

SPELEOBOTANICAL RESEARCH INTO THREE CAVES ON THE ISLAND OF RAB (CROATIA)

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Buzjak, S. & Vrbe, M: Speleobotanical research into three caves on the island of Rab (Croatia). Nat. Croat., Vol. 10, No. 3., 185–196, 2001, Zagreb.

During 1998, research was done into the flora of and certain ecological factors (temperature and relative humidity) in the entrance parts of three caves on the island of Rab. The caves lie in different vegetation zones and at different altitudes. In all, 32 kinds of plant were recorded: 29 spermatophytes and 3 pteridophytes. In comparison with research carried out in two of the caves at the beginning of the century, a change had occurred in the floristic composition. Particularly noteworthy is the reduction in the number of fern species in the interior of the cave.

Keywords: speleobotany, the island of Rab, ecological factors, flora, cave

Buzjak, S. & Vrbe, M: Speleobotaničko istraživanje triju spilja na otoku Rabu (Hrvatska). Nat. Croat., Vol. 10, No. 3., 185–196, 2001, Zagreb.

Tijekom 1998. godine istraživana je flora i neki ekološki čimbenici – temperatura i relativna vlaga zraka u ulaznim dijelovima triju spilja na otoku Rabu. Spilje se nalaze u različitim vegetacijskim zonama i na različitim nadmorskim visinama. Ukupno su zabilježene 32 vrste biljaka – 29 vrsta sjemenjača i 3 vrste papratnjača. U usporedbi s istraživanjima koja su provedena u dvije od tih spilja na početku 20. stoljeća zabilježene su promjene u florističkom sastavu. Posebno se ističe smanjenje broja vrsta papratnjača u unutrašnjosti spilja.

Ključne riječi: speleobotanika, otok Rab, ekološki čimbenici, flora, spilje

INTRODUCTION

The speleobotanical research into flora and certain ecological factors begun in 1995 in Velebit (VRBEK & FIEDLER, 2000) has been extended to other parts of the Croatian karst region. This work will discuss the flora of and certain ecological factors in three caves on the island of Rab. Two of them (Spilja na rtu Frkanj and Spilja iznad Jamine Drage) were investigated from the point of view of flora at the beginning of the 20th century by MORTON (1914), while HORVATIĆ (1939) did phytocenological research into Spilja na rtu Frkanj.

THE POSITION AND CLIMATE OF THE ISLAND OF RAB

Rab Island belongs to the Kvarner archipelago (Fig. 1). It runs parallel with the coast in the north-west to south-east direction (the Dinar line). The total area of the island comes to 93.6 km², its length is 22 km, and in width it varies from 3 to 10 km. In the Köppen classification the island's climatic type is Cfsax – transitional climate between maritime and continental. This is a moderately warm, rainy climate, with summers with a mean monthly temperature above 22 °C. The coldest month on the island of Rab is January (7.1 °C), and the hottest is July with a mean of



Fig. 1. Position of the island of Rab and the caves investigated

23.7 °C. The lowest relative humidity of the air also comes in July (59%), while November and December with 70% relative humidity in the air are the wettest months. Rab has no period of drought, but in June and July has a period of dryness, while September, October, November and December are on average the rainiest months. The average annual precipitation amounts to 1108.8 mm (ŠPANJOL, 1995).

THE ISLAND'S PHYTOGEOGRAPHICAL POSITION AND VEGETATION

The island of Rab lies totally in the zone of evergreen vegetation on the border with the deciduous zone of the Mediterranean phytogeographical region. The only part of the island that can be termed deciduous however is the northern slopes of Kamenjak that face Velebit. In this deciduous part of the epi-Mediterranean vegetational zone the climazonal vegetation *Ostrya* – *Quercetum pubescentis* (Ht.) Trinajstić 1977 has been completely destroyed, and the soil eroded down to the mother rock, and today the vegetation of the stone desert, the rubble and the coastal reefs is widespread there. The climazonal vegetation in the evergreen vegetation zone is *Orno* – *Quercetum ilicis* H-ić (1956) 1958. Apart from the natural evergreen forest of holm oak on the island there are major stands of cultivated conifers, such as for instance on the Frkanj peninsula, where Aleppo pine *Pinus halepensis* Miller has been planted and the stone pine *Pinus pinea* L. With degradation of evergreen forest and maquis, garrigue of the *Cisto-Ericetum arborea* H-ić 1958 association has arisen. Apart from evergreen garrigue, the deciduous scrub *Paliurus spina-christi* Miller is also quite well developed.

