Daily changes of reed periphyton composition in a shallow Hungarian lake (Lake Velence)

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Abstract

Reed periphyton stucture was investigated in the middle of summer in 1992. Five replicate samples were collected at mid-day over 25 days from living and sterilised reeds. Two weeks before sampling, a 20 cm portion of 150 below water level reed stems were cleaned with a brush. After cleaning they were covered with black nylon and aluminium foil. A day before starting the investigation, some substrata were collected as controls and examined under light microscope after preparation. Just before the experimental period the reed stems were uncovered and 150 pieces each 20 cm long cleaned and sterilised reed stems were placed in a frame. This frame was fixed under the water level to living reeds, at the same sampling point and depth.

The number of living and dead cells was counted and chlorophyll-a content of the periphyton was measured. The ratio of dead:live cells was higher in almost all the samples taken from sterilised reed, and was lowest at the beginning of the experiment. The abundance increased continuously over 11 days on both substrata, then there was a slow-increase period ("steady state"). The same tendency was observed in the chlorophyll-a content of cleaned green reeds. Changes in relative abundance of some diatoms was also examined during the investigation.

Introduction

One of the key areas in biology is the study of succession. These types of studies are fairly common in the aquatic environment; yet the study of periphytic algal succession has been poorly investigated in Hungarian shallow lakes to date. Succession of shallow-lake phytoplankton in Hungary has been studied mainly by Padisák (e.g. Padisák *et al.* 1988, 1990). The succession of periphyton of the River Danube has been studied by Ács & Kiss (1993). The process of natural succession is often disturbed by human interference, especially environmental pollution. One of the main aims of our study was to investigate the regeneration potential of attached algal communities in

Lake Velence, over a 1 month study period. The relationship between the quality of the substratum and the taxonomic composition of the reed periphyton was also studied.

Study area

Lake Velence is the second most important recreation centre in Hungary. It is located in the central part of the country, 45 km to the west of Budapest. The area of the lake is 24.5 km^2, the area of the water catchment region is 615 km^2. Average depth of the water is 1.2 m and the water is regularly mixed to the bottom. Our sampling station was at Rigya-mellék in the central part of the reed belt of the lake, at a point protected from the wind, where marked wave action occurred only during heavy storms.

Material and Methods

In the period between 12th July and 5th August 1992 samples were taken daily at the same time (around noon) from the sampling station. Two weeks before the investigations 155 pieces of reed were cleaned by brushing a 30 cm long section of submerged stems. This was then covered with aluminium foil and wrapped in black nylon foil. The reeds remained alive and rooted at their original site but no algal coating could be developed directly on their surface (these will be referred to as "cleaned green" reeds). The extended period in the dark killed any algal cells which survived cleaning.

Just before the first sampling day (day 0) the foils were removed. 5 reed stems were cut for microscopical examination to check their cleanliness. On the same day, 150 pieces of sterilised reed stems were fixed in a frame*. The frame was fixed to rooted reeds at the sampling points, just beside the living cleaned reed, exposing them to identical conditions. The upper parts of the sterilised reed stems were just below the water surface (these specimens will be referred to as "sterilised").

For sampling, the reed stems were cut 5 and 15 cm below the water surface and the resulting 10 cm stem lengths were carefully removed and placed in tubes. 5 replicates of cleaned, uncleaned and sterilised reed stems were sampled at a time. In the laboratory, the samples were washed into water of known volume which was subsequently split into two parts. One half of the sample was used for chlorophyll-a measurement according to the method of Felföldy (1987); the other half was used for taxonomic determinations, using the Utermöhl (1958) method, taking the statistical errors (Lund *et al.* 1958) into consideration. Diatoms were identified after digestion with H_2O_2.

Over the 25 days of the study period (on days 8, 14 and 25), control samples were taken from reed stems which were not previously cleaned. These specimens will be referred to as "uncleaned". "Uncleaned" control pieces were subjected to the same taxonomic study and chlorophyll-a determination.

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* (These reed stems were cleaned by brushing and sterilised before the experiment).

