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# THE ECOLOGICAL AND FLORISTIC CHARACTERISTICS OF LEDENA JAMA PIT ON VELEBIT MOUNTAIN – CROATIA

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**Vrbek, M. & Fiedler, S.: The ecological and floristic characteristics of Ledena jama pit on Velebit mountain – Croatia, Nat. Croat., Vol. 9, No. 2, 115–131, 2000, Zagreb.**

In the entrance of Ledena Jama pit, located on Velebit mountain (Croatia), flora and some ecological factors were investigated – momentary light intensity, daily air temperature and humidity during vegetational seasons in 1995–96. In consequence of the collected data, the entrance was divided into three zones. In the first two zones (+6 m to –23 m) it is mostly spermatophytes (122 species) and pteridophytes (5 species) that grow, while in Zone III (down to –40 m) most of the plants are bryophytes and algae. With each species, ecological values according to Landolt were associated: F – humidity value, L – light value, T – temperature value and W – life form. By analysing these values division into zones was confirmed. It was also established that the first two zones, as well as in composition of plant species, also vary in air temperature and humidity, soil moisture and light, which is reflected in the larger proportion of geophytes and alpine species present in Zone II.

**Key words**: speleobotany, ecological factors, flora, speleological features

**Vrbek, M. & Fiedler, S.: Ekološka i floristička obilježja Ledene jame na Velebitu – Hrvatska, Nat. Croat., Vol. 9, No. 2, 115–131, 2000, Zagreb.**

U ulaznom dijelu Ledene jame, koja se nalazi na Velebitu, tijekom vegetacijskih sezona 1995. i 1996. godine istraživani su flora i neki ekološki čimbenici – dnevno kretanje temperature i vlage zraka, te trenutna osvijetljenost. S obzirom na prikupljene podatke, ulaz je podijeljen u tri zone. U prve dvije zone (+6 m do –23 m) većinom rastu sjemenjače (122 vrste) i papratnjače (5 vrsta), dok u trećoj zoni ( do –40 m) uglavnom rastu mahovine i alge. Sa svakom vrstom povezane su ekološke vrijednosti prema Landoltu: F – vlažnost, L – osvijetljenost, T – temperatura i W – životni oblik. Analizom tih vrijednosti potvrđena je naša podjela na zone. Također je utvrđeno da se prve dvije zone razlikuju ne samo u biljnom sastavu, nego i u temperaturi i vlažnosti zraka, vlažnosti tla i osvijetljenosti što se odrazilo na veći udio geofita i alpskih vrsta u II. zoni.

**Ključne riječi**: speleobotanika, ekološki čimbenici, flora, speleološki objekti

## INTRODUCTION

In the entrances of speleological features such as caves and pits cryptogamous plants (algae, bryophytes, lichens and ferns) that are suited to reduced light and higher air and soil humidity predominate, though spermatophytes adapted to these conditions can also grow. The ecological factors that have the biggest impact on the floristic composition and numerousness of plants in these habitats are reduced light, air temperature and humidity, soil type, its quantity, temperature and humidity LÄMMERMAYER (1912, 1914, 1916), MORTON & GAMS (1925) IVANCICH (1926), TOMAŽIČ (1955), SAULI (1972), STOCH & DOLCE (1984), RAJCZY (1989), POLLI & POLLI (1989). During the Lukina jama '95 expedition on Mt Velebit (when the deepest pit in Croatia, Lukina jama –1395 m was explored) a start was made on systematic research into the flora and some ecological factors in the entrances of speleological features in Croatia. At that time four features were researched, Ledena jama being floristically the most interesting.

### The position of Ledena jama

Ledena jama is located in Lomska duliba on the northern part of Mt Velebit at 1240 m a.s.l. (Fig. 1). Velebit is one of the best known of the Dinaric mountains. It stretches from NW to SE for 145 km, following the lie of the Adriatic coastline. From the coastline to the continental foot of the mountain it is on average 14 km wide. In the plant life of the northern, inland part, members of the Euro-Siberian-North American region (Holarctic) are predominant, and there is also most of the vegetation of the Central European mountains – the Alps (FORENBACHER, 1990). The entrance of Ledena jama is on the edge of a *Festucetum pungentis* Ht. 1930 meadow which is gradually being overgrown by *Adenostylo alliariae – Piceetum abietis* Hartmans 1944 forest (Fig. 2).


**Fig. 1.** Position of Ledena jama pit in Croatia

**Fig. 2.** The entrance part of Ledena jama pit (photo: B. Vrbek)

The climate of the northern Velebit is, according to Köppen's classification, Boreal – Subarctic (BERTOVIĆ, 1975). The mean monthly temperatures range from –4.1 °C in January to 13.1 °C in July. The absolute maximum is 26.3°C and the absolute minimum is –28.6 °C. During the summer months in the valleys and dolines, during clear calm nights, a layer of very cold air is formed. About 5 cm from the ground it is 10–12 °C colder than on the neighbouring slopes (temperature inversion). The air relative humidity is unexpectedly great in March (86%) because of the orographic mist that is formed along the peaks of Velebit while the bura (local north-easterly wind) is blowing. Only in the summer months, which have the fewest numbers of misty days, is the mean monthly relative humidity of the air below 80% (76%–78%). The precipitation is fairly equally distributed throughout the year, the most arid part coming within the warm period of the year. In the cold period of the year the soil is covered with long-lasting snow (KIRIGIN, 1967).

