NAT. CROAT. | VOL. 19 | No 1 | 165–177 | ZAGREB | June 30, 2010

original scientific paper/izvorni znanstveni rad

FLORA AT SOME PIT AND CAVE ENTRANCES OF ŽUMBERAK, CROATIA

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Buzjak, S., Kletečki, N., Mitić, B. & Vujnović, T.: Flora at some pit and cave entrances of Žumberak, Croatia. Nat. Croat., Vol. 19, No. 1, 165–177, 2010, Zagreb.

This study presents results of floristic research into the entrances of seven speleological features of Žumberak, i.e. of three pits and four caves. One of them lies in Upper Triassic dolostones, three in Upper Cretaceous flysch and carbonate sediments, two in Badenian limestone and one in Quarternary travertine sediments. The flora was inventoried at the entrance areas and at different distances from the entrances into the speleological features. The recorded plants were analyzed both taxonomically and regarding the abundance in the type habitats (pit, cave). Furthermore, similarity between habitats (Sörensen index of similarity), ecological indicatory values and life forms were analyzed as well.

Key words: Žumberak, pit and cave entrances, flora

Buzjak, S., Kletečki, N., Mitić, B. & Vujnović, T.: Flora ulaznih dijelova nekih jama i spilja Žumberka (Hrvatska). Nat. Croat., Vol. 19, No. 1, 165–177, 2010, Zagreb.

U ovom radu prikazani su rezultati floristićkih istraživanja ulaznih prostora sedam speleoloških pojava na prostoru Žumberka (tri jame i četiri spilje) od kojih je jedna u gornjotrijaskim dolomitima, tri u gornjokrednim fliškim i karbonatnim naslagama, dvije u badenskim vapnencima i jedna u kvartarnim sedrenim sedimentima. Inventarizirana je flora na prostorima oko ulaza, te na različitim udaljenostima od ulaza. Zabilježene biljke podvrgnute su: taksonomskoj analizi, analizi zastupljenosti prema tipu staništa (jama, spilja), sličnosti između staništa (Sörensenov koeficijent sličnosti), te analizi ekoloških indikatorskih vrijednosti i životnih oblika.

Ključne riječi: Žumberak, ulazi jama i spilja, flora

INTRODUCTION

Žumberak is a distinct area situated partly in NW Croatia and partly in Slovenia. Its height ranges from 180 to 1178 m a. s. l., with the highest peak of Sveta

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Gera. The largest part of this area is karstic with numerous surface and underground karst relief forms, with over 150 recorded speleological features (pits and caves) (BUZJAK, 2006).

The geologic structure of the terrain is dominated by sedimentary rocks ranging stratigraphically from Mid-Upper Permian ($P_{2,3}$) to recent Quarternary (Q) alluvial and travertine sediments. The largest part of Žumberak is covered by Upper Triassic (T_3) sediments, dominated by dolostones and Upper Cretaceous sediments (K_2) in the form of carbonate-clastic flysch and limestone.

Due to its predominantly carbonate structure, this terrain tends to karst forming. Structurally, this is a boundary between the Inner Dinarides and the Zagorje-Mid-transdanubian shear zone, overthrusting on the External Dinarides (PAMIĆ & TOMLJENOVIĆ, 1998). The area of Žumberak is characterized by a moderately warm, rainy climate without an extremely dry period. Winters are the most arid part of the year with the precipitation peak in June. The mean temperatures of the coldest month in this area range from –4°C to +0.4°C, the mean temperature of the warmest month is about 21°C, which suggests cool summers, and seven months of the year have temperatures over 10°C (April to October) (PENZAR & PENZAR, 1982).

The relief affects wind directions, so most winds blow from the west and southwest (ŠUGAR, 1972). Žumberak is situated at the transition between the SE Alps and the NW Dinarides and in the phytogeographical aspect it represents a bridge between the Alps and the Dinarides (TRINAJSTIĆ, 1995). The largest part is covered by forests. Forests of sessile oak and common hornbeam (*Epimedio-Carpinetum betuli* (Ht. 1938) Borhidi 1963) are predominant in the lower mountain area, forests of pubescent oak and hop hornbeam (*Ostyro-Quercetum pubescentis* (Ht. 1950) Trinajstić 1979) grow on the steeper, warm slopes, while beech forests cover the highest areas (*Fagion illyricum* Horv. 1938). Only a small part of grass areas are of natural origin, and all other areas (mostly meadows and grasslands) are a result of deforestation.

