

Oceanological and Hydrobiological Studies
Vol. XXXIII, No. 2

Institute of Oceanography

(3-15)
2004

University of Gdańsk

Research Article

THE USE OF BENTHIC ALGAE, EXCLUDING DIATOMS AND CHARALES, FOR THE ASSESSMENT OF THE ECOLOGICAL STATUS OF RUNNING FRESH WATERS: A CASE HISTORY FROM GERMANY

ANTJE GUTOWSKI¹, JULIA FOERSTER², JOCHEN SCHAUMBURG³

¹*Hohenkampsweg 25, D-28355 Bremen, Germany*
e-mail: a.gutowski@t-online.de

²*University of Bremen, Dept. of Biology/Chemistry*
AG Kirst, Leobener Str. NW 2, D-28359 Bremen, Germany
e-mail: foerst@uni-bremen.de

³*Bavarian Water Management Agency*
Lazarettstr. 67, D-80636 Munich, Germany
e-mail: Jochen.Schaumburg@lfw.bayern.de

Key words: phytobenthos, running water, ecological status, WFD, assessment

Abstract

A biomonitoring program was developed to assess the ecological status of streams based on the phytobenthic algal community structure. The study presented here focuses on siliceous sites of streams in the central highlands of Germany. Phytobenthic algae belonging to eight classes and 74 taxa were grouped into four categories according to their ecological distribution pattern. A formula was designed to calculate an index ranging from +100 to -100 to assess stream health. Based on these values, the sampling sites were assigned to one of the five ecological quality classes required by the Water Framework Directive (WFD) of the European Union.

* Results of this paper were presented on an 5th International Symposium "Use of Algae for Monitoring Rivers" Cracow, 2-6 September 2003, Poland.

INTRODUCTION

In December 2000, Directive 2000/60/EG (the Water Framework Directive, WFD) was passed in the European Parliament and the Council (EU, 2000). According to this directive, member states of the European Union are obliged to assess and report the ecological status of all bodies of water exceeding a certain size limit. Five ecological classes were distinguished - high, good, moderate, poor, and bad. Ecological status is determined by both the physico-chemical properties of the waterbody and the community structure of the biota referred to as "biological quality elements" in the WFD. Phytobenthos is listed as one of the biological quality elements of the biota. For the assessment of ecological status, the taxonomic composition and abundance of the species have to be investigated and compared to the specific reference conditions for different types of streams and rivers.

In Germany, the Bavarian Water Management Agency coordinated a research project that was aimed at developing a new monitoring program to be used to assess the ecological status of different types of waterbodies with regard to aquatic flora, *i.e.*, macrophytes and phytobenthos, according to the criteria outlined in the WFD (Schaumburg *et al.* 2004). Until this time, no such program had existed in Germany. Moreover, existing protocols and comprehensive investigations of benthic algae mainly focus on diatoms, and knowledge about the present distribution of non-diatom benthic algae in Germany is scant. In Austria, non-diatom benthic algae have been used regularly in routine investigations, and detailed lists of indicator species based on saprobic or trophic conditions have been published (Rott *et al.* 1997, 1999). Although a list of 138 non-diatom taxa of benthic algae based on their preferences of trophic conditions (Schmedtje *et al.* 1998) has been compiled from the literature, no monitoring program has been proposed for the assessment of sampling sites using these algae.

For the research project presented in this paper, all classes of benthic algae other than diatoms and Charales were investigated twice (in winter 2000/2001 and summer 2001) at 152 sites in streams and rivers. Multivariate statistics was used to differentiate and define different types of running waters that presented characteristic species composition and abundance at reference conditions (pristine sites). Within the relatively pristine (reference) sites, five different types were distinguished according to the distribution pattern of the species. These types can be related to the different ecoregions and the geochemical influences of the watershed (Schaumburg *et al.* 2004). They are as follows: (1) sites in the Alps, (2) sites in the foothills of the Alps, (3) siliceous sites in the central highlands, (4) calcareous sites in the central highlands and central plains, (5) organic

sites in the central plains. A procedure to determine the ecological status of the sampling sites was developed for the latter three types. The case history presented in this paper is based on type (3) siliceous sites in the central highlands of Germany.

