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Research Article

EFFECT OF DIFFERENT LIGHT CONDITIONS ON CYANOBACTRIA AND ALGAL COMMUNITIES IN TATRA MTS STREAM (POLAND)

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Abstract

Different light conditions at the open and shaded sites caused by marginal vegetation affected the structure of cyanobacteria and algae communities, but had no effect on chlorophyll *a* content. In the open area *Hydrurus foetidus* (Villars) Trevisan, *Homoeothrix janthina* (Bornet et Flahault) Starmach, and diatoms (mainly *Achnanthes minutissima* Kütz. together with *A. biasolettiana* Grun. and species from the Gomphonema genus) were the most numerous. In shadow the abundance of *Hydrurus foetidus* drastically decreased, whereas the diatom biomass index, *Achnanthes minutissima* and *A. biasolettiana* showed a tendency to reduce their number. On the contrary, the abundance of green algae and *Cocconeis placentula* Ehr. var. *euglypta* Ehr. increased. Chlorophyll *a* contents of both sites obtain the highest values in summer - autumn and the lowest in the winter - spring seasons.

INTRODUCTION

For many years investigations on the poorly known ecological requirements of cyanobacteria and sessile algae in relation to light, temperature (Kawecka 1985, 1986, 1989), biogens (Kawecka 1977, 1993) and drought (Kawecka 2003) in the Tatra Mts streams have been carried out. The information was used to explain the mechanisms which lead to the zonal distribution of organisms along the streams, and their mosaic aggregations in small areas (Kawecka 1980). The algological literature provides several examples referring to the role of light in the differentiation of algal communities in running waters. There are several papers referring to the effect of drastic changes in light, *e.g*. caused by forest clearing on algal communities (Hill, Knight 1988, Lowe *et al*. 1986, Lyford, Gregory 1975, Murphy, Hall 1981, Hansmann, Phinney 1973), experimentally over-shading of the stream (Hepinstall, Fuller 1994, Towns 1981), over-shading by bridges (Kawecka 1985, 1986), or by rocks in the outlet of cave (Kawecka 1989). However, there have been fewer observations concerning the effects of natural changes of light which are formed, *e.g.* riparian vegetation (on the bank of a stream); (Robinson, Rushforth 1987, Lyford, Gregory 1975, O'Quinn, Sullivan 1983, Hornick *et al*. 1981)

The aim of the presented work was to recognise the structure, dynamics, and chlorophyll *a* content of cyanobacteria and algal communities, developing in natural variation in insolation**,** namely in the shade caused by marginal vegetation and close to it in an open area.

MATERIAL AND METHODS

The investigation was carried out in the 1987/1988 at 1-2 months intervals. The material was collected from the stones, and preserved in 4 % solution of formalin. In quantitative elaboration the methods according to Starmach (1969) and Kawecka (1980) were used. The structure of communities was characterised by the number of taxa, their abundance, and the diatom biomass index. The number of species was: very small to 30 taxa in communities, low between 31-70, medium 71-100, and high about 100.

The coverage of cyanobacteria and algae which formed a macroscopic aggregation was estimated according to the following scale of coverage: 1. the organisms form a small aggregation, 2. cover less than 25 % of the bottom area, 3. cover 25-50 %, 4. 50-75 %, 5. 75-100 % of the bottom area.

In order to obtain clean diatom frustules, part of the material was macerated in a mixture of sulphuric acid and potassium dichromate, and then cleaned on a centrifuge (3000 R/min). Solid preparations were fixed in "pleurax", a synthetic resin. The diatoms were identified according to Krammer, Lange-Bertalot (1986-1991).

The number of diatom cells was estimated by counting them in 10 microscopic fields delimited by a Zeiss micrometric net, mounted in a microscopic eyepiece. The percentage shares of each species in the community were counted, and the numerous species (over 5 %) were selected, remaining being determined as sporadic. The average size of cells of each diatom species was described, presenting it in multiples or fractions of the square of the micrometric net mesh. The coefficient of coverage was obtained by multiplying the abundance of species by its average size of cell. By summing the coefficient of coverage of all species in the communities, and multiplying those by 2 (accepted assimilation area), the conventional index of diatom biomass was calculated. This was used as a comparable value for the communities of diatoms at given stations.

