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Conservation assessment of the butterfly fauna along the River Sava between Krško and the state border

Naravovarstveno vrednotenje favne dnevnih metuljev ob reki Savi med Krškim in državno mejo

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Abstract: An inventory of butterfly fauna was carried out in 2008 within the southern part of the Ecological Important Area »the Sava River between Radeče and the state border with Croatia« with the aim of evaluating the most important areas for butterflies. Butterfly fauna was surveyed within a study area of 32 km^2, using the transect method. Twenty-one combined habitat types were included in the transect lines, with a total length of 19.2 km. The following parameters were used to evaluate the conservation importance of the combined habitat types: species richness of the combined habitat type, population density of species in combined habitat type, total population density of combined habitat type, maximum population density of species in combined habitat type, number of species with maximum population density in combined habitat type, number of threatened species in combined habitat type and number of threatened species with maximum population density in combined habitat type. A total of 69 species of butterflies (38% of Slovene butterfly fauna) were recorded, 10 of which are threatened on national or European level. The most important combined habitat types for butterflies are extensively managed dry grasslands, abandoned dry grasslands, some types of semi-intensively used grasslands, some types of ruderal communities, and dry woodland rides and edges. On the basis of the distribution of the most important combined habitat types in the study area, four important areas for butterflies were designated, with a total area of 6.6 km^2. They are important for preserving threatened species, ecological specialists and other rare or locally distributed species in the sub-pannonian part of SE Slovenia.

Key words: the River Sava between Krško and the state border, Ecological Important Area, butterflies, population density, species richness, index of distribution, threatened species, Habitats Directive

Izvleček: V južnem delu Ekološko pomembnega območja »Sava od Radeč do državne meje« (EPO Id: 63700), med Krškim in državno mejo s Hrvaško, smo v letu 2008 izvedli inventarizacijo favne dnevnih metuljev z namenom opredeliti naravovarstveno najpomembnejša območja za dnevne metulje v EPO. V raziskovanem območju s površino 32 km^2 smo na transektih dolžine 19,2 km z metodo transektnega popisa inventarizirali relativno številčnost vrst v 21 zbirnih habitatnih tipih. Za naravovarstveno ovrednotenje zbirnih habitatnih tipov smo uporabili naslednje parametre: vrstno bogastvo zbirnega habitatnega tipa, populacijska gostota vrste v zbirnem habitatnem tipu, celokupna populacijska gostota v zbirnem habitatnem tipu, maksimalna populacijska gostota vrste v zbirnem habitatnem tipu, število vrst z maksimalno populacijsko gostoto v zbirnem habitatnem tipu in število ogroženih vrst v zbirnem habitatnem tipu. Zabeležili smo 69 vrst dnevnih metuljev (38 % favne dnevnih metuljev Slovenije), med njimi 10 v nacionalnem ali evropskem merilu ogroženih vrst. Naravovarstveno najpomembnejši habitatni tipi za dnevne metulje so ekstenzivno gospodarjeni suhi travniki, zaraščajoča suha travišča, nekateri polintenzivno gospodarjeni travniki, nekatere ruderalne združbe ter gozdne poti

in robovi na suhih rastiščih. Na podlagi razširjenosti najpomembnejših zbirnih habitatnih tipov v raziskovanem območju smo opredelili štiri naravovarstveno pomembna območja za dnevne metulje s skupno površino 6,6 km2. Območja so pomembna za ohranjanje ogroženih in drugih ekološko specializiranih, redkih ali lokalno razširjenih vrst v območju subpanonske JV Slovenije.

Ključne besede: reka Sava med Krškim in državno mejo s Hrvaško, ekološko pomembno območje, dnevni metulji, populacijska gostota, vrstno bogastvo, indeks razširjenosti, ogrožene vrste, Direktiva o habitatih

Introduction

Butterflies are one of the most important invertebrate bioindicator groups (see, e.g., Kudrna 1986, Oostermeijer and Van Swaay 1998, Ricketts et al. 2002; Maes and Van Dyck 2005, Thomas 2005, Settele et al. 2009). Data on their distribution and numbers have been collected in Europe at least 20 years within the framework of the project »Butterfly Monitoring Schemes« (Van Sway and Van Strien 2008, Van Sway et al. 2008). The method for monitoring butterfly populations is well described, extensively tested and scientifically sound (Pollard and Yates 1993). Butterflies are the only invertebrate taxon for which it is currently possible to estimate rates of decline among terrestrial insects (De Heer et al. 2005, Thomas 2005). They are also representative indicators of trends observed in most other terrestrial insects, which together represent approximately two-thirds of the world's species (Thomas 2005). In 2007 as a result of the project »**S**treamlining **E**uropean 2010 **B**iodiversity **I**ndicators«, the European Environment Agency proposed 26 indicators for inclusion in the set of European biodiversity indicators (i.e. SEBI 2010 Indicators) (Van Sway and Van Strien 2008, Van Sway 2010). The biodiversity indicators offer a quick and easy tool for presenting general trends on the state of biodiversity (European Commission 2010). Butterflies were proposed as indicators for assessment of the state and trends in European grasslands (European Grassland Butterfly Indicator), which are the most important habitat of European species of butterflies (Van Sway 2010), since they are occupied by more than half of European species (280 species, 57%) (Van Sway et al. 2006).

The main goal of this research was inventory of butterfly fauna and, on the basis of the distribution and relative numbers of adults, to define from a nature conservation point of view important populations, habitat types and areas for butterflies along the lower course of the River Sava between Krško and the state border, i.e., in the southern part of the ecologically important area of the »Sava from Radeče to the state border« (EPO Id: 63700, http://www.naravovarstveni-atlas.si). In the analysis, we included other habitat types, such as those on the basis of which EPO was defined (i.e., river with gravel bars, river branches, oxbows, floodplain groves, fragments of floodplain forest; http://www.naravovarstveni-atlas.si), above all various types of grassland, woodland edges, tall herb communities and ruderal areas. We thus at the same time supplemented the currently knowledge of the fauna of EPO »Sava from Radeče to the state border«.

Review of existing data

There is relatively little published data about the butterfly fauna of the study area. The only planned research of butterfly fauna in the area of the lower Sava downstream from Krško was done by Rebeušek (2001). Older publications on the presence of some species of butterflies refer to the surroundings of Krško (e.g., Hafner 1909, Lorković 1993, 1996) and Bregana (e.g., Lorković and Mladinov 1971, Čelik et al. 2004). More numerous data have been published for the wider hinterland of the research area in the sub-Pannonian zoogeographic region (e.g., Kostanjevica, Novo Mesto, Tolsti vrh, Gorjanci, Kozje etc.) (e.g., Hafner 1909 – manuscript, Lorković 1927, Carnelutti and Michieli 1955, 1960, Sijarić 1991, Čelik et al. 2004, Čelik et al. 2005).

Material and Methods

Study area

The study area is situated in the south-eastern part of Slovenia (45° 54' 35" N, 15° 34' 32" E; WGS 84), at an altitude of 150 m. It belongs to the sub-Pannonian region (Carnelutti 1992), the northern part borders on the pre-Alpine region. It embraces the lowlands on both banks of the River Sava, from Krško in the north to the state border with Croatia by the settlement of Ribnica in the south; in the east it extends to the road Krško–Zgornji Obrež–Brežice–Dobova, and in the west to the road Žadovinek–Mrtvice–Krška vas–Čatež ob Savi, at first towards the south to the motorway Čatež ob Savi–Podgračeno (Fig. 1). It extends over an area of 32 km^2. The study area is mainly agricultural landscape. It is consisted of five landscape types (Denac et al. 2009): agricultural landscape (66%; arable fields, differently managed grasslands), mosaic of hedges, scrub, small farmland areas and small forest fragments where no habitat type predominates (14%), woodland (10%; mainly fragments of floodplain forest), river (8%; riverbed with banks, river branches, gravel bars) and other water bodies (2%; gravel pits, oxbows). In agricultural landscape, where arable fields and intensively used grasslands prevail (46% of the study area; cf. Trčak et al. 2008), the abandoned dry grasslands in early succession stages and the

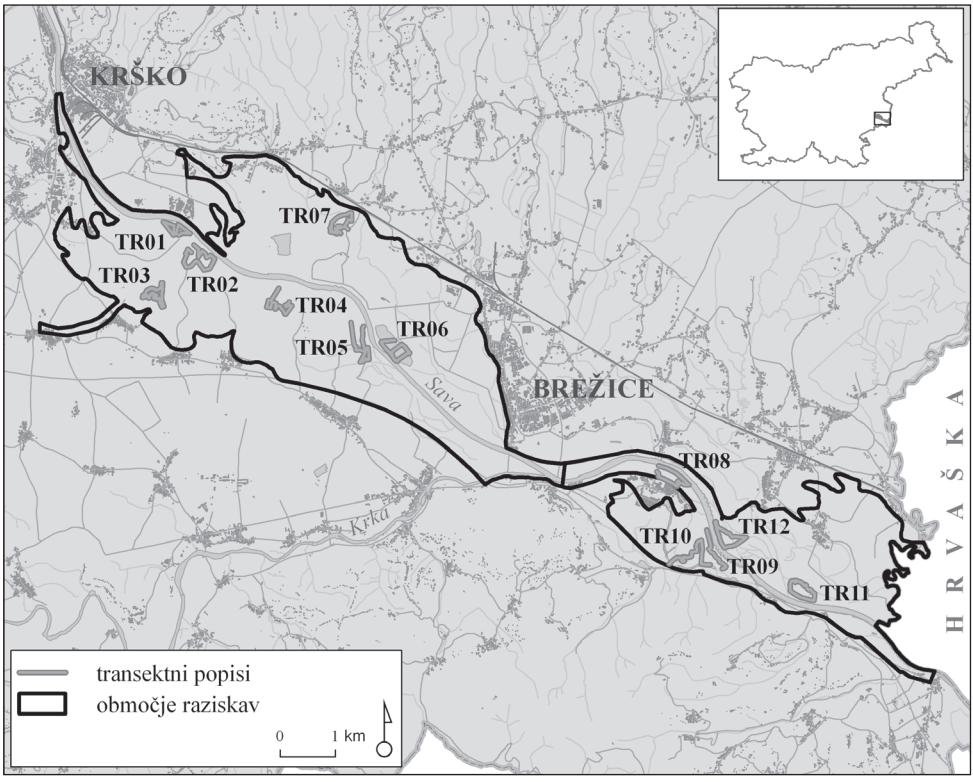


Figure 1: Study area and transect lines (TR) for inventory of butterflies along the River Sava between Krško and state border with Croatia in 2008.

Slika 1: Raziskovano območje in transekti (TR) za inventarizacijo dnevnih metuljev ob reki Savi med Krškim in državno mejo s Hrvaško v letu 2008.

extensively managed dry grasslands represent only a small part of the area (7%; cf. Trčak et al. 2008). The most extensive areas of these two types of grasslands extend in the NW part of the study area on the right bank of the River Sava. Minor areas are also in the northern part of the study area on the left bank of the River Sava, and in the SE part of the study area on the right and left bank of the River Sava. The important characteristic of the study area is also the presence of invasive allochthonous plant species (e.g. *Solidago gigantea*, *Solidago canadensis*, *Impatiens glandulifera*, *Rudbeckia laciniata*, *Echinocystis lobata*, *Fallopia japonica*, *Robina pseudoacacia*, *Ailanthus altissima*), widely distributed on moist ground of woodland areas, on river banks and near other water bodies. As pure stands they represent 2% of the study area, but in combination with other habitat types they actually extend over a much larger area (Trčak et al. 2008).