MATERIAL AND METHOD

During spring (07.04.1998 and 28.05.1998) and autumn (13.10.1998) we investigated the flora of and certain ecological factors in the entry parts of three caves on the island of Rab. These caves are **Spilja na rtu Frkanj**, **Spilja iznad Jamine Drage** in the eu-Mediterranean zone, and the **Spilja na Kamenjaku** in the epi-Mediterranean zone (Fig. 1). We collected and inventoried the plants that grew at various exposures and at various distances from the entrance. As for ecological factors, we measured temperature and relative humidity of the air from the entrance into the interior of the cave with a sling psychrometer. We prepared the material collected and deposited it in the Herbarium Collection (CNHM) of the Croatian Natural History Museum in Zagreb. For the purposes of identification we used the works *Flora Europaea* (TUTIN *et al.*, 1964–1980, 1993), *Iconographia florum partis Austro-orientalis Europae centralis* (JAVORKA & CSAPODY, 1991), *Flora d'Italia* (PIGNATTI, 1982) and *Mala flora Hrvatske* (DOMAC, 1994). We adjusted the nomenclature of the plants with the usage of the work *Flora Europaea* (TUTIN *et al.*, 1964–1980, 1993).

Spilja na rtu Frkanj lies on point Frkanj Point at 2 m a.s.l. in the immediate vicinity of the coast lying opposite the town of Rab. The entrance to the cave faces

north. The height of the entrance is 1.5 m, and at the broadest part it is 2.3 m wide. The cave's total length is about 4 m. It lies in a sparsely afforested wood of Aleppo pine and stone pine in the eu-Mediterranean vegetation zone.

Spilja iznad Jamine Drage is on the NW slopes of Kruna peak above Jamina Draga at a height of 110 m a.s.l. The entrance faces the northwest. At the widest, the breadth of the cave is 2.3 m, and it is 2.1 m high. The total length of the cave is 26.5 m. It is also located in the eu-Mediterranean vegetation zone and in degraded holm oak forest.

Spilja na Kamenjaku is located on the NE slope of Kamenjak facing Velebit at a height of 400 m a.s.l. This cave has a considerably smaller entrance than the other two considered. It is 0.8 m high, and 1 m wide. It faces north. The cave is 13 m long. It is located in the area of the epi-Mediterranean vegetation zone, where stone desert vegetation is widely distributed. In the entrance the ground is completely covered with sheep dung, for the animals take shelter here during the summer heat.

RESULTS AND DISCUSSION

At the entrance to Spilja na rtu Frkanj and in its immediate vicinity we noted 11 plant species (Tab. 1, Fig. 2). In the interior we did not find a single plant species. During his research at the beginning of the 20th century MORTON (1914) found 17 species at the entrance of the cave or in its immediate vicinity. Inside the cave he recorded as many as 8 species, 4 of them being ferns. On this occasion he found a new form of the fern *Adiantum capillus – veneris* L. f. *subintegrum* Morton et Paulin and determined in detail the morphological and anatomical differences between the specimens of *Asplenium hybridum* that grew on the rocks of the entrance and those that grew in the interior with a considerably reduced light intensity. HORVATIĆ (1939) did phytocenological research into the *Adiantum capillus – veneris* – *Phyllitis* H-ić (= *Eucladio-Phyllitetum*) association at the entrance to the cave. Like Morton, he too recorded the species *Adiantum capillus – veneris*, (also the typical and f. *subintegrum*) and the three other ferns: *Asplenium trichomanes*, *A. ceterach* and *A. hybridum*. In front of the entrance to the cave there are piles of trunks and branches that not only make access to the cave difficult but also constitute a barrier to the ingress of light into the cave interior. Because of the vicinity of the coast that in these times is used for swimming, the amount of people visiting the cave has increased considerably. This is shown by the trampled ground and the trash that we found inside. This will probably account for us not finding a single plant species growing inside the cave. The only fern species that we recorded on this occasion is *Asplenium hybridum*. It is endemic in the Kvarner region, and quite well distributed in Rab, especially on the old ramparts of Rab town. Unfortunately, we did not record either the species *Adiantum capillus – veneris* or the form of it described by Morton and Paulin. This is a rare species. As for other species, it is worth drawing particular attention to the species *Arum italicum*, which Morton did not record, while we

