Ber. nat.-med. Verein Innsbruck	Band 91	S. 7 - 42	Innsbruck, Nov. 2004

Benthic Algae and Mosses from Aquatic Habitats in the Catchment of a Glacial Stream (Rotmoos, Ötztal, Austria)

by

Doris GESIERICH & Eugen ROTT*)

Synopsis: The pilot project 'BioDivAlp – Biodiversity of an Alpine catchment' was an integrated approach to assess the microbial, botanical, and faunistic biodiversity of terrestrial and aquatic habitats with a focus on running waters for a 10 km2 alpine catchment in the Rotmoos Valley in the central part of the Alps. This investigation focuses on typical phytobenthos communities and some aspects of mosses. The habitat diversity ranges from 2 sites in the main stream (Rotmoosache), 5 spring streams and 5 glacier streams including an aquatic – terrestrial transition zone (FEN area). Observations were carried out in the years 2001 / 2002 and samples were taken at least once in July (2001) the time of maximum development of epilithic algal vegetation in high-altitude areas.

In sum 278 phytobenthos taxa were identified, the taxonomic groups most frequent and richest in species were diatoms (181 species) reaching highest numbers in the FEN area and some glacial streams, cyanophytes / cyanobacteria (42 species) in well buffered side streams and filamentous zygnematophytceae / desmids (40 species) in the FEN pool.

Glacier influenced streams in the Rotmoos valley are extremely poor in species other than diatoms with few taxa of blue-green algae, chrysophytes and chlorophytes whereas the clear springs and spring streams are characterised by a mix of exclusive epilithic running water taxa (e.g. *Chamaesiphon fuscus*), algae typical for wet places, spray zones and seasonally wet habitats (e.g. *Gloeocapsa*-species). Diatoms were found to be large in species numbers in all stream types independent from glaciation with *Achnanthes minutissima* dominating quantitatively at almost all sites. Additionally a large proportion of arctic-alpine and (ultra –) oligotrophic representatives in the subdominant taxa characterizing the species spectrum. Nearly 30% of all algal taxa found are (ultra)-oligotraphentic, respectively oligo-mesotraphentic and 28% of all classified taxa based on the red list of algae for and Austria are critically endangered, strongly endangered, endangered or as extremely rare, most of them within the FEN area.

1. Introduction:

Investigations on phytobenthos in aquatic habitats of the alpine zone have already been carried out in isolated studies e.g. in Switzerland (MESSIKOMMER 1942) and in Sweden (SKUJA 1964). An intensification of research on algal assemblages of lakes and streams started 30 years ago with studies in the Pyrenees (BESCH et al. 1972, BACKHAUS 1976), a study of the taxonomy and ecology of all algal groups (KAWECKA 1980, 1981) across

*) Anschrift der Verfasser: Mag. Doris Gesierich, Dr. Eugen Rott, Universität Innsbruck, Institut für Botanik, AG Hydrobotanik, Sternwartestr. 15, A-6020 Innsbruck.

Europe (including Austrian mountain streams) and the taxonomic studies by KANN (1978) in lower altitude Alpine regions excluding glacial streams.

Whilst phytobenthos in mountain streams of the Alps came into the centre of interest in recent years (e.g. PIPP & ROTT 1993, ROTT et al. 2000, UEHLINGER 1991) natural reference situations in remote high alpine areas have rarely been studied (UEHLINGER et al. 1998, HIEBER et al. 2001). The only detailed investigation of springs in natural mountain areas covers mainly montane and subalpine sites (CANTONATI et al. 1996, CANTONATI 1998), with one study reviewing all information given on benthic algae in high altitude streams of the Alps until now (ROTT et al. in press). The underlying importance of long-term studies of springs and spring fed streams in remote areas for pointing out long-term ecological changes has been recently claimed by CANTONATI & ORTLER (1998).

High altitude streams in the Alps constitute extreme habitats affected by increased sunlight and ultraviolet radiation in summer, limited nutrient availability, low mineral content, long lasting winter covers and flow related mechanical stress. They comprise open unshaded channels which favour the growth of epilithic algae (diatoms, cyanophytes / cyanobacteria and chrysophytes) as the main primary producer with lichen, mosses and in addition higher plants in springs (WETZEL 1983, LAMBERTI 1996, CANTONATI & ORTLER 2003). Primary production and organic matter fluxes tend to be low with high seasonal variations (e.g. WARD 1994). The River Continuum Concept by VANNOTE et al. (1980) is not applicable to the situation found in these high alpine streams lacking riparian vegetation, that may however be comparable to the features of large open medium-sized streams. For Austrian running waters algal assemblages typical for alpine and mountain regions are regulated by a limited set of water quality criteria (e.g. pH, conductivity, alkalinity, nutrient level) and are related partly to the catchment characteristics (e.g. geology, altitude) (PIPP & ROTT 1993, ROTT 1991, ROTT et al. 1997, 1999).

The objective of the Biodiversity Project – BioDivAlp - for a 10 km^2 high-alpine catchment in the Rotmoos Valley in the central part of the Alps was to assess and monitor the microbial, botanical, and faunistic biodiversity of terrestrial and aquatic habitats.

The present investigation has a focus on phytobenthos in running waters and concerns mainly the following subjects: (1) to find out if phytobenthos communities in high alpine streams differ from mountain streams; (2) to show how glaciers affect the phytobenthos; (3) to investigate benthic algae within a small catchment to identify eventual differences in all the various habitats found from nature-near glacial and spring-fed streams to aquatic-terrestrial transition zones including the dominating mosses; (4) to see if there are rare and / or endangered taxa; (5) to find out the driving variables.

2. Earlier investigations within the area:

Although the Rotmoosache was subject of intensive limnological investigations including the aquatic insect community and the environmental conditions responsible for its distribution and its trophic relationship (FÜREDER et al. 1998, 2000, 2001), intensive investigations of algae from this stream are missing. Recently, BATTIN et al. (2001) investigated sediment biofilm of the Rotmoos glacial stream indicating the bacteria community structure changes are related to chlorophyll with increasing distance from the glacier.

Generally studies on algae in the Ötztal including the Rotmoos valley are very scattered. First records on microalgae from various small ponds and bogs in the Ötztal including the Rotmoos valley and sites nearby the Schönwieshütte are dating back to the last century by SCHMIDLE (1895, 1896). In recent years investigations by ETTL (1968, 1970) and LENZENWEGER (LENZENWEGER et al. 1997) revealed the species richness of these periodically dry habitats including the records of rare taxa (e.g. *Staurastrum gurgeliense* SCHMIDLE). Generally a high number of green filamentous algae, not only in stagnant but also in running waters in these peat bogs accompanied by various microalgae and desmids have been recorded (DALLA TORRE & SARNTHEIN 1901, ETTL 1968).

3. Description of the study area:

3.1. Catchment characteristics:

The Rotmoos Valley is situated within the UNESCO Biosphere Reserve "Gurgler Kamm" in the Austrian Central Alps, Ötztal, Tyrol (46°50'N, 11°03'E between 2280 and 2450 m a.s.l.; Fig. 1a). It is dominated by a glacier-fed stream, the Rotmoosache (a tributary to the Gurgler Ache), which is 4.5 km long and drains a watershed of 10.3 km^2, of which 4.1 km^2 are glaciated (see FÜREDER et al. 2001). The catchment geology consists of gneisses and micaschists. A marble stripe characterises the upper part of the catchment (BATTIN et al. 2001). The dominant substrate consists of boulders, rocks and large cobbles, the average water depth is 30 to 50 cm, and mean velocities at baseflow vary between 70 and 80 cm s^{-1} (June 1996). The mean gradient from the glacial snout to the lowest sampling station is 7.2 %. The highest peaks in the catchment are above 3000 m a.s.l.

The different sampling sites are all situated down to 4500 m distance from origin (Table 1). The glacial stream sampling area is characterized by a strong influence of the glacier ranging from 40 to 60% glaciation of the catchment. The measured pH values for the investigated streams are ranging from slightly acid to alkaline conditions (pH 5.8 – 8.4), conductivity revealed higher variations from 17 µS cm^{-1} in a spring-fed stream area originating from siliceous subcatchment to 200 µS cm^{-1} in a spring-fed stream area originating from carbonate subcatchment. Total phosphorus (TP) values in the catchment are normally low but show highest values during glacial ablation (316 µg PO_4-P l^{-1}) in the main glacial stream together with dissolved nitrogen (DN) values increasing up to 520 µg l^{-1}. Generally DN values range from 115 µg l^{-1} to 465 µg l^{-1} in the groundwater influenced streams, whereas TP values range from 2 to 40 µg l^{-1}.

3.2. Site characteristics:

The selection criteria for the sampling sites were on the one hand geology and glaciation within the catchment and on the other hand the intention to include low order streams, springs and an aquatic - terrestrial ecotone, most of these habitats had been more or less neglected in limnological studies so far. Besides two sites of the Rotmoosache itself nine side streams (4 spring-fed streams, 5 glacial streams) have been studied and given largely new names related to the origin of their catchment. Additional microhabitats were investigated in the fen area and in the Schönwies spring-fed stream (Fig. 1b). The sampling sites are all situated above the regional tree line. All glacier influenced streams are situated on the left side of the RM bank (except KKS) whereas the spring-fed stream sites are situated on the right side (except SWS).

The main glacier stream within the Rotmoos catchment, the Rotmoosache (RM), is characterised by high channel instability and high variability of side channel formations. The bedrock consists mainly of cobbles, gravel and smaller portions of silt and sand. The Eiskögeleweg Bach (EKS) is influenced by glacial flour with its bedrock characterised by boulders and cobbles and the Hangendersee Bach (HSS) is in its upper part characterised by a waterfall leading to significant pool / riffle systems with sandy patches at the foot of the slope. The Hangender Ferner Bach (HFS) and the cascading stream Seelenkogelbach (SKS) are both characterised by a steep slope, large boulders and cobbles, with seepage reaches and small side tributaries the latter with a slightly steeper gradient at the foot of the slope. The Liebener glacial stream (LGS) near the glacier mouth is strongly influenced by glacier, formed recently by glacier retreat.

The Schönwies spring-fed stream (SWS) with its spring-fed stream area (SWSa) has mostly clear water influenced by several seepage springs (over a length of 100 m). The stream is variable in its channel position, episodically branched including riffles and larger straight segments. The Mutbach (MUS) is in its upper part a cascade forming siliceous stream system with a steep slope and flows over larger boulders lower down. The catchment of the MUS is characterised by steep western slopes of the Mut and influenced by pasturage. The MUS itself is permanently flowing during summer time but it still remains unclear if it is perennial or temporary. The Schneebergzug (SBS) with its clear water cascading over small steps of old moraine material and large boulders originates from a slope foot spring and is characterised by multiple sequences of steep and shallow units. The bedrock of the Kirchkogelkarbach (KKS), originating in the Kirchkogelkar and running down a steep moraine slope, is characterised by boulders and cobbles / moraine material. The FEN area, an aquatic-terrestrial transition zone nearby the 1850's moraine, is characterised by low flowing velocity from percolating seepage springs leading partly to stagnant conditions in some small bogs (can dry out completely!) where temperatures are higher in summer. It was studied considering 5 different microhabitats (macroalgae, stream, moss, pool, sedge). The pool itself was sampled once in September when it appeared as a 6 m long, 1.0-1.5 m wide and 0.2-0.3 m deep pool with several seepage springs and a small spring-fed stream downstream the 1850's moraine presumably in contact to the sedge microhabitat (sedge tufts and 10-20 cm wide and 5-10 cm deep brownish water filled steps of grazing animals).

4. Materials and methods:

Field work was carried out in the years 2001/2002. Most sites were sampled during the time of maximum development of epilithic algal vegetation with little coverings of snow in higher altitudes in July 2001. More frequent sampling took place in the main glacial stream Rotmoosache and its side stream (2 times in early spring, 1 time in summer and autumn) and in some of the side streams (SWS, SBS, FEN area, MUS).

Physical and chemical variables of the streams were measured directly in the field (pH, conductivity, temperature) and in the laboratory, having sampled approx. 500 ml of water were filtered through pre-combusted (450°C) GF-C glasfibre filter membranes for analysis of dissolved nutrients. Dissolved nitrogen (DN) was determined with a CENCO auto-analyser device whereas Total phosphorus (TP) was obtained chromatographically by applying the protocol according to VOGLER (1965).

For investigation of macro- and microalgae (in field and lab) a first screening of large areas in the field with a focus on macroalgae cover and growth forms for a selected subsampling of periphyton was undertaken. The samples were obtained by rinsing the surfaces with a toothbrush and dispersing the material into small quantities of water (normally not more than 50 - 100 ml). In the lab a definite number of microscopic subsamples from the stones obtained with the tip of a razor blade

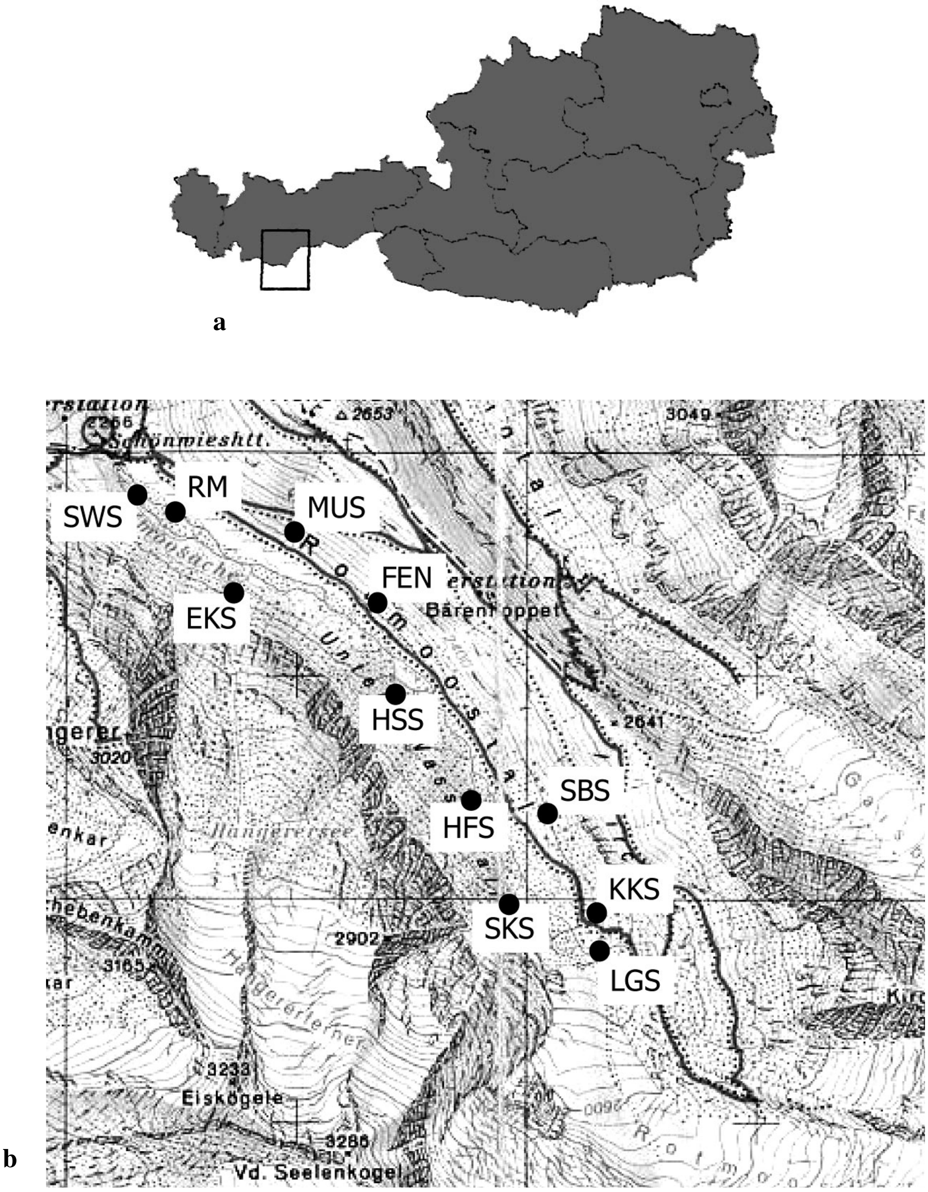


Fig. 1: **(a)** Position of the sampling area within Austria, (**b**) Position of the sampling sites within the Rotmoos catchment; EKS - Eiskögele Bach, FEN - Ecotone area, HFS - Hangender Ferner Bach, HSS - Hangendersee Bach, KKS - Kirchkogelbach, LGS - Liebener Bach, MUS - Mutbach, RM - Rotmoosache, SBS -Schneebergbach, SKS - Seelenkogelbach, SWS - Schönwies Bach.

or a knife was investigated to evaluate both macro- and microalgae of all taxonomic groups to the species level. Mixed washsamples, which were stored cool and dark, were used for diatom analysis (relative dominance). Cleaning process started immediately after return to the lab. For diatom analysis washsamples were centrifuged and cleaned by the hot concentrated peroxide method after a precleaning with weak hydrochloric acid when necessary. The final quality of the washsamples was checked by addition of few granula of potassium-bi-chromate and after final washing the samples were embedded into Naphrax diatom mount for species identification.

