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Sessile algal communities in a mountain stream in conditions of light gradation during its flow through a cave (West Tatra, Poland)

Barbara Kawecka

Polish Academy of Sciences, Institute of Freshwater Biology,
ul. Sławkowska 17, 31-016 Kraków, Poland

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Abstract — The light requirements of sessile algae were studied. *Hydrurus foetidus* and *Ceratoines arcus* developed under normal conditions. *Homoeothrix janthina*, *Achnanthes minutissima*, *A. pyrenaica*, *A. lanceolata*, *Diatoma hiemale* with *mesodon* variation, *Gomphonema intricatum* var. *pumilum*, *Meridion circulare* also grew where light was deficient. *Amphora ovalis* var. *pediculus* preferred the latter conditions, as did *Cocconeis placentula* var. *euglypta* and *Navicula cryptocephala*.

Key words: stream, sessile algae, ecology of algae, effect of light.

1. Introduction

The present study is a continuation of research on the light requirements of mountain stream sessile algae. Previous investigations were conducted using the light intensity gradient under bridges (Kawecka 1985, 1986). The present work aims at obtaining further information on sessile algae communities under the conditions of the light gradient formed during the flow of a stream through a cave.

2. Study area

The cave Wodna Pod Pisaną is situated in the upper section of the Kościeliska valley in the calcareous part of the Tatra Mts. The entrance to the cave can be found near the road on the right bank of the Kościeliski stream, which flows along the valley bottom. The cave is of horizontal development and about 300 m long. The stream flowing through the cave is fed partly by subterranean waters and partly by those of the Kościeliski stream. The stream flowing through the cave exits from it under the Pisana Rock in a northerly direction, at an altitude of 1020 m.

It runs through a fairly wide rocky corridor (about 1 m in height) for the last 5 m before its outflow from the cave. It drains into the Kościeliski stream about 10 m from the outflow.

The investigations were carried out twice, on 23. 04, and on 17. 10. 1986. Light was measured with a Type 102 luxometer. A significant light deficiency could be observed near the outflow, where only 4% of natural light penetrated. Light intensity further decreased with distance inside the cave, falling to a value of 0.4% of natural light about 1.5 m from its mouth. Deep in the cave at the point from which samples were taken complete darkness reigned. The water of the stream flowing out of the cave had a temperature of 4.1°C and a reaction of 7.2 (23. 04. 86). In April the water level of the stream was high and penetration into further sections of the corridor and the cave proved impossible. The level became relatively low in August, so that at that time material could be collected from the deeper parts of the corridor. Then, too, the bed of the Kościeliski stream was dry above the cave, flowing only after being fed by the water from the cave.

Seven localities were selected for study:

Station 1 — in the Kościeliski stream near the cave;
Station 2 — in the stream inside the cave;
Station 3 — in the stream inside the corridor about 3 m from the mouth of the cave;
Station 4 — in the stream inside the corridor about 1.5 m from the mouth of the cave;
Station 5 — in the proximity of the outflow from the cave;
Station 6 — in the stream flowing from the cave, about 2 m below the outflow, in the shade of the Pisana Rock;
Station 7 — about 10 m below the outflow from the cave.

3. Material and method

Algae were taken from stones, deposits from slime and mosses also being collected. A total of 21 samples was obtained. The material was preserved in a 4% solution of formalin. The quantitative evaluation of algae was carried out according to estimation methods proposed by S t a r m a c h (1969) and described in detail by K a w e c k a (1980). The degree of algae and moss cover forming macroscopic concentration on about 1—2 m² of the stream was estimated using the five-point scale of stream-bed area cover:

1 — organism scarce,
2 — organism covers less than 25%,
3 — organism covers 25—50%,
4 — organism covers 50—75%,
5 — organism covers 75—100%.

Solid preparations were made with "Pleurax" synthetic resin. On the basis of those preparations, the number of diatoms was determined by counting cells of each species in 10 fields of vision of a microscope equipped with a Zeiss micrometric net in the eyepiece. The percentage share of each species in the community was calculated and numerous (at least 5%) and sporadic (under 5%) species were determined. The coefficient of coverage was obtained by multiplying the number of a given species by its mean cell size. The size of cells of particular species was given in multiples or parts of the net mesh. By multiplying by 2 the total coefficients of coverage for all species, the arbitrary diatom biomass index was determined. It was described as very low at values below 400, low at 401—800, average at 801—1200, and high at above 1200.

