Butterfly species diversity and their floral preferences in the Rupa wetland of Nepal

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Abstract

The diversity of butterflies is known to some extent in Nepal, but the study of their interactions with nectar plant sources and floral attributes is limited. This study was conducted along the periphery of Rupa Wetland, a Ramsar site, from February to November 2019 to assess butterfly species diversity and to identify the factors influencing their foraging choices at nectar plants. We assessed the number of butterfly species, their abundance, and their floral foraging behavior, from 28 linear transects (500 m long each) placed in a stratified and random manner throughout the study area. Five factors, i.e., category of plant, flower colour, corolla shape, corolla depth, and the proboscis length of butterfly species were taken into account to assess the nectar plant choices of butterfly families. Moreover, species diversity at the family level, and overall, were determined through several indices. When examining overall butterfly diversity and abundance, we recorded a total of 1,535 butterflies belonging to 138 species within six families. For our examination of butterfly-nectar plant observations, we recorded a total of 298 individuals belonging to 31 species of butterfly visiting a total of 28 nectar plant species. Among the recorded butterflies, Zemeros flegyas was found to be the most abundant (92 individuals), while only a single individual each of the species Troides helena, Gandaca herina and Belonois aurota were recorded. Of the 28 nectar host plant species, Biden pilosa was the most popular and was visited by 13 species of butterflies. Overall, total butterfly visitation was found to be significantly influenced by plant category (herbaceous preferred over woody), floral colour (yellow, white, and purple preferred over pink), and corolla shape (tubular preferred over non-tubular). Moreover, there was a significant positive correlation ($r = 0.466$) between the proboscis length of butterflies and the corolla tube length of flowers ($p<0.001$).

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Key words : Lepidoptera, nectar plants, species diversity, corolla depth, proboscis length

Introduction

Nepal is remarkably diverse in flora and fauna due to its climatic and topographical variation. The dramatic differences in elevation and microclimate result in a variety of ecosystems, from tropical savannas along the Indian border, to subtropical broad leaf and coniferous forests in the Hilly region, to temperate broadleaf and coniferous forests on the lap of the Himalayas (MoFE, 2018). The land area of Nepal occupies just 0.1% of global area but comprises 3.2% of the world's floral diversity and 1.1% of global faunal diversity (MFSC, 2014).

Insects are one of the key indicators of healthy ecosystems, and they play a significant role in ecosystem functioning (Springett, 1978). Butterflies, one of the best-known pollinators and bio indicators, belong to the order Lepidoptera (suborder Rhopalocera) (Durairaj and Sinha, 2015). Out of around 20,000 species of butterflies recorded worldwide, Nepal is home to 668 species from 263 genera, which is about 4.3% of globally known species (Smith and Majupuria, 2006; Sajan and Pariyar, 2019; Panthee et al., 2018; Sapkota et al., 2020; Tamang, Nuppa, et al., 2019; Muhammad et al., 2018; Poel et al., 2020). Around 29 species and subspecies of butterflies are endemic to Nepal. These endemic species are disappearing slowly, and about 18% of the butterfly species found in the mid hill zones are considered threatened (ICIMOD [International Center for Integrated Mountain Development], 2007). A total of 142 species of butterflies found in Nepal are under the IUCN red list category, among which 12 are endangered, 43 are vulnerable, and 87 are susceptible (Paudel, Bhattarai and Kindlmann, 2012). Likewise, three species (*Teinopalpus imperialis* , *Troides aeacus* , and *Troides helena*) are placed under CITES Appendix II (Khanal, Chalise and Solanki, 2013).

Approximately 80% of known plant species worldwide are angiosperms, and a large percent of these species depend on insect pollination (Ackerman, 2000; Nimbalkar, Chandekar and Khunte, 2011). The immense diversity of pollinators, and plants requiring pollination, has resulted in the evolution of various mechanisms and strategies whereby plants attract specific pollinators to promote intraspecific pollen transfer (Larsson, 2005). Such mechanisms include evolving specific floral shapes (e.g., tubular flowers, or floral landing platforms), varying the sugar concentration in nectar, evolving a time lock mechanism for pollen release, and evolving special structures that prevent access to nectar and pollen (Freitas and Sazima, 2003). Essentially, the shape, size, structure and colour of flowers directly influence flower-visiting animals (Ilse, 1928; Erhardt, 1991; Boggs and Ross, 1993). Additionally, butterflies are often constrained in their feeding habits by the length of their mouthparts, as they cannot forage on plant species with corolla tube lengths longer than the length of their proboscis (Cruden and Hermann-Parker, 1979; Porter, 1992).

While insects are known to be critical to ecosystem functioning, the biodiversity of insects is threatened worldwide. There has been a dramatic decline among Lepidopterans that may lead to the extinction of 40% of species over the next few decades (Sánchez-Bayo and Wyckhuys, 2019). Minor changes in their habitat may lead to either migration or local extinction if the required attention is not given (Kunte, 1997) because many species require specific plants as food or sites for reproduction (Bernays and Graham, 1988). The biggest threat that humans pose to the survival of insects, including butterfly populations, is habitat destruction (New et al., 1995). Due to the rapid increase in global human population size, anthropogenic changes are impacting butterflies through both direct habitat loss as well as the loss of plant species on which butterflies depend (Hoyle and James, 2005). Moreover, butterflies are particularly sensitive to environmental changes (Stefanescu *et al* ., 2011), including the fast rise of industries, intense use of fertilizers and insecticides, climate change, nitrogen pollution, mono-cropping, forest fires, fragmentation, and habitat degradation, all of which make them vulnerable to extinction. As butterflies are known to be flagship species for insect conservation (Wagner, Nelson and Schweitzer, 2003; Tiple, Deshmukh and Dennis, 2005), any research efforts that target the conservation of butterfly species will automatically save many other species in the area. To protect this flagship group from further population declines, and potential species extinctions, studies examining their diversity, habitat suitability and nectar plant choices are necessary.

While there have been many studies on butterflies from different parts of Nepal (Smith and Majupuria, 2006; Khanal, 2006; Bhusal and Khanal, 2008; Khanal et al., 2013; Khanal et al., 2014; Rai, 2017; Suwal et al., 2019), previous studies have focused on the diversity, taxonomy and distribution of butterflies, and few studies have examined butterfly-plant interactions (Nepali et al., 2018; Shrestha et al., 2020). However, extensive ecological studies to determine the factors that influence butterfly foraging choices are crucial to improve the ecological utility of butterflies and to preserve them as indicator taxa. Given the lack of sufficient knowledge about butterfly diversity and their floral foraging preferences in Nepal, this research aimed to fulfill this gap by addressing two main objectives. The first objective was to examine butterfly diversity and abundance throughout the year at Rupa Wetland. This area is known to support high butterfly diversity (Smith, Sherpa and Shristi, 2016), but we still lack long-term studies (spanning multiple seasons) that quantify the abundance of different species. The second objective was to examine butterfly-nectar plant interactions, and to assess the factors influencing floral foraging choices. The information gained from our two objectives is necessary to conserve both butterflies and their preferred nectar plants in an effective and sustained manner.

2. Materials and methods

2.1 Study Area

Rupa Wetland (28°8'55"N 84deg6'40"E) (Figure 1), declared a Ramsar site in February 2016, is one of the most important wetlands of Nepal situated in Chitwan Annapurna Landscape at an elevation of 600 m above sea level (Paudel, Adhikari and Paudel, 2017). The lake serves as a famous tourist destination and also supports fish farming, thus providing a great source of income to local livelihoods (Rajbhandari and Shrestha, 2014). It is the third biggest lake of Pokhara valley with a total watershed area of 3,000 hectares and a lake area of 112 hectares. The lake provides suitable habitat for diverse butterflies, dragonflies, fish species, and some major wetland bird species (Gaut*am et al* >, 2019). The wetland is important for migratory birds, and 36 species of water birds have been recorded (Kafle *et al.* , 2008). This study was conducted in the catchment area of the lake. It constitutes 361 species of vegetation and 175 species of forest medicinal herbs (Dangol, 2015). The watershed area to the east of the wetland is covered with a mixed forest of Chilaune (*Schima wallichii*) and Katus (*Castanopsis indica*) with native wild flowers like

Damaifal (*Ardisia solanacea)* , Marantina's Swan flower (*Globba marantina*), and Kuro (*Bidens Pilosa)* , thus providing a favorable habitat for butterflies. The western hill slope is covered with a mix of native vegetation and cultivated land, while the northern slope consists of privately owned terraced land for agriculture crops, as well as some floating aquatic vegetation, grasses, and rice fields that are found along the lake shoreline.

