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HABITAT STRUCTURE IMPACT ON THE OCCURRENCE PREFERENCES AND BEHAVIOUR OF THE ENDANGERED SPECIES *Hipparchia hermione* (LEPIDOPTERA, NYMPHALIDAE) IN SLOVAKIA

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Abstract

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The aim of this study is to elaborate on the prior information about *Hipparchia hermione* ecology, examine its behaviour and find the habitat preferences of the species in specific study areas. The obtained results contribute to better management and conservation of the species and its habitats in Slovakia. Six types of behaviour were observed, with the exception of courtship dances, mating and perching. The most common types of behaviour observed were flight and food intake. The RDA analysis of behaviour and environmental variables resulted in a positive effect of free substrate and tall-herb vegetation on *H. hermione* abundance. The free substrate had a significant positive effect on all types of *H. hermione* behaviour. The results of the RDA analysis indicate butterflies' shrub preference. The notion of shrubs' presence having a positive effect on the representation of *H. hermione* is supported by another data set, according to which shrub vegetation provided ideal conditions for all types of observed behaviour. The abundance and diversity of nectaring plants did not have a statistically significant effect on species representation. Due to the environmental variables, the tree crowns' significance plays a vital role. The average values are of 50%. The number of *H. hermione* individuals in the study areas increased with the growing number of tree trunks over 20 cm and heights over 3 m and the growing number of caterpillar host plants (*Festuca ovina*). The data show that *Hipparchia* hermione butterflies depend more on the spatial and structural arrangement of the forest than on abundance or diversity of the flora in the study areas.

Key words: butterflies, biotope structure, behaviour, Borská nížina.

Introduction

Bionomy, ecology and ethology of the genus *Hipparchia* have been studied by several authors (García-Barros, 1988, 2000; García-Barros, Martín 1991; Jeanneret et al., 2003; Karlsson, Wiklund, 2005; Kudrna, 1977, 1984; Kwast, Sobczyk, 2000; Miller, 1968; Pinzari et al., 2018; Pinzari, Sbordoni, 2013; Sbordoni et al., 2018; Settele et al., 2008; Steiniger, Eitschberger, 1982). In Slovakia, there are a total of four different species of the genus *Hipparchia*, including *H. statilinus* (Hufnagel, 1766), *H. semele* (Linnaeus, 1758), *H. fagi* (Scopoli, 1763) and *H. hermione* (Linnaeus, 1764).

Hipparchia hermione is a significant ecosozoological butterfly species in Slovakia. It has never been more widely distributed in our territory, and it is currently only known from the sand biotopes of the Borská nížina lowland (Fig. 1). The species is relatively abundant in this area; however, it has been listed as an endangered species in the Red (ecozoological) list of butterflies (Lepidoptera) of Slovakia (Kulfan, Kulfan, 2001). There is evidence of the species occurrence in other parts of Slovakia (end of the 19th and beginning of the 20th centuries; first half of the 20th century) (Hrubý, 1964; Janovský et al., 2014; Reiprich, Okáli, 1989). However, these data were never confirmed by later findings. The main occurrence of *H. hermione* is at the military base of VVP Záhorie, which has ideal conditions for this species (Kalivoda et al., 2010). The active approach of the Slovak Army is the best management of this species' distribution area. Caterpillar food plants are generally fescue species, such as *Festuca rubra L.* (red fescue) or *F. ovina L.* (sheep fescue) (Pavlíčko, 2002). The imago can often be observed on bunches of thyme (*Thymus serpyllum*), where the species gathers in large numbers. They are also attracted to human sweat and various decaying organic residues. *Hipparchia hermnione* is a monovoltine species, with

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imagos appearing from July to late August or until the beginning of September. Imagos often rest on the ground or on tree trunks. The colouring of dark wings provides primary protection from predators as it blends perfectly with the ground on which the butterfly lands (Beneš et al., 2002).

The most significant differences of the landscapes of present and past centuries are the smaller areas of field, meadow and forest in the past (Novotný, Konvička, 2010). Increased interest in firewood and forest grazing had an impact mainly on populated lowlands and hills (Novotný, Konvička, 2010). Sparse forests and transitional areas (areas classified as forest/steppe), which are not suitable for modern forestry, provide ideal conditions for *H. hermione* individuals. The steep slopes of river canyons are a good example of these. To permanently maintain the *H. hermione* species, it is pivotal to restore its natural habitats (Novotný, Konvička, 2010). *Hipparchia hermione* habitat loss can also be caused by spontaneous site succession at the end of the grazing season. During succession, gradual changes in the community happen (Országhová et al., 2010). Such an example of habitat loss is sparse pine-oak forests on the walls of river canyons in the territory of the Czech Republic (Vltava, Otava and Sázava) and western Moravia (Dyje, Oslava, Jihlava) (Konvička et al., 2010). Findings of isolated individuals outside their normal habitat suggest that *H. hermione* used the entire structured landscape in the past, creating populations in suitable habitats. These habitats were connected by migration routes. Present migrating individuals often get lost in forests or on field paths without finding new habitats (Novotný, Konvička, 2010). Biological invasions and expansions have also contributed to many *H. hermione* population losses. Biological depletion is caused by invasive plants. Native vegetation is pushed out by invasive species, which can cause a change in light and moisture conditions and disturb the balance of soil nutrients. The greatest danger for the species lies in settling within the community with no local competition. An example is black locust (*Robinia pseudoacacia* L.), which can grow in rocky and nutrient-poor habitats such as steppes or rocky steppes (Konvička et al., 2010).