In the course of the sampling procedure, the following parameters were checked at the sampling station: water temperature, Secchi-transparency, pH and conductivity of the water. 11 samples of water were collected for chemical analyses. The following chemical analyses were performed: suspended matter, KOI (manganatic), HCO_3, CO_3, OPO_4, total-P, NO_2, NO_3, NH_3, total inorganic N, Na, K, Ca, Mg content.

In the course of counting, the proportion of dead cells was also determined.

Results

75 taxa were identified from the cleaned green stems, 66 from the sterilised reed and 47 from the uncleaned reed, with the following distribution: Cyanophyta 8, 6, 7, Euglenophyta 3, 4, 0, Chrysophyceae 0, 1, 0, Xanthophyceae 0, 1, 1, Bacillariophyceae 49, 42, 27 and Chlorophyta 18, 12, 12.

There was no direct correlation between water chemistry, number of individuals and chlorophyll-a content, thus only the average, minimum and maximum water chemistry parameters are included here (Table I).

Table I. The minimum, maximum and mean values of water chemistry parameters measured during the investigation.

	min.	max.	mean
pH	8.8	8.92	8.86
conductivity ($\mu S\ cm^{-2}$)	2573.52	3532.11	3250.02
suspended matter ($mg\ l^{-1}$)	4.4	33	19.19
KOI (Mn)	3.175	10.4003	8.91
HCO_3 ($mg\ dm^{-3}$)	109.19	320.25	242.51
CO_3 ($mg\ dm^{-3}$)	132	216	176.61
OPO_4 ($mg\ dm^{-3}$)	0.0137	0.1792	0.06
total–P ($mg\ dm^{-3}$)	0.047	0.4026	0.14
NO_2 ($mg\ dm^{-3}$)	0.0174	0.2646	0.06
NO_3 ($mg\ dm^{-3}$)	0.5876	1.2219	0.78
NH_3 ($mg\ dm^{-3}$)	0.7614	1.8889	1.41
total anorg. N (N $mg\ dm^{-3}$)	1.5052	2.9115	2.25
Na ($mg\ l^{-1}$)	390	560	461.96
K ($mg\ l^{-1}$)	50	135	77.76
Ca ($mg\ l^{-1}$)	7.5	12	9.50
Mg ($mg\ l^{-1}$)	200	311	247.74
water temperature (C°)	21	28.5	25.99
Secchi transparency (cm)	30	49	37.59

The number of individuals on the sterilised and the cleaned reeds did not reach that of the uncleaned green reeds during the 25 day study period (Fig. 1). The rapid increase in number of individuals slowed down for both substrata after the 11th day. The form of the curve is reminiscent of a saturation curve. The maximum number of individuals on cleaned green reeds was 0.82×10^6, on the sterilised reed 0.26×10^6, on the uncleaned green reed 1.86×10^6 (19th July), 3.89×10^6 (25th July) and 2.06×10^6 (5th August) cells cm^{-2}, respectively.

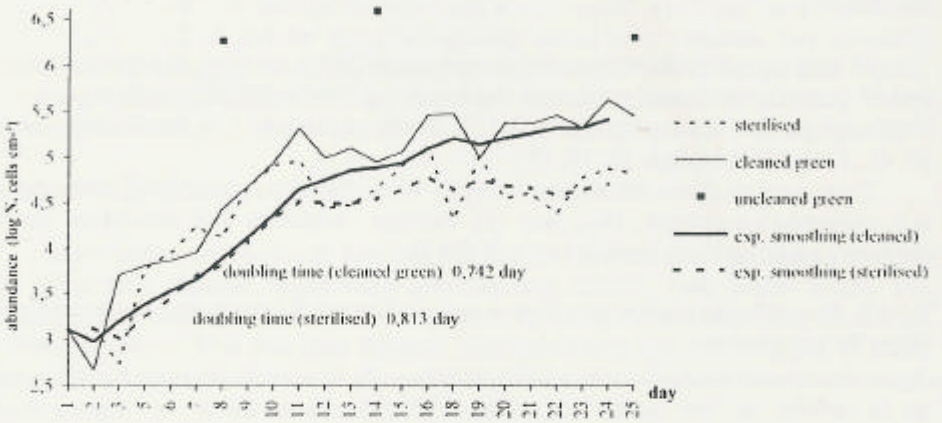

Fig. 1. The changes in algal abundance on cleaned green and sterilised reed stems and their exponential smoothing curve during the investigation. Algal abundance of uncleaned green reed also indicated.