Field methods

We surveyed the butterfly fauna of the study area from March to September 2008, at 12 sampling sites (Fig. 1). At each sampling site, butterflies were monitored using the line transect method (Pollard and Yates 1993, Thomas 2005) – 1 transect line/sampling site. Transect counts were conducted at a time interval of approximately 14 days (1 count in April, 2 counts in May, 1 count in June, 2 counts in July, 1 count in September). The entire length of the transect lines was 19,157 metres. Each transect line was divided into sections, each section represented a specific habitat type. The habitat types were identified exactly, to the 3rd and 4th levels of the methodology determined by Jogan et al. (2004). The 12 transect lines contained 53 sections.

In the field, it is not possible to distinguish between *Colias alfacariensis* Ribbe, 1905 and *Colias hyale* (Linnaeus, 1758), and also between *Leptidea sinapis* (Linnaeus, 1758) and *Leptidea reali* Reissinger, 1989. Therefore, the both *Colias* species were treated as a complex *C. alfacariensis*/*hyale*, and both *Leptidea* species as a complex *L. sinapis*/*reali* for the analysis.

Data analysis

Because of the large number of habitat types (40), we merged the 40 habitat types into 21 combined habitat types (Tab. 1) that we used in further analysis. A combined habitat type is a higher and more general defined category, which includes habitat types that are similar in terms of floristic composition, structure of vegetation and management. Therefore, **the length of the combined habitat type** is the sum of the lengths of all transect sections with habitat type belonging to those combined habitat type.

For data analysis we used the following parameters: population density, total population density, maximum population density, species richness, index of distribution of species in the study area, number of species which had maximum population density in specific combined habitat type and number of threatened species in specific combined habitat type.

The **population density** of each butterfly species in each combined habitat type was calculated according to Kitahara et al. (2008) as follows. The monthly count was determined as the mean of twice-monthly counts conducted in May-July or as the value of single counts in April, June and September. The mean monthly count over the season was then calculated using only those months when the species was observed to minimize the effect of variable voltinism between species. Finally, the population density (number of adults/month/100 m of combined habitat type) was obtained by dividing the mean monthly count by the length of the combined habitat type (in metres x 100). The population density of each threatened species in each combined habitat type in proposed important areas for butterflies was calculated in the same manner, except that we included in the length of the combined habitat type only sections in transects that lay within the proposed important area.

The **total population density** in each combined habitat type was the sum of population densities of all species observed in each combined habitat type.

The **maximum population density** of a species was the population density of species in the combined habitat type in which it was most abundant.

The **species richness** in each combined habitat type/important area for butterflies was the total number of butterfly species observed in each combined habitat type/important area for butterflies during the study period.

The **index of distribution of a species in the study area** was expressed as the number of transect lines in which the species was observed. We treated as a generally widespread species, those species with an index of distribution > 9 (> 75% of all transect lines), as rare/locally distributed species those with an index of distribution < 4 (< 25% of all transect lines).

Kendall rank correlation coefficient was used to test whether a relationship exists between the length of the combined habitat type and the following parameters: species richness of the combined habitat type, total population density, number of species with maximum population density in the combined habitat type, number of threatened species in the combined habitat type and number of threatened species with maximum population density in the combined habitat type. In the interpretation of species richness of the combined habitat types in relation to the length of the combined habitat type, we treated as "not different in terms of the length" those combined habitat types that differ in length by less than 50 m, and as "not different in terms of species richness" those combined habitat types that differ in number of species by less than 3.

To define the important areas for butterflies in the study area, first the conservation importance of the combined habitat types for butterflies was assessed. For the conservation evaluation of each combined habitat type, six parameters were used: species richness, median of population densities of species observed in the treated combined habitat type, total population density, number of species with maximum population density in the treated combined habitat type, number of threatened species in the combined habitat type and number of threatened species with maximum population density in the treated combined habitat type. The non-paramteric pairwise correlations were used to test the independence between parameters. Because of the small data set (21 combined habitat types) with a large number of tied ranks, Kendall's tau was applied. In the cases where the significant relationship between parameters was established, the actual values of Kendall's correlation coeficient shown only weak or moderate correlation. Therefore, all six parameters were used in the conservation assesment. They were applied as criteria in further conservation evaluation of the combined habitat types. For each criterion the combined habitat types were ranked according to parameter value. The rank 1 was assigned to the combined habitat type with the highest parameter value, and the rank 21 (in the case of data set without tied ranks) to the combined habitat type with the lowest value of parameter. The nature conservation value of each combined habitat type was determined as the median of ranks assigned to each combined habitat type within the scope off all criteria. The combined habitat types with the median value lower then 10,5 were defined as the most important for butterflies in the study area from the conservation point of view. Finally, the important areas for butterfly species were outlined on the base of the distribution of the most important combined habitat types within the study area. The distribution of all habitat types which were similar, in terms of floristic composition, structure of vegetation and management to the combined habitat types of transect lines was established from the map of habitat types of the study area (Trčak et al. 2008).

Statistical calculations were performed by SPSS 13.0 (SPSS Inc. 1989–2004). We used the program Arc Map 9.2 (ESRI Inc. 1999–2006) for outlining transects and important areas for butterfly species. The nomenclature of species of butterflies is taken from Van Sway et al. (2010), plant species from Martinčič et al. (2007), the typology of habitat types according to Jogan et al. (2004), threatened species according to the Red list of Lepidoptera of Slovenia (Uradni list RS 82/2002), the Decree on protected wild animal species (Uradni list RS 46/2004), the European Red list of Butterflies (Van Swaay et al. 2010), the Directive on the conservation of natural habitats and of wild fauna and flora (Directive 92/43/EEC) (hereinafter: Habitats Directive) and the Convention on the Conservation of European Wildlife and Natural Habitats (Uradni list RS 17/1999) (hereinafter: Bern Convention).

Results and discussion

Species richness and distribution of species in the study area

In the period from March to September 2008, we recorded 7396 individuals from 69 species in the transect lines (Tab. 1), which represents 38% of all butterfly species living in Slovenia.

In the only previous planned inventory of butterflies, which was carried out in the study area in 2001, 60 species were recorded (Rebeušek 2001). They included four species that we did not record in 2008: *Cyaniris semiargus* (Rottemburg, 1775), *Argynnis niobe* (Linnaeus, 1758), *Brentis ino* (Rottemburg, 1775) and *Neptis sappho* (Pallas, 1771). In view of the fact that all four species were observed in 2001 in areas in which we carried out transect counts, the reasons that we did not register these species in 2008 could be: (i) very low numbers of the populations, which reduces the probability of detection of the species in a transect line; (ii) the species do not live in the areas of the transect lines. In 2008, we found 13 species that had not been observed in 2001: *Aphantopus hyperantus* (Linnaeus, 1758), *Argynnis paphia* (Linnaeus, 1758), *Carcharodus alceae* (Esper, 1780), *Coenonympha arcania* (Linnaeus, 1761), *Leptotes pirithous* (Linnaeus, 1767), *Limenitis populi* (Linnaeus, 1758), *Lycaena hippothoe* (Linnaeus, 1761), *Melitaea didyma* (Esper, 1778), *Pieris mannii* (Mayer, 1851), *Satyrium acaciae* (Fabricius, 1787), *S. spini* (Dennis & Schiffermüller, 1775), *S. w-album* (Knoch, 1782) and *Thymelicus lineola* (Ochsenheimer, 1808).

Mostly intensively managed anthropogenic landscape of the study area is reflected in the species richness of butterfly fauna (69 species/32 km^2). It is lower than in Natura 2000 sites and some other important conservation areas in Slovenia, in which inventories of butterfly fauna are already performed. It is evident from the comparisons with the species richness of the following areas: Škocjanske jame Regional Park: 90 species/4 km^2 (Čelik 2004); Natura 2000 site "Radensko polje" – SI3000171: 68 species/7 km^2 (Rebeušek and Verovnik 2000); Natura 2000 site "Planinsko polje" – SI5000016: 78 species/10 km^2 (Čelik 2007); Natura 2000 site "Banjšice" – SI3000034: 78 species/12 km^2 (Čelik 2009).

Generally widespread species (= index of distribution > 9) in the study area are species that are not ecologically specialised, of which we recorded 19: *Aglais io* (Linnaeus, 1758), *Aricia agestis* (Dennis & Schiffermüller, 1775), *Boloria dia* (Linnaeus, 1767), *Brenthis daphne* (Bergsträsser, 1780), *Coenonympha glycerion* (Borkhausen, 1788), *C. pamphilus* (Linnaeus, 1758), *Colias crocea* (Geoffroy, 1785), *Cupido argiades* (Pallas, 1771), *Erynnis tages* (Linnaeus, 1758), *Gonepteryx rhamni* (Linnaeus, 1758), *Leptidea sinapis/reali* (Linnaeus, 1758/ Reissinger, 1989), *Maniola jurtina* (Linnaeus, 1758), *Melitaea athalia* (Rottemburg, 1775), *M. phoebe* (Dennis & Schiffermüller, 1775), *Ochlodes sylvanus* (Esper, 1777), *Pieris napi* (Linnaeus, 1758), *P. rapae* (Linnaeus, 1758), *Plebejus argus* (Linnaeus, 1758) and *Polyommatus icarus* (Rottemburg, 1775) (Tab. 1). Rare/ locally distributed species (index of distribution < 4; 21 species) occupy woodland rides (11 species), abandoned dry and semi-dry grasslands (9 species), extensively managed dry grasslands (8 species), semi-intensively managed grasslands (7 species), woodland edges (7 species), ruderal areas (5 species) and scrub (1 species) (Tab. 1).

Species richness of the combined habitat types

The species richest combined habitat types in the study area are extensive dry grasslands with erect brome (48 species), abandoned dry and semi-dry grasslands (STzS: 46, STzT: 41 species), semi-intensively managed dry grasslands with erect brome and tall oat-grass (40 species) and woodland rides on moist grund overgrown with autochthonous and allochthonous plant species (36 species) (Tab. 1).

The significant strong positive correlation exists between the length of the combined habitat type and its species richness ($\tau = 0.657$, $P<0.001$). From a comparison between combined habitat types that differ in length by less than 50 m and in number of species by more than 2 (Fig. 2a) and combined habitat types of different lengths that do not differ in terms of the number of species (Fig. 2b), we can conclude

Table 1: List of recorded species with population densities in combined habitat types in which a species appeared and index of distribution of species recorded in transect lines along the River Sava between Krško and the state border in 2008.

Tabela 1: Seznam registriranih vrst s populacijskimi gostotami v zbirnih habitatnih tipih in indeks razširjenosti vrst, zabeleženih na transektih ob reki Savi med Krškim in državno mejo v letu 2008.