## The morphology of Ledena jama

Ledena jama pit is a complex, 514 m deep speleological feature. Most of it is filled with ice and snow (névé). The particularity of Ledena jama is its entrance with dimensions of 74 m × 43 m. It gradually narrows towards the depth of –40 m, where there is a plug of ice that separates it from the rest of the passage. From its brink, the entrance is inclined towards a depth of about 15 m. In this part its sides are covered by rich plant cover over soil of various, but chiefly small thickness. Below this depth its sides are vertical and predominantly of bare rock. Soil could be found only on small shelves and in the cracks. The rock is intersected by fracture through which after rains and during the snow melting water comes out. At the depth of 40 m, at the top border of snow and ice, there is a 26 m long horizontal passage. Its bottom is covered by rock debris and ice.

## MATERIALS AND METHODS

During different seasons (spring, summer and autumn) of 1995 and 1996, we listed and collected plants growing in the immediate vicinity of Ledena jama, at its entrance, and at various depths and exposures in the pit itself. The material gathered there was dried and deposited in the Herbarium Collection of the Croatian Natural History Museum – CNHM, Zagreb. While determining the species, we used the standard keys and iconographies: TUTIN *et al*. (1964–1980, 1993), PIGNATTI (1982), JAVORKA & CSAPODY (1991), DOMAC (1994). The nomenclature of species were brought into line with the Flora Europaea (TUTIN *et al*., 1964–1980, 1993). The species of lower plants (mosses and algae) we were not able to determine, but their presence in various zones was also noted and recorded. As for ecological factors, we measured the momentary light intensity, the daily air temperature and the relative humidity changes outside near the entrance and at the lowermost border for the growth of plants in the pit itself. The light readings were taken with a Lunasix 3 lightmeter, and temperature and relative humidity with a Lambrecht thermo-hygrograph calibrated by Assman aspiration psychrometer (PENZAR & PENZAR, 1989).

In consequence of the ecological factors measured and the composition of plant species found, we divided the entrance part into three zones. With each species we associated the ecological values that we analysed according to LANDOLT (1977), excepting six species (*Hypericum richeri* subsp. *grisebachii*, *Leontodon hispidus* subsp. *danubialis*, *Lilium carniolicum*, *Poa media*, *Potentila australis* and *Scrophularia heterophylla* ssp. *laciniata* that are not discussed in his work. Thus we were able to calculate the mean ecological values of the first two zones, on the basis of which we gave their basic ecological characteristics. While analysing the data, we took into account the fact that we were working in a geographical and climatic region different from that which Landolt was working in. Therefore some data were not able to be used without a critical review. We analysed the following ecological values:

**F –** Humidity value, which indicates the average humidity of the soil during the vegetation period. Low values show little, high values great humidity;

**L –** Light value, which is characteristic of the average light intensity at which the plant can grow well during its vegetation period. Low values show little necessity for light, high values a great necessity for light.

**T –** Temperature value, characteristic of the average temperature that the plant receives during its vegetation period. Low values correspond to distribution at higher altitudes, high values indicate plants growing in the lowlands.

**W –** Life form, which defines the position of the surviving buds during the least advantageous season of the year.

## RESULTS AND DISCUSSION

Ledena jama has plant cover all the way down to –40 m, where the ice plug begins. Measurements of daily air temperature at various seasons of the year (except in winter, when access was too difficult) at a depth of –40 m show negligible or no differences during the day, but there were some differences from season to season. In spring at a depth of –40 m, temperatures were about 1 °C, in summer 0 °C and in autumn about 3.9 °C (Fig. 3) The higher temperatures observed in later spring (end of May) than in summer are probably the result of warming in consequence of higher precipitation in later spring. The relative humidity of the air at the same depth did not change during the day or from season to season, and was always 100%. Measurements of air temperature and relative humidity outside the pit showed the expected great daily changes in temperature as well as changes related to

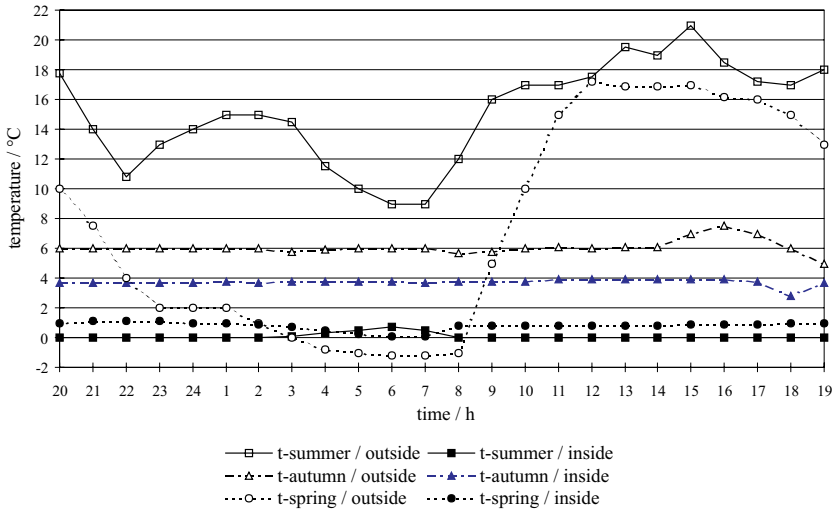



**Fig. 3.** Diurnal range of temperatures in different seasons outside Ledena jama and at the lower border of plant growth in the pit (–40 m)

the seasons and the geographical position of the feature. The only considerable divergence from what had been anticipated with respect to the location of the feature in a valley was during the summer measurements when there was a sudden warming during the night (between 22 and 04 hrs).

