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The phototrophic microvegetation of seminatural thermal springs in Karlovy Vary, Czech Republic.

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The phototrophic microvegetation of seminatural thermal springs in Karlovy Vary, Czech Republic. [1]

Jan Kaštovský and Jiří Komárek

With 3 figures and 3 tables

Abstract: The diversity of algal species in the classic thermal locality of Karlovy Vary Spa (Karlsbad) in western Bohemia, Czech Republic was investigated over the period 1995-1997. A total of 45 species (Cyanophyceae 14, Bacillariophyceae 27, Chlorophyceae 4) were found in mats, and six microzones were distinguished which reflect varying temperature conditions. The studied locality is the only remaining open outflow in the anthropogenically affected thermal springs of Karlovy Vary. However, distribution of cyanobacterial and algal species in the studied temperature gradient and the composition of mats are very similar to that observed in other natural hot springs. Original data from papers of the 19th century and formaldehyde preserved samples from years 1969, 1972, 1973 and 1977 were compared to recent collections, and showed that differences in diversity and number of thermal localities between the 19th century and the last third of the 20th century are relatively great. The species composition during the last 30 years, however, remained almost unchanged.

Key words: Cyanobacteria, algae, biodiversity, thermal springs, Karlovy Vary Spa, ecology, seasonality, anthropogenic factors, conservation.

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[1] This study is dedicated to the memory of Prof. Dr. Konstantinos Anagnostidis, who was interested in the microflora of hot springs in Karlovy Vary, but unfortunately could not finish his studies.

Introduction

Adspice, quam varie lapides et marmora pingit

Per quaecunque fluit; vix ipsa coloribus Iris

Collucet totidem !

Bohuslav Hasištejnský from Lobkovic about springs in Karlovy Vary Spa, A.D.1480 ?

The well-known thermal springs of Karlovy Vary (Karlsbad) in Czech Republic are classic algological localities (Agardh 1827, Corda 1836, 1839). For instance, the typical thermal cyanobacterium *Mastigocladus laminosus* was described from material of these springs (Cohn 1863). However, these thermal habitats were later studied only very sporadically, and only few short articles were published (Švorcová & Svobodová 1978). These classic localities suffered drastic changes during the 20th century. The natural springs of hot water were particularly destroyed by their intense use as water sources for spa activities. Almost all springs were closed and changed in the hot water supply system, and remained completely without phototrophic microvegetation. The only locality reminiscent of the previous situation is a semi-natural outflow from a broken underground tube deflecting the superfluous water from the spa into the river Teplá. This outflow can be considered the last locality with thermal algal vegetation in Karlovy Vary.

This study focused on:

1. The present state of communities of thermophilic cyanobacterial and eukaryotic algal species.
2. Autecology and distribution of particular algal and cyanobacterial species according to their dependence on the temperature gradient.
3. Synecological evaluation of the whole locality on the basis of the temperature gradient.
4. Comparison of the microvegetation existing in anthropogenically affected springs with that of natural springs.

Material and methods

The present thermal outflow into the river which we studied is relatively small and has a variable water flow rates that vary without regular periodicity. The maximal water-flow was 432 $l \cdot hr^{-1}$ (5.1.1996). At that time, the length of the mat comprising the thermal microflora was 164 cm, and the water depth was 4-5 cm. The lowest water-flow was measured on 2.8.1996 (105 $l \cdot hr^{-1}$); the water depth then was about 1-2 cm and the length of algal mat was 74 cm. The whole locality is situated on a concrete artificial plate on the bottom of the regulated channel-like riverbed of the stream Teplá, only about 30-50 cm above the water level. The locality is flooded in the spring (e.g., for 7 weeks in March – April 1996).

Samples were taken in monthly intervals (December 1995 - December 1997) directly from the concrete substrate. Part of the samples was preserved in 1,5% formaldehyde solution and algae were identified by light microscopy (Olympus CX 40). Part of the samples was used for cultivation and isolation of strains. Media Z (according to Zehnder in Staub 1961) enriched by SiO_2, and BG 11 were used for cultivation.

The pH and conductivity were measured in all samples by the combined pH meter Gryf 107, and temperature by the thermometer Gryf 209. For comparison of the original species diversity in Karlovy Vary hot springs with the present-day situation, data from old papers (Agardh 1827, Corda 1836, 1839, Cohn 1863) were taken into account and formaldehyde preserved samples from the years 1969, 1972, 1973 and 1977 were studied.

The physical and chemical composition of water was excerpted from Vylita (1995, see Tab. 1).

Results

Recent investigations revealed a total of 45 cyanobacterial and algal species (Cyanophyceae 14, Bacillariophyceae 27, Chlorophyceae 4 – see details in Table 2). Six zones varying in species composition of mats dependent on temperature were distinguished (Fig.1 and Tab 2).