MATERIAL AND METHODS

The flora was inventoried in the area of Žumberak around the entrances and at different distances from the entrance of seven speleological features; three pits (Puhaljka – PU, Tomaševićka – T and Jama na dugom bregu obr Gabrovice – G) and four caves (Spilja u kamenolomu – K, Propuh – P, Vilinske jame – V and Židovske kuće – Ž). The speleological features studied are shown on the geological map of the »Žumberak – Samoborsko gorje« Nature Park (Fig. 1), made in accordance with the Basic Geological Map of SFRJ – Zagreb sheet (ŠIKIĆ *et al.*, 1977) and Novo Mesto sheet (PLENIČAR *et al.*, 1975). The key to geological units on Fig. 1 covers only the age and sorts of rocks near the studied speleological features. The data for the geological substrata for Jama Tomaševićka pit and the caves Židovske kuće and Vilinske jame were obtained by terrain survey, and for the rest of the features from the mentioned map.

Vilinske jame is actually the name for a cave, a few smaller half-caves and wider cracks. They are situated near Tušin at 290 m a. s. l. (BUZJAK, 2001). The cave entrance faces SE, it is 4 m wide and 2.3 m high, sheltered by trees and bushes (Fig. 2). There is another entrance impenetrable for a grown-up person. Morpho-

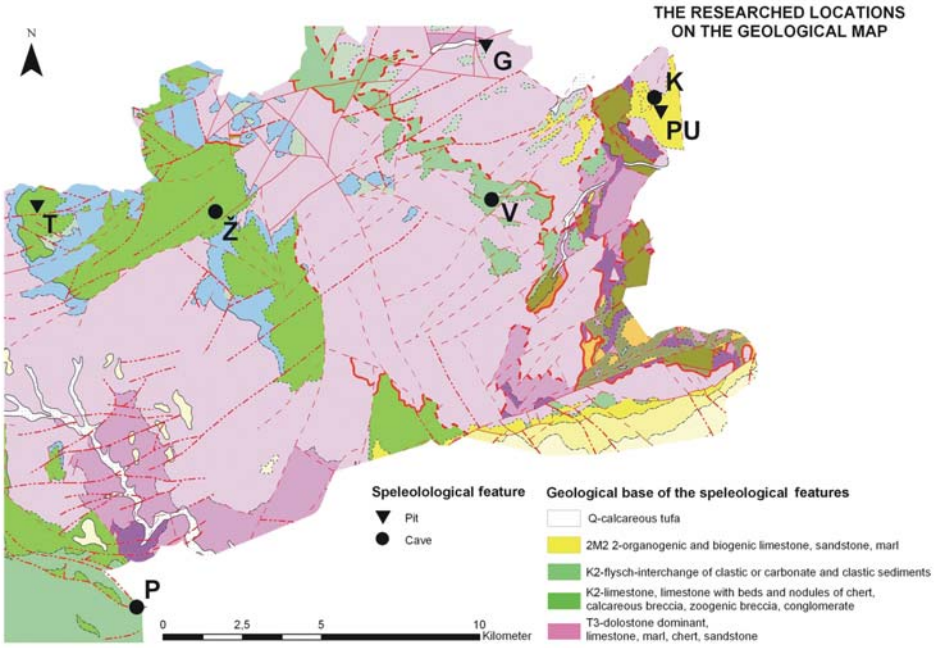

Fig. 1. The researched speleological features on the geological map of the »Žumberak-Samoborsko gorje« Nature Park: Propuh cave – P, Tomaševićka pit – T, Židovske kuće – Ž, Jama na dugom bregu obr Gabrovice pit – G, Spilja u kamenolomu cave – K, Puhaljka pit – P, Vilinske jame cave – V.

logically it is a simple cave. Vilinske jame were formed in the youngest sediments – Quarternary travertine or calc-tufa. According to its chemical structure travertine is a calcite ($CaCO_3$) and as such it has a cleaner mineral composition than the geological bases of the other speleological features researched. The immediate surroundings of the cave are covered by Upper Triassic dolostones and Upper Cretaceous carbonate sediments.