Identification of taxa to the generic and species level was undertaken using recent literature: Cyanophyceae: Geitler (1932), Komarek & Anagnostidis (1999) (Chroococcales), Komarek & Kovacik (1987) (*Homoeothrix*), Kann (1978); Chrysophyceae: Starmach (1985); Diatomophyceae: Krammer (1997ab, 2000), Krammer & Lange-Bertalot (1986, 1988, 1991ab); Lange-Bertalot (1993, 2001); Lange-Bertalot & Krammer (1989), Lange-Bertalot & Metzeltin (1996); Lange-Bertalot & Moser (1994); Reichardt (1997, 1999); Reichardt & Lange-Bertalot (1991); Chlorophyceae / Rhodophyceae / Dinophyceae / Xanthophyceae (for genus concept see John et al. (2003) and species Rott et al. (1999); Zygnematophyceae: Kadlubowska (1984) (filamentous Conjugatophyceae); Lenzenweger (1996, 1997a, 1999) (Desmidiaceae). For additional identification keys to genus level see John et al. (2003), Wehr & Sheath (2003). Taxonomic notes to the majority of running water species recorded from Austria are found in Rott et al. (1999). Mosses were identified to species level according to Frey et al. (1995).

The data were processed by numerical analysis. Similarities between samples and species were obtained by Twinspan (Hill 1979) based on presence / absence data only (pseudo-species cut levels 2). Due to the small number of samples only three division levels were considered.

5. Results:

5.1. The species spectrum of algae and mosses within the catchment:

In the Rotmoos catchment almost 280 phytobenthos taxa were identified (Table A1). Species numbers ranged from 124 in the FEN pool and 79 in the Schönwies spring-fed stream to 17 in the Liebener glacial stream formed recently by glacial retreat. The taxonomic groups most frequent and richest in species were diatoms (180 species), cyanophytes / cyanobacteria (48 species) and desmids (35 species). For diatoms the total number of taxa was highest in all FEN microhabitats (125 species) and in the main stream site of the Rotmoosache with the highest stream order 2 (63 species). *Achnanthes minutissima* was dominating the diatom species spectrum quantitatively at almost all sites. The dominating diatom genera in these high altitude sites were *Achnanthes*, *Cymbella* sensu lato, *Eunotia*, *Fragilaria*, *Gomphonema* and *Pinnularia* sensu lato. The chrysophytes *Hydrurus foetidus* and *Phaeodermatium rivulare* were the two most widely distributed non-diatom taxa in both glacial and spring-fed streams. Maximum species numbers of cyanophytes were found in the two spring-fed streams, SBS (18 species) and SWS (22 species). The dominating cyanophyte genera were *Homoeothrix* and *Chamaesiphon*. Zygnemales and desmids were mainly found in the FEN area close to the 1850's moraine (32 species). Moreover 10 species of mosses out of 7 genera were recorded at the spring area of SBS, at the source of the SBS and in parts of the FEN area (Table A2).

Table 1: Characterisation of the background conditions at 17 sampling sites in the Rotmoos valley; (nr.) - number of replicates; * - calcareous, n.d. – not determined.

				Water -conditions				
Description	**Abbrev. Site**	**Distance from origin [m]**	**Glaciation of catchment [%]**	**Temp.$_{Max}$ [°C]**	**pH**	**Cond. [µS cm^{-1}]**	**DN [µgN l^{-1}]**	**TP [µg l^{-1}]**
Rotmoos lotic stretch	RM lotic*	4500	40	7.0 (1)	7.7-8.0 (8)	49-169 (8)	230-520 (8)	1.5-315.7 (8)
Rotmoos Hydrurus microhabitat	RM Hydrurus*	4500	40	n.d.	n.d.	n.d.	n.d.	n.d.
Eiskögele Bach (glacial stream)	EKS	1400	40	10.6 (2)	6.2-8.6 (3)	35-47 (3)	n.d.	10.7 (1)
Hangendersee Bach (glacial stream)	HSS	1400	60	7.9 (2)	5.8-7.0 (3)	30-41 (3)	n.d.	39.6 (1)
Hangender Ferner Bach (glacial stream)	HFS	900	50	5.6 (2)	6.8-7.8 (2)	28-29 (2)	n.d.	n.d.
Seelenkogelbach (glacial stream)	SKS	950	50	4.1 (1)	7.8 (1)	26	n.d.	n.d.
Liebener Bach (glacial stream)	LGS*	0	60	6.2 (1)	7.8-8.1 (2)	90-118 (2)	n.d.	12.0 (1)
Schönwies Bach (spring stream)	SWS*	50	0	7.7 (2)	7.2-8.0 (4)	54-161 (4)	191-465 (3)	1.5-2.9 (3)
Schönwies Quelle (spring area)	SWSa*	0	0	2.4 (1)	7.0 (1)	44 (1)	333 (1)	2 .0 (1)
Mutbach (spring stream)	MUS	450	0	15.8 (2)	6.6-8.2 (4)	17-29 (4)	193-199 (2)	3.8 (2)
Schneebergbach (spring stream)	SBS*	20	0	12.5 (3)	8.1-8.3 (3)	162-200 (3)	275 (1)	6.7 (1)
Kirchkogelbach (spring stream)	KKS*	1350	0	9.1 (1)	7.8-8.1 (2)	97-113 (2)	n.d.	4.9 (1)
Fen pool	FEN pool	0	0	17.8 (1)	6.9-8.4 (3)	24-37 (3)	127-613 (2)	7.4-10.4 (2)
Charicetum fuscae	FEN sedge	0	0	17.8 (1)	6.9-8.4 (3)	24-37 (3)	127-613 (2)	7.4-10.4 (2)
Seepage spring stream	FEN stream	0	0	7.4 (1)	6.4-8.2 (5)	23-31 (5)	115-151 (2)	9.1-20.3 (4)
Fen moss	FEN moss	0	0	7.4 (1)	6.4-8.2 (5)	23-31 (5)	115-151 (2)	9.1-20.3 (4)
Zygnemales	FEN algae	0	0	n.d.	n.d.	n.d.	n.d.	n.d.

5.2. Ecological preferences of the species:

Trophic preferences were available for 55% of the benthic algae taxa (Table A1). Most species are oligotraphentic (9% ultra-oligotraphentic, 26% oligotraphentic, 21% oligo-mesotraphentic) and mesotraphentic (17%). 13% out of these were meso-eutraphentic, 6% eutraphentic, 6% eu-polytraphentic and 2% polytraphentic species (ROTT et al. 1999). On the account of conservation status based on the red list of algae for Germany (LANGE-BERTALOT 1996) and Austria (LENZENWEGER 1999a) 56% of the species found could be classified, 20% of them as critically endangered (1.5%) / strongly endangered (1.5%) / endangered (17%) or as extremely rare (2%), many found within the FEN area. 50% of the moss species found are either potentially endangered (*Scapania subalpina* and *S. uliginosa*, the dominating species of the so-called *Scapanietum uliginosae*-community) or (regionally) endangered (*Dicranella palustris*, *Philonotis seriata*, *Sphagnum recurvum* agg.) (Table A2).

Autecological notes are provided for species of the three dominant algal groups of diatoms (see Figs. PB3, PB4), cyanophytes / cyanobacteria (Fig. PB1) and desmids (Figs. PB5, PB6). Species either characteristic for a certain habitat or covering a wide range of sampling sites deserve special attention. Within the desmids, species which are strongly endangered or threatened according to the Red List are mentioned. Taxonomic notes are given for the blue-green algae *Tolypothrix penicillata* which is an interesting N_2-fixing component of oligotrophic aquatic habitats at high altitudes (Fig. PB2). Our material from MUS was so clearly interpretable that a detailed characterisation can be given.

Cyanophyceae

Ammatoidea normannii

A. normanni is scarcely distributed in oligotrophic waters and can be found on algae and stones in running or stagnant waters forming small dark brown, dense tufts of filaments (ROTT et al. 1999).

Calothrix fusca

C. fusca is distributed epilithic or epiphytic on various substrates most of all in mountain streams but also in lakes on plants and in the spray zone (KANN 1988).

Chamaesiphon polonicus

Ch. polonicus overgrows stones and boulders mostly on wet rocks and in mountain streams forming intensive red-brown coloured crusts and tolerating periods of desiccation with elongated spherical resting stages (ROTT et al. 1999).

Gloeocapsa dermochroa / Gloeocapsa sanguinea

Gloeocapsa species are epilithic taxa typical for the spray zone of streams with *G. dermochroa* occurring both in mountain streams and rocky lake shores (KANN 1988) and *G. sanguinea* preferring siliceous and carbonate rocks (ROTT et al. 1999).

Homoeothrix varians / Homoeothrix janthina

H. varians is a common and widely distributed species, likely to be found in mountain streams preferring calcareous rocks (PIPP & ROTT 1993), less frequent in fast flowing regions of larger rivers. *H. janthina* is a crenophilous species, more or less restricted to mountain streams, developing in masses in winter on granite rocks and other non calcareous rocks (ROTT et al. 1999, VANLANDINGHAM 1982).

Phormidium autumnale

The blue-green algae *Ph. autumnale* is a rheophilous form characteristic for alpine streams, developing skin-like blue-green or blue-black coatings on stones or sand and found even at higher flow velocities (ROTT et al. 1999).

Phormidium incrustatum

Ph. incrustatum occurs in springs, spring-fed streams, water cascades, streams and lakes in highly calcareous waters (ROTT et al. 1999).

Stigonema mamillosum

S. mamillosum occurs mainly on moist rocks together with *Gloeocapsa* species (ROTT et al. 1999).

Tolypothrix penicillata

It is attached in up to 1 cm long, heteropolar filamentous structures to more or less stationary rocky substrate (Figure PB2 A-J). Characterised by repeated dichotomous false branching it represents the fully heteropolar differentiated habitus of penicillate tufts (A). The filaments are 12–14 µm wide and they show (at least in younger segments) thin and tight, only scarcely lamellated sheaths. Trichomes are 8-10 µm wide and consist always – even in later stages of differentiation – of cells shorter than wide which in most cases are slightly constricted (torose) at the cross walls (H). The subapical meristematic portions of filaments stay isodiametric, consisting of short, discoid cells which are markedly constricted at the cross walls. The pigment-reduced endcell is longer and hemispherically rounded, respectively to some small extent even cupola-like vaulted (B). Although most of the branchings are tolypotrichoid and branches ± always deflect in sharp angles, no parallel running of new branches, resp. partitions with 2 or more trichomes in one sheath, could be observed. Heterocytes are represented rather frequently in the ecomorph studied and quite often occur in pair of a cluster of three in a line. They are most frequently placed at the base of tufts – "true basal" – (B, D) or "pseudobasal" at the deflection-point of tolypotrichoid (single) branchings (E, G, H, I). Additionally they can also be intercalary, for example as pairs of heterocytes (with oppositely arranged single-pores) which often are adjoined by two distally attached heterocytes thereby completing a row of four (F, I). Such type and arrangement of heterocytes (I) might be followed by formation of scytonematoid (double) false branching (F). Basal and pseudobasal heterocytes show most frequently spherical and hemi-spherical shape but can also be elongated cylindrical (B, D, E, G, H). The shape of intercalary heterocytes varies from spherical- to cylindrical (F, I, J). The inherent heteropolar aspect, for example the tuft-shaped habitus of these filamentous structures, as well as the isodiametric apical meristematic zones of these filaments topped off by rather inconspicuously rounded endcells, but also rich (true)basal as well as adaxial situated, double and triple heterocytes by all means commend assignment of this material to the species of

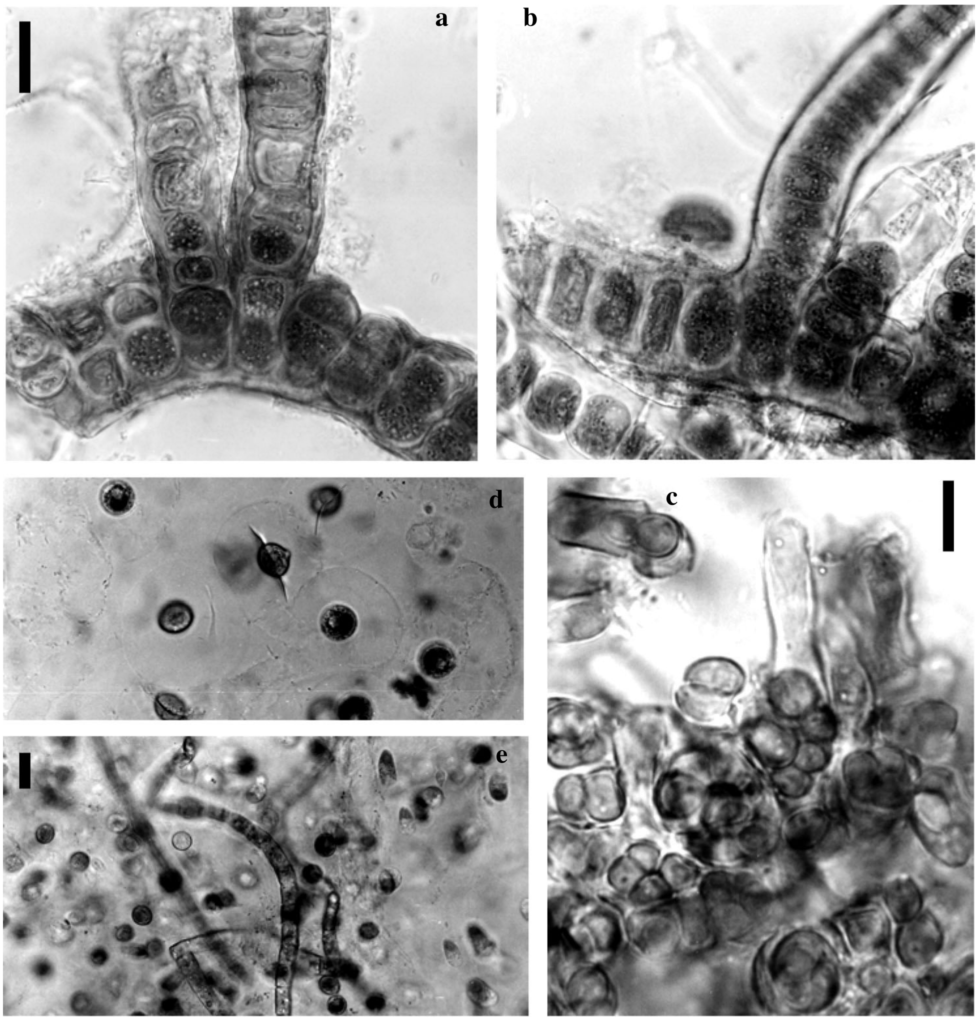
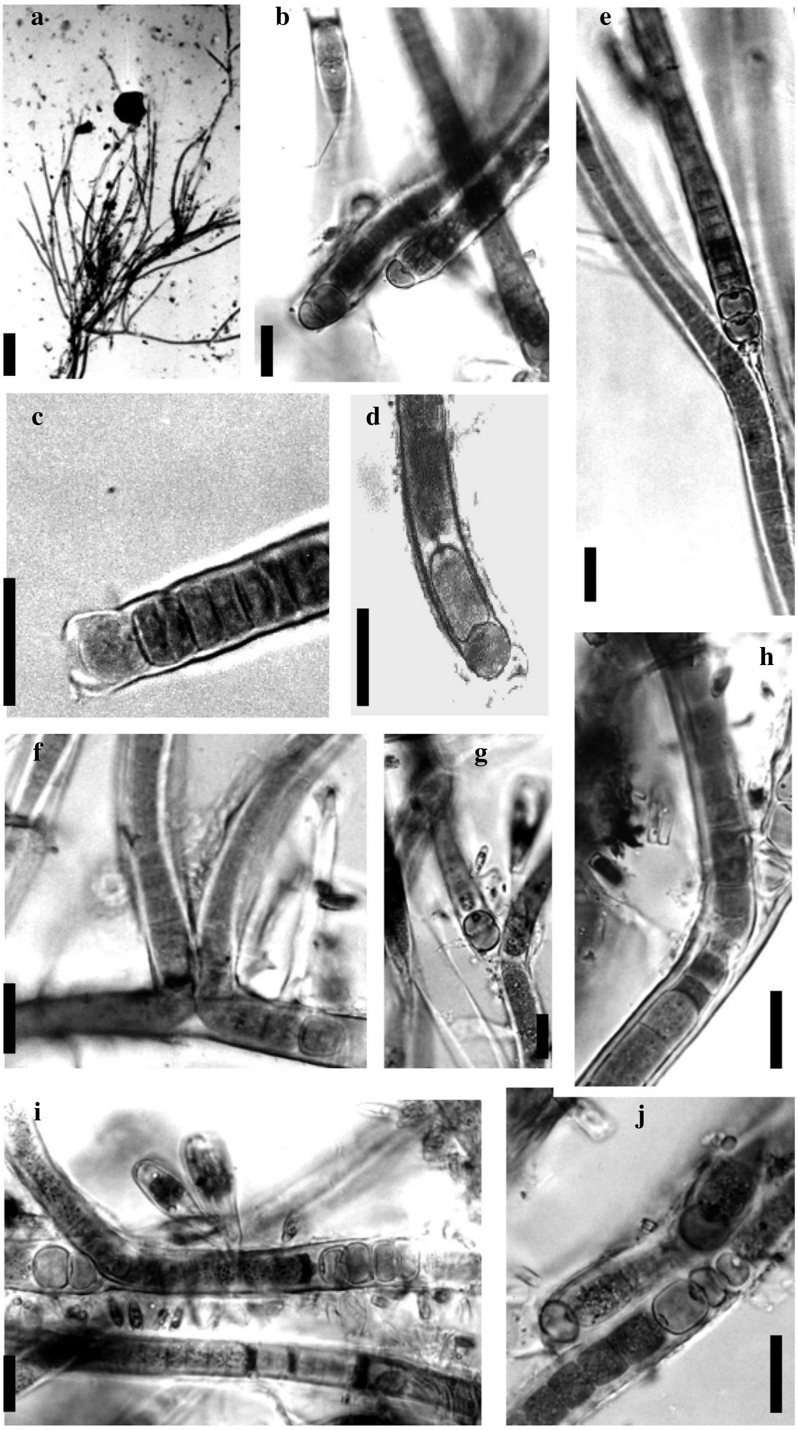


