COMPARATIVE STUDY OF RELATIVE HUMIDITY IN THE SHALLOW SUBTERRANEAN HABITATS (LIMESTONE AND SHALE SUBSTRATUM)

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Abstract. This paper approaches a very important issue that is still rarely studied in the literature, the ecologic factor relative humidity in the mesovoid shallow substratum (MSS) also called shallow subterranean habitat (SSH). Researches have been carried out in colluvial scree, of natural origin, with different substratum, limestone and epi-metamorphic crystalline schists, at different depths, of 0.5 and 1m, in Leaota Massif. This type of habitat presents certain particularities of some ecologic factors, amongst which we also include the standing higher level of the relative humidity. Considering the important ecologic functions of the MSS, not yet fully known, it is more necessary to make researches that can clarify the role of the lithological substratum regarding the variation the relative humidity value. This researches represent a part of a much wider study on the mesovoid shallow substratum, not only from the perspective of the main ecological factors, but also from the fauna perspective (invertebrates), study which started in 2014 and extended on a period of many years, approaching different aspects of the MSS. Such research studies on such a large period of time, which supposes the continuous, permanent monitoring of some main ecologic factors, are a breaking new ground not only for Leaota areal but also for Romania.

Keywords: relative humidity, mesovoid shallow substratum (MSS), shallow subterranean habitat (SSH), scree, Leaota.

Rezumat. Studiu comparativ al umidității relative în habitate subterane superficiale (substrat calcaros și șistos). Lucrarea de faţă abordează o problemă foarte importantă care este încă puţin studiată în literatura de specialitate, factorul ecologic umiditate relativă din mediul subteran superficial (MSS), numit si habitat subteran superficial (SSH). Cercetările au fost efectuate în grohotişuri coluviale de origine naturală, cu substrat diferit, calcare şi șisturi cristaline epimetamorfice, la adâncimi diferite, de 0,5 m și 1 m, în Masivul Leaota. Acest tip de habitat prezintă particularităţi ale unor factori ecologici, cum ar fi valoarea permanent mare a umidităţii relative. Având în vedere funcţia ecologică importantă a MSS, încă incomplet cunoscută, este cu atât mai necesar să fie efectuate cercetări care pot clarifica rolul substratului litologic în ceea ce priveşte variaţia umidităţii relative. Aceste cercetări reprezintă o parte dintr-un studiu mai extins al mediului subteran superficial, nu numai din punct de vedere al factorilor ecologici principali ci şi din punct de vedere faunistic (nevertebrate), studiu care a debutat în 2014 şi care se întinde pe o perioadă de mai mulţi ani, abordând diferite aspecte ale MSS. Astfel de cercetări pe o perioadă atât de lungă, care presupun monitorizarea permanentă a unor factori ecologici principali sunt un pionierat nu numai pentru zona Leaota, ci şi pentru România.

Cuvinte cheie: mediu subteran superficial (MSS), factori abiotici, temperatură, umiditate relativă, grohotişuri, Leaota.

INTRODUCTION

Scree represents a very interesting habitat type from the ecologic perspective, relatively little studied in Romania and not studied in Leaota Massif, until the debut of our research. This habitat type consisting of scree was called *mesovoid shallow substratum (MSS),* term introduced by researchers as JUBERTHIE et al. (1980), *or shallow subterranean habitat (SSH),* term introduced and used more recently by the biospeleologists CULVER & PIPAN (2009; 2012; 2014). One of the defining particularities of this type of habitat is represented by the fact that the relative humidity has very high values during the whole year (NITZU et al., 2014), much higher than on the surface of the soil. This creates favourable conditions for numerous species of invertebrates or even micro-mammals. They temporarily or permanently populate this type of habitat, which has complex ecologic functions, being able to function for some species as an ecological refuge (NITZU, 2016), facilitating others' migration towards other SSHs or towards the profound subterranean substratum, represented by caves (in many cases, the mesovoid shallow substratum and the caves are connected through a network of cracks, which ease the movement of some invertebrates (DOROBĂŢ, 2016). Others species permanently live in this type of habitat and even display specific adaptations. This is why the knowledge of the particularities of this type of habitat is very important and we hope that these researches would have a contribution to their knowledge.

