MICRO CLIMATE IN THE BELOJAČA KARST CAVE IN PANNONIAN SLOVENIA

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Belojača cave lies on the west corner of the Pannonian basin, on contact between the Eastern Karavanke Alpes and Haloze. Within the research about the Belojača cave a six-month research about its ecosystem characteristics was performed with an emphasis on micro climate. The information was collected by field measurements in the period from October 2016 to March 2017. Cave ecosytems are classified as extreme because their ecosystem characteristics change much slower and later than the characteristics of all other common ecosystems. Many animal species, especially bats are drawn to habitats like that. Bats are known for using caves like the Belojača cave for hibernation and mating. Belojača cave is one of the rarest karst caves on the west corner of the Pannonian basin. With the help of all the measurements and gathered data we successfully showed interesting correlations between micro climate characteristics of the Belojača cave.

Key words: *cave ecosystem, Belojača cave, water, soil, climate, bats.*

INTRODUCTION

The mountainous area of Boč and Macelj, where the Belojača cave is located, belongs to Pannonian Slovenia. In the south-east this region borders with Croatia, in the south-west it turns into Voglajn and Zgornjesotel mountains, in the northwest into Dravinjske gorice and in the northeast into Haloze. The Boč and Macelj region is characterized by moderate continental climate with an average annual rainfall of 1100 to 1200 mm, with average summer temperatures of 8°C to 10°C (Vovk Korže, 2013). The mountainous area Boč is the geological western extension of the Karavanke i.e. Posavina hills, therefore it consists primarily of more persistent triassic limestones and dolomites (Aničić 1984, Aničić 1985). Karst was developed on limestone and dolomite. Because of mostly limestone there are fewer surface watercourses (Novak, 1980), the surface is predominantly karstic and the water is rapidly infiltrated into the karstic underground (Gospodarič, 1960).

The Belojača cave is a natural value and knowing it is very important for the security regime of the cave (Bedjanič, 2009, Kamenšek, 2005). Up to now, many bats have been seen in Belojača, such as a lesser horseshoe bat (Rhinolophus hipposideros), a greater horseshoe bat (Rhinolophus ferrumeqinum), a Mediterranean horseshoe bat (Rhinolophus euryale), a Schreiber's bent-winged bat (Miniopterus schreibersi) and a greater mouse-eared bat (Myotis myotis) (Presettnik, 2007; Presetnik 2009). The cave is classified as an underground geomorphological natural value (Hlad, 1995). Previous research suggests that the Belojača cave and the nearby Brezno pod Domišaki are used by greater horseshoe bats for wintering (Presetnik, 2007). In Belojača there are up to 20 greater horseshoe bats. A Mediterranean horseshoe bat is relatively rare in Slovenia. This area is the northern border of their distribution (Kryštufek, Červeny 1997). The caves with constant climate and temperature, 10 - 12.5°C serve as their winter shelters. Bats usually overwinter in clusters, but they do not touch each other (Presetnik, 2009).

METHODOLOGY

Coolecting field data

The field work took place at four points, in front of the cave, at the entrance to the cave, and two points in the cave with the purpose of monitoring the abiotic factors and their fluctuations in the winter period. The measurement points were:

- sampling of the pre cave climate 1-100 m before the entrance to the cave
- sampling of the pre cave climate climate 2-5 m before the entrance to the cave
- sampling of the cave climate 3-5 m deep in the cave
- sampling of the cave climate 4-20 m deep in the cave

Field measurements were performed once a month (from the end of October 2016 to the end of March 2017). Measurement flow: the climate parameters were measured in front of the cave and in the cave (temperature, air movement, air humidity, ozone in the air, amount of light).

After six months, we compared the data on four-point microclimatic properties and demonstrated the correlation between the important values of the cave ecosystem.

