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Butterfly communities along an elevational gradient in the Tons valley, Western Himalayas: Implications of rapid assessment for insect conservation

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ABSTRACT

As time and money is limited, explicit, cost-effective, quick, and appropriate methods are needed to assist conservation planners and managers for making quick decisions. Butterflies promise to be a good model for rapid assessment and habitat monitoring studies because they are widespread, conspicuous, and easily recognizable and they are effective indicators of forest health. We conducted a rapid assessment of butterflies at five disturbance gradient sites that varied in elevation from 900 m a.s.l. to 3500 m a.s.l. for 20 days during March–April 2010 and recorded 79 butterfly species and 1504 individuals in the Tons valley in Western Himalayas. We were able to sample approximately 77% (123 species) of the estimated species richness on continuing the sampling until July 2010. Species richness at the study site is estimated to be 159 (95% CI: 145–210) species. Diversity was highest in heterogeneous habitats and decreased towards homogeneous habitats. Unique species were highly restricted to lowest disturbed sites. Using Pearson's correlation analysis, the strongest vegetative predictors of butterfly richness were plant species richness, canopy cover, and herb and shrub density. Butterfly species richness and abundance were highly correlated with altitude, temperature, relative humidity, fire signs, and livestock abundance. We also found positive cross-taxon correlation among butterflies, moths, and beetles across sites, indicating that butterflies can be used as surrogate or indicator taxa for insect conservation. Short sampling periods providing comprehensive estimates of species richness were reliable for identifying habitats and sites with the most conservation value in the Tons valley landscape.

Introduction

Himalayan ecosystems face mounting threats to biodiversity from anthropogenic disturbance. In recent decades, urbanization, commercial activities, and excessive resource use has reduced most natural forest habitats of this area to degraded remnants. Because of these threats, modern studies of biodiversity are critical for conservation of the remaining forests patches in the Himalayas. A full inventory of diversity of any area would require nearly impossible amounts of time, effort, and money (Lawton et al., 1998). To avoid the logistically impossible task of sampling entire communities, past efforts have concentrated on performing rapid inventories (Roberts, 1991), utilizing focal taxa approach (Noss, 1990; Pearson and Cassola, 1992; Pearson, 1994), and developing extrapolation techniques to estimate diversity in different habitats (Colwell and Coddington, 1994; Hammond, 1994; Kiester et al., 1996).

Conservation biologists should include insect diversity in planning conservation in tropical forests (Kremen et al., 1993; Meyers et al., 2000; Clark and May, 2002; Leather et al., 2008). Insects are appropriate because they represent a major proportion of animal species in tropical forests (Godfray et al., 1999; Putz et al., 2001; Lewis and Basset, 2007). Assuming that carefully selected focal taxa can serve as a proxy for overall biodiversity (Kerr et al., 2000; Uniyal et al., 2007), several insect taxa have been tested for their utility as indicators in various ecosystems at multiple spatial scales (McGeoch, 1998). Butterflies have been suggested due to their role as indicators in conservation planning (Ehrlich and Murphy, 1987; Brown, 1991; Kremen et al., 1993; Nelson and Andersen, 1994; DeVries et al., 1997) and are often proposed as bioindicators of forest health and surrogate taxa for various biodiversity groups (Sisk et al., 1994; Hayes et al., 2009). Butterflies fulfill many of the criteria proposed to define useful indicator groups: they have short generation times, are day-flying, diverse, and easily identifiable. Furthermore, butterfly taxonomy, distribution, and natural history are better described than for any other insect taxon (Gilbert and Singer, 1975; Van-Wright and Ackery, 1984; Brown, 1997). Butterflies are closely associated with other resource and ecosystem characteristics (Brown, 1991) and can be expected to act as

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ecological indicators and reflect diversity in other groups (Basset et al., 1998). They also have great potential as indicators to monitor ecosystem properties and local habitats because of their rapid response to change in local vegetation and climate conditions (Kremen, 1992; Murphy and Weiss, 1992; Parmesan, 1996).

The appeal of using indicator taxa is one of saving time, effort, and money. By focusing on one set of species in a location rather than all of the species, considerable time and limited resources can be saved (Gardner et al., 2008). The purpose of this paper was to demonstrate the importance of rapid assessment studies for selecting areas important for insect conservation in the Tons valley in Western Himalayas. We used an integrated approach by sampling across multiple habitats and land use types and by using multiple data collection techniques. We determined how much sampling effort was required for an adequate assessment of butterfly communities and evaluated the level of cross-taxon congruency between butterflies (Lepidoptera: Rhopalocera), moths (Lepidoptera: Heterocera), and beetles (Coleoptera) in the Western Himalayan landscape.

In the present study, we sampled butterflies in different natural sites (mixtures of riparian forest, pine forest, broadleaf forest, conifer forest, and alpine meadows) and agriculture habitats in the Tons valley, with the following objectives: (1) We assessed how much sampling effort is required for an adequate assessment of a butterfly community in the Western Himalayan landscape. Such an approach is essential for conservation programs aimed at Lepidoptera (Sparrow et al., 1994; Bonebrake and Sorto, 2009). (2) We then assessed the extent to which we were able to inventory the species present in the Tons valley. (3) We compared the butterfly diversity across different sites and forest habitats and tested the effect of habitat attributes that were the most accurate predictors of butterfly species richness and abundance across sites in the landscape. (4) We then discussed the potential utility of rapid assessment studies undertaken with limited sampling time for distinguishing their qualities with respect to butterflies (indicator taxa) and their performance as surrogates of other insect taxa diversity for boosting insect conservation in the Western Himalayan landscape.

Materials and methods

Study area

The study was conducted in upper catchment of the Tons valley in Uttarakhand state of India. The region falls under bio-geographic province 2B zone of the Western Himalayas (Rodgers and Panwar, 1988) and sub-region Garhwal Himalayas (Fig. 1). The study area is composed entirely of hills and high mountains. The valley is bounded in the north and north-east by the Shimla district of Himachal Pradesh, in the south by the Dehradun district, and in the east by the Yamuna forest division in Uttarakhand. The upper catchment of the Tons river lies in two protected areas (PAs), the Govind National Park (NP) and the Govind Wildlife Sanctuary (WLS) (Fig. 1).

Govind NP and Govind WLS are part of high Western Himalayan highland situated in Purola Tehsil of the Uttarkashi district (Uttrakhand) and lie between Lat—31° 02′–31° 20′ N and Long—77° 55′–78° 40′ E (Fig. 1). Two major rivers, Rupin and Supin, flow through the Govind NP and Govind WLS and merges at Naitwar village,