Because of lack of equipment we were not able to monitor daily changes in light values. Therefore we made a profile of the drop in lighting in the very short period from the entrance to a depth of –40 m. The profile was done in spring on the southern exposure of the entrance. Outside the entrance we recorded 11000 lux, at a depth of 23 m 700 lux, and at a depth of –40 m 175 lux (Fig. 4)

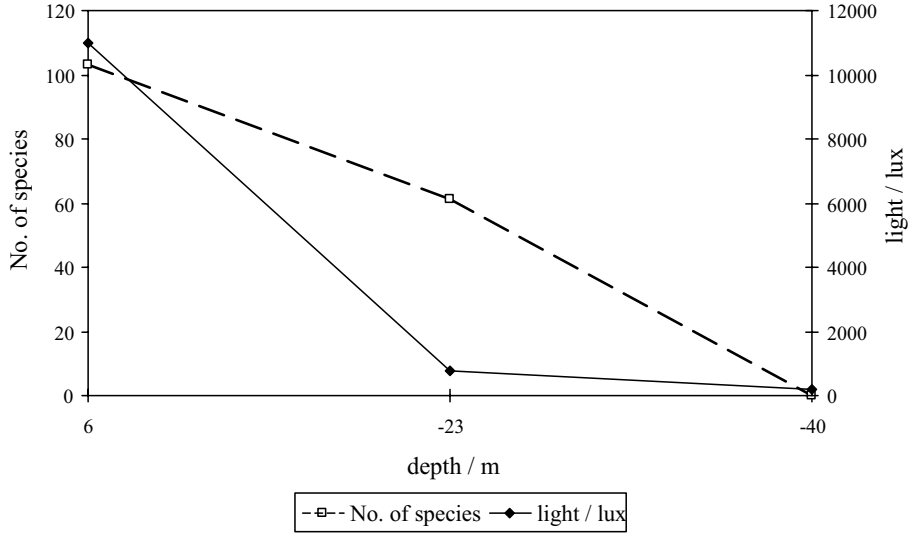



**Fig. 4.** Light and number of plant species in the entrance part of Ledena jama in relation to depth

The degree to which there is plant cover in Ledena jama up to –40 m in depth (to the ice plug) is a result of the large dimensions and morphology of its funnel-like entrance which makes possible the penetration of light sufficient for the development of plant life at this depth. If it were not for the ice plug, the light would penetrate deeper, and the pit would probably be overgrown with lower plants at even greater depths. Since it is located in the climatic region of the Boreal-Subarctic climate, lower air temperatures and elevated humidity should not be limiting factors for the development of plants at even greater depths.

With respect to the different ecological conditions and plant species that grow there, we divided the entrance of Ledena jama into three zones (Tab. 1, Fig. 5):

**Zone I** (from +6m to –6m), which because of the greater influence of the external microclimatic conditions is similar in its floristic composition to the grassland in

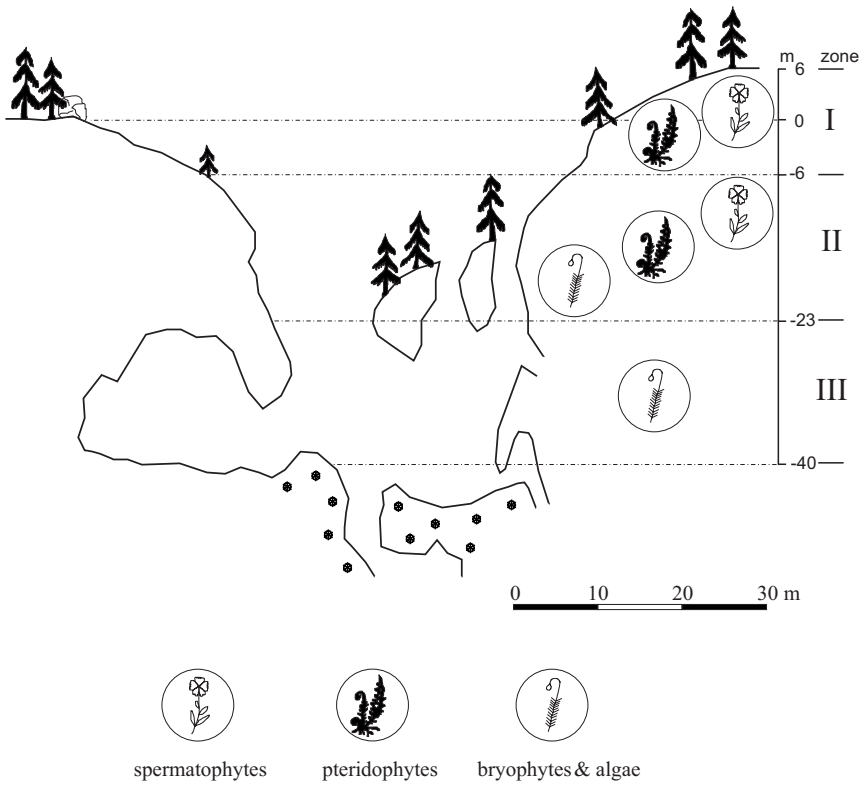



**Fig. 5.** Zonal distribution of the plants at the entrance part of Ledena jama pit

which Ledena jama is located; 99 species of spermatophytes and 4 species of pteridophytes growing individually were noted;

**Zone II** (–6m to –23m), which in terms of floristic composition is already considerably different from Zone I because of the greater influence of the internal microclimatic conditions; there are many more specimens of pteridophytes and bryophytes and algae; 57 species of spermatophytes and 4 species of pteridophytes were noted;

**Zone III** (–23m to –40m), in which, because of the great influence of the internal microclimatic conditions (lower temperatures, higher humidity, reduced light intensity), mostly bryophytes and algae grow, while of higher plants we found only shoots which were not identifiable.

