Attached algal vegetation and expected effects by a reduced water discharge with the River Ammerån as an example

Fastsittande alger och förväntad effekt av minskad vattenföring med Ammerån som ett exempel

Catarina Johansson, Doktor i växtbiologi, Stockholm.
cattis48@gmail.com

Abstract

The aims of the study was to describe the attached algal flora in the River Ammerån located in Mid-Sweden – and discuss possible effects of a lowered water flow (due to a proposed water-transfer). The algae were quantitatively sampled and biomass was calculated on a species basis. The river was found to house a riverine flora composed of algae such as *Zygnema b*, *Tolypothrix penicillata* and *Bulbochaete spp*. Stream diatoms such as *Achnanthes minutissima*, *Cymbella affinis*, *Eunotia spp.*, *Naviculas* and *Tabellarias* grew in between. A biomass range of 4 g/m^2 to almost 100 g/m^2 and a large amount of macroalgae (mean 44%) was found – typical for undisturbed rivers.

Key words: Attached algae, stream algae, biomass, reduced water discharge

Sammanfattning

Syftet med studien var att beskriva algfloran i Ammerån, ett biflöde till Indalsälven, och diskutera möjliga effekter av ett reducerat flöde. Anledningen var att vattenkraftsindustrin hade då (mitten av 1980-talet) föreslagit en överledning av vatten från de nedre delarna av Ammerån till Indalsälven för att öka uttaget av elenergi. Algerna samlades in med en kvantitativ metod och biomassan beräknades på artnivå. Ammerån visade sig innehålla en typisk rinnande-vatten-flora med dominerande arter som *Zygnema*, *Tolypothrix* och *Bulbochaete* och kiselalger som *Achnanthes* minutissima, *Cymbella* affinis, vissa *Eunotia-* , *Navicula-* samt *Tabellariaarter*. Ett reducerat flöde av föreslagen dignitet – 75 m^3/s till 2 m^3/s – skulle ge ett vattendrag som liknar en liten bäck med ett djup på några centimeter. Strömalgerna kommer att ersättas av arter som gynnas av låg vattenhastighet. Detta innebär att de inte är beroende av strömmande vatten för sin spridning och saknar ”strömbehovet” dvs snabbt näringsupptag för sin tillväxt. Den isbildning som bildas skrapar bort algvegetationen vissa delar av året och ger därmed minskad tillväxt.

The River Ammerån at Vårv located between site 3 and 7 in Fig 2. Foto: Pelles Fiske.

Introduction

The Ammerån was designated as a nature reserve and Natura 2000 area in 2003 after the Edeforsen power plant was demolished in 2002. The biodiversity is high both in terms of bottom animals and attached algae. The river is also a paradise for anglers as it is varied and alternating with strong currents, huge rapids and riverlakes (sel) which provides many habitats. The bedrock is rich in lime which also provides a special flora and fauna and resistance to acidification.

Why publish data from historical studies?

Older data from inventories can very well be used for follow-up and evaluation if sampling methodology and species determinations are documented and external disturbances are known. In the case of the Ammerån, it is particularly interesting because the river has been protected by law (nature reserve and Natura 2000 area) since 2003. The Ammerån would also be designated as a natural heritage and given even more status as a medium-sized pristine river. It could in the future constitute a valuable reference for the restoration of flowing water, such as when removing dams.

The study of algal vegetation of the Ammerån was initiated by the plans of building a tunnel from this water course into the larger River Indalsälven during the late 1980s, in order to increase the discharge to the two hydro-power stations there. The objective was to investigate the algal flora and discuss the possible impacts of the suggested changes. The tunnel has not yet (2025) been built and the effects discussed below are still applicable.

A tunnel of 3,5 km was planned to be built from Överammer to the Indalsälven at Selsviken. The tunnel would be created in rock and have a capacity at maximum of 80 m^3/s. The planned electrical addition is almost 200GWh per year. The planned changed water discharge is shown in Fig. 1.

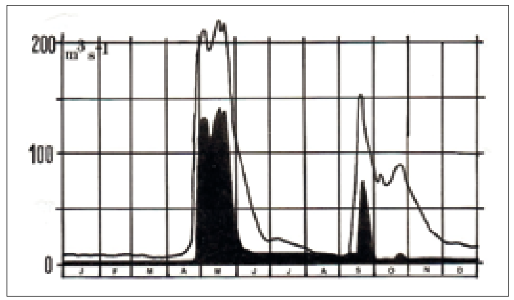

Fig. 1 Water discharge in the River Ammerån downstream Överammer 1983 – the discharge after the planned water-transfer in black.