Table 1

Estimation of abundance of non-diatom benthic algae using a five-point scale

estimated abundance	description
5	dominant, covers more than a third of the riverbed (>33%)
4	abundant, but covers less than a third of the riverbed (5-33%)
3	just visible in the field (covers max. 5%) or microscopically dominant
2	microscopically abundant
1	microscopically rare

MATERIAL AND METHODS

A total of 152 sampling sites were investigated. Of these, 26 belonged to type (3) siliceous sites in the central highlands. Most sites were sampled twice - in winter 2000/2001 and in summer 2001. Data from 51 sampling events were gathered from these 26 sites. The taxonomic composition and abundance of the benthic algae, excluding diatoms and Charales, were determined. The taxonomic composition was analyzed as accurately as possible. Taxa were determined to the species level whenever possible, and the abundance of the species was estimated on a five-point scale (see Table 1). A detailed description (in German) of the sampling procedure and a list of the literature used to determine the taxa can be found in "Vorläufige Kartieranleitung für Makrophyten und Phytobenthos" available at the following link:

http://www.bayern.de/lfw/technik/gkd/lmn/fliessgewaesser_seen/pilot/welcome.htm

Multivariate statistics (correspondence analysis) was employed using Canoco 4.5 to analyze the similarity of the species assemblages at different sites. The relationship between the species assemblages and the different environmental factors were investigated by means of canonical correspondence analysis with manual forward selection of relevant environmental parameters. The environmental factors tested included general information of the sampling site like width, estimated current velocity, main type of substrate *etc.*, the size of the watershed and its geochemical composition, and the chemical and physical

properties of the waterbody. These data were provided to the Bavarian Water Management Agency by local water authorities.

In addition to multivariate analysis, the occurrence of species that were recorded at least ten times in the whole data set was plotted in relation to relevant chemical parameters: pH, conductivity, NO₃-N, TP, O₂, chloride concentrations, water hardness, BOD₅.

Table 2

Average values of the chemical and physical properties of the waterbody at 145 sampling sites investigated in the project. Min = minimum value, Max = maximum value, N = number of sites with data present

	Min.	Max.	Average	N
Temperature (°C)	4.6	13.7	9.8	145
pH	5.82	8.39	7.73	145
Conductivity (20°C) (µS/cm)	56.3	2335.4	469.3	145
TN (mg/l)	0.79	17.51	4.36	73
NO ₃ -N (mg/l)	0.10	11.80	3.30	145
NO ₂ -N (mg/l)	0.00	0.43	0.04	97
NH ₄ -N (mg/l)	0.01	7.99	0.30	145
TP (mg/l)	0.013	0.843	0.150	141
SRP (mg/l)	0.003	0.517	0.077	138
O ₂ -content (mg/l)	6.43	12.37	10.51	145
O ₂ -saturation (%)	55.56	115.82	93.68	104
Chloride (mg/l)	2.54	723.77	43.00	145
Acid capacity pH 4.3 (mmol/l)	0.11	6.32	2.62	108
Water hardness (mmol/l)	0.19	5.40	2.05	111
BOD ₅ (mg/l)	0.80	11.50	2.55	122

RESULTS

Chemical and physical data were available for 145 of the 152 sampling sites. On average, most of them had a neutral to slightly alkaline pH (between 7.3 and 8.5). Only six sampling sites possessed average pH values below 7. The average conductivity ranged between 56 and 750 µS/cm. The average NO₃-N content ranged between 0.5 and 4.5 mg/l for most sampling sites, and the average TP content was between 0.013 and 0.250 mg/l. Further information on the extension of the chemical and physical values at the sampled sites is shown in Table 2.

A total of 238 taxa were noted; most taxa belonged to the Nostocophyceae (70 taxa), Chlorophyceae (54 taxa) and Charophyceae (49 taxa). These classes also showed the highest number of records, each comprising 20-25% of all the recorded species, respectively. Species which belong to the classes of Tribophyceae (14 taxa and 6% of all records), Florideo- and Bangiophyceae (12 taxa,

Table 3

Classification categories

category	description
A	sensitive species, characteristic of certain types of waterbodies (found at the most pristine sites)
B	less sensitive species, more widely distributed, indicate good conditions
C	tolerant species, indicate eutrophication when highly abundant
D	species prefer strongly eutrophic conditions

12% of all records) and Ulvophyceae (12 taxa, 7% of all records) were less frequently recorded. Detailed information on the distribution of these taxa is presented by Schaumburg *et al.* (2004). Of these, 74 taxa have been identified as suitable indicator species for siliceous sites. Based on (i) the results of multivariate analysis, (ii) the distribution of each taxon with regard to the chemical parameters listed above, and (iii) information taken from the literature, these 74 taxa were grouped into four categories (Table 3), which express their different sensitivity to ecological changes as well as to trophic and saprobic conditions.