Combined habitat type	GMvT	GPsS	GPsT	GPvT	GPvVs	GRsS	GRsT	GRvT	GRvVs	MTiA	MTpA	N	Rg	Rgm	Rgmz	STeB	STpA	STpBA	STzS	STzT	TVTp	
Length of combined habitat type (m)	549	501	381	2068	686	202	642	492	1246	1999	1243	50	448	476	287	2838	972	1057	1923	928	169	Index of distribution
Species	Population density																					
Aglais io	0,05	0,05	0,33	0,02			0,12	0,20	0,17	0,04	0,02			0,05	0,17	0,01	0,05		0,01	0,03	0,07	12
Aglais urticae		0,07	0,04				0,05			0,01	0,04		0,07	0,07		0,01				0,02		8
Anthocharis cardamines		0,20	0,13	0,16	0,07		0,08	0,05	0,04	0,03			0,11	0,16	0,35		0,03		0,04		0,30	9
Apatura ilia				0,08				0,14					0,04	0,04	0,23							3
Aphantopus hyperantus	0,05	0,10	0,46	0,01												0,03	0,03		0,49	0,24		5
Araschnia levana			0,07	0,09			0,04	0,05		0,01				0,11	0,26							5
Argynnis paphia		0,10		0,01						0,03						0,02						4
Aricia agestis		0,02		0,01		0,19				0,03	0,06		0,08		0,09	0,22	0,03	0,20	0,40	0,44		11
Boloria dia	0,02			0,01			0,12			0,28	0,28					0,48	0,72	0,56	0,46	0,10		10
Brenthis daphne	0,18			0,15	0,44		0,16	0,41	0,72		0,16			0,21	0,35			0,47	0,05	0,22		10
Callophrys rubi			0,13																0,05	0,11		3
Carcharodus alceae	0,05														0,09				0,01			3
Celastrina argiolus			0,07	0,05				0,05														5
Coenonympha arcania			0,59	0,02			0,08			0,05						0,10		0,07	1,39	3,18		5
Coenonympha glycerion	0,39			0,01		0,37	0,21	0,03	0,14	0,27	0,44	0,50				0,60	0,45	0,93	1,14	0,84		11
Coenonympha pamphilus	0,66			0,02	0,09	0,43	0,31	0,03	0,27	0,42	0,40	1,00	0,03		1,70	0,60	0,78	0,48	0,57	0,32	0,15	12
Colias alfacariensis/ hyale					0,02				0,03	0,02	0,01					0,06	0,02	0,13	0,05	0,02		8
Colias croca	0,39	0,22	0,03	0,04	0,07	0,25	0,16	0,30	0,13	0,31	0,83	0,75	0,81	0,18	2,31	0,88	0,32	0,79	0,42	0,40		12
Cupido argiades	0,87	0,22	0,39	0,05	0,02		0,23	0,28	0,08	0,10	0,24		0,95	0,18	1,31	0,36	0,15	0,19	0,45	0,36		12
Cupido minimus																0,02			0,05			2

Combined habitat type	GMvT	GPsS	GPsT	GPvT	GPvVs	GRsS	GRsT	GRvT	GRvVs	MTiA	MTpA	N	Rg	Rgm	Rgmz	STeB	STpA	STpBA	STzS	STzT	TVTp	
Length of combined habitat type (m)	549	501	381	2068	686	202	642	492	1246	1999	1243	50	448	476	287	2838	972	1057	1923	928	169	Index of distribution
Species	Population density																					
Erynnis tages	0,09	0,07	0,26		0,10		0,05	0,07	0,03	0,03					0,17	0,21	0,02	0,27	0,29	0,45		10
Glaucopsyche alexis			0,13													0,02		0,05				3
Gonepteryx rhamni	0,09	0,05	0,56	0,10	0,02	0,06	0,27	0,03	0,03	0,01	0,02		0,03	0,03	0,13	0,04	0,03	0,09	0,14	0,08	0,15	12
Hesperia comma																0,04		0,14	0,07	0,05		4
Heteropterus morpheus				0,02												0,04		0,09	0,18	0,65		4
Iphiclides podalirius			0,04	0,02															0,02			3
Issoria lathonia										0,01						0,02	0,03	0,02		0,02		5
Lasiommata megera	0,12				0,02	0,08			0,05							0,01						4
Leptidea sinapis/reali	0,11	0,20	0,45	0,16	0,16	0,20	0,34	0,22	0,26	0,19	0,39	0,40	0,04	0,04	0,21	0,22	0,22	0,33	0,58	0,74	0,53	12
Leptotes pirithous									0,08													1
Limenitis populi					0,07																	1
Limenitis reducta		0,03	0,31	0,01			0,05											0,02	0,01	0,05	0,10	5
Lycaena dispar													0,15		0,06		0,03					2
Lycaena hippothoe											0,04											1
Lycaena phlaeas							0,16		0,08									0,09	0,10			4
Lycaena tityrus	0,03					0,17			0,01		0,04					0,01	0,02	0,03	0,02	0,02		6
Maniola jurtina	0,32	0,37	2,26	0,18		2,72	1,21	0,10	0,10	0,66	0,30				0,17	0,86	0,27	1,40	1,20	0,70	0,07	12
Melanargia galathea	0,05	0,50	0,39			3,47	4,91			0,26	0,04			0,11		3,10	0,15	4,92	8,07	3,61		9
Melitaea athalia	0,06			0,05	0,02		0,31		0,51	0,21	1,73				0,41	0,38	0,82	0,65	0,09		0,49	10
Melitaea aurelia			0,13			0,50	0,08				0,10					1,39	0,05	0,19	0,59	0,38		7
Melitaea britomartis																0,07	0,05		0,07			4
Melitaea cinxia						0,12										0,19		0,19				4
Melitaea didyma									0,01							0,11		0,01				3
Melitaea phoebe				0,02			0,08		0,02	0,04	0,22				0,35	0,11	0,05	0,14		0,03		10
Minois dryas		0,40	0,59	0,05			1,13					0,50				0,24	0,03	0,26	2,65	2,45		5
Ochlodes sylvanus	0,03	0,03	0,22	0,03	0,05	0,17	0,13		0,17	0,10	0,12			0,04	0,06	0,04	0,10	0,17	0,10	0,07	0,69	12
Papilio machaon										0,01	0,06				0,09	0,02		0,06	0,02			8
Pararge aegeria					0,15									0,21								2
Pieris brassicae				0,02			0,05			0,05						0,03	0,03	0,03	0,02			8

Combined habitat type	GMvT	GPsS	GPsT	GPvT	GPvVs	GRsS	GRsT	GRvT	GRvVs	MTiA	MTpA	N	Rg	Rgm	Rgmz	STeB	STpA	STpBA	STzS	STzT	TVTp	Index of distribution
Length of combined habitat type (m)	549	501	381	2068	686	202	642	492	1246	1999	1243	50	448	476	287	2838	972	1057	1923	928	169	
Species	Population density																					
Pieris mannii										0,05	0,12							0,05	0,03			5
Pieris napi	0,02	0,10	0,31	0,20	0,09	0,20	0,03	0,04	0,05	0,07	0,02		0,02	0,29	0,42	0,00	0,01		0,04	0,08		12
Pieris rapae	0,22	0,36	0,39	0,13	0,28	0,59	0,56	0,26	0,14	0,36	0,47	0,40	1,05	0,32	0,38	0,54	0,27	0,43	0,22	0,22	0,12	12
Plebejus argus	0,20	0,12		0,01			0,23	0,03	0,33	0,19	1,01				0,04	0,23	0,84	0,88	0,44	0,32	0,15	10
Plebejus argyrognomon																0,04						1
Plebejus idas																0,07		0,05	0,16	0,05		3
Polygonia c-album		0,14	0,05	0,04				0,02	0,02					0,06					0,03			7
Polyommatus bellargus																0,02			0,05	0,16		3
Polyommatus icarus	0,55	0,02		0,02	0,04		0,31	0,30	0,01	0,22	0,32		0,59	0,18	1,22	0,71	0,37	0,53	0,57	0,61		12
Pontia daplidice													0,39			0,03	0,03					3
Pyrgus malvae	0,11							0,05	0,01					0,03		0,03	0,01	0,02	0,14	0,07		8
Satyrium acaciae				0,34			0,16									0,04		0,28	0,31	0,43		3
Satyrium pruni		0,10	0,20																	0,05		3
Satyrium spini			0,66				0,08		0,02													2
Satyrium w-album			1,05	0,01			0,08															2
Thymelicus lineola	1,64			0,48				2,03	0,16	0,40	0,48				2,44	0,21	1,03	1,14	0,47	0,54		9
Thymelicus sylvestris			0,26				0,16												0,16	0,32		2
Vanessa atalanta		0,04	0,08	0,00	0,03				0,02				0,07	0,08		0,00	0,01			0,01	0,06	8
Vanessa cardui				0,01			0,04							0,03		0,00		0,01		0,01		6
Zerynthia polyxena	0,05						0,58		0,02		0,08					0,05	0,08	0,02	0,13	0,22		7
Number of species	25	23	29	36	18	15	34	21	30	30	28	6	15	20	24	48	34	40	46	41	12	
Total population density	6,32	3,53	10,59	2,64	1,74	9,51	12,55	4,69	3,73	4,42	8,06	3,55	4,43	2,41	13,00	12,47	7,13	16,39	22,53	18,67	2,88	
Median of population densities	0,25	0,15	0.37	0,07	0,10	0,63	0,37	0,22	0,12	0,15	0,29	0,59	0,30	0,12	0,54	0,26	0,21	0,41	0,49	0,46	0,24	
No. of species with maximum population density	1	2	10	0	1	2	4	0	2	0	4	0	4	2	12	5	2	2	7	8	1	