Doubling time was estimated as 0.742 days on the cleaned green reed, and as 0.813 days on the sterilised reed between days 5th and 11th.

2–3% of cells were dead on the cleaned green reed until day 8, until day 6 on the sterilised reed. After this time the percentage ahead increased slowly to an average of 10% (little more on the sterilised reed, see Fig. 2). The proportion of dead cells on the uncleaned green reed was also around 10%. A much higher number of individuals occurred on the cleaned green reed than on the sterilised ones.

Chlorophyll-a content was significantly different on the two types of substratum. On the cleaned green reed it increased more or less gradually until day 19, then reached a "steady state" (Fig. 3). By this time, chlorophyll-a content of the samples matched that of the uncleaned green reeds. Chlorophyll-a content of the sterilised reed was almost constant or decreased slightly over the study period (chlorophyll-a content could only be detected reliably after day 10).

The Fig. 4 shows the cumulative relative abundance of the most abundant species (more than 5% in at least one sample). On cleaned green reed high relative abundance of *Achnanthes minutissima* Kütz. (ACHMIN) and *Gomphonema olivaceum* (Horn.) Bréb. (GOMOLI) was found in almost all samples. *Cymbella lacustris* (Ag.) Cl. (CYMLAC) and *Ctenophora pulchella* (Ralfs) (CTEPUL) had high relative

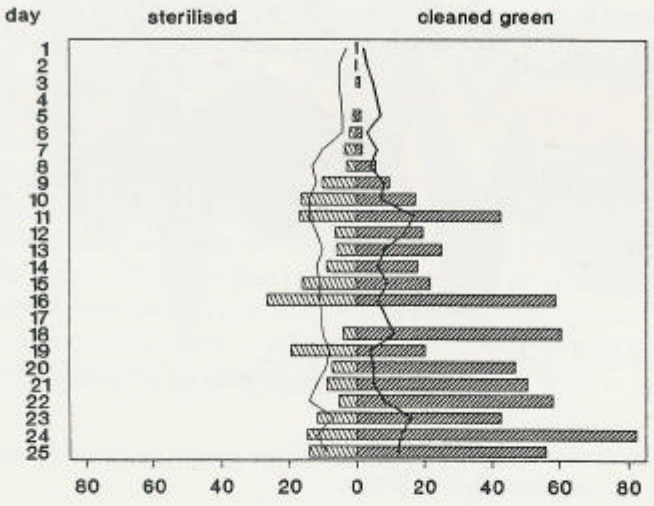

Fig. 2. The changes in periphytic algal abundance (bar, 10^4 ind. cm^{-2}) and dead cells (line, in percents) during the investigation.

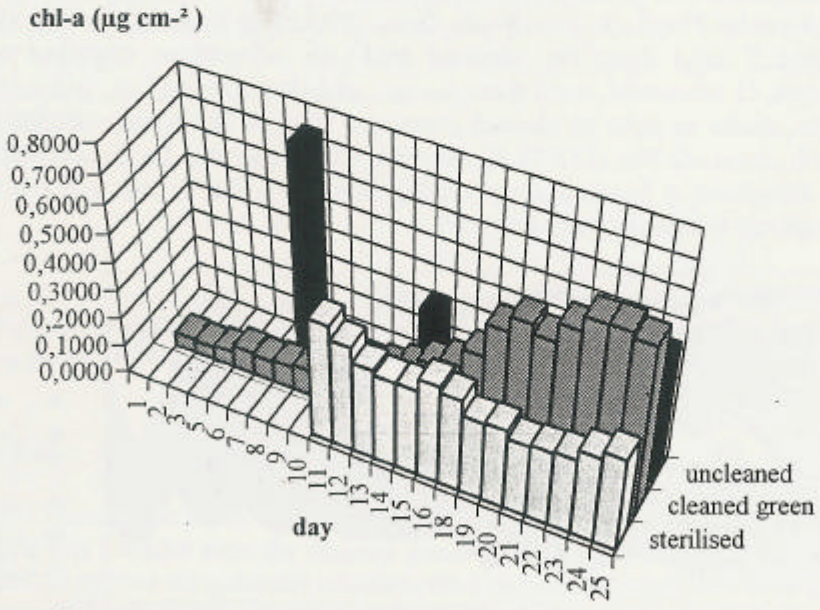

Fig. 3. The changes in chlorophyll-a content of periphyton, as 5 day running average, on cleaned green and sterilised reed stems during the investigation. Chlorophyll-a content of uncleaned green reed also indicated.