found a considerable number of specimens. The season of this research might well account for the differences in the floral composition established as against those of Morton and Horvatić. During our research at the entrance we noticed some species

Tab. 1. List of plants found in the caves investigated.

No.	List of plants	Kamenjak ¹	Jamina ²	Frkanj ³
1	<i>Aethionema saxatile</i> (L.) R. Br. subsp. <i>saxatile</i>		+	
2	<i>Arum italicum</i> Miller		+	+
3	<i>Asparagus acutifolius</i> L.			+
4	<i>Asplenium ceterach</i> L.		+	
5	<i>Asplenium hybridum</i> (Milde) Bange			+
6	<i>Asplenium trichomanes</i> L.	+	+	
7	<i>Campanula fenestrellata</i> Feer subsp. <i>istriaca</i> (Feer) Fedorov	+	+	
8	<i>Cardamine hirsuta</i> L.		+	
9	<i>Cymbalaria muralis</i> P. Gaertner, B. Meyer & Scherb. subsp. <i>muralis</i>	+	+	
10	<i>Dactylis glomerata</i> L. subsp. <i>hispanica</i> (Roth) Nyman			+
11	<i>Desmazeria rigida</i> (L.) Tutin	+	+	
12	<i>Euphorbia characias</i> L. subsp. <i>wulfenii</i> (Hoppe ex Koch) A.R. Sm.		+	
13	<i>Euphorbia fragifera</i> Jan			+
14	<i>Geranium purpureum</i> Vill.	+	+	
15	<i>Hordeum murinum</i> L.	+		
16	<i>Minuartia verna</i> (L.) Hiern. subsp. <i>collina</i> (Neilr.) Domin.	+		
17	<i>Myosotis discolor</i> Pers.		+	
18	<i>Parietaria judaica</i> L.	+	+	
19	<i>Petrorhagia saxifraga</i> (L.) Link		+	
20	<i>Phleum subulatum</i> (Savi) Ascherson & Graebner subsp. <i>subulatum</i>		+	
21	<i>Pistacia lentiscus</i> L.			+
22	<i>Ranunculus ficaria</i> L. subsp. <i>calthifolius</i> (Reichenb.) Arcangeli		+	
23	<i>Rubia peregrina</i> L.			+
24	<i>Rubus ulmifolius</i> Schott		+	+
25	<i>Stellaria media</i> (L.) Vill.	+		
26	<i>Tamus communis</i> L.			+
27	<i>Thymus longicaulis</i> C. Presl		+	
28	<i>Trifolium dubium</i> Sibth.		+	
29	<i>Trifolium pallidum</i> Waldst. & Kit.		+	
30	<i>Urtica dioica</i> L.	+	+	
31	<i>Valantia muralis</i> L.	+	+	
32	<i>Viola adriatica</i> Freyn			+

