, 1910)

Alpinia zerumbet(Persoon) B. L. Burtt & R. M. Smith *Jamides alecto dromicus*(Fruhstorfer, 1910)

*Generalization from Chao and Fang(2002), Ho and Chang(1998), Li(2004), Moore *et al.*(2002), Tsai *et al.*(2005), Yang(1995), Yang(2009), and Zhang-Jian *et al.*(2002, 2005)

Appendix 2. Species list of butterflies recorded in EEP during 2011.

Species name	Endemic species
Family Hesperiidae	
Borbo cinnara(Wallace, 1866)	

Burara jaina formosana(Fruhstorfer, 1911)	
Caltoris cahira austeni(Moore, 1883)	
Daimio tethys niitakana(Matsumura, 1907)	
Hasora badra(Moore, 1858)	
Parnara bada(Moore, 1878)	
Pelopidas agna(Moore, 1886)	
Potanthus confucius angustatus(Matsumura, 1910)	
Potanthus motzui(Hsu, Li, & Li, 1990)	Y
Seseria formosana(Fruhstorfer, 1909)	Y
Suastus gremius(Fabricius, 1798)	
Telicota bambusae horisha(Evans, 1934)	
Telicota ohara formosana(Fruhstorfer, 1911)	
Family Papilionidae	
Byasa impediens febanus(Fruhstorfer, 1908)	
Byasa polyeuctes termessus(Fruhstorfer, 1908)	
Graphium agamemnon(Linnaeus, 1758)	
Graphium doson postianus(Fruhstorfer, 1908)	
Graphium sarpedon connectens(Fruhstorfer, 1906)	
Pachliopta aristolochiae interposita(Fruhstorfer, 1904)	
Papilio bianor thrasymedes(Fruhstorfer, 1909)	
Papilio castor formosanus(Rothschild, 1896)	
Papilio demoleus(Linnaeus, 1758)	
Papilio helenus fortunius(Fruhstorfer, 1908)	
Papilio hermosanus(Rebel, 1906)	Y
Papilio memnon heronus(Fruhstorfer, 1929)	
Papilio nephelus chaonulus(Fruhstorfer, 1908)	
Papilio polytes polytes(Linnaeus, 1758)	
Papilio protenor protenor(Cramer, 1775)	
Papilio thaiwanus(Rothschild, 1898)	Y
Papilio xuthus(Linnaeus, 1767)	
Family Pieridae	
Appias indra aristoxemus(Fruhstorfer, 1908)	
Appias lyncida eleonora(Boisduval, 1836)	
Catopsilia pomona(Fabricius, 1755)	
Catopsilia pyranthe(Linnaeus, 1758)	
Cepora nadina eunama(Fruhstorfer, 1903)	
Eurema blanda arsakia(Fruhstorfer, 1910)	
Eurema hecabe(Linnaeus, 1758)	

Eurema brigitta hainana(Moore, 1878)
Hebomoia glaucippe formosana(Fruhstorfer, 1908)
Ixias pyrene insignis(Butler, 1879)
Leptosia nina niobe(Wallace, 1866)
Pieris canidia(Sparrman, 1768)
Pieris rapae crucivora(Boisduval, 1836)

Family Lycaenidae

Acytolepsis puspa myla(Fruhstorfer, 1909)
Arhopala birmana asakurae(Matsumura, 1910)
Artipe eryx horiella(Matsumura, 1929)
Celastrina lavendularis himilcon(Fruhstorfer, 1909)
Chilades pandava peripatria(Hsu, 1989)
Deudorix epijarbas menesicles(Fruhstorfer, 1912)
Freyeria putli formosanus(Matsumura, 1919)
Heliophorus ila matsumurae(Fruhstorfer, 1908)
Jamides alecto dromicus(Fruhstorfer, 1910) *Jamides bochus formosanus*(Fruhstorfer, 1909) *Lampides boeticus*(Linnaeus, 1767)
Leptotes plinius(Fabricius, 1793) *Megisba malaya sikkima*(Moore, 1884) *Nacaduba kurava therasia*(Fruhstorfer, 1916) *Prosotas nora formosana*(Fruhstorfer, 1916)
Rapala varuna formosana(Fruhstorfer, 1912) *Spindasis syama*(Horsfield, 1829)
Zizeeria maha okinawana(Matsumura, 1929)
Zizula hylax(Fabricius, 1775)