Zone No. 1 : Water temperature is higher than 53 °C in this zone and no phototrophic vegetation was found. The intense orange colour is caused by the high content of iron and iron bacteria (Švorcová 1980) in the sediment detritus. This habitat is restricted only to a small area around the water outflow. The unstable small mats develop only on sites with lower temperature (upper parts of stones near the water level, edges of this zone). The mats are composed almost exclusively of *Mastigocladus laminosus*, which was not in a good physiological state and survived under suboptimal conditions. Other species known from higher temperature (e.g. in springs from USA - Copeland 1936, Greece - Anagnostidis 1961, etc.) were absent in this locality.

Hot springs with temperatures over 50°C are colonised in other areas by very specialised, typical thermophilic species. However, these species are lacking in Karlovy Vary, very probably due to the periodic flooding, small extent and the unstable character of this biotope.

Zone No. 2 : Surrounding the previous zone is an area of stones moistened by hot vapor which supports an atmophytic community, and is colonised by small communities composed of *Mastigocladus laminosus* and *Leptolyngbya laminosa*. Other species of cyanobacteria and diatoms occur here only rarely.

Zone No. 3 : Large compact mats with blue-green colour are developed in this zone. *Mastigocladus laminosus* is dominant at temperatures higher than 40 °C (area 3a). *Lyngbya nigra* is frequently a co-dominant species. The typical temperature for area 3b is less than 40 °C. In this area *Mastigocladus laminosus* loses its dominant role and the algal community is more diversified. Among a rich community of cyanobacteria (*Mastigocladus laminosus, Lyngbya nigra, Phormidium okenii, Leptolyngbya laminosa, Geitlerinema* cf. *jasorvense, Leptolyngbya* cf. *thermobia, Leptolyngbya thermalis, Chroococcus* cf. *minutus* and *Spirulina meneghiniana*) the first diatoms appear (*Amphora coffaeformis, Pinnularia microstauron, Navicula radiosa, Rhopalodia gibberula, Navicula cincta, Entomoneis paludosa, Melosira varians, Surirella minuta, Navicula pupula, Diatoma vulgaris* etc.).

Zone No. 4 : Water temperature here is under 36 °C, and a mesothermophilic „diatom zone" is obvious (*Amphora coffaeformis, Pinnularia microstauron, Navicula radiosa, N. cincta, Achnantes* sp., *Entomoneis paludosa, Neidium productum, Rhopalodia gibberula, Nitzschia frustulum,* etc.), with cyanobacterial species sometimes present (*Phormidium okenii, Leptolyngbya* cf. *granulifera* and *Mastigocladus laminosus*). The colour of this zone is olive brown.

Zone No. 5 : In water with average temperature under 24 °C the dominant alga is the chlorophyte *Stigeoclonium* sp. Cyanobacteria and Bacillariophyceae are also present but in smaller amounts. This zone has a non-thermophilic species composition, growing almost over the whole year, since water temperature does not decrease substantially during the winter season (continual supply of thermal water).

Zone No. 6 : Semi-aquatic zone, only periodically under the water level due to fluctuations in hot spring flow. Cyanoprokaryotes (*Calothrix thermalis, Leptolyngbya cf. granulifera, Lyngbya nigra, Phormidium okenii, Chroococcus cf. minutus* and *Spirulina meneghiniana*) and numerous diatoms periodically thrive in this zone.

All the samples available from the years 1969, 1972, 1973 and 1977, collected in numerous other localities still existing at that time, surprisingly contain almost the same species composition as the recent assemblages. Only small differences in the presence/absence of a few rare species were registered (Tab.3). These findings imply that the remaining thermophilic localities represent an important refuge of a unique endangered microflora, needing urgent protection.

Discussion

Species composition of thermophilic algal assemblages in Karlovy Vary corresponds in principle to communities of thermal microvegetation from other regions in the fact that cyanobacteria are dominant and diatoms are subdominant, while chlorophytes occur only in the marginal parts with temperatures less than 30°C (Anagnostidis 1961, Anagnostidis & Golubi* 1966, Economou-Amilli 1976 and Pentecost 1995 from Europe, Copeland 1936 and Stockner 1967 from USA, Thomas & Gonzalvez 1965a, 1965 b, Jha & Kumar 1990 and Jha 1992 from India). A few thermophilic species (*Mastigocladus laminosus, Leptolyngbya laminosa, Phormidium okenii* etc.) are sometimes common in biotopes with thermal water. From this point of view, the springs in Karlovy Vary support the commonly known fact that thermal waters all over the world support algal communities which are uniform and contain certain cosmopolitan species. An increase of biodiversity with a decrease of temperature was also observed like in natural hot springs.