¹ Kamenjak – Spilja na Kamenjaku

² Jamina – Spilja iznad Jamine Drage

³ Frkanj – Spilja na Rtu Frkanj

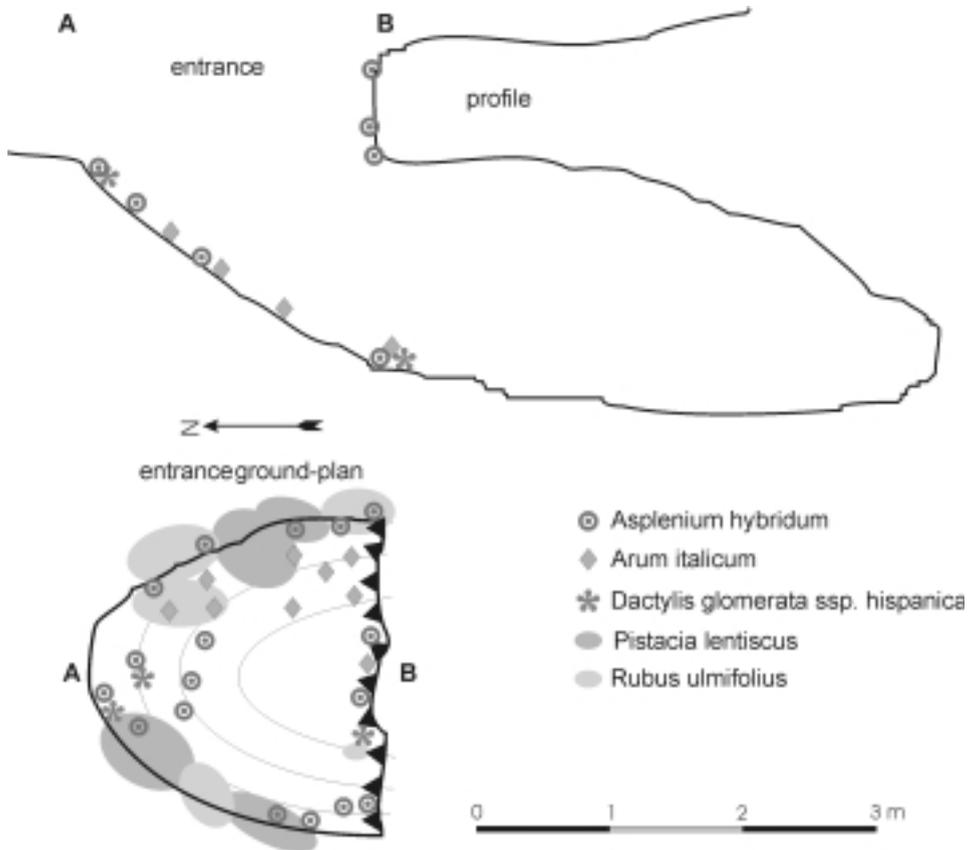


Fig. 2. Distribution of the most common plants in Spilja na rtu Frkanj

from the grass families (*Poaceae*) that we could not identify. Apart from recording plant species, Morton also measured the temperature at the entrance (20.8 °C) and in the interior (19–18 °C) of the cave (August 8, 1913, at 4 p.m.), as well as the intensity of light in which given species were growing in the interior.

At the entrance and immediate vicinity of Spilja iznad Jamine Drage (Tab. 1, Fig. 3) (Jamina in Morton's usage), we recorded 19 species, and Morton 14. In the interior of the cave we recorded 4 species (*Asplenium trichomanes*, *Cardamine hirsuta*, *Euphorbia characias* subsp. *wulfenii* and *Parietaria judaica*) while Morton noted 5 species (*Asplenium ceterach*, *A. ruta muraria*, *A. trichomanes*, *Adiantum capillus - veneris* and *Parietaria judaica*). It should be mentioned that we found only one species of fern, while Morton discovered as many as four. Also interesting is the presence of the species *Arum italicum* that Morton, as with the previous cave, did not record. Of the species that we recorded in the interior of the cave, *Asplenium trichomanes* grew deepest in (up to 8 m), facing NE only. It was also, together with *Parietaria judaica*, the most numerous species. It was quite surprising to find *Cardamine hirsuta* with

almost mature fruits at a depth of 2.5 m. In late spring the entrance was almost overgrown with species *Rubus ulmifolius* and *Urtica dioica*. In this cave too traces of human visitors were found, but seemingly in far fewer numbers, probably because access to the cave is more difficult. On August 7 at 3 p.m. Morton recorded 19 °C in the shade at the entrance, at a depth of 3 m 17.2 °C, and 16.3° at 23 m. The differences in species that we recorded, as compared with those of Morton, as already suggested, could be caused by a different research season, which should not however affect the presence of the said ferns in the interior of the cave.