Legend

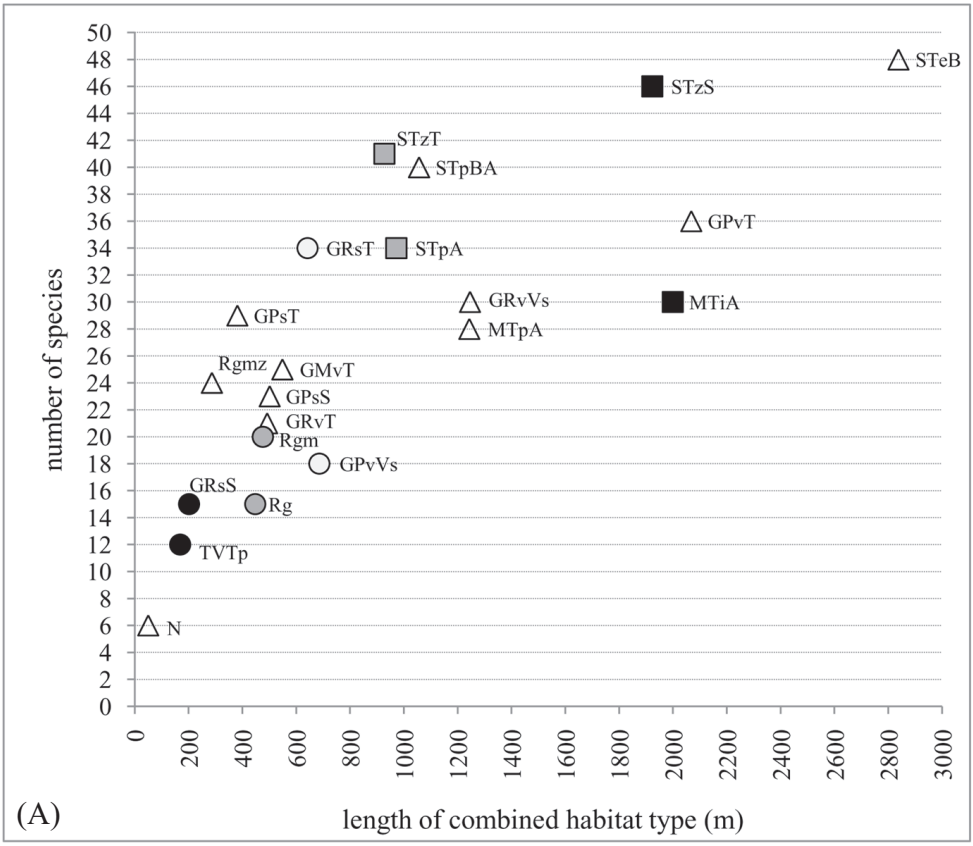
GMvT	Small shrubs on moist ground; presence of allochtonous and autochtonous plant species
GPsS	Woodland ride on dry ground; autochtonous plant species predominate
GPsT	Woodland ride on dry ground; presence of allochtonous and autochtonous plant species
GPvT	Woodland ride on moist ground; presence of allochtonous and autochtonous plant species
GPvVs	Woodland ride with tall herb communities on moist ground; presence of allochtonous and autochtonous plant species
GRsS	Woodland edge on dry ground; autochtonous plant species predominate
GRsT	Woodland edge on dry ground; presence of allochtonous and autochtonous plant species
GRvT	Woodland edge on moist ground; presence of allochtonous and autochtonous plant species
GRvVs	Woodland edge with tall herb communities on moist ground; presence of allochtonous and autochtonous plant species
MTiA	Mesophilous mesotrophic and eutrophic grasslands with tall oatgrass (*Arrhenathereum elatius* L.); intensively managed
MTpA	Mesophilous mesotrophic and eutrophic grasslands with tall oatgrass (*Arrhenathereum elatius* L.); semi-intensively managed
N	Arable fields
Rg	Area with ruderal vegetation; mostly bare ground, only some herb species
Rgm	Area with ruderal vegetation; mostly shrub species
Rgmz	Area with ruderal vegetation; shrub and herb species
STeB	Dry and semi-dry grasslands with erect brome (*Bromopsis erecta* Huds.); extensively managed
STpA	Dry and semi-dry grasslands with tall oatgrass (*Arrhenathereum elatius* L.); semi-intensively managed
STpBA	Dry and semi-dry grasslands with erect brome (*Bromopsis erecta* Huds.) and tall oatgrass (*Arrhenathereum elatius* L.); semi-intensively managed
STzS	Abandoned dry and semi-dry grasslands; autochtonous shrub and tree species predominate
STzT	Abandoned dry and semi-dry grasslands; presence of allochtonous and autochtonous shrub and tree species
TVTp	Common reed bed along semi-intensively managed moist mesotrophic grassland

that the type of vegetation or/and type of management in the combined habitat type are more important factors affecting species richness than the length of the combined habitat type. The influence of type of vegetation on the number of species in the combined habitat type is evident from the following comparisons: despite differences in length < 50 m, (i) dry woodland edges in which autochtonous plant species predominate (GRsS) are more species rich than common reed bed along semi-intensively managed moist mesotrophic grassland (TVTp) (Fig. 2a), and (ii) ruderal areas overgrown predominantly with shrubs (Rgm) are more species rich than mostly bare ruderal areas (Rg) (Fig. 2a), which are only a habitat for the thermoregulation of adults, and (iii) dry woodland edges (GRsT) are more species rich than woodland rides on moist ground overgrown with tall herb communities (GPvVs), among which predominate invasive allochthonous species that are not larval food plants or nectar plants of butterfly species that live in Slovenia (Fig. 2a); despite the shorter length (difference in length is more than 50 m; see Data analysis), (iv) ruderal areas overgrown with shrub and herb species (Rgmz) not differ in species richness from scrub (GMvT) and dry woodland rides (GPsS) (Fig. 2b), and (v) ruderal areas overgrown predominantly with shrub (Rgm) not differ in species richness from woodland rides on moist ground in which invasive allochthonous tall herb species predominate (GPvVs) (Fig. 2b), and (vi) dry woodland edges (GRsS) have the same number of species as bare ruderal

areas (Rg) (Fig 2b). That the management of the combined habitat type is a more important factor that influences species richness than its length is evident from the following comparisons: despite differences in length < 50 m, (i) abandoned dry grasslands in which autochtonous shrub and tree species predominate (STzS) are more species rich than intensively managed grasslands (MTiA) (Fig. 2a), and (ii) abandoned dry grasslands with approximately the same proportion of allochtonous and autochtonous shrub and tree species (STzT) are more species rich than semi-intensively managed grasslands with tall oat-grass (STpA) (Fig. 2a); despite the shorter length (difference in length is more than 50 m; see Data analysis), (iii) abandoned dry grasslands with approximately the same proportion of allochtonous and autochtonous shrub and tree species (STzT) not differ in species richness from semi-intensively managed dry grasslands with erect brome and tall oat-grass (STpBA) (Fig. 2b), and (iv) woodland edges (GRsT, GRvVs) and dry woodland rides (GPsT) not differ in species richness from semi-intensively and intensively managed grasslands with tall oat-grass (STpA, MTpA, MTiA) (Fig. 2b). Namely, woodland edges and dry woodland rides overgrown with autochthonous richly flowering species of herbs and shrubs are also feeding habitats of adults at the time when semi-intensively and intensively cultivated grasslands have already been mown.

Total population density, median of population densities of species, maximum population density of species

The total population density is not in correlation with the length of the combined habitat type



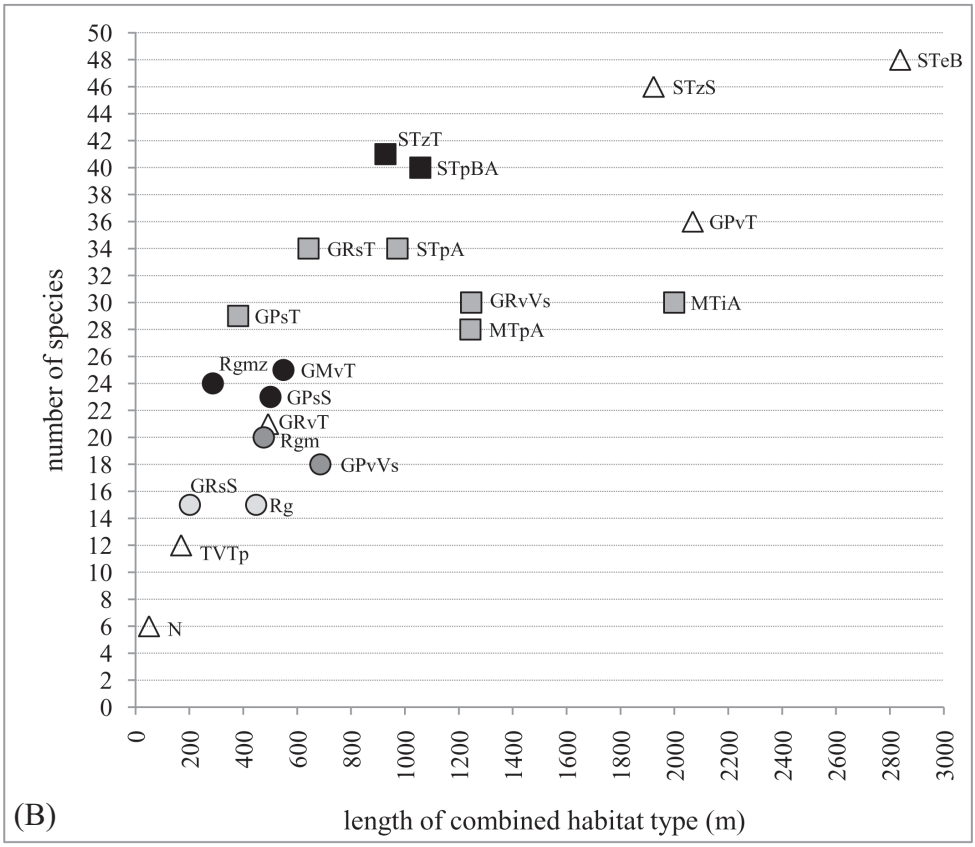


Figure 2: Species richness of the combined habitat type in relation to the length of the combined habitat type along the River Sava between Krško and the state border in 2008 (for abbreviations of the combined habitat types, see Tab. 1).
(A) – Comparison between combined habitat types that differ in length by less than 50 m and in the number of species by more than two. (B) – Comparison between combined habitat types that differ in length by more than 50 m and do not differ in terms of the number of species (for explanation, see Data analysis). ○ - combined habitat types that reflect the influence of type of vegetation, □ - combined habitat types that reflect the influence of management, △ - combined habitat types that are not included in comparison

Slika 2: Število vrst v zbirnih habitatnih tipih glede na dolžino zbirnega habitatnega tipa ob reki Savi med Krškim in državno mejo v letu 2008. (za razlago okrajšav zbirnih habitatnih tipov glej Tab. 1)
(A) – Primerjava med zbirnimi habitatnimi tipi, ki se v dolžini razlikujejo za manj kot 50 m in v številu vrst za več kot dve. (B) – Primerjava med zbirnimi habitatnimi ttipi, ki se v dolžini razlikujejo za več kot 50 m in v številu vrst za manj kot 3 (za razlago glej poglavje Data analysis). ○ - zbirni habitatni tipi, ki odražajo vpliv tipa vegetacije, □ - zbirni habitatni tipi, ki odražajo vpliv načina gospodarjenja, △ - zbirni habitatni tipi, ki niso vključeni v primerjavo

($\tau = 0.124$, $P>0.4$), despite the fact that there is a strong positive correlation between the species richness and the length of the combined habitat type (see above) and a moderate positive correlation between the species richness and the total population density ($\tau = 0.446$, $P<0.01$). Concerning the finding that there is no correlation between the total population density and the length of combined habitat type, we can conclude that the combined habitat types with the

highest total population densities are abandoned dry and semi-dry grasslands (STzS: 22,53; STzT: 18,67), semi-intensively managed dry grasslands with erect brome and tall oat-grass (STpBA: 16,39), shrub and herb-overgrown ruderal areas (Rgmz: 13,00), dry woodland edges (GRsT: 12,55) and extensively managed dry grasslands (STeB: 12,47) (Tab. 1). In all other combined habitat types, the total population densities are at least twice (up to 13x in GPvVs) lower than in combined habitat type with the highest total population density (STzS).

Total population density of the combined habitat type is also affected by the population densities of species that inhabit it, since the weak positive correlation between total population density and median value of population densities of species that occupy the combined habitat type is significant ($\tau = 0.313$, $P<0.01$). There is also a significant moderate positive correlation between total population density and the number of species with maximum population density in the combined habitat type ($\tau = 0.536$, $P<0.05$) (Fig. 3). The actual values of Kendall's correlation coeficient show that the number of species with maximum population density in a combined habitat type is a more important factor influencing total population density than the species richness of the combined habitat type and population densities of species that inhabit it.