In the first two zones a total of 128 species of plants were found (123 species of spermatophytes, 5 species of pteridophytes). Among them, 67 species grow only in Zone I, 25 only in Zone II, and 36 in Zones I and II (Fig. 6)

As for ferns, the following species were noted: *Asplenium trichomanes*, *A. trichomanes ramosum*, *A. ruta-muraria*, *Cystopteris fragilis* and *C. montana*. Species *A. ruta-*

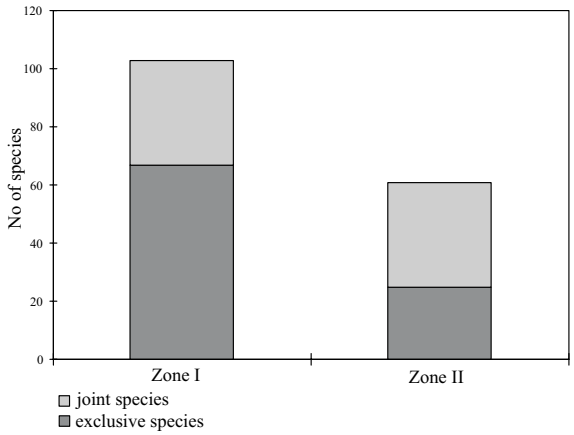



**Fig. 6**. Number of species in the entrance part of Ledena jama according to zones

*muraria* was observed only in Zone I and *C. montana* only in Zone II. The other species, which grow in both zones, were more numerous in Zone II that in Zone I. This can be explained by the different ecological conditions (rockiness and microclimatic conditions).

**Tab. 1.** List of plant species in the entrance part of Ledena jama and the pertinent ecological values according to Landolt

| No. | LIST OF PLANTS | ZONES | | ECOLOGICAL VALUES | | | |
|---|---|---|---|---|---|---|---|
| | | I | II | F | L | T | W |
| 1. | *Acinos alpinus* (L.) Moench subsp. *alpinus* | + | | 2 | 4 | 2 | c |
| 2. | *Adenostyles alliariae* (Gouan) A. Kerner | | + | 3 | 2 | 2 | h |
| 3. | *Agrostis canina* L. | + | | | 4 | 3 | h |
| 4. | *Anacamptis pyramidalis* (L.) L. C. M. Richard | | + | 2w | 4 | 4 | g |
| 5. | *Antennaria dioica* (L.) Gaertner | + | | 2 | 4 | 2 | c |
| 6. | *Anthoxanthum odoratum* L. | + | | 3 | 4 | 3 | h |
| 7. | *Anthyllis vulneraria* L. | + | | 1 | 4 | 4 | h |
| 8. | *Aquilegia nigricans* Baumg. subsp. *nigricans* | + | | 2 | 3 | 3 | h |
| 9. | *Arabis alpina* L. subsp. *alpina* | + | + | 3 | 4 | 2 | c |
| 10. | *Arabis hirsuta* (L.) Scop. | + | | 2w | 4 | 4 | u |
| 11. | *Arenaria serpyllifolia* L. subsp. *serpyllifolia* | + | + | 2 | 4 | 4 | u |
| 12. | *Aruncus dioicus* (Walter) Fernald | | + | 4 | 2 | 3 | h |
| 13. | *Asplenium ruta – muraria* L. | + | | 2 | 4 | 3 | h |
| 14. | *Asplenium trichomanes – ramosum* L. | + | + | 3 | 3 | 3 | h |
| 15. | *Asplenium trichomanes* L. | + | + | 3 | 3 | 3 | h |
| 16. | *Botrychium lunaria* (L.) Swartz | + | | 3 | 4 | 2 | g |

| No. | LIST OF PLANTS | ZONES | | ECOLOGICAL VALUES | | | |
|---|---|---|---|---|---|---|---|
| | | I | II | F | L | T | W |
| 17. | *Bromus erectus* Hudson | + | + | 2 | 4 | 4 | h |
| 18. | *Buphthalmum salicifolium* L. | + | + | 2w | 3 | 3 | h |
| 19. | *Calamagrostis varia* (Schrader) Host | + | + | 2w | 3 | 3 | h |
| 20. | *Campanula rotundifolia* L. | + | + | 2 | 4 | 4 | h |
| 21. | *Cardamine enneaphyllos* (L.) Crantz | | + | 3 | 3 | 3 | g |
| 22. | *Cardaminopsis croatica* (Schott, Nyman & Kotschy) Ják. | + | + | 3 | 3 | 3 | c |
| 23. | *Carex brachystachys* Schrank | | + | 4 | 3 | 2 | h |
| 24. | *Carex caryophyllea* Latourr. | + | | 2 | 4 | 3 | h |
| 25. | *Carex ornithopoda* Willd. | + | + | 2 | 3 | 3 | h |
| 26. | *Carex digitata* L. | + | + | 2 | 2 | 3 | h |
| 27. | *Carex ericetorum* Pollich | + | | 2 | 4 | 3 | h |
| 28. | *Carlina acaulis* L. | + | | 2 | 4 | 3 | h |
| 29. | *Chrysosplenium alternifolium* L. | | + | 5w | 2 | 3 | h |
| 30. | *Cirsium eriophorum* (L.) Scop. | + | | 2 | 4 | 2 | h |
| 31. | *Cirsium erisithales* (Jacq.) Scop. | | + | 3w | 2 | 3 | g |
| 32. | *Clematis alpina* (L.) Miller subsp. *alpina* | | + | 3 | 3 | 2 | h |
| 33. | *Coeloglossum viride* (L.) Hartman | | + | 3 | 4 | 2 | g |
| 34. | *Crepis alpestris* (Jacq.) Tausch | + | + | 2 | 4 | 2 | h |
| 35. | *Crocus vernus* (L.) Hill ssp. *albiflorus* (Kit.) Ascherson & Graebner | + | | 3 | 4 | 2 | g |
| 36. | *Cruciata glabra* (L.) Ehrend. | + | | 3 | 3 | 4 | g |
| 37. | *Cystopteris fragilis* (L.) Bernh. | + | + | 3 | 4 | 3 | h |
| 38. | *Cystopteris montana* (Lam.) Desv. | | + | 3 | 2 | 2 | h |
| 39. | *Daphne mezereum* L. | + | | 3 | 2 | 3 | n |
| 40. | *Doronicum austriacum* Jacq. | | + | 4 | 3 | 2 | h |
| 41. | *Dorycnium hirsutum* (L.) Ser. | + | | 1 | 3 | 5 | z |
| 42. | *Epilobium angustifolium* L. | + | | 3 | 4 | 3 | h |
| 43. | *Euphorbia carniolica* Jacq. | + | + | 3 | 2 | 4 | h |
| 44. | *Fragaria moschata* Duchesne | + | | 3 | 3 | 5 | h |
| 45. | *Galium anisophyllon* Vill. | + | + | 2 | 4 | 2 | h |
| 46. | *Galium lucidum* All. | + | | 1 | 4 | 4 | c |
| 47. | *Galium pumilum* Murray | + | + | 2 | 4 | 4 | h |
| 48. | *Gentiana asclepiadea* L. | + | + | 3w | 3 | 3 | h |
| 49. | *Gentiana lutea* L. subsp. *symphyandra* Murbeck | + | | 3 | 4 | 2 | h |
| 50. | *Gentiana utriculosa* L. | + | | 4w | 4 | 2 | t |
| 51. | *Gentiana verna* L. | + | + | 3w | 4 | 2 | h |
| 52. | *Geranium sylvaticum* L. | + | + | 3 | 3 | 2 | h |
| 53. | *Gymnadenia conopsea* (L.) R. Br. | + | | 3w | 4 | 3 | g |
| 54. | *Helianthemum nummularium* (L.) Miller | + | | 1 | 5 | 4 | z |
| 55. | *Heracleum sphondylium* L. | | + | 3 | 3 | 3 | h |
| 56. | *Hieracium pilosella* L. | + | | 2 | 4 | 3 | h |
| 57. | *Hippocrepis comosa* L. | + | | 2 | 4 | 3 | c |
| 58. | *Homogyne sylvestris* Cass. | | + | 3 | 3 | 2 | h |