MATERIALS AND METHODS

We have chosen, for the present paper, where we make an analysis on the variation of the RH ecologic factor, to focus on the interpretation of the results we had registered in two ecologic stationaries in natural origin scree, as far as possible from eventual human influences: stationaries Ghimbav and Popii Valley (Fig. 1); the first one was installed in limestone scree and the one in Popii Valley in schist scree. To permanently monitor the main ecologic factors, temperature (T) and relative humidity (RH) at different depths, we used the sampling method (NITZU et al., 2010) (through the samplers, we have collected at the same time, in a rhythmic manner, monthly, the fauna of invertebrates and micro-mammals also, our research having more objectives, not only the analysis of the ecologic factors). We introduced samplers in scree at different depths.

The samplers are made of PVC tube with a diameter of 8 cm; at its lower side, the tube has a hole around, from a height of 10 cm from the basis, on a length of 10-15 cm. Inside, we introduce a Barber trap, the diameter of the glass being the same as the internal diameter of the tube with a height of 10 cm, the margin of the glass being glued on the interior side of the tube. Through the holes we wade in the tube above the margin of the glass, the fauna elements enter (invertebrates, sometimes micro-mammals) and they are captured in the trap, which is partly filled with preservation liquid (ethylene glycol or ethyl alcohol). Data collecting on the relative humidity in the samplers (and also on the temperature) was made using DT 171 data-loggers, which were hanged above the Barber trap through a wire. The devices were set to record permanent registrations, during the whole monitoring period, from two to two hours. Data downloading was made on a monthly basis.

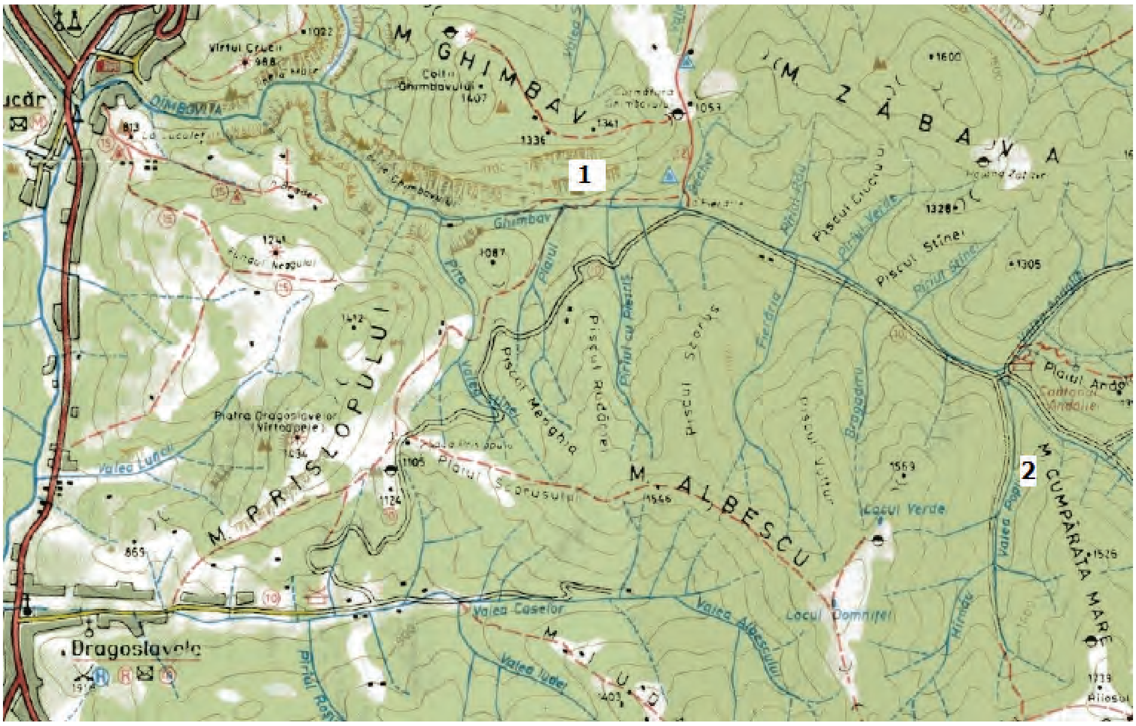

Figure 1. Location of ecological stationary: 1 – Ghimbav; 2 – Valea Popii (www.carpati.org/harti_harta/harta_harti/muntii/leaota-26/).