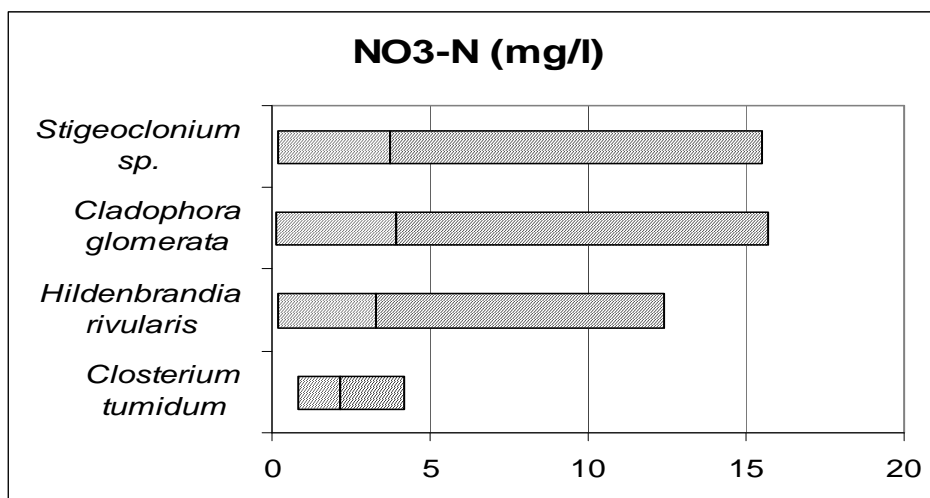


Fig. 1. Occurrence of *Closterium tumidum*, *Hildenbrandia rivularis*, *Cladophora glomerata* and *Stigeoclonium sp.* over the range of measured NO₃-N – contents (mg/l) of the waterbody. The whole range of recorded occurrences is presented. The left margin indicates the minimum and the right margin the maximum values. The line in the middle indicates the average value.

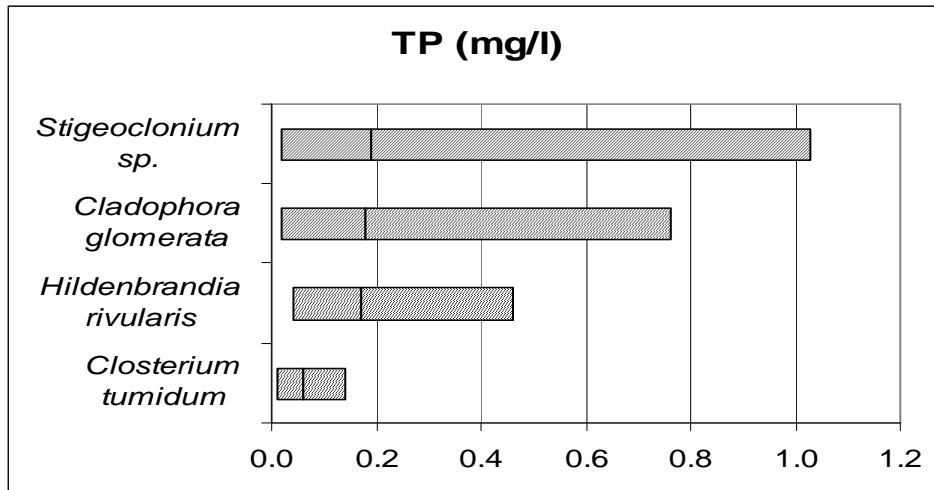


Fig. 2. Occurrence of *Closterium tumidum*, *Hildenbrandia rivularis*, *Cladophora glomerata* and *Stigeoclonium sp.* over the range of measured TP – contents (mg/l) of the waterbody. The whole range of recorded occurrences is presented. The left margin indicates the minimum and the right margin the maximum values. The line in the middle indicates the average value.