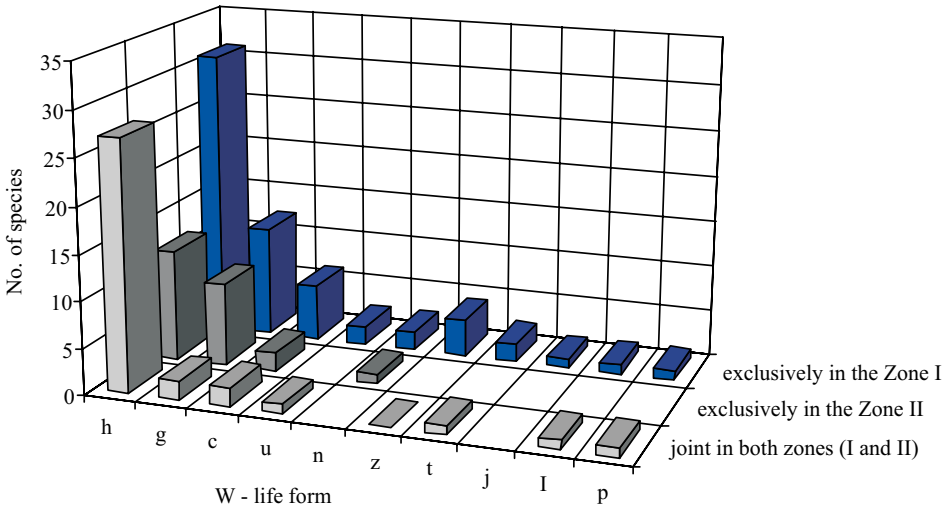
| No. | LIST OF PLANTS | ZONES | | ECOLOGICAL VALUES | | | |
|---|---|---|---|---|---|---|---|
| | | I | II | F | L | T | W |
| 59. | *Hypericum richeri* Vill. subsp. *grisebachii* (Boiss.) Nyman | + | + | | | | |
| 60 | *Iris graminea* L. | + | | 2 | 3 | 4 | g |
| 61. | *Isopyrum thalictroides* L. | | + | 4 | 2 | 5 | g |
| 62. | *Juniperus communis* L. subsp. *alpina* (Sauter) Čelak. | + | | 2 | 4 | 2 | j |
| 63. | *Juniperus communis* L. subsp. *communis* | + | | 2w | 4 | 4 | i |
| 64. | *Knautia drymeia* Heuffel subsp. *intermedia* (Pernh. & Wettst.) Ehrend. | + | | 3 | 2 | 4 | h |
| 65. | *Lathyrus pratensis* L. | + | | 3 | 3 | 4 | g |
| 66. | *Leontodon autumnalis* L. | + | | 3w | 4 | 3 | h |
| 67. | *Leontodon hispidus* L. subsp. *danubialis* (Jacq.) Simonkai | + | | | | | |
| 68. | *Leontodon hispidus* L. subsp. *hispidus* | + | + | 3 | 4 | 3 | h |
| 69. | *Lilium carniolicum* Bernh. ex Koch | + | | | | | |
| 70. | *Linum catharticum* L. | + | | 3w | 3 | 3 | u |
| 71. | *Lonicera alpigena* L. | | + | 3 | 2 | 2 | n |
| 72. | *Lotus corniculatus* L. | + | + | 2 | 4 | 3 | h |
| 73. | *Luzula campestris* (L.) DC. | + | | 3 | 4 | 3 | h |
| 74. | *Melampyrum velebiticum* Borbás | + | | 2 | 3 | 5 | t |
| 75. | *Mercurialis perennis* L. | + | | 3 | 1 | 3 | g |
| 76. | *Moehringia muscosa* L. | | + | 3 | 3 | 3 | c |
| 77. | *Muscari botryoides* (L.) Miller | + | | 3 | 4 | 4 | g |
| 78. | *Orchis mascula* (L.) L. | + | | 3w | 3 | 3 | g |
| 79. | *Orobanche alba* Steph. ex Willd. | + | | 2 | 4 | 3 | g |
| 80. | *Petasites albus* (L.) Gaertner | | + | 4w | 2 | 3 | g |
| 81. | *Phyteuma ovatum* Honckeny | + | | 4 | 3 | 2 | h |
| 82. | *Phyteuma spicatum* L. | + | + | 3 | 2 | 3 | h |
| 83. | *Picea abies* (L.) Karsten | + | + | 3 | 1 | 2 | i |
| 84. | *Plantago media* L. | + | | 2 | 4 | 3 | h |
| 85. | *Poa pratensis* L. | + | | 3 | 4 | 3 | h |
| 86. | *Poa alpina* L. | + | + | 3 | 4 | 2 | h |
| 87. | *Poa media* Schur | | + | | | | |
| 88. | *Polygala alpestris* Reichenb. | + | | 2 | 4 | 2 | h |
| 89. | *Polygonum viviparum* L. | + | + | 3 | 4 | 2 | h |
| 90. | *Populus tremula* L. | + | | 3 | 4 | 3 | p |
| 91. | *Potentilla australis* Krašan | + | | | | | |
| 92. | *Ranunculus montanus* Willd. | | + | 3w | 3 | 2 | h |
| 93. | *Ranunculus platanifolius* L. | + | + | 3w | 2 | 2 | h |
| 94. | *Ranunculus serpens* Shrank. subsp. *nemorosus* (DC.) G. López | + | | 3w | 3 | 3 | h |
| 95. | *Rhinanthus* sp. | + | | | | | |
| 96. | *Rhinanthus minor* L. | + | + | 3w | 4 | 3 | t |
| 97. | *Rosa* sp. | + | | | | | |