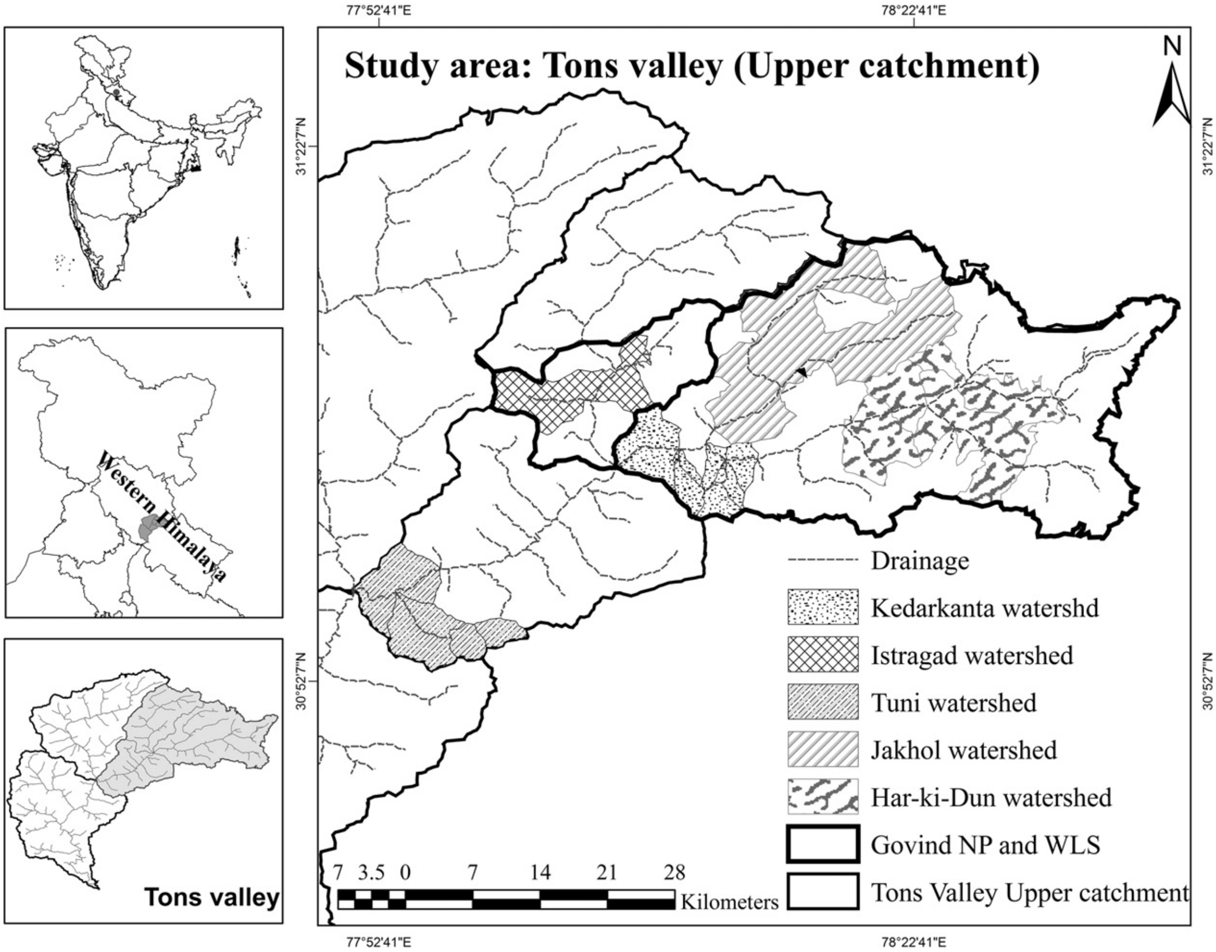

Fig. 1. Map of the Tons valley (upper catchment) showing locations of five sampling sites. Sites Kedarkanta, Istragad, Jakhol and Har-ki-Dun lies in protected areas (Govind NP and WLS), while site Tuni lies in unprotected area.

forming the river Tons. The altitude varies from 1290 m a.s.l. to 6323 m a.s.l.. The Govind WLS covers 953.12 km^2 of which 472.08 km^2 have been demarcated as National Park (NP) encompassing the upper catchment of river tons.

The climate of the area is typical Himalayan, with medium rainfall during July–August at lower altitudes. The average rainfall is 1500 mm, with extreme cold and snow during the three to four month winter. A permanent snowline occurs at 5000 m elevation.

About 47 villages are scattered throughout the Govind NP and Govind WLS (Anonymous, 1986). The people subsist mainly on livestock, cultivation, and forest products.

Sampling sites

We sampled five watersheds (i.e. Tuni, Istragad, Jakhol, Kedarkanta, and Har-ki-Dun) (Fig. 1) (Table 1) located from 900 m a.s.l. to 6323 m a.s.l.. They possessed a gradient of disturbance, such as natural, undisturbed forest to highly disturbed agricultural land. Istragad and Kedarkanta are managed under the PA Govind WLS. Jakhol and Har-ki-Dun are managed under PA Govind NP. Tuni is under high degree of anthropogenic disturbance and lies outside any formal PA.

Vegetation

The vegetation of the Tons valley is a mixture of tropical, temperate, subalpine, and alpine vegetation. The permanent vegetation is evergreen, intermixed with deciduous species at lower elevations (Champion and Seth, 1968).

Sub tropical zone

Dominant tree species include *Toona ciliata*, *Mallotus philippensis, Alnus nepalensis*, *Pinus roxburgii, Quercus leucotricophora, Q. dilatata, Rhododendron arboreum, Prunus cerasoides, Aesculus indica, Thamnocalamus* sp., and *Corylus corluns*. The shrubby habitat is dominated by *Colebrookia oppositifolia, Pyracantha crenulata,* and *Zizyphus mauritiana*.

Temperate zone

The dominant trees are *Quercus leucotrichophora, Q. semicarpifolia, Juglans regia, Corylus jacquemontii, Acer caesium, Meliosma dilleniaefolia, Taxus baccata, Thamnocalamus spathiflora,* and *Rhododendron arboreum*. The main shrub species are *Viburnum continifolium, Berberis* sp., and *Hippophae rhamnoides*.

Table 1
Survey details, disturbance characteristics, butterfly species richness, abundance, diversity and unique species recorded, for the five sampling sites in the Tons Valley during March–April 2010.

	Istragad	Jakhol	Tuni	Kedarkanta	Har-ki-Dun
Protection category	Govind WLS	Govind NP	Reserve Forest	Govind WLS	Govind NP
Logging intensity	Low	Low	High	Medium	Medium
Fire signs	Low	Medium	High	Medium	High
Livestock abundance	Low	Low	High	High	Medium
Human habitations	Very low	Medium	High	High	Medium
Altitude sampled (m)	1500–3500	1800–3500	900–2400	1250–3000	1800–3500
Habitats sampled[a]	6	6	6	6	6
No. of transects/trails	20	16	16	16	16
Effort (km)	6	4.8	4.8	4.8	4.8
Species richness	51	27	27	35	17
Genera richness	40	24	21	26	14
Individuals	488	100	259	540	117
Fisher's alpha	11.17	10.84	7.59	8.37	5.47
Unique species	20	4	11	5	1

[a] Six butterfly habitats were sampled uniformly across all five sites (e.g. Agriculture land, Mix riparian forest, Mix broadleaf forest, Pine forest, Conifer forest and Alpine meadows).

Sub alpine zone

The dense coniferous forest includes *Pinus wallichiana, Abies pindrow,* and *Taxus wallichiana* intermixed with broad leaved species such as *Quercus semecarpifolia, Rhododendron campanulatum,* and *Betula utilis.* The common shrubs are *Cotoneaster* sp., *Berberis* sp., and *Rosa webbiana*. Herbaceous species include *Delphinium* sp., *Swertia* sp., and *Pedicularis* sp.

Alpine zone

The alpine zone consists of *Rhododendron campanulatum* scrub above which lie meadows. The zone is dominated by herbaceous plants of different sizes, forms, and colours. Common species are *Cyanthus* sp., *Gentiana* sp., *Danthonia* sp., *Potentilla* sp., and *Rhododendron barbatum*. Medicinal plants, such as *Picrorhiza* sp. and *Nardostachys grandiflora,* are common in alpine zone.