RESULTS

The collected data are displayed in months from October 2016 to March 2017

October 2016

Table 1: Monitoring the microclimate of the Belojače cave October, 2016

CAVE CLIMATE	Point 1	Point 2	Point 3	Point 4
Temperature °C	13.9 °C	13,2 °C	12,8 °C	11,7 °C
Air movement km/h	0 km/h	0 km/h	0 km/h	0 km/h
Air humidity %	94 %	90 %	85 %	80 %
Ozone in the air	0	0	0	0
Luminance lux	1814 lux	615 lux	2,5 lux	0 lux

In October 2016, the conditions of the warm autumn were prevailing after a short rainy season, so the humidity outside the cave was higher than in the cave. The cave was still cold, and as the cold air is less sensitive to moisture, a big difference in humidity at all four points was felt. Four points of measured climatic data show a clear correlation of temperature drop, light intensity decrease, and moisture rise, which is consistent with the previous research, that the climate of the cave has retention or restraint, so in the summer it is cooler and less humid than the outside climate.

From the data collected in Table 1 it is apparent that the temperature falls from point 1 (the climate in front of the cave, to point 2, in front of the cave entry, and to points 3 and 4 in the cave). Likewise, there is an immediate link between decreasing the temperature and decreasing the amount of light so we can conclude that there is a positive correlation between the drop in the temperature from point 1 in front of the cave to point 4 in the cave.

There is a clearly noticeable decrease in the intensity of light by entering the cave (Figure 1).

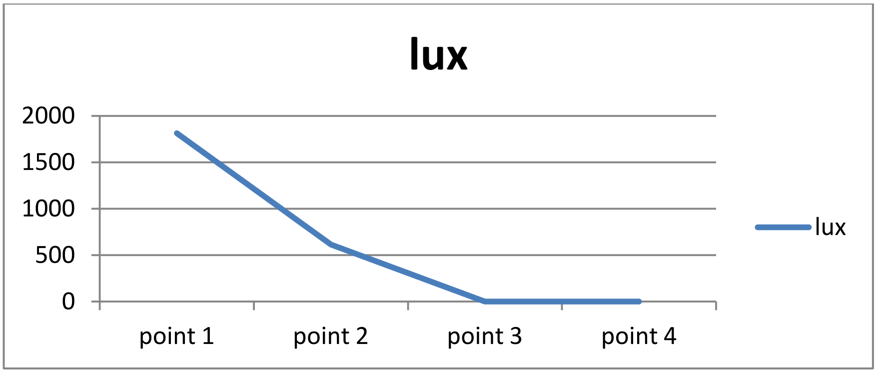

Figure : Decreasing the intensity of light from the entrance to the interior

November 2016

At the end of November the late autumn conditions prevailed, the air in front of the cave was 2.2°C and getting nearer to the cave the temperature was rising. Outside, in front of the cave at point 1, the temperature fell by more than 10°C from October to November. However, in the cave the drop was only 5°C. This is an important fact that confirms the fact that the cave climate is not changing fast.

Table 2: Monitoring of the microclimate of the Belojače cave November, 2016

CAVE CLIMATE	Point 1 1	Point 2	Point 3	Point 4
Temperature °C	2.2 °C	2.4°C	4°C	4.6 °C
Air movement km/h	0 km/h	0 km/h	0 km/h	0 km/h
Air humidity %	44 %	48%	54 %	62 %
Ozone in the air	0	0	0	0
Luminance lux	1475 lux	266 lux	5.2 lux	0 lux

The temperature at point 1 was -5 ºC, at point 2 it was -3 ºC, at the entrance to the cave -1 ºC, and only inside the cave it increased to 2ºC which indicates the importance of the cave ecosystem with stable temperatures. The difference in the moisture of the inner and outer space of the cave increased, the outside air was dry and the interior of the cave wet (ratio 1: 2.5).

With the temperature rise, the moisture has risen too, so there is a positive correlation between the elevated temperature and higher moisture content, and vice versa, the colder the less humid it is.