| No. | LIST OF PLANTS | ZONES | | ECOLOGICAL VALUES | | | |
|---|---|---|---|---|---|---|---|
| | | I | II | F | L | T | W |
| 98. | *Rubus saxatillis* L. | + | | 2 | 2 | 3 | h |
| 99. | *Salix caprea* L. | + | + | 3w | 3 | 3 | p |
| 100. | *Sambucus racemosa* L. | + | | 3 | 3 | 3 | n |
| 101. | *Saxifraga rotundifolia* L. | + | + | 4 | 2 | 2 | h |
| 102. | *Scrophularia heterophylla* Willd subsp. *laciniata* (Waldst. & Kit.) Maire & Petitmengin | + | + | | | | |
| 103. | *Senecio abrotanifolius* L. subsp. *abrotanifolius* | + | | 2 | 4 | 2 | g |
| 104. | *Senecio nemorensis* L. subsp. *fuchsii* (C. C. Gmelin) Čelak. | + | + | 3 | 3 | 3 | h |
| 105. | *Silene pusilla* Walds. & Kit. | | + | 4 | 3 | 2 | h |
| 106. | *Silene vulgaris* (Moench) Garcke | + | | 2 | 3 | 3 | h |
| 107. | *Stellaria graminea* L. | + | | 3w | 3 | 3 | h |
| 108. | *Symphytum tuberosum* L. | + | | 3 | 2 | 4 | g |
| 109. | *Thalictrum aquilegiifolium* L. | + | + | 4w | 3 | 2 | h |
| 110. | *Thalictrum minus* L. | + | + | 2 | 3 | 3 | h |
| 111. | *Thesium alpinum* L. | + | | 3 | 4 | 2 | h |
| 112. | *Thymus longicaulis* C. Presl. | + | | 1 | 4 | 5 | c |
| 113. | *Thymus praecox* Opiz subsp. *polytrichus* (A. Kerner ex Borbás) Jalas | | + | 2 | 4 | 2 | c |
| 114. | *Thymus pulegioides* L. | + | | 2 | 4 | 3 | c |
| 115. | *Trifolium alpestre* L. | + | | 2w | 3 | 4 | h |
| 116. | *Trifolium montanum* L. | + | | 2w | 4 | 3 | h |
| 117. | *Trifolium pratense* L. | + | | 3 | 3 | 3 | h |
| 118. | *Trollius europaeus* L. subsp. *europaeus* | + | | 4w | 4 | 2 | h |
| 119. | *Vaccinium myrtillus* L. | + | | 3 | 2 | 3 | z |
| 120. | *Vaccinium vitis – idaea* L. | + | | 3w | 3 | 2 | z |
| 121. | *Valeriana montana* L. | + | + | 3 | 3 | 2 | g |
| 122. | *Valeriana tripteris* L. | | + | 3 | 3 | 2 | g |
| 123. | *Veratrum album* L. | + | + | 4 | 4 | 2 | h |
| 124. | *Veronica chamaedrys* L. | | + | 3 | 3 | 3 | g |
| 125. | *Veronica urticifolia* Jacq. | | + | 3 | 2 | 3 | g |
| 126. | *Vicia cracca* L. | + | | 3 | 4 | 3 | h |
| 127. | *Viola biflora* L. | | + | 4w | 2 | 2 | h |
| 128. | *Viola canina* L. | + | | 3 | 4 | 3 | h |

## Analysis of ecological values according to Landolt

The greatest number of plant species growing in both (Zone I and II) zones are hemicryptophytes. The species of plants that grow exclusively in the Zone I or exclusively in the Zone II are also mostly hemicryptophytes. But in Zone II a greater number also are geophytes, which are considerably less abundant in Zone I than hemicryptophytes (Fig. 7).