Thus, Ghimbav stationary was installed on a limestone scree, which spreads on an area of nearly 80 meters long and approximately 25-30 meters wide on the southern slope of Ghimbav Mountain, continuing with a fixed scree, covered with forest and herbal vegetation, which goes down to the basis of the foresting road. The slope is located on the right side of the Ghimbav River. Here, we placed three samplers, at depths of 1m, 0.75m and 0.5m.

- Sampler 1, at a depth of 1m in mobile scree, altitude samplers due 879 meters; GPS coordinates - N 45°22´43.0”; E 25°13´49.4”.
- Sampler 2, at a depth of 0.75m, in mobile scree, altitude 883 meters; GPS coordinates - N 45°22´43.1” and E 25°13´49.2”.
- Sampler 3, at a depth of 0.5m, located at the basis of the slope, in a forest, in fixed scree, covered by a layer of soil and litter of approximately 10 cm. GPS coordinates of this sampler are: N 45°22´42,7”; E 25°13´49,3”, the altitude is 860 meters. The angle of inclination of the slope is 40°, southern exposure.

The second stationary, Popii Valley, was installed in colluvial scree consisting of meso-metamorphic crystalline schists. The position of this scree is on the left bank of Popii Brook, a left tributary of the Ghimbav, at approximately 600 meters upstream from the confluence point. As the surface of this schist scree, of natural origin, was small, we managed to place samplers with data-loggers for the measurement of the ecologic factors at barely 1m and respectively 0.5m. When we tried to place a sampler at 0.75m, we faced signs of scree destabilization, so that we preferred not to take any risks. The position of these two samplers is defined by the GPS coordinates N 45°21´41.6"; E 25°16´38,8", their altitude being 1076 meters.

Considering all of these, in order to comparatively analyze the values of the ecologic factor *relative humidity*, both in limestone MSS and in schist SSH, we consider the registrations from the common depths in the two stationaries, namely 0.5m and 1m, as we had no samplers at 0.75m depth in Popii Valley, as we installed in Ghimbav stationary, with limestone scree. In order to make an accurate analysis, we calculated exactly the period in which the stationaries functioned simultaneously: October and November 2014 and May-August 2015.

RESULTS AND DISCUSSIONS

Centralized results for the ecologic factor RH at 0.5m depth. For the three ecologic stationaries where we placed samplers at 0.5m depth, subsequently to the centralization of all the registered values and the calculus regarding the average monthly value, we synthetically present the following dates of the RH researched abiotic factor (Tables 1 - 5):

I. Subsequently to the analysis and processing of the data registered at the Ghimbav ecologic stationary, at a depth of 0.5m, between August and November 2014 and April and August 2015 (Table 1), we can present the following conclusions:

- The monthly average of the relative humidity reached absolute maximum values of 100% (saturated air in water vapors) in May, July and August 2015.
- The minimum value of the monthly average relative humidity was 98.46%, for August 2014.
- The lowest value of the relative humidity (RH) was 78.4%, on June 6, 2015, 6:28 a.m.; in June 2015, the value was slightly higher: 98.60%.
- The value of the monthly average humidity for the whole period was calculated as 99.20%.

Table 1. Monthly values of relative humidity (%) in the samplers at 0.5m depth in Ghimbav stationary.

STATIONARY GHIMBAV, SAMPLERS 0.5 METERS								
	APR.	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.
MONTHLY AVERAGE	99.48	100	98.60	100	99.23**	99.76	99.28	97.19
MAX. VAL.	100	100	100	100	99.95**	100	100	99.3
MIN. VAL.	92.3	100	78.4	100	94.35**	93.6	97.2	81.5

**= the average of the registrations for the respective month of 2014 and 2015

II. For the stationary placed in schist MSS in Popii Valley, we present the following data, at the depth of 0.5m.

The presented monitoring period in table 2 includes the periods between October and November 2014 and May and December 2015 (only the first 5 days of this month) (wintertime will be separately presented in the stationary analysis).

- The maximum monthly average of the relative humidity (RH) was determined as having an absolute value (100%), for August, November and December 2015.
- The minimum monthly average of the RH was 97.28% (October, 2014).
- The minimum value of the RH was 80.8%, registered on November 25 - 2014, 3:02 a.m.
- The average monthly relative humidity was calculated for the entire period as 98.74%.

Table 2. Monthly values of relative humidity (%) in the samplers at 0.5m depth in Popii Valley stationary.