Family Nymphalidae

Athyma cama zoroastes(Bulter, 1877) *Athyma perius*(Linnaeus, 1758)
Athyma selenophora laela(Fruhstorfer, 1908)
Cupha erymanthis(Drury, 1773)
Cyrestis thyodamas formosana(Fruhstorfer, 1898)
Danaus chrysippus(Linnaeus, 1758) *Danaus genutia*(Cramer, 1779)
Discophora sondaica tulliana(Stichel, 1905) *Euploea eunice hobsoni*(Butler, 1877)
Elymnias hypermnestra hainana(Moore, 1878) *Euploea mulciber barsine*(Fruhstorfer, 1904)
Euploea sylvester swinhoei(Wallace & Moore, 1866) *Euploea tulliolus koxinga*(Fruhstorfer, 1908) *Hestina assimilis formosana*(Moore, 1895) *Hypolimnas bolina kezia*(Bulter, 1877)
Junonia almana(Linnaeus, 1758) *Junonia iphita*(Cramer, 1779)
Junonia lemonias aenaria(Fruhstorfer, 1912) *Kallima inachus formosana*(Fruhstorfer, 1912)
Lethe chandica ratnacri(Fruhstorfer, 1908) *Lethe verma cintamani*(Fruhstorfer, 1909)
Limenitis sulpitia tricula(Fruhstorfer, 1908)
Melanitis leda(Linnaeus, 1758)
Melanitis phedima polishana(Fruhstorfer, 1908) *Mycalesis francisca formosana*(Fruhstorfer, 1908)
Mycalesis gotama nanda(Fruhstorfer, 1908) *Mycalesis zonata*(Matsumura, 1909)

Neptis hylas luculenta(Fruhstorfer, 1898)
Neptis nata lutatia(Fruhstorfer, 1913)
Neptis sappho formosana(Fruhstorfer, 1908)
Neptis taiwana(Fruhstorfer, 1908) Y
Parantica aglea maghaba(Fruhstorfer, 1909) *Parantica sita niphonica*(Moore, 1883)
Parantica swinhoei(Moore, 1883) *Penthema formosanum*(Rothschild, 1898)
Phalanta phalantha(Drury, 1773)
Polygonia c-aureum lunulata(Esaki & Nakahara, 1923) *Tirumala limniace limniace*(Cramer, 1775) *Tirumala septentrionis*(Butler, 1874) *Ypthima baldus zodina*(Fruhstorfer, 1911)
Ypthima multistriata(Butler, 1883)

*Based on the most recent records from TaiBNET(Catalogue of Life in Taiwan: http://taibnet.sinica.edu.tw/) and Name Lists of Butterflies of Taiwan(updated on 2011/05/15) by Butterfly Conservation Society of Taiwan(http://www.butterfly.org.tw/home.php)

Appendix 3. Number of butterfly species recorded during 2011.

Family	Month											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Hesperiidae	0	3	1	0	1	2	3	2	2	7	3	3
Papilionidae	1	2	3	6	6	6	10	10	9	9	3	3
Pieridae	6	7	6	8	5	4	4	3	5	5	5	7
Lycaenidae	5	4	3	6	5	9	10	2	5	12	6	11
Nymphalidae	5	9	9	7	14	16	20	10	20	21	16	15
Total	17	25	22	27	31	37	47	27	41	54	33	39

Appendix 4. Number of individual butterfly adults recorded during 2011.

Family	Month												
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Total
Hesperiidae	0	3	1	0	2	4	5	2	2	8	3	4	34
Papilionidae	1	2	5	7	13	21	41	14	17	21	3	4	149
Pieridae	33	83	35	43	23	50	46	23	19	38	15	48	456
Lycaenidae	9	20	4	15	15	38	67	10	20	39	24	273	534
						59	123		55	115		44	581
Total	48	131	75	76	98	172	282	81	113	221	84	373	1754
Nymphalidae	5	23	30	11	45	32	39						