It is interesting that the thermophilic cyanobacterial species occur in Karlovy Vary springs in lower temperatures in comparison with other thermal biotopes. A relative "psychrophility" is remarkable. The thermophilic species, including *Mastigocladus laminosus,* do not colonise the free hotter-water niche with more or less constant temperature above 53 °C. The observed population of *M. laminosus* belongs to a rather "low temperature form" (high temperature form of this species was described from 58 – 64 °C, and a middle temperature form from 57 - 58 °C; Castenholz 1973). This low temperature form was also observed earlier by Thomas & Gonzalvez (1965a) in India. According to Castenholz's (1969) definition of thermophilic species with growth optima over 45 °C, none of the species from Karlovy Vary could be classified as typical thermophiles. The typical thermophilic species *M. laminosus* was found in Karlovy Vary with a growth optimum of 39-41 °C. The distribution of cyanobacteria and algae in the sequentially cooled zones in Karlovy Vary is more or less similar to the distribution observed in the temperature zones of Yellowstone (Stockner 1967) except that in Yellowstone the temperatures are about 20°C higher. The high temperatures needed for growth of cyanobacteria decreases the content of soluble sulphides (Castenholz 1976). The pH is also important – cyanobacteria occur in alkaline and neutral springs up to 75°C (Brock 1967), but only to 55°C in acidic ones (Doemel & Brock 1977). However, the springs in Karlovy Vary are slightly alkaline and do not contain soluble sulphides (Tab. 1). The low species diversity and the low thermal tolerance of the cyanobacterial species at our locality are likely due to the irregular periodicity of the thermal springs, and to the periodical floods which interrupt the thermophilic character of the locality every year for several weeks. This is probably the main reason, why only very few typical thermophilic species survive at this locality, and the known thermophilic species seem to be adapted to lower temperatures. The algae must be here adapted rather to the fluctuation of temperatures than to the constant high temperature. Both factors, fluctuation in supply of thermal water combined with spring floods in the river Teplá play, therefore, a decisive role in this habitat.

In contrast, the "thermophility" of diatoms, which usually belongs to psychrophilic organisms, is also non-typical. The higher temperature limit in diatoms is normally reported to be 50.7°C (Copeland 1936), and the cells in higher temperatures than 52°C are reportedly dead frustules (Thomas & Gonzalves 1965b). However, diatoms were living in 51-53°C for a longer time in Karlovy Vary and survived in temperatures up to 55°C (living diatoms were found for the periods January/February 1996 and January/March 1997 without decrease in number in the community). Several species (especially *Amphora coffaeformis* and *Pinnularia microstauron*) seem to be, therefore, distinctly thermotolerant and their upper temperature limits are here higher, than has been previously supposed. However, the apparent temperature optimum in diatoms of Karlovy Vary (below 45°C) is identical with other observations (Economou-Amilli 1996, Thomas & Gonzalves 1965a,b). In addition, the majority of studied species were halotolerant.

A clear trend in the development of algal communities in the Karlovy Vary springs is the decrease of species diversity, very probably as a result of heavy anthropogenic pressure. Corda (1836, 1839) described 65 species of Oscillatoriales and numerous Conjugatophyceae, mainly members of the genera *Euastrum* and *Cosmarium*. Klemm (1913) found only 6 species of *Oscillatoria* (cited according to Švorcová & Svobodová 1978), but without any desmids. We have found 10 species of Oscillatoriales, but also not any Conjugatophyceae. However, pollution and eutrophication might also have played a role in the decrease of desmids. The number of all registered algal and cyanobacterial species is distinctly lower in comparison with other thermal regions (Copeland 1936). The reason is evidently the loss of thermal biotopes in Karlovy Vary. Reduction of species in open springs combined with other negative anthropogenic factors has also been observed in other thermal localities intensely used for spa activities (Jha 1990, Pentecost 1995).

A specific problem we faced is the taxonomic evaluation of *Mastigocladus laminosus* from this type locality. Two forms occurred over the whole period 1995-1997, designated by Anagnostidis (1961) as "status nostocoides" which changed during germination of hormogonia into "status oscilllarioides" (Fig. 3). Both stages comprise the unbranched morphotypes of *M. laminosus* (Fig. 2). This species is considered – according to Anagnostidis' concept – as having an extreme morphological plasticity. However, both mentioned forms, which evidently belong to one and the same taxon never produce the typical thallus of *M. laminosus* and corresponded rather to the genus *Chlorogloeopsis.* Wilmotte & al. (1993) transferred a really similar atypical strain of "*M. laminosus* PCC 7518" (originally isolated some site other than Karlovy Vary) to the genus *Chlorogloeopsis* based on similarity of the 16S rRNA sequence to another *Chlorogloeopsis* strain. *M. laminosus* occurs in the typical form also in Karlovy Vary, but the transitional forms to *Chlorogloeopsis*-like populations were never found. The phylogenetic relationship of the strains of morphologically typical *M. laminosus* with *Chlorogloeopsis*-like morphotypes using 16S rRNA sequence data will be the subject of further study.