STATIONARY VALEA POPII, SAMPLERS 0.5 METERS								
	MAY	JUN.	JUL.	AUG.	SEPT.	OCT.	NOV.	DEC.
MONTHLY AVERAGE	98.39	98.97	99.97	100	97.88	97.42**	98.67**	100*
MAX. VAL.	100	100	100	100	100	99.65**	99.9**	
MIN. VAL.	87.8	86.2	95.8	100	84.6	87.15**	90.4**	

*= for the first 5 days only
**= the average of the registrations for the respective month of 2014 and 2015

Centralized results for the RH ecologic factor at 1m depth. The situation of the centralized data for the samplers at 1m depth is displayed in tables 3 and 4.

At Ghimbav stationary, subsequently to the interpretation of the registered results (Table 3), we mention the following situation for the depth of 1 meter:

- The maximum value of the monthly average of the relative humidity (RH) was 99.89% in May 2015; a nearly identical value is the one specific to June 2015: 99.82%. Decreasingly come the values for October 2014, namely 99.75% and for September 2015, 99.73%.
- For August 2014, we registered the minimal value of the monthly average of the RH, of 98.57%.

- The maximum value of the RH was 100% and was noticed in successive days, during all the months except August 2014.
- The minimum value of the RH was 90.2%, reached in August 2016 (the 16th of August, at 22:15), as well as in July (the 6th of July, at 10:01 p.m.) and on the 6th of August 2015, 10:01 a.m.
- The annual amplitude of the relative humidity in the stationary was ΔRH_{annual} = 100%-90.2%=9.08%.
- The calculated monthly average RH for the whole period is 99.41%.

Table 3. Monthly values of relative humidity (%) in the samplers at 1m depth in Ghimbav stationary.

STATIONARY GHIMBAV, SAMPLERS 1 METERS								
	APR.	**MAY**	**JUN.**	**JUL.**	**AUG.**	**SEPT.**	**OCT.**	**NOV.**
MONTHLY AVERAGE	99.25	99.89	99.82	98.68	98.90**	99.73	99.75	99.76
VAL. MAX.	100	100	100	100	99.85**	100	100	100
VAL. MIN.	92.4	96.4	98	90.2	90.2**	97.1	98.2	97.1

*= only for the first 5 days in December
**= the average of the reporting for the respective month in 2014 and 2015

In the case of the sampler at 1m depth from the Ghimbav stationary, placed at the base of the mobile scree, before the forested area which covers the basis of the slope, we found the frozen sampler on the 5th of April, 2015. The registrations of the values of the ecologic factor temperature during April and even May 2015, thus in the middle of spring, shows that the sampler registered temperatures close to 0 °C or even negative temperatures (-0.2°C, in April, at 0.75m and 0.1°C at 1m; 0.9°C in May, at 1m). This shows in an indirect manner that, in certain conditions, it is possible for the slopes to be oversaturated by water. Finding ice at the basis of the sampler in April and May shows once again that there is water in the scree and that it freezes, and it will defrost very slowly. Although it seems impossible, as the scree has a high inter-clastic porosity, which would not allow water to gather, this phenomenon has a simple explanation. If water gather somewhere in the depth, at the basis of the scree, it means that there is a waterproof clay layer at the basis of the slope which stops the draining of water. This is confirmed by the forest that is found on the lower basis of the slope, which is fixed on this area, where we find clay material and also soil. If, after the precipitations, the level of the water in the scree almost reaches the surface, the inter-clastic spaces that are normally filled with air disappear, being filled with water. Thus, a more rapid thermic transfer is made from the surface to the depth and water freezes. The air in the low spaces, under 5mm diameter, is the best isolator. In conditions of humidity, water gradually substitutes the air in the pores of the rocks, thus leading to the increase of the thermal conductibility. Water is 23.2 more times a better conductor of warmth than air (λ_{water} = 0.58 W/mK). Once this thing happens, it will defrost very hard. This is due to the fact that during spring, once that, through evaporation or a slow surface draining, a part of the water disappears and free inter-clastic spaces appear again, with air, which give back the scree area above the ice the isolating proprieties.

By analyzing the gained results for both depths, of 0.5 and 1m, we conclude that the monthly average of the relative humidity has high values, of more than 97%, irrespective of the month or of the depth of the sampler. During many periods, at all depths, we even register absolute maximum values of 100% of the RH, for periods of days, as one can see in the tables. By analyzing the situation of all samplers, we only once found a minimum value of the RH under 80%. The minimum of the stationary was 78.4%, on the 6th of June 2015, 3:28 a.m., at 0.5m; also, between the 5th of June 3:28 p.m. and the 6th of June, 1:28 a.m., the RH went below 80%.