Fig. PB1: Cyanophytes / cyanobacteria and a chrysophyte from spring streams in the Rotmoos valley; **(a)**, **(b)** *Stigonema mamillosum*, **(a)** a biseriate filament with side branches, **(b)** a single seriate, true branched young filament, **(c)** *Siphononema polonicum* pleurocapsoid status from SBS, **(d)** *Hydrurus foetidus* irregular group of cysts enveloped in single mucilage and discoid structures, **(e)** *Hydrurus* vegetative aspect with epiphytes; **(a)**, **(b)**, **(d)** 400x, **(c)** 1000x Size bar 10µm, **(e)** 250x, Size bar 20 µm.

Fig. PB2: **(S. 17)** Morphological variations of the cyanophyte *Tolypothrix penicillata* found in MUS, **(a)** overview of tuft-like heteropolar structure with mainly single but one double branching, **(b-j)** microscopical details: **(b)** single and double basal heterocytes, **(c)** isodiametric apical meristematic zone with blown up endcell, **(d)** basal double-heterocyte – spherical and long cylindrical, **(e)** typical sharp-angled, tolypotrichoid branching with pseudo-basal double-heterocyte, **(f)** scytonematoid branching, **(g)** tolypotrichoid branching with pseudo-basal axial cells in the process of division and differentiation to double heterocyte, **(h)** tolypotrichoid branching with three pseudo-basal heterocytes in a row, **(i)** filament with a row of four intercalary heterocytes with intermediate double heterocyte (showing oppositely arranged pores) and followed by an axial, pseudo-basal, double-heterocyte, **(j)** intercalary double-heterocyte with oppositely arranged pores and adjoining newer and bigger heterocyte, subsequent vegetative cells are still meristematic and therefore torosely rounded, Size bars: A - 200µm, B-J 20µm.


a
b
e
c
d
h
f
g
i
j

T. penicillata (in the sense of GOLUBIC & KANN 1967), resp. to *T. distorta* var. *penicillata*. No branches running close to their original filaments for shorter or longer distance, or with two or more trichomes initially in one sheath could be observed. According to all descriptions this should be one of the main characteristic features of *T. penicillata*. On the contrary double and quadruple heterocytes with oppositely placed pores in intercalary position and scytonematoid (double) branchings are very specific to *T. distorta* (according to the comprehensive revision of this subject by GOLUBIC & KANN 1967). For a clear definition the seasonal variability of morphological features needs to be studied in future.

Diatomophyceae

Adlafia bryophila* / *Adlafia suchlandtii

Both species are aerophilous with *A. bryophila* occurring in wetted bryophytes and oligosaprobic water stretches (LANGE-BERTALOT 2001).

Diatoma mesodon

D. mesodon is one of the most common species in the spring areas of European mountain streams (SCHMITZ 1961) occurring in masses mostly in springs, troughs and running waters in mountain areas (KRAMMER & LANGE-BERTALOT 1991a).

Encyonema gaeumannii* / *Encyonema perpusillum

Both species prefer oligotrophic stretches of water, the former has its distribution in electrolyte poor nordic-alpine regions, the latter in acid waters with medium electrolyte content in the temperate to boreal zones (KRAMMER 1997b).

Encyonopsis falaisensis

E. falaisensis is a common species in the Alps and in the lowlands of the temperate and boreale zone preferring oligotrophic, oxygen rich biotopes, such as mountain streams and mosses (KRAMMER 1997b).

Eunotia bilunaris* / *Eunotia incisa* "*boreoalpina*" – Sippe / *Eunotia curtagrunowii

E. bilunaris is mostly epiphytic on senescent filamentous algae or phanerogams with an ecological focus on acid stagnant and flowing waters (bogs) with low electrolyte content, wetted mosses and trickled siliceous rocks. *E. incisa* and *E. curtagrunowii* both prefer electrolyte poor, acid and oligotrophic streams in mountain areas (KRAMMER & LANGE-BERTALOT 1991a, LANGE-BERTALOT & METZELTIN 1996).

Fragilaria arcus

F. arcus shows a preference for cold, oligotrophic fast flowing mountain streams or mosses with a preference for low nitrate values (KRAMMER & LANGE-BERTALOT 1991a, ROTT et al. 1999). It forms concentrations of cells in thalli of *Hydrurus foetidus* (RM *Hydrurus* site) (KAWECKA 1980).

Pinnularia subcapitata* var. *subrostrata

This species is widely distributed in oligotrophic, electrolyte poor stretches of water in the palae-arctic regions in Lapland (KRAMMER 2000).

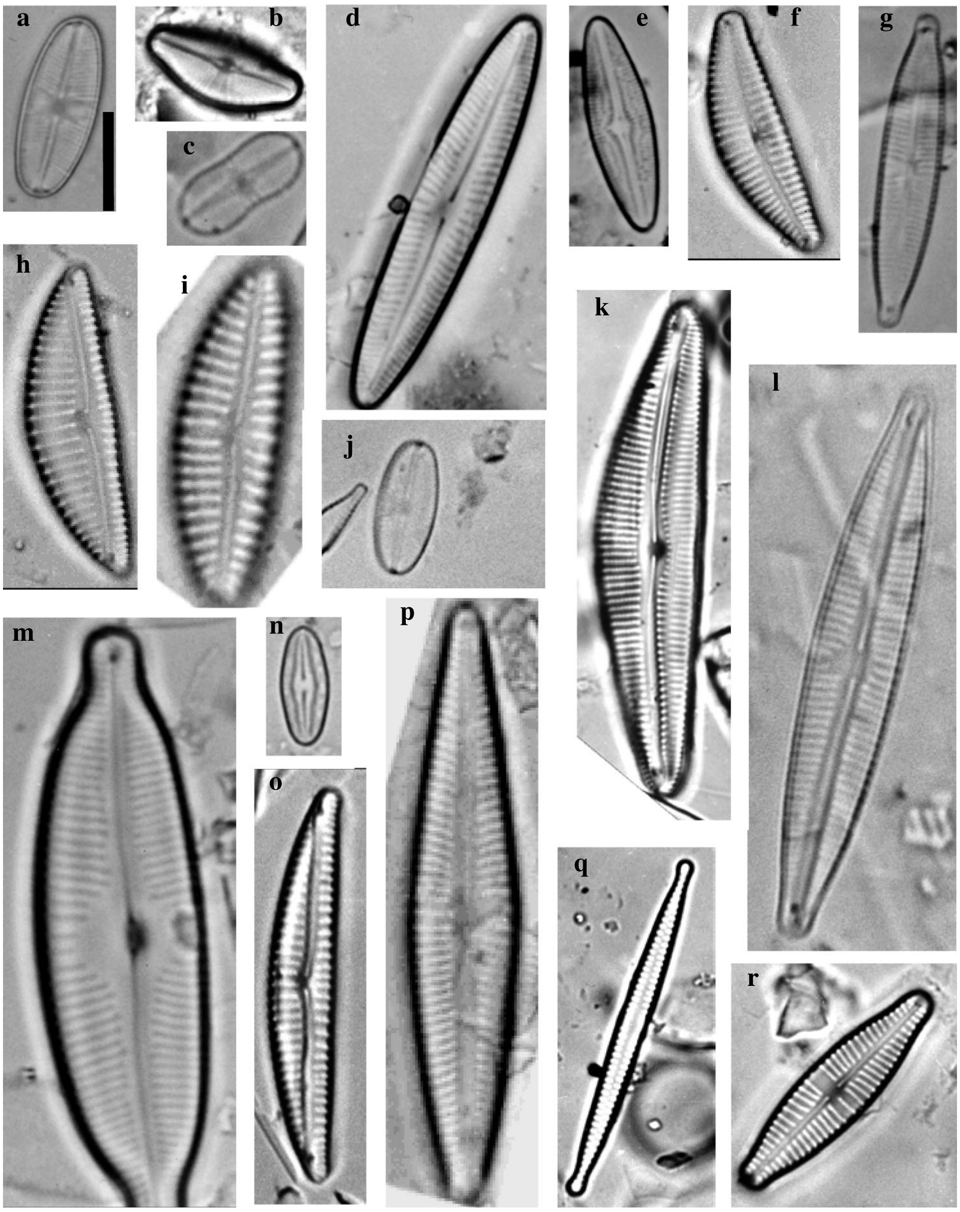


Fig. PB3: Typical diatoms from springs and streams in the Rotmoos valley 1, **(a)** Achnanthes bioretii, **(b)** *Achnanthes laevis*, **(c)** *Achnanthes didyma*, **(d)** *Cymbella subaequalis*, **(e)** *Brachysira brebissonii*, **(f)** *Cymbella affinis*, **(g)** *Encyonopsis falaisensis*, **(h)** *Cymbella silesiaca*, **(i)** *Encyonema alpinum*, **(j)** *Achnanthes scotica*, **(k)** *Cymbella helvetica*, **(l)** *Encyonopsis cesatii*, **(m)** *Cymbella naviculiformis*, **(n)** *Diadesmis gallica*, **(o)** *Encyonema neogracile*, **(p)** *Gomphonema angustum*, **(q)** *Fragilaria capucina* var. *austriaca*, **(r)** *Gomphonema micropus*; (Size bar 10µm).

Zygnematophyceae

Closterium striolatum

This species occurs in acid to neutral stretches of water and is characteristic for water filled steps of grazing animals (LENZENWEGER 1996).

Cosmarium impressulum* var. *alpicolum* / *C. speciosissimum* / *C. reniforme* var. *apertum

C. impressulum var. *alpicolum* basically and *C. speciosissimum* sporadically occurs in

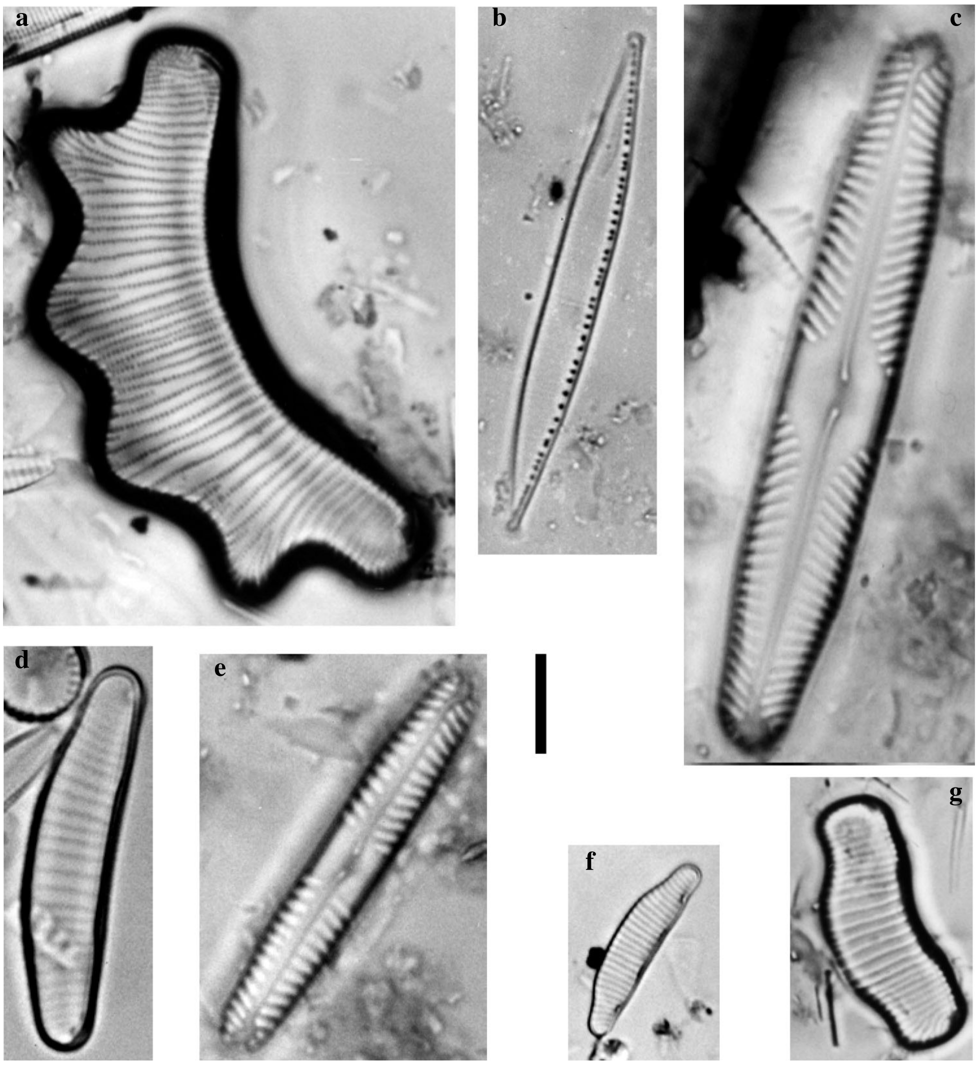


Fig. PB4: Typical diatoms from springs and streams in the Rotmoos valley 2, **(a)** *Eunotia tetraodon*, **(b)** *Nitzschia capitellata*, **(c)** *Pinnularia microstauron*, **(d)** *Eunotia bilunaris*, **(e)** *Eunotia incisa*, **(f)** *Pinnularia subcapitata* var. *subrostrata*, **(g)** *Pinnularia curtagrunowii* **(a-g)**; Size bar 10µm.

wetted sloping sites and alpine pools, the latter is only known from the Ötztal Alps for Austria. *C. reniforme* var. *apertum* is sporadically found in inner-alpine pools and the shorelines of lakes (LENZENWEGER 1999).