At the entrance to and in the immediate vicinity of Spilja na Kamenjaku (Tab. 1, Fig. 4) we recorded 11 species of plant, and 5 in the interior (*Asplenium trichomanes*, *Geranium purpureum*, *Parietaria judaica*, *Stellaria media* and *Urtica dioica*). All five species that grow in the interior also grow in the immediate vicinity of the cave. *Asplenium trichomanes* is the only fern that we recorded. With it in the interior of the cave there were many specimens of the species *Stellaria media* and *Urtica dioica*. The considerable number of specimens of the ruderal species *Urtica dioica* was the result of occasional visits to the cave by sheep that leave their dung on the floor of the cave. On the rock in which the entrance is located grows the endemic species *Campanula fenestrellata* subsp. *istriaca*. This cave has not been investigated previously; hence there are no comparative data.

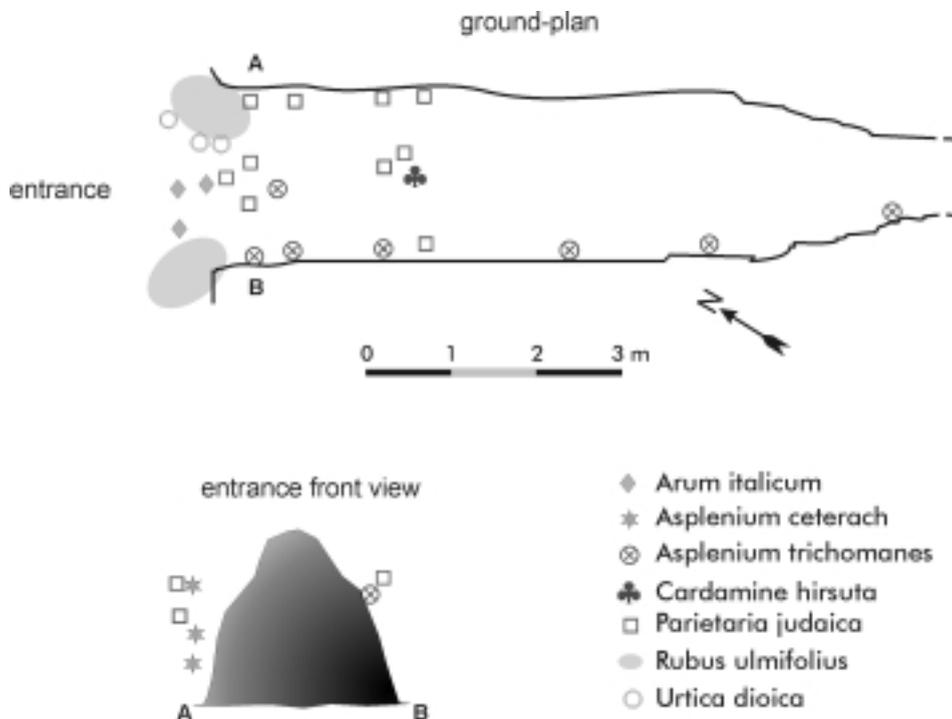


Fig. 3. Distribution of the most common plants in the entrance part of Spilja iznad Jamine Drage

