

# THE DEVELOPMENT OF THE VEGETATION IN LAMPLIT AREAS OF THE CAVE SZEMLO-HEGYI-BARLANG, BUDAPEST, HUNGARY

RAJCZY, M. - BUGZKO, K.

There are three conditions necessary for the life of the plants: water, inorganic nutrients and light. As in the caves it is only the third one lacking, the illumination of a cave unavoidably results in the development of vegetation of green plants in lamp-lit areas. The green coatings make a lot of problems all over the world being dangerous either in esthetical or in ecological point of view (Rajczy 1989). The biological research in the illuminated caves is in its initial stage. Some floristic data are available for the initial phase (Padisák et al. 1985) and for the final phases (e.g. P. Sikmáromy et al. 1986, Hajdú et Orbán 1981), but the pattern of the process in time and space is almost unknown. To trace this phenomenon it was the cave Szemlő-hegyi-barlang which seemed to be an ideal subject, because we had the opportunity to observe the development of the vegetation in the lamp-lit areas since its beginning. Anyhow, in this cave it is of crucial importance to prevent the development of the extended green coatings, because it is almost impossible (and very expensive, as well) to remove the thick formed carpets from the richly ornamented surface. We are going to give our brief summary of our experiences and results concerning the above.

## The description of the cave

The cave, situated in the territory of Budapest, is one of the tectonically preformed caves having been developed in the vicinity of the hot springs of Mts. Budai-hegység. The galleries of the cave were enlarged by the corrosion of thermal and cold waters most probably at the end of the pliocene. The length of the system exceeds 2 km. The walls are richly decorated by botryoidal stalactites originally precipitated from thermal waters as aragonite, as well as by small plates of calcite.

## The history of the cave

The entrance of the cave was accidentally discovered in 1930 while mining stones for a house. Since that time it has been one of the most popular destinations of cavers touring, teaching and exploring activities as it is very near to the city and its beauties are unique. Though there were several plans to open it to the public, unfortunately both entrances were vertical and so unsuitable for this purpose. There was a gallery, coming nearer to the slope of the hill, only discovered in 1973 and this removed all the difficulties. The opening plans were accepted soon after and the mining works began in 1974. By the first months of 1984 everything was finished inside the cave including the whole lighting system (Hazslinszky 1985). Then until the spring of 1986 there were only a few activities in the cave because the works continued outside (the reception building and the park). Actually the lighting system was rebuilt during the summer of 1986, because of the problems with the old one. Many of the old lamps were removed, more suitable lamps were used instead. Finally the cave could be opened at last in the autumn of 1986.

## Materials and methods

It was in March 1984 when we took samples from the lamp-lit areas first. This time we collected them from every green area. The second occasion was in January 1986, in the above mentioned "dark period" and the third time was one week before the opening of the cave (October 1986). That time, since the illumination system was completely rebuilt, we could find only a few lamps of the old system, which remained on their place after the reconstruction. As a consequence several lamps were marked out to trace the process. From this time on the lamp areas have been tested at least every six months (Table 1). Unfortunately the expansion of the green plants was much more rapid than we had thought. About half a year later the cave seemed to be very close to the "green explosion". We had no other choice: we had to sterilize the green surfaces. To extirpate the plants we used formaldehyde solution (2-4 vol.%) and only the really green surfaces were treated. The next samples were taken only during the autumn of 1988 to check the floristical consequences of the extirpations.

The algological collecting procedure was carried out by means of presterilized instruments. Both the visible green spots and the apparently intact surfaces were scraped off by knife into the collecting jars filled with fluid Bold medium (Stein 1973). The samples were then cultivated in the laboratory both in solid (11 g/l agar) and in liquid medium for the correct identification. The cultures were checked 2-4 times within 6 months (the first one was done 1-2 weeks after the beginning of the cultivation). Permanent microscopic slides were made for identification of diatoms using Horváth's method (1975). The location of the sampling points are mapped in Fig. 1.

The floristical composition was analysed by Jaccard's resemblance measure (Jaccard 1901) and the WPGMA fusion algorithm (Sneath Sokal 1973), using the SYN-TAX program package (Podani 1988).

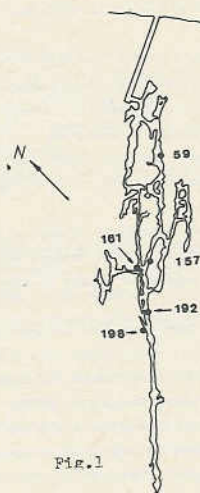


Fig. 1

Fig. 1. The schematic map of the cave. (redrawn from Hazslinszky (1985) - full circles: sampling points of the cluster analysis)

## Tables

Table 1. The dates of the observations, sampling and extirpations in the cave "Szemlő-hegyi-barlang".