Methods

Study area

We observed the behaviour of *H. hermione* adult stages in 2020 and 2021 in seven study areas near Studienka village (48°32´00″N, 17°08´00″E), near the alluvium of the Rudava river in western Slovakia (Fig. 2). Only results from 2021 were used for data processing by multivariate analysis, as the research was not continuously ongoing in 2020. The study area was 200 m^2. Butterfly observation took place every two weeks at an average time of 09:30–12:30. The observation in each study area lasted about 20 minutes. We recorded the number of *H. hermione* individuals, the occurrence time and the type of observed behaviour.

Observing Hipparchia hermione *ethology*

We recorded the ethological expressions of *H. hermione* by observing, without the use of invasive methods, with the purpose of disturbing butterflies the least during their natural behaviour in the study areas. We determined nine main types of behaviour:

- feeding: nectar intake on the nectaring plant (*Thymus serpyllum*),
- resting: resting in a shaded place,

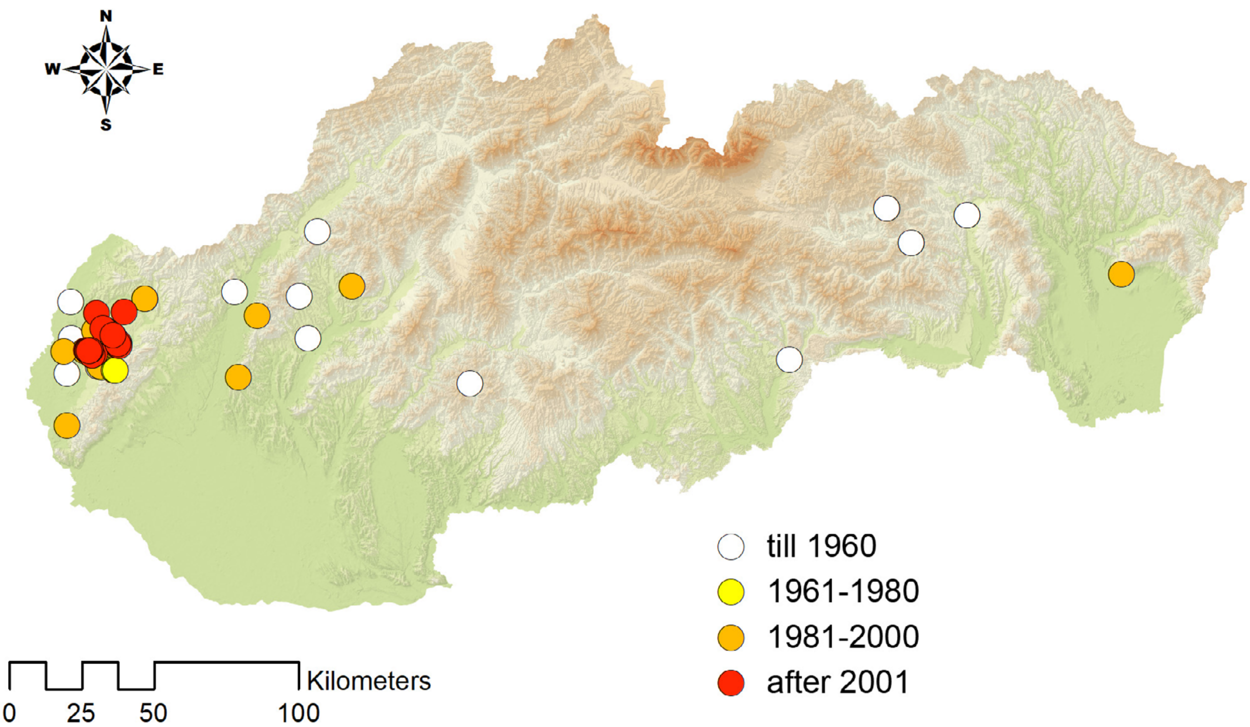

Fig. 1. Distribution of *Hipparchia hermione* in Slovakia during individual time periods.

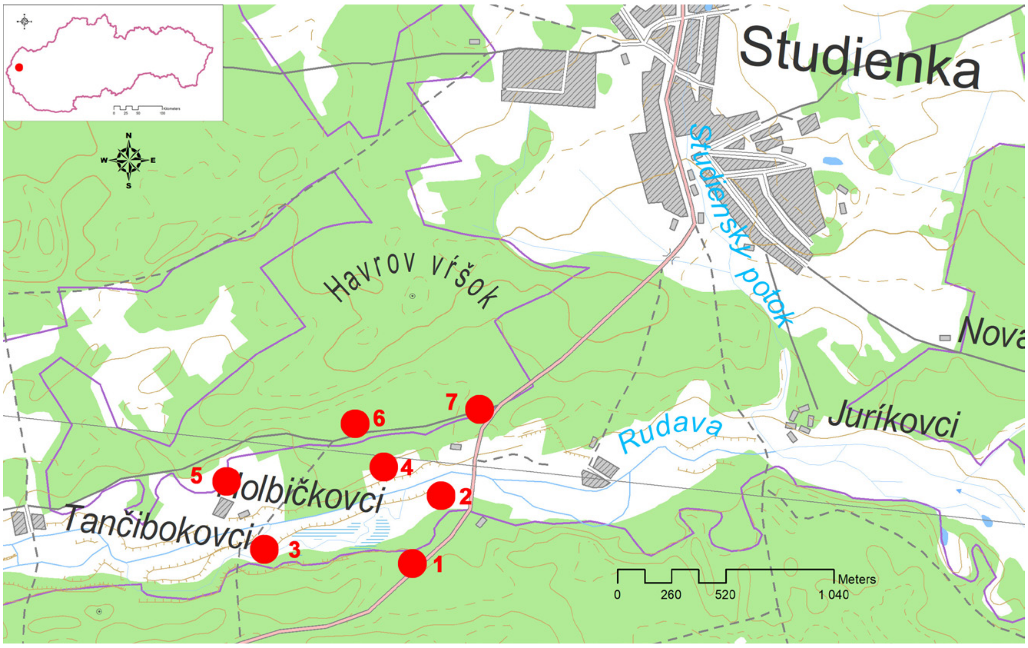

Fig. 2. Study areas' locations.