Conclusions

1. Spatial distribution of cyanobacterial and algal species in a temperature gradient of a small outflow belonging to the anthropogenically affected springs of Karlovy Vary is similar to that in natural hot springs. Cyanobacteria are the dominant group in high temperatures (over 36°C), and the relative abundance of Bacillariophyceae in the algal community increases with decreasing temperature. Chlorophyceae occur only in the marginal zones, next to the thermal locality. The whole spectrum of the species is similar to that in natural thermal springs, and in accordance with the assumption that thermophilic species are cosmopolitan.

2. The thermophilic cyanobacterium *M. laminosus* did not reach its usual temperature maximum in the studied localities. The form of *M. laminosus* observed in the Yellowstone National Park grows at 57 – 64°C, while the maximum temperature for its development in Karlovy Vary is 54 - 55°C. This adaptation might be attributed to the highly variable water temperature fluctuation, which is caused by the irregular flow regime of the hot spring. However, it should be mentioned that the branched type of *M. laminosus* observed in Karlovy Vary has certain morphological deviations from the types known from higher temperatures.

3. According to the literature, the maximal temperature for the growth of Bacillariophyceae is recorded at approx. 51°C. Bacillariophyceae grow over the whole year in temperatures of 53°C in Karlovy Vary, and grow up to 55 °C at the time of their maximal development in spring (January-February 1996 and January-March 1997) without any cell damage or decrease in algal abundance.

4. Most of the species at Karlovy Vary are halophilic or halotolerant.

5. The anthropogenic effect on the thermal assemblages has been destructive. In 1834-39, Corda and Agardh found 65 species of Oscillatoriales (today 10 remain) and large amounts of Conjugatophyceae, especially of the genera *Euastrum* and *Cosmarium,* which were not found recently. The present state of the thermophilic microvegetation, although it has remained stable over the last 30 years, is endangered and devalued. The area of suitable conditions for the very unique thermophilic microvegetation in Karlovy Vary is restricted to only one locality, which could be completely destroyed by any further technical activities in the riverbed of Teplá, which flows through the central part of the very populated spa of Karlovy Vary.

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Tab.1. The chemical composition of water (according to Vylita 1995).

Kations	Li^+	Na^+	K^+	Cu^{2+}	Be^{2+}	Mg^{2+}	Ca^{2+}	Sr^{2+}	Zn^{2+}	UO^{2+}	Mn^{2+}	Fe^{2+}
mg/l	2.91	1699	93.2	0.012	0.065	45.2	124.4	0.48	0.06	0.011	0.098	1.27

Anions	F^-	Cl^-	Br^-	I^-	HS^-	SO_4^{2-}	NO^{2-}	NO^{3-}	HPO_4^{2-}	$HasO_4^{2-}$	HCO^{3-}
mg/l	6.45	598.5	1.39	0.025	0	1629	0	0	0.359	0.203	2150

Nodisoc.	HBO_2	H_2SiO_3
mg/l	2.33	94.81

pH	total mineralisation	CO_2	conductivity 20 °C
6.91	6450 mg/l	813.2	6,64 mS/cm

Tab.2. : The species distributions in gradient of water temperature.