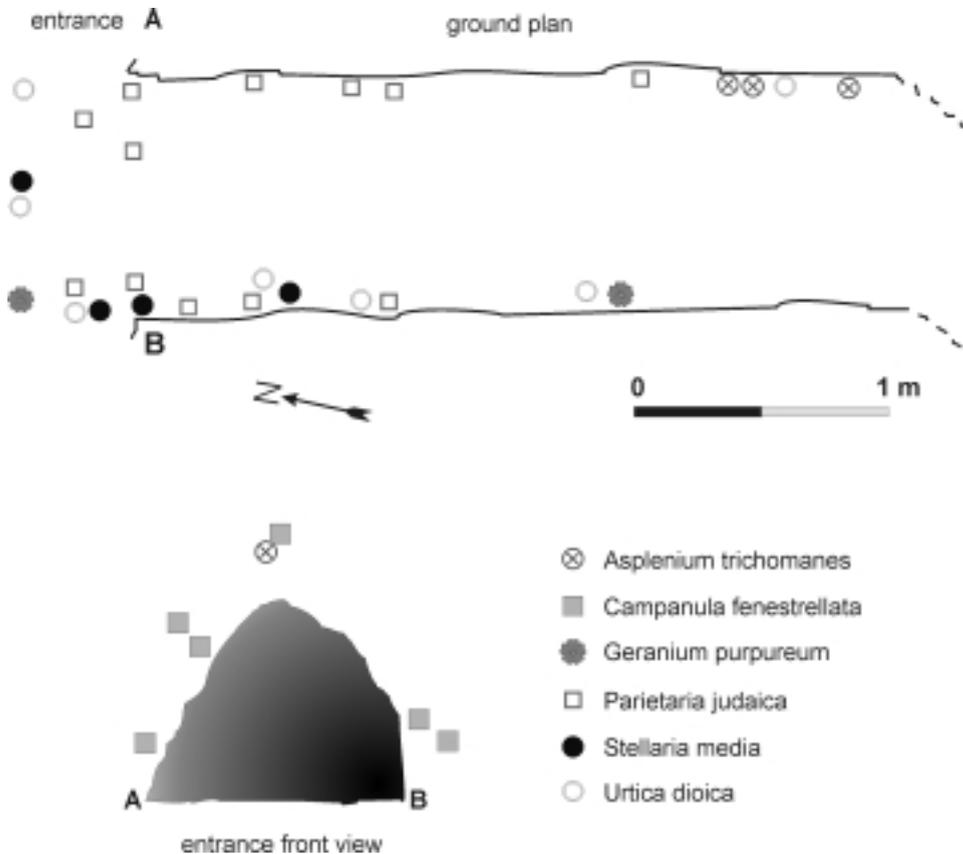


Fig. 4. Distribution of the most common plants in the entrance part of the Spilja na Kamenjaku

Not a single species was recorded in all three caves. Spilja iznad Jamine Drage and Spilja na Kamenjaku have 8 species in common, Spilja iznad Jamine Drage and Spilja na rtu Frkanj 2, while Spilja na Kamenjaku and Spilja na rtu Frkanj have not a single species in common. Since the Spilja na Kamenjaku and Spilja na rtu Frkanj are in different vegetation zones, with a considerably different habitat surrounding them, this might be expected. Nevertheless, we hoped that at least as far as ferns were concerned there would be some species in common. Comparing the results of our research with Morton's list from the Spilja na rtu Frkanj, we found that there were two species in common: *Asplenium trichomanes* and *Parietaria judaica* Morton recorded them just in front of the cave and inside it as well. The relatively large number of species common to the Spilja iznad Jamine Drage and Spilja na Kamenjaku is probably due to the similarity of the habitats, irrespective of the different vegetation zones. In Spilja na rtu Frkanj, a considerable number of species that did grow there have disappeared, probably because of human impact. We re-