Table 1. Habitat quality and structure parameters in study area 1.

<table>
<tr><td rowspan="2">Vegetation structure (%)</td><td colspan="3">Low-herb vegetation</td><td colspan="3">Tall-herb vegetation</td><td colspan="3">Free substrate</td><td colspan="3">Litter</td></tr>
<tr><td colspan="3">60</td><td colspan="3">30</td><td colspan="3">10</td><td colspan="3">0</td></tr>
<tr><td>Coverage of Festuca ovina (%)</td><td colspan="12">15</td></tr>
<tr><td rowspan="2">Tree height
(number of trees of a given height)</td><td colspan="4">Up to 1 m</td><td colspan="4">1–3 m</td><td colspan="4">More than 3 m</td></tr>
<tr><td colspan="4">10</td><td colspan="4">17</td><td colspan="4">10</td></tr>
<tr><td rowspan="2">Tree density
(number of trees of a given diameter)</td><td colspan="4">Up to 10 cm</td><td colspan="4">10–20 cm</td><td colspan="4">More than 20 cm</td></tr>
<tr><td colspan="4">10</td><td colspan="4">17</td><td colspan="4">10</td></tr>
<tr><td>Canopy cover (%)</td><td colspan="12">40</td></tr>
<tr><td rowspan="2">Factorial variables</td><td colspan="4">Diversity of nectaring plants</td><td colspan="4">Abundance of nectaring plants</td><td colspan="4">Abundance of shrub vegetation</td></tr>
<tr><td colspan="4">2</td><td colspan="4">1</td><td colspan="4">2</td></tr>
</table>

Table 2. Habitat quality and structure parameters in study area 2.

<table>
<tr><td rowspan="2">Vegetation structure (%)</td><td colspan="3">Low-herb vegetation</td><td colspan="3">Tall-herb vegetation</td><td colspan="3">Free substrate</td><td colspan="3">Litter</td></tr>
<tr><td colspan="3">100</td><td colspan="3">0</td><td colspan="3">0</td><td colspan="3">0</td></tr>
<tr><td>Coverage of Festuca ovina (%)</td><td colspan="12">0</td></tr>
<tr><td rowspan="2">Tree height
(number of trees of a given height)</td><td colspan="4">Up to 1 m</td><td colspan="4">1–3 m</td><td colspan="4">More than 3 m</td></tr>
<tr><td colspan="4">0</td><td colspan="4">0</td><td colspan="4">0</td></tr>
<tr><td rowspan="2">Tree density
(number of trees of a given diameter)</td><td colspan="4">Up to 10 cm</td><td colspan="4">10–20 cm</td><td colspan="4">More than 20 cm</td></tr>
<tr><td colspan="4">0</td><td colspan="4">0</td><td colspan="4">0</td></tr>
<tr><td>Canopy cover (%)</td><td colspan="12">0</td></tr>
<tr><td rowspan="2">Factorial variables</td><td colspan="4">Diversity of nectaring plants</td><td colspan="4">Abundance of nectaring plants</td><td colspan="4">Abundance of shrub vegetation</td></tr>
<tr><td colspan="4">3</td><td colspan="4">3</td><td colspan="4">1</td></tr>
</table>

Table 3. Habitat quality and structure parameters in study area 3.

	Low-herb vegetation	Tall-herb vegetation	Free substrate	Litter
Vegetation structure (%)	100	0	0	0
Coverage of *Festuca ovina* (%)	0			
Tree height (number of trees of a given height)	Up to 1 m	1–3 m	More than 3 m	
	0	0	0	
Tree density (number of trees of a given diameter)	Up to 10 cm	10–20 cm	More than 20 cm	
	0	0	0	
Canopy cover (%)	0			
Factorial variables	Diversity of nectaring plants	Abundance of nectaring plants	Abundance of shrub vegetation	
	3	3	1	

Table 4. Habitat quality and structure parameters in study area 4.

	Low-herb vegetation	Tall-herb vegetation	Free substrate	Litter
Vegetation structure (%)	90	0	0	10
Coverage of *Festuca ovina* (%)	50			
Tree height (number of trees of a given height)	Up to 1 m	1–3 m	More than 3 m	
	0	1	25	
Tree density (number of trees of a given diameter)	Up to 10 cm	10–20 cm	More than 20 cm	
	0	1	25	
Canopy cover (%)	40			
Factorial variables	Diversity of nectaring plants	Abundance of nectaring plants	Abundance of shrub vegetation	
	3	1	1	

- basking: resting in the sun – the butterfly points its folded wings towards the sun to receive maximum solar energy,
- flight: fast and straight,
- patrolling: a strategy in which males search for females to mate during almost continuous flight (Magnus, 1963; Scott, 1973, 1974; Rutowski, 1991),
- perching: a strategy in which males passively sit on the ground or vegetation in order to search for females to mate with. As soon as males notice a moving object that resembles a female of their own species, they fly to investigate the object (Scott, 1973, 1974; Rutowski, 1991; Garcìa-Barros, 2000). This behaviour is also common when protecting the territory from other males. When a male notices a male of the same species during perching, it flies to the «intruder,» which then flies away. A male that has successfully scared away its competitor will usually return to its original perching spot (Scott, 1974),
- courtship flight: interaction between a male and a female during flight, when the male releases pheromones by flapping his wings to affect the female (Holecová, 2012),
- mating: copulation between a male and a female,
- oviposition: after finding suitable vegetation, the female lays her eggs individually. The most common oviposition sites are dry grass stalks, decaying plant materials and ground. Eggs can rarely be attached to the base of grass tufts (Garcìa-Barros, 2000).