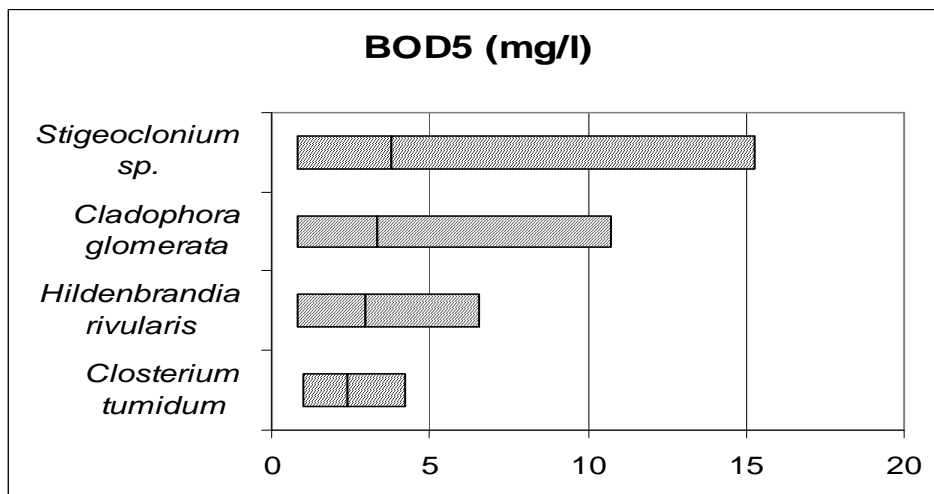


Fig. 3. Occurrence of *Closterium tumidum*, *Hildenbrandia rivularis*, *Cladophora glomerata* and *Stigeoclonium sp.* over the range of measured BOD₅ - contents (mg/l) of the waterbody. The whole range of recorded occurrences is presented. The left margin indicates the minimum and the right margin the maximum values. The line in the middle indicates the average value.

Table 4

List of indicator species at siliceous sites in the central highlands of Germany

A	<i>Closterium incurvum</i> , <i>C. intermedium</i> , <i>C. rostratum</i> , <i>C. striolatum</i> , <i>C. tumidum</i> , <i>Draparnaldia mutabilis</i> , <i>Tetraspora gelatinosa</i> , <i>Aphanocapsa fonticola</i> , <i>Chamaesiphon fuscus</i> , <i>Ch. polonicus</i> , <i>Ch. starmachii</i> , <i>Hydrococcus cesatii</i> , <i>H. rivularis</i> , <i>Phormidium corium</i>
B	<i>Bangia atropurpurea</i> , <i>Closterium leibleinii</i> var. <i>boergensenii</i> , <i>C. littorale</i> var. <i>crassum</i> , <i>C. praelongum</i> var. <i>brevius</i> , <i>C. tumidulum</i> , <i>Klebsormidium rivulare</i> , <i>Gongrosira debaryana</i> , <i>G. fluminensis</i> , <i>Microspora amoena</i> , <i>M. floccosa</i> , <i>Phaeodermatium rivulare</i> , <i>Audouinella</i> sp., <i>A. chalybaea</i> , <i>A. hermannii</i> , <i>A. pygmaea</i> , <i>Batrachospermum</i> sp., <i>B. gelatinosum</i> , <i>Chantransia</i> -stages, <i>Hildenbrandia rivularis</i> , <i>Lemanea</i> sp., <i>L. fluviatilis</i> , <i>Aphanothece stagnina</i> , <i>Chamaesiphon</i> sp., <i>Ch. confervicolus</i> , <i>Ch. incrustans</i> , <i>Ch. polymorphus</i> , <i>Ch. subglobosus</i> , <i>Chroococcopsis gigantea</i> , <i>Homoeothrix</i> sp., <i>Homoeothrix janthina</i> , <i>H. varians</i> , <i>Oscillatoria limosa</i> , <i>Phormidium autumnale</i> , <i>Tribonema</i> sp., <i>T. viride</i> , <i>T. vulgare</i> , <i>Ulothrix zonata</i>
C	<i>Closterium acerosum</i> , <i>C. ehrenbergii</i> , <i>C. ehrenbergii</i> var. <i>malinverianum</i> , <i>C. moniliferum</i> , <i>C. moniliferum</i> var. <i>concauum</i> , <i>C. strigosum</i> , <i>C. strigosum</i> var. <i>elegans</i> , <i>C. sublaterale</i> , <i>Oedogonium</i> sp., <i>Oscillatoria</i> sp., <i>Phormidium incrustatum</i> , <i>P. retzii</i> , <i>P. subfuscum</i> , <i>Pleurocapsa minor</i> , <i>Vaucheria</i> sp., <i>V. bursata</i> , <i>Cladophora glomerata</i> , <i>Rhizoclonium hieroglyphicum</i> , <i>Ulothrix</i> sp., <i>U. tenerrima</i> , <i>U. tenuissima</i>
D	<i>Stigeoclonium</i> sp., <i>Leptolyngbya foveolarum</i>