Generally widespread grassland species (*M. galathea*, *C. arcania*, *M. jurtina*, *M. dryas*, *T. lineola*, *C. crocea*, *M. athalia*, *C. pamphilus*) have the highest population densities in the study area (Fig. 4), which are also often found to be markedly more abundant in grassland habitats (grasslands, abandoned grasslands) elsewhere in Slovenia than other species (own observation); the species *M. dryas* is an exception. It is not widely distributed in Slovenia because it

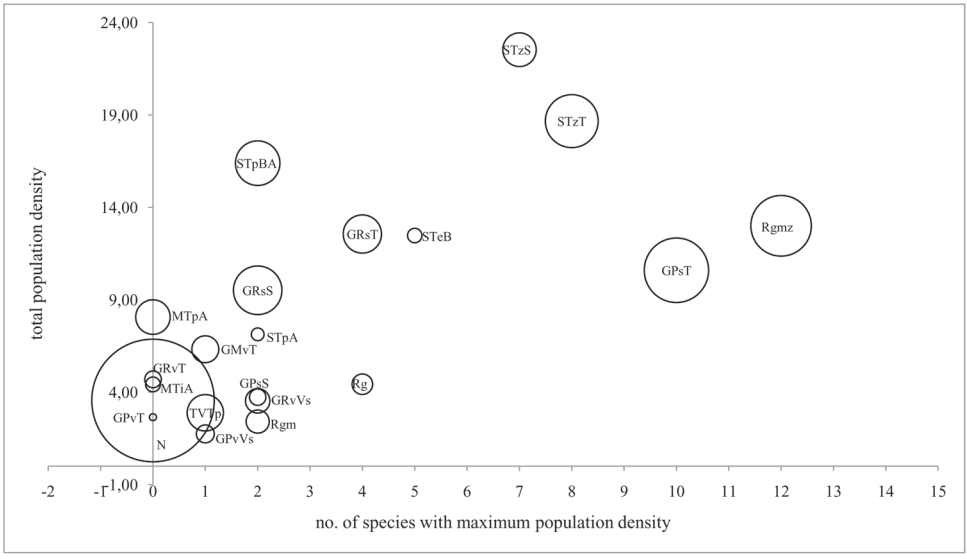


Figure 3: Total population density in relation to the number of species with the maximum population density in combined habitat type and the median value of population densities of species that inhabit combined habitat type in the study area along the River Sava between Krško and the state border in 2008 (median value of population densities of species is given by the diameter of the circle). (for abbreviations of the combined habitat types, see Tab. 1)

Slika 3: Celokupna populacijska gostota zbirnega habitatnega tipa glede na število vrst z maksimalno populacijsko gostoto v zbirnem habitatnem tipu in mediano vrednostjo populacijskih gostot vrst, ki poseljujejo zbirni habitatni tip za zbirne habitatne tipe ob reki Savi med Krškim in državno mejo v letu 2008 (mediano vrednost populacijskih gostot vrst v zbirnem habitatnem tipu določa premer kroga). (za razlago okrajšav zbirnih habitatnih tipov glej Tab. 1)

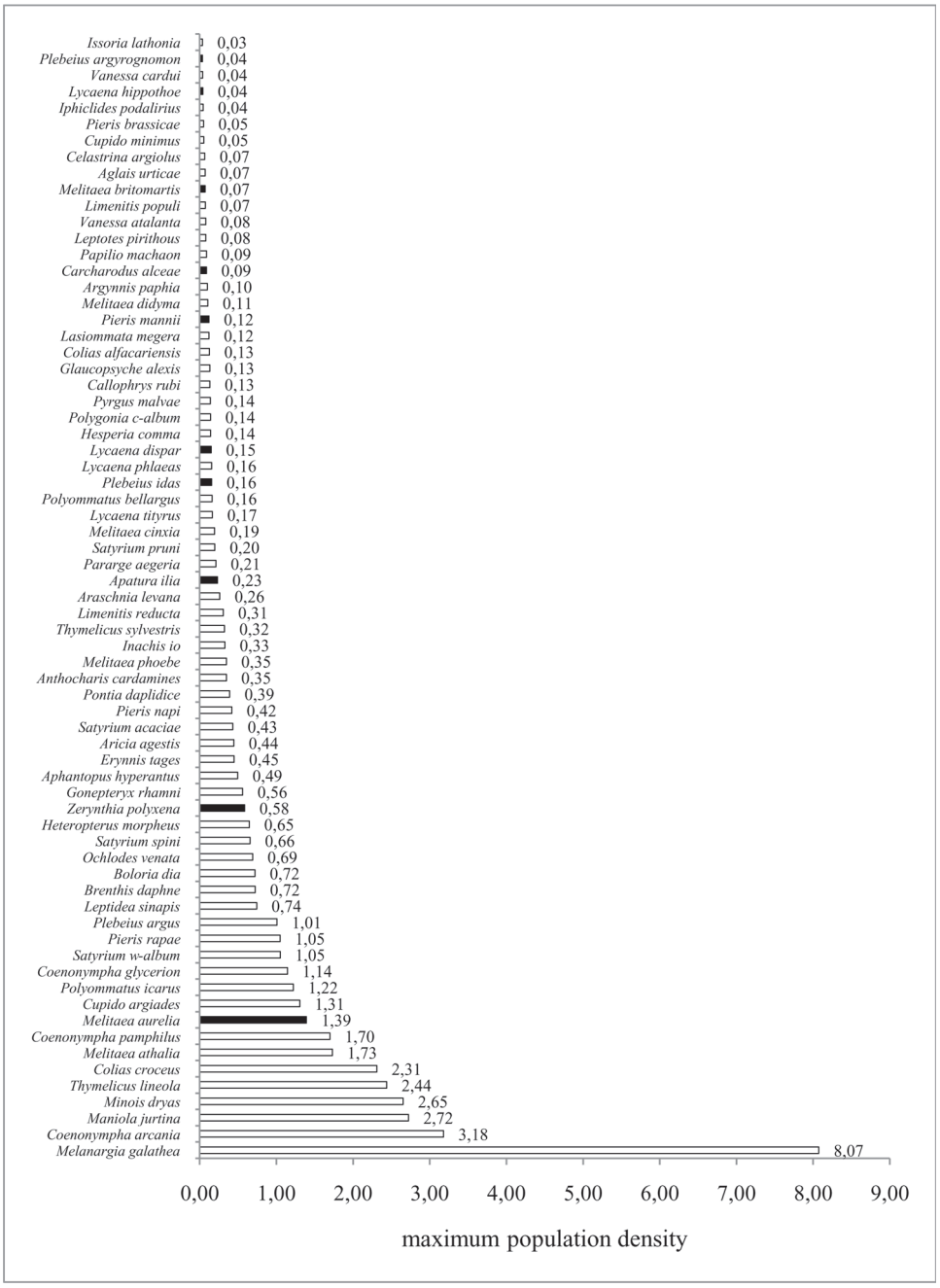


Figure 4: Comparison of maximum population densities of species recorded along the River Sava between Krško and the state border in 2008. The columns of threatened species are marked in black.

Slika 4: Primerjava maksimalnih populacijskih gostot vrst, zabeleženih ob reki Savi med Krškim in državno mejo v letu 2008. Črno obarvani stolpci označujejo ogrožene vrste.

mostly inhabits xerothermophilous grasslands. The caterpillars of the mentioned species feed on grasses (*Poaceae*), with the exception of the ubiquitous species *C. crocea*, of which the larval food plants are various low growing legume species (*Fabaceae*).

It can be concluded from comparison of maximum population densities the relation between the sizes of populations of recorded species. The maximum population density of the most abundant species, *M. galathea* e.g., is 2.5–5x greater than the maximum population density of other of the aforementioned grassland species and 50–250x greater than a third of the species with the lowest maximum population densities. In the first third of species (Fig. 4), two are threatened, *Melitaea aurelia* and *Zerynthia polyxena*, with maximum population densities of 14 and 6 adults/month/1 km of combined habitat type, which means that their populations are relatively abundant in comparison with other species. The finding that ecological generalists predominate in the first third of species, while the two threatened species are ecological specialists relying on dry or semi-dry abandoned and extensively or semi-intensively managed grasslands and dry forest edges, also indicates the importance of the study area for both mentioned species. Ecologically specialised species in the first third include also the monofagous species *Satyrium w-album*, whose caterpillars feed on the leaves of elm (*Ulmus* spp.). This is an arboreal species, which means that, because of the behaviour of the adults (staying in the crowns), it is difficult to detect in a transect counts. The high assessed maximum population density of the species indicates that the study area, primarily dry woodland rides, is important for maintain-

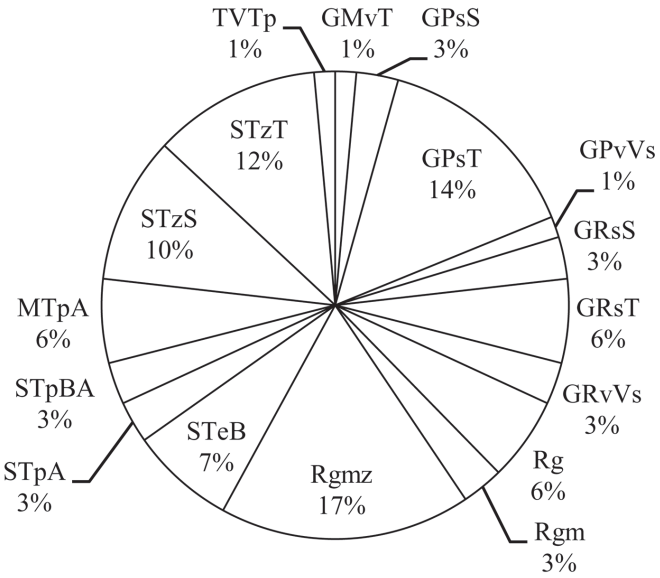


Figure 5: Distribution of the number of species with maximum population densities by combined habitat type for the species recorded along the River Sava between Krško and the state border in 2008. (for abbreviations of the combined habitat types, see Tab. 1)

Slika 5: Porazdelitev števila vrst z maksimalnimi populacijskimi gostotami po zbirnih habitatnih tipih za vrste zabeležene ob reki Savi med Krškim in državno mejo v letu 2008. (za razlago okrajšav zbirnih habitatnih tipov glej Tab. 1)

ing its populations. The main reason for high number of observed adults on the dry woodland rides were the extensive stands of annual fleabane (*Erigeron annus*) serving as nectar plant. Three threatened species (*Apatura ilia*, *Plebejus idas*, *Lycaena dispar*), with maximum population densities of 1-2 adults/month/1 km of combined habitat type belong in the second third of recorded species, and 5 threatened species (*Pieris mannii*, *Carcharodus alceae*, *Melitaea britomartis*, *Lycaena hippothoe*, *Plebejus argyrognomon*), with maximum population densities ≤ 1 adult/month/1 km of combined habitat type in the last third (Fig. 4).

The number of species with maximum population density in combined habitat type is not in correlation with the length of the combined habitat type ($\tau = 0.015$, $P>0.9$). Considering this finding, the distribution of maximum population densities of species by combined habitat types (Fig. 5) directly indicates the importance of individual combined habitat types for the existence of populations of butterflies in the study area. The recorded species achieved the highest population densities in 17 combined habitat types. Four combined habitat types in which none of the recorded species had the highest density are intensively cultivated grasslands, arable fields and woodland edges and rides on moist ground (Tab. 1). On dry grasslands (extensive, semi-intensive, abandoned) 24 (35%) species had highest population densities, 18 (26 %) species in ruderal communities, 13 (18 %) species on woodland rides, 8 (12 %) species on woodland edges, 4 (6 %) of species on mesophilous semi-intensively managed grasslands and one species each on common reed bed along semi-intensively managed moist mesotrophic grassland, on damp scrub and on woodland rides on moist ground overgrown with riverine shrubs and tall herb communities (Fig. 5).

