Effects of elevation gradient and aspect on butterfly diversity on Galičica Mountain in the Republic of Macedonia (south–eastern Europe)

M. Popović, B. Micevski, R. Verovnik

Abstract

Effects of elevation gradient and aspect on butterfly diversity on Galičica Mountain in the Republic of Macedonia (south–eastern Europe). The patterns of butterfly diversity and community changes in relation to elevation are an interesting and well–covered topic in ecology, but the effects of aspect have rarely been evaluated. Here we studied the changes in butterfly species richness and communities along the elevation gradient and aspect of Galičica Mountain. As expected, species richness changed with altitude, showing a bimodal pattern with two peaks and a declining trend towards higher altitude. Changes were well–correlated with the area in each altitudinal zone, while the effects of productivity were less clear. Butterfly communities at higher altitudes were the most distinct when grouped according to β diversity estimates, followed by mid– and low–altitude communities. Indicator species were found in mid–altitudes and for the combination of low–mid and mid–high altitudes, but not among aspects. Overall, aspect produced a less conclusive effect on species richness and community composition. South and north accounted for most of these differences despite dominant western and eastern and exposition of the mountain slopes. The community temperature index declined with altitude and on the northern aspect, showing these areas hosted more cold–adapted species. Notes on butterfly conservation are provided as 23 species known from historical surveys have not been recorded recently.

Data published through <u>GBIF</u> (Doi: 10.15470/jacl7y)

Key words: Species richness, Altitude, Exposition, Lepidoptera, iNEXT

Resumen

Efectos del gradiente de altitud y la orientación en la diversidad de mariposas de la montaña Galičica, en la República de Macedonia (Europa sudoriental). Los patrones de diversidad de mariposas y los cambios en las comunidades en relación con la altitud son un tema interesante y bien estudiado en ecología, pero los efectos de la orientación se han evaluado muy poco. En el presente estudio analizamos los cambios en la riqueza de especies de mariposas y sus comunidades a lo largo del gradiente de altitud y según la orientación de la montaña Galičica. De acuerdo con lo esperado, la riqueza de especies cambió con la altitud siguiendo un patrón bimodal con los máximos y una tendencia decreciente hacia mayores altitudes. Los cambios estuvieron bien correlacionados con la superficie de cada zona de altitud, mientras que los efectos de la productividad fueron menos evidentes. Las comunidades de mariposas a mayor altitud fueron las más peculiares cuando se agruparon según las estimaciones de la diversidad beta, seguidas de las comunidades a media altitud y a baja altitud. Se observaron especies indicadoras en altitudes medias y en la combinación de altitudes medias bajas y medias altas, pero no entre las orientaciones. En general, la orientación produjo un efecto menos concluyente en la riqueza de especies y la composición de las comunidades. La mayor parte de estas diferencias se produjeron en el norte y en el sur, a pesar de que las laderas de la montaña están predominantemente orientadas al oeste y el este. El índice de temperatura comunitaria disminuyó con la altitud y en la orientación norte, lo que pone de manifiesto que estas zonas albergaban más especies adaptadas al frío. Se proporcionan notas sobre la conservación de las mariposas, ya que recientemente no se han registrado 23 de las especies observadas en estudios históricos.

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Introduction

It is generally agreed that species diversity declines with altitude, somewhat repeating the more stable latitudinal pattern (Rahbek, 1995). However, changes with elevation are more complex and species diversity tends to follow four main patterns with rising altitude: decreasing, low plateau, low plateau with mid–elevation peak, and mid–elevation peak (McCain et al., 2010). These patterns could be explained by several ecological factors, including climate and productivity, species–area relationship, mid–domain effect, effects of ecotone, biotic factors, evolution, and historical circumstances (Colwell and Lees, 2000; Lomolino, 2001; McCain, 2007; McCain et al., 2010). While studying the effects of biotic and evolutionary factors requires detailed planning and study design, other factors can often be tested more easily. Relatively large mountain ranges with diverse geological structure and climate (from Continental to Mediterranean) make south–eastern Europe an interesting region for studies of elevation gradients in species diversity. At the same time, data on butterfly diversity in this region is scattered in a multitude of faunistic papers, while few studies address the butterfly diversity pattern (Mihoci et al., 2011; Zografou et al., 2014, 2017; Kaltsas et al., 2018). Similarly, the effect of aspect is only rarely taken into consideration when addressing the distribution patterns of butterflies in mountains (Gutiérrez, 1997; Mihoci et al., 2011). However, the aspect of the mountain slope is considered an important topographic factor (i.e. Bennie et al., 2008) and it could play a role in shaping butterfly communities.

The climate along the elevation gradient is known to affect insect biology (Hodkinson, 2005) and is predicted to produce the diversity pattern with mid–altitude peaks in temperate regions (Despland et al., 2012; McCain, 2007). Butterflies have shown the same patterns of diversity changes in the mountains as other animal groups, and these changes are commonly guided by variation in climate (MacNally et al., 2003; Gallou et al., 2017). Harsh conditions at a higher elevation have prompted numerous ecological adaptations in butterflies (Junker et al., 2010; Kevan and Shorthouse, 1970; Leingärtner et al., 2014) and it has been suggested that species communities at high elevations tend to show some evolutionary constraints (Pellissier et al., 2013). As the current global climate change induces rapid shifts in butterfly communities across continents (Devictor et al., 2012, Zografou et al., 2014), mountain systems have become increasingly important as refugia for species retracting pole–wards (Fleishman et al., 2000; Hampe and Petit, 2005; Wilson et al., 2007). These rapid changes can be traced by climate change indicators such as the community temperature index (CTI) (Schweiger et al., 2014; Zografou et al., 2014). This index also allows the comparison of extant communities within altitudinal gradient or aspects, where CTI values are expected to decline with altitude and on northern slopes.

We compiled a check–list of butterfly species (Papilionoidea) and a large dataset of all records for the Galičica mountain range in the south–western part of the Republic of Macedonia, combining data from the literature and the authors' field observations. The main goal of the study was to examine how butterfly species richness changes according to altitude and aspect of the mountain, which, in contrast to the near–by ranges, stretches in a north–south direction. We tested the effect of the area, ecosystem productivity and mid–domain effect on elevational patterns of species richness. In addition, we studied the similarities between butterfly communities and determined whether communities along the elevation gradient and aspect differed in community temperature indexes. We also provide notes on the potential extinction of several butterfly species in the area and discuss the conservation value of this mountain range.

Material and methods

Study area

Galičica is a calcareous mountain range at the junction of Macedonia, Albania and Greece and is shared between the two first mentioned states (fig. 1). It rises between the lakes of Prespa in the east and Ohrid in the west. The climate is mild–continental and Mediterranean, with climatic conditions stabilized by the presence of large water bodies. The mountain is situated on an elevated plain, with the base at 695 m and reaching the altitude of 2,265 m (Avramoski et al., 2010; Ćušterevska, 2016). It stretches in a south–north direction; the east and west are therefore dominant aspects. In 1958 the Macedonian part of Galičica was proclaimed a National Park, with a total area of 24,151 ha, and protected by the state (Matevski et al., 2011).

Data collation and preparation

A historical overview of butterfly fauna of Mt. Galičica was summarized by Krpač et al. (2011). This publication was geo–referenced within Biologer.org biodiversity database (Popović et al., 2020) and used as a baseline for our study. Besides records from the literature, we used an original dataset from Verovnik et al. (2010), unpublished data by I. Jugovic, A. Keymeulen, N. Micevski and the authors' personal records. Species observations of MP, RV and geo–referenced records from the literature can be downloaded after registration on Biologer.org or accessed through GBIF (Doi: 10.15470/jacl7y). Four major periods in butterfly studies can be recognized: i) an initial study in 1918; ii) short field surveys in the mid–19th century; iii) detailed inventory work in the seventies and eighties; and iv) intensive field studies by several experts from 1995 onwards. A detailed checklist of recorded species is given in supplementary material, differentiating historical (before 1995) and recent data.

Compiling species observations from different datasets could produce bias in the data and should be taken with caution. Thus, before proceeding to the statistical analysis, species occurrence records were subset to those with coordinate precision no less

than 2 km. The unique combination of the species name, locality name and year was used to create samples –lists of observed species– and was assumed to be equal to the list of species recorded at a single sampling event. The incidence of frequency of species was determined by combining the samples from a certain elevation zone, or aspect. To remove accidental individual observations, data were further subset to include only samples with more than five observed species.

Altitudes and aspects were extracted from a digital elevation model (European Environment Agency, 2016), while all GIS calculations were made using *raster* package in R (R Core Team, 2019). Altitude at each point of observation was extracted and used to divide samples in *n* classes of equal length between maximal and minimal altitude. Calculations were made starting from n = 20 and decreasing the value until good estimates were obtained (i.e. low standard errors, high sample coverage, and good representation of all classes). This resulted in 10 altitudinal classes from 689 m to 2,234 m. Aspect values were calculated in degrees and transformed to four major aspects (cardinal directions): north (0º–45º) and 315º–360º), east (45º–135º), south (135º–225º) and west (225º–315º). To determine dominant mountain aspects for each sample, we included the area in a radius of 1 km around the observation point (i.e. not only the aspect at the exact sampling location). The joint influence of several aspects was minimized by selecting samples with single aspects contributing more than 50%, and discarding data for samples with more uniform aspect contributions.

Species richness

To compare differences in species diversity between altitudinal classes and aspects, we used species richness measure as a representation of α diversity. Calculations were made using the iNEXT package in R, allowing construction of both rarefaction and extrapolation curves; this provided a robust estimate of the true species diversity even in cases with low and unequal sampling effort (Chao et al., 2014; Hsieh et al., 2016). Incidence frequencies prepared in the previous step were used as input data and are available in supplementary material.

The effect of an area on species richness was assessed by plotting the available area in each altitudinal class or aspect versus estimated species richness. The relationship between productivity and species richness was examined by plotting values of normalized difference vegetation index (NDVI) versus estimated species richness. NDVI was obtained from MODIS (Didan, 2015) between April and September 2017–2019 (representing the vegetation period for the last three years). Average NDVI values were then calculated for each altitudinal class and aspect. Since productivity is directly related to climate, productivity–richness relationship could reflect the influence of climate on butterflies along the altitudinal gradient (Levanoni et al., 2011; Pettorelli et al., 2005). The presence of mid–domain effect was checked by

plotting 95% CI of the null model (1,000 replicates) against observed species richness, using rangemodel *R* package in R (McCain, 2003; Colwell, 2008). Where applicable, statistical significance was checked using Spearman correlation test in R.