Some interesting examples of the distribution of relevant indicator species are given here, and their classification into the four categories is explained. The Charophyceae *Closterium tumidum* was found nine times but only at siliceous sites in the central highlands. Its occurrence is restricted to sites with low water hardness (0.2–0.4 mmol/l), low conductivity (68–135 μ S/cm), low nutrient concentrations (Figures 1, 2), and a low BOD₅ (Figure 3). *Closterium tumidum* was included in Category A.

The Florideophyceae *Hildenbrandia rivularis* was found 25 times. It was present in different types of rivers with a wider range of water hardness (0.2–4.4 mmol/l), conductivity (56–2335 μ S/cm), and pH (7–8.3). It tolerated higher amounts of NO₃-N (figure 1), but was more sensitive to P enrichment (Figure 2). Its presence was restricted to the lower classes of BOD₅ (Figure 3). *Hildenbrandia rivularis* was included in Category B.

The Ulvophyceae *Cladophora glomerata* was found 109 times in all types of running waters and occurred over a wide range with regard to pH, conductivity, and water hardness. It seemed to tolerate a higher degree of nutrient en-

richment (Figures 1, 2) and also some organic pollution (Figure 3). *Cl. glomerata* was classified as Category C.

The occurrence of *Stigeoclonium* sp. (N = 66) over the range of measured nutrient concentrations and organic pollution is shown in Figures 1, 2 and 3. Since it is tolerant of a broad range of eutrophic and saprobic conditions, *Stigeoclonium* sp. was included in Category D.

On final analysis, 74 taxa (belonging to eight classes: Bangiophyceae, Charophyceae, Chlorophyceae, Chrysophyceae, Florideophyceae, Nostocophyceae, Tribophyceae, and Ulvophyceae) were deemed to be useful indicators for the assessment of the ecological status of siliceous sampling sites in the central highlands and were grouped into four categories (Table 4).

For the type-specific assessment of the ecological status of a sampling site, the abundance of these species has to be taken into consideration. A formula was developed to calculate an index of ecological status using the sum of the squared abundances of the species per category,

$$Index = \frac{\sum_{i=1}^{n_A} Q_{Ai} + \frac{1}{2} \sum_{i=1}^{n_B} Q_{Bi} - \frac{1}{2} \sum_{i=1}^{n_C} Q_{Ci} - \sum_{i=1}^{n_D} Q_{Di}}{\sum_{i=1}^{n_A} Q_{Ai} + \sum_{i=1}^{n_B} Q_{Bi} + \sum_{i=1}^{n_C} Q_{Ci} + \sum_{i=1}^{n_D} Q_{Di}} \times 100 \quad (1)$$

where: Q_{Ai} (Q_{Bi} , Q_{Ci} , Q_{Di}) is the squared abundance of taxon i from Category A (B,C,D) with i in the summations running over all taxa belonging to A (B,C,D); *i.e.*, i from 1 to $n_{A(B,C,D)}$, respectively.