The Propuh cave is situated in the vicinity of the village of Radine Gorice at 179 m a. s. l. It is morphologically a simple cave, 19 m long, with two entrances.

One entrance faces west; it is 6.4 m wide and 2 m high. The other entrance faces east and is 3.9 m wide and 2 m high (BUZJAK & RAŠIĆ, 2005). The west entrance is at the edge of a meadow overgrown by hornbeam and hazel trees. The east entrance is situated in a blind valley inside a beech forest. The cave is formed in Upper Cretaceous (K_2) flysch, which is characterized by alternating clastic or carbonate and clastic sediments. These sediments are considered poorly permeable and are often covered by vineyards because of the suitable soil, its thickness and favourably sloping terrain.

The Tomaševićka pit is a simple pit, 44 m deep with the pit entrance 4×7 m in diameter. It is situated 2.4 km NW of the village Grič (N. BUZJAK, 2001) in a multi-stemmed beech coppice, at 905 m a. s. l.

Fig. 2. The Vilinske jame cave (Photo: N. Kletečki)

The Židovske kuće cave is a multi-level cave, 31 m long and 8 m deep with the entrance 7×5 m in diameter (Fig. 3). It is situated in the vicinity of Budinjak (N. BUZJAK, 2001), in a beech forest at 741 m a.s.l.

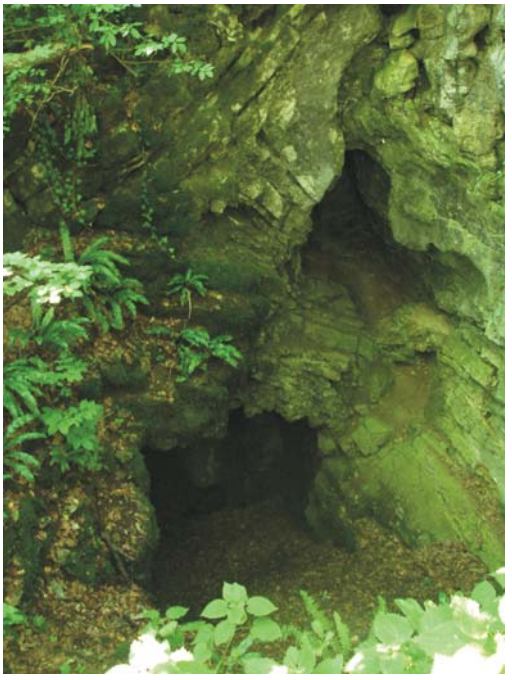

Fig. 3. The Židovske kuće cave (Photo: N. Buzjak)

Fig. 4. The Jama na dugom bregu obr Gabrovice pit (Photo: S. Buzjak)

The Tomaševićka pit and the Židovske kuće cave were formed in Upper Cretaceous (K_2) carbonate rocks of a very heterogeneous lithologic structure: calcareous breccia, zoogenic breccia with limestone interbeds, conglomerates, limestone with interbeds and nodules of chert. The site survey of both speleological features determined the geological base of layered limestone with chert interbeds.

The Jama na dugom bregu obr Gabrovice pit is a simple pit formed in Upper Triassic (T_3) dolostones, which are considered well water permeable. Its length is 7.7 m and the entrance opening dimensions are 1.4×1.2 m (Fig. 4). The pit is situated near Gabrovica in a beech forest at 350 m a. s. l. The ground around the pit is extremely thin because of the strong sloping of the terrain.

The Spilja u kamenolomu cave is situated in the vicinity of Otruševec at 247 m a. s. l. at the edge of a hornbeam forest. The dimensions of the entrance opening are 0.8×1.0 m and it faces NW. It is a 60 m long multi-level cave.

The Puhaljka pit is situated in the vicinity of the Spilja u kamenolomu cave at 252 m a. s. l. at the edge of a hornbeam forest. The dimensions of the entrance opening are 0.22×0.15 m.