Zones	1	2	3a	3b	4	5	6
Cyanophyta							
Calothrix thermalis (SCHWABE) HANSGIRG						(II)	IV - V (VI)
Cyanosarcina huebeliorum KOMAREK et ANAGNOSTIDIS							I
Geitlerinema cf. jasorvense			I - II (III)	II -(III)			
Chroococcus cf. minutus				(II - III)			I - III
Jaaginema sp.			I	I			
Komvophoron sp.		I - (II)	(I)	(+)			
Leptolyngbya cf. granulifera					I – II	II - III	IV
Leptolyngbya cf. thermobia		(II)	II	II			
Leptolyngbya laminosa (GOM.) ANAGNOSTIDIS et KOMAREK		III – IV	II - III - (IV)	II – III (IV)			
Leptolyngbya thermalis (ANAGN.) ANAGNOSTIDIS et KOMAREK		II	II	II			
Lyngbya nigra AGARDH		I – II	(II) III-IV (V)	II - IV	(II)		II - III (IV)
Mastigocladus laminosus COHN	VI	(IV)-V-VI	(III)-IV-(VI)	II – IV (V)	I – II	(+)	
Phormidium okenii (AG.ex GOM.) ANAGNOSTIDIS et KOMAREK			III - IV	II - IV	I – II	(II)	II - III
Spirulina meneghiniana ZANARDINI				(I - III)			I - II - (III)
Bacillariophyceae							
Achnanthes minutissima KUTZING			I - (II)	I	I - (II)	+	
Achnanthes sp.				I (IV)	I - II (IV)		II
Amphora coffaeformis (AGARDH) KUTZING		(+) – I - II	I - II (III)	(II) III (IV)	III – V	II - III	II - III
Aulacoseira subartica (O.MULLER) HAWORTH					(+ - I)	(+ - II)	
Cocconeis placentula EHRENBERG			(+)	(I)	(+ - I)		
Cyclotella meneghiniana KUTZING					(+ - I)		
Cymbella sp.			(I)		(I - II)	+	
Diatoma vulgaris BORY			I - (II)	II	+ - I (II)	I	
Entomoneis paludosa (W.SMITH) REIMER		(+)	I - II	I	I – III	II	+ - (I)
Fragilaria brevistriata GRUNOW			(I - II)	(+)	I - (II)		
Fragilaria construens (EHRENBERG) GRUNOW		(+)	(I)	I - (II)	I - (II)		
Fragillaria capucina var. rumpens (KUTZING) LANGE-BERTALOT			I	(I - II)	+ - I - (II)	(II)	
Fragillaria fasciculata (AGARDH) LANGE-BERTALOT			(I)	I	I - (II)	I	(I)
Fragillaria ulna (NITZSCH) LANGE-BERTALOT			(I)	I	+ - I (III)	(II)	
Melosira varians AGARDH			I - II (V)	(I - III)	I - III - (V)	II	I - (II)
Meridion circulare (GREVILLE) AGARDH			(+)	(+ - II)	+ - I (II)	(I)	(+)
Navicula cincta (EHRENBERG) RALFS			I - (II)	I - II	I - II (III)	(I - II)	II
Navicula lanceolata (AGARDH) EHRENBERG					I		
Navicula pupula KUTZING			I - II	(II)	I		
Navicula radiosa KUTZING			II	(I) II (III)	I - III (IV)	(II)	I - II - (III)
Neidium productum (W.SMITH) CLEVE			(II)	I	I – II	I - II (III)	(I)
Nitzschia frustulum (KUTZING) GRUNOW				(+)	II	(II)	
Nitzschia recta HANTZSCH			(I)	I	+		
Pinnularia microstauron (EHRENBERG) CLEVE		I – II	I - II (III)	I – III (IV)	III – V	II - III	I - II
Rhopalodia gibberula (EHRENBERG) O. MULLER			I - (II)	II	I - II (III)	(I)	
Surirella minuta KUTZING		(+)	+ - II	I - II	I (III)	II	(+ - II)
Surirella tenera GREGORY					(+)		
Chlorophyceae							
Klebsormidium flaccidum (KUTZING) SILVA, MATTOX et BLACKWELL							I
Scenedesmus gutwinskii CHOD.						(+)	
Scenedesmus quadricauda (TURP) BREBISSON sensu CHOD.						(+)	
Stigeoclonium sp.					I - II (III)	V	

<u>Relative abundance of species :</u>

+ ... less 0,1 %

I ...0.1 – 1 %

II ...1 – 5 %

III ...5 – 20 %

IV ...20 – 50 %

V...50 – 90 %

VI ...90 – 100 %

(+ - VI) ....in this abundance species occur very rare

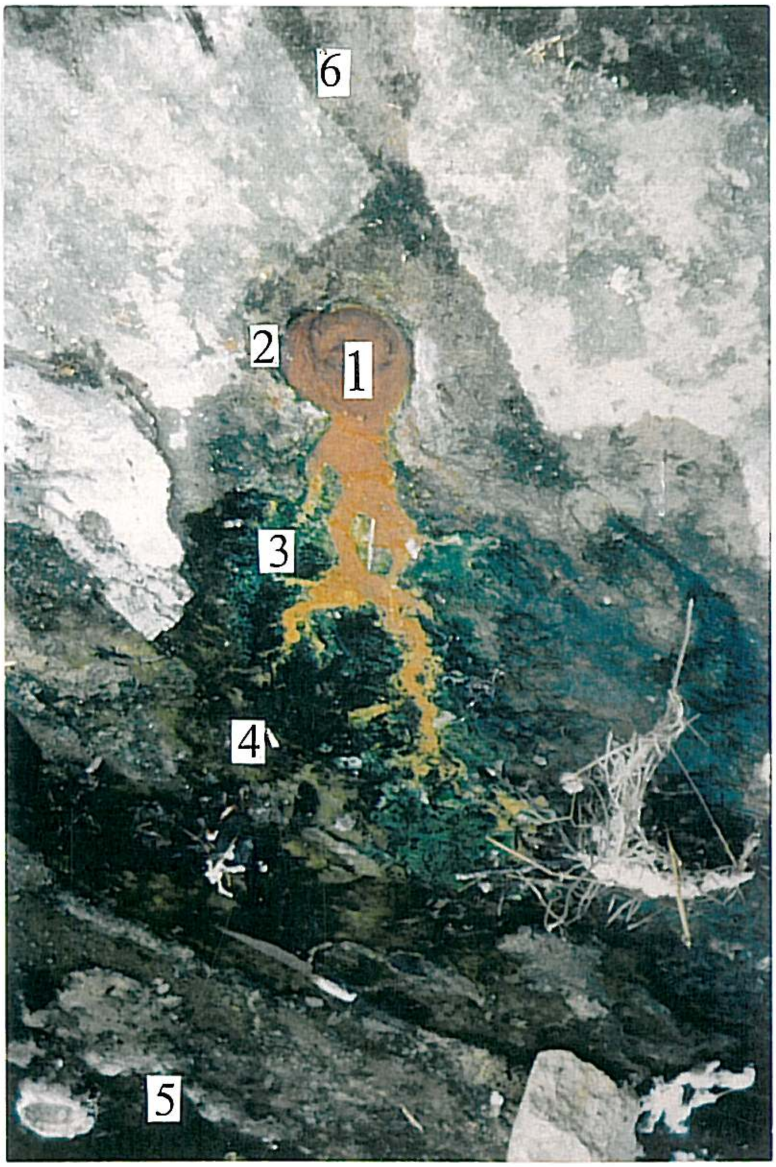
Tab.3. : The comparison of biodiversity between years 1969, 1972, 1973 and 1977 and "recent" (1995 and 1997).