2.2 Data collection

The study area was fully explored from January to December 2019 throughout Nepal's four seasons: pre-monsoon (March to May), monsoon (June to September), post monsoon (October to November), and winter (December to February) (GoN, 2011). To address our first objective (assessing butterfly diversity and abundance), we collected data from March to November 2019; data was not collected during the winter due to the lack of butterflies during this season, as they are intolerant to cold temperatures (McDermott Long *et al* >, 2017). To address our second objective (examining butterfly foraging choices), we collected data from February to July 2019, which covered the flowering periods of diverse plant species in the study area.

Data for both objectives was collected using the transect count method described by Pollard (1977). A total of 28 transects, 500 m long each, were arranged in a stratified and random manner at an interval of 100 m apart along the lake's edge (i.e., scrubland where maximum butterflies were observed) (Figure 1a). Each transect was walked at a slow, constant pace and all butterflies within 5 m of the observer walking the transect (to either side, in front, and above) were counted and recorded. Each transect was walked twice per month, resulting in a total of 18 replicates for the butterfly diversity and abundance data, and 12 replicates for the butterfly foraging data. Transect lines were walked in the morning between 8:00 to 12:00 h on sunny days (avoiding rainy and windy days) so that maximum butterfly species could be spotted (Caldas and Robbins, 2003). Butterflies were identified in the field based on their behavioral and morphological characteristics following Smith and Majupuria (2006) and plants were identified based on leaf, floral, and fruit characteristics following Storrs and Storrs (1990).

Additionally, for data collected on butterfly foraging choices, attempts were made to catch every feeding butterfly seen on each transect by using a sweep net. Proboscis length was determined by restraining the tip of the unfurled proboscis with forceps or a needle and measuring the distance from the base to the tip (Ehrlich and Raven, 1964). Moreover, the flower corolla at which the butterfly was observed was plucked to measure the corolla tube length. Corolla depth was measured from the most convenient point from which a butterfly might place the proboscis to the corolla base, where the nectar was available. For each plant species, we also recorded plant category (herbaceous or woody), flower colour, and corolla shape (tubular or non-tubular). Finally, for the butterfly diversity and abundance data, we used the number of butterfly sightings to categorize each species as very rare (<2 sightings), rare (2-15 sightings) not rare (15-50 sightings), common (50-100 sightings) and very common (>100 sightings) to determine the site-specific status of each butterfly species (Tiple et al., 2005; Shrestha et al., 2018).

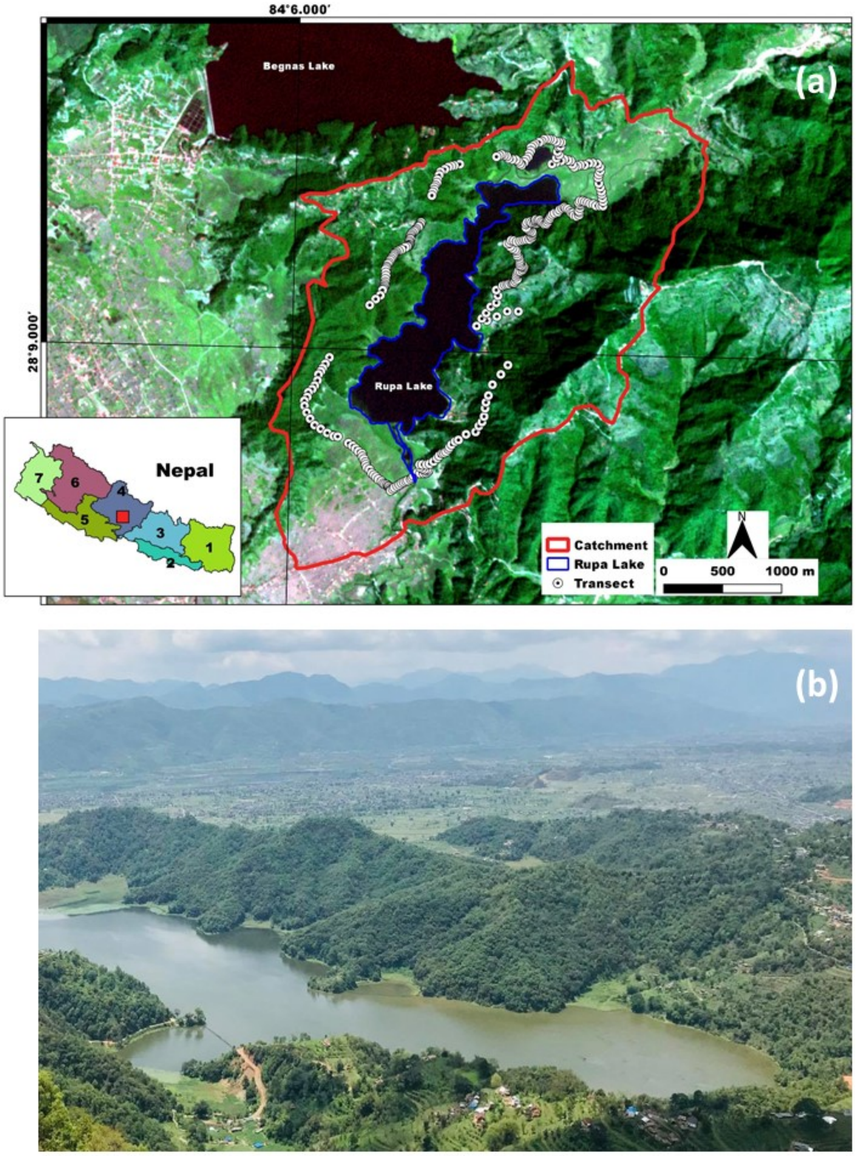

Figure 1 (a) Geographic location of the study area shown on Rapid eye image from March 16, 2019; Rupa

Lake is outlined in blue, the catchment area is outlined in red, and white markers indicate the locations of study transects. (b) A photograph of Rupa Wetland, showing the land use and land cover types in the study area (@Damodar Bhakta Thapa).

2.3 Data analysis

We calculated the Shannon-Weiner diversity index (Shannon and Weaver, 1949), Simpson Index (Simpson, 1949), species richness, Pielou's evenness (Pielou, 1966), Margalef's richness index (Margalef, 1958), and relative abundance of each butterfly family to quantify butterfly diversity in the Rupa wetland. The Shannon-Weiner diversity index provides information about the community composition of species; the higher the number, the higher the species diversity. Simpson's index is a weighted arithmetic mean of proportional abundance and measures the probability that two individuals randomly selected from a sample will belong to the same species. It is a dominance index because it gives more weight to common or dominant species, whereas the Shannon-Weiner index gives more weight to rare species. Simpson's index ranges from to 0 to 1 with 0 representing infinite diversity and 1 representing no diversity, so the larger the value of D, the lower the diversity. Species richness denotes the total number of species observed within an area. Margalef's index was used as a simple measure of species richness (Margalef, 1958) and Pielou's evenness index (e) was used for calculating the evenness of species (Pielou, 1966). Species abundance denotes the total number of individuals observed during the study period.

Shannon Index (H) $=-\sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{p}_{\mathrm{i}} \ln \mathrm{p}_{\mathbf{i}}$ .... Eq. 1

Simpson Index (D) $=\frac{1}{\sum_{\mathrm{i=1}}^{\mathbf{n}} \mathbf{p_i}}$..............................Eq.2

Pielou's evenness index (e) $= \frac{H}{ln(S)}$..................Eq. 3

Margalef's richness index $= \frac{S-1}{\ln{(N)}}$................... Eq. 4

Where, H is the Shannon-Weiner species diversity index, D is the Simpson's diversity index, S is the number of species,p_i is the proportion of individuals belonging to the i^{th} species, and N is the total number of individuals.

For our butterfly-plant interaction data, we used generalized linear modelling (GLM) (Nelder and Wedderburn, 1972) to identify the factors affecting nectar plant choice by butterflies. Butterfly species abundance was used as the dependent variable whereas flower colour, plant category, and corolla shape were used as independent variables with a Poisson distribution. We used nested likelihood ratio tests (Neyman and Pearson, 1933) to choose the best model, followed by Turkey's post-hoc tests (Tukey, 1949) in the case of significant predictors. Differences were considered significant at $p<0.05$. Additionally, Pearson's correlation coefficient was used to test for a significant relationship between the proboscis length of butterflies and the corolla depth of flowers.