Sampling

We employed a stratified-random sampling design to record patterns of butterfly species composition in both dominant and important vegetation types. We broadly classified six types of butterfly habitats (agriculture land, mixed riparian forest, mixed broadleaf forest, pine forest, conifer forest, and alpine meadows) consistently present across each of the five sites. Only habitats accounting for the major proportion of the sampling area were selected. Opportunistic sampling was also conducted in rare habitats to increase species inventory of the area. Two sampling approaches, direct search and indirect search, were used. A total of 42 line transects and 42 random forest trail/dirt tracts were walked to sample butterflies for 20 days during the spring season (March–April 2010) and for 50 days during the summer season (May–July 2010). We sampled in areas between the elevations of 900 m a.s.l. to 3500 m a.s.l. across all sites.

All transect lengths were 300 m and transects were traversed on foot within 30 min. Abundance data were collected when cloud cover was less than 70% and between 0900 and 1300 hrs, the most favorable conditions for butterfly flight. We recorded all butterflies seen during the transect walk in an imaginary $5 \times 5 \times 5$ (m) box around the observer. We also employed traps baited with a mixture of rotten bananas and beer fermented for 5 days. Baited traps were alternately placed 5 m to the left and right of the transect at every 100 m. Thus, there were 3 baited traps on each of the transects. Specimens captured in these traps were included in the species inventory, but not in species richness estimations.

In addition to transects and traps, we also used opportunistic sightings at mud puddles, nectar sources, and other resource rich sites. Butterflies that were too fast or too distant to reliably identify during flight were not counted. Butterflies that could not be readily identified visually were either photographed or captured using a hand held sweep net and were released after identification. The few voucher specimens that we collected were deposited at the insect repository of the Wildlife Institute of India in Dehradun.

Study organisms

We sampled all butterflies of Hesperioidea and Papilionoidea (Order: Lepidoptera, Suborder: Rhopalocera). We documented 5 butterfly families (i.e. Hesperiidae, Papilionidae, Pieridae, Lycaenidae, and Nymphalidae) in our study area and identified them to species level following Wynter-Blyth (1957) and Evans (1932). Here, we used the nomenclature from Kehimkar (2008).

We also sampled moths (Lepidoptera: Heterocera) and beetles (Coleoptera) in a similar study area. Details of sampling methods and species inventory are in Uniyal et al. (2011). In the present paper, the data collected on beetles and moths was used to evaluate cross-taxon congruence with butterflies and to prioritize areas of high insect diversity. We also evaluated the use of butterflies as a surrogate indicator taxon for insects to improve conservation in the Tons valley landscape.

Vegetation, disturbance, and microclimate sampling

We quantified vegetation for each transect using stratified-random sampling. Circular plots (10 m radius) were established at the centre of each transect at 100 m intervals to quantify trees. Circular plots (5 m radius) were established on either side (5 m from center) of each transect at 100 m intervals to quantify shrubs. In each of these plots, two plots (1 m diameter) were established within the 5 m shrub plot to estimate herb abundance and grass cover. Within each vegetation plot, we measured flowering plant species richness, average density of trees, shrubs, and herbs, grass cover, and canopy cover (using canopy densitometer). We also quantified disturbance parameters, including logging, fire signs, and livestock abundance. Fire signs (number of signs of past fire inside the plot) and logging (number of logged trees) were recorded in a 10 m radius plot at 100 m intervals at the centre of each transect. Here, livestock abundance refers to number of livestock observed on transects during sampling. Microclimatic variables, such as temperature, relative humidity (RH), and wind speed, were recorded using a digital thermometer, digital hygrometer, and digital anemometer (Forestry suppliers, USA), respectively. Topographic information, such as altitude, aspect, and slope, were also recorded on transects using an altimeter, compass, and clinometer (Forestry suppliers, USA), respectively.

Data analysis

Species richness estimates

Species richness estimates (non-parametric) were calculated based on individual-based species accumulation curves (Gotelli and Colwell, 2001) for assessing sampling effort and efficiency using program EstimateS (Colwell, 2009). We used program EcoSim (Gotelli and Entsminger, 2004) to generate rarefaction curves for comparing species richness estimates between sites.

We also used another technique for estimating total species richness of the area based on a model developed by Singh and Pandey (2004), which suggests that the species proportion of the family Papilionidae is an indicator of total butterfly (Rhopalocera) species richness of an area across the Indian subcontinent for which Papilionidae richness is known. The mean proportion (7.4%) of family Papilionidae can, thus, be used to estimate the total species richness of an area in the Western Himalayas for which Papilionidae species is known.

Species diversity and community composition analysis

We calculated Fisher's alpha index to compare diversity of butterflies across five sites (watersheds) and six habitats (agriculture land, mixed riparian forest, mixed broadleaf forest, pine forest, conifer forest, and alpine meadows) using program Past 1.73 (Hammer et al., 2007). To calculate diversity in habitats, we pooled butterfly abundance falling under same habitat category from five sampling sites (Istragad, Tuni, Jakhol, Kedarkanta, and Har-ki-Dun).

We performed community-level analysis using non-metric multidimensional scaling (NMDS) analysis in program Past, ver. 1.73 (Hammer et al., 2007) to look at the grouping between sites. The ordination was based on Bray–Curtis dissimilarity matrix (single link) of ecological distance. To test for degree of differences across sites, one-way ANOVA was performed using program SPSS (SPSS 16.0, 2007).

Effect of microclimatic, habitat, and disturbance characteristics

Pearson correlation coefficients (r) were calculated using program SPSS (SPSS 16.0, 2007) to examine the relationship between butterfly species richness, abundance, and plot (transect) level microclimatic, habitat, and disturbance characteristics. All variables were tested for normality. Strongly skewed variables were transformed prior to analyses (i.e. butterfly, moth, and beetles species richness, abundance, and plant species richness data were square root transformed) to examine associations of butterfly species richness and abundance with microclimatic, habitat, and disturbance variables.

Results

Species richness and abundance

We recorded a total of 1504 individuals of 79 butterfly species from 55 genera and 5 families on the Tons valley transects in 20 days and approximately 45 sampling hours (Appendix A). We sampled seven individuals of two species (*Elynias hypermnestra* and *Mycalesis perseus*) in baited traps that we would have not seen otherwise. Opportunistic sightings at ponds and other microhabitats (not on transects) added six more species to the list. Thirteen individuals of seven species (*Heliophorus brahma, Dodona durga*, *Lethe rohria, Stibochiona nicea*, *Celanorrhinus leucocera*, *Celanorrhinus dhanada,* and *Sarangesa purendra*) were only recorded in opportunistic sightings (not on transects).

A total of 123 butterfly species were recorded (Appendix B) during the entire sampling period. A total of 108 butterfly species were recorded during the second sampling period (summer season), adding 44 more butterfly species to inventory produced during rapid assessment(first survey). There were 94 butterfly species recorded from PAs.