Cyanophyta	1969	1972	1973	1977	1995	1997
Cyanosarcina huebeliorum KOMÁREK et ANAGNOSTIDIS	0	0	1	0	1	1
Blenothrix sp.	0	0	0	1	0	0
Calothrix thermalis (SCHWABE) HANSGIRG	0	1	1	1	2	1
Geitlerinema cf. jasorvense	2	1	1	2	2	2
Chroococcus cf. minutus	1	1	1	1	1	1
Jaaginema sp.	1	1	0	1	1	1
Komvophoron sp.	1	1	1	1	1	1
Leptolyngbya cf. granulifera	0	0	0	1	1	1
Leptolyngbya cf. thermobia	1	1	0	1	1	1
Leptolyngbya laminosa (GOM.) ANAGNOSTIDIS et KOMÁREK	2	1	2	2	2	2
Leptolyngbya thermalis (ANAGN.) ANAGNOSTIDIS et KOMÁREK	1	1	1	1	1	1
Lyngbya nigra AGARDH	2	2	2	2	2	2
Mastigocladus (Chlorogloeopsis sp.)	1	1	2	2	2	1
Mastigocladus laminosus s.s. COHN	2	2	1	1	0	2
Phormidium cf. Subcapitatum	0	0	1	0	0	0
Phormidium okenii (AG.ex GOM.) ANAGNOSTIDIS et KOMÁREK	2	2	2	2	2	2
Pseudanabaena sp.	1	0	0	0	1	1
Spirulina major KÜTZING	0	0	0	1	0	0
Spirulina meneghiniana ZANARDI	0	1	1	1	1	1
Bacillariophyceae						
Achnanthes lanceolata (BRÉBISSON) GRUNOW	0	1	1	0	0	0
Achnanthes minutissima KÜTZING	1	1	1	1	1	0
Achnanthes sp.	1	1	0	0	0	1
Amphora coffaeformis (AGARDH) KÜTZING	2	2	2	2	2	2
Asterionella formosa HASSAL	0	1	0	1	0	0
Aulacoseira subartica (O. MÜLLER) HAWORTH	0	1	1	1	1	1
Cocconeis placentula EHRENBERG	1	1	1	0	1	1
Cyclotella meneghiniana KÜTZING	0	0	1	1	1	1
Cymbella caespitosa (KUTZING) BRUN	0	1	0	0	0	0
Cymbella minuta HILSE ex RABENHORST	1	1	1	1	0	0
Cymbella sp.	0	0	0	0	0	1
Diatoma hyemalis (ROTH) HEIBERG	1	0	0	0	0	0
Diatoma vulgaris BORY	0	1	1	1	1	1
Entomoneis paludosa (W.SMITH) REIMER	1	1	1	1	1	1
Fragilaria brevistriata GRUNOW	0	0	0	0	1	0
Fragilaria construens (EHRENBERG) GRUNOW	1	1	1	1	1	1
Fragillaria capucina var. rumpens (KÜTZING) LANGE-BERTALOT	0	1	0	0	1	0
Fragillaria fasciculata (AGARDH) LANGE-BERTALOT	0	1	1	0	1	1
Fragillaria ulna (NITZSCH) LANGE-BERTALOT	1	1	1	1	1	1
Melosira varians AGARDH	0	1	1	1	1	1
Meridion circulare (GREVILLE) AGARDH	0	1	1	1	1	1
Navicula cincta (EHRENBERG) RALFS	1	1	1	1	1	1
Navicula lanceolata (AGARDH) EHRENBERG	0	0	0	1	1	1
Navicula pupula KÜTZING	0	1	1	1	1	0
Navicula radiosa KÜTZING	1	1	1	1	1	0
Neidium productum (W.SMITH) CLEVE	0	1	1	1	1	1
Nitzschia frustulum (KÜTZING) GRUNOW	1	1	1	0	1	0