Attached algae together with mosses are important primary producers in running waters especially in mountainous areas where phytoplankton and macrophytes are rare or absent. These algae constitute the whole primary production on which the heterotrophic organisms are dependent (besides allochtonous material). Attached algae consist of many different species of different features and shapes according to type of habitat.

Characteristic features of stream algae

Limnologists have long recognized that there are algae which grow best in torrents. This is believed to depend on a positive effect of current upon mineral uptake and respiration (Whitford 1960, Whitford & Schumacher 1961, 1964 and Schumacher & Whitford 1965). Microhabitat conditions and species-specific effects by current are related to size and growth habitats of cells (Stevenson 1983,Stevenson & Pan 1999, Rier & Stevenson 2002).

Algae living in fast-flowing waters have special qualifications, partly in order to remain attached to the substrate, and partly not to be torn into pieces by the current as follows.

1. The lattice type, which follows the movements of water, allowing it to percolate between algal branches; includes algae such as *Hydrurus*, *Batrachospermum*, *Draparnaldia*, *Stigeoclonium*, *Cladophora* and colony- forming diatoms such as *Didymosphenia* and *Cymbella*.

2. The cylindrical type, also waving along with water movements; includes algae such as *Tetraspora gelatinosa* and diatoms in gelatinous tubes such as *Cymbella ventricosa*.

3. The half-spherical compact type, which is resistant to water pressure; includes algae such as colonies of *Nostoc, Rivularia, Chaetophora* and *Audouinella*.

4. The disc or crust type, which is more flattened and pressed to the substrate than the foregoing type, with algae such as *Hildenbrandia, Heribaudiella, Coloechaete* and crustforming blue-green algae.

The groups correspond in principle to two basic mechanisms:

1. The large surface of the algal body is flexible or branched enough to become permeable to water. The friction is also reduced by excretion of jelly or gelatinous substances.

2. Reduced surface with a solid construction.

Between the above-mentioned groups there are transitional cases. Species which are particular oxygen- and nutrient demanding need a large surface of the body and are found in the lattice- or cylindrical type.

Also algae, which do not have special stages for passing the winter or cannot manage freezing in other ways are able to survive in fast-flowing water if not too shallow. Dispersal of algae with propagules which are non-motile is favoured by the running water, provided the propagules are able to attach themselves to suitable surfaces.

Macro- and microalgae (diatoms)

The algae have been divided into macro- and microalgae. This is based on the fact that macro-algae are visually conspicuous in the field while the micro algae can only be identified in the microscope. The macro algae in the Ammerån consist of blue-green algae, green algae and red algae, while the microalgae here are made up of diatoms. Despite the fact that the diatom Didymosphenia geminata is visible as tufts (the silica cell attached in jelly stalks) by eye it has been included in the micro algal part.

Species identification

The following main floras were used for identification of the algal species:

- Hustedt, F. 1930. Bacillariophyta (Diatomeae). 2. Aufl. Süsswass. - Flora Mittel-eur. 10:1-466.
- Geitler , L. 1939 - 1932. Cyanophyceae. - Rabenh. Kryptogamen-Flora Dtl. Öst. Schweiz 14:1-196
- Bourrelly, P. 1966. Les algues d´deau douce I - III Paris.
- Israelson, G. 1942. The freshwater Florideae of Sweden. Symbolae Botanicae Upsaliensis VI:1.

The identification of diatom species have changed over time. Nowadays new floras are available and some of the species in this study have changed names and/or have been split or compiled into new taxa.

The number of stream species

Ability to survive and grow in rapids and fast-flowing streams exists only in a relatively restricted number of species. Therefore, rapids often have few species especially of macro algae, often occurring in great amount.

The mean number of algal species is only nine based ona study from 500 streams in the Swedish county of Jämtland – including mostly rivulets in mountains and forests. In comparison, lowland streams in some parts of the above area can host hundreds of species at one sampling locality such as regulated reservoirs around 20 and river-lakes (Swedish sel) around 30. The Jämtland study (Johansson 1982) also identified the factors which are most decisive for presence or absence of algal species such as current velocity, concentrations of major ions (measured as conductivity), pH, altitude, exposure to light and size of stream (width, depth).