3. Results

3.1 Butterfly species and their individuals

All together, 1,535 individuals of 138 species representing all six families of butterflies were counted and recorded in the single wetland. Among them, Punchinello (*Zemeros flegyas,* 92 individuals) and Grey pansy (*Junonia atlites,* 80 individuals) butterflies were the most abundant species, followed by Straight swift (*Parnara guttata,* 69 individuals), Common five ring (*Ypthima baldus,* 45 individuals), and Common grass yellow (*Eurema hecabe,* 38 individuals) butterflies. The least common species included Pioneer (*Belonois aurota,* 1 individual), Common batwing (*Troides helena,* 1 individual), Tree yellow (*Gandaca harina,* 1 individual), Pale Wanderer (*Pareronia avatar,* 2 individuals), Yellow orange tip (*Ixias pyrene,* 2 individuals), Peablue (*Lampides boeticus,* 3 individuals), Chocolate albatross (*Appias lyncida,* 4 individuals), Dark cerulean (*Jamides bochus,* 5 individuals), and Dark pierrot (*Tarucus ananda,* 8 individuals) butterflies (Annex 1).

The family with the most observed individuals was the Nymphalidae family (650 individuals of 62 spp), followed by Lycaenidae (319 individuals of 29 spp), Pieridae (181 individuals of 20 spp), Hespiridae (163 individuals of 10 spp), Riodinidae (132 individuals of 4 spp) and Papilionidae (90 individuals of 13 spp) (Figure 2).

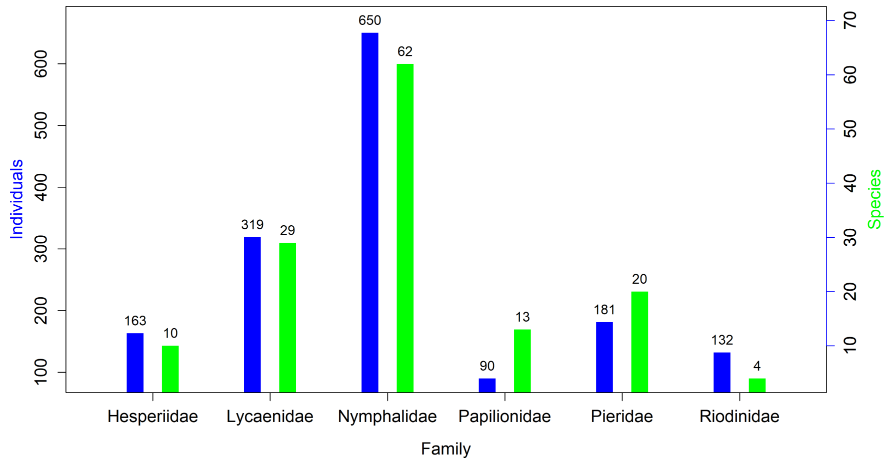

Figure 2. The number of individuals and species of each butterfly family observed in Rupa Wetland, Nepal.

3.2 Species diversity, evenness and richness

In our study area, we observed 3 common, 29 not rare, 61 rare, and 45 very rare butterfly species (Annex 1). Family Nymphalidae had the highest Shannon diversity index of 3.50 while family Riodinidae showed the lowest diversity with a value of 0.84. The overall Shannon diversity index, Simpson's index, species richness, Pielou evenness and Margalef richness index of butterfly fauna in Rupa wetland (pooling all families) were 4.33, 0.98, 138, 0.87, and 18.67, respectively. Diversity indices for each family in the Rupa Wetland are summarized in Table 1.

Table 1. The Shannon-Weiner diversity index, Simpson diversity index, species richness, Pielou's evenness, and Margalef's richness index calculated for each butterfly family observed in Rupa Wetland, Nepal, as well as the overall values when data from all families were pooled together.

Family	**Shannon Index**	**Simpson Index**	**Species richness**	**Pielou evenness**	**Margalef's Richness Index**
Hesperiidae	1.72	0.76	10.00	0.75	1.23
Lycaenidae	2.99	0.94	29.00	0.89	3.82
Nymphalidae	3.50	0.96	62.00	0.85	8.31
Papilionidae	2.11	0.85	13.00	0.82	1.64
Pieridae	2.48	0.89	20.00	0.83	2.59
Riodinidae	0.84	0.46	4.00	0.60	0.41
All families	4.33	0.98	138	0.87	18.67

3.3 Effects of flower color, plant category and corolla shape on butterfly abundance

Out of the 138 butterfly species observed, only 31 species consisting of 298 individuals were observed feeding at flowers; they were recorded at a total of 28 nectar plant species. When all 31 butterfly species were analyzed together, results of the GLM revealed that butterfly visitation was significantly influenced by plant category ($\chi^2{}_1 = 0.50$, $p = 0.48$), flower colour ($\chi^2{}_4 = 12.3$, $p = 0.015$), and corolla shape ($\chi^2{}_1 = 1.22$, $p = 0.27$) (Figure 3). Butterflies significantly preferred the flowers of herbaceous plants over woody plants (Figure 3A), and tubular flowers over non-tubular flowers (Figure 3C). Moreover, Tukey's test revealed that butterfly abundance was significantly greater at yellow, white, and purple flowers than at pink flowers ($p < 0.05$; Figure 3B). Examining each butterfly family separately revealed different results (Figure 4). For four of the families (Lycaenidae, Nymphalidae, Papilionidae, and Pieridae), none of the tested factors (flower color, plant category, and corolla shape) were shown to significantly influence butterfly abundance at flowers (Figure 4D-O). However, Hesperidae abundance was found to be significantly influenced by both flower colour ($\chi^2{}_3 = 12.1$, $p = 0.007$), with more butterflies observed at yellow flowers than purple flowers (Figure 4B), and flower shape ($\chi^2{}_1 = 5.78$, $p = 0.02$), with more butterflies observed at tubular flowers than non-tubular flowers (Figure 4C).

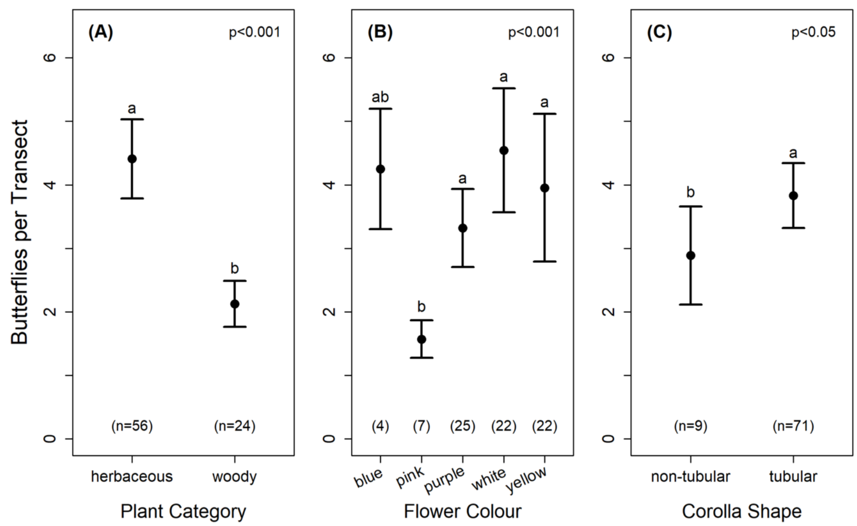

Figure 3. The mean (± SE) number of butterflies observed per transect at (A) the flowers of herbaceous versus woody plant species, (B) different floral colours, and (C) non-tubular versus tubular flowers. Within each graph, different lowercase letters indicate significant differences. Numbers in parentheses at the bottom of each graph indicate the sample sizes (number of sightings).