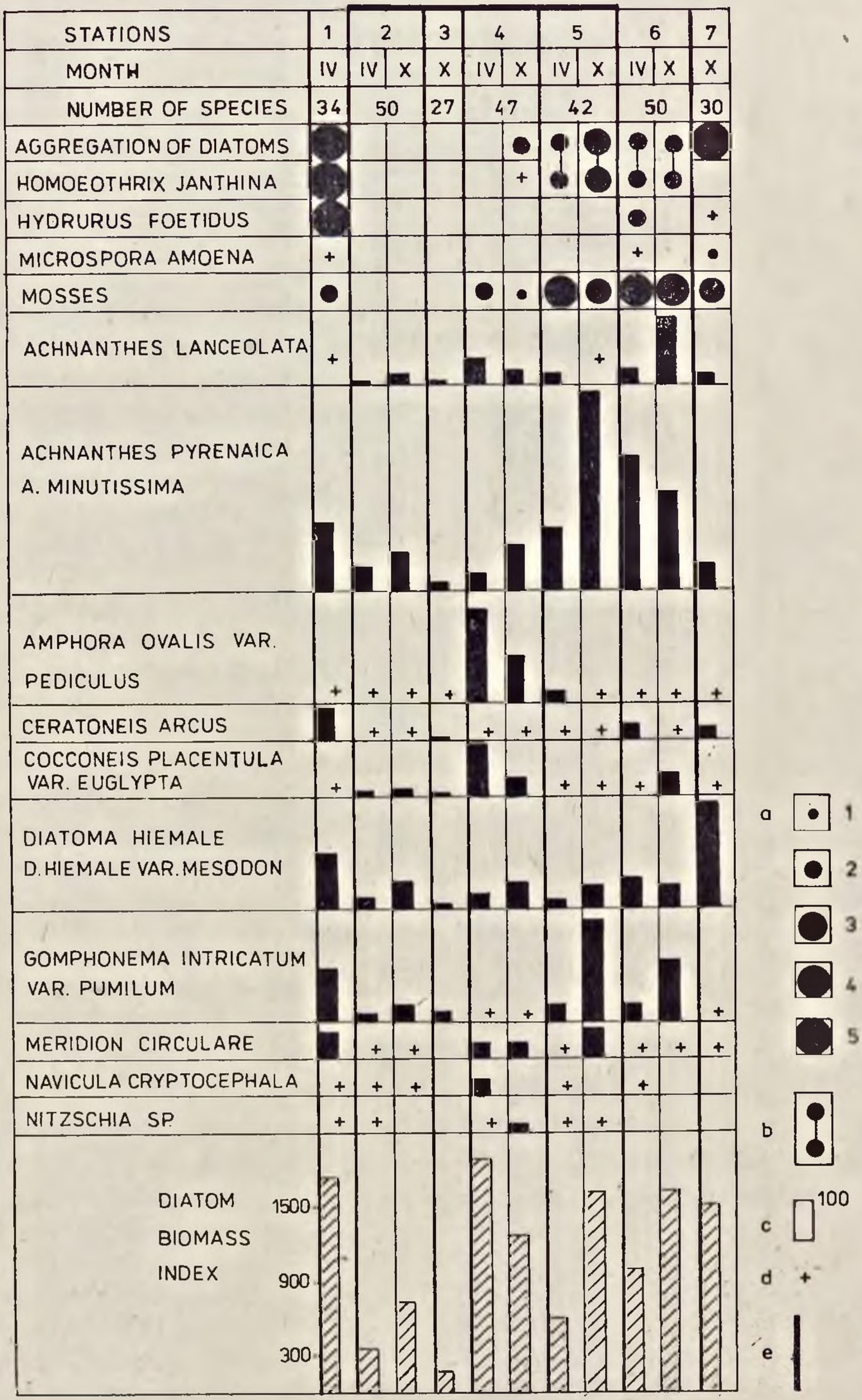
4. Results

The formation of algal communities in the stream under light gradient conditions is presented in fig. 1. Under natural conditions of light, i.e. in the Kościeliski stream near the cave (Station 1) and in the stream flowing out of the cave (Stations 6, 7), *Homoeothrix janthina, Hydrurus foetidus*, and diatoms dominated. The high index of diatom biomass was mainly caused by the development of *Achnanthes pyrenaica* with the accompanying *A. minutissima*, of *Diatoma hiemale* with *mesodon* variety, of *Gomphonema intricatum* var. *pumilum*, and of *Ceratoneis arcus*.