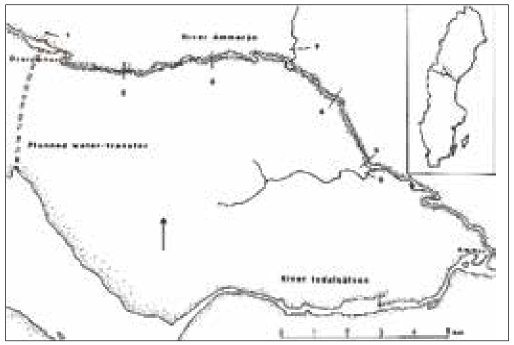

Fig. 2 Sampling sites:1 Springhällan (reference site about 50 km upstream Överammer), 2 Grundforsen, 3 Stor-klinsen, 4 Mettedet, 5 Olsforsen (500 downstream), 6 Ammerbäcken (tributary), 7 Färsån (tributary).

Methods

Data of the River Ammerån

The river is a middle-sized oligotrophic stream which earlier was used for log-floating and had therefore been channelized in some places. Fig 2 shows the location in Sweden and studied sites in the River Ammerån.

The high calcium values (Table 1) depend on the Cambro-Silurian bedrocks and soils posted further upstream, in the Hammerdal area by the two branches and a few tributaries in the river. In the lower reaches, including the studied part, the bed consists mainly of boulders of granites and gneisses, except site 5 where pieces of schist prevail.

Table 1 Hydro-chemical values measured at Skyttmon along the River Ammerån, monthly sampled, May 1986 - January 1987.

	mean	min	max
pH	7,54	6,96	7,86
Sum inorganic N (µg/l)	97	97	216
Total N (µg/l)	403	248	647
PO4-P (µg/l)	3	1	8
Total P (µg/l)	9	5	22
Calcium (mequiv/l)	0,909	0,537	1,045
Conductivity (mS/m2)	10,42	6,41	11,70

Sampling

In the littoral zone a quantitative method was used. The river was sampled 10-12 of September 1986. In mid-Sweden the algal community reaches maximal growth in august-september while one visit gives a good estimation of species composition. Sixty samples per locality were collected in order to reach 95% confidence limits of less than 20% of the mean value of chlorophyll a (Johansson 1980). The littoral zone reaches from the surface down to 0.5 m. The collection of the algae was performed as follows: 20 random samples of 2 cm^2 surface area were brushed off the stones by a sample apparatus (Fig. 3) and pooled in one litre of water. This is repeated 3 times and from each of the 3 pooled samples, one subsample of 25 ml was taken for analysis of algal volume (= 75 ml in total).

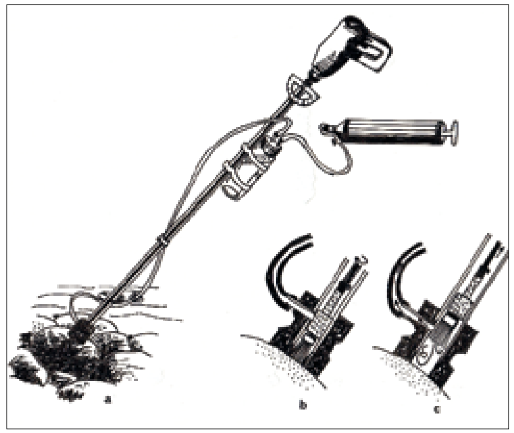

Fig. 3 Sampling equipment a) Sampling apparatus for attached algae on rocks and stones in rivers b) Brushing off the stones c) The algae suspended in the water are sucked into the bottle.

After sedimentation, the volume of each species was calculated according to geometric shapes (Edler 1979) from microscopic measurements. The volume/m^2 was converted to gram wet-weight/m^2 using a factor 1, although the diatoms are somewhat heavier than water. All algae sampled are assumed to be alive since the high velocity current will flush off any dead material.

On deeper bottom parts (> 0.50 m) a qualitative sampling approach was used: algae were scraped off from 10 stones into a bucket from which subsamples were taken. In the microscope the cover of the species was evaluated according to a 1-6 scale.