The amount of chlorophyll *a* was measured according to SCOR – UNESCO (1971) method. Previously carefully cleaned and marked stones were exposed in the stream for about 1 month. The material was collected and the projection of stones on the surface was computed. The rate of biomass increased during 1 month was described, the results being given in 1 m^2 unit. The light intensity was measured during the collecting of periphyton by a luxmeter – type 102 and the value of its deficiency was presented as percentage in relation to the natural environment.

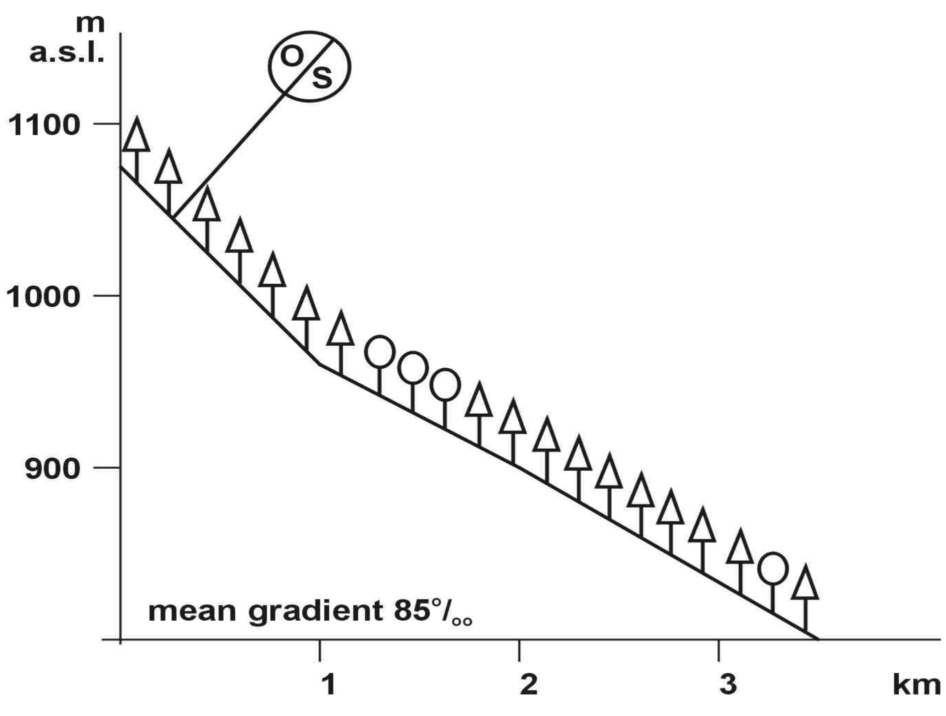

Fig. 1. Olczyski stream – localisation of sampling stations: O – open, S – shaded.

STUDY AREA

The area of study was the Tatra Mts, which are the highest part of the Carpathian massif (max. alt. 2663 m). The investigation was carried out in the Olczyski stream. The stream (about 8.5 km long) flows out from the Olczyski vauclusian springs (alt. circa 1060 m.), which is situated on the Olczyska pasture. In the upper and middle course (about 3.5 km) it flows through the Tatra National Park, in the forest zone. At the altitude of about 880 m it leaves the Tatras and flows out on the Zakopane Basin. It is fed by the Zakopianka stream at the altitude of 760 m. The drainage of the stream is mixed. The upper part is built on pleistocene, crystalline moraine sediments and the stream water is weakly mineralised, oligotrophic in character. By increasing limestone and dolomite rocks the water becomes mezotrophic in character (Kawecka 1985, Oleksynowa, Komornicki 1989).

The investigations were carried out in the upper part of the stream at an altitude of about 1030 m. (Fig. 1). The stream is 7 m. wide and 0.2-0.5 m. deep, the bottom being stony, scantly covered with moss. Two sites were selected, each in an area of about 1 $m.^2$ One of them was situated close to the bank of the stream area in shade under the trees, and the second in an open area in about 2 m. distant from the bank. The conditions at both sites were similar with the exception of the amount of solar radiation. The current was 0.7-1.1 m s^{-1}, temperature 3.8-5.5 ^{o} C. and pH 7-7.2. The light intensity at the shaded station was reduced by 80-90 % (in the months 03, 05, 06, 08) and of 30-60 % (in the months 10, 11, 02) in relation to the station of open area. According to Szarek (1994) the dose of photosynthetically active radiation (PAR) reaching the shaded site in Tatra Mts stream constituted 21-31 % of that reaching the open area.