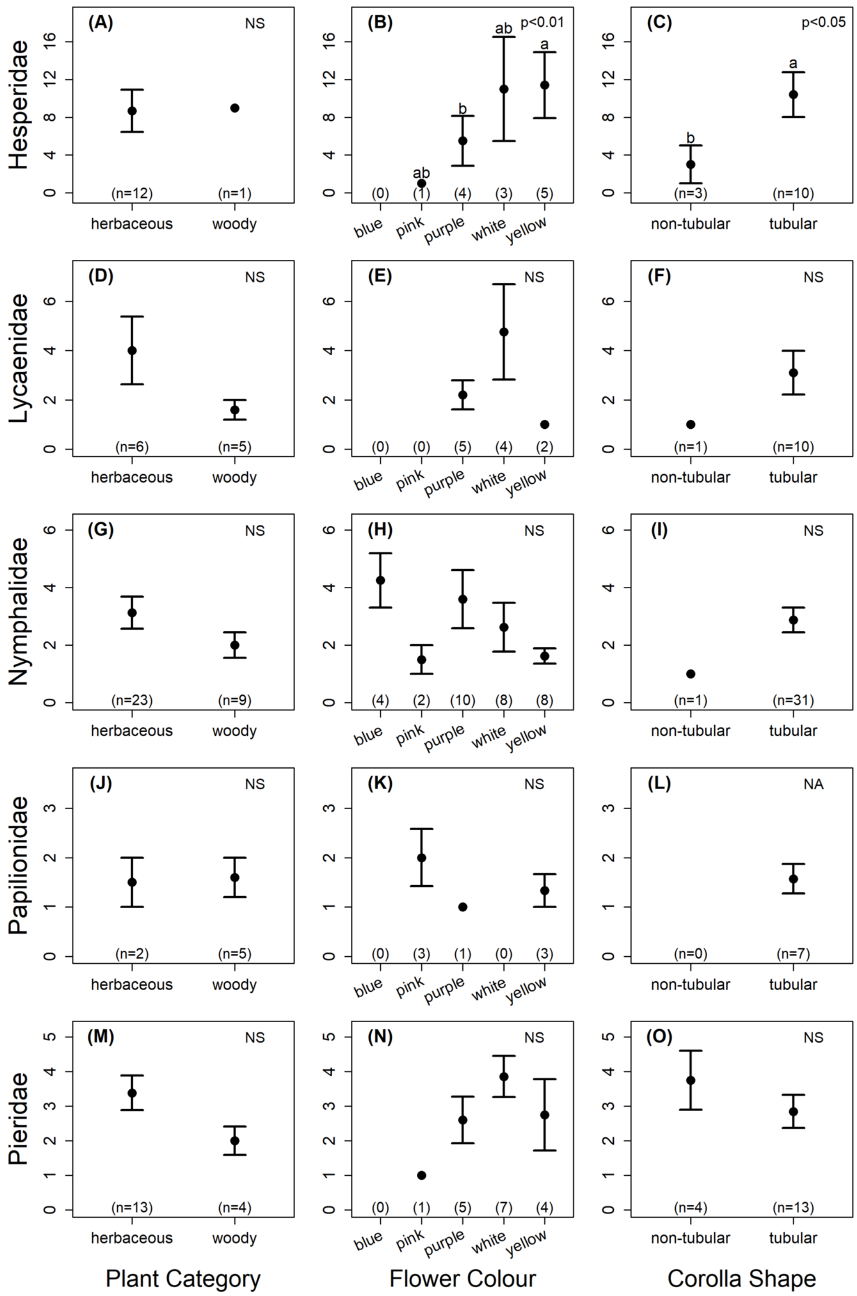

Figure 4. The mean (± SE) number of butterflies observed per transect for each of 5 butterfly families observed: (A-C) Hesperidae, (D-F) Lycaenidae, (G-I) Nymphalidae, (J-L) Papilionidae, and (M-O) Pieridae. Graphs show the number of butterflies at (A, D, G, J, M) the flowers of herbaceous versus woody plant species, (B, E, H, K, N) different floral colours, and (C, F, I, L, O) non-tubular versus tubular flowers. Within each graph, different lowercase letters indicate significant differences. Numbers in parentheses at the bottom of each graph indicate the sample sizes (number of sightings).

3.4 Number of butterfly species feeding at nectar plant species

To ascertain the popularity of nectar plant species, the total number of butterfly species observed feeding on each plant species was counted. Twenty-eight nectar host plant species were observed receiving butterfly visits. *Bidens pilosa* was visited by the most butterfly species (13 species), followed by *Eupatorium odoratum* (11 species),*Lantana camara* (10 species), and *Ageratum houstonianum* (6 species); 15 plant species were visited by a single butterfly species (Figure 3A). *Parnara guttata* butterflies visited the most plant species (10 species), followed by *Catopsilia pyranthe* (5), Eurema hecabe (5) and *Appias lyncida* (4), whereas 9 butterfly species visited only a single plant species (Figure 3B).

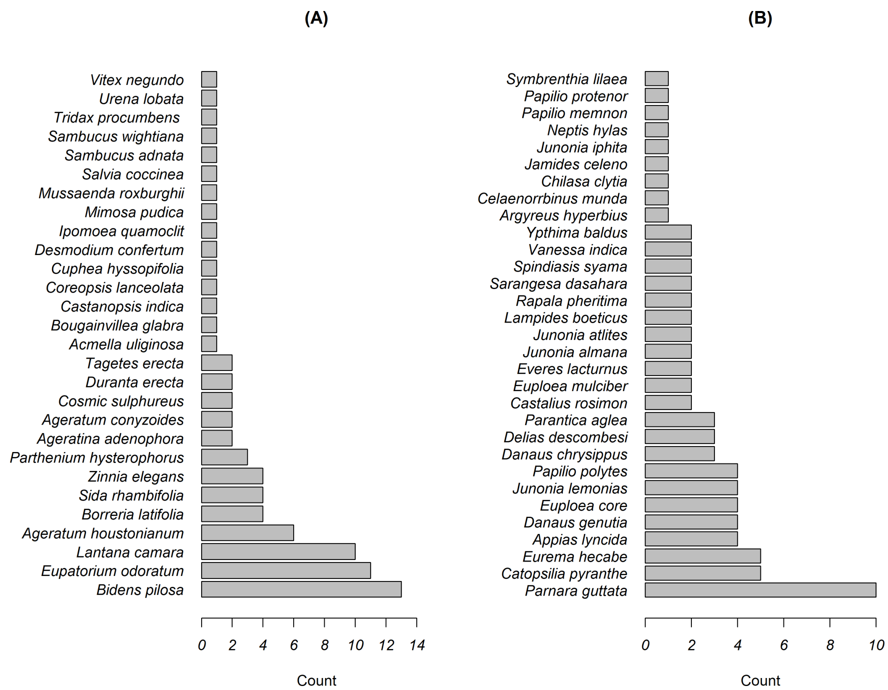

Figure 5. Plant species visited by number of butterflies species (A) and number of plant species visited by each butterfly species (B).

3.5 Correlation between proboscis length and corolla tube length

Our results show a significant correlation between the proboscis length of butterflies and the corolla tube length of visited flowers ($p < 0.001$, $r = 0.466$; Figure 6). The shortest mean proboscis length was 7.10 mm for Lycaenidae and the longest was 25.71 mm for Papilionidae (Appendix 3). Similarly, the shortest mean corolla tube length was 4.38 mm for flowers visited by Hesperidae butterflies and the longest was 19.43 mm for flowers visited by Papilionidae butterflies.

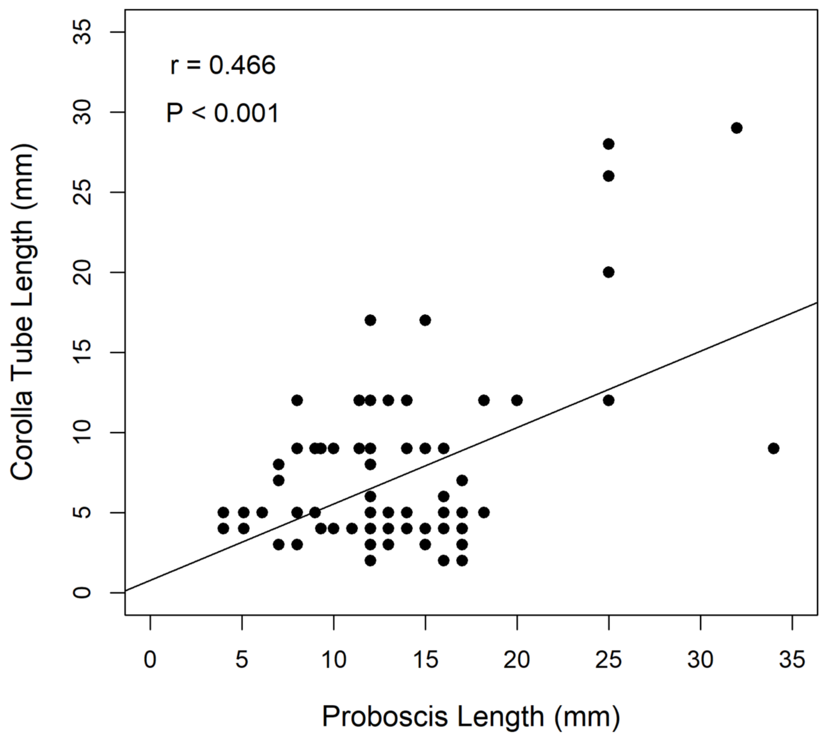

Figure 6. A scatterplot showing the significant positive correlation between butterfly proboscis length and corolla tube length of the flowers they foraged at in Rupa Wetland, Nepal.