Code	Date	No. of algological samples	Extirpations
A	March, 1984	16	
B	Jan 28, 1986	11	
C	Oct 23, 1986	15	
D	Jan 8, 1987	13	
E	Feb 17, 1987		+
F	May 26, 1987		+
G	Oct 26, 1987		
H	Nov 5, 1987		+
I	Feb 12, 1988		
J	Sep 12, 1988	5	+
K	Feb 6, 1989		

Table 2. The number of the lamp-lit areas with visible green plots and the total number of the lamps in the beginning of 1988 (A-K: codes of collecting trips as in Table 1).

Lamp types	Total	A	B	C	D	E	F	G	H	I	J	K
Incandescent lamps												
ordinary lamps (40-60 W)	17	8										
safety illumination	22			2	4	4	4	11	13	2	7	13
level illumination	89			3	17	19	14	21	24	9	17	25
spot lights (100-150 W)	49					2	2	7	8	12	8	7
headlamps (100-300 W)	36					3	3	8	11	12	9	6
headlamps (1000-1500 W)	2	1	1	1	1	1	1	1	1	1	1	2
iodine lamps (500 W)	6							2	1	1	3	4
sodium lamps (500 W)	4								1	1		1
Total	208	18	9	6	27	29	36	54	64	32	42	64

## Results and discussion

### Floristical data

During our 5 year study altogether 35 algal taxa were identified from among 60 samples collected from the illuminated part of the cave. Moreover, at least 3 moss and 1 fern species live there. The number of juvenile moss shoots was very low though their protonemata were collected frequently so we could not identify them. As regards for the fern, we have found only 2 fern prothallia this winter. The distribution of different algal phyla is quite uniform (Fig. 2), every taxonomical group of the algae that is common in Hungarian soils and waters is detectable here.

The most frequent species was *Fragilaria pinnata*, which was observed in 65% of the samples. Other common species were *Phormidium foveolarum*, *Fragilaria brevistriata*, *Chlorohormidium flaccidum*, *Navicula cryptocephala*, *Plectonema schmidlei* and moss protonemata. They occurred in 13-37% of the samples. Further 8 species were found 3-6 times (5-10%). Nine more species turned out to be rare (there were only in 2 samples) and the rest 11 species were only once found.



We could distinguish no characteristic distribution pattern of the common species. Their occurrence seem to be sporadic, namely the frequent species can be collected in very different parts of the cave.

To answer the interesting question whether it is the place, the environment, or the succession (the changes in time) is more decisive in the composition of the lamp flora, we performed cluster analysis. For this purpose the data of those lamps were used which remained on their original place after the reconstruction. The result clearly shows us, that the quality of the substrate is a crucial factor for the flora (Fig. 3). The samples from the same substrate are closer to one another than those taken at the same time. The samples from clay are the closest from the area of the lamp No. 198 (see Table 3).

Table 3. List of species in the samples used for cluster analysis. A-J: codes of collecting trips as in Table 1 (A samples were not taken into consideration as mentioned above). Lamps (see Fig. 1): 157 and 161 - ordinary lamps of the safety system, concrete; 192 - ordinary lamp of the level illumination, moist concrete; 59 - ordinary lamp of the level illumination, moist limestone surface; 198 - big headlamp, clayey surface.)

Species	157				192				161			59					198		
	A	B	C	D	A	B	C	D	A	B	J	A	B	C	D	E	A	B	C
Chroococcus minor (Kg.) Nag.				+															
Phormidium foveolarum (Mont.) Gom.						+	+		+	+	+				+	+			+
Plectonema schmidlei Limanowska							+	+							+	+	+	+	
Hormogonales sp.							+	+								+			
Nostoc sp.							+	+											
Amphora delicatissima Krasske										+									
Fragilaria brevistriata Grun.		+	+			+							+	+	+	+			
Fragilaria pinnata Ehr.		+	+	+		+	+		+	+	+	+	+	+	+	+	+	+	+
Navicula cryptocephala Kttz.			+	+						+									+
Monodus subterranea Boye-Petersen						+													
Vischeria stellata (Chod.) Pasch.							+									+		+	
Chlorella sp.		+	+	+			+	+	+	+		+						+	+
Chlorohormidium																+		+	+
flaccidum (Kttz.) Fott							+	+											
Choriocystis guttula Hind.										+			+	+	+				+
Stichococcus bacillaris Nag.											+								
Stichococcus minor Nag.															+				
Gongrosira sp.								+	+										+
moss protonemata											+		+		+	+	+	+	+
Total number of species	2	4	2	5	1	7	6	5	3	6	4	5	5	5	8	5	4	7	6