Family composition across sites

Across the five sites, there were no significant differences in family (5 families) species richness (one-way ANOVA: $F_{4,4}=2.0$, $P=0.11$) or genera richness (one-way ANOVA: $F_{4,4}=1.25$, $P=0.31$) of butterflies. A total of 79 butterfly species of 55 genera and five families were recorded. Family Papilionidae accounted for 18% (14 species) (Fig. 2) of all species across sites. Kedarkanta (8) and Istragad (7) had the highest number of swallowtail species, while Har-ki-Dun had a lowest (3) number of species. We recorded a total of 12 species in the family Pieridae, which comprised 15% of all species (Fig. 2). The highest number of Pierid species was recorded at Kedarkanta (9) and the lowest at Istragad (8), which accounted for 33% and 30%,

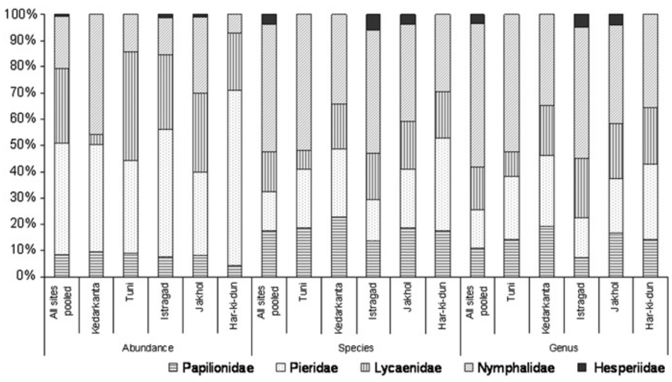

Fig. 2. Relative composition of butterfly families showing variation in abundance, number of genus and species across five sampling sites in the Tons valley.

respectively, of total butterfly species at these sites. A total of 12 species (15%) of the family Lycaenidae were recorded. The highest number of species of this family was recorded at Istragad (9 species; 18% of total species at this site) and the lowest at Tuni (9 species and 6% of total species at this site) (Fig. 2). In the family Nymphalidae, a total 39 species (49%) were recorded belonging to 30 genera. The highest number of species in this family were recorded at Istragad (9 species; 18% of total species at this site) and lowest at Tuni (9 species and 6% of total species at this site) (Fig. 2). Only 3 species from 2 genera of the family Hesperiidae and contributed only 3.7% of the total species recorded (Fig. 2).

We observed significant differences in 5 butterfly families abundance across sites (one-way ANOVA: $F_{4,4}=3.91$, $P=0.009$). A total of 1504 individuals were recorded, of which the families Pieridae (42.68%) and Lycaenidae (28.45%) accounted for the major proportion, followed by Nymphalidae (20.07%), Papilionidae (8.24%), and Hesperiidae (0.53%) (Fig. 2). Family Pieridae sightings were highest at site Har-ki-Dun and were lowest at site Jakhol (Fig. 2). Family Lycaenidae sightings were very low in Kedarkanta (4% of total abundance at site).

Species richness estimates and inventory completeness

We calculated six non-parametric estimators of species richness (Table 2). However, the Chao1 estimate of species richness produced the largest estimates of species richness in the Tons valley. We followed suggestions of Sorensen et al. (2002) and Scharff et al. (2003) and used it for inventory completeness values, giving the ratio between observed and estimated richness. Using the Chao1 estimate, we detected 49% of the estimated species richness during the first survey (rapid assessment). The Chao2 estimate (lowest estimate of species richness) suggested that 89% of the butterfly fauna was detected. During the entire sampling period, we detected 123 butterfly species. Using the highest species richness estimates (Chao1), we were able to sample 75–80% of the butterfly fauna at the Tons valley. We estimate butterfly species richness to be 145–210 species (CI 95%) using the highest estimator (Chao1) for the whole sampling period.

Using the family ratio extrapolation (Papilionidae proportion) method (Singh and Pandey, 2004), the species richness estimate for the Tons valley was 175 species for the first survey. Using this method, the total species richness of the study area was estimated to be 229 species for the complete study period. With this method, we detected 45% of the estimated species richness during the complete sampling period. Using both non-parametric and family ratio extrapolation methods of species richness estimation, we provide an estimate of 145–230 butterfly species in the tons valley landscape.

Table 2
Species richness estimates including SD (standard deviation) calculated using program EstimateS.

Estimates of species richness		
Estimators	For first survey	For total sampling period
ACE	100 (0)	159 (14.2)
ICE	103 (0)	132 (11.7)
Chao1	162 (42.3)	152 (26.7)
Chao2	90 (10.1)	131 (7.3)
Jack1	95 (9.9)	141 (4.2)
Jack2	105 (0)	130 (2.1)

The ACE is "Abundance-based Coverage Estimator" and the ICE is "Incidence-based Coverage Estimator". Chao1 and Chao2 estimators are based on Chao (1987). Jack1 and Jack2 are 1st and 2nd order Jackknife richness estimators. For review see Magurran (2004).

Diversity and community analysis

We observed significant differences (one-way ANOVA: $F_{4,78}=3.38$, $P=0.009$) in species composition across 5 sampling sites. We used Fisher's alpha as a measure of diversity. Fisher's alpha for sites (Table 1) was highest for Istragad (11.17), followed by Jakhol (10.8). Sites Kedarkanta (8.36) and Tuni (7.58) had the next highest diversity with Har-ki-Dun (5.46), which was similar to the pattern found in species richness across sites. We also calculated Fisher's alpha for different forest types sampled. Agriculture land (16.2) contained the highest diversity followed by mixed riparian forest (15.15) and mixed broadleaf forest (12.93), while diversity was quite low in homogenous habitats, such as pine forest (11.64), followed by conifer forest (7.89), and alpine meadows (4.34).

Sites and habitats comparison

Istragad and Kedarkanta had the highest species richness (Fig. 3a). The 95% confidence intervals for species richness at lowest number of individuals (rarified at lowest number (98) of individuals, found at Har-ki-Dun) of sites Istragad (19–28 species) and Kedarkanta (20–27 species) were higher than Jakhol (20–25 species) and Tuni (16–23 species). Species richness intervals were significantly lower for Har-ki-Dun (14–17 species). Non-metric multidimensional scaling (NMDS) analysis showed that Istragad and Kedarkanta were grouped together and Har-ki-Dun and Jakhol were grouped together (Fig. 4). Tuni did not group with any of the sites and showed a different assemblage pattern from the other four sites (Fig. 4). There were 40 unique species that were found only at a single site (Table 1). Istragad (20) and Tuni (11) had the highest number of unique species. Sites

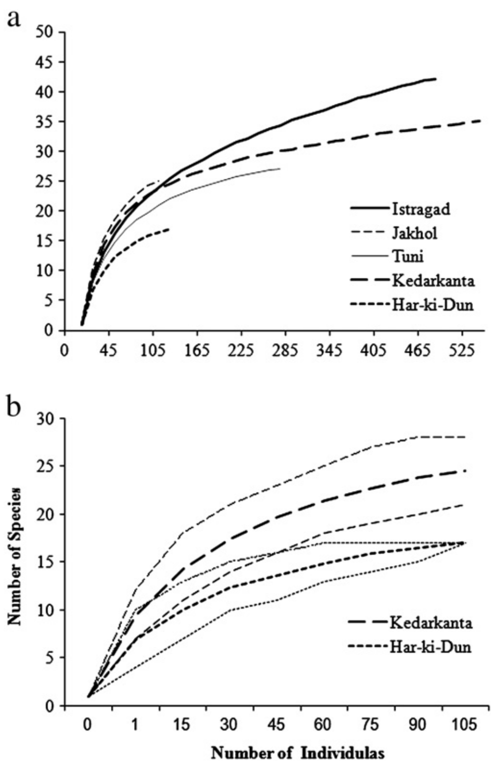

Fig. 3. (a) Individual-based rarefaction curves for five sampling sites and (b) with 95% confidence intervals for sites Kedarkanta and Har-ki-Dun, showing that sampling was enough to differentiate habitats though having short sampling period. Diversity was compared at lowest number of Individuals, observed at site Jakhol.