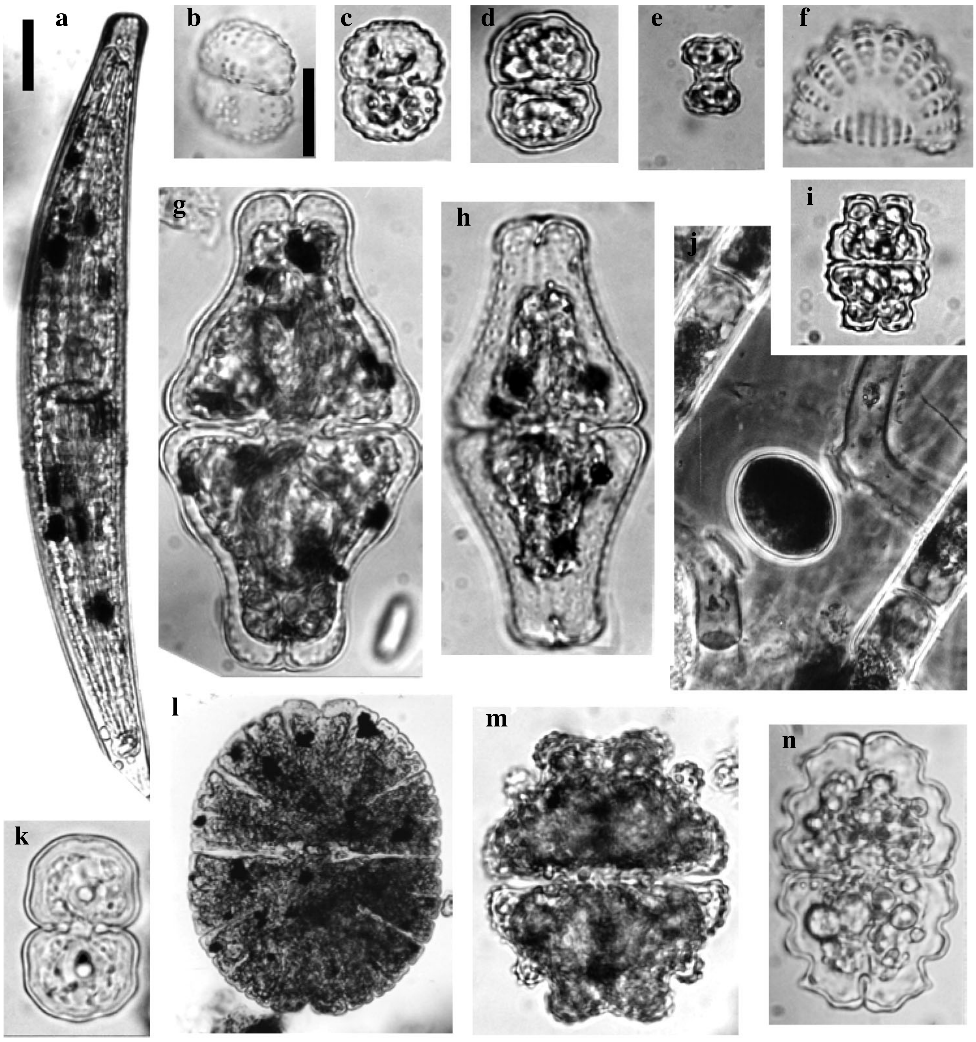


Fig. PB5: Unicellular desmids and filamentous zygnemalean from a fen area near the 1850's moraine in the Rotmoos valley. **(a)** *Closterium striolatum*,**(b)**, **(c)** *Cosmarium subcostatum* var. *minus*, **(d)** *Cosmarium impressulum* var. *alpicolum*, **(e)** *Cosmarium novae-semliae* var. *sibiricum*, **(f)** *Cosmarium speciosissimum*, **(g)** *Euastrum ansatum* var. *pyxidatum*, **(h)** *Euastrum ansatum*, **(i)** *Mougeotia ovalis* with zygospore, **(j)** *Euastrum denticulatum*, **(k)** *Cosmarium difficile*, **(l)** *Micrasterias denticulata*, **(m)** *Euastrum verrucosum* var. *alatum*, **(n)** *Euastrum bidentatum*; **(l)** 250x; **(a)**, **(i)**, **(m)** 400x, others 630x; Size bar each 20μm.

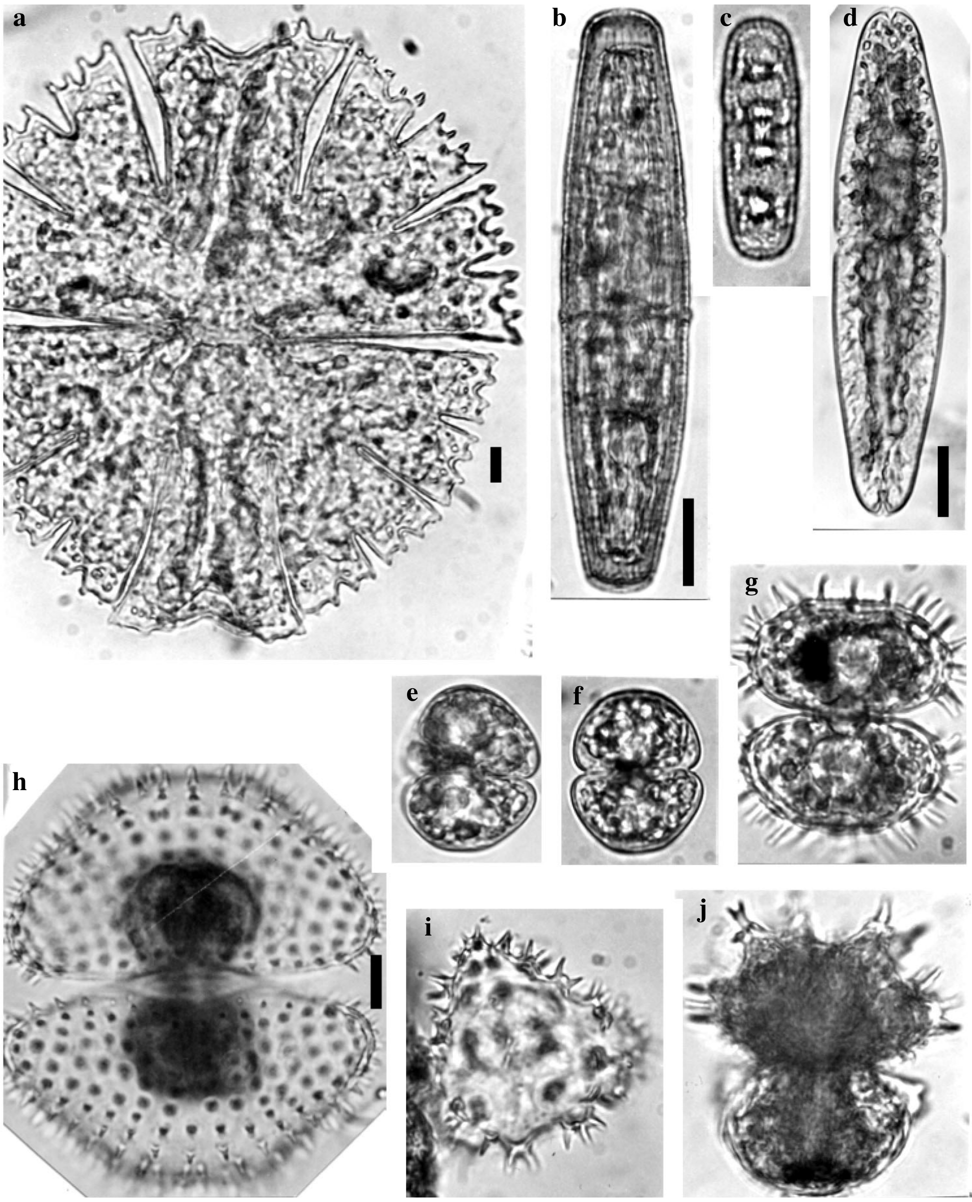


Fig. PB6: Desmids from the FEN pool. **(a)** *Micrasterias papillifera*, **(b)** *Penium spirostriolatum*, **(c)** *Penium cylindrus*, **(d)** *Tetmemorus granulatus*, **(e)**, **(f)** *Staurastrum orbiculare* var. *ralfsii*, **(g)** *Staurastrum teliferum*, **(h)** *Staurastrum pyramidatum*, **(i)**, **(j)** *Staurastrum monticulosum* in **(j)** apical view; **(a)** 250x, **(b-j)** 630x, except **(d)** 400x, Size bar 20µm; **(h)** 80x, Size bar 100µm.

Euastrum inerme / Euastrum bidentatum

E. inerme is a very rare species only reported from Carinthia (BECK-MANNAGETTA 1931) with not known environmental preferences, whereas *E. bidentatum* is an accompanying species of slightly acid bogs, alpine pools and wood pools but also neutral marshy meadows and wetted sloping sites (LENZENWEGER 1996).

Micrasterias denticulata / Micrasterias papillifera

Both species occur among several other moderately acid habitats in wetted sloping sites, *M. denticulata* tends to occur in lowland areas up to 1000 m in the Alps and *M. papillifera* is also found up to 2500 m (LENZENWEGER 1996).

Penium spirostriolatum

P. spirostriolatum is a common species in slightly acid bogs, alpine pools and fen areas up to 2000 m (LENZENWEGER 1996).

Staurastrum monticulosum / Staurastrum pyramidatum

S. monticulosum typical for slightly acid alpine fen areas and *S. pyramidatum* is rarely found in spring bogs, wetted slopes and fen pools in the Central Alps up to 2700 m (LENZENWEGER 1997a).

5.3. The grouping of samples according to TWINSPAN:

Data processing by TWINSPAN for the phytobenthos communities resulted in the following sample groups (Figure 2): on the highest division level the FEN area containing several species of Zygnemales and desmids accompanied by several diatom taxa from the genera *Pinnularia* (e.g. *P. borealis*), *Eunotia* (e.g. *E. exigua*, *E. incisa*) and *Cymbella* sensu lato (e.g. *Encyonema perpusilla*, *E. gaeumannii*) is separated from the others (see Table A1). On the second division level the main glacier stream RM was separated, characterised by several species of the genera *Achnanthes* (e.g. *A. laevis*, *A. bioretii*, *A. biasolettiana*) and *Cymbella* sensu lato (e.g. *Encyonema fogedii*) together with *Gomphonema* species (e.g. *G. angustum*). Finally, on the third division level, the samples from the spring-fed streams (mainly calcareous substrates) are distinguished from the glacial side-streams with low buffering capacity and of siliceous origin. Both are characterised by small amounts of the diatom Diadesmis gallica with the spring-fed streams dominated by several blue-green taxa from the genera *Homoeothrix* (e.g. *H. janthina*, *H. gracilis*), *Chamaesiphon* (e.g. *Ch. fuscus*, *Ch. polonicus*), some *Gloeocapsa* - species (e.g. *G. alpina*) and small amounts of *Siphononema polonicum* accompanied by several diatom taxa, none of them in higher abundances. Within the glacial streams there are several taxa of the genera *Pinnularia* (e.g. *P. submicrostauron*, *P. acidoclinata*) and *Encyonema* (e.g. *E. caespitosa*, *E. minutum*) found.

5.4. The species dominance for the site groups:

A) Glacial streams

Most of the glacial streams in the Rotmoos valley are extremely poor in species other than diatoms with few taxa of blue-green algae (11), chrysophytes (2) and chlorophytes (1)

(Table A1). The running water stretches are characterised by fast-growing, thin covers of microalgae (*Phaeodermatium rivulare*, diatoms) occurring all year round, mostly in the main stream of the Rotmoosache but also in several side streams together with the chrysophyte *Hydrurus foetidus* (Table 3). The diatom communities show high species numbers although the majority of taxa do not occur in large numbers. *Achnanthes minutissima* is the first quantitatively dominating species together with *Diatoma mesodon* (except the Rotmoosache) and *Fragilaria arcus* in the majority of glacial streams (Table 2).

Rotmoosache (RM)

The chrysophyte *Hydrurus foetidus* is the only macroalga present forming dense dark brown mucilagineous patches either in the main stream and / or the side channels, during a restricted spatio-temporal window in early spring (April) when the first winter cover openings appear (ROTT et al., in press.). The only other algae (except diatoms) found almost all year round was *Phaeodermatium rivulare*. It formed light brown covers with different diatom taxa, wherein *Achnanthes minutissima* is clearly dominating. *Fragilaria arcus* is

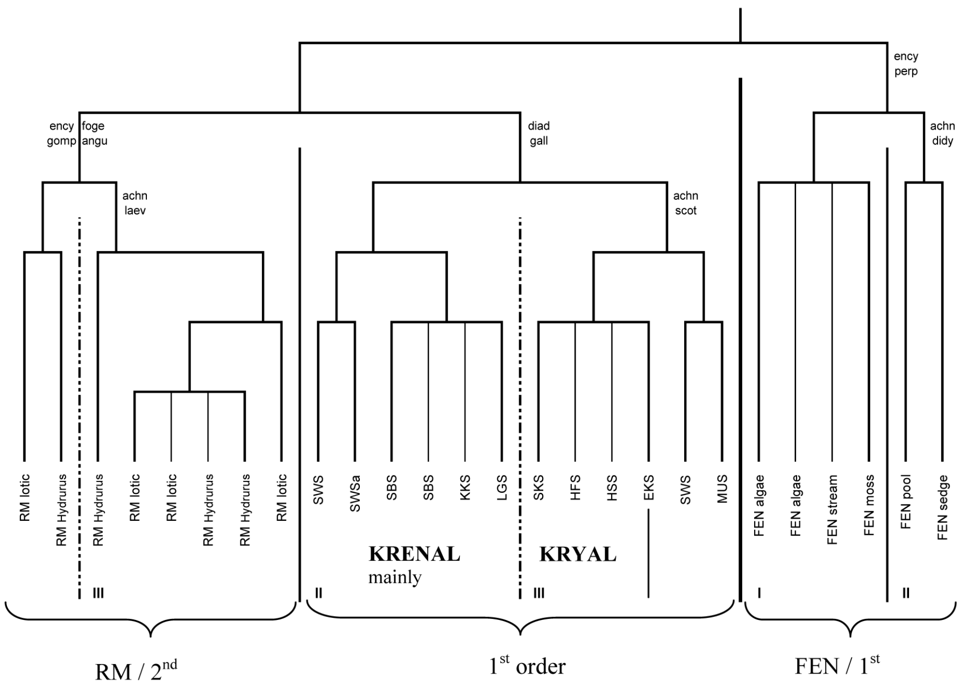


Fig. 2: Grouping of samples according to TWINSPAN for all habitats and all algae (presence/absence), the indicator species are shown at each division: ency foge – *Encyonema fogediana*, gomp angu – *Gomphonema angustum*, achn laev – *Achnanthes laevis*, diad gall – *Diadesmis gallica* var. *perpusilla*, achn scot – *Achnanthes scotica*, ency perp – *Encyonema perpusilla*, achn didy – *Achnanthes didyma*.

widely distributed, numerous and most densely associated to *Hydrurus* within the glacier streams accompanied by *Diatoma mesodon*, typical for spring-fed streams.

Eiskögeleweg Bach (EKS)

Generally a low number of taxa (29) can be recorded. The nitrogen fixing *Tolypothrix penicillata*, a typical component of soft water spring-fed streams (although it can also be found in mountain lakes) is distributed in small amounts together with *Phaeodermatium rivulare*. Within the diatoms the genus richest in taxa is *Achnanthes* (7) with a slightly higher frequency of *A. scotica*, an oligotraphentic species.

Hangender-See Bach (HSS)

On the whole 41 algal taxa could be recorded with the filamentous green alga *Microspora* sp. occurring macroscopically. Besides the blue-green algae *Calothrix fusca* and *Chamaesiphon incrustans* diatoms were dominating the species spectrum with the genera *Cymbella* / *Encyonema* (8) and *Achnanthes* (6) richest in taxa.

Hangender Ferner Bach (HFS)

It hosts the highest number of taxa within the glacier streams (except RM) (56) with diatoms (48) dominating accompanied by several blue-green algae (7). Macroscopically the chrysophyte *Hydrurus foetidus* can be found. The microscopic aspect is formed by several blue-green epilithic taxa typical for the spray zone of streams like *Gloeocapsa sanguinea*, *Chamaesiphon polonicus* and *Homoeothrix fusca* together with diatoms. Within the diatoms the genera *Achnanthes* (8), *Cymbella* / *Encyonema* (8) and *Fragilaria* (6) were richest in taxa.