Habitat quality and structure assessment

We recorded the following parameters in individual study areas (Tables 1–7):

- vegetation structure (%): low-herb vegetation up to 15 cm, tall-herb vegetation, free substrate, litter,
- abundance (coverage %) of the caterpillar host plant (*Festuca ovina*),
- tree height (height and species representation): up to 1m, 1–3 m and more than 3 m,
- tree density (the number of trees of a given diameter): up to 10 cm, 10–20 cm and over 20 cm,
- the canopy cover (%),
- factorial variables: diversity of nectaring plants (1: 1 species; 2: 2–4 species; 3: more than four species), abundance of nectaring plants (1: low abundance; 2: medium abundance, 3: high abundance) and abundance of shrub vegetation (1: low abundance; 2: medium abundance; 3: high abundance).

Using the redundancy analysis, we expressed the influence of environmental variables (tall-herb vegetation, free substrate, litter, low-herb vegetation, diversity of nectaring plants, abundance of shrub vegetation and nectaring plants) on *Hipparchia hermione* spatial dispersion and behaviour. Using the Monte Carlo test (iteration 499), we determined the significance of environmental variables in the Canoco5 programme (Ter Braak, Šmilauer, 2012).

Table 5. Habitat quality and structure parameters in study area 5.

	Low-herb vegetation	Tall-herb vegetation	Free substrate	Litter
Vegetation structure (%)	30	50	10	10
Coverage of *Festuca ovina* (%)	50			
Tree height (number of trees of a given height)	Up to 1 m	1–3 m	More than 3 m	
	0	2	20	
Tree density (number of trees of a given diameter)	Up to 10 cm	10–20 cm	More than 20 cm	
	2	5	15	
Canopy cover (%)	70			
Factorial variables	Diversity of nectaring plants	Abundance of nectaring plants	Abundance of shrub vegetation	
	2	2	1	

Table 6. Habitat quality and structure parameters in study area 6.

	Low-herb vegetation	Tall-herb vegetation	Free substrate	Litter
Vegetation structure (%)	60	30	10	0
Coverage of *Festuca ovina* (%)	60			
Tree height (number of trees of a given height)	Up to 1 m	1–3 m	More than 3 m	
	0		34	
Tree density (number of trees of a given diameter)	Up to 10 cm	10–20 cm	More than 20 cm	
	4	10	20	
Canopy cover (%)	70			
Factorial variables	Diversity of nectaring plants	Abundance of nectaring plants	Abundance of shrub vegetation	
	2	2	1	

Table 7. Habitat quality and structure parameters in study area 7.

	Low-herb vegetation	Tall-herb vegetation	Free substrate	Litter
Vegetation structure (%)	60	20	20	0
Coverage of *Festuca ovina* (%)	90			
Tree height (number of trees of a given height)	Up to 1 m	1–3 m	More than 3 m	
	0	0	44	
Tree density (number of trees of a given diameter)	Up to 10 cm	10–20 cm	More than 20 cm	
	0	0	44	
Canopy cover (%)	50			
Factorial variables	Diversity of nectaring plants	Abundance of nectaring plants	Abundance of shrub vegetation	
	1	1	1	

We used the Shapiro–Wilk test to perform the analysis on data distribution normality in the programme Statistica Cz. Ver. 7.0 (StatSoft Inc., 2004). Due to the normality violation, we used the non-parametric Kruskal–Wallis test to find the difference in the number of individuals between study areas and collection dates.

Results

In 2021, six of the nine observed behaviours – feeding, resting, basking, flight, patrolling and oviposition – were recorded. Courtship flight, perching and mating were not recorded in any of the study areas (Table 8). The most common types of behaviour observed were flight (33 individuals) and feeding (31 individuals). Oviposition, with only three recorded individuals, was the least prevalent. The overall largest number of feeding butterflies was observed in study areas 6 and 7. The largest number of resting butterflies was observed in study area 12. The largest number of basking butterflies was observed in study area 7. The largest number of flying butterflies was observed in study areas 5 and 7. The largest number of patrolling butterflies was observed in study area 5.

Using the redundancy analysis [RDA, SD (length of gradient = 2.5 on the first ordination axis)], we expressed the impact of environmental variables (tall-herb vegetation, free substrate, litter, low-herb vegetation) on the *H. hermione* spatial dispersion (Fig. 3). The values of the explained species data variability are

Table 8. An overview of *Hipparchia hermione* behaviour regarding the investigated study area.

	Study area 1	Study area 2	Study area 3	Study area 4	Study area 5	Study area 6	Study area 7	Total
Feeding	2	2	1	5	2	10	9	**31**
Resting	0	4	1	2	2	3	12	**24**
Basking	1	0	0	0	0	0	5	**6**
Flight	2	6	1	0	10	4	10	**33**
Patrolling	0	1	0	0	4	0	0	**5**
Oviposition	0	0	0	0	0	1	2	**3**
Total	**5**	**13**	**3**	**7**	**18**	**18**	**38**	**102**

56.6% on the first ordination axis and 64.1% on the second cumulative ordination axis. Due to the effect of environmental variables, the variability increased to 86.5 and 97.7%, respectively. Tall-herb vegetation ($p = 0.0308$) and free substrate ($p = 0.0220$) had a statistically significant effect on *H. hermione* dispersion. Other variables, including the canopy cover ($p = 0.902$) and low-herb vegetation ($p = 0.876$), did not have a statistically significant effect on the butterfly's spatial structure.