RESULTS

Communities of cyanobacteria and algae in the Olczyski stream in open and shaded sites

In Olczyski stream 66 taxa was found; in the open area 54 and in the shaded site 63 species, among them the diatoms prevailed.

Different light conditions affected the structure of cyanobacteria and algal communities (Fig.2). *Hydrurus foetidus* developed well mostly in the open area, while green-algae were numerous in the shade. At both stations *Homeothrix janthina* developed abundantly, but in the open area it formed a dense population, and the threads were longer than those growing in shade. Diatoms were abundant both in open and shaded areas.

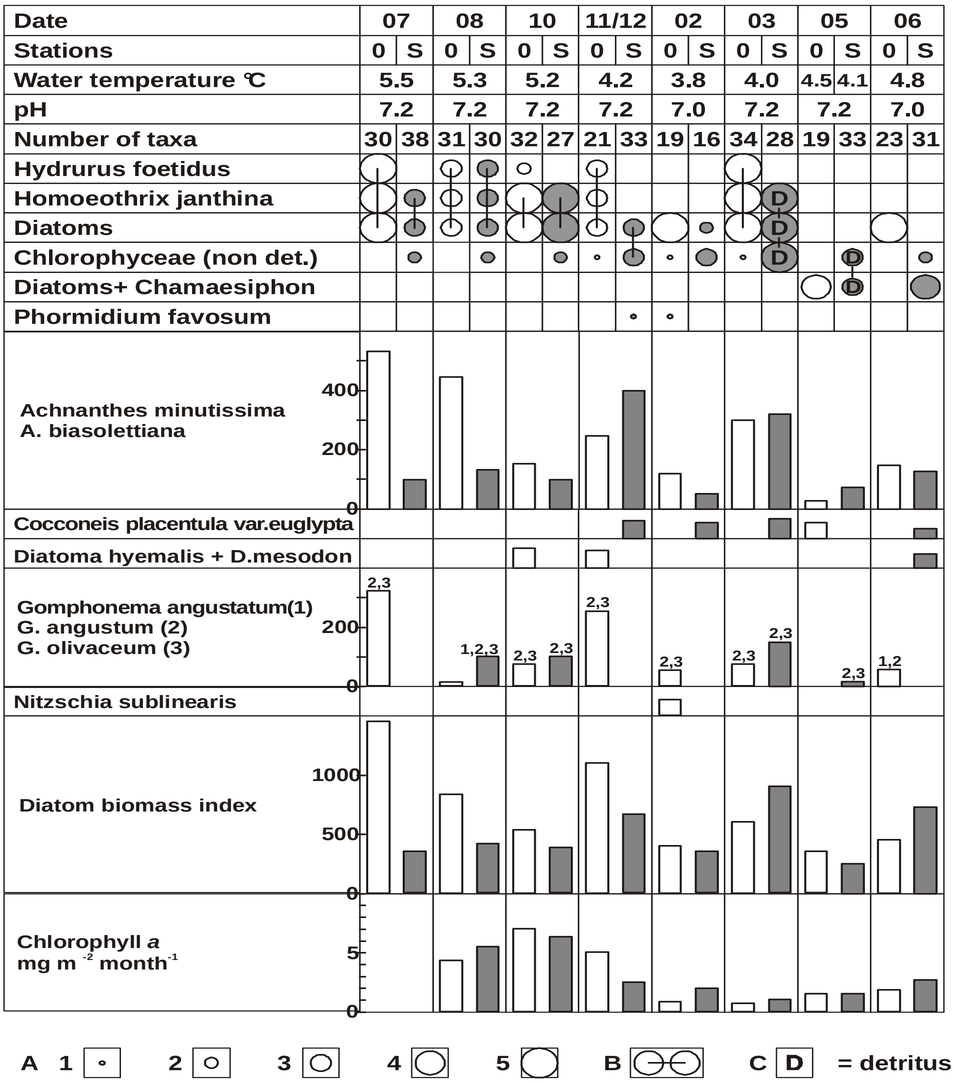

Fig. 2. Community structure of cyanobacteria and algae, and the content of chlorophyll *a* in Olczyski stream, in open (O) and shaded (S) stations. Species forming macroscopic aggregations; A – scale of coverage: 1 – organisms form a small aggregations, 2 – cover less than 25% of the bottom area, 3 – 25-50%, 4 – 50-75%, 5 – 75-100% of the bottom area. B – the coverage includes a group of organisms, C – the samples contain large amount of detritus. Scale bars; the most numerous species of diatoms (>5%), and their abundance (number of cells in 10 microscopic fields). Sporadic species: *Chamaesiphon curvatus* Nordstedt,