The sampling work was carried out 10-12 September 1986 while the summer flora still remained. The following sampling sites were chosen (Fig. 2): The Springhällarna (1) a reference site (50 km upstream the outlet of a planned transfer at Överammer). Further downstream were the Grundforsen (2), the Storklinsen (3), the Mettedet (4) and the Olsforsen (5) and two tributaries the Ammerbäcken (6) and the Färsån (7). The localities in the mainstream are all about 50 m wide sections with fast-flowing water on a bottom of cobbles. The tributary of Ammerbäcken is a small stream with high insolation while the Färsån is a shaded stream surrounded by dense spruce forest.

Sites 2-5 will be influenced by heavily reduced water discharge, current and turbulence, especially during spring and autumn, in case the transfer plan is carried out.

Results and discussion

Biomass

The main results concerning biomass (Fig. 4, tables 2-3) are:

- The biomass range, 4 g/m^2 – almost 100 g/m^2, which is similar to that in other oligotrophic rivers in Jämtland.
- The proportion of macroalgae contra diatoms varies from 9 to 79% with a mean of 44%.
- Sites 2 - 4 in the main channel have an algal biomass of around 40 g/m^2 and the macroalgal part is around 50%. These sites together with site 5 are those which would be influenced by the reduced water flow.

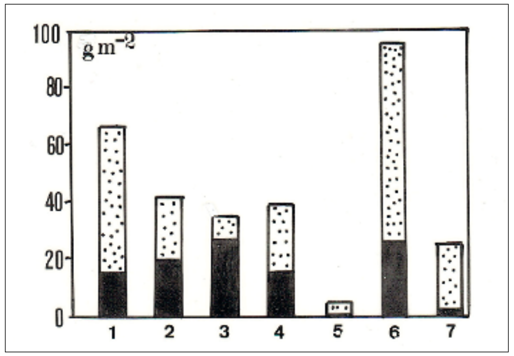

Fig. 4. Algal biomass at the sites 1-7 in the River Ammerån 1986. Black columns indicate macroalgae and dotted diatoms in g/m2. For site explanation see Fig. 2

The tributary Ammerbäcken (6) had the highest biomass (95.5 g/m^2) of all sites and was dominated by the diatoms. The rivulet was considered to constitute a likely estimate of future autumn conditions in a reduced Ammerån.The light conditions of the other tributary (site 5) was too low for such comparisons.

Biomass measurements in other northern Swedish water courses in late summer are all of the same magnitude as here in the Ammerån. For instance one comparable site in the River Kalixälven had a biomass of around 40 g/m^2, increasing from 10 g/m^2 in une to 40 g/m^2 in October 1986 (Johansson unpublished) and a small light exposed rivulet close to the mountains 150 km NW of the Ammerån had around 20 g/m^2 (Johansson 1980). Colonization studies in a river on Vancouver island (Stockner & Shortreed 1976), Ohio river (Reiter & Carlsson 1986) and in River Kalixälven (Johansson unpublished) showed developed biomasses between 10 and 25 g/ m^2 during an exposure time of 4 to 6 weeks. Biomass studies in montane running waters are fairly rare in the literature.

Reiter and Carlsson (1986) maintain the hypothesis that algal mat growth eventually creates a situation where the velocities near and within the algal mat (local velocities) become more or less independent of the free-water velocity. If applied to field conditions this would suggest that attached algal communities in a given stretch of a stream, if undisturbed, should be converging in terms of numbers, biomass and species composition. The above authors also remark that the degree of turbulence in natural waters is of great importance. The rapid changes in direction of flow, shear force and pressure caused by turbulent flow is important for the development of an algal pattern. The turbulence will be considerably reduced if the transfer takes place, especially at minimum flow. The watercourse will simply turn into a rill.

A possible scenario after the transfer has taken place will be a reduced current, discharge and turbulence which could be comparable to present conditions in the tributary of the Ammerbäcken (site 6) with a heavy biomass of the green alga *Ulothrix zonata* and the diatom *Synedra ulna*.

Species composition

The following features of the algal flora were:

- A typical running water macro flora occurred on sites 2-4 with the expected dominance of *Zygnema b, Tolypothrix distorta v. penicillata* and especially in deeper parts *Bulbochate spp.* and *Didymosphenia geminata*.
- Great amounts of typical torrential diatom species such as *Achnanthes minutissima v. cryptocephala, Cymbella affinis, Eunotia pectinalis, E. pectinalis v. minor, Navicula radiosa, Synedra ulna, Tabellaria fenestrata och T. flocculosa.*
- Species number was highest in the mainstream.