Threatened species

We recorded 10 threatened species in the study area in 2008 (Tab. 2), which is 18% of the threatened butterfly species in Slovenia. The species *Lycaena dispar* and *Zerynthia polyxena* are on the list of Annexes of the Habitats Directive and the Bern Convention, which include 14 (Habitats Directive) and 13 (Bern Convention) of the butterfly species of Slovenia; on the Red List of the Lepidoptera of Slovenia, they are classified in the category of vulnerable species (36 butterfly species); they are among protected animal species of Slovenia, whereby the animals (27 species of butterfly) and their habitats (26 species of butterfly) are protected. The remaining eight threatened species on the Red List of the Lepidoptera of Slovenia are in the category of vulnerable species. Two (*Melitaea aurelia*, *M. britomartis*) of them are on the European Red List of Butterflies in the category of potentially threatened species (NT) and the remaining six among species for which there is a low risk of extinction (LC).

The index of distribution indicates (Tab. 2) that 6 threatened species (*A. ilia*, *C. alceae*, *L. dispar*, *L. hippothoe*, *P. argyrognomon*, *P. idas*) are rare or very locally distributed in the study area. Threatened species occupy 17 combined habitat types (Fig. 6). Four combined habitat types in which none of the threatened species were recorded are arable fields, common red bed, woodland rides on moist ground overgrown with riverine shrubs and tall herb communities and dry woodland rides.

The number of threatened species in combined habitat type is in significant positive correlation with the length of the combine habitat type ($\tau = 0.406$, $P<0.05$), the species richness of the combined habitat type ($\tau = 0.566$, $P<0.01$), total population density ($\tau = 0.645$, $P<0.001$) and the number of species with the maximum population density in the combined habitat type ($\tau = 0.479$, $P<0.01$). The number of threatened species with maximum population densities in combined habitat type is not in correlation with the length of the combine habitat type ($\tau = 0.158$, $P>0.4$) or the species richness of the combined habitat type ($\tau = 0.214$, $P>0.2$).

Seven threatened species were recorded on extensively managed dry grasslands (STeB) and on abandoned dry grasslands with tall oatgrass overgrown with autochthonous woody species (STzS). These are xerothermophilous or mesophilous thermophilous species: *C. alceae*, *M. aurelia*, *M. britomartis*, *P. mannii*, *P. argyrognomon*, *P. idas* and *Z. polyxena*. Four xerothermophilous species are the most abundant in these habitats (Tab. 2). The species ***M. aurelia***

Table 2: List of threatened species recorded in transect lines along the River Sava between Krško and the state border in 2008. Threat categories, number of habitat types in which species appeared, index of distribution of species, maximum population density of species and combined habitat types in which a species achieves maximum population density are shown. (for abbreviations of the combined habitat types, see Tab. 1)

Tabela 2: Seznam ogroženih vrst, zabeleženih na transektih ob reki Savi med Krškim in državno mejo v letu 2008. Prikazane so kategorije ogroženosti vrst, število zbirnih habitatnih tipov, v katerih je bila vrsta opažena, indeks razširjenosti vrst, maksimalna populacijska gostota vrst ter zbirni habitatni tip, v katerem vrsta dosega maksimalno populacijsko gostoto. (za razlago okrajšav zbirnih habitatnih tipov glej Tab. 1)

Species	[1] RS	[2] RSE	[3] UZŽV	[4] FFH	[5] BERN	No. of [6] HT	Index of distribution	Maximum population density	HT in which a species achieves maximum population density
Apatura ilia	V	LC				5	3	0,23	Rgmz
Carcharodus alceae	V	LC				3	3	0,09	Rgmz
Lycaena dispar	V	LC	1, 2	II, IV	II	3	2	0,15	Rg
Lycaena hippothoe	V	LC				1	1	0,04	MTpA
Melitaea aurelia	V	NT				9	7	1,39	STeB
Melitaea britomartis	V	NT				3	4	0,07	STeB
Pieris mannii	V	LC				4	5	0,12	MTpA
Plebejus argyrognomon	V	LC				1	1	0,04	STeB
Plebejus idas	V	LC				4	3	0,16	STzS
Zerynthia polyxena	V	LC	1, 2	IV	II	9	7	0,58	GRsT

[1] RS = Red list of Lepidoptera of Slovenia (Uradni list RS 82/2002)
[2] RSE = European Red list of Butterflies (Van Swaay s sod. 2010)
[3] UZŽV = Decree on protected wild animal species (Uradni list RS 46/2004)
[4] FFH = Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora
[5] BERN = Convention on the Conservation of European Wildlife and Natural Habitats
[6] HT = combine habitat type

has the most numerous populations on extensive, semi-intensive and abandoned dry grasslands with erect brome and dry woodland edges, where autochthonous plant species predominate. The food plants of the caterpillars are ribwort plantain (*Plantago lanceolata*), various species of speedwell (*Veronica* spp.) and cow-wheat (*Melampyrum* spp.) (Beneš and Konvička 2002a). In the northern part of the study area (northeast of the settlement of Brege, southwest of the settlement of Zgornji Obrež), where there are extensive mosaics of extensive and abandoned dry grasslands in early succession stages, there are very good living conditions for the species, so their populations are relatively numerous in comparison with other butterfly species (Fig. 4). The species ***M. britomartis*** appears mainly on extensive and abandoned dry grasslands with erect brome. The food plants of the caterpillars are large speedwell (*Veronica teucrium*), yellow rattle (*Rhinantus minor*) (Ebert and Rennwald 1993a, Beneš and Konvička 2002b) and ribwort plantain (*Plantago*

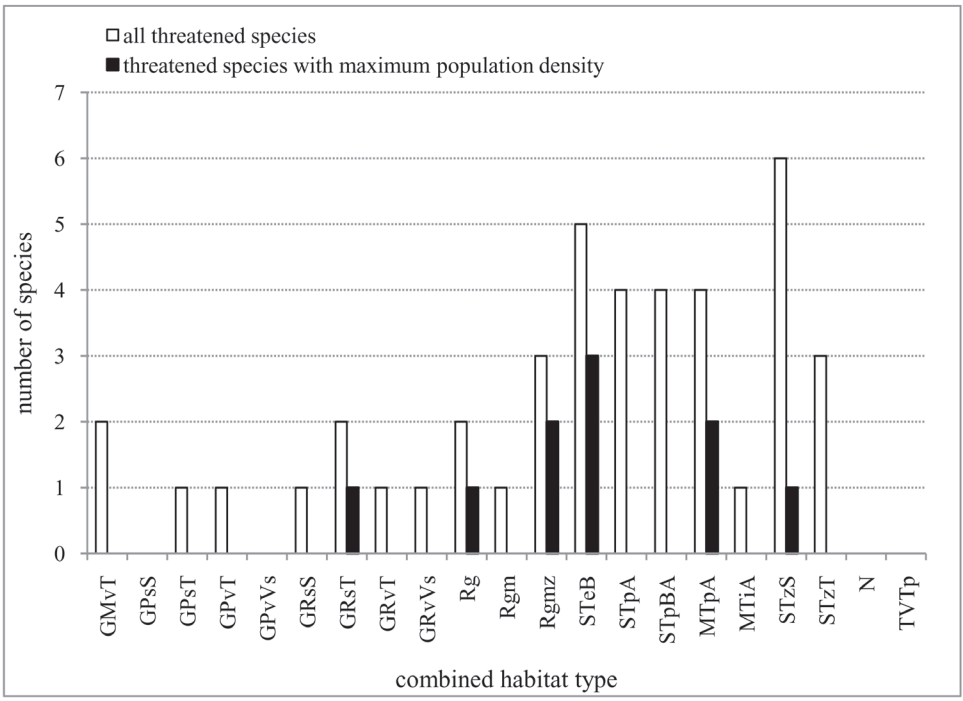


Figure 6: Importance of combined habitat types for threatened species recorded in transect lines along the River Sava between Krško and the state border in 2008. Combined habitat types inhabited by threatened species (white columns) and combined habitat types in which threatened species have maximum population densities (black columns) are shown. (for abbreviations of the combined habitat types, see Tab. 1)

Slika 6: Število ogroženih vrst po zbirnih habitatnih tipih v transektnih linijah ob reki Savi med Krškim in državno mejo v letu 2008. Belo obarvani stolpci označujejo zbirne habitatne tipe, ki jih poseljujejo ogrožene vrste, črno obarvani stolpci pa zbirne habitatne tipe v katerih imajo ogrožene vrste maksimalne populacijske gostote. (za razlago okrajšav zbirnih habitatnih tipov glej Tab. 1)

lanceolata) (SBN 1991, Tolman and Lewington 1997). The species ***P. argyrognomon*** was recorded in 2008 in only one location, in the southern part of the area, south of the settlement of Mihalovec, on extensive dry grassland with erect brome. The food plants of the caterpillars are crown vetch (*Coronilla varia*) and liquorice milkvetch (*Astragalus glycyphyllos*) (Ebert and Rennwald 1993b, Beneš 2002a). In research in 2001 (Rebeušek 2001), the species was found only in the northern part of the area, on the right bank of the Sava, east of the settlement of Brege. The species ***P. idas*** appears on extensive, semi-intensive and abandoned dry grasslands with erect brome. The caterpillars feed on various species of the legume family (Fabaceae), above all black medic (*Medicago lupulina*), red clover (*Trifolium pratense*), silky leaf woadwaxen (*Genista pilosa*), bird's-foot trefoil (*Lotus corniculatus*), honey clover (*Melilotus albus*), common kidney vetch (*Anthyllis vulneraria*), common broom (*Sarothamnus scoparius*) (Beneš 2002b), and common sea-buckthorn (*Hippophaë rhamnoides*) from the oleaster family (Elaeagnaceae) (Huemer 2004).

On semi-intensively managed grasslands seven threatened species were recorded, 2 of which achieve maximum population density on mesophilous grasslands (MTpA) (Tab. 2). The hygromesophilous species ***L. hippothoe*** was only recorded on mesophilous grassland with tall oat-grass south of the settlement of Loče.

The food plants of the caterpillars are common sorrel (*Rumex acetosa*) (Ebert and Rennwald 1993b, Weidenhoffer and Fric 2002), sheep's sorrel (*R. acetosella*) and bistort (*Polygonum bistorta*) (SBN 1991). The xerothermophilous species ***P. mannii*** appears on semi-intensive and abandoned dry grasslands and on mesophilous semi-intensive grasslands – such as are a mosaic of central European xerophilous lowland grasslands on relatively dry soils with erect brome and intensively cultivated grasslands. The caterpillars feed on garlic cress (*Peltaria alliacea*), candytuft species (*Iberis* spp.) as well as other species from the crucifer family (Brassicaceae) (SBN 1991, Beneš 2002c, Huemer 2004).