Achnanthes lanceolata (Bréb.) Grun*,, A. lanceolata* (Bréb.) Grun*.* var. *haynaldii* (Schaarschmidt) Cl*., A. laevis* Oestrup var*. laevis, Achnanthes* sp*., Amphora pediculus (*Kütz.) Grun.*, Asterionella formosa* Hassall*,*, *Campylodiscus* sp., *Cocconeis placentula* Ehr, var. *euglypta* Ehr*., C. placentula* Ehr var. *klinoraphis* Geitler.*, Cocconeis* sp., *Cyclotella* sp., *Cymbella affinis* Kütz., *C. delicatula* Kütz.*, C. naviculiformis* Auerswald*, C. silesiaca* Bleisch *C. sinuata* Greg*., Cymbella* sp. *Diatoma hyemalis* (Roth) Heiberg, *D. mesodon* (Ehr.) Kütz, *D. ehrenbergii* Kütz.*, D. tenuis* Agardh*, D. vulgaris* Bory, *Denticula tenuis* Kütz.*, Eunotia minor (*Kütz.) Grun., *Fragilaria arcus* (Ehr.)Cl., *F. capucina* Desmazières *vaucheriae*-Group*, F. pinnata* Ehr, *Fragilaria ulna* (Nitzsch) Lange –Bertalot, *Fragilaria* sp., *Frustulia vulgaris* (Thwaites) De Toni*, Gomphonema intricatum* Kütz.*, G olivaceum* (Hornemann) Bréb. var*. calcareum* (Cl.) Cl*., Meridion circulare* (Greville) Ag*., N. capitata* Ehr*. var. capitata, Navicula cryptocephala* ütz., *N. lanceolata* (Agardh) Ehr.*, N. pupula* Kütz.*, N. radiosa* Kütz.*, N. tripunctata* (O. F. Müller) Bory, *N. veneta* Kütz.*, Navicula* sp*., Navicula* sp.1*, Nitzschia dissipata* (Kütz.) Grun., *N. palea* (Kütz.) W. Smith, *Nitzschia* sp.1*, Nitzschia* sp.2, *Rhoicosphaenia curvata* (Kütz.) Grun., *Surirella brebissonii* Krammer & Lange-Bertalot, var. *kuetzingii* Krammer & Lange-Bertalot*, Surirella* sp.1, *Surirella* sp.2, *Tabellaria flocculosa* (Roth) Kütz.

Among them the highest population was formed by *Achnanthes minutissima*, with accompanying *A. biasolettiana* and species from the Gomphonema genus. They showed a tendency to decrease in the shaded station, where in contrast the abundance *of Cocconeis placentula* var. *euglypta* increased. Diatom biomass index was mostly low, showing tendency to decrease in shade in comparison with the open area.

Different light conditions had no effect on chlorophyll *a* contents; at both stations the amounts of chlorophyll *a* obtained low and similar value.

Annual observations showed in winter-spring seasons decrease in growth of cyanobacteria and algae communities. The diatoms dominated, and green - algae spread also at open site. In the consequence, in winter-spring seasons a distinct decrease in chlorophyll *a* content was observed, the highest value was obtained in summer and autumn.

DISCUSSION

The investigation showed that the natural shading of the stream by bank vegetation affected the structure of algal communities in relation to that in open site. However, the changes were not as distinct as in the case of the artificially reduced light, which exceeded up to 90% of that natural (Towns 1981, Kawecka 1985, 1986, 1989)). According to Robinson & Rushforth (1987), Lyford & Gregory (1975), and Hornick *et al.* (1981), the communities of algae are distinctly subjected to the effect of the bank-side vegetation. On the other hand O'Quinn, Sullivan (1983) did not find significant changes in the structure of diatom communities in streams at shaded and non-shaded stations.