Only diatoms were encountered inside the cave (Station 2). As the organisms formed small populations, the biomass index was low. The most frequent cells were those of *Achnanthes minutissima, A. pyrenaica, Diatoma hiemale* with *mesodon* variety, *Gomphonema intricatum* var. *pumilum, Cocconeis placentula* var. *euglypta*. Some cells of *Diatoma hiemale, Ceratoneis arcus*, and *Cymbella ventricosa* had well-developed chloroplasts but most specimens were dead.

The development of algae was very weak in the rocky corridor about 3 m from the mouth of the cave (Station 3). They did not form macroscopic concentrations, detritus dominating the material collected. The diatom communities present here were poor in taxa, they formed small populations and their biomass index was very low. Most of the cells were dead, only a few *Diatoma hiemale* and *Navicula* sp. specimens possessing well-developed chloroplasts.

About 1.5 m from the mouth of the cave (Station 4), there was a sudden development of diatoms, which formed macroscopic concentrations. A number of species occurred in large populations, causing the diatom biomass index to attain high values (in April even higher than those established for localities situated outside the cave). This was mainly caused by the development of *Amphora ovalis* var. *pediculus, Cocconeis placentula* var. *euglypta*, and species of the genus *Achnanthes*.


STATIONS
1 2 3 4 5 6 7
MONTH
IV IV X X IV X IV X IV X X
NUMBER OF SPECIES
34 50 27 47 42 50 30
AGGREGATION OF DIATOMS
HOMOEOTHRIX JANTHINA
HYDRURUS FOETIDUS
MICROSPORA AMOENA
MOSSES
ACHNANTHES LANCEOLATA
ACHNANTHES PYRENAICA
A. MINUTISSIMA
AMPHORA OVALIS VAR. PEDICULUS
CERATONEIS ARCUS
COCCONEIS PLACENTULA VAR. EUGLYPTA
DIATOMA HIEMALE
D. HIEMALE VAR. MESODON
GOMPHONEMA INTRICATUM VAR. PUMILUM
MERIDION CIRCULARE
NAVICULA CRYPTOCEPHALA
NITZSCHIA SP.
DIATOM BIOMASS INDEX
1500
900
300
a
1
2
3
4
5
b
c
100
d
e

A further development of algae was observed in the proximity of the outflow (Station 5), where *Homoeothrix janthina* and diatoms developed well. Of the latter, *Achnanthes minutissima* and *A. pyrenaica*, and *Gomphonema intricatum* var. *pumilum* significantly increased their populations, particularly in October. The diatom biomass index reached high values, similar to those from localities situated on the surface.

5. Discussion

Information on the light requirements of mountain stream algae is very scarce. Observations in the conditions of a strong light gradient permit a certain evaluation of their requirements in this respect. The