Seelenkogelbach (SKS)

It is characterised by a low number of taxa (29) and the scarce occurrence of the blue-green algae *Phormidium autumnale*, a lithorheophilous form and *Phaeodermatium rivulare*. Microscopically only diatoms occurred with the genus *Achnanthes* (6) richest in taxa.

Liebener glacial stream (LGS)

It is characterised by the lowest number of taxa found (17) with only 3 taxa other than diatoms with the two blue-green taxa *Homoeothrix varians* and *Hydrococcus rivularis* typical for mountain streams (ROTT et al. 1999).

B) Spring-fed streams

These clear spring-fed streams are characterised by a mix of exclusive epilithic running water taxa (*Chamaesiphon* – *Homoeothrix* association), algae typical for wet places, spray zones and seasonally wet habitats (e.g. *Diadesmis gallica*, *Gloeocapsa* species) accompanied by several mosses and clear water lichens close to the emerging zone (Table A1, A2). Additionally larger colonies of the N_2-fixers *Nostoc* sp. and *Tolypothrix penicillata* typical for nutrient poor soft water streams occurred (Table 3). Within the diatoms *Achnanthes minutissima* is dominating the species spectrum at all sites, together with species preferring fast flowing mountain streams (e.g. *Fragilaria arcus*) and typical forms from spring-fed streams (e.g. *Diatoma mesodon*) (Table 2).

Schönwies spring-fed stream (SWS) and spring-fed stream area (SWSa)

The spring-fed stream itself shows highest taxa numbers (except the fen area) with 29 non-diatom taxa and with several Zygnemales species (*Spirogyra* sp., *Mougeotia* sp., *Zygnema* sp.) visible to the naked eye. The blue-green algae are dominated mainly by exclusive epilithic running water taxa such as the cyanophytes / cyanobacteria *Phormidium autumnale* and *Clastidium setigerum* accompanied by *Homoeothrix varians* / *H. gracilis*, several *Chamaesiphon* and *Gloeocapsa* species. As regards the diatoms (50), the great majority of species occurs with single specimens, with the genera *Fragilaria* (10) and *Achnanthes* (9) being the most species rich.

The spring-fed stream area is characterised by the mosses *Drepanocladus* sp. and *Philonotis seriata*. The algal flora comprising 6 diatom taxa and 15 other algae is dominated by macroscopic aspects of the Zygnemales *Spirogyra* sp. (green), the chrysophyte *Chrysocapsa* sp. (mucilaginous brown), the xanthophyte *Vaucheria* sp. (few filaments in moss) and the blue-green *Tolypothrix penicillata*, typical for nutrient poor soft water streams frequent in occurrence as well as the larger colonies of the N_2-fixer *Nostoc* sp. Within

Table 2: Common diatom taxa from 17 sites in the Rotmoos valley and their frequency; (all algae with frequent / dominant occurrence at least at one site and/or with rare occurrence at least at 8 sampling sites); dominant – black square, frequent – dark grey square, rare – light grey square; Trophic value – TW (after Rott et al. 1999): ultra-oligotraphentic all values < 0.5, oligotraphentic 0.6 - 1.0, oligo - mesotraphentic 1.1 - 1.5, mesotraphentic 1.6 - 2.0; meso - eutraphentic 2.1 – 2.5; (for abbreviations of sites see Table 1).

	GLACIER STREAMS							SPRING STREAMS					FEN					
	RM lotic	RM Hydrurus	EKS	HSS	HFS	SKS	LGS	SWS	SWSa	MUS	SBS	KKS	FEN stream	FEN pool	FEN algae	FEN moss	FEN sedge	TW
Diatomophyceae																		
Achnanthes minutissima Kützing	F	D	F	F	F	F	D	D	D	F	F	D	F	R	R	R	R	1.2*
Diatoma mesodon (Ehrenb.) Kützing	R	R	F	F	F	F	F	R	F	F	R	F	R			R	R	0.7*
Achnanthes helvetica (Hust.) Lange-Bert.	R	R	R	R	R	R		R		R		R	R	R	R	R	R	0.6*
Encyonopsis falaisensis (Grun.) Krammer	R	R		R	R	R	R			R	R		R	R	R	R	R	0.4*
Fragilaria arcus (Ehrenb.) Cleve	R	F	R	R	R	R	R	R		R	R	F	R					1.0*
Cymbella subaequalis Grun.	R	R			R			R	R	R	R		R	R	R	R	R	1.0
Encyonema silesiacum (Bleisch in Rabenh.) D.G. Mann	R	R					R	R		R	R	R	R	R	R	R	R	2.0
Fragilaria gracilis - Sippen	R	R	R		R			R		R	R		R	R	R	R	R	n.d.
Diadesmis gallica var. *perpusilla* (Grun.) Lange-Bert.			R	R	R	F		R		R	F	R	R		R	R	R	1.2
Nitzschia perminuta (Grun.) M.Peragallo	R	R		R				R			R	R	R	F	R	R	R	2.3
Tabellaria flocculosa (Roth) Kützing	R	R		R	R			R				R	R	R	R	R	R	0.8*
Eunotia exigua (Breb.) Rabenh.	R	R	R	R	R					R			R	R	R	R	R	0.5*
Brachysira brebisonii Ross	R	R		R	R			R					R	R	F	R	R	1.1
Achnanthes scotica Flower & Jones			R	F	R	R		R		R			R		F	R	R	n.d.
Achnanthes laevis Oestrup	R	R	R		R	R	R	R		R	R				R			1.2
Achnanthes petersenii Hustedt	R	R		R		R	R	R	R	R	R						R	0.6
Denticula tenuis Kützing	R	R		R	R	R		R					R	R		R		1.4*
Encyonema minutum (Hilse in Rabenh.) D.G. Mann	R	R	R	R	R	R	R	R				R	R					2.0*
Eunotia incisa "*boreoalpina* " - Sippe	R	R	R			R				R			R	R	R	R	R	n.d.
Fragilaria capucina var. *austriaca* (Grun.) Lange-Bert.		R		R	R		R	R		R	R		R	R		R		0.5*
Frustulia saxonica Rabenh.			R	R	R	R				R			R	R	R	R	R	0.4
Adlafia bryophila (Petersen) Lange-Bert.	R	R			R					R			R	R	F	R	R	1.3
Fragilaria pinnata Ehrenb.	R	R		R	R			R			F			R			R	2.2*
Gomphonema tergestinum Fricke		R	R	R	R	R	R				F	R						1.4*
Adlafia suchlandtii (Hust.) Lange-Bert.			R					R			R		R	R	F	R	R	0.6
Reimeria sinuata (Gregory) Kociolek & Stoermer	R	R		R	R	R		R		R		R						2.1*
Achnanthes biasolettiana Grun.	R	R	R		R					R			R	R			R	1.3*
Gomphonema micropus Kützing	R	R	R	R	R	R					R	R						2.0
Brachysira neoexilis Lange-Bert.	R				R	R		R					R	R	R	R		1.2
Caloneis tenuis (Gregory) Krammer		R								R	R		R	R	R	R	R	1.1
Nitzschia hantzschiana Rabenh.				R		R		R			R			R	R	R	R	2.0
Pinnularia obscura Krasske					R	R		R					R	R	R	R	R	2.0
Gomphonema parvulius (Lange-Bert. & Reich.) Lange-Bert. & Reich.			R		R	R				R			R	R		R	R	n.d.
Navicula exilis Kützing			R	R	R					R	R			R		R	R	2.0
Total number of Diatoms	63	61	27	38	48	27	14	50	6	41	46	19	68	89	57	60	65	

the diatoms *Achnanthes altaica*, an oligotraphentic species and *Cymbella subaequalis*, preferring oxygen rich biotopes occurred in slightly higher abundances.

Mutbach (MUS)

The stream, characterised by 41 diatom species and 12 other algal taxa, showed small tufts of the blue-green *Tolypothrix penicillata* and small quantities of several epilithic running water taxa such as *Phormidium autumnale*, *Clastidium setigerum* and *Chamaesiphon polonicus* together with *Homoeothrix janthina*. The diatom species composition is characterised by slightly higher abundances of *Diatoma mesodon* and *Fragilaria gracilis* - Sippen the first one typical for springs and mountain streams the second one characteristic for oligosaprobic waters. The great majority of other species appears within the genera *Achnanthes* (9) and *Fragilaria* (6).

Schneebergzug (SBS)

The upper emerging zone is entirely covered by the mosses *Cratoneuron commutatum* and *Drepanocladus exannulatus* (var. *rotae*) (Table A2).

In the fast flowing section stones are covered with a very thin algal cover revealing a rich microscopic flora characterised by the blue-green algae *Calothrix fusca*, *Ammatoidea normanii* and *Homoeothrix gracilis* together with several running water taxa (e.g. *Homoeothrix varians*, *Chamaesiphon polonicus*, *Ch. fuscus*, *Phormidium incrustatum*). In addition few millimetre large colonies of the N_2-fixers *Nostoc* sp. were recorded. Within the diatoms the oligotraphentic *Diadesmis gallica* var. *perpusilla* is worthy of note accompanied by *Gomphonema tergestinum* and *Fragilaria pinnata*. The genus *Cymbella* / *Encyonema* (8) was richest in taxa.

Kirchkogelkarbach (KKS)

The investigation on this stream shows 19 diatom taxa and 18 other algae. Macroscopically it was characterised by brown covers of mainly *Phaeodermatium rivulare* accompanied by *Hydrurus foetidus*. The main blue-green algae are *Phormidium autumnale* and *Gloeocapsa alpina*, which is a sign for water level fluctuations. Additionally typical running water species occur, e.g. *Homoeothrix varians* and *Chamaesiphon polonicus*. Within the diatoms *Fragilaria arcus*, preferring fast flowing streams, *Diatoma mesodon* preferring springs together with *Encyonema minutum* and *Cymbella sinuata* show slightly higher abundances.

C) FEN area

Several Zygnematophyceae (e.g. *Mougeotia ovalis*, *Spirogyra* sp.) and green algae (e.g. *Oeodogonium* sp., *Microspora* sp.) differentiate the shallow, partially wetted parts of this habitat macroscopically from the glacial and spring-fed streams. However the running water site of the FEN area is in contrast to the other microhabitats characterised by typical running water forms, such as *Chamaesiphon polonicus*, *Clastidium setigerum* and *Homoeothrix varians*.

Within the more stagnant FEN microhabitats the cyanophyceae *Stigonema mamillo-*

sum forming brownish black covers on wet stones could be found associated with *Ammatoidea normannii* and two different *Gloeocapsa* species. *Aphanothece stagnina* and *Chroococcus* sp. representing species living on soft mud, on damp earth or on damp rocks also occurred. The chlorophyceae species *Haematococcus pluvialis*, *Oocystis solitaria* and *Pediastrum tetras* particularly found in lentic waters, small freshwater lakes and ponds, the latter also in nutrient rich freshwaters were restricted to this habitats. Among the remarkably large number of desmids there are several species characteristic for moderately acid habitats (e.g. *Euastrum bidentatum*) and several diatoms of the genus *Eunotia*. In addition aerophilous species such as *Adlafia bryophila*, *A. suchlandtii* and *Pinnularia obscura* occur in all fen microhabitats together with species of the genera *Cymbella* / *Encyonema* (18) (e.g. *E. gaeumannii*), *Achnanthes* (15) (e.g. *A. altaica*) and *Pinnularia* (13) (e.g. *P. subcapitata* var. *subrostrata*).

Concerning moss species found within the fen area *Scapania* sp. dominated at the spring mouth, *Philonotis seriata* in a secondary spring and *Dicranella palustris* in sedge stands (*Carex* sp.).

Table 3: Benthic algae except diatoms from 17 sites in the Rotmoos valley and their frequency (all algae with frequent / dominant occurrence at least at one site and/or with rare occurrence at least at 4 sampling sites); dominant – black square, frequent – dark grey square, rare – light grey square; Trophic value – TW (after Rott et al. 1999): ultra - oligotraphentic all values < 0.5, oligotraphentic 0.6 - 1.0, oligo - mesotraphentic 1.1 - 1.5, mesotraphentic 1.6 - 2.0; (for abbreviations of sites see Table 1).

	RM lotic	RM Hydrurus	EKS	HSS	HFS	SKS	LGS	SWS	SWSa	MUS	SBS	KKS	FEN stream	FEN pool	FEN algae	FEN moss	FEN sedge	TW
Cyanobacteria / Cyanophytes																		
Homoeothrix varians Geitler		R			R		R	R	R		R	R	R					1.4*
Tolypothrix penicillata Thuret **(M)**			R						R	F	R			R	R		R	0.6
Chamaesiphon polonicus (Rostaf.) Hansgirg					R			R	R	R	R	R	R					1.2*
Phormidium autumnale Agardh ex Gomont **(M)**						R		R	R	R	R	R		R				1.7*
Calothrix fusca Bornet et Flahault				R						R	F	R	R					1.2
Nostoc sp. **(M)**									R		F	R		R				n.d.
Ammatoidea normanni W. & G.S. West **(M)**					R						F	R	R					1.2
Chamaesiphon minutus (Rostaf.) Lemmermann		R						R	R		R							0.6*
Chamaesiphon fuscus (Rostaf.) Hansg. **(M)**								R	R		R	R						0.7*
Gloeocapsa alpina Näg. em. Brand								R			R	R			R			0.6
Clastidium setigerum Kirchner (M)								R		R	R	R	R					0.4*
Homoeothrix gracilis (Hansg.) Komarek & Kovacik								R			F	R						0.8*
Chrysophyceae																		
Phaeodermatium rivulare Hansgirg **(M)**	D	F	R			R	R	F	R	R	R	D						1.8*
Hydrurus foetidus (Vill.) Trevisan **(M)**	D	D			R			F				F						1.3*
Chrysocapsa sp. **(M)**									F									n.d.
Chlorophyceae																		
Oedogonium sp. **(M)**								R		R			R		R			n.d.
Zygnematophyceae																		
Zygnema sp. **(M)**								R	R				D		D	D		n.d.
Mougeotia sp. **(M)**								R					R		F			n.d.
Spirogyra sp. **(M)**								R	F							F		n.d.
Total number of 'Non Diatoms'	**2**	**4**	**2**	**3**	**8**	**2**	**3**	**29**	**15**	**12**	**26**	**18**	**11**	**35**	**17**	**5**	**10**	
	GLACIER STREAMS							SPRING STREAMS					FEN					

6. Discussion:

With almost 280 species found the total biodiversity of benthic algae found in this small high alpine catchment (10 km²) is high compared to a recent study on the taxonomic composition of benthic algae in the Roseg River (Switzerland) carried out in 5 different channel types in the floodplain with 60 algal taxa recorded (BÜRGI et al. 2003). This seems to be a consequence of the large variability of investigated sites within the Rotmoos valley (glacial streams, springs and wetlands), but when regarding the running water stretches only almost 169 species are present. Secondly it could be due to compound sampling and to lower taxonomic resolution in the Roseg River study. Above all the total species number comprises about 30% of the 1000 species found within a study of 1100 sites of more than 200 rivers in Austria (ROTT et al. 1997, 1999). Since no corresponding study of a whole catchment has been carried out until now, a comparison with epilithic diatom assemblages from 40 sites in high mountain streams (20 were located in the Southern Alps - Natural Parks of Trentino, Italy and 20 in the Himalaya - northwest India, Nepal) indicated nearly the same number of diatom taxa found with 16% of the Rotmoos taxa corresponding to the most frequent and abundant diatoms there (CANTONATI et al. 2001).

When considering former investigations of the main glacial stream Rotmoosache in September 1974 (KAWECKA 1980) with 24 taxa recorded, the number of taxa in the present study was fairly high (65), due to 4 intensively investigated sampling dates during all seasons and the attention to rare taxa and patch specific sampling. In the course of a study on 19 high altitude streams in the glaciated Central Alps in Osttirol with a glaciation of 10% to more than 30% (PFISTER 1989) a similar species composition can be found, with 50% of the species occurring within the running water stretches of the present study. A high number of epilithic blue-green taxa (e.g. *Chamaesiphon fuscus*, *Homoeothrix janthina*, *H. varians*) were found in almost all sites, most of them known from mountain streams (KANN 1978, PFISTER 1992, PIPP & ROTT 1993, ROTT et al. 1999, ROTT et al. in press), accompanied by diatoms which is typical for benthic algae communities in high altitude streams (ROTT et al. in press) and the chrysophytes *Hydrurus foetidus* and *Phaeodermatium rivulare*.