Discussion

A total of 1,535 individuals from 138 species representing all six families of butterflies were counted and recorded in the single wetland. Similarly, Smith et al (2016) recorded a total of 174 butterfly species in Rupa and Begnas Lakes. In our study, the Nymphalidae had the highest diversity followed by the Lycaenidae family. Previous studies have also reported Nymphalidae to have the highest species richness, followed by Lycaenidae and others (Kunte, 1997; Prajapati, Shrestha and Tamrakar, 2000; Shrestha *et al* ., 2018; Tamang, Joshi and Shrestha, 2019). Moreover, similar findings have also been reported in other wetlands in India, such as at Oussudu Lake (Murugesan, Arun and Prusty, 2013) and the Kole Wetlands (Sarath, Sreekumar and Nameer, 2017). The rich biodiversity of butterfly fauna in Rupa Wetland is likely due to the rich vegetation in this area, which offers abundant floral resources for them to forage on. Interestingly, there was large variation in diversity among families. Some butterfly families observed in Rupa Wetland had quite high diversity (i.e., Nymphalidae), while others had lower diversity (i.e., Riodinidae and Hesperiidae), which may be due to a number of reasons. One possible explanation is that most nymphalids are polyphagous in nature, which makes it easier for them to utilize a variety of habitats (Janz, 2005). A second possible explanation may be that many species in this family are strong active fliers, which likely helps them cover large areas when searching for resources (Eswaran and Pramod, 2005; Padhye et al., 2006). Additionally, the families with relatively low diversity in Rupa Wetland may be limited by a lack of appropriate host plants; a study in South Germany found that the butterfly families with lower species richness were limited by a lack of host plants for the growing caterpillars (Steffan-Dewenter and Tscharntke, 1997).

When examining all butterfly species pooled together, all three factors examined (plant category, flower colour, and corolla shape) were found to significantly influence butterfly visitation at nectar plants. Butterflies visited the flowers of herbaceous plant species significantly more often than the flowers of woody species. Similar to our results, a previous study in Japan found that nectar utilization by adult butterflies was substantially higher at herbaceous plants than at woody species, even though the study was conducted in and near a woodland (Kitahara, Yumoto and Kobayashi, 2008). Additionally, a study by Santhosh and Basavarajappa, (2016) found that weeds contributed the most nectar to butterfly species, followed by shrubs, herbs, trees and climbers. Nimbalkar et al., (2011) also reported that visits of butterflies were more frequent to the flowers of herbs and shrubs than to the flowers of trees. This apparently common preference that butterfly species exhibit towards herbaceous plants may be due to the abundance of such host plants. For example, a study conducted by Sengupta and Ghorai (2013) in the hill forests of West Bengal, India found that Pierid and Hesperid butterfly families were mostly dependent on epiphytic flora due to large availability of Ochideaceae plants within their study area. Because herbaceous species appear to offer attractive floral resources to butterflies, maintenance of herbaceous plants in probable habitats may be one method to increase the richness and diversity of butterfly species.

In addition to plant category, flower colour was also found to influence butterfly visitation. In our study, butterflies visited yellow, white, and purple flowers significantly more often than pink flowers. Previous studies examining floral colour preferences in butterflies have reported a wide range of results. For example, one study in India found that butterflies visited red, yellow, blue and purple flowers more often than white and pink flowers (Tiple, Deshmukh and Dennis, 2005). In contrast, a different study in India found that butterflies preferred yellow, white, pink and blue flowers (Santhosh and Basavarajappa, 2016). The overall preference for yellow, white, and purple flowers in our study appears to be driven by Hesperidae, Lycaenidae, and Pieridae, as these families were rarely (0-1 individuals per transect) seen visiting pink or blue flowers (Figure 4). In contrast, Nymphalidae butterflies visited blue flowers more often than the other colors, and Papilionidae visited pink flowers most often, although the differences were not significant. Similar to our results, a previous study found that a Nymphalid butterfly species showed a color preference for both blue and yellow flowers (Ômura and Honda, 2005), and a different study reported that a Papilionidae species preferred red and purple flowers (Kandori and Yamaki, 2012). The diverse findings reported in previous studies is unsurprising given that there is high variation in floral rewards, both within and across plant species (Ya*n et al* ., 2016). Moreover, butterflies are known to be quick learners, and will readily choose high-rewarding colors over innate color preferences (Blackiston et al., 2011; Kandori and Yamaki, 2012). Thus, further research is necessary to determine the innate and acquired color preferences of Nepalese butterflies.

The third trait examined, corolla shape, revealed that butterflies visited tubular flowers significantly more often than non-tubular flowers. Our results are similar to those of Tiple and colleagues (2005), who also found that butterflies in India visited tubular flowers more often than non-tubular flowers. Moreover, the findings of Nimbalkar et al., (2011) also showed that most butterflies prefered tubular flowers over non-tubular ones. Raju et al., (2004) reported butterflies feeding on both tubular and non tubular flowers, but exhibited a preference for tubular flowers. This generally universal preference that butterflies have for tubular flowers is unsurprising, given the suitable morphological fit between butterfly proboscises and tubular corolla tubes (Sultana *et al* ., 2017).

Not only did we find that butterflies preferred tubular flowers, but we also observed a significant correlation between the proboscis length of butterflies and the corolla tube length of visited flowers. This finding indicates that butterfly with short proboscises prefer flowers with short corolla tube lengths and vice versa. At the same time, this finding supports the use of proboscis length as a morphological indicator of resource utilization in butterflies. Similar findings were recorded in the study by (Corbet, 2000) which showed that the maximum corolla depth of potential nectar plants limits the species feeding on them to those with sufficiently long proboscises; short-tongued butterfly species are therefore unable to feed on deep flowers. Moreover, (Sultana *et al.* , 2017) found that the proboscis had significant role in the co-evolution between butterflies and their nectaring plants. They reported that flowers are only fed upon when they remain within the range of the proboscis length. Szigeti et al (2020) investigated the relation between flower visits and the proboscis length of Clouded Apollo butterflies and found that the longer the proboscis, the more likely such butterflies were to forage on plants with the deepest corollas. Our study shows that Lycaenidae and Pieridae butterflies prefer flowers with relatively shallow corollas, Nymphalidae and Hesperidae with moderately deep corollas, and Papilionidae butterflies with the deepest corollas. A previous study by (Tiple, Khurad and Dennis, 2009) in central India also showed that Papilionids foraged on flowers with long corolla tubes. Similarly, (Ranta and Lundberg, 1980) reported that species with the longest proboscises were able to utilize the highest range of corolla tube depths. Thus, a long proboscis permits feeding on a greater variety of flowering plant species.

When analyzing butterfly visitation by family, Hesperidae were found to prefer yellow flowers over purple, and tubular flowers over non-tubular, but for the remaining four families examined (Lycaenidae, Nymphalidae, Papilionidae, and Pieridae), none of the tested factors (plant category, flower colour, and corolla shape) were shown to significantly influence butterfly abundance at flowers. This lack of significant findings may be due to small sample sizes, as we only observed 32 Lycaenidae, 90 Nymphalidae, 11 Papilionidae, and 52 Pieridae individuals foraging, in contrast to the 113 Hesperidae individuals observed foraging. Additionally, it is possible that individual species within each family have different preferences, resulting in the apparent lack of preferences at the family level. Moreover, butterfly foraging preferences appear to be flexible, as a previous study has suggested that although butterfly species may seem to exhibit specific preferences, their choices ultimately depend on the relative abundance of preferred traits (Arroyo *et al.* , 2007). Thus, more detailed studies (particularly at the species level) are necessary to fully understand butterfly foraging preferences. Such information is necessary to promote the diversity of butterfly species, which will ultimately help balance the diverse ecosystems that these important pollinators occupy.