At the Springhällarna (site 1), 76% of the biomass consisted of diatoms (Table 2). Among these *Amphipleura pellucida*, *Synedra ulna* and its variety *danica* dominated with regard to wet-weight. *Achnanthes minutissima v. minutissima*, a small diatom, was however very frequent with 26 * 109 individuals per m^2. This implies that if these individuals, with 45 μm^2 surface area, were arranged side to side, they would cover the whole bottom as one cell-layer. The number of species at this site was twice as high as at the other sites, which possibly depends on the slow-flowing water upstream, and locally, where the samples were taken. Some large diatoms may derive from the river-lake located further upstream.

The Grundforsen (2), Storklinsen (3), Mettedet (4) and Olsforsen (5) sites are typical rapids with roughly 10 true stream species as follows:

- *Zygnema b* and *Mougeotia* a – two green algae dominating at all sites
- *Bulbochaetae spp.* also a green alga normally found in unregulated torrents, appeared at Mettedet (4).
- *Tolypothrix distorta v. penicillata* – a bluegreen alga - normally found in unregulated rivers – was found at all sites.
- Diatoms occurred in large quantities with species such as *Cymbella affinis*, *Diatoma elongatum*, *Tabellaria flocculosa* and *Didymosphenia geminata*.
- Macroalgae made up a relatively large part (around 50%) of the total biomass at these sites, which is normal for undisturbed torrents with high turbulence.

The Ammerbäcken tributary (6) had 10 species where the diatom *Synedra ulna* made up half of the biomass. The green alga *Ulothrix zonata* made up 25% and *Didymosphenia geminata* 16%. The latter is a diatom with gelatinous stalk, on top of which the algal silica-enclosed cell is attached. This alga creates cm-long tufts on river bottoms, often downstream of regulated surface-released reservoirs. This often causes severe problems for fishing when torn-off pieces of the alga get stuck in the nets or filling up spaces between stones on the bottoms.

The Färsån (7), which runs through dense spruce forest, with a bottom substrate of partly moss-coated rocks and partly algal vegetation made up almost exclusively of diatoms. This is normal for relatively small, shaded rivulets in coniferous forests in Scandinavia. *Eunotia-species* are normally found in large quantities in acid streams (Round 1960, Sheath et al 1982) and the above mentioned Diatoma in cold, northern streams (Johansson 1982).

The species structure in the River Ammerån coincides with that which is normally expected in medium- sized rivers with moderate or high current velocity and with stone bottom in the middle of Sweden (Quennerstedt 1965). From the investigation in this part of Sweden (Johansson 1982), rivers with habitat factors comparable with those in the River Ammerån showed a conspicuous flora of green algae such as *Bulbochaete, Zygnema, Mougeotia* and *Microspora* (in different proportions in different rivers) which was found in the present river. In addition a myriad of diatom cells of genera such as *Tabellaria, Achnanthes, Eunotia, Fragilaria* and *Cymbella* were attached to the

artikel

Table 2. Algal biomass per site
1 Springhällan, 2 Grundforsen, 3 Stor-klinsen, 4 Mettedet,5 Olsforsen, 6 Ammerbäcken, 7 Färsån (d=deep zone, cover 1-6)