The present investigation showed no greater differences in the number of taxa at the two stations. Contrary to this finding Robinson & Rushforth (1987) found a pronounced decrease in the number of taxa in the naturally shaded sector of a stream.

Shade limited the development of most algae, although the response of the different species was not uniform. *Homoeothrix janthina* occurred at both stations, confirming the earlier opinion concerning the wide spectrum of its light requirements (Kawecka 1986, 1989). In the populations growing in shade the filaments were always shorter than in those growing in the open area. It may be supposed that this was associated with the light conditions at the investigated stations. On the other hand, Round (1968) recorded a reverse reaction, *i.e*. the elongation of thalli in forms occurring in the shade and the development of dense and glomerate thalli in those living in the open area.

In the shade *Hydrurus foetidus* rarely appeared, forming abundant conglomerations at the sunny station. This confirms the earlier suggestions that *H. foetidus* prefers good light conditions (Hovasse & Joyon 1960, Parker *et al.* 1973, Kawecka 1981, 1986), although Squires *et al*. (1973) reported its occurrence also under ice.

In general, the limited development of diatoms was manifested by a tendency to a decrease in their biomass index. *Achnanthes minutissima*, together with *A. biaselettiana*, and species of the genus Gomphonema, showed a wide spectrum of light requirements. However these organisms preferred exposed sites, confirming previous observations (Kawecka 1985, 1986, 1989). Lowe *at al*. (1986) also stressed the increased numbers of *A. minutissima* in the stream sectors exposed by forest cutting. On the other hand *Cocconeis placentula* var. *euglypta* preferred shaded sites, this confirming earlier observations (Kawecka 1985, 1986, 1989). McIntire & Wulff (1969) reported that the species of the genus Cocconeis appear at the low intensity of irradiation and *C. placentula* var. *euglypta* can even be regarded as a shade-adapted organism (Robinson & Rushforth 1987). Some non-identified green algae can also be classed in this group. They distinctly preferred shaded sites and developed there abundantly. In the short-day period (autumn and winter) they spread over wider areas, colonising the sectors of the stream in exposed places.

Numerous authors have found that shade limited the growth of the periphyton (Lyford & Gregory 1975, Sumner & Fisher 1979, Murphy & Hall 1981, Keithan & Love 1985, Lowe *et al*. 1986, Robinson & Rushforth 1987, Hill & Knight 1988, Hepinstall & Fuller 1994). Sumner & Fisher (1979) observed the greatest amounts of chlorophyll *a* coinciding with the maximum light intensity early in May (before the development of leaves) and again in autumn (after leaf fall), this corresponding with the degree of shading of the stream bed by the vegetation.

The present study, however, showed that the natural variation in insolation of the stream did not affect the growth of the organisms, since the content of chlorophyll *a* was similar at the stations in the open area and in the shade. McConnell & Sigler (1959), Hornick *et al*. (1981), Aboal *et al.* (1996), and Szarek (1994) suggested similar conclusions.

In the investigated stream the amount of chlorophyll *a* was sometimes even higher at the shaded station than in the sun, probably owing to the more abundant development of green algae in the shade. Similarly Pajda-Stos (1991) observed an increase in chlorophyll *a* content in algae growing in Tatra Mts lake in conditions of limited light intensity. This is due to the higher content of pigments in plants growing in the shade than in those growing in full light (Więckowski 1977). This is important from the ecological standpoint, permitting the greater productivity in conditions of poor light (McIntire *et al*. 1964).

Changes in chlorophyll *a* content throughout the year were similar at the two stations investigated with a tendency to increases in the summer-autumn months and decreases in the winter-spring season. This observation shows that the local factors do not play a significant role, while the growth of organisms depends above all on the complex of environmental agents, which are subjected to seasonal changes. The winter reduction in chlorophyll *a* content may also be associated with the short-day period, although one of the most important factors is the magnitude of water discharge. The autumn period favours the development of algae on account of the usually low and stabilised water flow in mountain streams. In spring, in the periods of thaw and spate, the thalli of algae are always severely damaged (Kawecka 1980). Similarly Szarek (1994) reported that in a Tatra stream the content of chlorophyll *a* in the periphyton was to the highest degree affected by the water level. This confirms the statement of Biggs and Close (1989), that growth dynamics should always be considered with the hydrological regime of a river.

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