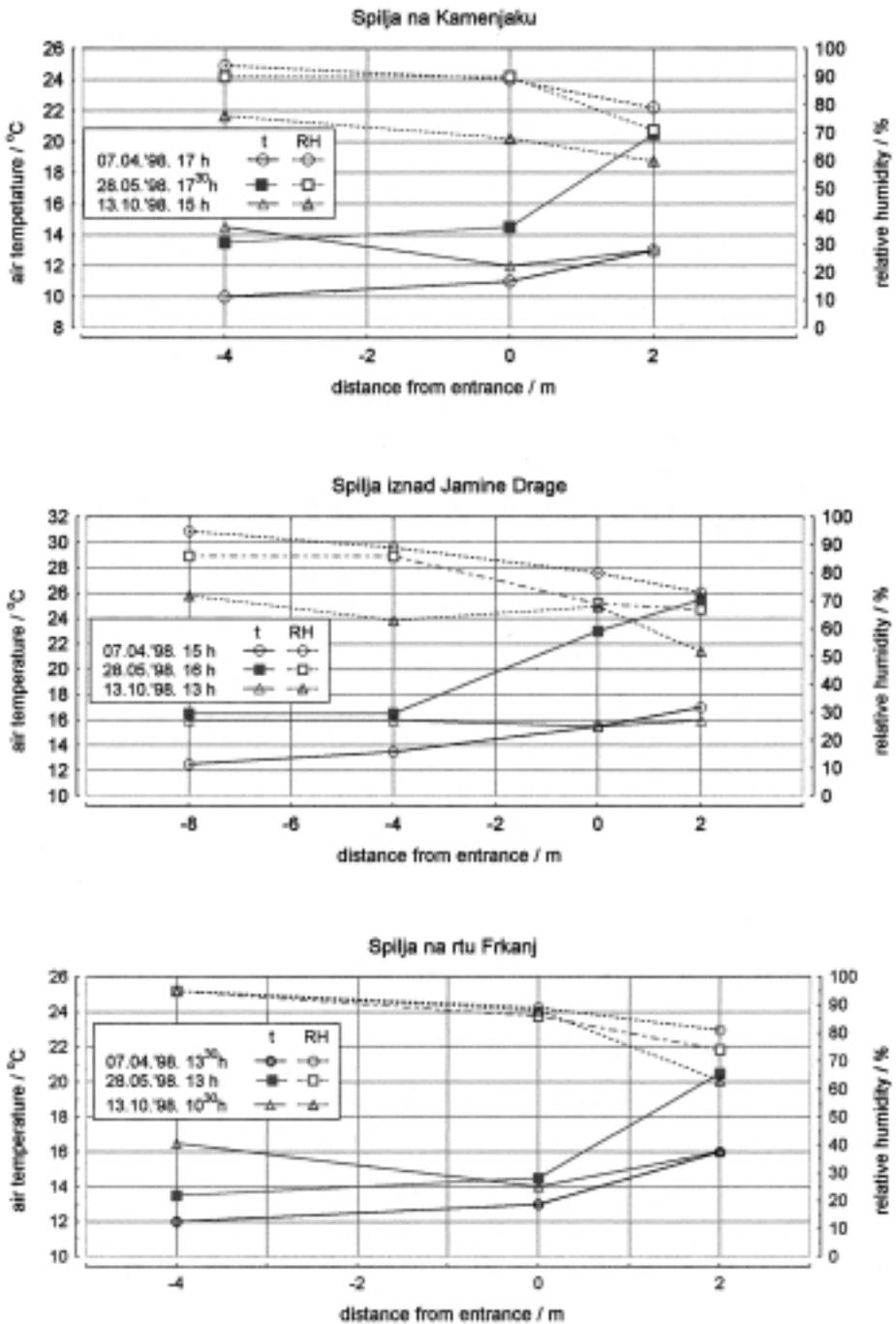


Fig. 5. Changes in temperature and relative humidity in the caves investigated.

corded fewer fern species in all three caves than Morton. In these two caves he reported a total of 5 species, while we could report only 3, only one of them being in the interior of a cave (*Asplenium trichomanes*).