The Puhaljka pit and the Spilja u kamenolomu cave were formed in marine calcareous sediments of the Upper Tortonian, that is Badenian ($_2M_2^2$). These are breccias, conglomerates, calcareous sandstone, marl, lithothamnium limestone as well as clayish-sandy calcareous marls. Both these speleological features were most probably formed in biogenic lithothamnium limestone, which contains a high percentage of $CaCO_3$ (93 %) and has a high porosity, so there is an extreme tendency to karst formation.

The plants at the entrance areas were inventoried in different vegetation periods of 1997, 1998, 2002, 2003, 2005, and 2007. The plants which could not be determined on site were collected and subsequently determined, and part of the material was

inventoried and deposited in the Herbarium Collection of the Croatian Natural History Museum (CNHM) in Zagreb.

Standard keys and iconographies were used for determination of the species (DOMAC, 1994; HORVATIĆ & TRINAJSTIĆ, 1976–1981; JAVORKA & CSAPODY, 1991; PIGNATTI, 1982; TRINAJSTIĆ, 1975–1986; TUTIN *et al.*, 1964–1980, 1993). Taxon nomenclature was adjusted with Flora Croatica Database (FCD) (NIKOLIĆ, 2010). The recorded plants were analyzed both taxonomically and by their abundance in the type habitats (Sörensen index of similarity, SMITH, 1986), and the life forms and ecological indicatory values were also analyzed. The protected taxa have been singled out according to the Nature Protection Act (ANON., 2005 and 2008) and Regulation for proclaiming the wild taxa protected and strictly protected (ANON., 2009). Life forms and ecological indicatory values for the majority of taxa have been determined according to LANDOLT (1977). Ecological indicatory values for the taxa not found in the mentioned work were determined according to the phytocenological connections to other species, based on the affinity and personal experience, while life forms for only a few species were determined according to PIGNATTI (1982). For the presentation of life forms we used the following abbreviations:

Geophyta	G
Hemicryptophyta	H
Therop./Hemicryp.	T/H
Therophyta	T
Phanerophyta	P
Chamaephyta	Ch

We analyzed the following ecological indicatory values:

The soil moisture (F) – shows the average moisture of the ground during the vegetation period. Lower values indicate lower moisture, and higher values indicate higher moisture of the ground.

Soil reaction (R) – indicates the content of free H-ions in the ground. Lower values indicate acid soils and higher values indicate alkaline soils.

The light value (L) – indicates the average light intensity necessary for the growth of the plant during the vegetation period. Lower values indicate a lower, and higher values indicate a higher necessity for light.

The temperature (T) – determines (based on the sea level at which the plant grows) the average temperature to which the plant is exposed during the vegetation period. Lower values indicate the distribution of the species at higher altitudes (at lower temperatures), and higher values indicate the plants growing in the lowlands (at higher temperatures).

Continentality (K) – gives information about daily and yearly temperature fluctuations and air humidity which a plant tolerates. Lower values indicate minor temperature fluctuations, and high air humidity, while higher values indicate major temperature changes and low air humidity.

Nutritional value of the soil – determines the nutritional contents of the soil (especially nitrogen). Lower values indicate low and higher values high nutritional soil contents.

RESULTS AND DISCUSSION

We recorded 80 plant taxa, 23 of which (28.75%) belong to the protected Croatian flora (Tab. 1). The Propuh cave has the greatest number of taxa (33) and the Jama na dugom bregu obr Gabrovice pit has the smallest number (9).

Tab. 1. The list of the taxa recorded according to their habitats: Propuh cave – P, Tomaševićka pit – T, Židovske kuće cave – Ž, Jama na dugom bregu obr Gabrovice pit – G, Spilja u kamenolomu cave – K, Puhaljka pit – P, Vilinske jame cave – V.
*The taxa in bold are protected by the Nature Protection Act