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Fig. 1. Sessile algal communities in the stream flowing through the cave. a — cover scale; b — cover includes a group of species; c — numerous species and number of cells; d — sporadic species; e — section of cave. Sporadic species: *Chamaesiphon curvatus* Nordst. — 4, *Ch. polonicus* (Rost.) Hansg. — 4, *Phormidium* sp. — 4, *Achnanthes clevei* Grun. — 4, *A. kryophila* Peters. — 2, *A. lanceolata* (Bréb.) Grun. var. *capitata* O. Müll. — 3, *A. lanceolata* (Bréb.) Grun. var. *ventricosa* Hust. — 4, *A. lapponica* Hust. — 2, *A. laterostrata* Hust. — 2, *A. linearis* (W. Sm.) Grun. — 2, *A. microcephala* (Ktz.) Grun. — 4, *Cocconeis diminuta* Pant. — 2, *C. pediculus* Ehr. — 4, *C. placentula* Ehr. var. *klinoraphis* Geitl. — 3, *Cymbella aequalis* W. Sm. — 2, *C. naviculiformis* Auersw. — 2, *C. sinuata* Greg. — 4, *C. ventricosa* Ktz. — 1, *Denticula tenuis* Ktz. var. *crassula* (Näg.) Hust. — 4, *Diatoma vulgare* Bory var. *capitulatum* Grun. — 4, *D. vulgare* Bory var. *ehrenbergii* (Ktz.) Grun. — 4, *Eunotia arcus* Ehr. — 4, *E. pectinalis* (Dilw.? Ktz.) Rabh. — 2, *Eunotia* sp. — 2, *Fragilaria capucina* Desm. — 4, *F. intermedia* Grun. — 4, *F. leptostauron* (Ehr.) Hust. — 2, *F. pinnata* Ehr. — 1, *F. pinnata* Ehr. var. *lancettula* (Schum.) Hust. — 2, *Gomphonema angustatum* (Ktz.) Rabh. — 4, X, *G. angustum* Ag. — 2, X, *G. olivaceum* (Lyngb.) Ktz. — 4, *Melosira* sp. — 2, *Melosira* sp. — 4, *Meridion circulare* Ag. var. *constricta* (Ralfs) V. H. — 2, *N. contenta* Grun. — 2, *N. crypocephala* Ktz. var. *veneta* (Ktz.) Grun. — 4, *N. gracilis* Ehr. — 4, *N. menisculus* Schum. — 4, X, *N. gallica* (W. Sm.) Lagerst. — 4, X, *N. pupula* Ktz. — 3, *N. radiosa* Ktz. — 4, *Nitzschia dissipata* Ktz.) Grun. — 1, *N. hantzschiana* Rabh. — 3, *N. kützingiana* Hilse — 2, *N. palea* (Ktz.) W. Sm. — 4, *Pinnularia microstauron* (Ehr.) Cl. — 2, *Rhoicosphenia curvata* (Ktz.) Grun. — 4, *Stauroneis phoenicentron* Ehr. — 4, *Surirella ovata* Ktz. — 2, *Synedra ulna* (Nitzsch) Hhr. — 1, *Ulothrix zonata* (Weber et Mohr) Ktz. — 3.

X — species identified according to the key by Krammer, Lange-Bertalot (1986); others according to Siemińska (1964). 1 — encountered in all stations; 2 — encountered in some stations inside the cave; 3 — encountered in some stations outside the cave; 4 — encountered in some stations both inside and outside the cave present study of algal development in a stream flowing through a cave and investigations based on the shady places under bridges carried out earlier (Kawecka 1985, 1986) confirm and complement each other.

These three series of study demonstrate that most of the observed stream algae prefer natural light conditions, tolerating its limited penetration to varying extent. *Hydrurus foetidus* and *Ceratoneis arcus* develop in natural light conditions, while *Homoeotrix janthina* has a wider living scale, tolerating light deficiency but not developing when this deficiency is increased. On the other hand, *Achnanthes minutissima, A. pyrenaica, A. lanceolata, Diatoma hiemale* with *mesodon* variation, *Gomphonema intricatum* var. *pumilum,* and *Meridion circulare* have a wide spectrum with regard to light. They form fairly large populations in natural light, *Achnanthes minutissima, A. pyrenaica,* and *Gomphonema intricatum* var. *pumilum* also develop well when it is deficient, and all of them survive in condition of still greater light deficiency. There are also organisms which prefer light deficiency, especially *Amphora ovalis* var. *pediculus.* Hickman (1974), too, describes it as a markedly shade-loving form. It tolerates light deficiency as well, being one of the most frequently encountered diatom in a cave in Hungary (Claus 1955). A tendency to seek shade is also exhibited by *Cocconeis placentula* var. *euglypta* — a finding confirmed by Castenholz (1960) and by *Navicula cryptocephala.*

In the studied stream flowing through the cave 40 species of diatom were found in complete darkness. The taxa encountered belong to common forms, and their communities do not differ in composition from those occurring in streams flowing on the surface in the Tatra Mts. This shows that they originated here with the drift and they do not constitute specific autochtonous associations. Claus (1955) reported only 10 diatom species from a cave in Hungaria, while were recorded 17 from another one (Claus 1962), all of which also are among common forms. Clair et al. (1981) found 26 taxa of diatoms, also of wide distribution, in a cave system in Oregon. On the other hand, Van Landingham (1965) encountered 16 species of diatom, 4 of which he described as probably new for science, in a cave in Kentucky. Besides, Carter (1971) reported 94 species, including 5 new for science, from a cave in Scotland.