Changes in butterfly communities

To estimate the similarity between butterfly communities (β diversity) at different altitudes and aspects of Mt. Galičica, we used the probability version of the Chao–Jaccard index, provided by CommEcol package in R. This index is less biased than classic similarity indices and it is not sensitive to the omission of some species from the samples (Chao et al., 2005). The results are shown as unrooted dendrograms produced in ape package in R.

In addition to providing the Chao–Jaccard estimate, we used the indicator value index to search for indicator species of a certain elevation zone and aspect (Cáceres and Legendre, 2009). Elevation zones were grouped according to the estimates suggested by Chao–Jaccard index in three elevation classes (low, mid and high altitudes). Estimates were obtained using package indicspecies in R using IndVal.g estimator with 1,000 permutations.

To test whether climate had any effects on shaping the butterfly communities we calculated the community temperature index (CTI) for each delineated altitudinal class and aspect of Mt. Galičica. CTI values were calculated as an average of the species temperature index (STI), accounting also for butterfly abundance (Schweiger et al., 2014). If the climate affected the distribution of butterflies in communities, it could be expected that CTI would decline from the southern to the northern aspect and from lower altitudes towards the top of the mountain. Differences were statistically tested using ANOVA and pairwise t–test in R. Since the test could be affected by unequal sampling, different season, or year of observation, we used only our recent field observations that were collated with an even sampling effort and over the same period.

Results

A total of 4,137 occurrence records from Mt.Galičica were collated, most of these (2,376) being new field observations (see also the dataset published through GBIF (Doi: 10.15470/jacl7y). After removing duplicates and imprecise records, we retained 2,883 observations for the analysis. A total of 168 species were recorded for Mt. Galičica, 159 of which were known before 1995, while 145 were confirmed in recent studies (supplementary material). The decline in species was also evident from an estimated 152 ± 15 species before 1995 to an estimated 143 ± 3 species in the recent period (sample coverage 0.90 and 0.99 respectively). Compared to the overview by Krpač et al. (2011), three species were recorded for the first time: *Colias caucasica* Staudinger, 1871 (already noted by Verovnik et al., 2010), *Satyrium pruni* (Linnaeus, 1758) and *Melitaea ornata* Christoph, 1893.
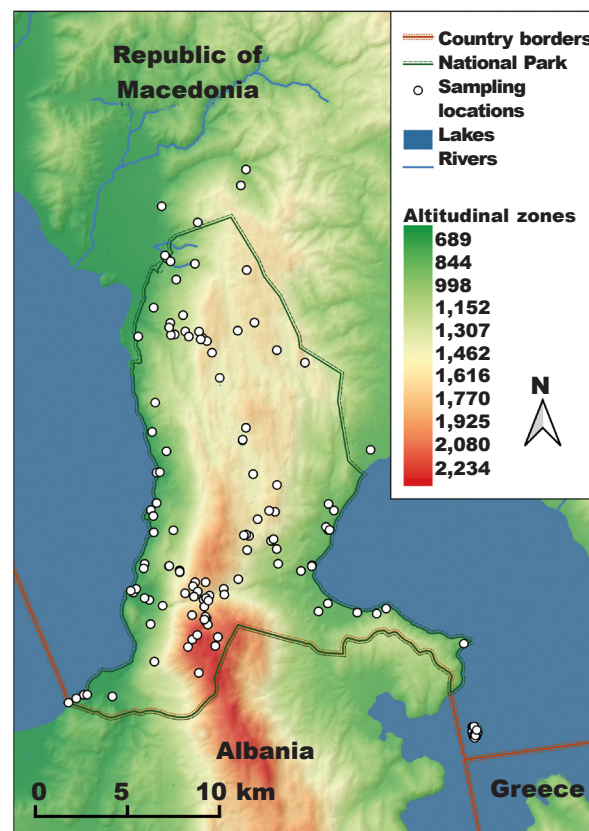
Fig. 1. Galičica mountain range in the Republic of Macedonia shown on a relief map, with altitudes corresponding to the altitudinal classes given in the manuscript. Blue indicates the lakes of Ohrid (to the west) and Prespa (to the east). All butterfly sampling locations are shown as white circles.

Fig. 1. Mapa de relieve en el que se muestra la cadena montañosa Galičica en la República de Macedonia, con altitudes que se corresponden con las clases de altitud que figuran en el manuscrito. El color azul indica los lagos de Ohrid (al oeste) y Prespa (al este). Todos los sitios de muestreo de mariposas se indican con círculos blancos.

Species richness indices

Estimated sample coverage for the iNEXT analysis ranged from 0.69 to 0.97 for altitudinal classes and from 0.61 to 0.98 for aspects, with the lowest estimate being for the southern aspect (supplementary material). Butterfly species richness on Mt. Galičica showed a bimodal distribution along the altitudinal span, with peaks at about 1,100 m and 1,500 m, and a declining trend towards the higher elevations (fig. 2A). We observed a strong correlation between the size of the area available in each altitudinal zone and estimated species richness (fig. 2A); this relation was statistically significant (rho = 0.81, S = 32, *P* = 0.008). A comparison of species diversity among different aspects of the mountain showed a more uniform pattern, with somewhat lower estimates for species richness on the northern and eastern slopes and higher richness estimates for the southern and the western slopes (fig. 2B). The correlation between estimated species richness and

the area available in different aspects of the mountain was not significant (rho = –0.20, S = 12, *P* = 0.917). Most of the area of the mountain comprises western and eastern slopes due to the mountain predominant south–north direction (fig. 1, 2B). However, it should be noted that observed and estimated species richness showed a large discrepancy for the southern aspect, while large standard errors and small sample coverage indicate imprecise calculations.

We were unable to determine a clear correlation between ecosystem productivity and butterfly species richness along the altitude, although estimates were close to significant (rho = 0.60, S = 66, *P* = 0.073) and some positive relation is clearly visible in the graph (fig. 2C). The highest discrepancies were near the second peak in species richness (fig. 2C). NDVI tended to increase to about 1,000 meters, then slowly decline towards the highest altitudes. In contrast, the NDVI index showed a similar distribution along the mountain aspects, with somewhat lower values
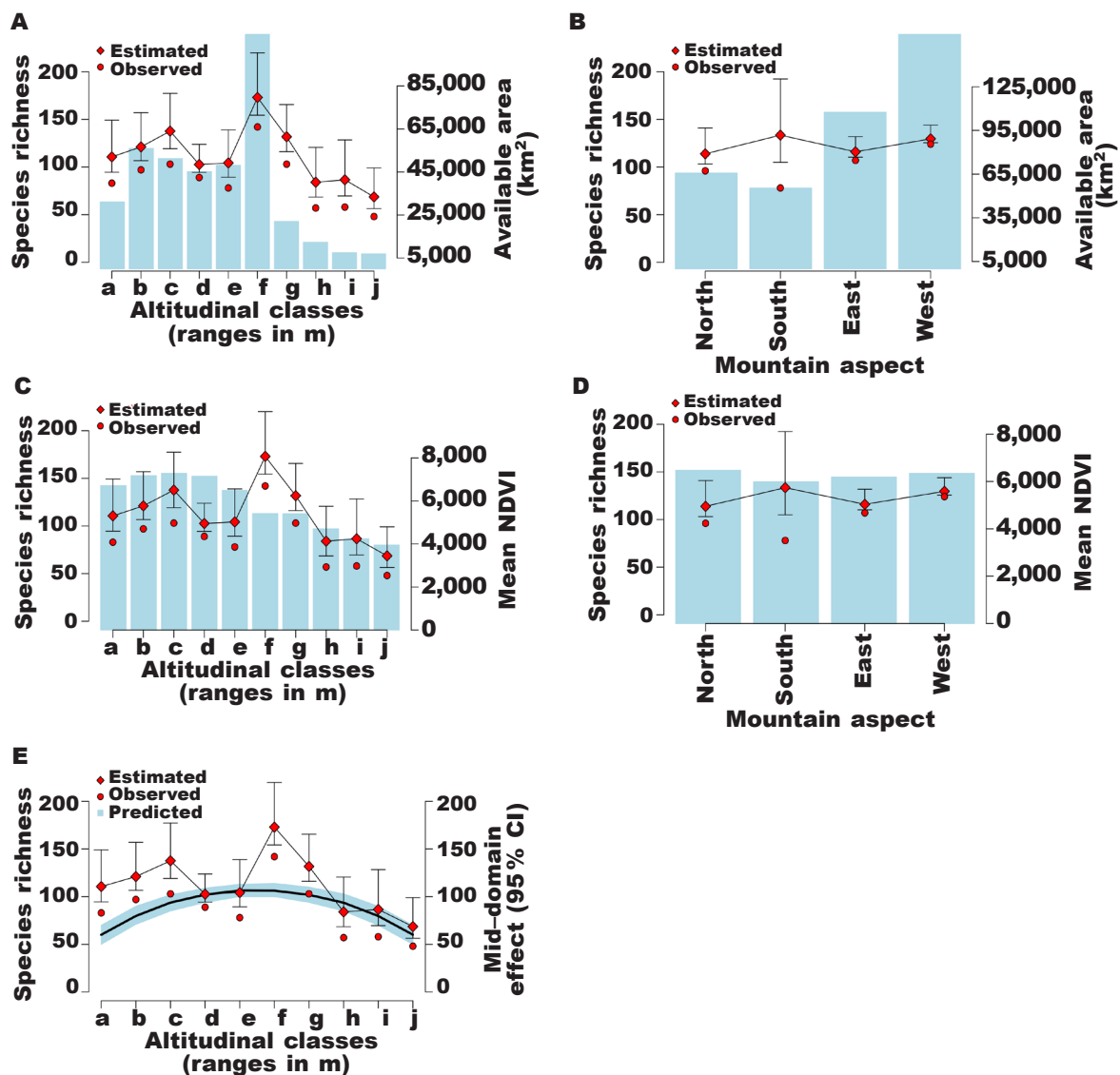
Fig. 2. The relationship between species richness at different altitudes and aspects of Mt. Galičica and several predictor variables. Upper graphs show the comparison of available area (histogram) and species richness (lines) for each altitudinal class (A) and aspect (B). The middle graphs depict a similar comparison for productivity (histogram of mean NDVI values) and species richness (lines) between altitudinal class (C) and aspect (D). The lower graph (E) shows the 95 % confidence interval for the null model prediction (blue area) constructed to test the mid–domain effect. Estimated values of species richness are shown as diamonds with lower and upper confidence intervals. Observed species richness values are indicated by circles. Altitudinal classes: a, 689–844; b, 844–998; c, 998–1,152; d, 1,152–1,307; e, 1,307–1,462; f, 1,462–1,616; g, 1,616–1,770; h, 1,770–1,925; i, 1,925–2,080; j, 2,080–2,234.