Biomass (g/m²)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**2d**	**3d**	**4d**	**5d**
Tolypothrix distorta v. penicillata	-	0,9	-	0,3	0,2	-	-	6	-	-	-
Chamaesiphon spp.	-	-	0,1	-	-	-	-	-	-	-	-
Nostoc parmelioides	-	-	-	-	-	-	-	3	-	-	-
Ulothrix zonata	-	-	-	-	-	24	-	-	-	-	-
Microspora palustris v. minor	-	-	-	-	-	-	-	2	-	-	-
Bulbochaete spp.	1,9	-	-	1,5	-	-	-	3	6	-	2
Zygnema b	-	19	27	12	-	-	-	-	2	-	-
Mougeotia a	14	0,6	0,7	1,3	0,2	0,5	1,6	-	3	-	-
Batrachospermum moniliforme	-	-	-	-	-	-	-	-	2	-	-
Lemanea fluviatilis	-	-	-	-	-	1,6	-	-	-	-	-
Achnanthes minutissima v. cryptocephala	2,3	-	0,3	-	-	0,4	0,2	1	4	4	-
Achnanthes pelucida	6,8	-	-	-	1,4	-	-	2	-	-	-
Anomoeoneis exilis	0,9	0,3	-	-	-	-	-	-	1	-	-
Ceratoneis arcus v. linearis	-	-	-	-	-	1,1	-	-	-	-	1
Cocconeis placentula v. euglypta	-	0,1	-	-	-	-	-	-	-	-	1
Cymbella affinis	4,1	3,4	0,2	2	1,7	2	-	2	-	4	3
C. cesatii	1	-	-	-	-	-	-	-	-	1	-
C. cuspidata	-	0,8	-	-	-	-	-	-	-	-	-
C. cymbiformis	2,1	-	-	-	-	-	-	-	-	-	-
C. lanceolata	-	-	0,3	-	-	-	-	2	-	-	-
C. microcephala	0,4	-	-	-	0,1	-	-	3	-	-	-
C. prostrata	-	-	-	-	-	-	-	1	-	-	-
C. proxima	-	-	-	-	-	-	-	-	1	-	-
C. ventricosa	-	-	-	-	-	-	-	1	1	-	1
Denticula tenuis								1			
Diatoma elongatum	4,7	-	0,3	1,4	-	-	-	-	-	-	-
D. elongatum v. tenuis	0,4	-	-	-	-	0,4	2,4	-	-	2	-
Didymosphenia geminata	-	-	-	13	-	16	-	2	4	2	-
Epithemia argus	-	-	-	-	-	-	-	2	2	-	-
Eunotia arcus	-	-	-	-	-		-	-	-	-	- 2
E. pectinalis	-	-	-	-	-	-	5,6	-	2	3	2
E. pectinalis v. minuta	-	-	-	2,5	-	-	2,1	3	-	2	2
E. praerupta	3,1	-	-	-	-	-	-	-	-	-	-
Fragilaria crotonensis	2,3	-	-	-	-	-	-	-	-	-	-
F. intermedia	-	-	-	-	-	-	0,1	-	-	-	-
F. construens v. venter	0,1	-	-	-	-	-	-	-	-	-	-
Frustulia rhomboides v. saxonica	-	-	-	-	-	-	-	1	-	-	-
Gomphonema acuminatum v. brebissonii	-	-	-	-	-	-	-	-	2	-	-
G. constrictum	-	-	-	-	-	-	-	-	1	-	-
G. intricatum	-	0,2	-	-	-	-	-	1	-	-	-
G. intricatum v. pumila	-	-	-	-	-	-	-	1	-	-	-
G. longiceps v. subclavata	-	0,6	0,3	-	-	-	-	2	-	-	1
G. parvulum	0,5	-	-	-	-	-	-	-	-	-	-
Gyrosigma acuminatum	-	1,4	-	-	-	-	-	-	-	-	-
Navicula radiosa	-	-	-	-	-	-	-	2	1	-	2
N. pupula	0,2	-	-	-	-	-	-	-	-	-	-
Nitzschia dissipata	-	-	-	-	-	-	-	1	-	-	-
N. liniaris	0,6	-	-	-	-	-	-	-	-	-	1
N. romana	1	-	-	-	-	-	0,1	-	-	-	-
Pinnularia appendiculata	-	-	-	-	-	-	-	-	-	-	2
Rhopalodia gibba	-	-	-	-	-	-	-	3	2	-	-
Synedra rumpens	1,9	-	-	-	-	-	-	-	-	-	-
S. ulna	6,3	2,6	-	3,2	0,7	49	8,5	2	4	3	2
S. ulna v. danica	6,3	-	-	-	-	-	-	-	-	-	-
Tabellaria fenestrata	1,9	-	1,7	-	-	-	-	3	2	-	2
T. flocculosa	3,7	12	3,7	0,5	-	0,4	3,7	-	3	-	2
Sum g/m² alt cover	**67**	**42**	**34**	**38**	**4,3**	**96**	**24**	**50**	**43**	**21**	**26**

artikel

boulders underneath the green algae or more seldom as epiphytes on some of them.