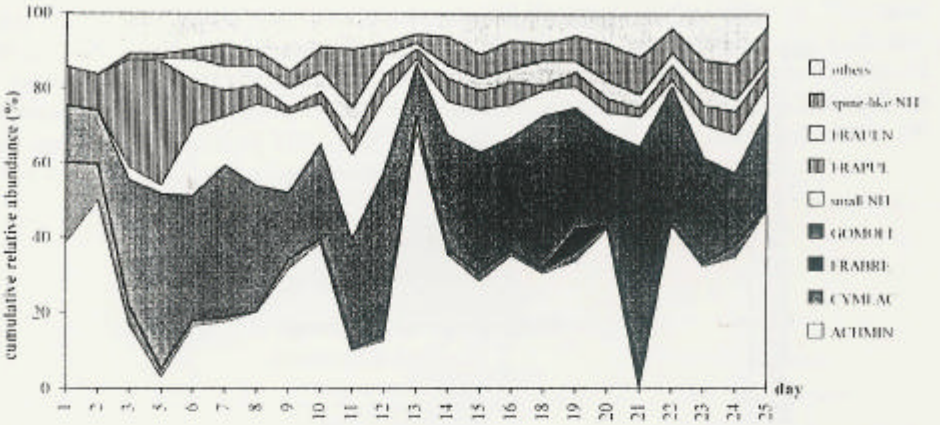

Fig. 4. The change in relative abundance of most abundant species on cleaned green reed stems during the investigation. See abbreviations in text.

abundances at the beginning of the sampling period but decreased later. The relative abundance of a small *Nitzschia* sp. (small NIT), a spine-like *Nitzschia* sp. (spine-like NIT) and *Synedra ulna* (Nitzsch) (SYNULN) was small until day 5, increased later and remained stable. *Fragilaria brevistriata* Grun. (FRABRE) appeared on day 18 and disappeared 2 days later. On sterilised reed, the occurrences displayed by *A. minutissima*, *G. olivaceum*, small *Nitzschia* sp., spine-like *Nitzschia* sp., *pulchella* and *ulna* were similar to those on cleaned green reed (Fig. 5).The relative abundance of *Cocconeis placentula* Ehr. (COCPLA) increased a little after day 18. Occasionally, the relative abundance of *Navicula cryptocephala* Kütz. (NAVCRY) was over 5% but it was completely missing in some samples.

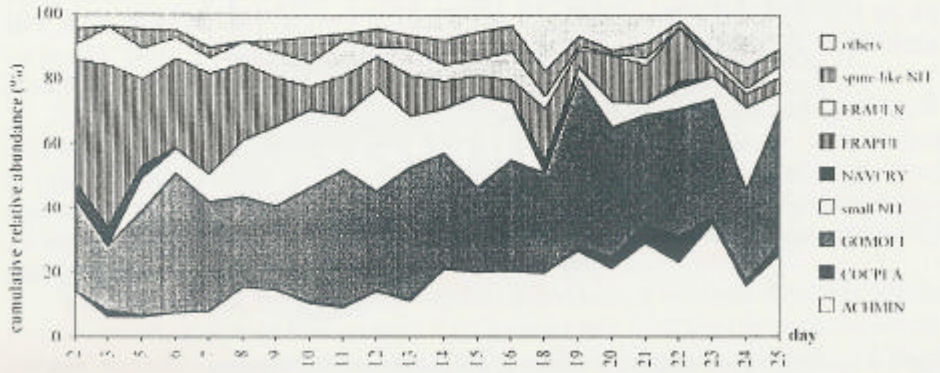

Fig. 5. The change in relative abundance of most abundant species on sterilised reed stems during the investigation. See abbreviations in text.