Fig. 2. La relación entre la riqueza de especies en diferentes altitudes y orientaciones de la montaña Galičica y varias variables predictivas. En los gráficos superiores se muestra la comparación de la superficie disponible (histograma) y la riqueza de especies (líneas) de cada clase de altitud (A) y orientación (B). En los gráficos centrales se muestra una comparación parecida entre la productividad (histograma de los valores medios del índice normalizado diferencial de la vegetación) y la riqueza de especies (líneas) entre clases de altitud C) y orientación (D). En el gráfico inferior (E) se muestra el intervalo de confianza del 95 % para la predicción del modelo nulo (superficie azul) elaborada para comprobar el efecto del dominio medio. Los valores estimados de la riqueza de especies se señalan con rombos con los límites inferior y superior del intervalo de confianza. Los valores de la riqueza de especies observada se indican con círculos. Altitudinal classes: a, 689–844; b, 844–998; c, 998–1,152; d, 1,152–1,307; e, 1,307–1,462; f, 1,462–1,616; g, 1,616–1,770; h, 1,770–1,925; i, 1,925–2,080; j, 2,080–2,234.
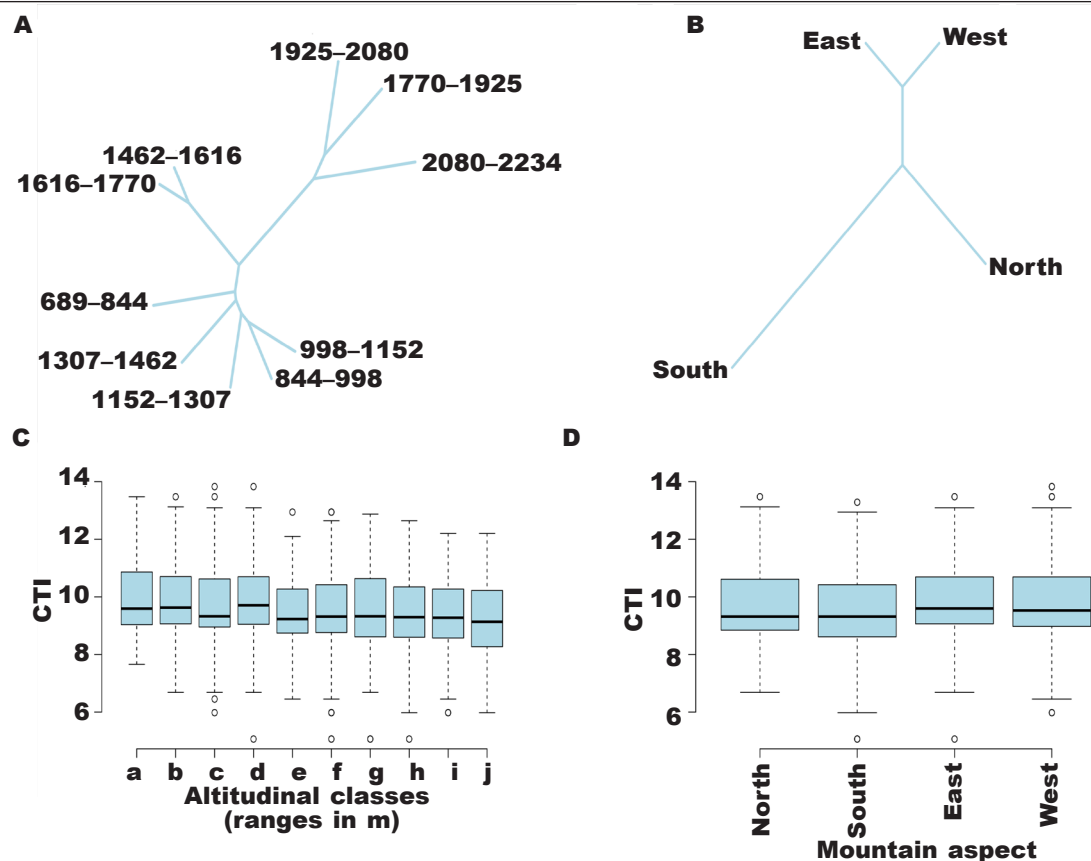
Fig. 3. A, cluster dendrogram constructed from Chao–Jaccard dissimilarity index of β diversity among butterfly communities at different altitudinal zones; B, mountain aspects; C, box–plots showing mean values for the community temperature index (CTI) of butterfly assemblages along elevation gradient; and D, box–plots showing butterfly assemblages at different aspects of Mt. Galičica. Detailed statistics with results of pairwise comparison in CTI values are given in supplementary material. For abbreviations of altitudinal classes see fig. 2.

Fig. 3. A, dendrograma de grupos elaborado a partir del índice de similitud de Chao–Jaccard de la diversidad β entre las comunidades de mariposas de diferentes zonas de altitud; B, orientaciones de la montaña; C, diagramas de caja en los que se muestran los valores medios del índice de temperatura comunitaria de los ensamblajes de mariposas a lo largo del gradiente de altitud, D, diagramas de caja en los que se muestran los ensamblajes de mariposas en las distintas orientaciones de la montaña Galičica. En material suplementatario se proporcionan estadísticas detalladas con resultados de la comparación por pares de valores del índice de temperatura comunitaria. Para las abreviaturas de las clases de altitud, véase la fig. 2.

on the warmer mountain slopes (fig. 2D); this could not be correlated with estimated species richness (rho = –0.80, S = 18, *P* = 0.333). We found no strong evidence for mid–domain effect on species richness as most points fell outside the confidence interval predicted by the null model (fig. 2E).

Changes in species communities

The Chao–Jaccard dissimilarity index was generally higher for communities at more distant altitudinal levels, with values ranging from 0.15 to 0.7 (more details available in supplementary material). Communities at the highest altitudes were clearly the most distinctive,

but those at mid–elevations also tended to form a separate group in the dendrogram (fig. 3A). Communities on different aspects showed lower differentiation with a dissimilarity index ranging from 0.1 to 0.36 (supplementary material). Eastern and western aspects hosted practically the same communities, while some differences were evident for northern and especially southern aspects (fig. 3B).

The indicator value index was computed for 127 and 75 species along the altitude and aspect, respectively. Indicator species were found in the mid–altitude zone and for the combination of low–mid and mid–high zones (table 1), while no indicator species were found for the mountain aspects.

Table 1. Indicator species for three altitudinal zones of Mt. Galičica. Altitudinal zones were delineated using the values of the Chao–Jaccard estimate (fig. 3) to three zones: low elevation (689–1,462 m), mid elevation (1,462–1,770 m) and high elevation (1,770–2,234 m). Only statistically significant indicator species are listed.

Tabla 1. Especies indicadoras de tres zonas de altitud de la montaña Galičica. Utilizando los valores de la estimación de Chao–Jaccard (fig. 3) se definieron tres zonas según la altitud: altitud baja (689–1.462 m), altitud media (1.462–1.770 m) y altitud alta (1.770–2.234 m). Solo se muestran las especies indicadoras estadísticamente significativas.

Mid elevation zone (15 species)

Parnassius apollo

Pyrgus alveus

Carcharodus floccifera

Hesperia comma

Hamearis lucina

Favonius quercus

Lycaena thersamon

Plebejus argyrognomon

Brenthis hecate

Kirinia climene

Lasiommata petropolitana

Hyponephele lycaon

Hyponephele lupina

Satyrus ferula

Pseudochazara geyeri

Mid and high elevation (5 species)

Parnassius mnemosyne

Lycaena candens

Polyommatus eros

Boloria graeca

Melanargia russiae

Mid and low elevation (18 species)

Iphiclides podalirius

Pyrgus cinarae

Thymelicus lineola

Pieris balcana

Pieris ergane

Leptidea sinapis

Lycaena phlaeas

Plebejus argus

Aricia agestis

Polyommatus admetus

Lysandra bellargus

Argynnis paphia

Issoria lathonia

Polygonia c–album

Coenonympha pamphilus

Maniola jurtina

Melanargia galathea

Brintesia circe

The community temperature index (CTI) values differed significantly between altitudinal zones ($F = 4.904$, df = 9, $P << 0.001$) and also between different aspects ($F = 3.558$, df = 3, $P = 0.014$). A declining trend was visible in average CTI values towards the higher altitudes, although the zone around the mid–elevations deviated from the linear decline pattern (fig. 3C). Statistical significance in pairwise comparisons between altitudinal zones was observed only for more distant altitudinal classes, with and the first two altitudinal zones accounting for most of this significance (details in supplementary material).However, the comparison of communities at different mountain aspects showed more uniform distribution of CTI (fig. 3D), and only the values on the northern aspect were significantly lower (supplementary material).

Discussion

Butterfly diversity and its potential decline

Despite the relatively small area studied, butterfly fauna of Mt. Galičica in the Republic of Macedonia is extremely rich, with 168 species recorded. This is comparable to other high biodiversity mountain regions in the Balkan Peninsula, such as Stara Planina in Serbia with 167 species (Langourov, 2019; Popović and Đurić, 2014), Stara Planina in Bulgaria with184 species (Kolev, pers. comm.), Shar Planina with 169 species (Jakšić, 1998; Melovski, 2003), Mt. Olympus with 155 species (Pamperis, 2009), Vitosha with 155 (Beshkov, 2014), Rila with 174, and Pirin with 195 (Kolev, pers. comm.). In addition to high butterfly diversity, Galičica is an important area for butterfly

conservation due to the presence of one threatened (*Phengaris arion*) and 17 near–threatened species at the continental level (van Swaay et al., 2010), and 21 threatened species at a national level (Krpač and Dacremont, 2012). This mountain has also been recognized as a prime butterfly area in Europe (Jakšić, 2003).

The absence of new records for as many as 23 species together with a lower estimated number of species in the recent period is noteworthy, however, and might indicate true extinctions of several taxa. The majority of potentially extinct species include habitat specialists, such as *Anthocharis damone*, *Euchloe penia*, *Tarucus balkanicus*, *Pseudochazara amalthea* and *Spialia phlomidis* that were known only from the open rocky habitats, once abundant above Ohrid town. This area in particular (authors pers. observ.) and the entire mountain is becoming overgrown due to abandonment of pasturing, with forest cover increasing on Mt. Galičica from 40 % to 58 %, and pastures declining from 50 % to 24 % in the last decades (Despodovska et al., 2012). Similar patterns have been found throughout Mediterranean Europe, with open grassland butterflies declining due to increased forest cover (Slancarova et al., 2016; Ubach et al., 2020). The lack of new records for woodland species such as *Limenitis camilla*, *Neptis rivularis* and *Erebia ligea* is difficult to explain given the increased forest cover. However, these butterflies are linked to more humid habitats, and recent changes in climate –with prolonged droughts and higher aridity– could cause their decline. The same could be true for the extinction of *Erebia oeme,* one of seven high alpine species (Varga and Varga–Sipos, 2001) recorded for Mt. Galičica.