Among plants that grow only in Zone I, most of the species recorded occur chiefly in mountain regions (T3 – 32 species) and are widely distributed. There are also a large number of plants that grow mainly in subalpine (T2 – 14 species) and mountain regions (T4 – 12 species), and four species that grow in the lower areas of southern Europe (T5). Plants that grow only in Zone II are mostly distributed in subalpine and mountain areas (T2 – 13 species, T3 – 9 species, T4 – 1 species, T5 – 1 species). Plants that grow in both zones (I and II) have an approximately equal ratio of mountain species (T3 – 16 species) and species that are distributed in subalpine areas (T2 – 13 species) (Fig. 8). The average temperature value (T) in Zone I came to 3 and in Zone II to 2.7. On the basis of these values and of the composition of the plant species it can be concluded that in Zone I mainly mountain species grow, unlike Zone II where mountain and alpine species grow in more or less equal proportions.




h - hemicryptophytes, g - geophytes, c - herbaceous chamaephytes, u - therophytes / hemicryptophytes, n - deciduous nanophanerophytes, z - woody chamaephytes, t - therophytes, j - evergreen nanophanerophytes, i - evergreen phanerophytes, p - deciduous phanerophytes

**Fig. 7.** Life forms (W) for individual species by zones

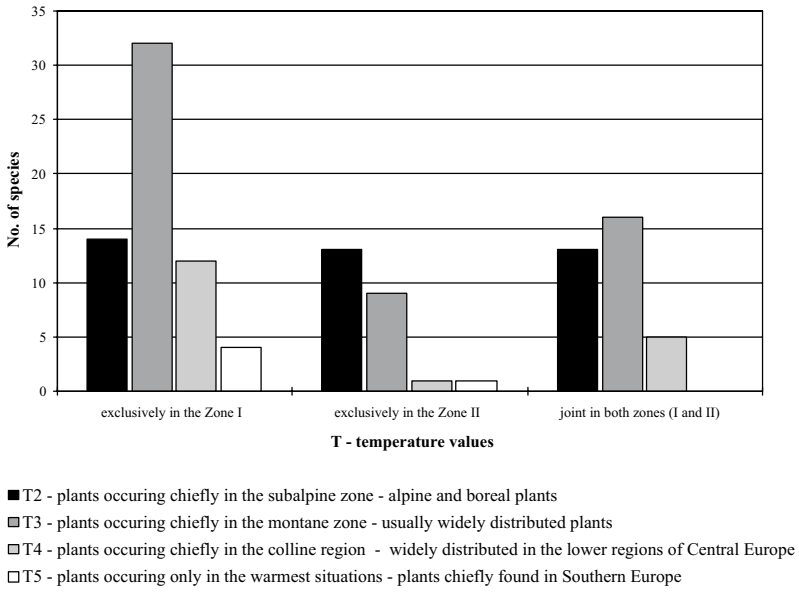



**Fig. 8.** Temperature values (T) for individual species by zones

The plant species that grow only in Zone I usually grow on dry (F2 – 20 species, F2w – 4 species) and moderately wet (F3 – 22 species and F3w – 7 species ) but also on very dry (F1 – 5 species), and very wet (F4 – 1 species and F4w – 3 species) soils. Because of the composition of the plants that grow in Zone I and the average humidity value (F=2.6) we can conclude that in this zone the habitat is dry to moderately wet. Species that grow only in Zone II show that this is a wet habitat (F2 – 1 species, F2w – 1 species, F3 – 12 species, F3w – 2 species, F4 – 5 species, F4w – 2 species, and F5w – 1 species), which is confirmed by the mean humidity value (F=2.9) in Zone II. Species that grow in both zones usually grow on dry (F2 – 10 species, F2w – 2 species) and moderately wet (F3 – 14 species, F3w – 5 species) soils, only three species growing on very wet soils (F4 – 2 species, F4w – 1 species) (Fig. 9).

As many as thirty-eight plants that grow only in Zone I need a lot of light (L4), seventeen that need half shade (L3), and five that need shade (L2). Unlike this, only two species that grow only in Zone II need a lot of light (L4), while eleven species need half shade (L3), and ten species need shade (L2). Species that grow in both zones (I and II) have considerable light requirements (L4 – 15 species, L3 – 13 species, L2 – 5 species, L1 – 1 species) (Fig. 10). On the basis of the composition of plant species and the average light value in Zone I, which comes to 3.4, we can conclude that this is a lighter habitat than Zone II, whose plant species and average light value (L=3) characterise a habitat mainly in the half shade.

Analysis of the ecological values according to Landolt have confirmed our division into three zones. According to this analysis, Zone I (+6 to –6 m) can be charac-