Ruderal areas are inhabited by 3 threatened species, which also achieve maximum population density in these habitats (Tab. 2). The mesophilous species ***A. ilia*** lives on light rides of riverine forests and on abandoned ruderal areas near the woody riverine vegetation. The food plants of the caterpillars are aspen (*Populus tremula*), black (*P. nigra*) and white (*P. alba*) poplar and willow, above all goat willow (*Salix caprea*) and white willow (*S. alba*) (Ebert and Rennwald 1993a, Vrabec 2002, Huemer 2004). The xerothermophilous species ***C. alceae*** inhabits abandoned dry grasslands and ruderal areas that are overgrown with shrubs and herb species, among which are the food plants of caterpillars. These are species from the mallow genus, mainly greater musk-mallow (*Malvea alcea*), musk mallow (*M. moschata*) and common mallow (*M. neglecta*) and common hollyhock (*Alcea rosea*) (Ebert and Rennwald 1993b, Beneš 2002d). The hygrophilous species ***L. dispar*** appears mainly in ruderal areas that are either predominantly bare and only partially overgrown with tall herbs or overgrown with shrubs and herbs, and on semi-intensively managed dry grasslands with tall oat-grass. The food plants of the caterpillars are water dock (*Rumex hydrolapathum*), Scottish dock (*R. aquaticus*), broad-leaved dock (*R. obtusifolius*), curled dock (*R. crispus*) and common sorrel (*R. acetosa*) (Ebert and Rennwald 1993b; SBN 1991).

On woodland edges three threatened species were recorded, the species ***Z. polyxena*** has the most numerous populations in these habitats (Tab. 2). It inhabits sunny woodland edges on both dry and moist ground, abandoned dry grasslands, semi-intensive mesophilous grasslands and extensive or semi-intensive dry grasslands, in which there are sunny hedges, which are favourable habitats for the food plants of the caterpillars - birthwort (*Aristolochia clematitis*).

Important areas for butterflies

The conservation evaluation of each combined habitat type based on the ranking of the combined habitat types according to six criteria (i.e. species richness, median of population densities of species observed in the treated combined habitat type, total population density, number of species with maximum population density in the treated combined habitat type, number of threatened species in the combined habitat type, number of threatened species with maximum population density in the treated combined habitat type) shows (Fig. 7) that 8 combined habitat types have median of ranks lower than 10,5. These combined habitat types are defined as most important for butterfly species in the study area. The difference in ranks between the combined habitat types with median of ranks lower than 10,5 and combined habitat with median of ranks higher than 10,5 is highly significant (Mann–Whitney $Z = -7.34$; $P<0.001$). The most important combined habitat types for butterflies in the study area are extensively managed dry grasslands (STeB), abandoned dry grasslands in early succession stages (STzS, STzT), semi-intensively managed dry grasslands with erect brome (*Bromopsis erecta*) and tall oatgrass (*Arrhenathereum elatius*) (STpBA), semi-intensively managed mesophilous grasslands with tall oatgrass (MTpA), ruderal areas overgrown with shrub and herb species (Rgmz) and dry woodland rides and edges in which allochtonous and autochtonous plant species are present (GPsT, GRsT).

On the basis of the distribution of the most important combined habitat types we identified four important areas for butterfly species in the study area: (1) Žadovinek–Brege, (2) Čateške Toplice–Prilipe, (3) Loče–Mihalovec and (4) Zgornji Obrež (Fig. 8). The number of species in important areas ranges between 57% (Loče–Mihalovec) to 84% (Žadovinek–Brege) of the species richness of the study area (Tab. 3). Considering the maximum population densities of

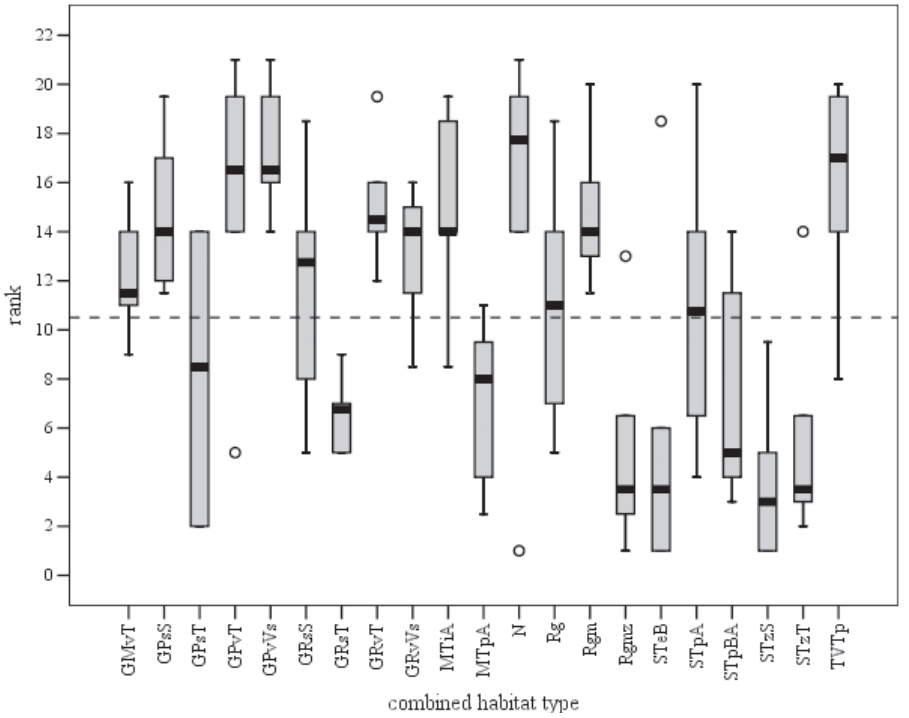


Figure 7: Nature conservation value of each combined habitat type in the study area along the River Sava between Krško and the state border, based on the ranking of the combined habitat types according to six criteria. (for explanation, see Data analysis; for abbreviations of the combined habitat types, see Tab. 1)

Slika 7: Naravovarstvena vrednost zbirnih habitatnih tipov v raziskovanem območju ob reki Savi med Krškim in državno mejo, ocenjena z rangiranjem zbirnih habitatnih tipov po šest kriterijih (za razlago glej poglavje Data analysis). (za razlago okrajšav zbirnih habitatnih tipov glej Tab. 1)

threatened species, the area Žadovinek–Brege is most important for two species (*M. aurelia*, *P. idas*), the area Čateške Toplice–Prilipe for four species (*A. ilia*, *C. alceae*, *P. mannii*, *L. dispar*), the area Loče–Mihalovec for two species (*L. hippothoe*, *P. argygnomon*), and the area Zgornji Obrež also for two species (*M. britomartis*, *Z. polyxena*) (Tab. 3).

Designated areas for butterflies are important (i) for preserving high butterfly species richness in the mainly intensively used agricultural landscape along the lower course of the River Sava between Krško and the state border with Croatia, and (ii) for preserving viable populations of threatened and other ecologically specialised, rare or locally distributed species (Tab. 3) and preventing their isolation in the region of sub-pannonian southeast Slovenia.

Acknowledgement

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Table 3: Important areas for butterfly species along the River Sava between Krško and the state border with Croatia. Species richness, number of threatened species, population densities and combined habitat types of threatened species, and other rare/local distributed species or ecological specialists are shown for each important area. Bold text indicates the maximum population density of threatened species in the important area. (for abbreviations of the combined habitat types, see Tab. 1)

Tabela 3: Vrstno bogastvo, število ogroženih vrst, populacijske gostote in zbirni habitatni tipi ogroženih vrst ter druge redke/lokalno razširjene/ekološko specializirane vrste v naravovarstveno pomembnih območjih za dnevne metulje ob reki Savi med Krškim in državno mejo s Hrvaško. S krepkim tiskom je označena maksimalna populacijska gostota ogrožene vrste v območju. (za razlago okrajšav zbirnih habitatnih tipov glej Tab. 1)

Name of important area	No. of species	No. of threatened species	Threatened species	Population density	Combined habitat type	Rare / local distrubuted species / ecological specialists
Žadovinek – Brege (3.9 km^2)	58	6	*Carcharodus alceae*	**0,02**	STzS	*Iphiclides podalirius, Melitaea didyma, Satyrium pruni, S. acaciae, Glaucopsyche alexis, Polyommatus bellargus, Aphantopus hyperantus, Heteropterus morpheus*
			Melitaea aurelia	**1,70**	STeB	
			Melitaea aurelia	0,50	GRsS	
			Melitaea aurelia	0,26	STzS	
			Melitaea aurelia	0,09	STzT	
			Melitaea aurelia	0,07	STpBA	
			Melitaea britomartis	**0,06**	STeB	
			Pieris mannii	**0,03**	STzS	
			Plebeius idas	**0,21**	STzS	
			Plebeius idas	0,09	STzT	
			Plebeius idas	0,09	STeB	
			Plebeius idas	0,07	STpBA	
			Zerynthia polyxena	**0,31**	STzT	
			Zerynthia polyxena	0,05	STeB	
Čateške Toplice - Prilipe (1.2 km^2)	48	7	*Apatura ilia*	**0,23**	Rgmz	*Iphiclides podalirius, Melitaea didyma, Satyrium spini, S. w-album, S. acaciae*
			Apatura ilia	0,15	GPvT	
			Apatura ilia	0,14	GRvT	
			Carcharodus alceae	**0,09**	Rgmz	
			Carcharodus alceae	0,06	GMvT	
			Lycaena dispar	**0,07**	STpA	
			Lycaena dispar	0,06	Rgmz	
			Melitaea aurelia	**0,48**	STpBA	
			Melitaea aurelia	0,26	MTpA	
			Melitaea aurelia	0,10	STpA	
			Melitaea britomartis	**0,10**	STpA	
			Pieris mannii	**0,16**	STpBA	
			Pieris mannii	0,11	MTpA	
			Zerynthia polyxena	**0,16**	MTpA	
			Zerynthia polyxena	0,15	STpA	
			Zerynthia polyxena	0,08	STpBA	
			Zerynthia polyxena	0,06	GMvT	

Loče - Mihalovec (1.1 km^2)	39	6	*Lycaena dispar*	**0,02**	MTpA	*Limenitis populi, Melitaea didyma*
			Lycaena hippothoe	**0,07**	MTpA	
			Melitaea britomartis	**0,10**	STeB	
			Pieris mannii	**0,13**	MTpA	
			Plebeius argyrognomon	**0,19**	STeB	
			Zerynthia polyxena	**0,05**	STeB	
			Zerynthia polyxena	0,03	MTpA	
			Zerynthia polyxena	0,03	GRvVs	
Zgornji Obrež (0.4 km^2)	49	3	*Melitaea aurelia*	**1,54**	STzS	*Iphiclides podalirius, Satyrium pruni, S. spini, S. w-album, Polyommatus bellargus, Aphantopus hyperantus, Heteropterus morpheus*
			Melitaea aurelia	0,84	STzT	
			Melitaea aurelia	0,17	GPsT	
			Melitaea aurelia	0,08	GRsT	
			Melitaea britomartis	**0,26**	STzS	
			Zerynthia polyxena	**0,58**	GRsT	
			Zerynthia polyxena	0,51	STzS	
			Zerynthia polyxena	0,07	STzT	