Table 5

Derivation of five ecological quality classes from calculated index values

calculated index	Ecological quality class
≥ 50	1
≥ 25	2
≥ 0	3
≥ -50	4
< -50	5

Theoretically, this index ranges from +100 (when only species from Category A are present at the sampling site) to –100 (when the sampling site contains only species belonging to Category D). Borders had to be set to delineate the five “ecological quality classes” that are required by the WFD (Table 5). In order to calculate an index and derive the ecological status class of a sampling

site, at least five of the taxa listed as indicator species should be found. If there are fewer species present, the total sum of the squared abundances should be ≥ 16 in order to calculate the index.

An example of the application of this formula to three siliceous sites in the central highlands is shown below (Table 6). The species list shows which category the taxon belongs to, and its abundance was estimated using the five-point scale explained above (see Table 1). In order to calculate the index, these estimated values have to be squared and then summed per category. Using this calculated index, each sampling site is assigned to one of the five ecological quality classes according to the values in Table 5.

Table 6

Example of the assessment of the ecological status of three sampling sites belonging to type (3) siliceous sites in the Central Highlands. The species list is presented and the abundance of each species is estimated on a five-point scale (see table 1). The index is calculated using formula (1)

Taxon	Category	sampling site		
		A	B	C
<i>Closterium intermedium</i>	A	1		
<i>Closterium rostratum</i>	A	1		
<i>Draparnaldia mutabilis</i>	A	3		
<i>Phormidium corium</i>	A	3		
<i>Audouinella chalybaea</i>	B		3	
<i>Audouinella hermannii</i>	B		3	
<i>Chamaesiphon incrustans</i>	B		1	
<i>Closterium tumidulum</i>	B	3	1	
<i>Hildenbrandia rivularis</i>	B		4	
<i>Lemanea fluviatilis</i>	B		2	
<i>Microspora amoena</i>	B	1	2	2
<i>Mougeotia</i> sp.	B	1		
<i>Phormidium retzii</i>	B	3		
<i>Ulothrix zonata</i>	B	4		
<i>Vaucheria bursata</i>	B		4	
<i>Batrachospermum</i> sp.	B	3	1	
<i>Chantransia</i> - stages	B	2	2	
<i>Closterium strigosum</i>	B		1	
<i>Closterium strigosum</i> var. <i>elegans</i>	B	1		
<i>Microspora</i> sp.	B		1	
<i>Oscillatoria limosa</i>	B	2		
<i>Cladophora glomerata</i>	C	1	3	
<i>Oedogonium</i> sp.	C	2	2	3
<i>Oscillatoria</i> sp.	C			1
<i>Vaucheria</i> sp.	C		4	3
<i>Closterium ehrenbergii</i>	C		4	
<i>Closterium moniliferum</i>	C		1	
<i>Stigeoclonium</i> sp.	D		1	5
Index		56.3	15.2	-67.7
Ecological quality class		1	3	5

DISCUSSION

The method developed in the project is the first attempt to assess the ecological status of a sampling site by evaluating the species composition and abundance of the phytobenthic algal community other than diatoms and Charales. This method should be tested broadly in future investigations and has to be compared to assessment programs using other groups of organisms. Methods based on the distribution of Bacillariophyceae and Macrophytes (including Charales) were also developed within the scope of the project and will be presented elsewhere (Schaumburg *et al.* 2004).

For the siliceous sites in the central highlands, 74 species from eight different classes were identified as useful indicator species for the assessment of ecological status. The community composition and the ecological requirements of the relevant taxa were investigated. Support was found in the literature for the autecological data of the species presented here.

Closterium tumidum was found only rarely before, mostly at acidic to neutral sites (Růžička 1977) with oligo- to mesotrophic conditions (Förster 1982). It was included in Category A because it was characteristic for the most pristine siliceous sites.

In the present study, the Florideophyceae *Hildenbrandia rivularis* tolerated some nutrient enrichment but was sensitive to organic pollution. Its presence still indicates good conditions. This is in accordance with other findings. Based on a broad literature survey, Schmedtje *et al.* (1998; see references therein) describe the occurrence of *Hildenbrandia rivularis* in the range of oligo-mesotrophic to eutrophic conditions, with the center in mesotrophic conditions. In Rott *et al.* (1999), *Hildenbrandia rivularis* is classified as an indicator for meso- to eutrophic conditions. According to Rott *et al.* (1997), the alga can tolerate moderate loads of organic pollution. On the other hand, Dell'Uomo (1991) reports *Hildenbrandia rivularis* at natural sites unaffected by or only slightly subjected to pollution and identifies it as a reliable indicator for excellent water quality.