Species richness pattern

The estimated richness of butterfly species on the elevation gradient of Galičica Mt. shows a bimodal distribution pattern, with two peaks and a declining trend towards the higher elevations. The decline in species richness between the two peaks was evident even when zones between 1,152 and 1,462 m were grouped together for the analyses (results not shown here), showing that the estimates were not caused by unequal or small sample sizes. Altitudinal patterns for butterfly species richness usually show similar, declining trend towards high elevations with peaks in mid–altitudes (Gutierrez and Menendez, 1995; Gutiérrez, 1997; Wilson et al., 2007; Levanoni et al., 2011; Stefanescu et al., 2011; Despland et al., 2012; Gallou et al., 2017; and the overview in Kaltsas et al., 2018). However, a bimodal pattern is not a rare phenomenon for butterflies peaking at midaltitudes and it has often been recorded in other studies (Gutierrez and Menendez, 1995; Levanoni et al., 2011; Stefanescu et al., 2011, Gallou et al., 2017). There is also considerable evidence for the monotonic decline in butterfly diversity along the elevation gradient (Mihoci et al., 2011; Leingärtner et al., 2014; Kaltsas et al., 2018), but an insignificant trend (Kaltsas et al., 2018) and increase in species richness (Wettstein and Schmid, 1999; Pyrcz et al., 2009) has also been reported. Note that the

increase in species richness with altitude is more likely to be caused by specific habitat composition (Wettstein and Schmid, 1999) or by the study of an exclusively montane taxonomic group (Pyrcz et al., 2009).

Species richness was significantly correlated with the area available in each altitudinal class on Galičica Mt., providing strong evidence for species–area relationship. In a similar manner, richness seemed to follow the ecosystem productivity (NDVI) until the prominent peak at about 1,500 m, which is probably caused by the vast area available in this altitudinal zone (coinciding with a large mountain plateau). Numerous studies have shown that butterfly diversity is correlated with precipitation and temperature (Mac Nally et al., 2003; Acharya and Vijayan, 2015). Productivity is derivative of these variables and is predicted to peak at mid altitudes along with species richness of butterflies, but heterogeneity in productivity was also an important predictor (Levanoni et al., 2011). The mid–domain hypothesis suggests that communities developing at high and low altitudes overlap in the mid–range, creating a peak in species richness, as predicted by theoretical models (Colwell and Lees, 2000; McCain et al., 2010). Although we found weak evidence that species richness follows pure predictions of the mid–domain model (fig. 2E), it is not impossible that some patterns in species diversity could be caused by overlapping of the communities from higher and lower elevation zones (see the discussion below). Diversity of butterflies along the elevation gradient could also be affected by heterogeneity of habitats, human disturbance (Lien, 2013; Gallou et al., 2017), biotic interactions, and evolutionary history (Pellissier et al., 2013). With so many factors involved, it is more likely that the actual species richness pattern is a product of these factors (Lomolino, 2001).

The effects of aspect on species communities are better studied in plants (i.e. Gallardo–Cruz et al., 2009; Holland and Steyn, 1975) and little is known about its effect on butterfly diversity. On the similarly oriented Toiyabe range in Nevada, eastern slopes are shown to host more butterfly species (Fleishman et al., 1997). This was explained by more diverse habitats on the eastern slopes and better connectivity, allowing intrusion of southern faunal elements. On Mt. Biokovo in Croatia, butterfly richness was higher on northern slopes than on the very steep and vegetation–poor southern aspects, which are also more exposed to strong bora winds (Mihoci et al., 2011). Our results did not provide any conclusive evidence on the effects of aspect on butterfly richness, despite the unequal distribution of the aspects in Mt Galičica. Somewhat lower estimates of species richness were observed in the northern and eastern exposures, but the estimates for the southern aspect were unreliable and discrepancy between observed and estimated species richness was strong (fig. 2B, 2D).

Community changes

Changes in butterfly communities along the altitude (fig. 3A) coincided well with the transition zones of major forest communities on Galičica Mt., with oak forest up to 1,200/1,400 m and beech forests up to

1,900 m (Matevski et al., 2011). Interestingly, only the mid–elevation zone (1,462–1,770 m) had unique indicator species (15), and it shared some indicator species with lower (18) and higher elevation zones (5). This mid–elevation zone also had the highest species richness, and at least partially, this richness could be attributed to the overlapping species from higher and lower elevation zones, providing some evidence for mid–domain or ecotone effects. The changes observed in the community temperature index over the altitudes (fig. 3C) matched our theoretical assumptions. As altitude increased, the communities were composed of more cold adapted species, resulting in lower values of CTI, but these changes were subtle.

In contrast to clear separation of high altitude species by the Chao–Jaccard index, no indicator species were found for butterfly communities in the highest elevation zone as high altitude species were shared with mid–elevations (table 1). Butterfly species at higher elevations are known to have distinctive ecological adaptations that restrict their distribution (Kevan and Shorthouse, 1970; Leingärtner et al., 2014) and some of them are known to have evolved as separate lineages in the Balkan refugia during the last glaciations (Varga and Varga–Sipos, 2001; Schmitt and Varga, 2012). Admittedly, the number of high alpine species is low for Mt. Galičica, but such a pattern is also observed on other calcareous mountains in the Mediterranean region of south–east Europe (i.e. Sijarić, 1983; Mihoci et al., 2011; Kaltsas et al., 2018) and could probably be explained by predominant xeric conditions and limited alpine areas above 2,000 m. Finally, a small sample size at the highest altitudes in our study and the low number of high altitude species could limit the number of estimable indicator species.

The most striking result regarding aspect of Galičica Mt. is the lack of differentiation in species assemblages between western and eastern slopes even though they are the dominant aspects on the mountain and clearly separated by a central mountain plateau. A similar result was obtained in a study comparing tree cover on Mt. Galičica; it showed that only southern and northern slopes hosted distinctive communities, while western and eastern aspects were similar in species composition (Matevski et al., 2011). This is in line with lower estimates of CTI for butterflies on the northern aspect. Northern slopes receive less insolation (Geiger et al., 1995) and thus host more cold–adapted species. The butterfly assemblage on the northern aspect are therefore likely affected by local ecological factors such as woodland cover, which is more extensive at colder and more humid parts of this calcareous massif.

Conclusion

Altitude was found to be a strong driver in shaping butterfly species diversity, with species richness peaking twice at mid–altitudes and declining towards the top of the mountain. The explanation for this pattern is likely linked to a highly significant species–area relationship, with possible effects of ecosystem productivity (surrogate for climate) and community overlap. According to the β diversity estimates, most distinctive butterfly fauna was found close to the top of the mountain. However, indicator species were confined to the mid–elevation zone or shared between mid–low and mid–high elevations.

The effect of aspect was not as strong and easy to interpret as the effect of altitude. Comparing all the evidence, it can be concluded that eastern and western aspect have similar richness and species composition and some subtle differences were found when contrasting southern and northern slopes, the latter with marginally lower butterfly richness.

Habitat changes on Mt. Galičica in recent decades, especially the decline of pasturing, have already played a strong role in shaping butterfly communities and have probably caused extinction of several habitat specialist butterfly species. Habitats could easily be restored and sustained with traditional grazing, creating a system that would benefit the local communities, maintain the diverse calcareous grasslands, and enable long–term survival of the unique butterfly communities of Mt. Galičica.

Acknowledgements

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Supplementary material

Details of recorded species and results of statistical analyses. The dataset contains a checklist of butterfly species recorded for Mt. Galičica, given separately for historical and recent periods, altitudinal classes, and four major aspects of the mountain. The original matrix used to calculate the species richness index is provided and detailed results of statistical analyses mentioned in the paper are given.

Información detallada sobre las especies registradas y los resultados de los análisis estadísticos. La base de datos contiene una lista de comprobación de las especies de mariposa registradas en la montaña Galičica, desglosadas por período (histórico y reciente), clase de altitud y cuatro orientaciones principales de la montaña. Se proporciona la matriz original que se utilizó para calcular el índice de riqueza de la especie y los resultados detallados de los análisis mencionados en el informe.

A. Species checklist: A, before1995; B, after1995; C, 689–844; D, 844–998; E, 998–1152; F, 1152–1307; G, 1307–1462; H, 1462–1616; I, 1616–1770; J, 1770–1925; K, 1925–2080; L, 2080–2234; W, west; N, north; E, east, S, south..

Species	A	B	C	D	E	F	G	H	I	J	K	L	W	N	E	S
Papilionidae																
Papilioninae																
Iphiclides podalirius (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+				+		+	+
Papilio machaon Linnaeus, 1758	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+
Parnassiinae																
Parnassius apollo (Linnaeus, 1758)	+	+						+	+	+		+	+	+		
Parnassius mnemosyne (Linnaeus, 1758)	+	+				+		+	+	+	+	+	+	+	+	+
Zerynthia cerisy (Godart, [1824])	+	+	+										+			
Zerynthia polyxena ([Denis & Schiffermüller], 1775)	+															

Species checklist. (Cont.)

Species	A	B	C	D	E	F	G	H	I	J	K	L	W	N	E	S
Hesperiidae																
Hesperiinae																
Ochlodes sylvanus (Esper, 1777)	+	+	+	+	+	+		+	+	+			+	+	+	+
Hesperia comma (Linnaeus, 1758)	+	+						+	+				+			
Thymelicus acteon (Rottemburg, 1775)	+	+		+		+		+							+	+
Thymelicus lineola (Ochsenheimer, 1808)	+	+	+	+	+	+	+	+	+		+		+	+	+	+
Thymelicus sylvestris (Poda, 1761)	+	+		+	+	+	+	+	+	+	+		+	+	+	+
Pyrginae																
Spialia orbifer (Hübner, [1823])	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+
Spialia phlomidis (Herrich–Schäffer, 1845)	+				+			+								
Carcharodus alceae (Esper, 1780)	+	+	+	+		+		+					+			+
Carcharodus floccifera (Zeller, 1847)	+	+						+	+			+				
Carcharodus lavatherae (Esper, 1783)	+	+			+			+					+			
Carcharodus orientalis Reverdin, 1913	+	+	+	+	+			+	+				+		+	+
Muschampia tessellum (Hübner, [1803])	+															
Erynnis marloyi (Boisduval, 1834)		+						+								
Erynnis tages (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pyrgus alveus (Hübner, [1803])	+	+					+	+	+				+			
Pyrgus armoricanus (Oberthür, 1910)	+	+		+	+	+		+	+				+	+	+	
Pyrgus carthami (Hübner, [1813])	+			+				+							+	
Pyrgus cinarae (Rambur, 1839)	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+
Pyrgus malvae (Linnaeus, 1758)	+	+	+	+	+	+	+	+		+	+		+	+	+	+
Pyrgus serratulae (Rambur, 1839)	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+
Pyrgus sidae (Esper, 1784)	+	+	+	+	+			+	+	+	+	+	+	+	+	+

Species checklist. (Cont.)