The ordination graph shows that the largest cluster with the most days of observation was formed close to the tall-herb vegetation and free substrate. The presence of free substrate was the most significant factor on each day when *H. hermione* was recorded. The outcome demonstrates that study areas with free substrate and tall-herb vegetation are the most favourable localities for the *H. hermione* activity.

Using the redundancy analysis (RDA, SD (gradient length) = 2.7 on the first ordination axis), we expressed the influence of environmental variables (tall-herb vegetation, free substrate, litter, low-herb vegetation) on *H. hermione* behaviour (feeding, basking, resting, patrolling, flight, oviposition) (Fig. 4). The values of explained data variability are 54.91% on the first ordination axis and 82.81% on the second cumulative ordination axis. Due to the environmental variables effect, the variability increased to 63.26 and 95.4%. Free substrate ($p = 0.0178$) and low-herb vegetation ($p = 0.0388$) had a statistically significant effect on butterfly behaviour. Other variables, including the canopy cover ($p = 0.298$) and tall-herb vegetation ($p = 0.108$), did not have a statistically significant effect on butterfly behaviour. The graph shows that the largest cluster with the most days of observation was formed close to the free substrate. The outcome demonstrates that the free substrate had a positive effect on all behavioural types of *H. hermione*.

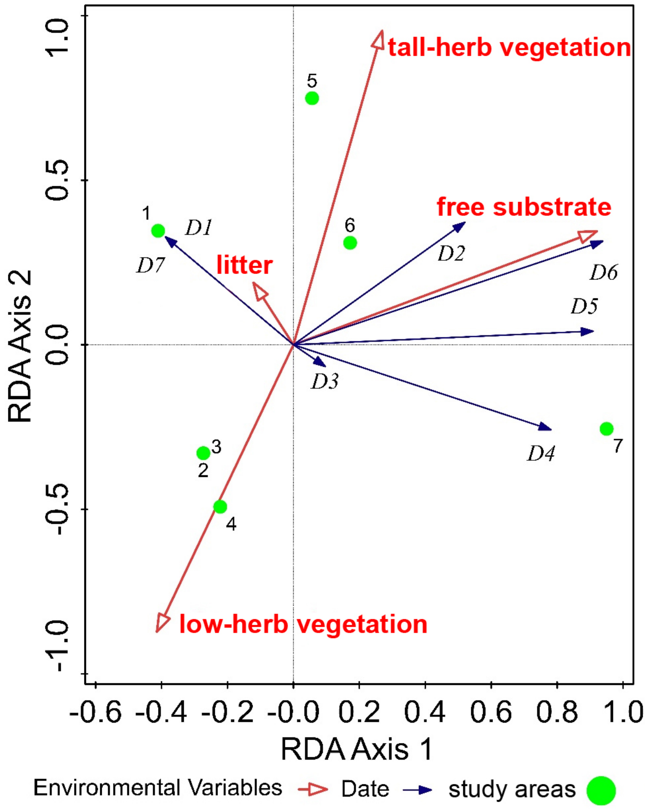

Fig. 3. RDA analysis of *Hipparchia hermione* and environmental variables.

Using the redundancy analysis [RDA, SD (length of gradient) = 2.7 on the first ordination axis], we expressed the impact of variables (diversity of nectaring plants; abundance of shrub vegetation and abundance of nectaring plants) on *H. hermione* spatial dispersion (Fig. 5). The values of explained species data variability are 53.41% on the first ordination axis and 63% on the second cumulative ordination axis. Due to the effect of variables, the variability increased to 82.67 and 97.63%. The abundance of shrub vegetation had a statistically significant effect ($p = 0.0138$) on the dispersion of *H. hermione*. Other variables, including the abundance of nectaring plants ($p = 0.908$) and diversity of nectaring plants ($p = 0.322$), did not have a statistically significant effect on the spatial dispersion of *H. hermione*. The graph shows that the largest cluster with the most days of observation was formed close to the abundance of shrub vegetation. The outcome demonstrates that *H. hermione* favours localities with shrubs.

Using the redundancy analysis [RDA, SD (gradient length) = 2.7 on the first ordination axis], we expressed the influence of variables (diversity of nectaring plants, abundance of shrub vegetation and abundance of nectaring plants) on the behaviour (feeding, basking, resting, patrolling, flight and oviposition) of *H. hermione* (Fig. 6). The values of explained data variability are 82.61% on the first ordination axis and 90.01% on the second cumulative ordination axis. Due to the effect of variables, the variability increased to 86.15 and 95.9%. The abundance of shrub vegetation ($p = 0.0164$) had a statistically significant effect on butterfly behaviour. Other variables, including abundance