The highly diverse FEN area is a special habitat with different kinds of biotopes as for example shallow parts desiccating in some parts of the year and characterised by macroscopic visible mats of filamentous Zygnemales in association with typical representatives of wet rocks (e.g. *Stigonema mamillosum*) and a large number of desmids and diatoms. About 50% of the desmid taxa occurring have a distribution range up to 2000 and 2500 m in Alpine regions (e.g. *Cosmarium difficile*). This corresponds to a supposed differentiation of algal vegetation with an increase in arctic-alpine species in altitudes above 2300 - 2400 m regulated by light and temperature (LENZENWEGER 1997b). In addition about 25% of these desmid taxa (e.g. *Closterium striolatum*, *Micrasterias papillifera*) correspond to investigations on small pools, shallow stagnant watercourses and wetted slopes of the Glocknergruppe in the inner valley of Fusch (Salzburg, Austria) at 2100 m altitude (LENZENWEGER 1997b). Regarding the diatom species composition 64% of the species found in the FEN habitats are restricted to this area, amongst them *Encyonema perpusilla*, *Eunotia bilunaris* and *Gomphonema hebridense* distributed in all microhabitats and characteristic of electrolyte poor waters.

In addition to benthic algae, mosses were found as primary producers in two spring-fed streams and in the spring-fed stream area of the FEN, in agreement with situations described by Cantonati & Ortler (2003). The amphibic zone of the calcareous SBS is entirely covered by *Cratoneuron commutatum*, a common and widely distributed tuft building species often found in mass development in calcareous springs, occurring together with *Drepanocladus exannulatus* (var. *rotae*). Parts of the FEN area are characterised by mosses and clear water lichens. *Scapania subalpina*, a circumboreal - montane species found on moist and wet earth, and *S. uliginosa*, an arctic-alpine species avoiding calcareous habitats (Frey et al. 1995), and both potentially endangered in the perialpine area, are the dominating species within the FEN. These are accompanied by *Dicranella palustris*, distributed on wet sandy substrate along rivers, ditches and springs in higher altitudes in the Alps and *Sphagnum recurvum* agg. found in bogs, are both (regionally) endangered species. In addition *Philonotis seriata* is occurring, common along ditches and springs in mountain areas of Scandinavia and Scotland and in Middle Europe mostly above 1000 m.

Trophic preferences were available for nearly 55% of the benthic algae taxa, out of them 56% indicate (ultra)-oligotraphentic, respectively oligo-mesotraphentic conditions comparable to the Southern Alps were 80% of diatom taxa only could be classified, amongst them 54% indicating oligo-, oligo-mesotraphentic conditions. When considering the conservation status of algae based on the Red List for Germany (Lange-Bertalot 1996) and Austria (Lenzenweger 1999a) 56% of the taxa found could be classified, 20% of them as endangered or extremely rare, most of them within the FEN area. Within the diatom taxa 72% could be classified with 12% classified as endangered or extremely rare which is comparably lower as in the Southern Alps were 48% out of 92% classified diatom taxa were classified to various degreees as endangered or as extremely rare (Cantonati et al. 2001), mainly due to the presence of acidophilous species typical of low mineral content waters. Many critically and strongly endangered species were especially found on the siliceous substrata of the FEN area (e.g. *Eunotia bilunaris*, *E. tetraodon*, *E. inerme*) in agreement with the findings of studies from mountain and high mountain springs in the Alps (Cantonati 1998). The soft water FEN habitats additionally included many species with boreo-alpine distribution (approximately one third of the species found) which was also the case in two studies on springs of the Pyrenees and the Southern Alps (Sabater & Roca 1992, Cantonati 1998).

The most essential driving variables for the phytobenthos communities within the Rotmoos catchment were the following: (1) glacial influence, (2) water level fluctuations and (3) geochemical variables.

Glacial meltwater contributing to stream discharge, mainly in the Rotmoosache glacial stream (unpubl. data) than in the smaller cascading side streams, has a negative effect on the species numbers of algae except diatoms. A higher percentage of glaciation in the catchment generally causes a considerable reduction in species numbers of algae except diatoms (especially from > 30-40% glaciation) (see ROTT et al. in press). Especially in the extreme glacier streams of the Rotmoos valley the numbers of blue-greens is reduced to two species mainly due to the harsh environmental conditions. The reduction of cyanophyte taxa by glacier waters was also recorded from high altitude streams in Osttirol (PFISTER 1989). Generally algal communities in glacier streams tend to be small in number of taxa, dominated by diatoms, cyanophytes and the chrysophyte *Hydrurus foetidus* (e.g. KANN 1978, KAWECKA 1980, 1981, VAVILOVA & LEWIS 1999, HIEBER et al. 2001). However diatoms seem to be more resistant against glacial ablation reaching higher species numbers also in higher glaciated streams (e.g. 38 diatom species in HSS, 60% glaciation) compared to the study on the Roseg glacier stream where a reduction in diatom species richness from 21 to 6 taxa was recorded when approaching the proglacial area. According to ROTT et al. (in press) effects on diatoms should occur from > 60% catchment glaciation only. This enforces the need to carry out some more detailed studies of the diatom flora in the proglacial area within the Rotmoos catchment.

The strong runoff variability in high altitude streams leads to a vertical zonation in the stream bed with well known rheobiontic stream taxa, which are mainly epilithic (crust forming) (e.g. *Chamaesiphon fuscus*, *Clastidium setigerum*, *Homoeothrix varians*, *Fragilaria arcus*) and rheophilous stream taxa (e.g. *Homoeothrix fusca*, *H. gracilis*) found in the permanently wetted perimeter (PIPP & ROTT 1993, ROTT et al. 1997, 1999). Some rheophilous N_2-fixing cyanophytes (e.g. *Tolypothrix penicillata*) are occurring in smaller streams, spring areas and shallow parts of the FEN (ROTT et al. 1999). These taxa are likely to be seriously affected by eventual nitrogen enrichment within the catchment due to airborne pollutants, climatic effects or pasturage by sheeps and horses. In addition taxa adapted to desiccation and to some extent resistant against flow were recorded (e.g. *Gloeocapsa* ssp., *Diadesmis gallica* var. *perpusilla*) in the amphibian zone. Diatoms were found to be the most important component of the benthic algal flora of the running water stretches (75% of the species found), as it is the case e.g. in the Southern Alps (CANTONATI 1998). They comprise mainly widespread species as dominant diatom taxa and several subdominant taxa characteristic for high altitude and / or alpine waters (ROTT et al. in press), as it is the case for 23% of the diatom taxa within the Rotmoos valley.

Despite glacial influence and runoff variability, geochemical variables (conductivity, pH) were found to be among the most important factors determining presence and relative abundance of taxa, as it has been described for algal communities in all kinds of biotopes (e.g. lake littoral, KANN 1988; mountain streams and rivers, PIPP & ROTT 1993, CANTONATI et al. 1996, 1998). Furthermore it is presumed that high altitude streams tend to be nutrient limited, with periodical nutrient enrichments due to glacial meltwater (inorganic P - compounds) and snowmelt (N- and organic P-compounds) (ROBINSON et al. 2002).

7. Zusammenfassung:

Im Rahmen des Biodiversitätsprojektes BioDivAlp „Alpenforschung – Biodiversität alpiner Lebensräume" wurde in den Jahren 2001/2002 die Artenvielfalt im Rotmoostal, einem 10 km^2 großen, alpinen Einzugsgebiet in den Zentralalpen, erhoben. Einbezogen wurden Fließgewässerorganismen des Makrozoobenthos, der Aufwuchsalgen, Protisten und Bakterien ebenso wie die für alpine Böden bedeutende Evertebratenfauna. Die vorliegende Teiluntersuchung umfasst alle Algengruppen und die dominierenden Wassermoose, welche Bestandesstruktur und Diversität wesentlich mitbestimmen.

Die Habitatdiversität reicht von 2 Stellen im Hauptbach (Rotmoosache), 5 Quellbächen und 5 Gletscherbächen bis hin zu einem aquatisch - terrestrischen Hangfuß-Quellkomplex mit Aspekten von moosreichen Quellfluren, einem Quellbach, seggenreichen Niedermooransätzen und einem Moortümpel. Insgesamt konnte für das gesamte Einzugsgebiet mit 278 Taxa aus 8 Großgruppen eine hohe Artenzahl gefunden werden. Die Gruppe der Kieselalgen ist mit 181 Taxa am artenreichsten, gefolgt von den Blaualgen / Cyanobakterien mit 42 Taxa (Schwerpunkt in den Quellbächen). Die subterrestrischen fädigen Jochalgen / Zieralgen mit 40 Taxa dominieren in mehreren Mikrohabitaten des Hangfuß-Quellkomplexes, die sich als Hot-Spot der Biodiversität mit charakteristischen Algen für Quellstandorte und Moore (z.B. *Euastrum bidentatum*) erweisen. Nahezu 30% aller gefundenen Algentaxa sind (ultra)-oligotraphent bzw. oligo-mesotraphent und 28% aller Arten gelten in den Roten Listen als vom Aussterben bedroht, (stark) gefährdet bzw. selten.

Die hochalpinen Bäche weisen eine hohe Variation der Artenzahlen auf, wobei die Kieselalgen selbst in den extremen gletschergespeisten Bächen meist verhältnismäßig artenreich, aber individuenarm sind. Die übrigen Algengruppen, hier vor allem mit Fließgewässerformen, sind in den quellgespeisten Seitenbächen der untersuchten Abschnitte in Abhängigkeit vom Kalkgehalt am artenreichsten, vor allem die Gruppe der Blaualgen wird bei zunehmender Vergletscherung zurückgedrängt.

Acknowledgements: Special thanks to Mag. Nico Binder for carrying out the field work and large parts of diatom determination and the laboratory staff Josef Franzoi and Werner Müller for chemical analysis of water samples and data evaluation. Thanks to Dr. Ludwig Pernegger for his close look at the *Tolypothrix* material and to Mag. Gerhard Buzas for identifying the mosses.

This study was part of the pilot project "*ALP-2000 Biodiversity of an Alpine catchment: An integrated approach to assess microbial, botanical, and faunistic diversity of terrestrial and aquatic habitats in the Rotmoos Valley, Tirol 2001-2003*" funded by the Austrian Academy of Sciences.

8. References:

BACKHAUS, D. (1976): Beiträge zur Ökologie der benthischen Algen des Hochgebirges in den Pyrenäen. II. Cyanophyceen und übrige Algengruppen. – Internat. Rev. ges. Hydrobiol. **61**: 471 - 516.

BATTIN, T.J., A. WILLE, B. SATTLER & R. PSENNER (2001): Phylogenetic and Functional Heterogeneity of Sediment Biofilms along Environmental Gradients in a Glacial Stream. -Appl. Env.

Microbiol. **67**(2): 799 - 807.
BATTIN, T.J., A. WILLE & R. PSENNER (2003): Ecology of stream microbial biofilms in a glacial catchment. Submitted to Limnology and Oceanography.
BECK-MANNAGETTA , G. (1931): Die Algen Kärntens. Erste Grundlagen einer Algenflora von Kärnten. – Beih. Bot. Centralbl., Abt. 2, **47**: 211- 342.
BESCH, W.K., D. BACKHAUS, J. CAPLANCQ & P. LAVANDIER (1972): Données écologiques sur les algues benthiques de haute montagne dans les Pyrénées. I Diatomées. – Annales de limnologie **8**: 103 - 118.
BÜRGI, H.R., P. BURGHERR & U. UEHLINGER (2003): Aquatic flora. – In WARD, J.V. & U. UEHLINGER (eds.): Ecology of a glacial floodplain. – Kluwer Academic Press: 139 – 151.
CANTONATI, M. (1998): Diatom communities of springs in the Southern Alps. – Diatom Research **13**: 201 - 220.
CANTONATI, M., G. CORRADINI, I. JÜTTNER & E. COX (2001): Diatom assemblages in high mountain streams of the Alps and the Himalaya. – Nova Hedwigia, Beiheft **123**: 37 - 61.
CANTONATI, M. & K. ORTLER (1998): Using spring biota of pristine mountain areas for long term monitoring. – Hydrology, Water Resources and Ecology in Headwaters (Proceedings of the Headwater '98 Conference held at Merano/Meran, Italy, April 1998). – IAHS Publ. 248: 379 - 385.
- (2003): Flora and vegetation. – In: Italian habitats 5. Mountain streams. Ministero dell'Ambiente e della Tutela del Territorio. – Museo Friulano di Storia Naturale. ISBN 8888192107: 29 - 55.
CANTONATI, M., E. ROTT & E. PIPP (1996): Ecology of Cyanophytes in mountain springs of the River Sarca catchment (Adamello-Brenta Regional Park, Trentino, Northern Italy). -Algological Studies **83**: 145-162.
DALLA TORRE, K.W. v. & L. v. SARNTHEIN (1901): Flora der gefürsteten Grafschaft Tirol, des Landes Vorarlberg und des Fürstentumes Liechtenstein, 2.Band, Die Algen von Tirol, Vorarlberg und Liechtenstein. – Wagner, Innsbruck, 210 pp.
ETTL, H. (1968): Ein Beitrag zur Kenntnis der Algenflora Tirols. – Ber. nat. - med. Verein Innsbruck **56**: 177 - 354.
- (1970): Ein Beitrag zur Kenntnis der Algenflora Tirols II. – Ber. nat. - med. Verein Innsbruck **58**: 89 - 124.
FREY, W., J.-P. FRAHM, E. FISCHER & W. LOBIN (1995): Die Moos- und Farnpflanzen Europas. 6. Aufl. – Kleine Kryptogamenflora Bd. 4, 426 pp.
FÜREDER, L., C. SCHÜTZ, R. BURGER & M. WALLINGER (1998): High alpine streams as models for ecological gradients. – IAHS Publication **248**: 387 - 394.
- (2000): Seasonal abundance and community structure of Chironomidae in two contrasting high alpine streams. – Verh. internat. Verein. Limnol. **27**: 1596 - 1601.
FÜREDER, L., C. SCHÜTZ, M. WALLINGER & R. BURGER (2001): Physico-chemistry and aquatic insects of a glacier-fed and a spring-fed alpine stream. – Freshwater Biology **46**: 1673 - 1690.
GEITLER, L. (1932): Cyanophyceae von Europa. Rabenhorst´s Kryptogamenflora von Deutschland, Österreich und der Schweiz. – Akademische Verlagsgesellschaft Leipzig. **14**, 1196 pp.
GOLUBIC, S. & E. KANN (1967): Zur Klärung der taxonomischen Beziehungen zwischen *Tolypothrix distorta* KÜTZING und *T. penicillata* THURET (Cyanophyta). – Schweiz. Z. Hydrol. **29**: 145 - 160.
GRIMS, F. & H. KÖCKINGER (1999): Rote Liste gefährdeter Laubmoose (Musci) Österreichs. 2. Fassung. – In: H. NIKLFELD (ed.) Rote Liste gefährdeter Pflanzen Österreichs. – Grüne Reihe BMUJF **10**: 157 - 171.
HIEBER, M., CT. ROBINSON, S.R. RUSHFORTH & U. UEHLINGER (2001): Algal communities associated with different alpine stream types. – Arctic, Antarctic & Alpine Research **33**: 447 - 456.

HILL, M.O. (1979): TWINSPAN - a Fortran program for arranging multivariate data in an ordered two-way table by classification of individuals and attributes. – MS Dept. Ecology and Systematics, Cornell University, Ithaca, New York, 48 pp.

JOHN, D.M., B.A. WHITTON & A.J. BROOK (2003): The Freshwater Algal Flora of the British Isles. An Identification Guide to Freshwater and Terrestrial Algae. – Cambridge University Press. ISBN 0 521 77051 3, 702 pp.

KADLUBOWSKA, J.K. (1984): Conjugatophyceae I. – In: ETTL, H., J. GERLOFF, H. HEYNIG & D. MOLLENHAUER (Hrsg.): Süßwasserflora von Mitteleuropa. **16** – G. Fischer, Jena, 532 pp.