Most of the cells encountered in the studied stream flowing deep in the cave were dead. Only single cells of the species *Diatoma hiemale, Ceratoneis arcus,* and *Cymbella ventricosa* had a well-developed chloroplast. As the time interval during which those cells remained in the cave is unknown, it would be difficult to draw any conclusions as to their survival under such conditions. However, Van Landingham (1965) also reported a well-developed chloroplast in diatoms present in the cave he studied.

6. Polish summary

Zbiorowiska glonów osiadłych w potoku górskim w warunkach gradacji światła przy przepływie przez jaskinię (Tatry Zachodnie, Polska)

Zbadano zbiorowiska glonów osiadłych w potoku górskim w warunkach gradacji światła w celu uzyskania informacji na temat ich wymagań odnośnie do tego czynnika.

Obiektem badań był potok przepływający przez Jaskinię Wodną pod Pisaną (wysokość 1020 m). Na granicy wypływu potoku z jaskini panował głęboki cień, światło zostało tu bowiem zredukowane o 96%. Wchodząc głębiej w korytarz skalny, uległo dalszej redukcji i około 1,5 m od wylotu z jaskini dochodziło już tylko 0,4% światła naturalnego.

Formowanie się zbiorowisk glonów w potoku w warunkach gradacji światła przedstawiono na rys. 1. W naturalnym świetle (st. 1, 6, 7) w zbiorowisku dominowały *Homoeothrix janthina, Hydrurus foetidus* z towarzyszącymi im okrzemkami *Achnanthes pyrenaica, A. minutissima, Diatoma hiemale* z odmianą *mesodon, Gomphonema intricatum* var. *pumilum, Ceratoneis arcus, Meridion circulare*. Wskaźnik biomasy okrzemek był wysoki.

W potoku płynącym w głębi jaskini (st. 2) spotykano tylko okrzemki, zbiorowiska ich były dość bogate w taksony, ale większość komórek była martwa. Około 3 m od wylotu z jaskini (st. 3) notowano drobne populacje okrzemek, większość komórek była również martwa. Wskaźnik biomasy był bardzo niski. Około 1,5 m od wylotu z jaskini (st. 4) nastąpił gwałtowny rozwój okrzemek, w tym głównie *Amphora ovalis* var. *pediculus, Cocconeis placentula* var. *euglypta* oraz gatunków z rodzaju *Achnanthes*. Wskaźnik biomasy okrzemek osiągnął wysokie wartości w kwietniu, nawet wyższe niż na stanowiskach poza jaskinią. Na granicy wylotu (st. 5) obserwowano dalszy rozwój glonów. Dobrze rozwijał się *Homoeothrix janthina* wraz z okrzemkami, głównie *Achnanthes pyrenaica, A. minutissima, Gomphonema intricatum* var. *pumilum, Meridion circulare*. Wskaźnik biomasy okrzemek był wysoki.

Badania potwierdziły i uzupełniły wcześniejsze obserwacje dotyczące wymagań glonów potoku górskiego odnośnie do światła. Większość organizmów preferuje naturalne warunki światła, przy czym w różnym stopniu tolerują ograniczony jego dopływ. *Hydrurus foetidus* oraz *Ceratoneis arcus* rozwijają się w naturalnych warunkach. *Homoeothrix janthina, Achnanthes pyrenaica, A. minutissima, A. lanceolata, Diatoma hiemale* z odmianą *mesodon, Gomphonema intricatum* var. *pumilum, Meridion circulare* rosną także przy jego deficycie. *Amphora ovalis* var. *pediculum* preferuje niedobór światła, podobne tendencje wykazuje *Cocconeis placentula* var. *euglypta* i *Navicula cryptocephala*.

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