Cladophora glomerata is often reported under eutrophic conditions (Van den Hoek 1963, Schmedtje *et al.* 1998, Rott *et al.* 1999) where it can reach nuisance levels (Whitton 1970, Holmes and Whitton 1981). However, it apparently avoids sites that are impacted by heavy metals (Whitton 1970, Rott *et al.* 1999). Rott *et al.* (1997) name the alga as a saprophilic species. According to Dell'Uomo (1991), *Cladophora glomerata* can be found from good to rather polluted sites. This concurs with the current results; *Cladophora glomerata* occurred in a wide range of conditions with regard to water nutrient content, and it tolerated some organic pollution. Similar findings are reported in

Schmedtje *et al.* (1998). In this study *Cladophora glomerata* was classified as Category C because mass development indicates disturbed conditions with high nutrient loads.

Although it was not possible in the current study to identify *Stigeoclonium* to the species level, the occurrence of this genus provided valuable information. The species of this genus tolerate eutrophication and grow abundantly in rivers with high levels of organic material, for example, in areas immediately below sewage facilities (Simons *et al.* 1999; John *et al.* 2002; see also reports in Schmedtje *et al.* 1998).

St. tenue is a very common species that prefers sites with high loads of nutrients and organic substances (Backhaus 1968). It is also resistant to Cu and other toxic metals (Fjerdingsstad 1964). McLean and Benson-Evans (1974) support Fjerdingsstad's view that *St. tenue* is a saprophilous species. Fricke and Steubing (1984) as well as Dell'Uomo (1991) see it as a good indicator for rather polluted water. Other species of the same genus, like *St. farctum*, *St. lubricum*, and *St. protensum*, also grow at sites with higher nutrient loads (Backhaus 1968). In the River Meuse, *St. protensum* favored sites with a certain degree of pollution and was absent from healthy sites. Principal component analysis showed that *St. protensum* belongs to the group of taxa that reach maximum abundance at polluted sites (Descy 1973).

The sampling sites investigated in this project covered a wide range of different nutrient conditions and degrees of organic pollution. The impact of acidification or pollution by heavy metals or other toxins was not investigated. However, published reports and data on the tolerance levels of different benthic algae to the impact of these factors were taken into consideration for the classification of the species. So far, the assessment method is based only on taxa that were found in the current investigations. No species were included based exclusively on literature data. Hopefully, further investigations using the methods proposed here may yield more species to be used as indicator species.

ACKNOWLEDGEMENTS

The authors wish to thank Peter Pfister who sampled some of the siliceous sites in southern Germany, Dieter Mollenhauer for support and critical advice, Gunter-Otto Kirst for the possibility to work in his study group and Kurt Handke for help in the identification of the desmids. The manuscript was greatly improved by the comments of an anonymous reviewer.