For Popii Valley stationary, the calculus leads to the following results corresponding to the sampler of 1m (Table 4):

- The maximum value of the monthly RH average was 100%, for September and December 2015.
- The minimum value of the monthly RH was 96.20%, for October 2014.
- The maximum RH value was 100%, registered during more days in all months, except October 2014.
- The minimum RH value was 85.3%, reached twice in the same day: the 25th of November 2014, 3:02 a.m. and 6:02 a.m.
- We conclude that the annual amplitude of the relative humidity in this stationary was ΔRH_{annual} = 100%-85.3% = 14.7%.
- The calculated monthly RH average for the whole period is 99.06%.

By centralizing the results for both depths, of 0.5 and 1m, we notice that, without any exceptions, the relative humidity of the air in the samplers is high, (the monthly average did not decrease below 96.2%), irrespective of the period of the year, often for many days, weeks and even one month, thus reaching the value of 100%.

Table 4. Monthly values of relative humidity (%) in the samplers at 1m depth in Popii Valley stationary.

STATIONARY VALEA POPII, SAMPLERS 1 METERS								
	MAY	**JUN.**	**JUL.**	**AUG.**	**SEPT.**	**OCT.**	**NOV.**	**DEC.**
MONTHLY AVERAGE	97.73	99.19	99.99	99.99	100	98.06**	98.79**	100*
VAL. MAX.	100	100	100	100	100	99.4**	100**	100*
VAL. MIN.	90.2	90.5	98.9	99	100	92.55**	92**	100*

*= for the first 5 days only
**= the average of the registrations for the respective month of 2014 and 2015

Considering the fact that in Popii Valley we had installed data-logger during the winter season also, for the monitoring of temperature and relative humidity abiotic factors, the results regarding the RH factor confirm the situation of all the year, namely that this ecologic factor has a value of 100% or close to it nearly all the length of the period when the reporting had been done (DOROBĂȚ & DOBRESCU, 2016). This leads to the formation of the dew point on clasts and, evidently, on the walls of the tubes of the samplers (DOROBĂȚ & DOBRESCU, 2015a; b).

We placed a survey at the depth of 0.75 m only in Ghimbav location (for the reasons shown above) and we cannot compare these results with the ones obtained at Popii Valley stationary. However, analyzing the results for the survey of 0.75 m from Ghimbav stationary, we notice that things are confirmed; as with the others surveys, the relative humidity had values close to saturation or even 100%. Practically, only in August 2014, the relative humidity did not reach its maximum value, although it was very close (99.6%). In all other months, there were days when this ecological factor reached its maximum value (Table 5).

Table 5. Monthly values of relative humidity (%) in the samplers at 0.75m depth in Ghimbav stationary.

STATIONARY GHIMBAV, SAMPLERS 0.75 METERS								
	APR.	**MAY**	**JUN.**	**JUL.**	**AUG.**	**SEPT.**	**OCT.**	**NOV.**
MONTHLY AVERAGE	98.08	99.66	99.99	99.76	98.51**	99.75	99.88	98.41
MAX. VAL.	100	100	100	100	99.8**	100	100	100
MIN. VAL.	90	83.8	98.5	98.3	90.2**	97.1	97.7	83.8

*= for the first 5 days only
**= the average of the registrations for the respective month of 2014 and 2015

CONCLUSIONS

For depths of at least 0.5 meters, the relative humidity of the air in the SSH (MSS) is very high, irrespective of the period of the year or the type of geological substratum, limestone or crystalline schists.

Frequently, the value of RH is 100%, reaching the saturation and forming the dew point. 100% values of RH can continuously persist for more than one month, the dew point being specific to the MSS, irrespective of the rock type, schist or limestone.

At a depth of minimum 0.5m, the annual amplitude of the relative humidity has been low, under 15% in both stationaries, the value of the RH factor slightly fluctuating during the year.

In certain conditions, some areas of the MSS can be flooded, completely saturated with water.

Due to this particularity, namely very high values of the RH during the whole year, reaching even 100%, conditions appear for these scree areas (MSS, SSH) to function as a shelter for many invertebrate species, when the surface conditions become improper, as for example, summers when draught occurs.

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