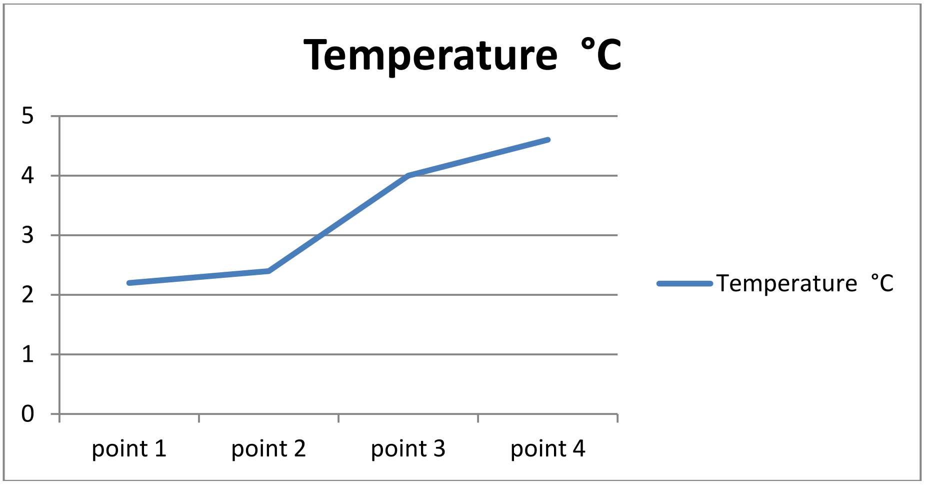

Fig. 2: Temperature increase as approaching closer to the cave.

December 2016

Table 3: Monitoring of the Belojače cave - December 2016

CAVE CLIMATE	Point 1	Point 2	Point 3	Point 4
Temperature °C	-5 °C	-3 °C	-1 °C	2 °C
Air movement km/h	0 km/h	0 km/h	0 km/h	0 km/h
Air humidity %	36 %	50 %	62 %	82 %
Ozone in the air	0	0	0	0
Luminance lux	883 lux	156 lux	4.6 lux	0 lux

January 2017

The month of January 2017 was the coldest in the half-year measurement period, the temperatures were negative at three measuring points, only in the cave the temperature was 0°C. This was a particularly cold winter period in general, so it is not surprising that the daily temperatures were below the freezing point. At that time the humidity was also very low, only 20% at the first point, 24% at the second measurement point and 68% in the cave. During the measurement the environment was covered with snow, which probably influenced the amount of light at the measuring point 1.

Table 4: Microclimate monitoring - January 2017

CAVE CLIMATE	Point 1	Point 2	Point 3	Point 4
Temperature °C	-10 °C	-5 °C	-1 °C	0 °C
Air movement km/h	0 km/h	0 km/h	0 km/h	0 km/h
Air humidity %	>20 %	24 %	54 %	68 %
Ozone in the air	0	0	0	0
Luminance lux	2150 lux	330 lux	1,2 lux	0 lux

Table 4 shows positive correlations between low temperatures and elevated humidity, which means that at negative temperature the humidity completely disappears. The temperature in the Belojača cave did not exceed 15°C.

February 2017

At the end of February 2017 the warming occurred after a long, severe winter, which was visible in temperatures and humidity (positive correlation was maintained). The measurements were made after abundant precipitation.

Table 5: Monitoring the cave microclimate - February 2017

CAVE CLIMATE	Point 1	Point 2	Point 3	Point 4
Temperature °C	4°C	6°C	6°C	6°C
Air movement km/h	0 km/h	0 km/h	0 km/h	0 km/h
Air humidity %	66 %	56%	81%	86%
Ozone in the air	0	0	0	0
Luminance lux	1876 lux	265 lux	0 lux	0 lux

March 2017

The temperature and humidity of the air in March 2017 was varied and unparalleled with autumn, which is why the pits became very cold in winter. That is why the pre-climate climate is warmer than the one in the pit, and we conclude that the heat storage effect has been lost during the winter months.