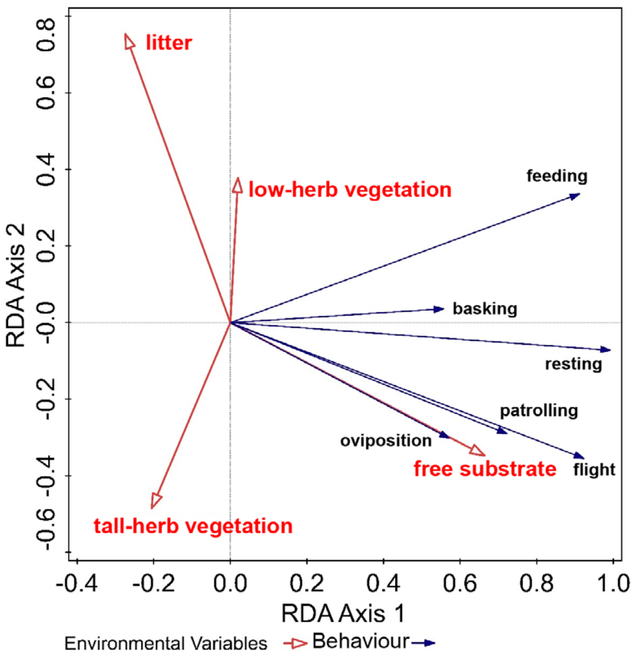

Fig. 4. RDA analysis of *Hipparchia hermione* behaviour and environmental variables.

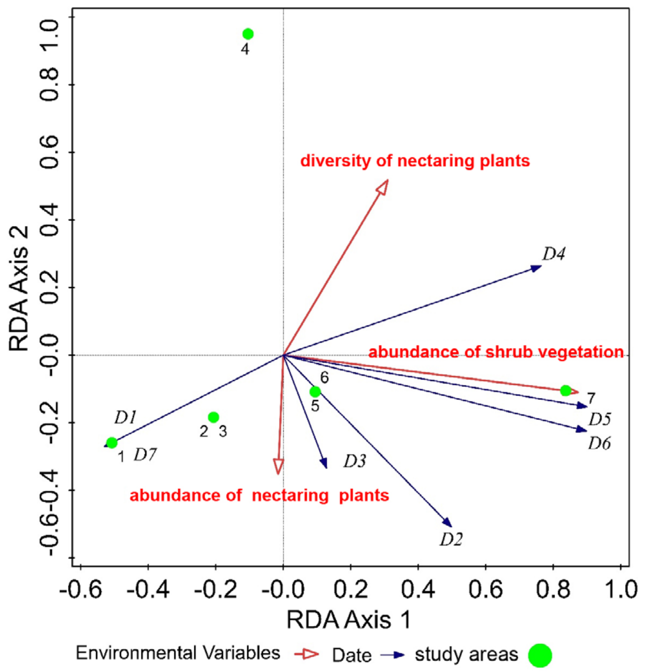

Fig. 5. RDA analysis of *Hipparchia hermione* and environmental variables.

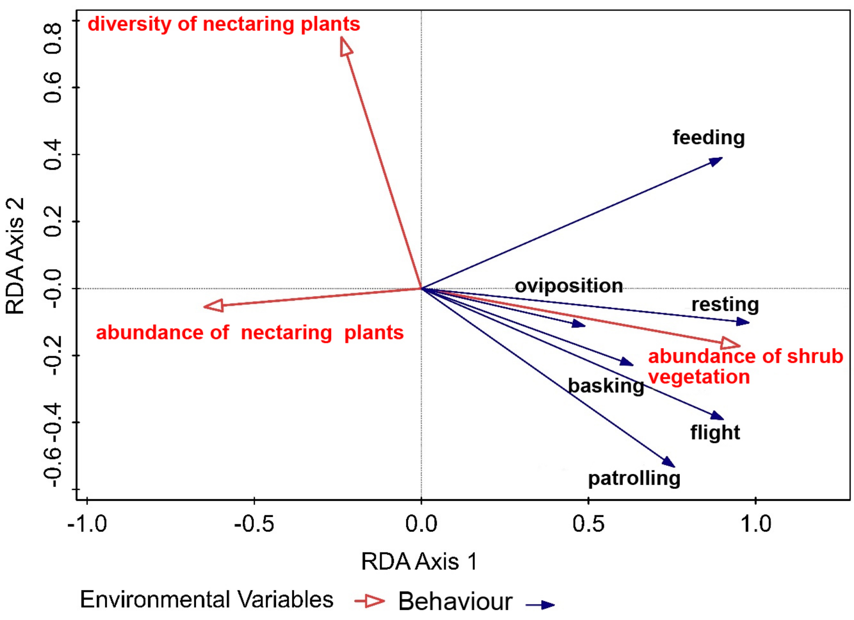

Fig. 6. RDA analysis of *Hipparchia hermione* behaviour and environmental variables.

(p = 0.182) and diversity (p = 0.634) of nectaring plants, did not have a statistically significant effect on butterfly behaviour. The outcome demonstrates that shrub vegetation provided ideal conditions for all types of *H. hermione* behaviour.

Due to the violation of data distribution normality (Shapiro–Willk W test, p = 0.00006), we used the non-parametric Kruskal–Wallis test, by which we confirmed a significant difference in population sizes between the investigated areas (p = 0.0189) (Fig. 7) and the collection dates (p = 0.0071) (Fig. 8). This is due to the rapid increase in the species' abundance within a few days. The abundance peaked at the beginning of the flight period. There was a significant fluctuation in abundance probably due to microclimatic reasons.

Discussion

According to Novotný and Konvička (2010), *H. hermione* survives in small colonies in sparse pine forests and forest steppes.