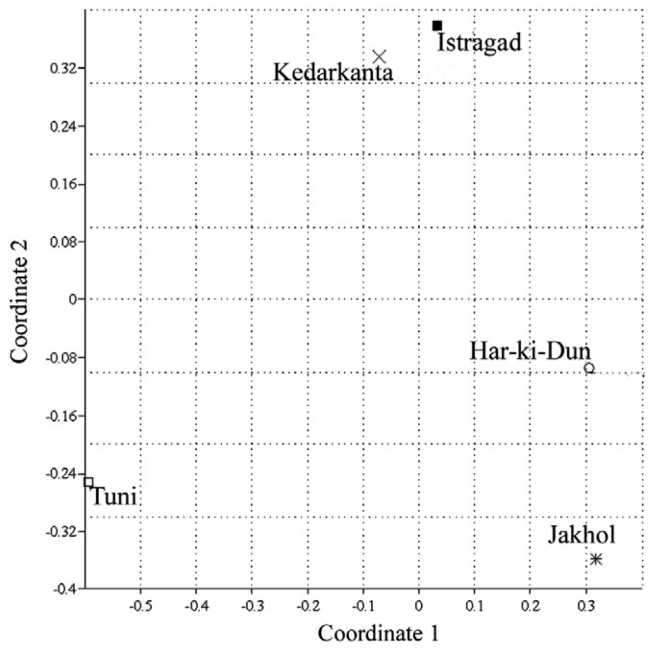

Fig. 4. Non-metric multidimensional scaling (NMDS) ordination plot showing similarities in butterfly composition between five sampling sites in the Tons valley. Sites managed under similar protection category grouped together. Site Tuni is managed under very low protection category (reserve forest) and separates apart showing a unique butterfly assemblage than other sites.

Kedarkanta (5) and Jakhol (4) had next highest unique species, while Har-ki-Dun contained only one unique species.

Habitat attributes and effect of microclimatic variables

Microclimatic variables, such as temperature, had significant positive influence on species richness ($r = 0.69$, $N = 42$, $P < 0.01$) and abundance ($r = 0.74$, $N = 42$, $P < 0.01$) (Table 3). Relative humidity had a slight negative influence on butterfly species richness ($r = -0.35$, $N = 42$, $P < 0.05$) and a negative association with abundance ($r = -0.20$, $N = 42$, $P > 0.05$) (Table 3). Wind speed did not contribute significantly to either variation in butterfly species richness ($r = 0.20$, $N = 42$, $P > 0.05$) or abundance ($r = 0.27$, $N = 42$, $P > 0.05$) across sampling locations (Table 3).

Elevation was an important factor in accounting for variation in butterfly species richness ($r = -0.81$, $N = 42$, $P < 0.01$) and abundance ($r = -0.55$, $N = 42$, $P < 0.01$) across sampling locations (Table 3).

The other cardinal variables that were associated with butterfly species richness and habitat specificity involved vegetation cover. Plant species richness was positively associated with butterfly species richness ($r = 0.87$, $N = 42$, $P < 0.01$) and abundance ($r = 0.65$, $N = 42$, $P < 0.01$) (Table 3). Variation in butterfly abundance and species richness across sampling plots was highly predicted by herb density (Abundance: $r = 0.95$, $N = 42$, $P < 0.01$; Butterfly species richness: $r = 0.74$, $N = 42$, $P < 0.01$) and shrub density (Abundance: $r = 0.82$, $N = 42$, $P < 0.01$; Butterfly species richness: $r = 0.69$, $N = 42$, $P < 0.01$), but poorly predicted by canopy cover (Table 3).

Fire and livestock abundance were negatively associated with butterfly species richness (Fire signs: $r = -0.36$, $N = 42$, $P < 0.05$; Livestock abundance: $r = -0.33$, $N = 42$, $P < 0.01$) and abundance (Fire signs: $r = -0.49$, $N = 42$, $P < 0.05$; Livestock abundance: $r = -0.31$, $N = 42$, $P < 0.05$) (Table 3). Surprisingly, logging activities were positively correlated with butterfly species richness ($r = 0.32$, $N = 42$, $P < 0.05$) (Table 3).

Table 3
Relationship of butterfly species richness and abundance with microclimatic, vegetation, disturbance variables and cross taxa correlation with moths (Lepidoptera) and beetles (Coleoptera) across sampling sites in the Tons valley: table presents correlation values (Pearson's r) and a level of significance ($^{*}P<0.05$, $^{**}P<0.01$). Number of sites ($N = 42$) for all variables except moth species richness and beetles species richness, where ($N = 26$).

	Butterfly Species richness	Abundance
Altitude	-0.816^{**}	-0.553^{**}
Temperature	0.693^{**}	0.749^{**}
Relative humidity	-0.359^{*}	-0.208
Wind speed	0.209	0.270
Plant species richness	0.871^{**}	0.659^{**}
Canopy cover	0.538^{**}	0.187
Shrub density	0.693^{*}	0.823^{**}
Herb density	0.745^{**}	0.959^{**}
Logging	0.328^{*}	0.227
Fire signs	-0.366^{*}	-0.337^{*}
Livestock abundance	-0.493^{**}	-0.312^{*}
Moths species richness/ abundance	0.825^{**}	0.732^{*}
Beetles species richness/ abundance	0.673^{**}	0.785^{*}

**Correlation is significant at 0.01 level (2-tailed).
*Correlation is significant at 0.05 level (2-tailed).

Species of conservation priority

Five observed butterfly species (*Lampides boeticus, Everes argiades diorides, Libythea lepita*, *Euploea mulciber,* and *Polytemis discreta*) are listed in the Wildlife (Protection) Act of India, 1972 (Anonymous, 2006) (Appendix A). However, these species occurred in very few habitats and in low abundance in the study area.

Considering distribution in the Himalayas, eight species (*Potanthus dara, Paranassius epaphus, Colias erate, Celastrina argiolus, Aricia astrasche, Callerebia scanda, Limenitis trivena,* and *Hestina nama*) had the smallest geographical distribution (in northwest, western, and central Himalayas, but not in eastern Himalayas). These eight species also occurred at a very low abundance and were restricted to Istragad and Jakhol. These two sites had the lowest level of disturbance and accounted for highest number of unique species. Therefore, they are highly important for protection of butterflies and other insect species, as well in the Tons valley landscape.

Discussion

Species richness estimates

In the Himalayas, butterfly distribution shifts with season (dry and wet seasons) and with change in climatic condition (e.g. snowfall, temperature fluctuation, forest fire, etc.) (Mani, 1986), which makes sampling complicated. Thus, a complete survey of the Tons valley requires more sampling time. We sampled late in the season for a longer duration (three months) than first survey (20 days) in May–July 2010. However, sampling for the whole season, we recorded 123 species in the area. Using the highest species richness estimates, we sampled 75–80% of the butterfly fauna of the Tons valley. We provided a reasonable and valuable estimate of 145–210 species (using Chao1) from the study area.

Species richness estimators are based on assumptions that the community being sampled is present at all times during sampling. However, due to seasonality effects, many butterfly species may have not been flying during the sampled period. As in current sampling, we recorded 44 more species in the second sampling and missed 18 species in the rapid sampling that were present. Thus, because species richness estimators (ICE, Chao1, Chao2, etc.) are sensitive to seasonality problems, it is better to take into account seasonality effects and local migrations of butterflies. Solutions to this problem can be to sample during the early and late periods of seasons and then draw conclusions about estimates of species richness in any area.

The family ratio extrapolation approach has its own assumptions and uncertainties. It assumes a strong correlation between finding the focal species and the target species. In this instance, it seems likely that focal species are easier to find than non-focal species given the detection bias towards the focal species. Therefore, it is possible that 229 species (using the Papilionidae proportion method) might be an overestimate of species richness. Species richness estimated by the family ratio extrapolation method was also close to the highest species richness estimate by non-parametric species richness estimators. Using both methods of species richness estimation, we were able to provide a reasonable and valuable estimate of 145–230 species from the study area.