Species	A	B	C	D	E	F	G	H	I	J	K	L	W	N	E	S
Pieridae																
Dismorphiinae																
Leptidea duponcheli (Staudinger, 1871)	+	+		+	+	+		+					+	+	+	+
Leptidea sinapis (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+				+	+	+	+
Coliadinae																
Gonepteryx cleopatra (Linnaeus, 1767)	+		+										+			
Gonepteryx farinosa (Zeller, 1847)	+															
Gonepteryx rhamni (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Colias alfacariensis Ribbe, 1905	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Colias caucasica Staudinger, 1871		+						+			+					
Colias crocea (Geoffroy, 1785)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pierinae																
Aporia crataegi (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Pontia edusa (Fabricius, 1777)	+	+	+	+			+	+	+		+	+	+	+	+	
Pieris balcana Lorković, [1969]	+	+	+	+	+	+	+	+	+				+	+	+	+
Pieris brassicae (Linnaeus, 1758)	+	+	+	+	+	+	+	+					+	+	+	+
Pieris ergane (Geyer, [1828])	+	+	+	+	+	+	+	+	+				+	+	+	+
Pieris krueperi Staudinger, 1860		+														
Pieris mannii (Mayer, 1851)	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+
Pieris napi (Linnaeus, 1758)	+	+	+			+		+	+		+		+	+	+	
Pieris rapae (Linnaeus, 1758)	+	+	+	+	+			+	+		+		+	+	+	+
Euchloe ausonia (Hübner, [1804])	+	+	+		+	+							+			

Species checklist. (Cont.)

Species	A	B	C	D	E	F	G	H	I	J	K	L	W	N	E	S
Euchloe penia (Freyer, 1851)	+		+										+			
Anthocharis cardamines (Linnaeus, 1758)	+	+	+		+		+	+					+		+	+
Anthocharis damone Boisduval, 1836	+															
Anthocharis gruneri Herrich–Schäffer, 1851	+	+			+	+		+	+	+			+		+	+
Riodinidae																
Nemeobiinae																
Hamearis lucina (Linnaeus, 1758)	+	+			+		+	+	+				+	+	+	
Lycaenidae																
Lycaeninae																
Lycaena alciphron (Rottemburg, 1775)	+	+	+	+	+			+			+	+	+	+	+	
Lycaena candens (Herrich–Schäffer, 1844)	+	+			+			+	+	+	+	+	+	+	+	+
Lycaena dispar ([Haworth], 1802)	+															
Lycaena phlaeas (Linnaeus, [1760])	+	+	+	+	+	+	+	+	+			+	+	+	+	+
Lycaena thersamon (Esper, 1784)	+				+			+	+							
Lycaena tityrus (Poda, 1761)	+	+		+		+	+	+	+				+	+	+	+
Lycaena virgaureae (Linnaeus, 1758)	+	+			+	+	+	+	+	+		+	+	+		
Theclinae																
Favonius quercus (Linnaeus, 1758)	+	+			+			+	+							
Callophrys rubi (Linnaeus, 1758)	+	+	+		+	+	+	+	+		+		+	+	+	+
Satyrium acaciae (Fabricius, 1787)	+	+		+	+	+	+	+	+			+	+	+	+	
Satyrium ilicis (Esper, 1779)	+	+	+	+	+			+	+	+			+	+	+	
Satyrium pruni (Linnaeus, 1758)	+			+											+	
Satyrium spini ([Denis & Schiffermüller], 1775)	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+

Species checklist. (Cont.)

Species	A	B	C	D	E	F	G	H	I	J	K	L	W	N	E	S
Polyommatinae																
Leptotes pirithous (Linnaeus, 1767)	+	+	+	+	+				+				+			
Lampides boeticus (Linnaeus, 1767)	+	+			+			+								
Celastrina argiolus (Linnaeus, 1758)	+	+	+	+	+	+	+	+					+		+	+
Tarucus balkanicus (Freyer, 1844)	+															
Phengaris alcon ([Denis & Schiffermüller], 1775)	+							+								
Phengaris arion (Linnaeus, 1758)	+							+								
Pseudophilotes vicrama (Moore, 1865)	+	+	+	+	+		+	+	+				+		+	
Scolitantides orion (Pallas, 1771)	+	+	+		+	+	+	+	+				+		+	+
Iolana iolas (Ochsenheimer, 1816)	+															
Glaucopsyche alexis (Poda, 1761)	+	+	+	+	+	+	+	+			+		+	+	+	+
Cupido alcetas (Hoffmansegg, 1804)	+	+						+								
Cupido argiades (Pallas, 1771)	+			+				+							+	
Cupido decoloratus (Staudinger, 1886)	+	+			+			+					+			
Cupido minimus (Fuessly, 1775)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Cupido osiris (Meigen, 1829)	+	+	+	+	+	+	+	+			+		+	+	+	+
Plebejus argus (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+
Plebejus argyrognomon (Bergsträsser, 1779)	+	+			+	+		+	+				+	+		
Plebejus idas (Linnaeus, [1760])	+	+		+	+	+		+	+	+	+		+	+	+	+
Eumedonia eumedon (Esper, 1780)	+	+			+			+		+	+	+	+	+		
Kretania sephirus (Frivaldszky, 1835)	+	+		+	+	+	+	+	+	+	+		+	+	+	+
Cyaniris semiargus (Rottemburg, 1775)	+	+	+	+	+	+	+	+		+	+	+	+	+	+	
Aricia agestis ([Denis & Schiffermüller], 1775)	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+

Species checklist. (Cont.)

Species	A	B	C	D	E	F	G	H	I	J	K	L	W	N	E	S
Aricia anteros (Freyer, 1838)	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+
Aricia artaxerxes (Fabricius, 1793)	+	+		+		+	+	+		+	+	+	+	+		
Lysandra bellargus (Rottemburg, 1775)	+	+	+	+	+	+	+	+	+		+		+	+	+	+
Lysandra coridon (Poda, 1761)	+	+	+		+	+	+	+	+			+	+	+	+	
Polyommatus admetus (Esper, 1783)	+	+	+	+	+	+	+	+	+				+	+	+	+
Polyommatus amandus (Schneider, 1792)	+	+	+	+	+	+	+	+	+	+		+	+	+	+	+
Polyommatus damon ([Denis & Schiffermüller], 1775)	+	+	+				+	+	+	+	+	+	+	+		
Polyommatus daphnis ([Denis & Schiffermüller], 1775)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Polyommatus dorylas ([Denis & Schiffermüller], 1775)	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+
Polyommatus eros (Ochsenheimer, 1808)	+	+			+		+	+	+	+	+	+	+	+	+	
Polyommatus icarus (Rottemburg, 1775)	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Polyommatus orphicus Kolev, 2005		+														
Polyommatus ripartii (Freyer, 1830)	+	+	+	+		+	+	+	+				+		+	+
Polyommatus thersites (Cantener, 1835)	+	+		+	+	+	+	+	+	+		+	+	+		+
Nymphalidae																
Limenitidinae																
Limenitis camilla (Linnaeus, 1764)	+							+								
Limenitis reducta Staudinger, 1901	+	+	+	+	+		+	+				+	+		+	
Neptis rivularis (Scopoli, 1763)	+															
Heliconiinae																
Issoria lathonia (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+
Brenthis daphne ([Denis & Schiffermüller], 1775)	+	+		+	+	+		+	+				+	+	+	+
Brenthis hecate ([Denis & Schiffermüller], 1775)	+	+						+	+							

Species checklist. (Cont.)

Species	A	B	C	D	E	F	G	H	I	J	K	L	W	N	E	S
Argynnis pandora ([Denis & Schiffermüller], 1775)	+	+	+	+		+		+	+	+		+	+	+	+	+
Argynnis paphia (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+	+			+	+	+	+
Speyeria aglaja (Linnaeus, 1758)	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+
Fabriciana adippe ([Denis & Schiffermüller], 1775)	+	+	+	+	+	+		+	+	+			+	+	+	+
Fabriciana niobe (Linnaeus, 1758)	+	+	+	+		+	+	+	+	+	+	+	+	+	+	
Boloria dia (Linnaeus, 1767)	+	+			+											
Boloria euphrosyne (Linnaeus, 1758)	+	+		+	+	+	+	+			+	+	+	+	+	+
Boloria graeca (Staudinger, 1870)	+	+						+	+	+	+	+	+	+		+
Apaturinae																
Apatura ilia ([Denis & Schiffermüller], 1775)	+	+	+	+		+							+		+	
Apatura iris (Linnaeus, 1758)	+	+						+								
Nymphalinae																
Araschnia levana (Linnaeus, 1758)		+														
Vanessa atalanta (Linnaeus, 1758)	+	+	+	+	+	+	+	+					+		+	+
Vanessa cardui (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+
Aglais io (Linnaeus, 1758)	+	+		+	+			+	+	+	+	+	+	+	+	
Aglais urticae (Linnaeus, 1758)	+	+	+	+			+	+	+	+	+		+	+	+	
Polygonia c–album (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+				+		+	
Polygonia egea (Cramer, 1775)	+		+					+						+		
Nymphalis antiopa (Linnaeus, 1758)	+	+			+						+	+	+	+		
Nymphalis polychloros (Linnaeus, 1758)	+	+		+	+			+					+		+	
Nymphalis xanthomelas ([Denis & Schiffermüller], 1775)		+			+				+							
Euphydryas aurinia (Rottemburg, 1775)		+	+	+	+	+	+	+	+		+	+	+	+	+	+

Species checklist. (Cont.)