No.	LIST OF PLANTS	P	T	Ž	G	K	PU	V
1	*Acer campestre* L.			+				
2	*Adoxa moschatellina* L.	+		+				
3	*Allium ursinum* L.					+		
4	***Anemone nemorosa* L.**	+				+	+	
5	*Aposeris foetida* (L.) Less.			+			+	+
6	***Arum maculatum* L.**	+						
7	***Asarum europaeum* L.**	+		+		+	+	+
8	*Asplenium ruta-muraria* L.							+
9	*Asplenium scolopendrium* L.	+	+	+	+	+		+
10	*Asplenium trichomanes* L.	+	+	+		+		+
11	***Asplenium trichomanes-ramosum* L.**					+		
12	*Athyrium filix-femina* (L.) Roth.		+					
13	*Barbarea vulgaris* R. Br.	+						
14	***Caltha palustris* L.**	+						
15	*Cardamine impatiens* L.	+						
16	*Carex digitata* L.	+						
17	*Carex hirta* L.					+		
18	*Chrysosplenium alternifolium* L.		+					
19	*Cornus sanguinea* L.	+						
20	*Corylus avellana* L.	+		+		+	+	+
21	***Crocus vernus* (L.) Hill ssp. *vernus***						+	
22	***Cyclamen purpurascens* Mill.**	+		+	+			+
23	*Cystopteris fragilis* (L.) Bernh.	+						
24	***Dryopteris filix-mas* (L.) Schott**		+					
25	*Epimedium alpinum* L.					+	+	
26	*Eupatorium cannabinum* L.		+					
27	*Fagus sylvatica* L.		+	+				
28	*Fragaria moschata* Duchesne			+				
29	*Fragaria vesca* L.					+		+
30	***Galanthus nivalis* L.**	+						
31	***Galium odoratum* (L.) Scop.**			+				
32	*Galium* sp.		+					
33	***Geranium robertianum* L.**	+		+				
34	*Glechoma hederacea* L.							+

35	*Glechoma hirsuta* Waldst. et Kit.	+		+				
36	*Hedera helix* L.	+	+	+	+		+	
37	***Helleborus odorus* Waldst. & Kit. ex Willd.**						+	
38	*Heracleum sphondylium* L			+				
39	*Isopyrum thalictroides* L.	+						
40	*Lactuca* sp.		+					
41	*Lamium galeobdolon* (L.) L.			+	+			
42	*Lamium maculatum* L.		+					
43	*Lamium orvala* L.	+		+				
44	*Lathyrus vernus* (L.) Bernhardt							+
45	*Mercurialis perennis* L.	+		+	+			+
46	*Moehringia trinervia* (L.) Clairv.	+						
47	*Mycelis muralis* (L.) Dumort.	+	+	+				
48	*Myosoton aquaticum* (L.) Moench	+						
49	*Ostrya carpinifolia* Scop.						+	
50	***Oxalis acetosella* L.**	+	+					
51	*Oxalis dillenii* Jacq.	+						
52	*Picea abies* (L.) Karsten				+			
53	***Polypodium vulgare* L.**	+		+				
54	*Polystichum aculeatum* (L.) Roth		+	+		+		
55	***Polystichum illyricum* Borbas**	+			+			
56	*Polystichum lonchitis* (L.) Roth		+					
57	*Polystichum setiferum* (Forssk.) Woynar				+			
58	*Potentilla micrantha* Ramond ex DC.			+				
59	*Prenanthes purpurea* L.		+					
60	*Primula vulgaris* Huds.							+
61	*Pulmonaria officinalis* L.	+		+			+	
62	*Quercus cerris* L.			+				
63	***Ranunculus ficaria* L.**						+	
64	***Ranunculus lanuginosus* L.**	+	+					
65	***Rosa* sp.**			+				
66	*Rubia peregrina* L.		+					
67	*Rubus hirtus* Waldst. & Kit.		+	+				
68	*Salvia glutinosa* L.		+					
69	*Sambucus nigra* L.							+
70	***Sambucus racemosa* L.**			+				
71	***Sanicula europaea* L.**			+			+	
72	*Scilla bifolia* L.			+				
73	***Scrophularia nodosa* L.**	+						
74	*Senecio ovatus* (P.Gaertn., B.Mey. et Scherb.) Willd.		+					
75	*Stellaria media* (L.) Vill.			+				
76	***Symphytum tuberosum* L.**	+		+			+	
77	*Taraxacum officinale* Weber	+						
78	*Urtica dioica* L.							+
79	***Vinca minor* L.**						+	
80	*Viola* sp.			+	+			
	TOTAL:	33	21	32	9	11	14	14

The Propuh cave has two horizontal entrance areas which lie in different vegetation stands, and the Jama na dugom bregu obr Gabrovice pit has only one vertical entrance area, which is smaller than the entrance areas of the Propuh cave. The morphology of the entrance area and the different vegetation stands probably have the strongest influence on the number of taxa recorded. Larger entrance areas enable more light to reach the plants in the pits and caves, so they can grow further from the entrances. Some earlier studies already showed how the morphology of the entrance (form and size in the first place), as well as the vegetation zone in which the speleological features are situated, determine the floristic composition and the abundance of the species which grow at the entrance parts of caves and pits (FIEDLER & BUZJAK, 1998; S. BUZJAK, 2001, BUZJAK & VRBEK, 2001).