Inventory completeness

We sampled approximately 50% of the estimated butterfly species richness in 20 days of sampling in the Tons valley. Despite the difficulties of sampling such a diverse group in such a short period of time, we were able to find significant differences in diversity across sites and were able to provide estimates of butterfly species richness in the area. Sampling for more time would have improved the estimates of species richness. For this, we sampled again during May–July 2010 to account for seasonality effects and recorded 44 more species (a total 123 species) from the Tons valley. Using the non-parametric species richness estimates, inventory completeness was approximately 77% (Table 2) in the study area. It can be considered as comprehensive sampling, as Cardoso (2009) recommended 80% of inventory completeness as comprehensive sampling for arthropod inventories. Gupta (2004) documented 48 species from the Govind NP and WLS, while we recorded 94 (75% of the species richness encountered in whole study area) species from the same region.

We wanted to determine whether our sampling period was sufficient to detect butterfly compositional differences between sites. Kedarkanta and Har-ki-Dun differed significantly, well before the last 30–40 individuals were sampled in rarefaction plot (Fig. 3b). Thus, we confirmed that we were able to determine the butterfly composition of sites in short sampling time. We were also able to differentiate between Har-ki-Dun and Jakhol though there were fewer differences in their species richness in the given short sampling period.

Species–habitat relationships

Butterflies: vegetation and anthropogenic factors

There was an obvious association between butterfly species richness and vegetation parameters, such as plant species richness, herb and shrub density, and canopy cover. Herb and shrub density were major predictors of butterfly abundance. Logging was positively associated with butterfly species richness and abundance. Forest fire and livestock abundance had significant negative effects on butterfly species richness and abundance. Logging creates open patches. Because these patches maintain a relatively high temperature, they may be important for butterfly thermoregulation requirements. Similar results were found by Devi and Davidar (2001), Ghazoul (2002), Cleary (2004), and Akite (2008) studying effects of logging on butterfly diversity. On the other hand, forest fire and livestock grazing directly impacts shrub and herb abundance and had significant correlations with butterfly abundance and species richness in the current study. Little information is available on the distribution of adult and larval resources, distribution, and habitat requirement of generalist and specialist species, interaction, and responses of rare species with these factors, flight behaviour, thermal requirements, and predation differences in the different habitats. Therefore, we could use these observations for designing habitat monitoring protocol in the area.

Habitat evaluation

We found higher butterfly diversity in agriculture land than in natural or semi- natural forest habitats. However, the numbers of butterfly species were highest in natural forest, such as mixed riparian forest. High diversity may be better supported in complex habitat conditions and higher resource heterogeneity. Thus, the observed high diversity in agriculture land may be due to the availability of a variety of microhabitats, vegetations, and high minerals and resource richness due to the anthropogenic activities associated with it (Spitzer et al., 1993; Devi and Davidar, 2001; Bhardwaj and Uniyal, 2009). These results support a growing consensus that human dominated landscapes can support diverse assemblages of butterflies (Horner-Devine et al., 2003; Barlow et al., 2008). However natural sites, such as Istragad and Jakhol, contained some of the highest butterfly diversity among the undisturbed sites. However, these two sites also contained a large number of unique species (23 species), indicating that natural forest and undisturbed sites are important for conservation of such species. Both frugivorous and non-frugivorous butterflies may visit agriculture habitats but rely primarily on forest resources for nutrition, mating, and reproduction. Adults use resources found in the open but depend on forest fragments for larval host plants. In addition, both adult and larval host plants are found both in and out of the forest (Horner-Devine et al., 2003). Kedarkanta, Har-ki-Dun, and Tuni are highly disturbed sites and were covered largely by human dominated mixed scrub, pine forest, and agriculture lands. Natural diverse habitats, such as mixed broadleaf forest and alpine meadows, were also under immense anthropogenic pressure at these sites because they support daily livelihood requirements (fodder, fire-wood, herb collection and livestock grazing etc.) of the villagers. Our results suggest that Istragad and Jakhol support a range of forest butterfly species and need more protection.

Site similarities in butterfly composition classified into three protection regimes were well supported by the NMDS ordination plot (Fig. 4). Istragad and Kedarkanta, which lie in Govind WLS, were grouped together because they are both managed under a lower degree of protection. Jakhol and Har-ki-Dun were grouped together because they both lie in the high level of protection regime in Govind NP. Tuni separated apart from other sites in the NMDS plot showing unique butterfly composition, as it had areas of highest disturbance, dense human habituations, and low quality forest and protection (managed under reserve forest). Nevertheless, it supported a moderately diverse butterfly assemblage (Table 1) made up primarily of widespread, generalist, and migrant species. During snowfall at higher elevations, species migrates to lower elevation warm areas and on rise of temperature, butterflies migrate back to higher elevations of the valley.

Butterflies as surrogate taxa for insect diversity

Other insect communities (moths and beetles) were also sampled in the area. A positive cross-taxon correlation was found in species richness and abundance of butterflies, moths, and beetles (Table 3) (Uniyal et al., 2011). Patterns of species turnover were correlated for lepidoptera, indicating that the butterfly and moth species richness and abundance shifts similarly across sites (Uniyal et al., 2011). In the absence of data for more insect communities, we could use this assessment as an indicator of biodiversity because insect species patterns may follow similar patterns as the butterflies. This may result from overlap in the location of host plants, degree of disturbance, or similarity of thermal tolerance. Although correlations between species richness, abundance, and diversity of butterflies and other insect groups are imperfect (Singer and Ehrlich, 1991;

Ricketts et al., 2002; Schulze et al., 2004), but in the absence of more complete insect data, we suggest that Istragad and Jakhol are likely to be important sites for general insect conservation in PAs (Govind NP and WLS) in the Tons valley. Nonetheless, the conservation issue must be carefully considered before butterflies are used as a surrogate for insect biodiversity because differences in distribution of rare species of butterflies, moths, and beetles across sites have not been measured. The global scale and rapidity of biodiversity destruction (Wilson, 1988) forces most ecologists to accept the practical need for quick surveys of biodiversity in conservation planning and management (Roberts, 1991). However, these can ultimately be justified only by testing their accuracy against large samples and long term studies that partition diversity into spatial and temporal dimensions.

There are approximately 427 species of butterflies in the Western Himalayas (Wynter-Blyth, 1957). We would not expect to record comparable number species at such a small site as the upper catchment of the Tons valley because it lacks representation from lower elevations (500–900 m), a major repository of species found in the Western Himalayas. However, we were able to provide a reasonable estimate and sampled 75–80% of the butterfly fauna of the Tons valley. We recommend sweep netting supplemented with fruit baits and opportunistic random searches in all possible habitats to inventory butterflies in the Himalayan landscape.

It is extremely difficult to sample biodiversity in a given area, as time and money is limited. Butterflies constitute a model system for large sample, long term monitoring studies to quickly survey biodiversity. To select and prioritize areas for biodiversity conservation, rapid assessments of biodiversity indicator taxa can be an important, helpful, quick, and cost-effective tool for conservation managers. These observations were also supported by the significant positive cross-taxon congruency between butterflies, moths, and beetles species richness and abundance across sites. Jakhol and Istragad are currently managed under different degrees of protection regimes (in Govind NP and WLS respectively), and were the most promising sites, supporting a large number of unique forest species and high butterfly, moth, and beetle diversity. Thus, management practices should be revised so as to give protection to these sites. Our study also confirms the importance of natural and semi-natural habitats for butterflies in the Tons valley. As Tuni supports a large number of generalist butterfly species, it also supports a unique butterfly assemblage. Tuni is currently managed under a low degree of protection (reserve forest). Efforts are needed to check or minimise anthropogenic activities (e.g. grazing, logging, looping (collection of leaves for fodder), herb collection, wood cutting, forest fire, etc.) that lead to habitat degradation and fragmentation. There have been very few studies on the biogeographical distribution of the Himalayan butterfly fauna in the last 50 years. As the Himalayan forests are under large threats of habitat degradation and forest fragmentation, there is an urgent need to perform such studies on butterflies, especially for species which are endemic to the Himalayan region and subregions. It is our expectation that the results presented and discussed here will help conservation planners and managers by aiding them in the selection of biodiversity rich areas and by giving attention to remaining fragmented habitats facing human alterations, which will increase biodiversity conservation efforts in the area.