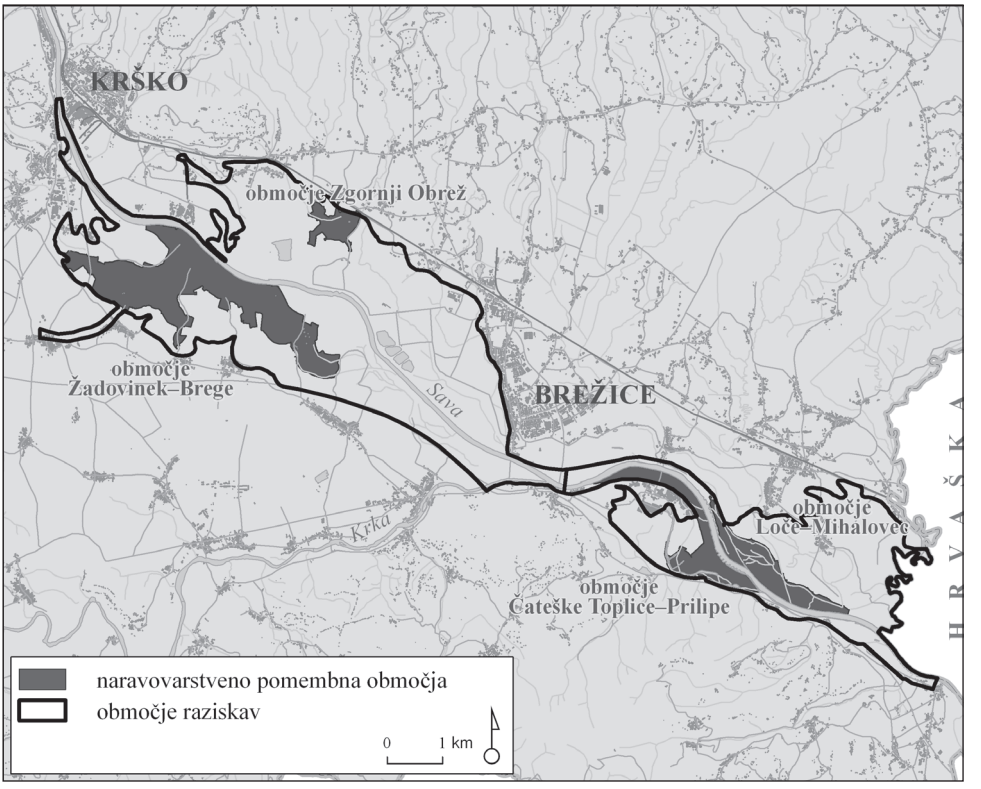

Figure 8: Important areas for butterfly species in the study area along the lower course of the River Sava between Krško and the state border with Croatia.

Slika 8: Naravovarstveno pomembna območja za dnevne metulje v raziskovanem območju ob spodnjem toku reke Save med Krškim in državno mejo s Hrvaško.

Povzetek

Dnevni metulji so ena izmed najpomembnejših nevretenčarskih bioindikatorskih skupin. So edini nevretenčarski takson za katerega je trenutno možno oceniti stopnjo upadanja številčnosti populacij in so reprezentativni indikatorji trendov opaženih pri večini kopenskih žuželk, ki predstavljajo približno dve tretjini vseh svetovnih vrst. Evropska okoljska agencija jih je, z namenom zmanjšanja upadanje biodiverzitete do leta 2010, v okviru projekta »**S**treamlining **E**uropean 2010 **B**iodiversity **I**ndicators« leta 2007 uvrstila med evropske biodiverzitetne indikatorje (SEBI 2010 Indicators), s katerimi se vrednoti splošne trende v stanju biodiverzitete v Evropi. Dnevni metulji so bili izbrani kot indikatorji za oceno stanja in trendov evropskih travišč (European Grassland Butterfly Indicator), ki so najpomembnejši habitati evropskih vrst dnevnih metuljev, saj jih poseljuje več kot polovica (280 vrst, 57%) evropskih vrst.

V južnem delu Ekološko pomembnega območja »Sava od Radeč do državne meje« (EPO Id: 63700), med Krškim in državno mejo s Hrvaško, smo v letu 2008 izvedli inventarizacijo favne dnevnih metuljev z namenom opredeliti naravovarstveno najpomembnejša območja za dnevne metulje v EPO. Raziskovano območje s površino 33 km^2 je obsegalo približno 1 km širok pas na obeh bregovih reke Save. Območje je pretežno kmetijska krajina, saj 66 % površine zavzemajo njive in različno gospodarjeni travniki. Prevladujejo njive in intenzivno gospodarjeni travniki (46 % površine raziskovanega območja), medtem ko ekstenzivno gospodarjeni suhi travniki in opuščena suha travišča v zgodnjih fazah zaraščanja zavzemajo le 7 % površine območja. Predvsem na vlažnih rastiščih (npr. gozdni robovi in poti, obrežja reke, gramoznic in mrtvic), so priostne invazivne alohtone rastlinske vrste, ki kot samostojni sestoji predstavljajo kar 2 % površine območja, v kombinaciji z drugimi habitatnimi tipi po so razširjene na veliko večji površini.

Favno dnevnih metuljev smo inventarizirali s standardizirano metodo transektnega popisa na 12 transektih. Na vsakem transektu smo šteli odrasle osebke v časovnem intervalu pribl. 14 dni (1x v aprilu, 2x v maju, 1x v juniju, 2x v juliju, 1x v septembru). Vsak transekt je bil razdeljen na odseke, vsak odsek je predstavljal določen zbirni habitatni tip. Na transektih s skupno dolžino 19,2 km smo opredelili 21 zbirnih habitatnih tipov. Z indeksom razširjenosti smo identificirali splošno razširjene ter redke/lokalno razširjene vrste v raziskovanem območju. V procesu opredelitve naravovarstveno pomembnih območij za dnevne metulje smo najprej ovrednotili zbirne habitatne tipe v transektih. Za določitev naravovarstvene vrednosti vsakega zbirnega habitatnega tipa smo uporabili naslednje parametre: vrstno bogastvo zbirnega habitatnega tipa, populacijska gostota vrste v zbirnem habitatnem tipu, celokupna populacijska gostota v zbirnem habitatnem tipu, število vrst z maksimalno populacijsko gostoto v zbirnem habitatnem tipu, število ogroženih vrst v zbirnem habitatnem tipu in število ogroženih vrst z maksimalmo populacijsko gostoto v zbirnem habitatnem tipu. S Kendallovim korelacijskim koeficientom smo ugotavljali povezanost med uporabljenimi parametri. Parametre smo uporabili kot kriterije v nadaljnem postopku evalvacije tako, da smo v okviru vsakega kriterija (parametra) zbirne habitatne tipe rangirali (od 1 do 21) glede na vrednost parametra. Rang 1 smo pripisali zbirnemu habitatnemu tipu z največjo in rang 21 (v primeru različnih rangov) zbirnemu habitatnemu tipu z najmanjšo vrednostjo parametra. Zbirne habitatne tipe z mediano vrednostjo rangov nižjo od 10, 5 smo definirali kot najpomembnejše za dnevne metulje. Naravovarstveno pomembna območja za dnevne metulje smo nato opredelili na podlagi razširjenosti najpomembnejših zbirnih habitatnih tipov v raziskovanem območju, pri čemer smo vključili tudi habitatne tipe (podobne po floristični sestavi in strukturi vegetacije ter gospodarjenju najpomembnejšim zbirnim habitatnim tipom) izven transektnih linij.

Zabeležili smo 69 vrst dnevnih metuljev (38 % favne dnevnih metuljev Slovenije), med njimi 10 v nacionalnem ali evropskem merilu ogroženih vrst (*A. ilia*, *C. alceae*, *L. dispar*, *L. hippothoe*, *M. aurelia*, *M. britomartis*, *P. manni*, *P. argyrognomon*, *P. idas*, *Z. polyxena*). 19 vrst je splošno razširjenih (ekološko nespecializirane vrste), 21 vrst je redkih/lokalno razširjenih, med njimi je 6 ogroženih vrst. Vrstno najbogatejši zbirni habitatni tipi so ekstenzivno gospodarjeni suhi travniki (48 vrst), opuščena suha travišča

(46 oz. 41 vrst), polintenzivno gospodarjeni suhi travniki (40 vrst) in vlažne gozdne poti (36 vrst). Registrirane vrste imajo največje populacijske gostote na ekstenzivnih, polintenzivnih in zaraščajočih se suhih travnikih (24 vrst), na ruderalnih površinah (18 vrst), na gozdnih poteh (13 vrst) in gozdnih robovih (8 vrst). Na intenzivno gospodarjenih travnikih, njivah ter vlažnih gozdnih robovih in poteh nobena vrsta nima najštevilčnejših populacij. Največje populacijske gostote imajo splošno razširjene travniške vrste (*M. galathea*, *C. arcania*, *M. jurtina*, *M. dryas*, *T. lineola*, *C. crocea*, *M. athalia*, *C. pamphilus*). Primerjava maksimalnih populacijskih gostot med vrstami kaže, da v raziskovanem območju živijo pomembne populacije dveh ogroženih vrst, *M. aurelia* in *Z. polyxena*, ter ekološko specializirane vrste *S. w-album*. Ogrožene vrste imajo največje populacijske gostote na ekstenzivnih in zaraščajočih se suhih travnikih, mezofilnih polintenzivno gospodarjenih travnikih, ruderalnih združbah in na suhih gozdnih robovih.

Osem zbirnih habitatnih tipov je z naravovarstvenega vidika najpomembnejših za dnevne metulje v raziskovanem območju, to so: ekstenzivno gospodarjeni suhi travniki, opuščena suha travišča v zgodnjih fazah zaraščanja, polintenzivno gospodarjeni travniki s pokončmim stoklascem in visoko pahovko, polintenzivno gospodarjeni mezofilni travniki z visoko pahovko, ruderalne površine zaraščajoče se z grmovjem in zeliščnimi vrstami ter gozdni robovi in poti na suhih rastiščih. Na podlagi njihove razširjenosti smo v raziskovanem območju opredelili 4 naravovarstveno pomembna območja za dnevne metulje (Žadovinek–Brege, Čateške Toplice–Prilipe, Loče–Mihalovec in Zgornji Obrež), s skupno površino 6,6 km^2. Število vrst v predlaganih območjih dosega 57 % (Loče–Mihalovec) do 84 % (Žadovinek–Brege) vrstnega bogastva raziskovanega območja. Upoštevaje maksimalno populacijsko gostoto ogroženih vrst v predlaganih območjih, je območje Žadovinek–Brege najpomembnejše za dve vrsti (*M. aurelia*, *P. idas*), območje Čateške Toplice–Prilipe za štiri vrste (*A. ilia*, *C. alceae*, *P. mannii*, *L. dispar*), območje Loče–Mihalovec za dve (*L. hippothoe*, *P. argygnomon*) in območje Zgornji Obrež za dve ogroženi vrsti (*M. britomartis*, *Z. polyxena*). Predlagana območja so pomembna za ohranjanje razmeroma velikega vrstnega bogastva dnevnih metuljev v pretežno intenzivno obdelani kmetijski krajini ob reki Savi med Krškim in državno mejo, in za ohranjanje viabilnih populacij ogroženih in drugih ekološko specializiranih, redkih ali lokalno razširjenih vrst ter preprečevanje njihove izoliranosti v območju subpanonske JV Slovenije.

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