From all the recorded taxa the greatest number of families (32), genera (59), and species (68) belong to the division of spermatophytes (Tab. 2). Within the mentioned division, the class Magnoliopsida stands out regarding abundance, with 63 taxa, and within the mentioned class the *Ranunculaceae* and *Lamiaceae* families stand out with 6 species each. The family *Ranunculaceae* also stands out in the number of protected species (5 out of 6 recorded). Four species of the class Filicopsida in the division Pteridophyta are protected by the Nature Protection Act. Two of the mentioned species belong to the family *Dryopteridaceae*, which, with 5 species, is best represented within the mentioned class.

Tab. 2. Presence of individual taxonomic categories in researched habitats

	Family	Genus	Species
PTERIDOPHYTA	4	6	12
SPERMATOPHYTA			
Gymnospermae	1	1	1
Angiospermae			
– *Magnoliopsida*	28	54	63
– *Liliopsida*	3	4	4
Total	36	65	80

Using the Sörensen index of similarity, we noticed the greatest floristic similarity between the caves Propuh and Židovske kuće (0,46) and the lowest between the pits Tomaševićka and Puhaljka (0.06) (Tab. 3). We recorded as many as 15 common species at the Propuh and Židovske kuće caves, and only 1 common species on the locality of the Tomaševićka and Puhaljka pits (*Hedera helix* L.). The low similarity of the mentioned speleological features is probably due to their location in different forest stands and at different sea levels (Tomaševićka pit at 905 m a. s. l. in a forest of multi-stemmed beech coppice, and Puhaljka pit at 252 m a.s.l. at the edge of a hornbeam forest).

Analyzing the ecological indices, we noticed equable values for all speleological features except the light index (Tab. 4). Jama na dugom bregu obr Gabrovice pit, with a light index of 1.57, shows the smallest value because it is a very shady habitat where the smallest number of taxa was recorded. The species *Hedera helix* was

Tab. 3. Sörensen index of similarity for plant species depending on their habitat

	Propuh	Tomaševićka	Židovske kuće	Spilja u kamenolomu	Gabrovica	Puhaljka	Vilinske jame
Propuh	–	0.22	0.46	0.23	0.24	0.25	0.25
Tomaševićka		–	0.26	0.12	0.13	0.06	0.11
Židovske kuće			–	0.19	0.29	0.3	0.3
Spilja u kamenolomu				–	0.1	0.32	0.4
Gabrovica					–	0.09	0.26
Puhaljka						–	0.21
Vilinske jama							–

Tab. 4. Mean ecological index values according to Landolt

	L	T	K	F	R	N
Propuh	2.47	3.46	2.53	3.21	3.22	3.28
Tomaševićka	2.22	3.17	2.5	3.22	3.05	3.33
Židovske kuće	2.31	3.65	2.48	3.03	3.21	3.17
Spilja u kamenolomu	1.57	3.57	2.14	3.14	3.33	2.86
Gabrovica	2.5	3.4	2.4	3.1	3.3	2.8
Puhaljka	2.17	3.75	2.25	2.92	3.42	3.08
Vilinske jama	2.57	3.43	2.5	2.07	3.43	3.07
UKUPNO	2.25	3.48	2.51	3.13	3.18	3.25

L – light value, T – temperature, K – continentality, F – soil moisture, R – soil reaction, N – nutritional value

not recorded only in Spilja u kamenolomu cave and Vilinske jame cave, i.e. in speleological features where the ecological light index shows the highest values. The light index for *Hedera helix* is 2, which determines a plant that needs shade and grows in shady places with mostly 3 – 10% relative light exposure. All the speleological features investigated are characterized by shadiness, moderate soil moisture and nutritional value and low soil acidity.