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Appendix A. Number of individuals for each of 79 species sampled at each of the five sites during 20 days of sampling and total species richness at each of the sites in the Tons valley

Species	Tuni	Kedarkanta	Istragad	Jakhol	Har-ki-Dun
Family: Papilionidae					
Paranassius epaphus Oberthür	–	1	5	–	–
Paranassius hardwickii Gray	–	13	9	1	2
Graphium cloanthus Westwood	3	1	–	–	–
Graphium doson (C. & R. Felder)	–	–	–	1	–
Graphium agamemnon (Linnaeus)	1	–	–	–	–
Graphium eurous (Leech)	–	–	1	–	–
Chilasa clytia (Linnaeus)	–	2	3	–	–
Papilio polytes romulus Cramer	5	–	2	–	–
Papilio protenor protenor Cramer	–	16	12	3	1
Papilio demoleus Linnaeus	1	–	–	–	–
Papilio machaon Linnaeus	–	8	5	2	2
Papilio polyctor polyctor Boisduval	–	2	–	–	–
Atrophaneura aristolochiae (Fabricius)	14	7	–	–	–
Troides aeacus (C. & R. Felder)	–	–	–	1	–
Family: Pieridae					
Eurema blanda (Boisduval)	5	–	7	–	–
Eurema laeta laeta (Boisduval)	4	2	5	–	–
Gonepteryx rhamni (Linnaeus)	–	28	45	3	7
Catopsilia pomona (Fabricius)	19	42	112	–	53
Colias fieldii Ménétriés	–	17	11	3	4
Colias erate (Esper)	–	1	–	–	–
Pieris brassicae (Linnaeus)	–	32	16	3	9
Pieris canidia (Sparrman)	68	41	29	15	2
Pieris rapae (Linnaeus)	–	–	–	–	3
Pontia daplidice (Linnaeus)	–	14	12	5	–
Delias belladonna (Fabricius)	4	–	–	–	–
Belenois aurota (Fabricius)	6	12	–	3	–
Family: Lycaenidae					
Rapala iarbus (Fabricius)	–	–	1	–	–
Lycaena phlaeas (Linnaeus)	–	13	1	5	3
Lycaena pavana Kollar	2	3	–	–	–
Heliophorus brahma Moore[a]	–	–	2	–	–
Heliophorus sena Kollar	–	8	–	1	–
Lampides boeticus (Linnaeus)	8	137	78	13	14
Zizeeria karsandra (Moore)	–	49	12	6	9
Pseudozizeeria maha (Kollar)	–	–	1	–	–
Acytolepis puspa (Horsfield)	–	13	41	5	–
Celastrina huegelli Moore	–	–	1	–	–
Dodona durga (Kollar)[a]	–	–	2	–	–
Family: Nymphalidae					
Libythea lepita Moore	–	–	2	–	1
Tirumala limniace (Cramer)	–	–	1	–	–
Danaus genutia (Cramer)	–	–	–	1	–
Danaus chrysippus (Linnaeus)	1	2	2	–	–
Parantica sita (Kollar)	–	–	1	–	–
Euploea mulciber (Cramer)	–	1	–	–	–
Euploea core (Cramer)	5	2	–	–	–
Melantis leda (Linnaeus)	1	–	–	–	–
Lethe rohria (Fabricius)[a]	–	–	2	–	–
Lethe verma (Kollar)	–	–	1	–	–
Lasiommata schakra Kollar	9	–	–	–	–
Elymnias hypermnestra (Linnaeus)[b]	–	–	4	–	–
Mycalesis perseus (Fabricius)[b]	–	–	2	1	–
Aulocera saraswati (Kollar)	–	–	–	1	–
Ypthima sakra Moore	–	–	1	–	–
Arggyres hyperbius (Linnaeus)	7	1	–	–	–
Fariciana kamala (Moore)	–	–	1	–	–
Issora lathonia (Linnaeus)	–	17	13	–	2
Palanta phalantha (Drury)	–	–	1	–	–
Athyma perius (Linnaeus)	–	1	–	–	–
Athyma opalina (Kollar)	–	–	–	1	–
Neptis hylas (Linnaeus)	–	12	–	9	1
Neptis Mahendra Moore	–	4	–	5	–
	2	–	1	–	–

Appendix A (*continued*)

Species	Tuni	Kedarkanta	Istragad	Jakhol	Har-ki-Dun
Cyrestis thyodamas Boisduval					
Pseudergolis wedah (Kollar)	–	–	2	1	–
Stibochiona nicea (Gray)[a]	–	–	1	–	–
Hestina nama (Doubleday)	–	–	–	1	–
Sephisa dichroa (Kollar)	2	–	1	–	–
Symbrenthia hippoclus (Cramer)	1	–	–	–	–
Vanessa indica (Herbst)	–	9	1	–	–
Vanessa cardui (Linnaeus)	63	7	6	–	1
Aglais cashmiriensis (Kollar)	–	21	11	7	3
Nymphalis xanthomelas (Denis & Schiffermüller)	–	–	4	–	–
Kaniska canace (Linnaeus)	1	–	2	–	–
Junonia orithiya (Linnaeus)	17	1	5	2	–
Junonia hierta (Fabricius)	3	–	–	–	–
Junonia atlites (Linnaeus)	2	–	–	–	–
Junonia lemonias (Linnaeus)	5	–	2	–	–
Kallima inachus (Boisduval)	–	–	1	–	–
Family: Hesperiidae					
Celanorrhinus leucocera (Kollar)[a]	–	–	2	–	–
Celanorrhinus dhanada (Moore)[a]	–	–	1	1	–
Sarangesa purendra Moore[a]	–	–	4	–	–
Total species richness	**51**	**27**	**27**	**35**	**17**

[a] Opportunistic sightings: species not recorded on the transects.
[b] Species only recorded in fruit-baited traps and not by any other method.