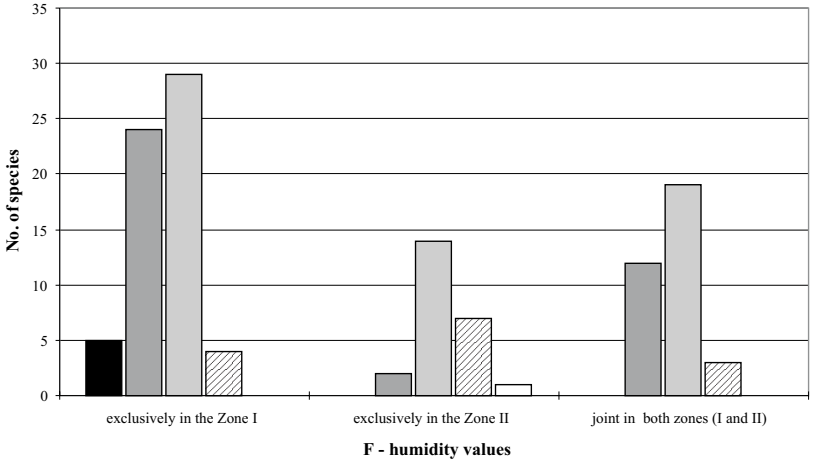



**Fig. 9**. Humidity values (F) for individual species by zones

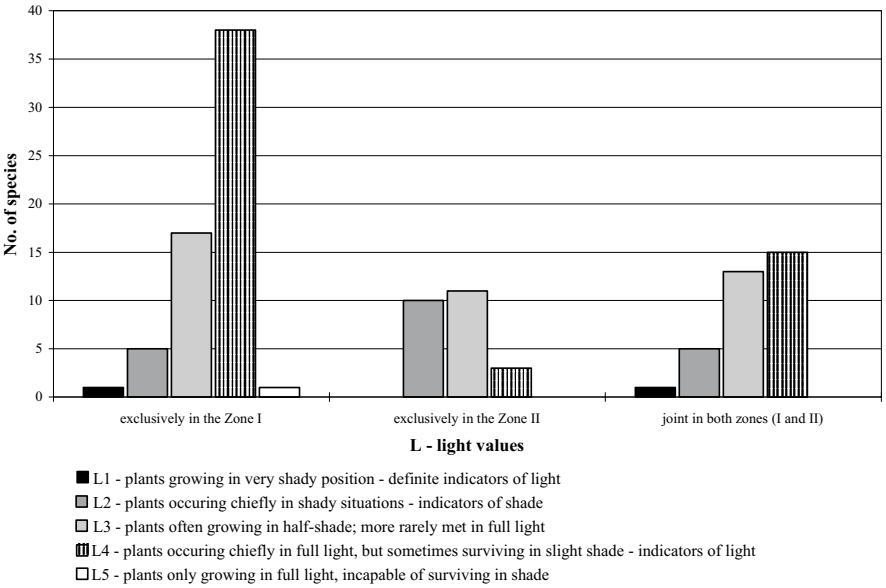



**Fig. 10.** Light values (L) for individual species by zones

terised as a dry or moderately wet and light habitat where the greatest number of mountain species and hemicryptophytes grow. Zone II (–6 to –23 m) is a wetter and more shaded habitat, with equal amounts of alpine and mountain species and a large proportion of geophytes.

## CONCLUSION

The entrance of Ledena jama has plant cover as far as the ice plug, down to–40 m in depth. Distribution of the plant cover to this depth is related to the large dimensions of the entrance and its morphology (funnel type), which enables enough light to penetrate for plant growth. Since Ledena jama is located in the Boreal – Subarctic climatic area, the lower temperatures and the increased moisture should not be limiting factors for the development of plants in the deeper parts of the pit. It is probably more influenced by light and lack of soil. With reference to the ecological factors measured and the composition of plant species, we divided the entrance into three zones. In the first two zones (+6 m to –23 m) it is mostly spermatophytes (122 species) and pteridophytes (5 species) that grow, while in Zone III (down to–40 m) most of the plants are bryophytes and algae. By analysing the ecological values of the pit according to Landolt we confirmed our division into zones and established the fact that the first two zones (I and II), as well as in composition of plant species, also vary in air temperature and humidity, amount of moisture in the soil, and light, which is reflected in the larger proportion of geophytes and alpine species present in Zone II.

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## SAŽETAK

### Ekološka i floristička obilježja Ledene jame na Velebitu – Hrvatska

M. Vrbek & S. Fiedler

Ledena jama se nalazi na Sjevernom Velebitu na nadmorskoj visini od 1240 m. To je 514 m duboka jama složene morfologije, većim dijelom ispunjena snijegom i ledom. Njena posebnost je ulaz dimenzija 74 × 43 m koji se od ruba postupno suzuje do dubine od 40 m gdje počinje ledeni čep koji ulazni dio odvaja od ostatka jame. Tijekom vegetacijskih sezona (proljeća, ljeta i jeseni) 1995. i 1996. godine popisivane su i prikupljane biljke koje rastu na površini oko ulaza, te na različitim dubinama ulaznog dijela jame. U isto su vrijeme praćeni i pojedini ekološki čimbenici: dnevno kretanje temperature i vlage zraka, te trenutna osvijetljenost. U skladu s njihovim vrijednostima i zabilježenim biljnim vrstama, ulazni dio jame podijeljen je na tri zone:

I. zonu (od +6 m od razine ulaza do –6 m) koja je zbog jačih utjecaja vanjskih mikroklimatskih obilježja po floističkom sastavu slična livadi oko ulaza,

II. zonu (–6 m do –23 m) koja se zbog jačeg utjecaja unutrašnjih mikroklimatskih čimbenika (smanjene osvijetljenosti, niske ali uglavnom stalne temperature zraka i visoke relativne vlage) po svom floističkom sastavu znatno razlikuje od I. zone, te su češće paprati, mahovine i alge, te

III. zonu (–23 m do –40 m), u kojoj, zbog najjačeg utjecaja navedenih unutarnjih mikroklimatskih čimbenika, rastu uglavnom mahovine i alge.

U I. i II. zoni zabilježeno je 128 biljnih vrsta. Sa svakom vrstom povezane su ekološke vrijednosti prema Landoltu. Pri tom je izostavljeno šest vrsta koje on nije spomenuo. Analizirane su sljedeće ekološke vrijednosti: F – vlažnost, L – osvijetljenost, T – temperatura i W – životni oblik. Njihovom analizom potvrđena je naša podjela ulaznog dijela Ledene jame na tri zone. Također je utvrđeno da se prve dvije zone razlikuju ne samo u biljnom sastavu, nego i u temperaturi i vlažnosti zraka, vlažnosti tla i osvijetljenosti što se odrazilo na veći udio geofita i alpskih vrsta u II. zoni.