Temperature and relative humidity measurements provided similar results in all three caves (Fig. 5). In spring (beginning of April and end of May) a fall in temperature towards the interior was recorded, but there was an overall rise in the temperatures of the caves. In autumn the lowest values were recorded at the very entrances, while in the interior the values were still considerably higher than in spring. If we factor in Morton's measurements, it can be concluded that from spring to summer in the entrance parts of the caves the air gradually heats up, and from autumn to winter gradually cools. We recorded the highest temperatures in autumn in the Spilja na rtu Frkanj. This was predictable since the cave is just below the surface and is small in dimensions compare to the size of the opening, the influence of the air on the surface being greater. This is backed up by the temperatures that we found in spring, which were lower than those in the Spilja iznad Jamine Drage. We found the lowest temperatures at the same distance from the entrance (4 m) in the Spilja na Kamenjaku. Since the entrance is frequently exposed to the bora and since it is located in the epi-Mediterranean vegetation zone, this is not an unexpected result. The relative humidity of the air measured was greatest at the beginning of April, and lowest in autumn. Just as changes in the outside temperature were reflected in the air temperature in the cave, so changes in the relative humidity on the surface affected the relative humidity in the interior of the cave. Only in the Spilja na rtu Frkanj did these values not change, always standing at 95%. This was the highest value recorded. We recorded the lowest relative humidity (68%) in autumn in the Spilja na Kamenjaku. Since we do not have any systematic measurements of temperature and relative humidity over a long period of time, it is hard to assume that perhaps changes in the microclimates of the cave might have had some responsibility for the disappearance of certain species of ferns.

It is interesting to compare the values for relative humidity and air temperature in the Rab caves with values obtained in caves on the island of Cres (Jama na Sredi – eu-Mediterranean zone and Banićeva pećina – epi-Mediterranean zone: FIEDLER & BUZJAK, 1998). Irrespective of the fact that all the caves are located in the same vegetation zones, it can be noticed that the relative humidity values in the Rab caves are considerably lower, and the air temperature higher. This is another proof that the morphology and the dimensions of the entrance and of the whole of the feature have a crucial impact on the microclimatic features of the entrance areas of caves and caverns, and thus also on the floristic composition in their immediate vicinity and in the interior.

CONCLUSION

During speleobotanical research into three caves on the island of Rab, a total of 32 species of plants were recorded. Of these, there were 29 of spermatophytes and 3 of pteridophytes. Two species were endemic to the Kvarner region – *Asplenium hybridum*

and *Campanula fenestrellata* subsp. *istriaca*. The total number of ferns, as compared with Morton's research, had decreased, particularly in the interior of the caves. The changes in the floristic composition were mainly brought about by human activity – stopping the penetration of light into the cave through stopping up the entrance with branches (Spilja na rtu Frkanj) and by frequent visits. Unfortunately, then, the rare species *Adiantum capillus – veneris* has vanished. Since we do not have any systematic measurements of temperature and relative humidity over a long period of time, it is hard to assume that perhaps changes in the microclimates of the cave might have had some responsibility for the disappearance of certain species of ferns. The values of temperature and relative humidity measured changed in a predictable manner according to distance from the entrance. They were also in line with the climatic features of the areas in which the caves are located and the morphology and dimensions of the entrance to and channels of the caves.

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SAŽETAK

Speleobotaničko istraživanje triju spilja na otoku Rabu (Hrvatska)

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Otok Rab pripada skupini Kvarnerskih otoka. Najvećim dijelom se nalazi u eumediteranskoj vegetacijskoj zoni. Tijekom 1998. godine u ulaznim dijelovima triju spilja na otoku Rabu istraživana je flora i neki ekološki čimbenici. Spilje se nalaze u različitim vegetacijskim zonama – dvije u eumediteranskoj i jedna u epimediteranskoj vegetacijskoj zoni. Popisivane su i prikupljane biljke koje rastu na različitim

ekspozicijama i udaljenostima od ulaza. Na površini i na različitim udaljenostima od ulaza mjerena je trenutačna temperatura i relativna vlaga zraka. Ukupno je zabilježeno 29 vrsta sjemenjača i 3 vrste papratnjača. Od toga dvije vrste su kvarnerski endemi: *Asplenium hybridum* i *Campanula fenestrellata* subsp. *istriaca*. Vrlo rijetka vrsta *Adiantum capillus – veneris*, koju je F. Morton zabilježio 1913. godine u dvije istraživane spilje, nažalost nije nađena. Zabilježen je i znatno manji broj vrsta papratnjača i to posebno u unutrašnjosti spilja. Mjerenja ekoloških čimbenika pokazala su očekivane promjene ovisno o udaljenosti od ulaza, klimatskog područja u kojem se spilje nalaze, te morfologiji i dimenzijama ulaznog otvora i cijele spilje.