Table 6: Microclimate monitoring - March 2017

CAVE CLIMATE	Point 1	Point 2	Point 3	Point 4
Temperature °C	9 °C	7 °C	8 °C	7 °C
Air movement km/h	0	0	0	0
Air humidity %	70 %	66 %	96 %	84 %
Amount of ozone in air	0	0	0	0
Amount of illuminance lux	2680	239	0	0

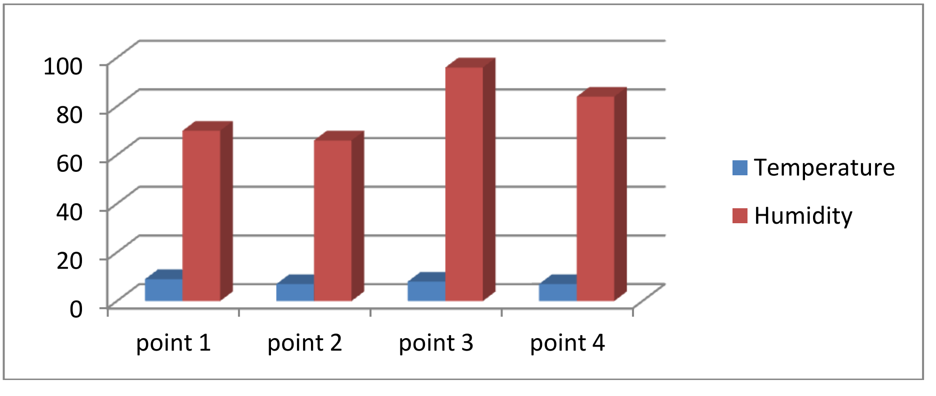

Fig. 3: In March 2017, the atmosphere was warmed outside the cave rather than inside the cave and the highest humidity was at point 3 bin front of the pit

At point 3, in front of the entry into the Belojača cave, the humidity was the highest in March, 96%, which can be explained with equal temperatures in the front and in the cave. Point 3 is the boundary point of both ecosystems.

Correlations between the microclimatic properties of the Belojača cave

The data from the field measurements of the quality of the pre-cave and the cave climate says that air is without features, since ozone was never measured. The illuminance shows a decrease from the distance from the cave, that is, the more we were at the cave, the darker it was, and vice versa. Over 2000 lux were measured at point 1 - the pre-cave climate and a half less at point 2, while points 3 and 4 in the cave were almost without illuminance (with the exception of January with 1,2 lux).

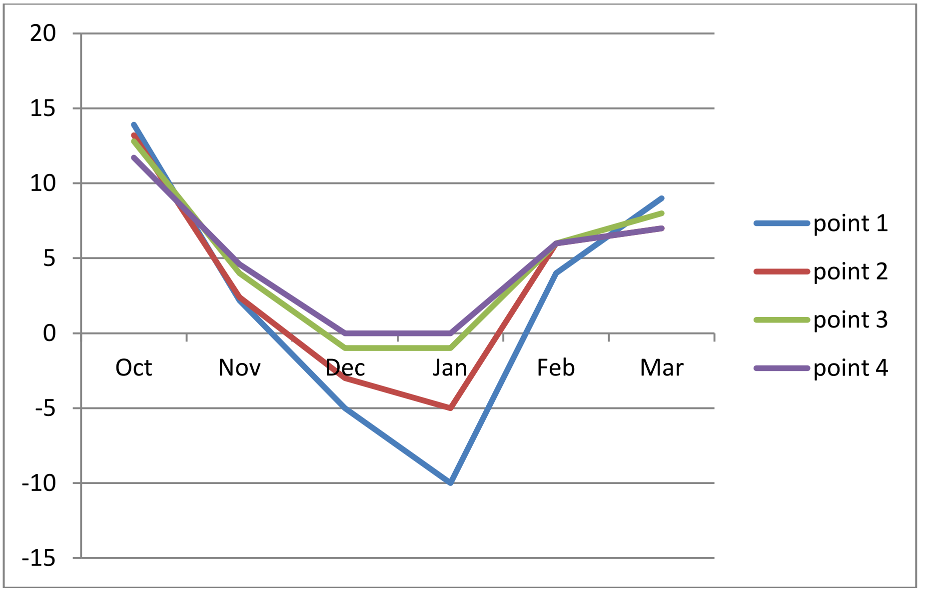

Fig. 4: Temperatures from October 2016 to March 2017 point to low oscillation of point 4 and minimal difference in microclimate between outer space and the interior of the cave in March 2017.