The species with the highest relative abundances were *A. minutissima* and *G. olivaceum* on both types of substratum. On cleaned green reed the relative abundance of *G. olivaceum* was generally higher than *A. minutissima* until day 12 (Fig. 6; except days 1, 2, 3 and 10), but after day 13 (except on days 15, 18 and 21) the latter was more abundant. In the coating collected from uncleaned reed the relative abundance of *A. minutissima* was always higher. In the sterilised reed coating the relative abundance of *G. olivaceum* was always higher than that of *A. minutissima* (Fig. 7). While the relative abundance of *A. minutissima* surpassed 40% on several occasions on the cleaned green reed, on sterilised reed it never attained this value and generally contributed less than 20%. On the cleaned green reed the relative abundance of *C. lacustris* surpassed 10% in the first two samples, but it decreased below 5% from day 3. On sterilised reed, however, it never exceeded 5%. The relative abundance of *C. placentula* exceeded 5% on the sterilised reed samples by the end of the study period, but was always under 5% on cleaned green reed.

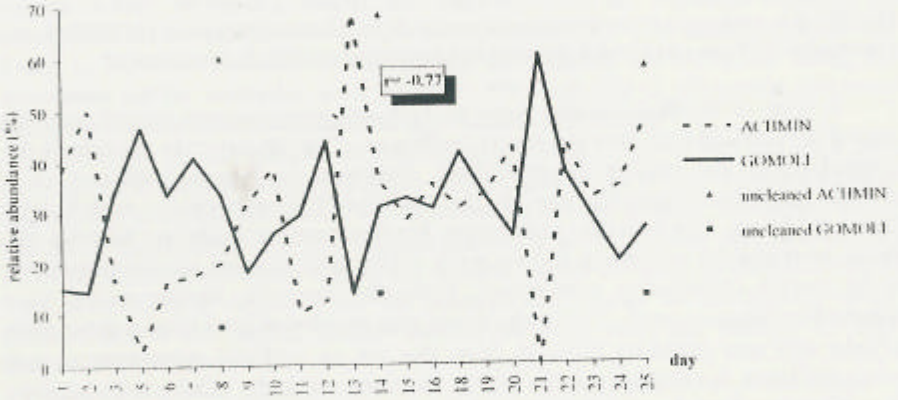

Fig. 6. The changes in relative abundance *of Achnanthes minutissima* (ACHMIN) and *Gomphonema olivaceum* (GOMOLI) on cleaned green reed stems during the investigation; relative abundance on uncleaned green reed stems also indicated.

Discussion

No direct correlation between the water chemistry parameters and the cell numbers was revealed even for cleaned green reed. This is, however, not surprising because, in spite of using natural substrata, the experimental conditions were artificial. Cleaning the reeds caused severe perturbation. Similarly, in the case of sterilised reed, an empty substratum was colonised while the water chemistry reflected the daily changes of the water body.

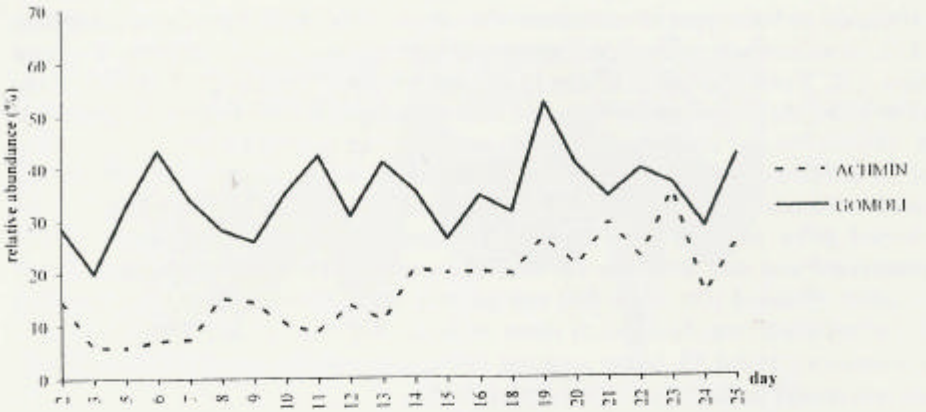

Fig. 7. The changes in relative abundance *of Achnanthes minutissima* (ACHMIN) and *Gomphonema olivaceum* (GOMOLI) on sterilised reed stems during the investigation.