Appendix B. Complete list of 123 butterflies recorded in the Tons valley during the entire sampling period (March–July 2010). Species in bold (15 species) were present in the first rapid survey (spring season) but were absent during the second survey (summer season)

Common name	Species
Family: Papilionidae	
Common Red Apollo	*Paranassius epaphus* Oberthür
Common Blue Apollo	*Paranassius hardwickii* Gray
Common Bluebottle	*Graphium sarpedon* (Linnaeus)
Glassy Bluebottle	*Graphium cloanthus* Westwood
Common Jay	*Graphium doson* (C. & R. Felder)
Tailed Jay	***Graphium agamemnon*** (Linnaeus)
Sixbar Swordtail	*Graphium eurous* (Leech)
Tawny Mime	***Chilasa agestor*** (Gray)
Common Mime	*Chilasa clytia* (Linnaeus)
Common Mormon	*Papilio polytes romulus* Cramer
Spangle	*Papilio protenor protenor* Cramer
Lime	*Papilio demoleus* Linnaeus
Yellow Swallowtail	*Papilio machaon* Linnaeus
Common Peacock	*Papilio polyctor polyctor* Boisduval
Rose Windmill	***Atrophaneura latreillei*** (Donovan)
Common Rose	*Atrophaneura aristolochiae (Fabricius)*
Golden Birdwing	*Troides aeacus* (C. & R. Felder)
Family: Pieridae	
Three Spot Grass Yellow	*Eurema blanda* (Boisduval)
Small Grass Yellow	*Eurema brigitta* (Cramer)
Spotless Grass Yellow	*Eurema laeta laeta* (Boisduval)
Common Brimestone	*Gonepteryx rhamni* (Linnaeus)
Common Emigrant	*Catopsilia pomona* (Fabricius)
Mottled Emigrant	*Catopsilia pyranthe* (Linnaeus)
Dark Clouded Yellow	*Colias fieldii* Ménétriés
Pale Clouded Yellow	***Colias erate*** (Esper)
Common Wanderer	*Pareronia valeria* (Cramer)
Large Cabbage White	*Pieris brassicae* (Linnaeus)
Green-Veined White	*Pieris napi* (Linnaeus)
Indian Cabbage White	*Pieris canidia* (Sparrman)
Small Cabbage White	*Pieris rapae* (Linnaeus)
Bath White	*Pontia daplidice* (Linnaeus)
Himalayan Blackvein	*Aporia leucodice* (Eversmann)
Great Blackvein	*Aporia agathon* (Gray)
Hill Jezebel	*Delias belladonna* (Fabricius)

Appendix A (*continued*)

Common name	Species
Pioneer	*Belenois aurota* (Fabricius)
Family: Lycaenidae	
Common Gem	*Porita hewitsoni* Moore
Yamfly	*Loxura atymnus* (Stoll)
Indian Red Flash	*Rapala iarbus* (Fabricius)
Common Silverline	*Spindasis vulcanus* (Fabricius)
Common Copper	*Lycaena phlaeas* (Linnaeus)
White Bordered Copper	*Lycaena pavana* Kollar
Golden Sapphire	***Heliophorus brahma*** Moore
Green Sapphire	*Heliophorus androcles* (Doubleday & Hewitson)
Sorrel Sapphire	*Heliophorus sena* Kollar
Pea Blue	*Lampides boeticus* (Linnaeus)[a]
Dark Grass Blue	*Zizeeria karsandra* (Moore)
Pale Grass Blue	***Pseudozizeeria maha*** (Kollar)
Chapman's Cupid	*Everes argiades diorides* Chapman[a]
Common Hedge Blue	*Acytolepis puspa* (Horsfield)
Hill Hedge Blue	*Celastrina argiolus* (Linnaeus)
Large Hedge Blue	*Celastrina huegelli* Moore
Orange Bordered Argus	*Aricia astrarche* Bergstrasser
Common Meadow Blue	*Polymmatus eros*
Tailed Punch	*Dodona eugenes* Bates
Common Punch	*Dodona durga* (Kollar)
Family: Nymphalidae	
Common Beak	*Libythea lepita* Moore[a]
Club Beak	*Libythea myrrha* Godart
Blue Tiger	***Tirumala limniace*** (Cramer)
Dark Blue Tiger	*Tirumala septentrionis* (Butler)
Striped Tiger	*Danaus genutia* (Cramer)
Plain Tiger	*Danaus chrysippus* (Linnaeus)
Glassy Tiger	*Parantica aglea* (Stoll)
Chestnut Tiger	***Parantica sita*** (Kollar)
Striped Blue Crow	*Euploea mulciber* (Cramer)[a]
Common Crow	*Euploea core* (Cramer)
Common Evening Brown	*Melantis leda* (Linnaeus)
Great Evening Brown	***Melantis zitenius*** (Herbst)
Common Treebrown	*Lethe rohria* (Fabricius)
Common Forester	*Lethe insana* (Kollar)
Straight-Banded Treebrown	*Lethe verma* (Kollar)
Common Wall	*Lasiommata schakra* Kollar
Common Palmfly	***Elymnias hypermnestra*** (Linnaeus)
Common Bushbrown	*Mycalesis perseus* (Fabricius)
Great Satyr	*Aulocera padma* (Kollar)
Common Satyr	*Aulocera swaha* (Kollar)
Striated Satyr	*Aulocera saraswati* (Kollar)
Ringed Argus	*Callerebia ananda* (Moore)
Common Argus	*Callerebia nirmala* (Moore)
Pallid Argus	***Callerebia scanda*** (Kollar)
Himalayan Fivering	*Ypthima sakra* Moore
Large Silverstripe	*Argynnis pandora* (Denis & Schiffermüller)
Indian Fritillary	*Arggyres hyperbius* (Linnaeus)
Common Silverstripe	*Fariciana kamala* (Moore)
Queen of Spain Fritillary	*Issora lathonia* (Linnaeus)
Rustic	*Cupha erymanthis* (Drury)
Common Leopard	*Palanta phalantha* (Drury)
Indian White Admiral	*Limentis trivena* Moore
Common Sergeant	*Athyma perius* (Linnaeus)
Himalayan Sergeant	*Athyma opalina* (Kollar)
Common Lascar	*Pantoporia hordonia* (Stoll)
Yerbury's Sailer	*Neptis yerburyi* Butler
Common Sailer	*Neptis hylas* (Linnaeus)
Clear Sailer	*Neptis clinia* (Moore)
Himalayan Sailer	*Neptis Mahendra* Moore
Broad-Banded Sailer	*Neptis sankara* (Kollar)
Broadstick Sailer	*Neptis narayana* Moore
Baronet	*Euthalis nais* (Forester)
Common Map	*Cyrestis thyodamas* Boisduval
Tabby	*Pseudergolis wedah* (Kollar)
Popinjay	*Stibochiona nicea* (Gray)
Common Castor	*Ariadne merione* (Cramer)
Circe	***Hestina nama*** (Doubleday)
Western Courtier	*Sephisa dichroa* (Kollar)
Himalayan Jester	***Symbrenthia hypselis*** (Godart)
Common Jester	*Symbrenthia hippoclus* (Cramer)
Indian Red Admiral	*Vanessa indica* (Herbst)
Painted Lady	*Vanessa cardui* (Linnaeus)
Indian Tortoiseshell	*Aglais cashmiriensis* (Kollar)

Appendix B (*continued*)

Common name	Species
Large Tortoiseshell	*Nymphalis xanthomelas* (Denis & Schiffermüller)
Eastern Comma	*Polygonia agea* (Cramer)
Blue Admiral	*Kaniska canace* (Linnaeus)
Blue Pansy	*Junonia orithiya* (Linnaeus)
Yellow Pansy	*Junonia hierta* (Fabricius)
Chocolate Pansy	*Junonia iphita* (Cramer)
Grey Pansy	***Junonia atlites*** (Linnaeus)
Peacock Pansy	***Junonia almana*** (Linnaeus)
Lemon Pansy	*Junonia lemonias* (Linnaeus)
Orange Oakleaf	*Kallima inachus* (Boisduval)
Family: Hesperiidae	
Orange Awlet	*Bibasis jaina* (Moore)
Common spotted Flat	*Celanorrhinus leucocera* (Kollar)
Himalayan Yellow Flat	*Celanorrhinus dhanada* Moore
Spotted Small Flat	*Sarangesa purendra* Moore
Himalayan Grass Dart	*Potanthus dara* (Kollar)
Himalayan Swift	*Polytemis discreta* (Elwes & Edwards)[a]

[a] Species protected in Indian Wildlife Protection Act, 1972 (Anonymous, 2006).

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