At an inventory of the River Råneälven, which is the same size as the River Ammerån but further north in Sweden, the above mentioned *Bulbochaete* community was striking also here, being especially developed in great amounts downstream of Mårdsel (Johansson unpublished). In other rivers in Scandinavia the same torrential algal flora has been recognised such as the River Altaälven before the regulation (Lindstrøm 1983), the River Trysilälven (Johansson 1982) and the River Namsen (Johansson 1983).

The same stream genera and many species are also found in unregulated rivers in other countries and continents under similar surrounding conditions such as Carnation Creek (Stockner & Shortreed 1976), other Canadian rivers (Charlton & Hickman 1986), brooks in the Tatra mountains (Kawecka 1986), Greenland streams (Johansson 1980, Kawecka & Leo 1985) and Austrian streams where the blue-green algae dominated (Kann 1943, 1966, 1978).

Consequences of a water-transfer

The main physical changes are:

- Reduced mean depth from above 1 m to 0.2 m during summer time, while during winter time from 0.5 m to deep frozen circumstances.
- Reduced mean width of riverbasin from 10 - 15 m to about 2 m during summer.
- Reduced discharge from 75 m³/s to 2 m³/s during spring and automne.

The impacts on algal vegetation is expected as follows:

- The algal vegetation will be reduced (as the water course itself).
- Algae such as *Tolypothix distorta v. penicillata, Bulbochate spp.* and *Zygnema b* will probably be reduced or become extinct.
- The colonisation of diatoms during autumn will stop due to the abruptly lowered discharge.
- A heavy growth of *Spirogyra spp.* and *Ulothrix spp.* would probably occur in late summer. Oxygen depletion would probably occur during late summer.

The proposed reduction of discharge, which is especially drastic during autumn and early spring, leads to lowered current velocity, turbulence, depth and water volume, and in winter to more drastic effects of freezing. In short: a much smaller watercourse.

The result will be a switch to an attached algal community similar to that normally found in brooks, in this case probably very alike the algal flora in the tributary of the Ammerbäcken. Algal species which probably in this case will be reduced or become extinct are macro algae such as the blue-green alga *Tolypothrix distorta v. penicillata* and the green algae *Bulbochaete spp.* and *Zygnema b*. The species number will also be reduced accordingly.

The normally successive decrease of water discharge during late autumn (Fig. 1) is suggested to be abruptly reduced from 75 m³/s to almost 2 m³/s in less than a month and earlier than natural. The normal build-up of the diatom community is reduced since the water level and consequently the area for colonisation is reduced by 2/3 of natural – up to 30% of either side of the littoral zones along the river will be dried out.

The riverine species will probably be replaced by species favoured by slow-flowing water, which are not dependent on running water for their dispersal and do not have the ”current demand” (= quick nutrient supply) for growth.

There is also a risk that green algae such as *Spirogyra* and *Ulothrix* can grow very heavily during summer and the small pools in between stones and boulders will become choked up.

Under natural conditions diatoms are capable of with-standing a certain degree of ice-scouring, since recovery takes place rather fast (Muller-Haeckel & Håkansson 1978, Stevenson 1983). The damage will be more prevalent at the very reduced low-flow suggested, and perennials, such as red algae, probably cannot survive under such circumstances.

One very important fact that should be taken into consideration is that undisturbed rivers of this size are very rare in Scandinavia and should remain undisturbed in the future.

Table 3 Species list with author names of attached algae from the sampling 10-12 September 1986.

CYANOPHYTA
Tolypothrix distorta f. penicillata (Ag. Koss.
Chamaesiphon spp.
Nostoc parmelioides Kütz.

CHLOROPHYTA
Ulothrix zonata (Web. et Mohr) Kütz.
Microspora palustris v. minor Wichm.
Bulbochaete spp.
Mougeotia a (Israelson 1949)