Humidity flow at all four measuring points by months suggests that humidity in the pit was preserved between 60 and 90% during the winter period, while at other points it dropped to 20% (Figure 5).

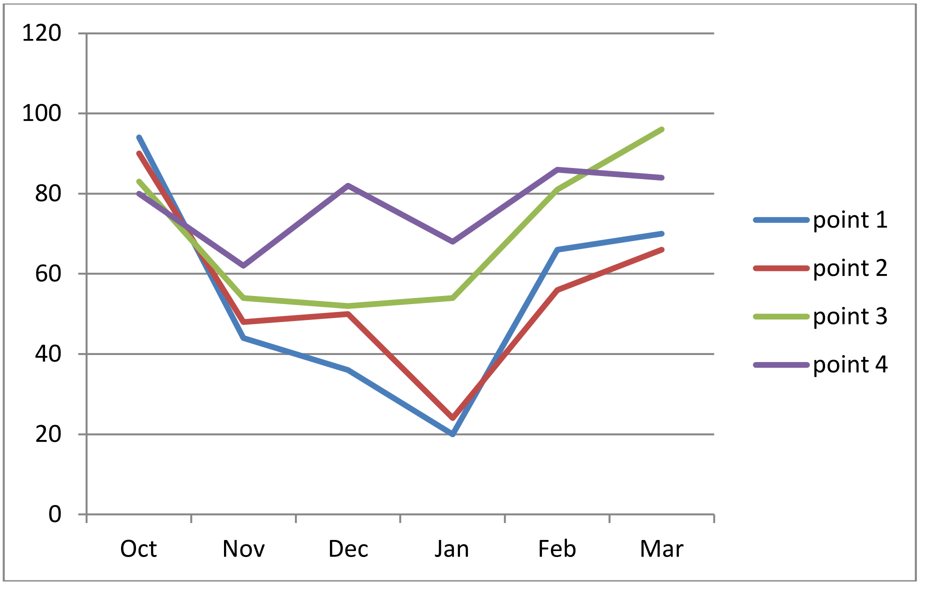

Fig. 5: Humidity from point 1 to point 4

The comparison of cave climate (Point 4) indicates an evenly temperature and humidity change by months.

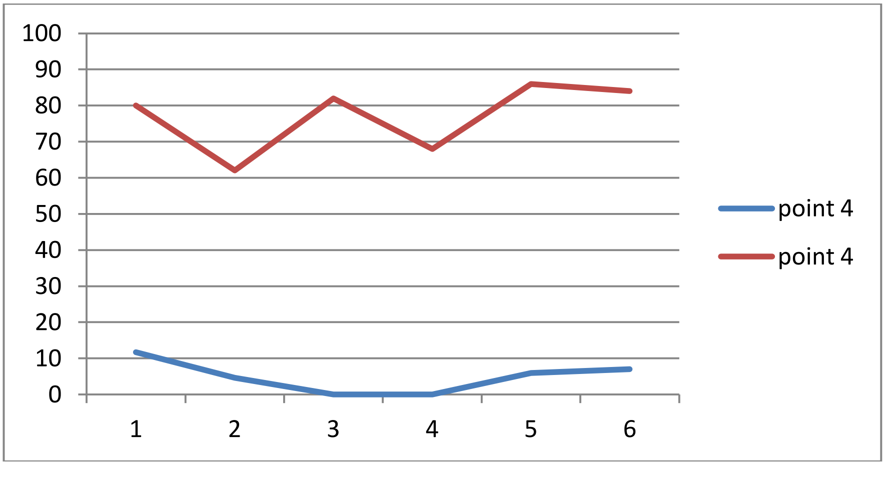

Fig. 6: Cave microclimate of Point 4.

Unlike point 4, the movement of temperature and humidity varies considerably in the summer months and the largest difference is in the warmest period, compared to the cold part of the year. Comparison of humidity (red line) and temperature at point 1 (Figure 7).