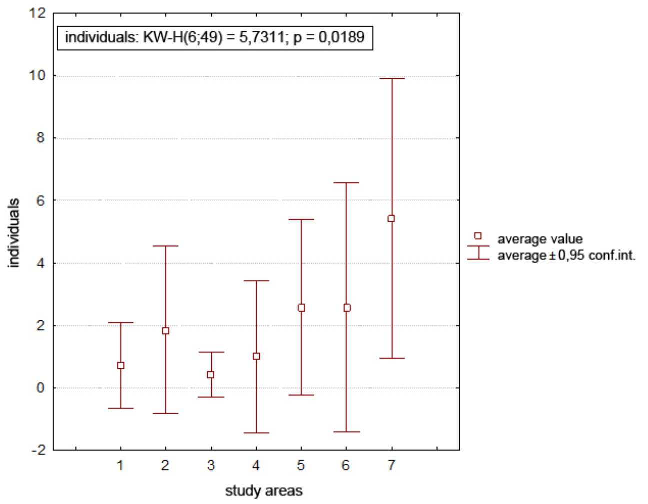

Fig. 7. Kruskal–Wallis test of the *Hipparchia hermione* number in study areas 1–7.

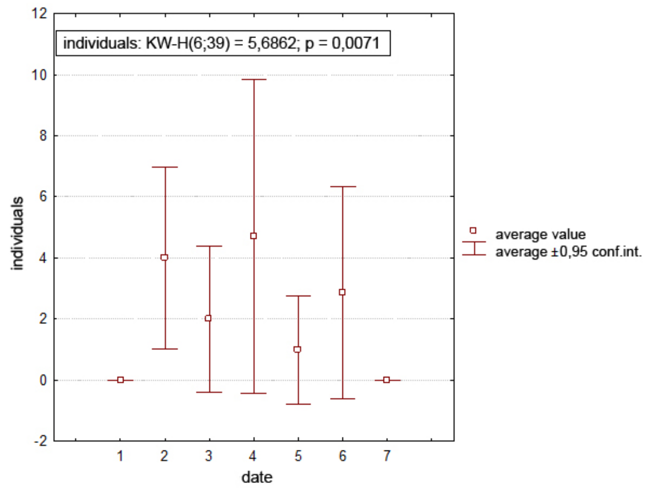

Fig. 8. Kruskal–Wallis test of the *Hipparchia hermione* number during collection dates.

The largest number of *H. hermione* (38 individuals) was recorded in study area 7 supposedly due to the ideal canopy cover (50%). Záňková (2014) claims that *H. hermione* favours areas with 20–50% canopy cover. According to Novotný and Konvička (2010), localities with open tree crowns are favourable for *H. hermione* butterflies. Furthermore, in study area 7, there were evenly dispersed clumps of creeping thyme (*Thymus serpyllum*) and abundantly represented sheep fescue (*Festuca ovina*) (90%). Clumps of creeping thyme were interspersed among the row-planted pines, on whose trunks we could find basking or resting butterflies. The lowest number of *Hipparchia* hermione (three individuals) was recorded in study area 3 possibly due to the absence of tree crowns. As a result, butterflies lacked a suitable ground for resting and seeking protection. The colouring of dark wings provides primary protection from predators as it blends with the bark of pine trees (Beneš et al., 2002) providing the perfect camouflage.

In study area 1, a relatively low number of *H. hermione* (five individuals) was also observed. Although the study area had a rather high percentage of canopy cover (40%), it appears that *H. hermione* individuals only flew across this area. Nectaring plants such as *Thymus serpyllum* were abundant in this study area. *Festuca ovina*, the food plant of caterpillars, was also present (15%). The fact that the rock graylings did not stay at this research site was most likely due to its proximity to the road (5 m). *Hipparchia hermione* activity could be affected by traffic.

A total of 13 individuals of *H. hermione* were recorded in study area 2. The majority of them were observed during the flight. Study area 2 was in an open location along a pine forest. Because there were no trees in this area, butterflies mostly flew through it. Nonetheless, there were others resting in the grass. Despite the richness and diversity of nectaring plants in this study area, we found only two feeding individuals. Given the abundance of nectaring plants, this number is essentially insignificant.

There were no records of all six types of observed behaviour in any of the study areas. However, in study area 7, only patrolling was not recorded. Resting was the most commonly observed behaviour (12 individuals). Flight (10 individuals) and food intake (9 individuals) were also common behaviours. According to the findings, study area 7 provided ideal conditions for *H. hermione* to engage in all types of observed behaviour.

The most common behaviours were flight (33 individuals) and food intake (31 individuals). *Hipparchia hermione* butterflies were mostly observed flying across the study area. The butterflies usually flew directly above the vegetation. We recorded a comparable number of individuals taking food. All imagos were feeding on nectar from creeping thyme (*Thymus serpyllum*).

The RDA analysis result of *Hipparchia hermione* and environmental variables demonstrates that study areas with the free substrate and tall-herb vegetation are the most favourable for the *H. hermione* activity. The outcome further demonstrates that the free substrate had an impact on all types of observed behaviour. According to Záňková (2014), resting on free substrate, rock outcrops and dead trees are the most common types of behaviour.

The statistically significant effect of shrub vegetation quantity on species representation ($p = 0.0138$) was an intriguing finding. The results of the RDA analysis suggest that *H. hermione* favours areas with shrubs. The reason for this preference can be the tendency of *H. hermione* to rest, bask and perch on trees. Additionally, shrubs can offer protection from danger. However, Konvička et al. (2010) state that *H. hermione* requires an open, almost "savanna-like" tree and shrub floor. According to Konvička et al. (2010), the optimal tree density should reach a maximum of 0.6. The positive effect of the shrub vegetation's presence on the *H. hermione* activity was also supported by the following RDA analysis result, according to which the shrub vegetation provided an ideal environment for all recorded behaviour types.