REFERENCES

- Backhaus, D., 1968, *Ökologische Untersuchungen an den Aufwuchsalgen der obersten Donau und ihrer Quellflüsse, II. Die räumliche und zeitliche Verteilung der Algen (Ecological investigations on the benthic algae of the upper Danube and its sources, II. The spatial and seasonal distribution of algae)*, Arch. Hydrobiol. Suppl. XXXIV (Donauforschung III) (1/2) 24-73
- Descy, J.P., 1973, *La Végétation Algale Benthique de la Meuse Belge et ses Relations avec la Pollution des Eaux (The benthic algal vegetation of the Belgian river Meuse and its relations to water pollution)*, LEJEUNIA, 66, 1-62
- Dell'Uomo, A., 1991, *Use of Benthic Macroalgae for Monitoring Rivers in Italy*, [in:] *Use of algae for monitoring rivers*, Whitton, B.A., Rott, E., Friedrich, G. (eds.), Institut für Botanik, Universität Innsbruck, 129-137
- European Union, 2000, *Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Communities in the field of water policy*, Official Journal of the European Communities, L 327/1, 22.12.2000
- Förster, K., 1982, *Conjugatophyceae, Zygnematales und Desmidiaceae (excl. Zygnemataceae)*, [in:] *Das Phytoplankton des Süßwassers, 8. Teil, 1. Hälfte*, Huber-Pestalozzi, G.(ed.), Schweizerbart, Stuttgart, 543
- Fricke, G., Steubing, L., 1984, *Die Verbreitung von Makrophyten und Mikrophyten in Hartwasser-Zuflüssen des Ederstausees, (The distribution of macrophytes and microphytes in hardwater tributaries of the Eder-reservoir)*, Arch. Hydrobiol., 101(3), 361-372
- Fjordingstad, E., 1964, *Pollution of streams estimated by benthic phytomicroorganisms. I. A saprobic system based on communities of organisms and ecological factors*, Int. Rev. Ges. Hydrobiol., 49, 63-131
- Holmes, N.T.H., Whitton, B. A., 1981, *Phytobenthos of the River Tees and its tributaries*, Freshw. Biol., 11, 139-163
- John, D. M., Whitton, B. A., Brook, A. J., 2002, *The freshwater algal flora of the British Isles: An identification guide to freshwater and terrestrial algae*. Cambridge University Press, Cambridge, 702 pp.
- McLean, R., O., Benson-Evans, K. 1974, *The distribution of Stigeoclonium tenue Kütz. in South Wales in Relation to its use as an Indicator of organic pollution*, Br. Phycol. J., 9, 83-89
- Rott, E., Hofmann, G., Pall, K., Pfister, P., Pipp, E., 1997, *Indikationslisten für Aufwuchsalgen, Teil 1: Saprobien Indikation (Indication lists for periphytic algae. Part 1: Saprobic indication)*, Bundesministerium für

- Land- und Forstwirtschaft (Federal Ministry of Agriculture and Forestry), Wien, 73 pp.
- Rott, E., Pfister, P., Van Dam, H., Pipp, E., Pall, K., Binder, N., Ortler, K., 1999, *Indikationslisten für Aufwuchsalgen in österreichischen Fließgewässern, Teil 2: Trophieindikation sowie geochemische Präferenz, taxonomische und toxikologische Anmerkungen (Indication lists for periphytic algae in running waters of Austria, Part 2: Trophic indication and geochemical preference, taxonomic and toxicologic remarks)*, Bundesministerium für Land- und Forstwirtschaft (Federal Ministry of Agriculture and Forestry), Wien, 248 pp.
- Růžička, J., 1977, *Die Desmidiaceen Mitteleuropas (The Desmids of Central Europe)*, Vol. 1, 1, Schweizerbart, Stuttgart, 290 pp.
- Schaumburg, J., Schmedtje, U., Köpf, B., Schranz, C., Schneider, S., Meilinger, P., Stelzer, D., Hofmann, G., Gutowski, A., Foerster, J., 2004, *Makrophyten und Phytobenthos in Flüssen und Seen. Leitbildbezogenes Bewertungsverfahren zur Umsetzung der EG-Wasserrahmenrichtlinie (Macrophytes and Phytobentos in Rivers and Lakes. An overall conceptual assessment procedure for the realization of the EU- Water Framework Directive)*, Informationsberichte des Bayerischen Landesamtes für Wasserwirtschaft (Information Reports of the Bavarian Water Management Agency) 1/4, in prep.
- Schmedtje, U., Gutowski, A., Hofmann, G., Leukart, P., Melzer, A., Mollenhauer, D., Schneider, S., Tremp, H., 1998, *Trophiekartierung von aufwuchs- und makrophytendominierten Fließgewässern (Mapping of the trophic status of running waters dominated by periphytic algae and macrophytes)*, Informationsberichte des Bayerischen Landesamtes für Wasserwirtschaft (Information Reports of the Bavarian Water Management Agency) 4/98, 501 pp.
- Simons, J., Lokhorst, G. M., van Beem, A. P., 1999, *Benthische zoetwateralgen in Nederland (Benthic freshwater algae in the Netherlands)*, KNNV Uitgeverij, Utrecht, 280 pp.
- Van den Hoek, C., 1963, *Revision of the European Species of Cladophora*, Leiden, Reprint Koeltz, Koenigstein, 1976, 248 pp.
- Whitton, B. A., 1970, *Biology of Cladophora in Freshwaters*, Water Res., 4, 457-476