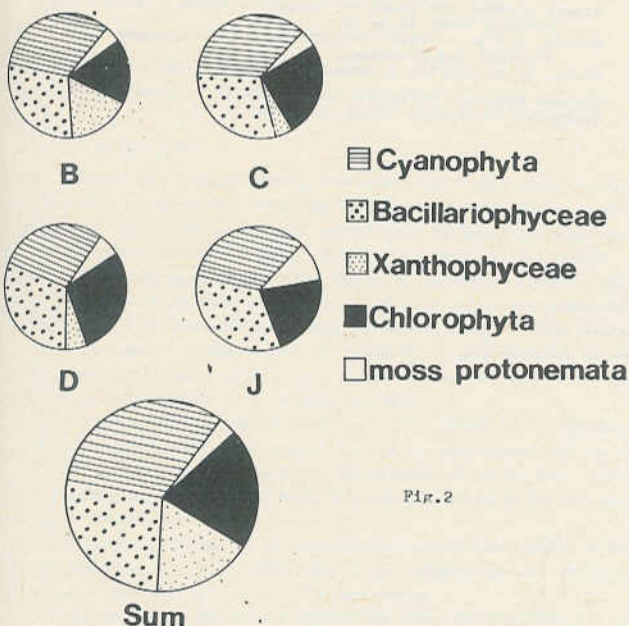


Fig. 2. Species numbers of the taxonomical groups in the samples. Analysis of the process

We began our study after a 3 year period, while the miners were working in the cave. Macroscopic green patches were found around 18 lamps (details in Table 2) and 12 species could be detected and cultivated from the samples (including moss protonemata). This means that 2 years before the opening of the cave several algal species (especially diatoms) and at least one moss species lived in the lampülit areas. The algae were identified by Zs. P.-Komáromy and J. Padisák using slightly different methods, so their data were not taken into account in the further analyses.

The first sampling was followed by a long dark period (almost one and a half year) when the lighting system was not used. The second sampling was carried out at the end of this period. Naturally, the number and the size of the green patches reduced and the number of the lamps with a visible lamp flora reduced as well by the half (9 lamps). The total number of species was 24. The average number of species per sample was 6, which is high comparing with that of the other caves. Using the data of P.-Komáromy et al. (1985) in the cave Anna-barlang there were only 6.5 species per lamp,

though this cave had welldeveloped, extended green carpets around almost all of its lamps. An average of 6.2 species per sampling site could be counted in the case of Baradla cave using the data of Hajdú and Orbán (1981).

Our next visit was one week before the opening of the cave. At that time there were green patches around 7 lamps and at least 20 plant species lived there. The average number of species per lamp was 3.6, which was fairly low, perhaps in consequence of the reinstallation (between our second and third collecting trip the total electric system was rebuilt, and we could find altogether 5 original sampling points).

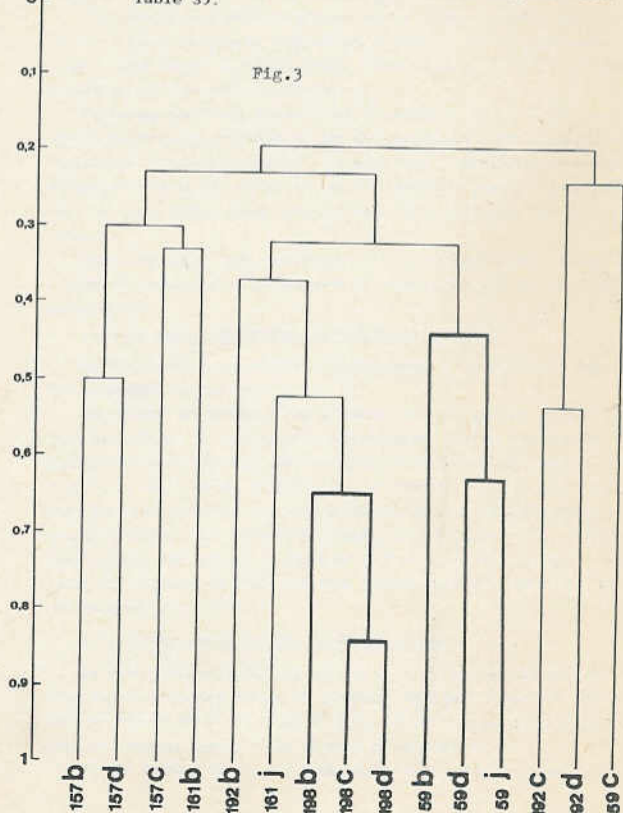
After the opening of the cave the number of the green lampülit areas were quickly increasing (Table 2). Three months later 25 lamps had already definite vegetation. No significant change could be found either in the species composition, in the distribution, or in the number of species (Fig. 2).