Species	A	B	C	D	E	F	G	H	I	J	K	L	W	N	E	S
Melitaea arduinna (Esper, 1783)		+	+	+	+			+					+		+	
Melitaea athalia (Rottemburg, 1775)	+	+	+	+	+		+	+	+			+	+	+	+	
Melitaea aurelia Nickerl, 1850		+						+							+	
Melitaea cinxia (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+
Melitaea diamina (Lang, 1789)	+	+						+								
Melitaea didyma (Esper, 1778)	+	+	+	+	+	+	+	+	+	+	+		+	+	+	+
Melitaea ornata Christoph, 1893		+	+	+	+	+	+	+					+		+	+
Melitaea phoebe ([Denis & Schiffermüller], 1775)	+	+	+	+	+	+	+	+	+		+	+	+	+	+	+
Melitaea trivia ([Denis & Schiffermüller], 1775)	+	+	+	+	+			+	+			+	+	+	+	
Libytheinae																
Libythea celtis (Laicharting, 1782)	+	+		+											+	
Satyrinae																
Coenonympha arcania (Linnaeus, [1760])	+	+		+	+	+	+	+	+	+		+	+	+	+	+
Coenonympha leander (Esper, 1784)	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+
Coenonympha pamphilus (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+				+	+	+	+
Kirinia climene (Esper, 1783)	+	+						+	+							
Kirinia roxelana (Cramer, 1777)	+	+	+	+	+	+		+					+		+	+
Pararge aegeria (Linnaeus, 1758)	+	+	+		+	+		+					+			+
Lasiommata maera (Linnaeus, 1758)	+	+			+	+		+	+	+	+		+	+		
Lasiommata megera (Linnaeus, 1767)	+	+	+	+		+		+	+				+	+		
Lasiommata petropolitana (Fabricius, 1787)	+	+				+		+	+	+				+		+
Melanargia galathea (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+	+			+	+	+	+
Melanargia larissa (Geyer, [1828])	+	+		+	+	+	+	+	+				+	+	+	+

Species checklist. (Cont.)

Species	A	B	C	D	E	F	G	H	I	J	K	L	W	N	E	S
Melanargia russiae (Esper, 1783)	+	+				+		+	+	+	+	+	+	+	+	
Hipparchia fagi (Scopoli, 1763)	+	+		+		+		+	+				+		+	+
Hipparchia fatua Freyer, 1843	+	+						+					+			
Hipparchia senthes (Fruhstorfer, 1908)	+	+							+							
Hipparchia statilinus (Hufnagel, 1766)	+	+	+	+		+		+					+	+	+	
Hipparchia syriaca (Staudinger, 1871)	+	+		+				+	+						+	
Brintesia circe (Fabricius, 1775)	+	+	+	+	+	+	+	+	+	+			+	+	+	+
Arethusana arethusa ([Denis & Schiffermüller], 1775)	+	+	+	+		+	+	+	+				+		+	+
Satyrus ferula (Fabricius, 1793)	+	+		+			+	+	+	+			+	+	+	
Chazara briseis (Linnaeus, 1764)	+	+	+	+	+	+		+	+				+	+	+	
Pseudochazara amalthea (Frivaldszky, 1845)	+															
Pseudochazara geyeri (Herrich–Schäffer, 1846)	+	+			+		+	+	+				+			
Hyponephele lupina (Costa, 1836)	+	+	+					+	+					+		
Hyponephele lycaon (Kühn, 1774)	+	+			+	+		+	+	+	+		+	+	+	
Aphantopus hyperantus (Linnaeus, 1758)	+	+		+	+	+		+					+		+	
Pyronia tithonus (Linnaeus, 1771)	+	+	+	+				+	+				+	+	+	
Maniola jurtina (Linnaeus, 1758)	+	+	+	+	+	+	+	+	+		+		+	+	+	+
Erebia ligea (Linnaeus, 1758)	+															
Erebia medusa ([Denis & Schiffermüller], 1775)	+	+			+	+	+	+	+	+	+	+	+	+	+	+
Erebia melas (Herbst, 1796)	+	+								+	+	+		+		
Erebia oeme (Hübner, [1804])	+							+								
Summary	159	145	84	98	104	90	79	143	104	58	59	49	125	97	108	79

B. Altitude incidence frequency: A, 689–844; B, 844–998; C, 998–1152; D, 1152–1307; E, 1307–1462; F, 1462–1616; G, 1616–1770; H, 1770–1925; I, 1925–2080; J, 2080–2234

Species	A	B	C	D	E	F	G	H	I	J
Melanargia russiae	0	0	0	1	0	15	7	2	6	2
Erynnis tages	4	4	5	2	2	14	2	1	1	1
Aricia anteros	0	1	4	3	2	4	2	2	2	2
Carcharodus orientalis	3	1	2	0	0	3	2	0	0	0
Coenonympha leander	0	1	2	1	3	18	3	4	4	2
Erebia oeme	0	0	0	0	0	2	0	0	0	0
Glaucopsyche alexis	3	3	3	1	1	7	0	0	1	0
Cupido minimus	2	4	4	3	5	13	2	2	1	1
Cyaniris semiargus	3	3	4	1	6	13	0	2	3	2
Lycaena tityrus	0	2	0	1	1	10	1	0	0	0
Polyommatus dorylas	0	5	4	4	5	20	6	1	3	2
Anthocharis cardamines	2	0	3	0	1	4	0	0	0	0
Boloria euphrosyne	0	2	4	2	3	11	0	0	2	1
Cupido osiris	3	4	2	2	3	7	0	0	1	0
Eumedonia eumedon	0	0	1	0	0	8	0	1	2	2
Kretania sephirus	0	1	4	1	4	13	3	2	1	0
Melitaea cinxia	2	3	5	2	2	20	2	0	4	1
Parnassius mnemosyne	0	0	0	0	1	13	2	2	2	1
Polyommatus icarus	9	12	10	6	6	17	4	1	5	2
Polyommatus thersites	0	1	1	1	1	6	2	1	0	1
Pyrgus serratulae	2	4	2	2	2	7	1	2	1	0
Pyrgus sidae	1	2	1	0	0	10	2	3	4	1
Anthocharis gruneri	0	0	1	1	0	6	1	1	0	0
Cupido decoloratus	0	0	2	0	0	2	0	0	0	0
Hyponephele lycaon	0	0	1	2	0	13	6	1	1	0
Lycaena candens	0	0	1	0	0	9	1	4	6	2
Polyommatus amandus	1	1	1	4	4	17	2	1	0	2
Pyrgus cinarae	4	3	3	2	3	15	6	1	2	0
Aglais urticae	1	2	0	0	2	10	3	1	1	0
Coenonympha pamphilus	8	8	8	4	5	19	1	0	0	0
Erebia medusa	0	0	4	2	6	17	3	1	2	1
Gonepteryx rhamni	3	4	1	3	1	10	5	1	2	1
Issoria lathonia	3	4	2	5	2	20	6	3	1	0
Pyrgus malvae	1	3	7	1	7	10	0	1	2	0
Arethusana arethusa	1	1	0	2	2	7	2	0	0	0
Brintesia circe	2	6	5	4	1	10	7	1	0	0
Colias alfacariensis	5	4	5	4	5	21	3	2	1	1
Colias crocea	12	11	7	5	4	24	7	1	3	1
Lycaena virgaureae	0	0	1	1	2	12	9	2	0	1
Maniola jurtina	7	10	8	3	3	11	2	0	1	0

B. Altitude incidence frequency. (Cont.)

Species	A	B	C	D	E	F	G	H	I	J
Parnassius apollo	0	0	0	0	0	7	5	1	0	1
Pieris balcana	2	1	2	1	1	1	2	0	0	0
Pieris mannii	1	1	1	2	2	7	3	2	2	0
Plebejus argus	6	6	6	4	2	12	7	2	0	1
Polyommatus ripartii	1	3	0	4	3	9	5	0	0	0
Satyrium acaciae	0	1	1	2	1	8	5	0	0	1
Satyrus ferula	0	2	0	0	1	9	8	2	0	0
Speyeria aglaja	0	3	2	3	1	9	8	1	1	2
Spialia orbifer	5	2	5	2	2	7	3	0	1	1
Thymelicus lineola	1	3	3	2	1	10	3	0	1	0
Vanessa cardui	7	7	4	1	2	17	4	0	4	1
Hesperia comma	0	0	0	0	0	3	1	0	0	0
Hyponephele lupina	1	0	0	0	0	1	2	0	0	0
Lysandra coridon	4	0	1	3	3	7	2	0	0	1
Papilio machaon	4	4	1	2	1	6	3	1	2	0
Polyommatus daphnis	4	4	2	4	4	10	2	1	1	1
Pontia edusa	3	5	0	0	1	4	3	0	1	1
Argynnis paphia	5	7	3	2	3	12	1	1	0	0
Chazara briseis	1	3	1	3	0	3	2	0	0	0
Leptidea sinapis	5	1	3	3	1	5	1	0	0	0
Melanargia galathea	1	6	5	4	1	8	3	1	0	0
Melitaea didyma	2	4	2	6	2	23	6	2	3	0
Ochlodes sylvanus	1	1	1	2	0	8	1	1	0	0
Scolitantides orion	1	0	2	2	2	6	1	0	0	0
Melitaea phoebe	3	4	2	1	1	9	2	0	1	1
Melitaea trivia	3	4	4	0	0	12	3	0	0	1
Polyommatus admetus	1	7	2	4	1	1	1	0	0	0
Pseudophilotes vicrama	1	2	5	0	1	11	1	0	0	0
Carcharodus lavatherae	0	0	2	0	0	1	0	0	0	0
Leptidea duponcheli	0	3	5	5	0	3	0	0	0	0
Leptotes pirithous	1	1	1	0	0	0	2	0	0	0
Satyrium ilicis	1	1	3	0	0	2	2	1	0	0
Aricia agestis	4	9	3	5	2	9	4	2	1	0
Aporia crataegi	4	6	5	3	1	10	2	3	2	1
Argynnis pandora	1	4	0	3	0	3	1	1	0	1
Aricia artaxerxes	0	0	1	0	3	4	0	1	4	2
Boloria graeca	0	0	0	0	0	2	3	4	3	2
Erebia melas	0	0	0	0	0	0	1	2	1	1
Fabriciana adippe	3	4	3	4	0	2	6	1	0	0
Fabriciana niobe	1	1	0	1	1	6	5	2	1	1
Polyommatus eros	0	0	1	0	2	7	1	2	4	2