Conclusions

This study examined the different factors affecting the choice of nectar plants of some Himalayan butterflies. Our findings show that plant category, flower colour, corolla shape, and corolla tube length all influenced butterfly foraging. The study suggests that Rupa Lake is a resource enriched habitat for different butterfly species. The wild patches within the wetlands are flourishing foraging grounds for butterflies, but are subjected to human disturbances. The management of such habitats is urgently required for the conservation of butterfly diversity. Before our study, Rupa was considered important in terms of PES (payment for ecosystem services), tourism, and recreation, but never realized in terms of harboring such diverse pollinators, which not only play an important role in the wetland area, but also in the surrounding agriculture farmlands too. Thus, our study further emphasizes the need to protect such wetlands for multiple purposes. This study not only confirms the importance of providing nectar resources for butterflies, but also reveals which types of resources are most appropriate for butterfly fauna. Cultivating native plant species preferred by butterflies will provide a more suitable habitat for these important pollinators. Finally, the high butterfly diversity found in the shrubland surrounding Rupa Lake reveals that conservation of such areas is necessary, and we recommend that such areas be declared as butterfly parks or butterfly zones to promote public awareness and conservation efforts.

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DATA AVAILABILITY STATEMENT

Data are available on Dryad.URL:

https://datadryad.org/stash/share/sl1Gxc2KGVXJVqFWj40UmuBRAUAnWYo0JEffP0meEw4

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Appendix

Annex 1: Diversity of Butterfly in Rupa Wetland, Nepal. Based on number of sightings butterfly species were categorized into very rare (< 2 sightings), rare (2–15 sightings), not rare (15–50 sightings), and common (50–100 sightings). Single individual of Common batwing (Troides helena) was recorded in the study area which was categorized as Least Concern species according to IUCN Red List Data.

Scientific Name	Local Name	Individuals	Family	Butterfly Status
Lethe confuse	Banded tree brown	10	Nymphalidae	Rare
Ypthima baldus	Common five ring	45	Nymphalidae	Not rare
Ypthima nikaea	Moore's five ring	5	Nymphalidae	Rare
Ypthima huebneri	Common four ring	30	Nymphalidae	Not rare
Ypthima newara	Newari three ring	6	Nymphalidae	Rare
Ypthilma confuse	Confusing three ring	2	Nymphalidae	Very rare
Junonia almana	peacock pansy	12	Nymphalidae	Rare
Junonia lemonias	Lemon pansy	35	Nymphalidae	Not rare
Junonia orithyra	Blue pansy	2	Nymphalidae	Very rare
Junonia atlites	Grey pansy	80	Nymphalidae	Common
Junonia iphita	Chocolate pansy	27	Nymphalidae	Not rare
Tirmala septentrionis	Dark blue tiger	1	Nymphalidae	Very rare
Parantica tytia	Chestnut tiger	1	Nymphalidae	Very rare
Danaus genutia	Common tiger	5	Nymphalidae	Rare
Danaus chrysippus	Plain tiger	7	Nymphalidae	Rare
Parantica aglea	Glassy tiger	15	Nymphalidae	Rare
Euploea mulciber	Striped blue crow	3	Nymphalidae	Rare

Scientific Name	**Local Name**	**Individuals**	**Family**	**Butterfly Status**
Euploea core	Common Indian Crow	6	Nymphalidae	Rare
Hestina nama	Circe	2	Nymphalidae	Very rare
Elymnias hypermnestra	Common palmfly	1	Nymphalidae	Very rare
Elymnias malelas	Spotted palmfly	2	Nymphalidae	Very rare
Tanaecia lepidea	Grey count	29	Nymphalidae	Not rare
Tanaecia julii	Common earl	43	Nymphalidae	Not rare
Orsotrioena medus	Jungle brown	33	Nymphalidae	Not rare
Mycalesis francisca	Lilacine bush brown	7	Nymphalidae	Rare
Mycalesis malsara	White line bush brown	10	Nymphalidae	Rare
Mycalesis mineus	Dark brand bushbrown	5	Nymphalidae	Rare
Mycalesis perseus	Common bush brown	18	Nymphalidae	Not rare
Melanitis leda	Common evening brown	20	Nymphalidae	Not rare
Melanitis phedima	Dark evening brown	16	Nymphalidae	Not rare
Lethe insana	Common forester	1	Nymphalidae	Very rare
Nemetis mekara	Straight red forester	1	Nymphalidae	Very rare
Argyreus hyperbius	Indian fritillary	6	Nymphalidae	Rare
Symbrenthia niphanda	Blue tailed jester	1	Nymphalidae	Very rare
Symbrenthia hypselis	Spotted jester	1	Nymphalidae	Very rare
Symbrenthia lilaea	Common jester	10	Nymphalidae	Rare
Pantoporia hordonia	Common Lascar	8	Nymphalidae	Rare
Euthalia aconthea	Common baron	11	Nymphalidae	Rare
Neptis hylas	Common sailor	29	Nymphalidae	Not rare
Neptis cartica	Plain sailor	7	Nymphalidae	Rare
Neptis sankara	Broad banded sailor	2	Nymphalidae	Very rare
Neptis zaida bhutanica	Pale green sailor	1	Nymphalidae	Very rare
Kallima inachus	Orange oakleaf	4	Nymphalidae	Rare
Doleschallia bisaltide	Autumn leaf	1	Nymphalidae	Very rare
Cyrestis thyodamas	Common map	5	Nymphalidae	Rare
Chersonesia risa	Common maplet	9	Nymphalidae	Rare
Cupha erymanthis	Rustic	1	Nymphalidae	Very rare
Phalanta phalantha	Common leopard	15	Nymphalidae	Rare
Polyura athamas	Common nawab	2	Nymphalidae	Very rare
Aglais cashmirensis	Indian tortoiseshell	2	Nymphalidae	Very rare
Limenitis danava	Common commodore	3	Nymphalidae	Rare
Ariadne merione	Common castor	15	Nymphalidae	Rare
Hypolimnas bolina	Great eggfly	4	Nymphalidae	Rare
Vanessa indica	Indian red admiral	6	Nymphalidae	Rare
Vanessa cardui	Painted lady	2	Nymphalidae	Very rare
Athyma nefte	Colour sergeant	1	Nymphalidae	Very rare
Athyma selenophora	Staff sergeant	1	Nymphalidae	Very rare
Athyma ranga	Blackvein sergeant	2	Nymphalidae	Very rare
Athyma perius	Common sergeant	12	Nymphalidae	Rare
Abrota ganga	Sergeant major	1	Nymphalidae	Very rare
Cethosia biblis	Leopard lacewing	3	Nymphalidae	Rare
Vagrans egista	Vagrant	5	Nymphalidae	Rare
Papilio polytes	Common Mormon	22	Papilionidae	Not rare
Papilio helenus	Red Helen	19	Papilionidae	Not rare
Atrophaneura aidoneus	Common batwing	1	Papilionidae	Very rare
Papilio protenor	Spangle	8	Papilionidae	Rare
Papilio bianor	Common Peacock	3	Papilionidae	Rare