Analyzing the life forms (Fig. 5), we determined that 48% of the taxa are hemicryptophytes and 21% are geophytes. All the other forms recorded range from 1 – 5 %. This corresponds to the climate of the entire researched area – moderate climatic zone, where more than half of the species belong to hemicryptophytes.

CONCLUSIONS

We researched three pits and four caves. One of them lies in Upper Triassic dolostones, three in Upper Cretaceous flysch and carbonate sediments, two in Badenian limestone and one in Quarternary travertine sediments. At the entrance areas of the speleologic features investigated, 80 plant taxa were recorded altogether, 23 (28.75%) of them are the taxa protected by the Nature Protection Act. The great-

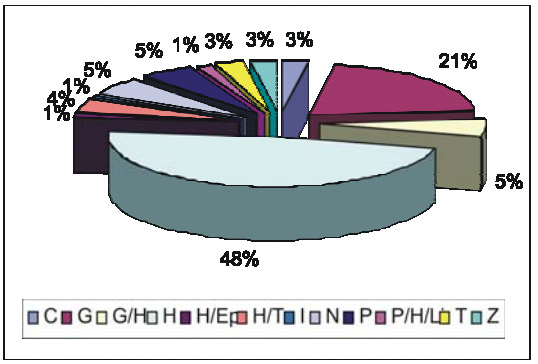

Fig. 5. Life forms of the recorded taxa in the researched habitats

est number of families, genera and species belong to the Spermatophyta division. Propuh cave has the greatest (33) and Jama na dugom bregu obr Gabrovice pit the smallest number of taxa (9). The greatest floristic similarity was noticed between the Propuh and Židovske kuće caves, and the lowest between the Tomaševićka and Puhaljka pits. All the researched speleological features are characterized by shadiness, moderate soil moisture and nutrition value, and low soil acidity. Life form analysis has determined that as many as 48% of the taxa belong to hemicryptophytes, and 21% to geophytes. Floristic similarities and differences, as well as the number of taxa recorded at particular speleological features are highly correlated with the morphology of the entrance area and the ecological factors affected by it, as well as the vegetation stands where the features are situated.

Received March 23, 2010

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SAŽETAK

Flora ulaznih dijelova nekih jama i spilja Žumberka (Hrvatska)

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Na području Žumberka inventarizirana je flora na prostorima oko ulaza te na različitim udaljenostima od ulaznog dijela u sedam speleoloških pojava, tri jame (Puhaljka, Tomaševićka i Jama na dugom bregu obr Gabrovice) i četiri spilje (Spilja u kamenolomu, Propuh, Vilinske jame i Židovske kuće), od kojih je jedna u gornjotrijaskim dolomitima, tri u gornjokrednim fliškim i karbonatnim naslagama, dvije u badenskim vapnencima i jedna u kvartarnim sedrenim sedimentima. Biljke su popi-

sivane u različitim vegetacijskim sezonama 1997., 1998., 2002., 2003., 2005. i 2007. godine. Na istraživanom području ukupno je zabilježeno 80 svojti biljaka koje su rasle na ulaznim prostorima istraživanih speleoloških pojava. Od svih zabilježenih svojti odjelu Spermatophyta pripada najveći broj porodica, rodova i vrsta. Najvećim brojem svojti ističe se spilja Propuh, a najmanjim Jama na dugom bregu obr Gabrovice. Najveću floristička sličnost uočili smo između spilja Propuh i Židovskih kuća, a najmanju između jama Tomaševićke i Puhaljke. Analizom ekoloških indeksa uočili smo njihove ujednačene vrijednosti kod svih speleoloških pojava s izuzetkom indeksa za osvjetljenje koji je najmanji kod Jame na dugom bregu obr Gabrovice koja se nalazi na najzasjenjenijem staništu. Sve istraživane speleološke pojave obilježava zasjenjenost, umjerena vlažnost i hranjivost te slaba kiselost tala. Analizom životnih oblika utvrdili smo kako 48% svojti pripada hemikriptofitima, 21% geofitima. Florističke sličnosti i razlike, kao i broj zabilježenih svojti u pojedinim speleološkim pojavama usko su povezani s morfologijom ulaznog prostora i njime uvjetovanim ekološkim čimbenicima.