KANN, E. (1978): Systematik und Ökologie der Algen österreichischer Bergbäche. – Archiv für Hydrobiologie / Suppl. **53**: 405- 643.

- (1988): Zur Autökologie benthischer Cyanophyten in reinen europäischen Seen und Fließgewässern. – Archiv für Hydrobiologie / Algological Studies **50 - 53**: 473 - 495.

KAWECKA, B. (1980): Sessile algae in European mountain streams. 1. The ecological characteristics of communities. – Acta Hydrobiol. **22**: 361 - 420.

- (1981): Sessile algae in European mountain streams. 2. Taxonomy and autecology. – Acta Hydrobiol. **23**: 17 - 46.

KOMAREK, J & L. KOVACIK (1987): Revision of several species of the genus *Homoeothrix* (Cyanophyta). – Preslia. **59**: 229 - 242.

KOMAREK, J. & K. ANAGNOSTIDIS (1999): Cyanoprokaryota 1.Teil: Chroococcales. – In: ETTL, H., G. GÄRTNER, H. HEYNIG & D. MOLLENHAUER (Hrsg.): Süßwasserflora von Mitteleuropa. 19/1. – Fischer, Stuttgart, 548 pp.

KRAMMER, K. (1997a): Die cymbelloiden Diatomeen. Teil 1: Allgemeines und *Encyonema* Part. – Bibliotheca Diatomologica **36**, 382 pp.

- (1997b):. Die cymbelloiden Diatomeen. Teil 2: *Encyonema* Part., *Encyonopsis* and *Cymbellopsis*. – Bibliotheca Diatomologica **37**, 469 pp.

- (2000): The genus *Pinnularia*. – Diatoms of Europe Vol. **1**, 703 pp.

KRAMMER, K. & H. LANGE-BERTALOT (1986): Bacillariophyceae, 1. Teil. Naviculaceae. – In: ETTL, H., J. GERLOFF, H. HEYNIG & D. MOLLENHAUER (Hrsg.). Süßwasserflora von Mitteleuropa **2/1**. – Fischer, Stuttgart, 876 pp.

- (1988): Bacillariophyceae, 2. Teil. Bacillariaceae, Epithemiaceae, Surirellaceae. – In: ETTL, H., J. GERLOFF, H. HEYNIG & D. MOLLENHAUER (Hrsg.). Süßwasserflora von Mitteleuropa **2/2**. – Fischer, Stuttgart, 596 pp.

- (1991a): Bacillariophyceae, 3. Teil. Centrales, *Fragilaria*ceae, *Eunotia*ceae. – In: ETTL, H., J. GERLOFF, H. HEYNIG & D. MOLLENHAUER (Hrsg.). Süßwasserflora von Mitteleuropa **2/3**. – Fischer, Stuttgart. 576 pp.

- (1991b): Bacillariophyceae. 4. Teil. Achnanthaceae. Kritische Ergänzungen zu *Navicula* (Lineolatae) und *Gomphonema*, Literatur. – In: ETTL, H., J. GERLOFF, H. HEYNIG & D. MOLLENHAUER (Hrsg.). Süßwasserflora von Mitteleuropa **2/4**. –Fischer, Stuttgart. 437 pp.

LAMBERTI, G.A. (1996): The role of periphyton in benthic food webs. p. 533 - 572. – In: STEVENSON R.J., M.L. BOTHWELL & R.L.LOWE. Algal Ecology. Freshwater benthic ecosystems. – Academic Press.

LANGE-BERTALOT, H. (1993): 85 neue Taxa und über 100 weitere neu definierte Taxa ergänzend zur Süßwasserflora von Mitteleuropa Vol. 2. J. Cramer, Berlin. – Bibliotheca Diatomologica **27**, 454 pp.

- (1996): Rote Liste der limnischen Kieselalgen (Bacillariophyceae) Deutschlands. – Schriftenreihe für Vegetationskunde **28**: 633 - 677.

- (2001): *Navicula* sensu stricto. 10 Genera Separated from *Navicula* sensu lato. *Frustulia*. – Diatoms of Europe Vol. **2**, 526 pp.

LANGE-BERTALOT, H. & K. KRAMMER (1989): *Achnanthes* – eine Monographie der Gattung. – Bibliotheca Diatomologica **18**, 393 pp.

LANGE-BERTALOT H. & G. MOSER (1994): *Brachysira*-Monographie der Gattung. Wichtige Indikator-Species für das Gewässer-Monitoring und *Naviculadicta* nov. gen. Ein Lösungsvorschlag zu dem Problem *Navicula* sensu lato ohne *Navicula* sensu stricto. – Bibliotheca Diatomologica 29, 212 pp.

LANGE-BERTALOT, H. & D. METZELTIN (1996): Indicators of oligotrophy, 800 taxa representative of three ecologically distinct lake types. Carbonate buffer - oligodystrophic - weakly buffered soft water. – Iconographia Diatomologica. Annotated Diatom Micrographs **2**, 390 pp.

LENZENWEGER, R. (1996) : Desmidiaceenflora von Österreich, Teil 1. – Bibliotheca Phycologia **101**, Cramer, 162 pp.

- (1997a): Desmidiaceenflora von Österreich, Teil 2. – Bibliotheca Phycologia **102**, Cramer, 216 pp.

- (1997b): Beitrag zur Kenntnis der Desmidiaceen der alpinen Lagen der Glocknergruppe im inneren Fuschertal (Bundesland Salzburg, Austria). – Wissenschaftliche Mitteilungen aus dem Nationalpark Hohe Tauern Bd. **3**: 27 - 36.

- (1999): Desmidiaceenflora von Österreich, Teil 3. – Bibliotheca Phycologia **104**, Cramer, 218 pp.

- (1999a): Rote Liste gefährdeter Zieralgen (Desmidiales) Österreichs. 2. Fassung. – In: H. NIKLFELD (ed.) Rote Liste gefährdeter Pflanzen Österreichs. 2. Aufl. – Grüne Reihe des BMUJF, Wien **10**: 276 - 281.

LENZENWEGER, R., G. GÄRTNER & S. PFATTNER (1997): Zur bemerkenswerten Wiederentdeckung von *Staurastrum gurgeliense* SCHMIDLE und *Staurastrum sparseaculeatum* SCHMIDLE in Obergurgl (Ötztal, Tirol). – Ber. nat. - med. Verein Innsbruck Band **84**: 75 - 80.

MESSIKOMMER, E. (1942): Beitrag zur Kenntnis der Algenflora und Algenvegetation des Hochgebirges um Davos. – Beiträge zur geobotanischen Landesaufnahme der Schweiz, Heft 24. – Mitt. botan. Museum Univ. Zürich **158**, 452 pp.

PFISTER, P. (1992): Phytobenthos communities from 2 Tyrolean mountain streams. Part 1: Cyanophyceae, chrysophyceae, chlorophyceae, rhodophyceae. – Algological Studies **65**: 43 - 61.

- (1989): Gutachten über die Bestandesaufnahme der pflanzlichen Lebewelt in 19 Bächen der Osttiroler Tauernregion (Stand 1987). – Osttiroler Kraftwerks Ges.m.b.H. Matrei in Osttirol. 50pp. + Anhang.

PIPP, E. & E. ROTT (1993): Bestimmung der ökologischen Wertigkeit österreichischer Fließgewässer nach dem Algenaufwuchs. – Blaue Reihe des Bundesministeriums für Umwelt, Jugend und Familie. ISBN 3-901412-01-8, 147 pp.

REICHARDT, E. (1997) : Taxonomische Revision des Artenkomplexes um *Gomphonema pumilum*. – Nova Hedwigia **65**: 99 - 129.

- (1999) : Zur Revision der Gattung *Gomphonema*: Die Arten um *G. affine* / *insigne*, *G. angustatum* / *micropus*, *G. acuminatum* sowie gomphonemoide Diatomeen aus dem Oberoligozän in Böhmen. – Iconographia Diatomologica **8**, 203 pp.

REICHARDT, E. & H. LANGE-BERTALOT (1991): Taxonomische Revision des Artenkomplexes um *Gomphonema angustum*, *G. dichotomum*, *G. intricatum*, *G. vibrio* und ähnliche Taxa. – Nova Hedwigia **53**: 519 - 544.

ROBINSON, C.T, U. UEHLINGER, F. GUIDON, P. SCHENKEL & R. SKVARC (2002): Limitation and retention of nutrients in alpine streams of Switzerland. – Verhandlungen der internationalen Vereinigung für Limnologie **28**: 263 – 272.

ROTT, E. (1991): Methodical aspects and perspectives of the use of periphyton for monitoring and protecting rivers. – In: WHITTON, B,A., G. FRIEDRICH & E. ROTT (eds.): The use of algae for monitoring rivers. – Symposium Düsseldorf. Print Inst.f.Botanik, Universität Innsbruck: 9 - 16.

ROTT, E., G. HOFMANN, K. PALL, P. PFISTER & E. PIPP (1997): Projekt BMLF: Indikations-listen für Aufwuchsalgen in Fließgewässern in Österreich. Teil 1: Saprobielle Indikation. Bundesministerium für Land- und Forstwirtschaft, Wasserwirtschaftskataster, Wien. ISBN 3-85 174-017-03, 73 pp.

ROTT, E., E. PIPP, P. PFISTER, H. VANDAM, K. ORTLER, N. BINDER & K. PALL (1999): Indikationslisten für Aufwuchsalgen in österreichischen Fließgewässern. Teil2: Trophieindikation sowie geochemische Präferenz, taxonomische und toxikologische Anmerkungen. – Bundesministerium für Land- und Forstwirtschaft, Wasserwirtschaftskataster, Wien. ISBN 3-85 174-25-4, 248 pp.

ROTT, E., L. WALSER & M. KEGELE (2000): Ecophysiological aspects of macroalgal seasonality in a gravel stream in the Alps (River Isar, Austria). – Verh. internat. Verein. Limnol. **27**: 1622 – 1625.

ROTT, E., M. CANTONATI, L. FÜREDER & P. PFISTER (in press): Benthic algae in high altitude streams of the Alps – a neglected component of aquatic biota. – Developments in Hydrobiology / Hydrobiologia.

ROTT, E., B. SONNTAG, C. SCHÜTZ, A. WILLE & L. FÜREDER (in press): *Hydrurus* in glacial streams – an ephemeral microhabitat for micro-organisms and insects.

SABATER, S. & J.R. ROCA (1992): Ecological and biogeographical aspects of diatom distribution in Pyrenean springs. – British Phycological Journal **27**: 203 - 213.

SAUKEL, J. & H. KÖCKINGER (1999): Rote Liste gefährdeter Lebermoose (Hepaticae) und Hornmoose (Anthocerotales) Österreichs. 2. Fassung. – In: H. NIKLFELD (ed.) Rote Liste gefährdeter Pflanzen Österreichs. – Grüne Reihe BMUJF **10**: 172 - 179.

SCHMIDLE, W. (1895, 1896): Beiträge zur alpinen Algenflora. – Österr. Bot. Z. 1895: 249-253; 305-311; 346-350; 387-391; 454-459; 1896: 20-25; 59-65; 91-94.

SCHMITZ, W. (1961): Fließgewässerforschung – Hydrographie und Botanik. – Intern. Ver. theor. ang. Limnol. Verh. **14**: 541 - 586.

SKUJA, H. (1964): Grundzüge der Algenflora und Algenvegetation der Fjeldgegenden um Abisko. – Nova Acta Reg. Soc. Scient. Ups. Ser. IV, 18, Nr. **3**, 465 pp.

STARMACH, K. (1985): Chrysophyceae und Haptophyceae. – In: ETTL, H., J. GERLOFF, H. HEYNIG & D. MOLLENHAUER (Hrsg.): Süßwasserflora von Mitteleuropa **1**. – G. Fischer, Jena, 515 pp.

UEHLINGER, U. (1991): Spatial and temporal variability of the periphyton biomass in a prealpine river (Neckar, Switzerland). – Archiv für Hydrobiologie **123**: 219 – 237.

UEHLINGER, U., R. ZAH & H.R. BÜRGI (1998): The Val Roseg Project: Temporal and spatial patterns of benthic algae in an Alpine stream influenced by glacier runoff. – In: K. KOVAR, U. TAPPEINER, N.E. PETERS & R.G. VRAIG (eds.): Hydrology, Water Resources and Ecology in Headwaters. – IAHS Press, Wallingford, U. K.: 419 - 424.

VANNOTE, R.L., G.W. MINSHALL, K.W. CUMMINS, J.R. SEDELL & C.E. CUSHING (1980): The river continuum concept. – Canadian Journal of Fisheries and Aquatic Sciences **37**: 130 – 137.

VANLANDINGHAM, S.L. (1982): Guide to the identification, environmental requirements and pollution tolerance of blue-green algae (Cyanophyta). – Environmental Monitoring and Support Laboratory Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio, 341pp.

VAVILOVA, V.V. & W.M. LEWIS (1999): Temporal and altitudinal variations in the attached algae of mountain streams in Colorado. – Hydrobiologia **390**: 99 - 106.

VOGLER, P. (1965): Probleme der Phosphoranalytik in der Limnologie und ein neues Verfahren zur Bestimmung von gelöstem Orthophosphat neben kondensierten Phosphaten und organischen Phosphorsäureestern. – Int. Rev. ges. Hydrobiol. **50**: 33 - 48.

WARD, J.V. (1994): Ecology of alpine streams. – Freshwater Biology 3**2**: 277 - 294.

WEHR, J.D. & R.G. SHEATH (2003): Freshwater Algae of North America. Ecology and Classification. – Academic Press, London. ISBN 0 12 741550-5, 918 pp.

WETZEL, R.G. (1983): Limnology. 2nd ed. – W.G. Saunders Co., Philadelphia, 743pp.

9. Anhang:

Table A1: Benthic algae species list including indication of sampling sites; red list classification (RL) according to LANGE-BERTALOT (1996) for diatoms, LENZENWEGER (1999a) for desmids and trophic indication values (TW) according to ROTT et al. (1999); 1 – critically endangered; 2 - strongly endangered 3 – endangered, G - probably endangered, R - extremely rare, V – reduced in numbers, * - presently not endangered, ** - definitely invulnerably, ● - to be expected within the area, D - insufficient data, # - preliminery species concepts according to LANGE-BERTALOT & METZELTIN (1996).