Nitzschia linearis (AGARDH) W.SMITH	0	1	0	1	1	1
Nitzschia recta HANTZSCH	1	0	1	1	1	1
Pinnularia microstauron (EHRENBERG) CLEVE	2	2	2	2	2	2
Rhopalodia gibberula (EHRENBERG) O.MÜLLER	1	1	1	1	1	1
Stauroneis smithii GRUNOW	0	1	0	0	0	0
Surirella minuta KÜTZING	0	0	1	1	1	1
Surirella tenera GREGORY	0	0	1	1	1	1
Chlorophyceae						
Klebsormidium flaccidum (KÜTZING) SILVA, MATTOX et BLACKWELL	0	0	0	0	1	1
Rhizoclonium sp.	0	0	1	0	0	0
Scenedesmus gutwinskii CHODAT	0	0	0	0	1	1
Scenedesmus quadricauda (TURP.) BRÉBISSON sensu CHODAT	0	0	0	0	1	1
Scenedesmus sp.	0	0	0	0	1	1
Stigeoclonium sp.	0	0	0	0	2	1

0 … unobserved
1…observed
2…very abundant species

Fig.1 : View to the locality, numbers = numbers of microzones.



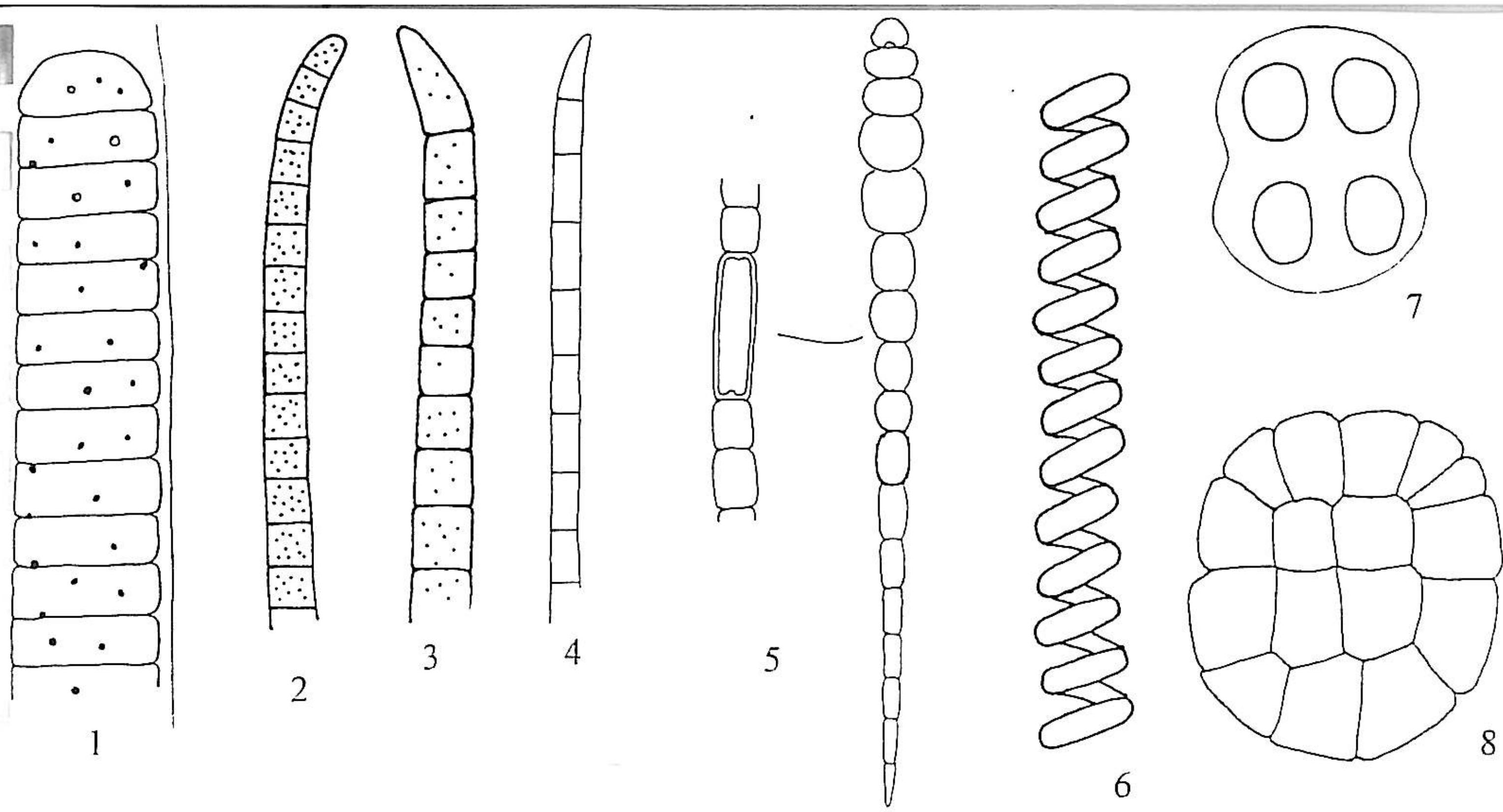


Fig.2: 1. *Lyngbya nigra*, 2. *Geitlerinema* cf. *jasorvense*, 3. *Phormidium okenii*, 4. *Leptolyngbya laminosa*, 5. *Calothrix thermalis*, 6. *Spirulina meneghiniana*, 7. *Chroococcus minutus* s.l., 8. *Cyanosarcina huebeliorum*, 9. – 13. Different forms of *Mastigocladus laminosus*.

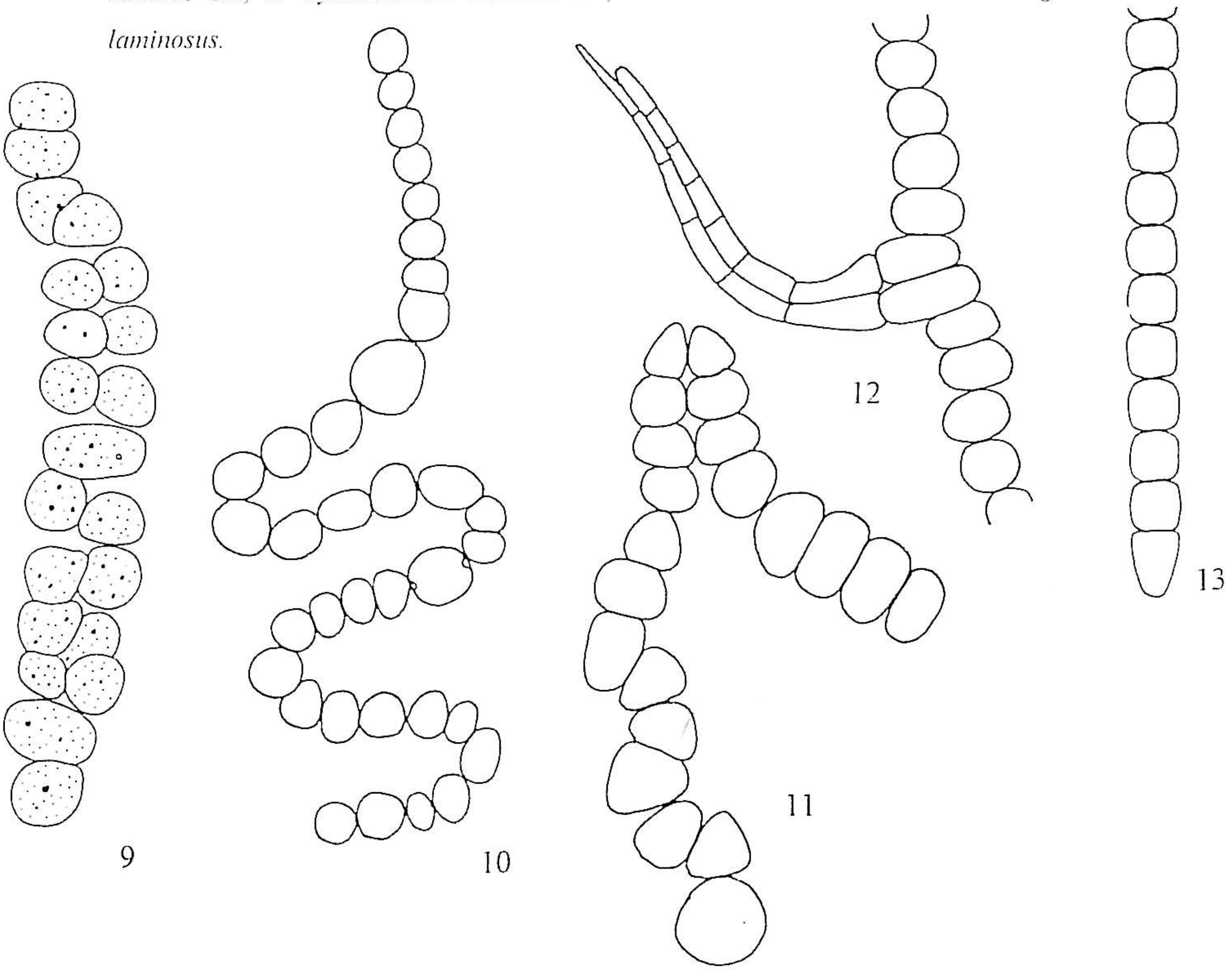


Fig. 3. : The life cycle of "*Mastigocladus*" (morphotype *Chlorogloeopsis* sp.). 1. "forma oscillarioides", 2."forma nostocoides", 3. "*Chlorogloeopsis* sp," , 4. Germination of akinetes.