Scientific Name	Local Name	Individuals	Family	Butterfly Status
Papilio paris	Paris Peacock	8	Papilionidae	Rare
Graphium sarpedon	Common Bluebottle	3	Papilionidae	Rare
Papilio memnon	Great Mormon	12	Papilionidae	Rare
Troides helena	Common birdwing	1	Papilionidae	Very rare
Pachliopta aristolochiae	Common Rose	1	Papilionidae	Very rare
Graphium chirnoides	Veined Jay	2	Papilionidae	Very rare
Graphium agamemnon	Tailed Jay	9	Papilionidae	Rare
Papilio machaon	Common Yellow Swallowtail	1	Papilionidae	Very rare
Pseudocoladenia dan	Fulvous Pied Flat	19	Hesperiidae	Not rare
Tagiades menaka	Spotted snow flat	8	Hesperiidae	Rare
Tagiades litigiosa	Water Snow Flat	2	Hesperiidae	Very rare
Notocrypta curvifascia	Restricted Demon	3	Hesperiidae	Rare
Telicota bambusae	Dark palm Dart	22	Hesperiidae	Not rare
Parnara guttata	Straight swift	69	Hesperiidae	Common
Sarangesa dasahara	Common Small Flat	23	Hesperiidae	Not rare
Iambrix salsala	Chestnut bob	15	Hesperiidae	Rare
Ochus subvittatus	Tiger hopper	1	Hesperiidae	Very rare
Spialia galba	Indian skipper	1	Hesperiidae	Very rare
Catopsilia pomona	Common Emigrant	12	Pieridae	Rare
Catopsilia pyranthe	Mottled Emigrant	16	Pieridae	Not rare
Pieris cannida	Indian Cabbage White	4	Pieridae	Rare
Pieris brassicae	Large Cabbage White	2	Pieridae	Very rare
Hebomoia glaucippe	Great Orange Tip	5	Pieridae	Rare
Appias lyncida	Chocolate albatross	4	Pieridae	Rare
Eurema andersonii	One spot grass yellow	5	Pieridae	Rare
Eurema blanda	Three-spot-grass Yellow	29	Pieridae	Not rare
Eurema hecabe	Common Grass Yellow	38	Pieridae	Not rare
Cepora nadina	Lesser Gull	14	Pieridae	Rare
Cepora nerissa	Common Gull	12	Pieridae	Rare
Delias hyparete	Painted jezabel	5	Pieridae	Rare
Delias acalis	Red Breast jezabel	1	Pieridae	Very rare
Delias eucharis	Common jezabel	1	Pieridae	Very rare
Delias descombesi	Red-spot Jezabel	22	Pieridae	Not rare
Delias pasithoe	Red-Base Jezabel	5	Pieridae	Rare
Pareronia avatar	Pale wanderer	2	Pieridae	Very rare
Gandaca harina	Tree yellow	1	Pieridae	Very rare
Ixias pyrene	Yellow orange tip	2	Pieridae	Very rare
Belonois aurota	Pioneer	1	Pieridae	Very rare
Dodona egeon	Orange Punch	5	Riodinidae	Rare
Abisara neophron	Tailed Judy	30	Riodinidae	Not rare
Dodona adonira	Striped punch	5	Riodinidae	Rare
Zemeros flegyas	Punchinello	92	Riodinidae	Common
Jamides celeno	Common Cerulean	34	Lycaenidae	Not rare
Jamides alecto	Metallic Cerulean	30	Lycaenidae	Not rare
Zizina otis	Lesser Grass Blue	22	Lycaenidae	Not rare
Zizeeria karsandra	Dark Grass Blue	12	Lycaenidae	Rare
Zizeeria maha	Pale Grass Blue	10	Lycaenidae	Rare
Arhopala paramuta	Hooked Oakblue	23	Lycaenidae	Not rare
Jamides bochus	Dark Cerulean	5	Lycaenidae	Rare
Arhopala amantes	Large Oakblue	2	Lycaenidae	Very rare

Scientific Name	Local Name	Individuals	Family	Butterfly Status
Arhopala centaurus	Centaur Oakblue	1	Lycaenidae	Very rare
Rapala nissa	Common Flash	20	Lycaenidae	Not rare
Castalius rosimon	Common Pierrot	7	Lycaenidae	Rare
Tarucus ananda	Dark Pierrot	8	Lycaenidae	Rare
Curetis bulis	Bright sunbeam	5	Lycaenidae	Rare
Spindiasis syama	Club silverline	1	Lycaenidae	Very rare
Spindasis lohita	Long-brand silverline	2	Lycaenidae	Very rare
Everes lacturnus	Indian Cupid	9	Lycaenidae	Rare
Prosotas nora	Common lineblue	15	Lycaenidae	Rare
Prosotas dubiosa	Tailless lineblue	20	Lycaenidae	Not rare
Heliophorus epicles	Purple Sapphire	14	Lycaenidae	Rare
Acytolepsis puspa	Common hedge blue	23	Lycaenidae	Not rare
Lestranicus transpecta	White banded hedge blue	6	Lycaenidae	Rare
Lampides boeticus	Pea blue	3	Lycaenidae	Rare
Catochrysops strabo	Forget-me-not blue	2	Lycaenidae	Very rare
Loxura atymnus	Yamfly	1	Lycaenidae	Very rare
Zeltus amasa	Fluffy tit	1	Lycaenidae	Very rare
Rapala pheritima	Copper flash	24	Lycaenidae	Not rare
Rapala manea	Slate flash	12	Lycaenidae	Rare
Chliaria othona	Orchid tit	2	Lycaenidae	Very rare
Anthene emolus	Ciliate Blue	5	Lycaenidae	Rare

Annex 2: Factors influencing the butterfly to feed in the nectar plants. T= Tubular and NT= Non tubular

S.N	Butterfly species	Scientific Name	Proboscis length (mm)	Plant species	Plant category	Flower color	Flower shape	Corolla length (mm)
1	Red Admiral	*Vanessa indica*	18.2	*Lantana camara*	woody	yellow	T	12
2	Common tiger	*Danaus genutia*	10	*Eupatorium odoratum*	woody	purple	T	9
3	Glassy tiger	*Parantica aglea*	13	*Parthenium hysterophorus*	herb	white	T	3
4	Plain Tiger	*Danaus chrysippus*	13	*Lantana camara*	woody	yellow	T	12
5	Red Admiral	*Vanessa indica*	18.2	*Bidens pilosa*	herb	white	T	5
6	Indian Fritilary	*Argyreus hyperbius*	12	*Zinnia elegans*	herb	pink	T	2
7	Common tiger	*Danaus genutia*	13	*Sida rhambifolia*	herb	yellow	NT	3
8	Common jester	*Symbrenthia lilaea*	13	*Lantana camara*	woody	yellow	T	12

S.N	Butterfly species	Scientific Name	Proboscis length (mm)	Plant species	Plant category	Flower color	Flower shape	Corolla length (mm)
9	Chocolate Pansy	*Junonia iphita*	13	*Ageratina adenophora*	herb	purple	T	3
10	Peacock pansy	*Junonia almana*	11.4	*Lantana camara*	woody	yellow	T	12
11	Grey pansy	*Junonia atlites*	13	*Ageratum cony-zoides*	herb	white	T	3
12	Grey pansy	*Junonia atlites*	13	*Ageratum housto-nianum*	herb	blue	T	4
13	Lemon pansy	*Junonia lemo-nias*	12	*Bidens pilosa*	herb	white	T	5
14	Common tiger	*Danaus genutia*	8	*Lantana camara*	woody	yellow	T	12
15	Striped blue crow	*Euploea mul-ciber*	9.3	*Eupatorium odora-tum*	herb	purple	T	9
16	Common indian crow	*Euploea core*	12	*Ageratum housto-nianum*	herb	blue	T	4
17	Common indian crow	*Euploea core*	12	*Tagetes erecta*	herb	yellow	T	17
18	Common sailor	*Neptis hylas*	7	*Ageratina adenophora*	herb	purple	T	3
19	Common tiger	*Danaus genutia*	10	*Ageratum housto-nianum*	herb	blue	T	4
20	Glassy tiger	*Parantica aglea*	13	*Bidens pilosa*	herb	white	T	5
21	Glassy tiger	*Parantica aglea*	13	*Ageratum housto-nianum*	herb	blue	T	4
22	Plain Tiger	*Danaus chrysip-pus*	13	*Bidens pilosa*	herb	white	T	5
23	Common five ring	*Ypthima baldus*	5.1	*Borreria latifolia*	herb	purple	T	4
24	Peacock pansy	*Junonia almana*	11.4	*Eupatorium odora-tum*	woody	purple	T	9
25	Plain Tiger	*Danaus chrysip-pus*	11	*Ageratum housto-nianum*	herb	purple	T	4
26	Striped blue crow	*Euploea mul-ciber*	9.3	*Ageratum housto-nianum*	herb	purple	T	4