During bright, windless days, *H. hermione* individuals were the most active and could be seen in bigger flocks in places with food sources. However, there was no correlation between the number of *H. hermione* individuals and the presence of nectaring plants in the study areas. The abundance and variety of nectaring plants did not have a statistically significant effect on the species representation. It follows that the *H. hermione* number was not increasing with the growing abundance and variety of nectaring plants. Further, creeping thyme and sheep fescue were simultaneously found in every investigated study area. The outcome demonstrates that the choice of localities is not likely to be primarily influenced by the host plants' and nectaring plants' presence. The low density of *H. hermione* individuals feeding in study area 3, where a diversity and abundance of nectaring plants were the most common, supports this finding. The outcome supports the claim made by Novotný and Konvička (2010) that the spatial and vertical structures of localities, rather than the species forest composition, restrict *H. hermione* distribution.

According to Záňková (2014), the abundance of trees with trunk diameters over 20 cm and a height over 3 m had a negative effect on *H. hermione* presence in the study areas. However, according to our observation, the number of *H. hermione* individuals was growing with the increasing number of trees with trunk diameters over 20 cm and over 3 m. The largest number of individuals was recorded in study area 7, with the largest number of trees with a trunk diameter over 20 cm and a height over 3 m (44 trees).

According to further findings made by Záňková (2014), the presence of *H. hermione* individuals in the study areas depends on the caterpillar host plant's (*Festuca* rubra, *F. ovina*) occurrence. She also states that butterflies do not favour localities without grass or with continuous grass cover. This statement is supported by our observation, in which the number of butterflies increased with the growing number of caterpillar host plant (*F. ovina*). The lowest records of *Hipparchia hermione* with no caterpillar host plant (*Festuca* ovina) were made in study area 3. A significant number of butterflies were seen in research areas 5 and 6, which had average host plant representation values (50–60%). The largest number of *Hipparchia hermione* individuals was recorded in study area 7, where the sheep fescue (*Festuca ovina*) had the largest representation (90%). However, due to the proven positive impact of the free substrate, it is important that the localities do not have a continuous plant cover.

After evaluating the impact of all investigated environmental variables, we found that study area 7 had the largest representation of *Hipparchia* hermione with the largest number of trees with a trunk diameter over 20 cm and a height over 3 m (44 trees), the largest representation of sheep fescue (*Festuca ovina*) (90%) and 50% canopy cover.

According to John et al. (2020), *Hipparchia hermione* butterflies prefer unconnected deciduous stands on steeper slopes or other types of forest clearings and edges. As a result of our research, it has been shown that *H. hermione* requires open, well-lit clearings with the presence of shrubs, tall vegetation, free substrate, caterpillar host plants (*Festuca ovina*) and imago food plants (*Thymus* serpyllum). The most crucial factors are the canopy cover and the host plant representation, which should not be too high or too low. By producing the ideal environment for *Hipparchia hermione* individuals, such as by cutting overly thick and unlit forest stands, the distribution area can be expanded. According to Konvička et al. (2010), the technique of "relighting rocky forest-steppes and scree sparse pines" is also suitable.

It is crucial to preserve meadows and clearings where *H. hermione* individuals congregate in order to prevent their succession. The management of the localities should include extensive mowing and grazing. The local plant community would gradually deteriorate if the areas were not routinely mowed or grazed. Rich plant biodiversity is ensured by extensive mowing and grazing. Cattle grazed on the plants in research areas 2, 3 and 4. The excrements in these study areas regularly fertilised the soil. As a result, the soil was rich in nutrients, providing ideal conditions for the growth of various plant species. According to Konvička et al. (2010), it is advised to reintroduce local and extensive forest grazing and begin the rejuvenation of overgrown xerothermic habitats.

The management must be adjusted to meet the needs of this endangered species, and attention must be given to its long-term maintenance in order to accomplish the spread of *H. hermione*. The preservation of these areas must be a priority at the same time. According to John et al. (2020), in order to conserve these butterflies, there is a need for more strictly protected areas with more diversified and richer management.

Conclusion

We recorded six types of *H. hermione* behaviour. The RDA analysis results of behaviour and environmental variables indicate a positive effect of free substrate on *H. hermione* abundance. There was also a positive effect of a tall-herb vegetation. At the same time, free substrate had a significant impact on all types of *H. hermione* behaviour. The RDA analysis suggests that butterflies favour localities with shrubs. The notion of shrubs' presence having a positive effect on the representation of *H. hermione* is supported by another data set, according to which shrub vegetation provided ideal conditions for all types of observed behaviour. The abundance and diversity of nectaring plants did not have a statistically significant effect on species representation. The number of *H. hermione* was not increasing with the growing abundance and diversity of nectaring plants.

Concerning the environmental variables, the canopy cover factor is important and should not be too high or too low, ideally around the average (50%). The finding further demonstrates that the number of *H. hermione* individuals increased with the growing number of tree trunks over 20 cm and heights over 3 m and the growing number of caterpillar host plants (*Festuca ovina*). Since it has been shown that the free substrate has a positive impact on the activity of *Hipparchia* hermione, the localities should not have a continuous plant cover. In conclusion, it seems like *H. hermione* individuals are more likely to be dependent on the spatial and structural arrangement of the forest than on the flora's abundance and diversity.

Extensive mowing and grazing should be part of the localities' management. Forest stands should be well lit. In order to better understand the bionomics of *H. hermione*, further knowledge about the species' daily behaviour and habitat preferences is needed. Therefore, it is important to focus more attention on the future monitoring of this endangered species. The management of the localities should include extensive mowing and grazing.

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