B. Altitude incidence frequency. (Cont.)

Species	A	B	C	D	E	F	G	H	I	J
Satyrium spini	2	1	0	3	1	4	3	1	1	2
Aglais io	0	4	2	0	0	4	2	1	1	1
Lasiommata maera	0	0	1	1	0	1	1	1	1	0
Lasiommata petropolitana	0	0	0	1	0	4	2	1	0	0
Nymphalis antiopa	0	0	1	0	0	0	0	1	1	0
Coenonympha arcania	0	1	1	3	1	4	1	1	0	1
Polyommatus damon	2	0	0	0	2	4	1	1	1	2
Hipparchia fagi	0	1	0	2	0	1	2	0	0	0
Melanargia larissa	0	5	1	4	1	4	3	0	0	0
Brenthis hecate	0	0	0	0	0	1	1	0	0	0
Pyronia tithonus	2	1	0	0	0	1	1	0	0	0
Hipparchia syriaca	0	2	0	0	0	1	2	0	0	0
Lasiommata megera	6	4	0	3	0	4	1	0	0	0
Plebejus idas	0	1	1	2	0	7	1	1	1	0
Pieris rapae	6	8	2	0	0	6	1	0	1	0
Thymelicus sylvestris	0	2	2	3	1	9	3	1	2	0
Lycaena phlaeas	3	6	1	2	1	7	1	0	0	1
Hipparchia statilinus	2	3	0	2	0	4	0	0	0	0
Pseudochazara geyeri	0	0	1	0	1	4	1	0	0	0
Lampides boeticus	0	0	1	0	0	1	0	0	0	0
Spialia phlomidis	0	0	1	0	0	1	0	0	0	0
Pieris brassicae	4	2	1	1	1	1	0	0	0	0
Araschnia levana	0	0	0	0	0	0	0	0	0	0
Erynnis marloyi	0	0	0	0	0	1	0	0	0	0
Euphydryas aurinia	1	1	2	2	2	17	1	0	1	1
Hamearis lucina	0	0	1	0	1	8	1	0	0	0
Melitaea arduinna	3	1	1	0	0	4	0	0	0	0
Melitaea athalia	1	3	4	0	1	12	1	0	0	1
Vanessa atalanta	1	4	2	4	1	6	0	0	0	0
Plebejus argyrognomon	0	0	1	1	0	3	1	0	0	0
Melitaea aurelia	0	0	0	0	0	2	0	0	0	0
Lysandra bellargus	4	3	4	4	5	9	1	0	2	0
Nymphalis polychloros	0	3	1	0	0	1	0	0	0	0
Pararge aegeria	2	0	1	2	0	2	0	0	0	0
Callophrys rubi	3	0	1	1	4	4	1	0	2	0
Pyrgus alveus	0	0	0	0	1	3	1	0	0	0
Hipparchia fatua	0	0	0	0	0	1	0	0	0	0
Brenthis daphne	0	6	2	3	0	8	1	0	0	0
Kirinia roxelana	1	4	1	3	0	1	0	0	0	0
Lycaena alciphron	1	1	1	0	0	1	0	0	1	1
Polygonia c–album	1	2	1	1	1	6	1	0	0	0

B. Altitude incidence frequency. (Cont.)

Species	A	B	C	D	E	F	G	H	I	J
Celastrina argiolus	1	2	1	1	1	5	0	0	0	0
Cupido alcetas	0	0	0	0	0	1	0	0	0	0
Limenitis reducta	2	9	1	0	2	8	0	0	0	1
Pyrgus carthami	0	2	0	0	0	1	0	0	0	0
Hipparchia senthes	0	0	0	0	0	0	1	0	0	0
Iphiclides podalirius	6	6	5	3	1	7	1	0	0	0
Carcharodus flocciferus	0	0	0	0	0	4	1	0	0	1
Apatura ilia	1	1	0	1	0	0	0	0	0	0
Euchloe ausonia	2	0	1	1	0	0	0	0	0	0
Euchloe penia	1	0	0	0	0	0	0	0	0	0
Satyrium pruni	0	1	0	0	0	0	0	0	0	0
Libythea celtis	0	3	0	0	0	0	0	0	0	0
Cupido argiades	0	2	0	0	0	1	0	0	0	0
Polygonia egea	1	0	0	0	0	1	0	0	0	0
Gonepteryx farinosa	0	0	0	0	0	0	0	0	0	0
Kirinia climene	0	0	0	0	0	2	1	0	0	0
Pieris krueperi	0	0	0	0	0	0	0	0	0	0
Nymphalis xanthomelas	0	0	1	0	0	1	0	0	0	0
Melitaea ornata	2	1	3	2	3	5	0	0	0	0
Pieris napi	1	0	0	1	0	3	1	0	1	0
Aphantopus hyperantus	0	1	2	1	0	1	0	0	0	0
Favonius quercus	0	0	1	0	0	2	2	0	0	0
Lycaena thersamon	0	0	1	0	0	1	2	0	0	0
Pyrgus armoricanus	0	2	2	1	0	2	1	0	0	0
Pieris ergane	2	2	2	1	2	7	1	0	0	0
Carcharodus alceae	1	1	0	5	0	2	0	0	0	0
Colias caucasica	0	0	0	0	0	2	0	0	1	0
Melitaea diamina	0	0	0	0	0	2	0	0	0	0
Apatura iris	0	0	0	0	0	1	0	0	0	0
Boloria dia	0	0	2	0	0	0	0	0	0	0
Zerynthia cerisy	2	0	0	0	0	0	0	0	0	0
Gonepteryx cleopatra	1	0	0	0	0	0	0	0	0	0
Thymelicus acteon	0	1	0	1	0	1	0	0	0	0
Limenitis camilla	0	0	0	0	0	1	0	0	0	0
Phengaris alcon	0	0	0	0	0	1	0	0	0	0
Phengaris arion	0	0	0	0	0	1	0	0	0	0
Polyommatus orphicus	0	0	0	0	0	0	0	0	0	0
No, of samples:	17	24	15	8	8	45	17	6	8	2
No. of count:	84	98	104	90	79	143	104	58	59	49
No. of occurences:	228	323	261	220	175	967	267	90	115	64

C. Aspect incidence frequency: W, west; N, north; E, east; S, south.

Species	W	N	E	S
Melanargia russiae	4	9	3	0
Erynnis tages	11	4	6	2
Aricia anteros	5	4	2	2
Carcharodus orientalis	3	0	1	1
Coenonympha leander	9	6	4	1
Erebia oeme	0	0	0	0
Glaucopsyche alexis	5	1	5	1
Cupido minimus	12	4	6	2
Cyaniris semiargus	13	4	6	0
Lycaena tityrus	2	2	2	1
Polyommatus dorylas	11	6	9	3
Anthocharis cardamines	3	0	2	1
Boloria euphrosyne	9	1	4	1
Cupido osiris	8	2	4	2
Eumedonia eumedon	2	3	0	0
Kretania sephirus	9	3	1	1
Melitaea cinxia	11	4	8	1
Parnassius mnemosyne	6	3	2	1
Polyommatus icarus	26	11	10	4
Polyommatus thersites	1	1	0	1
Pyrgus serratulae	7	4	3	2
Pyrgus sidae	2	6	4	1
Anthocharis gruneri	3	0	1	2
Cupido decoloratus	1	0	0	0
Hyponephele lycaon	4	2	1	0
Lycaena candens	1	8	2	1
Polyommatus amandus	7	3	3	3
Pyrgus cinarae	9	7	2	1
Aglais urticae	3	3	4	0
Coenonympha pamphilus	23	2	8	1
Erebia medusa	10	4	5	1
Gonepteryx rhamni	9	5	4	2
Issoria lathonia	10	7	6	3
Pyrgus malvae	12	2	6	1
Arethusana arethusa	4	0	2	1
Brintesia circe	10	4	5	1
Colias alfacariensis	19	4	7	2
Colias crocea	30	8	8	3
Lycaena virgaureae	3	8	0	0
Maniola jurtina	15	4	7	1
Parnassius apollo	1	4	0	0

Species	W	N	E	S
Pieris balcana	3	1	2	1
Pieris mannii	6	7	1	1
Plebejus argus	15	7	7	2
Polyommatus ripartii	10	0	2	1
Satyrium acaciae	5	1	1	0
Satyrus ferula	3	3	1	0
Speyeria aglaja	5	5	4	1
Spialia orbifer	12	2	3	2
Thymelicus lineola	6	2	2	1
Vanessa cardui	16	3	5	1
Hesperia comma	1	0	0	0
Hyponephele lupina	0	1	0	0
Lysandra coridon	10	1	1	0
Papilio machaon	6	3	3	2
Polyommatus daphnis	10	5	3	1
Pontia edusa	7	2	2	0
Argynnis paphia	11	3	5	1
Chazara briseis	6	1	2	0
Leptidea sinapis	8	1	3	1
Melanargia galathea	7	5	4	1
Melitaea didyma	10	6	8	4
Ochlodes sylvanus	1	2	1	1
Scolitantides orion	8	0	2	1
Melitaea phoebe	6	1	7	1
Melitaea trivia	8	2	5	0
Polyommatus admetus	8	1	5	1
Pseudophilotes vicrama	10	0	2	0
Carcharodus lavatherae	2	0	0	0
Leptidea duponcheli	8	1	2	2
Leptotes pirithous	2	0	0	0
Satyrium ilicis	3	1	2	0
Aricia agestis	11	7	4	3
Aporia crataegi	12	7	8	1
Argynnis pandora	4	2	4	1
Aricia artaxerxes	4	5	0	0
Boloria graeca	2	5	0	1
Erebia melas	0	3	0	0
Fabriciana adippe	7	3	4	1
Fabriciana niobe	5	5	2	0
Polyommatus eros	4	7	1	0
Satyrium spini	6	2	1	1