S.N	Butterfly species	Scientific Name	Proboscis length (mm)	Plant species	Plant category	Flower color	Flower shape	Corolla length (mm)
27	Common indian crow	*Euploea core*	12	*Bidens pilosa*	herb	white	T	5
28	Common indian crow	*Euploea core*	12	*Zinnia elegans*	herb	pink	T	6
29	Common five ring	*Ypthima baldus*	5.1	*Bidens pilosa*	herb	white	T	5
30	Lemon pansy	*Junonia lemonias*	12	*Cuphea hyssopifolia*	woody	purple	T	8
31	Lemon pansy	*Junonia lemonias*	12	*Lantana camara*	woody	yellow	T	12
32	Lemon pansy	*Junonia lemonias*	12	*Eupatorium odoratum*	herb	purple	T	9
33	Club silverline	*Spindiasis syama*	8	*Eupatorium odoratum*	woody	purple	T	9
34	Common cerulian	*Jamides celeno*	6.1	*Vitex negundo*	woody	purple	T	5
35	Copper flash	*Rapala pheritima*	9	*Eupatorium odoratum*	woody	purple	T	9
36	Copper flash	*Rapala pheritima*	9	*Bidens pilosa*	herb	white	T	5
37	Pea blue	*Lampides boeticus*	7	*Tridax procumbens*	herb	white	T	8
38	Club silverline	*Spindiasis syama*	8	*Lantana camara*	woody	yellow	T	12
39	Common pierrot	*Castalius rosimon*	8	*Sida rhambifolia*	herb	yellow	NT	3
40	Indian cupid	*Everes lacturnus*	4	*Bidens pilosa*	herb	white	T	5
41	Indian cupid	*Everes lacturnus*	4	*Desmodium confertum*	herb	purple	T	4
42	Pea blue	*Lampides boeticus*	7	*Duranta erecta*	woody	purple	T	7
43	Common pierrot	*Castalius rosimon*	8	*Bidens pilosa*	herb	white	T	5

S.N	**Butterfly species**	**Scientific Name**	**Proboscis length (mm)**	**Plant species**	**Plant category**	**Flower color**	**Flower shape**	**Corolla length (mm)**
44	Great Mormon	*Papilio memnon*	34	*Eupatorium odoratum*	woody	purple	T	9
45	Common mime	*Chilasa clytia*	14	*Lantana camara*	woody	yellow	T	12
46	Common mormon	*Papilio polytes*	25	*Ipomoea quamoclit*	herb	pink	T	26
47	Common mormon	*Papilio polytes*	25	*Mussaenda roxburghii*	woody	yellow	T	28
48	Spangle	*Papilio protenor*	32	*Salvia coccinea*	herb	red	T	29
49	Common mormon	*Papilio polytes*	25	*Lantana camara*	woody	yellow	T	12
50	Common mormon	*Papilio polytes*	25	*Bougainvillea glabra*	woody	pink	T	20
51	Mottled Emigrant	*Catopsilia pyranthe*	16	*Bidens pilosa*	herb	white	T	5
52	Mottled Emigrant	*Catopsilia pyranthe*	16	*Zinnia elegans*	herb	pink	T	2
53	Common grass yellow	*Eurema hecabe*	15	*Parthenium hysterophorus*	herb	white	T	3
54	Red spot jezeble	*Delias descombesi*	16	*Sambucus adnata*	herb	white	NT	4
55	Chocolate Albatross	*Appias lyncida*	14	*Bidens pilosa*	herb	white	T	5
56	Mottled Emigrant	*Catopsilia pyranthe*	16	*Eupatorium odoratum*	woody	purple	T	9
57	Chocolate Albatross	*Appias lyncida*	14	*Sambucus wightiana*	herb	white	NT	4
58	Common grass yellow	*Eurema hecabe*	15	*Borreria latifolia*	herb	purple	T	4
59	Common grass yellow	*Eurema hecabe*	15	*Eupatorium odoratum*	woody	purple	T	9
60	Mottled Emigrant	*Catopsilia pyranthe*	16	*Bidens pilosa*	herb	white	T	5

S.N	Butterfly species	Scientific Name	Proboscis length (mm)	Plant species	Plant category	Flower color	Flower shape	Corolla length (mm)
61	Common grass yellow	*Eurema hecabe*	15	*Sida rhambifolia*	herb	yellow	NT	3
62	Red spot jezeble	*Delias descombesi*	16	*Eupatorium odoratum*	herb	purple	T	9
63	Red spot jezeble	*Delias descombesi*	16	*Castanopsis indica*	woody	white	NT	4
64	Common grass yellow	*Eurema hecabe*	15	*Tagetes erecta*	herb	yellow	T	17
65	Mottled Emigrant	*Catopsilia pyranthe*	16	*Zinnia elegans*	herb	yellow	T	6
66	Chocolate Albatross	*Appias lyncida*	14	*Eupatorium odoratum*	herb	purple	T	9
67	Chocolate Albatross	*Appias lyncida*	14	*Lantana camara*	woody	yellow	T	12
68	Straight Swift	*Parnara guttata*	17	*Sida rhambifolia*	herb	yellow	NT	3
69	Straight Swift	*Parnara guttata*	17	*Borreria latifolia*	herb	purple	T	4
70	Common small flat	*Sarangesa dasahara*	12	*Parthenium hysterophorus*	herb	white	T	3
71	Himalayan spotted flat	*Celaenorrbinus munda*	20	*Urena lobata*	herb	pink	NT	12
72	Straight Swift	*Parnara guttata*	17	*Bidens pilosa*	herb	white	T	5
73	Straight Swift	*Parnara guttata*	17	*Ageratum conyzoides*	herb	white	T	3
74	Common small flat	*Sarangesa dasahara*	12	*Borreria latifolia*	herb	purple	T	4
75	Straight Swift	*Parnara guttata*	17	*Coreopsis lanceolata*	herb	yellow	T	4
76	Straight Swift	*Parnara guttata*	17	*Cosmic sulphureus*	herb	yellow	T	3
77	Straight Swift	*Parnara guttata*	17	*Mimosa pudica*	herb	purple	NT	2

S.N	Butterfly species	Scientific Name	Proboscis length (mm)	Plant species	Plant category	Flower color	Flower shape	Corolla length (mm)
78	Straight Swift	*Parnara guttata*	17	*Cosmic sulphureus*	herb	yellow	T	3
79	Straight Swift	*Parnara guttata*	17	*Acmella uliginosa*	herb	yellow	T	4
80	Straight Swift	*Parnara guttata*	17	*Duranta erecta*	woody	purple	T	7

Annex 3. Descriptive statistics (by family) for butterfly proboscis length (in mm) and corolla tube length (in mm) of flowers visited by butterflies

	Family	Number	Mean	Standard deviation	Median	Inter quartile range	Range
Proboscis length (mm)	Hesperidae	13	16.46	2.15	17	0	12–20
	Nymphalidae	32	11.63	2.80	12	2.25	5.1–18.2
	Pieridae	16	15.18	0.83	15	1.25	14–16
	Lycaenidae	11	7.10	1.75	8	1.45	4–9
	Papilionidae	7	25.71	6.42	25	3.5	14–34
Corolla tube length (mm)	Hesperidae	13	4.38	2.60	4	1	2–12
	Nymphalidae	32	6.69	3.84	5	5	2–17
	Pieridae	16	6.63	3.96	5	5	2–17
	Lycaenidae	11	6.55	2.70	5	3.5	3–12
	Papilioni dae	7	19.43	8.44	20	15	9–29

Annex 4. Photoes of butterflies species observed in Rupa Lake. a. Vanessa indica feeding on *Lantana Camara* b. Argynnis hyperbius on *Zinnia elegans* c.**Danaus genutia** on *Sida rhambifolia* d. Junonia iphita on *Ageratum adenophora* e. Junonia almana on *Lantana camara* f. Junonia lemonias on *Bidens pilosa* g. Euploea mulciber on *Ageratum conyzoides* h. Euploea core on *Ageratum conyzoides* I. Euploea core on *Zinnia elegans* j. Parantica aglea in *Ageratum conyzoides* k. Spindasis lohita on *Lantana camara* l. Danaus chrysippus on *Bidens pilosa* m. Junonia almana on *Lantana Camara* n. Danaus chrysippus on *Ageratum conyzoides* o. Junonia lemonias on *Lantana camara* p. Delias **pasithoe** on *Eupatorium odoratum*q. Danaus genutia on *Ageratum conyzoides* r. Junonia lemonias on *Cuphea hyssopifolia* s. Vanessa cardui on *Ageratum adenophora* t. Eurema andersoni on *Urena Lobata*u. Delias descombesi on Lantana Camara v. Everes lacturnu s on *Desmodium confertum* w. Catopsilia pomona on *Zinnia elegans* x. Tagaides litigiosa on Lantana camara y. Papilio memon on Eupatorium odoratum z. Papilio protenor on *Salvia Coccinea*