In spite of similar doubling times on both substrata, increase in cell numbers ceased on sterilised reed after the day 11 leading to a "steady state". In the case of the cleaned reeds the number of individuals continued to increase although at a considerably slower pace after day 11. The observed differences can be explained by two hypotheses. One possible explanation invokes nutrient exchange between the living reed and the periphyton formed on it, which may be even more intensive for some species (*Achnanthes minutissima*, *Cymbella lacustris*). Similar results were reported by Shamess *et al.* (1985) who found that periphyton on a natural substratum (*Typha* sp.) was distinctly different from that on an artificial substratum in two eutrophic lakes. According to Allen (1971), there are metabolic relationships between macrophyte and epiphyton. The macrophytes act as a source of phosphate for their epiphyte, especially in oligotrophic and mesotrophic lakes (Burkholder & Wetzel 1989). The water of Lake Velence was mesotrophic over the study period. Cattaneo & Kalff (1979) found some evidence of nutrient transfer from the host to the epiphyte. Microorganisms on an artificial substratum were more phosphate-limited.

Although environmental conditions were identical for both types of substratum, and there was similar exposure to wave movement for all, we could still observe that, in the case of better developed coating, periphyton on sterilised reed was ready to peel off.

As we did not have any method for studying the compounds excreted by the reed, or the chemical composition of the reed itself, we cannot solve the above problem yet. Both factors probably contribute to the observed phenomena.

The low number of dead cells at the beginning of the study period and their subsequent increase later, indicate that stem cleaning was adequate and that no algae remained on the stems after the cleaning procedure.

While the number of individuals remained about one order of magnitude lower on cleaned green and sterilised reed than on uncleaned green reed, the chlorophyll-a content attained corresponding concentrations to the uncleaned green reed. This is probably explained by the large number of *Achnanthes minutissima* cells in the sample, which, due to their small size, have a lesser effect on the chlorophyll-a content than on cell numbers.

On cleaned green reed, significant negative correlation ($p<10\%$ level) was found between the relative abundances of *A. minutissima* and *G. olivaceum*. It seems that these two species competed in the coating and that *A. minutissima* was more competitive here. On uncleaned green reed there was always significant dominance of *A. minutissima*. On sterilised reed, *A. minutissima* could never "beat" *G. olivaceum*. This may also be explained by nutrient exchange between *A. minutissima* and the host plant.

Several authors (e.g. Goldsborough & Hickman 1991; Otten & Willemse 1988) have pointed out that the physical conditions of the substratum (roughness of the surface, colour, wettability, electrostatic attraction etc.) are important modifiers of accumulation. On hydrophobic substrata the tightly adherent *Cocconeis placentula* was found to be more abundant (Goldsborough & Hickman 1991). In our study the substratum surface properties were the same. We think that *C. placentula* was more competitive under harsh circumstances (e.g. nutrient limitation).

After day 25 the number of individuals on cleaned green and sterilised reed remained lower than on uncleaned green reed, in spite of the calculated doubling time and average mortality rate which would theoretically have allowed this density to be attained within 10 days. This phenomenon can be explained by heavy emigration of the small algae which reproduce rapidly but compete poorly for nutrient (Sommer 1981). This observation is supported by the chlorophyll-a content of the coating which attained that of the control samples (uncleaned green reed) due initially to large (basically filamentous) algae.

Summary

We found that reed periphyton in Lake Velence could not recover from the perturbation caused by our test over the 25 days of the study period. The number of algal cells did not reach that of the uncleaned reeds. The average doubling time of the periphytic algae (approx. day 10) should be enough to regenerate the coating, but extensive emigration of the rapidly reproducing but poor nutrient competitor small-sized species probably occurred. We can predict from the increase in relative abundance of filamentous algae that the chlorophyll-a content could reach that of the uncleaned reeds.

The increase in the number of individuals on both substrata was quite similar until day 11. After this period, however, growth practically ceased on sterilised reed while it continued at a slower pace on cleaned green reed. The reason for this difference could lie in the metabolic relationship between macrophyte and periphyton, ensuring a phosphate supply for periphyton on the cleaned green reed, while the lower number of

individuals of *Achnanthes minutissima* on sterilised reed reflects lower phosphate supply resulted in exfoliation of the coating.

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