C. Aspect incidence frequency. (Cont.)

Species	W	N	E	S	Species	W	N	E	S
Aglais io	3	3	5	0	*Cupido alcetas*	0	0	0	0
Lasiommata maera	2	2	0	0	*Limenitis reducta*	8	0	6	0
Lasiommata petropolitana	0	2	0	1	*Pyrgus carthami*	0	0	2	0
Nymphalis antiopa	1	2	0	0	*Hipparchia senthes*	0	0	0	0
Coenonympha arcania	3	1	2	2	*Iphiclides podalirius*	13	0	3	2
Polyommatus damon	5	2	0	0	*Carcharodus flocciferus*	0	0	0	0
Hipparchia fagi	1	0	1	1	*Apatura ilia*	2	0	1	0
Melanargia larissa	4	1	4	2	*Euchloe ausonia*	3	0	0	0
Brenthis hecate	0	0	0	0	*Euchloe penia*	1	0	0	0
Pyronia tithonus	1	1	1	0	*Satyrium pruni*	0	0	1	0
Hipparchia syriaca	0	0	2	0	*Libythea celtis*	0	0	2	0
Lasiommata megera	11	1	0	0	*Cupido argiades*	0	0	2	0
Plebejus idas	2	2	3	1	*Polygonia egea*	0	1	0	0
Pieris rapae	7	3	2	1	*Gonepteryx farinosa*	0	0	0	0
Thymelicus sylvestris	5	5	3	2	*Kirinia climene*	0	0	0	0
Lycaena phlaeas	5	2	4	1	*Pieris krueperi*	0	0	0	0
Hipparchia statilinus	4	1	2	0	*Nymphalis xanthomelas*	0	0	0	0
Pseudochazara geyeri	3	0	0	0	*Melitaea ornata*	10	0	1	1
Lampides boeticus	0	0	0	0	*Pieris napi*	2	2	1	0
Spialia phlomidis	0	0	0	0	*Aphantopus hyperantus*	1	0	1	0
Pieris brassicae	4	1	2	1	*Favonius quercus*	0	0	0	0
Araschnia levana	0	0	0	0	*Lycaena thersamon*	0	0	0	0
Erynnis marloyi	0	0	0	0	*Pyrgus armoricanus*	2	1	2	0
Euphydryas aurinia	9	1	5	2	*Pieris ergane*	10	1	2	1
Hamearis lucina	2	1	1	0	*Carcharodus alceae*	5	0	0	2
Melitaea arduinna	4	0	1	0	*Colias caucasica*	0	0	0	0
Melitaea athalia	6	1	6	0	*Melitaea diamina*	0	0	0	0
Vanessa atalanta	8	0	2	1	*Apatura iris*	0	0	0	0
Plebejus argyrognomon	2	1	0	0	*Boloria dia*	0	0	0	0
Melitaea aurelia	0	0	1	0	*Zerynthia cerisy*	2	0	0	0
Lysandra bellargus	9	3	6	2	*Gonepteryx cleopatra*	1	0	0	0
Nymphalis polychloros	1	0	3	0	*Thymelicus acteon*	0	0	1	1
Pararge aegeria	4	0	0	1	*Limenitis camilla*	0	0	0	0
Callophrys rubi	6	2	3	1	*Phengaris alcon*	0	0	0	0
Pyrgus alveus	2	0	0	0	*Phengaris arion*	0	0	0	0
Hipparchia fatua	1	0	0	0	*Polyommatus orphicus*	0	0	0	0
Brenthis daphne	2	1	6	1	No. of samples:	43	18	22	5
Kirinia roxelana	3	0	4	1	No. of count:	125	97	108	79
Lycaena alciphron	2	1	1	0	No. of occurences:	789	311	360	114
Polygonia c–album	3	0	2	0					
Celastrina argiolus	3	0	1	1					

D. iNEXT results.

Species diversity along the altitude

Site	Diversity	Observed	Estimator	SE	LCL	UCL
689–844	Species richness	83,000	110,608	12,951	94,519	149,167
689–844	Shannon diversity	66,285	85,008	4,705	75,787	94,230
689–844	Simpson diversity	55,019	67,441	3,943	59,713	75,169
844–998	Species richness	97,000	121,091	11,850	106,675	156,990
844–998	Shannon diversity	77,059	91,880	4,047	83,948	99,813
844–998	Simpson diversity	64,438	74,349	3,581	67,331	81,367
998–1152	Species richness	103,000	137,669	14,020	119,168	177,338
998–1152	Shannon diversity	82,603	107,548	5,664	96,446	118,650
998–1152	Simpson diversity	68,703	84,897	4,806	75,478	94,316
1152–1307	Species richness	89,000	102,611	6,913	94,322	123,809
1152–1307	Shannon diversity	77,298	93,318	4,236	85,017	101,620
1152–1307	Simpson diversity	69,178	84,955	3,730	77,645	92,264
1307–1462	Species richness	78,000	104,250	11,809	89,316	138,891
1307–1462	Shannon diversity	64,473	85,910	5,012	76,086	95,733
1307–1462	Simpson diversity	54,486	68,851	4,231	60,559	77,144
1462–1616	Species richness	142,000	172,998	15,409	154,341	219,865
1462–1616	Shannon diversity	103,897	112,314	2,642	107,135	117,493
1462–1616	Simpson diversity	86,511	91,226	2,198	86,917	95,534
1616–1770	Species richness	103,000	131,735	11,876	116,194	165,581
1616–1770	Shannon diversity	81,311	103,106	5,516	92,295	113,917
1616–1770	Simpson diversity	66,431	79,330	4,000	71,490	87,169
1770–1925	Species richness	57,000	84,022	12,386	68,481	120,599
1770–1925	Shannon diversity	51,233	80,620	8,806	63,362	97,879
1770–1925	Simpson diversity	45,654	72,388	5,650	61,314	83,462
1925–2080	Species richness	58,000	86,601	13,877	69,615	128,431
1925–2080	Shannon diversity	48,638	70,802	6,017	59,009	82,595
1925–2080	Simpson diversity	41,111	54,667	4,437	45,970	63,364
2080–2234	Species richness	48,000	68,643	10,060	56,353	99,017
2080–2234	Shannon diversity	45,336	68,643	5,463	57,935	79,350
2080–2234	Simpson diversity	42,711	68,036	5,622	57,017	79,054

D. iNEXT results. (Cont.)

Species diversity among aspect

Site	Diversity	Observed	Estimator	SE	LCL	UCL
West	Species richness	124,000	129,573	4,034	125,561	143,887
West	Shannon diversity	96,009	103,447	2,277	98,984	107,911
West	Simpson diversity	79,712	86,017	2,359	81,394	90,640
North	Species richness	96,000	113,818	8,891	103,071	140,897
North	Shannon diversity	77,184	91,294	3,434	84,563	98,024
North	Simpson diversity	65,693	76,302	3,096	70,234	82,369
East	Species richness	107,000	115,938	5,001	110,214	131,857
East	Shannon diversity	87,801	100,338	3,604	93,275	107,401
East	Simpson diversity	75,711	86,800	3,300	80,332	93,267
South	Species richness	78,000	133,441	21,194	104,882	192,340
South	Shannon diversity	70,867	126,492	11,606	103,746	149,239
South	Simpson diversity	63,684	112,656	9,078	94,863	130,449

Sample size and coverage: R, reference sample size; N, number of incidences; E, estimated sample coverage

Site	R	N	E
689–844	12	216	0.8649
844–998	12	311	0.9153
998–1152	10	251	0.8476
1152–1307	6	214	0.9026
1307–1462	7	168	0.8250
1462–1616	24	943	0.9704
1616–1770	9	258	0.8628
1770–1925	4	86	0.6926
1925–2080	6	109	0.7591
2080–2234	2	62	0.6993

West	30	759	0.9830
North	11	300	0.9183
East	10	350	0.9459
South	4	110	0.6111

E. Chao–Jaccard index results.

Altitude

	689–844	844–998	998–1152	1152–1307	1307–1462	1462–1616	1616–1770	1770–1925	1925–2080
844–998	0.2513177								
998–1152	0.3376132	0.2387167							
1152–1307	0.3437091	0.2470656	0.2832329						
1307–1462	0.3708842	0.3384661	0.2720918	0.3048585					
1462–1616	0.3527273	0.2205645	0.1748401	0.2227487	0.2130300				
1616–1770	0.4744143	0.3493652	0.3781755	0.3296548	0.3750253	0.1487054			
1770–1925	0.7020725	0.6203558	0.5698512	0.5668958	0.5279188	0.4342156	0.3534065		
1925–2080	0.6205775	0.5939941	0.5057070	0.5960947	0.4564142	0.4054947	0.5004729	0.3588677	
2080–2234	0.7005445	0.6614784	0.6237028	0.6917293	0.5526742	0.4963037	0.5426195	0.4617424	0.4147123

Slope

	West	North	East
North	0.1756463		
East	0.1045850	0.2362962	
South	0.2336987	0.3604528	0.2442342

F. Indicator value.

Mid elevation group (1462–1770 m), 15 indicator species

Species	A	B	Stat	P–value
Hesperia comma	1,00	1,00	1,00	0,016
Brenthis hecate	1,00	1,00	1,00	0,016
Kirinia climene	1,00	1,00	1,00	0,016
Hamearis lucina	0,92	1,00	0,96	0,038
Pyrgus alveus	0,91	1,00	0,95	0,031
Favonius quercus	0,91	1,00	0,95	0,016
Parnassius apollo	0,90	1,00	0,95	0,028
Hyponephele lycaon	0,88	1,00	0,94	0,042
Hyponephele lupina	0,88	1,00	0,94	0,029
Carcharodus flocciferus	0,88	1,00	0,94	0,041
Lycaena thersamon	0,88	1,00	0,94	0,028
Satyrus ferula	0,87	1,00	0,93	0,040
Pseudochazara geyeri	0,86	1,00	0,93	0,038
Lasiommata petropolitana	0,85	1,00	0,92	0,028
Plebejus argyrognomon	0,83	1,00	0,91	0,032

F. Indicator value. (Cont.)

Mid (1462–1770 m) and low elevation group (689–1462 m), 18 indicator species

Species	A	B	Stat	P–value
Coenonympha pamphilus	1,00	1,00	1,00	0,010
Pieris balcana	1,00	1,00	1,00	0,010
Leptidea sinapis	1,00	1,00	1,00	0,010
Polyommatus admetus	1,00	1,00	1,00	0,010
Polygonia c–album	1,00	1,00	1,00	0,010
Iphiclides podalirius	1,00	1,00	1,00	0,010
Pieris ergane	1,00	1,00	1,00	0,010
Maniola jurtina	0,97	1,00	0,99	0,043
Brintesia circe	0,97	1,00	0,99	0,027
Argynnis paphia	0,97	1,00	0,98	0,037
Melanargia galathea	0,96	1,00	0,98	0,031
Thymelicus lineola	0,96	1,00	0,98	0,040
Lycaena phlaeas	0,95	1,00	0,98	0,045
Plebejus argus	0,93	1,00	0,97	0,027
Lysandra bellargus	0,93	1,00	0,97	0,048
Pyrgus cinarae	0,93	1,00	0,97	0,038
Issoria lathonia	0,92	1,00	0,96	0,045
Aricia agestis	0,92	1,00	0,96	0,030

Mid (1462–1770 m) and high elevation group (1770–2234 m), 5 indicator species

Species	A	B	Stat	P–value
Boloria graeca	1,00	1,00	1,00	0,006
Melanargia russiae	0,99	1,00	0,99	0,002
Parnassius mnemosyne	0,98	1,00	0,99	0,005
Lycaena candens	0,98	1,00	0,99	0,007
Polyommatus eros	0,92	1,00	0,96	0,025