The process of the vegetation development was so dangerous, that we had to do something to prevent it. We tried to sterilize the green covers as a first trial. Unfortunately our succession study could not be continued because of this rude disturbance, but the controlling of the process was going on from time to time (Table 2 and Fig. 3). In Fig. 4 the cumulative number of the lamp floras is plotted against the time as a percentage of the total number of the lamps (cumulative here means that even those areas were taken into account which were not green having been extirpated). In Table 2 there are the actual numbers of the lamps having green plots nearby concerning the lamp types as well as the total numbers of them (as they were so at the beginning of 1988). The safety lighting system consists of ordinary lamps and this system is on during the time when there are visitors in the cave (they are independent from the partitions of the normal lighting system). The level illumination is working together with the headlamps in several partitions: they are only on during the time when visitors are walking through certain parts of the cave. Thus the ordinary lamps of the safety system are working 4-7 times longer than those of the level illumination. This fact can easily be seen in Fig. 5 where the cumulative number of the ordinary lamps (those of the safety and the normal system respectively) having a visible lamp flora is plotted against the time. The breaking points in the plot show the extirpations: 3 general treatises were performed (see Table 2). The extirpations in November of 1987 were of crucial importance. It is easy to recognize that in the autumn of 1987 the velocity of the expansion of the vegetation accelerated dangerously: within 10 days the actual number of lamp floras increased by 20%! A similar process was recognized at the beginning of 1989, thus this spring another treatise is going to be performed.

## Conclusions

1. In spite of the fact that quite a lot of species live in the cave (at least 39 species including mosses and fern), there are only a few taxons causing visible green plots in the cave Szemlő-hegyi-barlang, namely filamentous green and blue-green algae as well as moss protonemata.
2. It is generally accepted that the appearance of the

Fig. 3. Dendrogram of a selection of the samples (from Table 3).





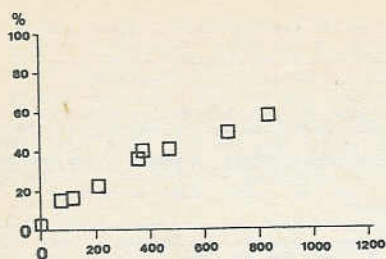


Fig. 4. Cumulative number of lamp floras as a percentage of the total number of the lamps (even the extirpated areas are taken into consideration). Horizontal axis: time in days since the opening of the cave.

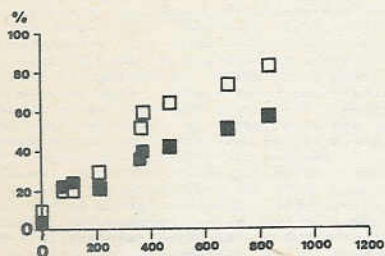


Fig. 5. Cumulative number of the ordinary lamps having green plots nearby as a percentage of the total number of them. (Open rectangles: safety lighting system; full rectangles: normal lighting system). Horizontal axis: time in days since the opening of the cave.

mosses indicates the next phase in developing the vegetation in lamp-lit areas. We would like to emphasize that moss protonemata settle down among the first colonists. Their behaviour is very similar to that of the algae. The mass of moss protonemata causes macroscopic green patches rather early and fairly often.

3. The quality of the substrate is very important for the settling of the plants. The clean, smooth limestone surface resists intact for a longer time than a dirty, clayey one. Beside the physical features of the clay the inhomogeneity and diversity of its surface is to be fundamental. Consequently to keep the walls as clean as possible in the showpart of the caves is of importance.

4. From among other show-caves we have no comparative data what is the necessary time for the appearance of the troublesome vegetation. We are convinced by our experiences that at least twice a year one must check the area and the green plots must be extirpated to avoid the explosion-like expansion of the vegetation.

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