	RM lotic	RM Hydrurus	EKS	HSS	HFS	SKS	LGS	SWS	SWSa	MUS	SBS	KKS	FEN pool	FEN sedge	FEN stream	FEN moss	FEN algae	TW	RL
Cyanophyceae																			
Ammatoidea normanni					X						X	X			X			1,2	
Ammatoidea simplex															X			1.2*	
Aphanocapsa sp.					X			X					X						
Aphanothece saxicola												X						1,7	
Aphanothece stagnina														X					
Calothrix fusca				X						X	X	X			X			1,2	
Calothrix sp.											X								
Chamaesiphon fuscus								X	X		X	X						0.7*	
Chamaesiphon incrustans				X				X				X						1.7*	
Chamaesiphon investiens								X										1.2*	
Chamaesiphon minutus		X						X	X		X							0.6*	
Chamaesiphon polonicus					X			X	X	X	X	X			X			1.2*	
Chamaesiphon rostafinskii										X								0.3*	
Chroococcus sp.													X						
Clastidium rivulare								X										0.8*	
Clastidium setigerum								X		X		X			X			0.4*	
Dichothrix gypsophila											X							1.2*	
Entophysalis sp.								X											
Gloeocapsa alpina								X			X	X					X	0,6	
Gloeocapsa dermochroa								X			X	X						1.1*	
Gloeocapsa sanguinea					X							X					X	1,2	
Homoeothrix fusca					X					X								0,6	
Homoeothrix gracilis								X			X	X						0.8*	
Homoeothrix janthina								X	X	X								1.5*	
Homoeothrix varians		X			X		X	X	X		X	X			X			1.4*	
Hydrococcus rivularis							X											1.7*	
Lyngbya martensiana											X								
Nostoc sp.									X		X	X	X						
Oscillatoria sancta											X							3,5	
Phormidium autumnale						X		X	X	X	X	X	X					1.7*	
Phormidium incrustatum											X							2.4*	
Phormidium subfuscum								X			X	X						1.6*	
Phormidium uncinatum											X								
Pleurocapsa minor								X			X							2.3*	
Pseudanabaena sp.					X														
Schizothrix sp.								X											
Siphononema polonicum											X	X						0.6*	
Stigonema mamillosum													X				X	0,3	
Synechococcus sp.											X								
Tolypothrix penicillata			X						X	X	X		X	X			X	0,6	
Woronichinia sp.													X						
Xenococcus sp.										X									
Chrysophyceae																			
Chrysocapsa sp.									X										
Hydrurus foetidus	X	X			X			X				X						1.3*	
Phaeodermatium rivulare	X	X	X			X	X	X	X	X	X	X						1.8*	
Diatomophyceae																			
Achnanthes altaica											X					X	X	1,7	G

	RM lotic	RM Hydrurus	EKS	HSS	HFS	SKS	LGS	SWS	SWSa	MUS	SBS	KKS	FEN pool	FEN sedge	FEN stream	FEN moss	FEN algae	TW	RL
Achnanthes biasolettiana	X	X	X		X					X			X	X	X			1.3*	**
Achnanthes bioretii	X	X			X			X	X				X					1,8	V
Achnanthes cf. *grischuna*	X																		*
Achnanthes cf. *kryophila*		X								X			X	X	X	X	X		3
Achnanthes cf. *saccula*	X									X			X	X	X	X	X	0,6	•
Achnanthes cf. *stewartii*			X			X		X		X									•
Achnanthes cf. *subatomoides*		X	X					X					X		X	X	X	2.1*	V
Achnanthes didyma													X	X	X				3
Achnanthes flexella								X					X					0,3	3
Achnanthes helvetica	X	X	X	X	X	X		X		X		X	X	X	X	X	X	0.6*	*
Achnanthes sp.													X	X	X	X	X		
Achnanthes laevis	X	X	X		X	X	X	X		X	X						X	1,2	*
Achnanthes lanceolata	X	X		X	X						X	X						3.3*	**
Achnanthes lanceolata ssp. *frequentissima*	X	X		X	X													2.8*	**
Achnanthes minutissima	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	1.2*	**
Achnanthes minutissima var. *jackii*	X																	1,2	D
Achnanthes petersenii	X	X		X		X	X	X	X	X	X			X				0,6	3
Achnanthes pusilla													X					0,6	3
Achnanthes scotica			X	X	X	X		X		X				X	X	X	X		R
Adlafia bryophila	X	X			X					X			X	X	X	X	X	1,3	
Adlafia minuscula	X	X						X			X		X					1,1	
Adlafia suchlandtii			X					X			X		X	X	X	X	X	0,6	V
Amphipleura pellucida							X	X										2,1	*
Amphora cf. *veneta*											X							3,8	**
Amphora inariensis	X	X								X	X							2.1*	3
Amphora libyca								X										3.5*	**
Amphora pediculus	X		X	X	X			X			X	X						2.8*	**
Aulacosira sp.										X			X	X	X	X	X		
Brachysira brebissonii	X	X		X	X			X					X	X	X	X	X	1,1	*
Brachysira neoexilis	X				X	X		X					X		X	X	X	1,2	*
Caloneis hyalina													X						
Caloneis silicula					X	X					X		X					2,5	*
Caloneis tenuis		X								X	X		X	X	X	X	X	1,1	G
Cavinula cf. *intractata*				X	X														
Chamaepinnularia mediocris												X	X	X	X	X	X	0,6	V
Chamaepinnularia schauppiana					X								X			X	X		
Cocconeis pediculus	X	X	X				X	X										2.6*	**
Cocconeis placentula				X	X	X		X		X		X			X			2.6*	**
Cyclotella sp.	X	X	X		X														
Cymbella affinis	X	X		X	X			X			X				X			0.7*	*
Cymbella amphicephala											X							1,1	V
Cymbella aspera													X					1,7	V
Cymbella cistula					X													2,3	V
Cymbella delicatula	X	X													X			0.3*	G
Cymbella ehrenbergii		X																2,2	V
Cymbella naviculacea													X		X	X	X		3
Cymbella naviculiformis	X	X											X	X	X	X		1,8	*
Cymbella subaequalis	X	X			X			X	X	X	X		X	X	X	X	X	1,0	G
Cymbella subcuspidata													X	X					
Denticula tenuis	X	X		X	X	X		X			X		X		X	X		1.4*	*
Diadesmis gallica var. *perpusilla*			X	X	X	X		X		X	X	X		X	X	X	X	1,2	**
Diatoma ehrenbergii	X							X										1.6*	**
Diatoma hyemalis									X									1.0*	*

	RM lotic	RM Hydrurus	EKS	HSS	HFS	SKS	LGS	SWS	SWSa	MUS	SBS	KKS	FEN pool	FEN sedge	FEN stream	FEN moss	FEN algae	TW	RL
Diatoma mesodon	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X		0.7*	*
Diatoma vulgaris								X			X							2,0	D
Diploneis boldtiana		X																	•
Diploneis cf. *elliptica*											X							1,7	*
Diploneis cf. *petersenii*										X				X				1,3	3
Diploneis marginestriata											X								3
Diploneis marginulata													X						
Diploneis oblongella											X							1,0	V
Encyonema neogracile var. *tenuipunctatum*																	X	0,6	3
Encyonema alpina	X			X							X							0,6	G
Encyonema caespitosa				X	X								X					2,1	**
Encyonema cf. *vulgare*													X						
Encyonema falaisensis	X	X		X	X	X	X			X	X		X	X	X	X	X	0.4*	G
Encyonema fogedii	X	X						X											
Encyonema gaeumannii											X		X	X	X	X	X	0,6	
Encyonema minutum	X	X	X	X	X	X	X	X				X			X			2.0*	*
Encyonema neogracile	X	X											X	X	X	X	X		
Encyonema perpusilla													X	X	X	X	X	0,5	
Encyonema silesiacum	X	X					X	X		X	X	X	X	X	X	X	X	2,0	*
Encyonopsis cesatii				X				X		X				X	X	X	X	0,6	*
Encyonopsis microcephala				X	X		X						X				X	1.2*	*
Encyonema lange-bertalotii	X	X												X					
Epithemia sp.					X					X	X								
Eunotia #3 JÖ														X	X	X	X		
Eunotia arcus								X		X								1,1	
Eunotia bilunaris													X	X	X	X	X	0,7	2
Eunotia cf. *groenlandica*													X			X			•
Eunotia cf. *pseudoparal-leloides*										X									•
Eunotia curtagrunowii			X			X							X		X	X			
Eunotia exigua	X	X	X	X	X					X			X	X	X	X	X	0.5*	**
Eunotia incisa "*borealis*"	X	X	X			X				X			X	X	X	X	X		*
Eunotia inflata													X		X				
Eunotia islandica													X						D
Eunotia pectinalis														X	X	X		1,1	V
Eunotia tetraodon															X		X		2
Eunotia valida													X						
Fragilaria arcus	X	X	X	X	X	X	X	X		X	X	X			X			1.0*	**
Fragilaria brevistriata	X	X																3.0*	**
Fragilaria capucina var. *austriaca*		X		X	X		X	X		X	X		X		X	X		0.5*	G
Fragilaria capucina var. *capucina*	X	X								X								1,8	**
Fragilaria capucina var. *vaucheriae*	X	X						X		X								1.8*	**
Fragilaria construens f. *binodis*								X										2,3	*
Fragilaria construens f. *venter*								X		X			X	X	X	X	X	2,3	**
Fragilaria exigua													X	X				0,6	
Fragilaria gracilis	X	X	X		X			X		X	X		X	X	X	X	X		
Fragilaria oldenburgiana								X						X					D
Fragilaria pinnata	X	X		X	X			X			X		X	X				2.2*	**
Fragilaria tenera					X													1,0	V
Fragilaria ulna	X				X			X			X							3.5*	*
Fragilaria virescens								X							X			1,4	V
Frustulia crassinervia																	X	0,4	V
Frustulia saxonica			X	X	X	X				X			X	X	X	X	X	0,4	V

	RM lotic	RM Hydrurus	EKS	HSS	HFS	SKS	LGS	SWS	SWSa	MUS	SBS	KKS	FEN pool	FEN sedge	FEN stream	FEN moss	FEN algae	TW	RL
Frustulia sp.	X	X																	
Gomphonema #4 JÖ													X	X	X	X	X		
Gomphonema amoenum	X	X						X					X		X	X	X	0,4	3
Gomphonema anglicum										X									
Gomphonema angustum	X	X																1.0*	V
Gomphonema clavatum	X	X								X			X	X	X	X			*
Gomphonema coronatum					X						X								3
Gomphonema exilis													X		X	X			
Gomphonema hebridense													X	X	X	X	X	0,9	V
Gomphonema micropus	X	X	X	X	X	X					X	X						2,0	*
Gomphonema olivaceum var. *minutissimum*	X	X																1.2*	*
Gomphonema pala													X	X					
Gomphonema parvulius			X		X	X				X			X	X	X	X			
Gomphonema sp.								X					X	X	X				
Gomphonema sphaenovertex													X				X		
Gomphonema tergestinum		X	X	X	X	X	X				X	X						1.4*	G
Gomphonema truncatum															X			1,9	*
Hantzschia amphioxys	X										X							3.6*	**
Hygropetra balfouriana										X			X	X				0,6	R
Luticola acidoclinata				X														2,9	
Meridion circulare	X	X		X							X	X			X			2.5*	**
Navicula angusta						X		X		X						X	X	0,6	3
Navicula cari		X																2,6	**
Navicula cf. *scutelloides*															X			2,7	
Navicula cryptocephala		X																3.5*	**
Navicula cryptotenella	X	X					X				X							2.3*	
Navicula exilis			X	X	X					X	X		X	X		X		2,0	G
Navicula heimansoides													X						3
Navicula radiosa				X						X	X		X					0,6	**
Navicula tripunctata						X												3.1*	**
Navicula trivialis	X	X																3,3	**
Naviculadicta bremensiformis													X	X	X	X			3
Neidium affine	X	X											X	X	X			0,6	V
Neidium affine var. *linearis*															X				
Neidium affine var. *longiceps*													X					0,6	G
Neidium bisulcatum													X		X			0,6	3
Nitzschia acidoclinata					X	X					X		X	X	X		X	2,3	*
Nitzschia alpina								X			X		X		X		X	0,6	G
Nitzschia cf. *tubicola*	X	X																3,4	*
Nitzschia fonticola	X			X														1,9	**
Nitzschia gracilis								X			X	X	X	X			X	2.5*	*
Nitzschia hantzschiana				X		X		X			X		X	X		X	X	2,0	*
Nitzschia perminuta	X	X		X				X			X	X	X	X	X	X	X	2,3	*
Nitzschia pura	X	X											X					1.9*	*
Nitzschia subacicularis	X																	2,9	R
Pinnularia acidoclinata			X																
Pinnularia biceps													X	X					
Pinnularia borealis	X	X																1,9	**
Pinnularia borealis var. *sublinearis*			X													X			
Pinnularia divergentissima var. *minor*														X		X	X		D
Pinnularia flexuosa													X						•
Pinnularia irrorata													X						
Pinnularia microstauron	X	X											X	X	X			1,0	V

	RM lotic	RM Hydrurus	EKS	HSS	HFS	SKS	LGS	SWS	SWSa	MUS	SBS	KKS	FEN pool	FEN sedge	FEN stream	FEN moss	FEN algae	TW	RL
Pinnularia neglectiformis														X					
Pinnularia notabilis														X					G
Pinnularia obscura					X	X		X					X	X	X	X	X	2,0	**
Pinnularia ovata													X						
Pinnularia permicrostauron													X						
Pinnularia pisciculus																X			
Pinnularia stidolphii													X				X		
Pinnularia subcapitata		X																	*
Pinnularia subcapitata var. *subrostrata*			X		X								X	X		X	X		*
Pinnularia submicrostauron				X															D
Pinnularia tirolensis var. *julma*													X	X					
Pinnularia viridiformis																	X		G
Pinnularia viridis													X		X			1,3	*
Reimeri sinuata	X	X		X	X	X		X		X		X						2.1*	**
Sellaphora laevissima														X				1,1	V
Sellaphora pupula				X	X								X	X	X	X		3.7*	**
Stauroneis prominula													X				X		
Stauroneis siberica													X	X		X			
Stenopterobia cf. *delicatissima*																X	X	0,5	3
Surirella linearis	X				X						X	X				X	X	1,0	*
Surirella sp.																	X		
Tabellaria flocculosa	X	X		X	X			X				X	X	X	X	X	X	0.8*	**
Chlorophyceae																			
Gongrosira debaryana								X										2.1*	
Gongrosira incrustans											X							1.8*	
Haematococcus pluvialis													X						
Microspora sp.				X											X		X		
Oedogonium sp.								X		X					X		X		
Oocystis solitaria													X						
Pediastrum tetras													X						
Sphaerobotrys fluviatilis								X										3.1*	
Stigeoclonium sp.																	X		
Zygnematophyceae																			
Closterium closterioides													X						3
Closterium lunula									X		X								
Closterium striolatum													X	X					3
Cosmarium botrytis											X				X				3
Cosmarium difficile																X			*
Cosmarium impressulum var. *alpicolum*													X						
Cosmarium margaritiferum													X	X					3
Cosmarium novae-semliae var. *sibiricum*													X						
Cosmarium ochthodes													X						3
Cosmarium portianum													X						*
Cosmarium speciosissimum													X						
Cosmarium subcostatum var. *minus*													X						3
Cosmarium vexatum var. *concavum*																	X		D
Euastrum aboense													X	X					3
Euastrum ansatum var. *pyxidatum*													X	X			X		3
Euastrum bidentatum													X						3
Euastrum denticulatum													X						3

	RM lotic	RM Hydrurus	EKS	HSS	HFS	SKS	LGS	SWS	SWSa	MUS	SBS	KKS	FEN pool	FEN sedge	FEN stream	FEN moss	FEN algae	TW	RL
Euastrum inerme														X					1
Euastrum verrucosum var. *alatum*													X						3
Micrasterias denticulata													X	X					3
Micrasterias denticulata var. *angulosa*													X	X					3
Micrasterias papillifera													X	X					3
Mougeotia ovalis																X	X		
Mougeotia sp.								X							X		X		
Penium cylindrus													X						3
Penium sp.													X						
Penium spirostriolatum													X						2
Sphaerozosma sp.																	X		
Spirogyra sp.								X	X							X			
Staurastrum crenulatum								X					X						3
Staurastrum monticulosum													X						2
Staurastrum orbiculare var. *ralfsii*													X						
Staurastrum pyramidatum																X			2
Staurastrum teliferum var. *ordinatum*													X						
Tetmemorus granulatus													X						3
Zygnema sp.								X	X						X	X	X		
Dinophyceae																			
Gloeodinium montanum								X	X										
Rhodophyceae																			
Chantransia sp.								X		X									
Xanthophyceae																			
Vaucheria sp.									X										
Total number of Diatoms	**63**	**61**	**27**	**38**	**48**	**27**	**14**	**50**	**6**	**41**	**46**	**19**	**89**	**65**	**68**	**60**	**57**		
Total number of 'Non Diatoms'	**2**	**4**	**2**	**3**	**8**	**2**	**3**	**29**	**15**	**12**	**26**	**18**	**35**	**10**	**11**	**5**	**13**		
Total number of Taxa	**65**	**65**	**29**	**41**	**56**	**29**	**17**	**79**	**21**	**53**	**72**	**37**	**124**	**75**	**79**	**65**	**70**		

Table A2: Distribution of mosses in spring areas of the Rotmoos valley and classification according to the Red List of Hepaticae and Anthocerotales (SAUKEL & KÖCKINGER 1999) and Red List of Musci (GRIMS & KÖCKINGER 1999) from Austria: 3 endangered, 4 potentially endangered, -r: 0, 1, 2, 3, 4 regionally endangered in the perialpine area.

	SWS	SBS	FEN moss	FEN sedge	Red List
Musci					
Cratoneuron commutatum (HEDW.) ROTH		X			
Dicranella palustris (DICKS.) CRUNDW. ex WARB.			X		- r:3
Drepanocladus exannulatus (var. *rotae*) (DE NOT.) LOESKE		X			
Drepanocladus sp.	X				
Philonotis seriata MITT.	X		X	X	3
Sphagnum recurvum agg.				X	4 r:3
Sphagnum sp.			X		
Tortella sp.				X	
Hepaticae					
Scapania subalpina (NEES ex LINDENB.) DUM.				X	4
Scapania uliginosa (NEES ex LINDENB.) DUM.			X	X	4