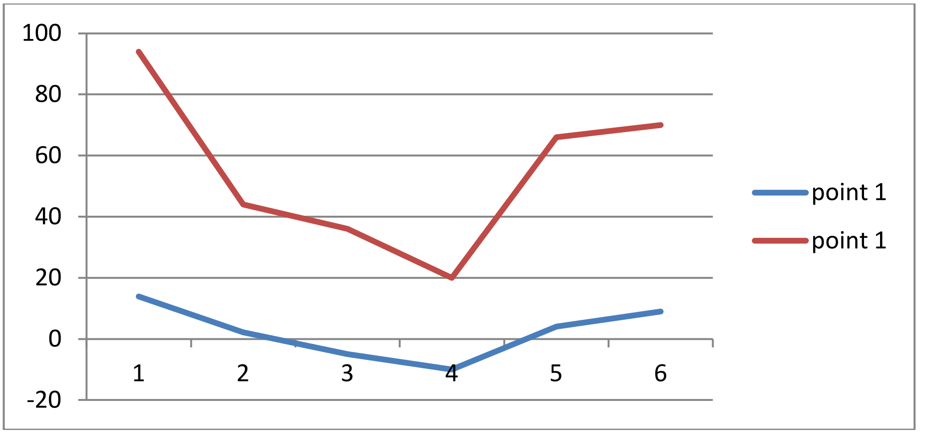

Fig. 7: Comparison of humidity (red line) and temperature at point 1.

Air humidity change in % indicates major changes in front of the cave and less in the cave (Figure 8).

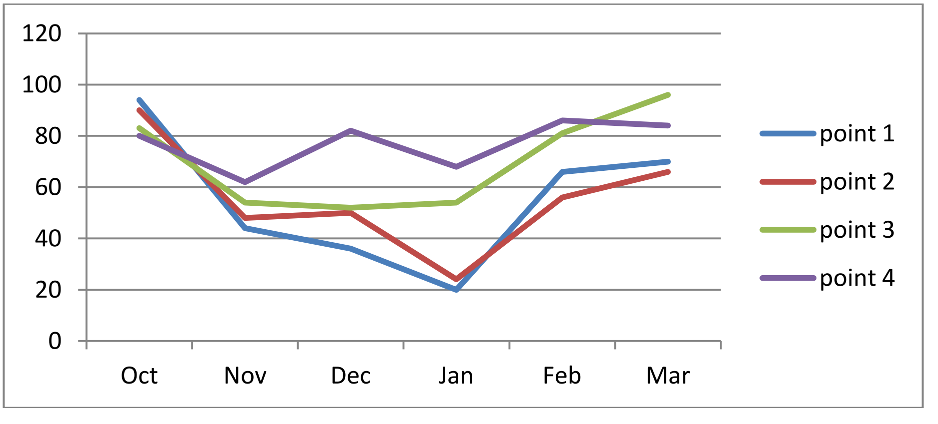

Fig. 8: Air humidity change in front of and inside the cave.

CONCLUSION

Knowing the microclimate properties of the cave ecosystem is useful from the standpoint of distinctive features. A half-year exploration of the Belojača cave ecosystem with an emphasis on microclimate points to the typical properties of the cave climate seen through the delay of temperature (due to constant climate in the cave) compared to the autumn and spring periods. Humidity and temperature data correlate positively so that with the drop in temperature moisture decreases as well. With measurements deeper in the pit, the temperature would be even higher, and consequently, the humidity as well. Cave Belojača has favourable conditions for wintering, remains warm and humid in winter, as shown by the results of our measurements. This is what makes it a convenient place for bats, namely they overwinter at 5 ºC to 10 ºC and hibernate at temperatures between 7 ºC and 10 ºC, from which we can conclude that the interior of the Belojača cave is a favourable ecosystem for these animals as well as microclimatic factors are a favourable environment for bats (cave ecosystem).

The cave ecosystem is protected as a natural value due to the microclimatic conditions, water, vegetation and animal peculiarities, making them an important potential for green tourism, education and raising awareness among people.

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