BACILLARIOPHYTA
Achnanthes minutissima v. cryptocephala Kütz.
Amphipleura pellucida Kütz.
Anomoeoneis exilis (Kütz.) Cleve
Ceratoneis arcus v. linearis Holmboe
Cocconeis placentula v. euglypta (Ehr.) Grun.
Cymbella affinis Kütz.
C. cesatii (Rab.) Grun.
C. cuspidata Kütz.
C. cymbiformis Ag.
C. lanceolata (Ag.) Ag.
C. microcephala Grun.
C. prostrata (Berk.) Grun.
C. proxima Reim.
C. ventricosa Ag.
Denticula tenuis Kütz.
Diatoma elongatum (Lyngb.) Ag.
D. elongatum v. tenuis (Ag.) Kütz.
Didymosphenia geminata (Lyngb.) M. Schmidt
Epithemia argus (Ehr.) Kütz.
Eunotia arcus Ehr.
E. pectinalis (Dillw. Kütz.) Rab.
E. pectinalis v. minor (Kütz.) Rab.
E. praerupta Ehr.
Fragilaria crotonensis Kitton
F. intermedia Grun.
F. construens v. venter (Ehr.) Grun.
Frustulia rhomboides v. saxonica (Rab.)de Toni
Gomphonema acuminatum v. brebissonii (Kütz.) Grun.
G. constrictum Ehr.
G. intricatum Kütz.
G. intricatum v. pumila Grun.
G. longiceps v. subclavata Grun.
G. parvulum (Kütz.) Kütz.
Gyrosigma acuminatum (Kütz.) Rab.
Navicula radiosa Kütz.
N. pupula Kütz.
Nitzschia dissipata (Kütz.) Grun.
N. linearis W. Smith
N. romana Grun.
Pinnularia appendiculata (Ag.) Cleve
Rhoplodia gibba (Ehr.) O. Müll
Synedra rumpens Kütz.
S. ulna (Nitz.) Ehr.
S. ulna v. danica (Kütz.) Grun.
Tabellaria fenestrata (Lyngb.) Kütz.
T. flocculosa (Roth) Kütz.U.

References

Brittain, J., Lillehammer, A. & R. Bildeng 1984. The impact of a water transfer scheme on the benthic macroinvertebrats of a Norwegian river 189 - 199. - In: Regulated rivers, A. Lillehammer & S.J. Saltveit (eds).

Charlton, S.E.D. & M. Hickman 1984. Seasonal physical and algal changes in five rivers flowing through the oil sands region of Alberta, Canada. - Int. Revue ges Hydrobiol. 69:297 - 332.

Edler, L. (ed.) 1979. Recommendations for marine biological studies in the Baltic Sea. Phytoplankton and chlorophyll. - The Baltic marine biologists 5:1-38.

Johansson, C. 1980. Attached algal vegetation in two stony streams in NW Jämtland, Sweden. - Medd. Växtbiol. inst. 1:1-15.

Johansson, C. 1980. Attached algal vegetation in some streams from the Narsaq area, South Greenland. - Acta phytogeogr. suecica. 68:89-96.

Johansson, C. 1982. Attached algal vegetation in running waters of Jämtland, Sweden. - Acta phytogeogr. suecica 71:1-84.

Johansson, C. 1983. Namsen vassdraget. Bentiske alger. - Report NIVA 113/83:63-77.

Kann, E. 1943. Krustenalgen in Alpenbächen. - Arch. Hydrobiol. 40: 459-473.

Kann, E. 1966. Der Algenaufwuchs in einigen Bächen Österreichs. - Verh. Int. Ver. Limnol. 16:646-654.

Kann, E. 1978. Systematik und Ökologie der Algen österreichischer Bergbäche. - Arch. Hydrobiol. Suppl. 53: 405-643.

Kawecka, B. 1985. Ecological characteristics of sessile algal communities in the Olsyski stream (Tatra mts, Poland) with special consideration of light and temperature. - Acta Hydrobiol. 27:299-310.

Kawecka, B. & J. W. Leo 1985. Diatom communities in some streams of Southern Greenland. - Acta Hydrobiol. 27:311-319.

Müller-Haeckel, A. & H-L Håkansson 1978. The diatom-flora of a small stream near Abisko (Swedish Lapland) and its annual periodicity, judged by drift and colonization. - Arch. Hydrobiol. 84:199-217.

Quennerstedt, N. 1965. The major rivers of northern Sweden. - Acta phytogeogr. suecica 50:198-204.

Reiter, M.A. & R.E. Carlsson 1986. Current velocity in streams and the composition of benthic algal mats. - Can J. Fish. Aquat. Sci. 43:1156-1162.

Rier, S. T. and R. J. Stevenson. 2002. Effects of light, dissolved organic carbon, and inorganic nutrients on the relationship between algae and heterotrophic bacteria in stream periphyton. Hydrobiologia 489:179-184.

Round, F.E. 1960. A note on the diatom flora of some springs in Malham Tarn area of Yorkshire. - Arch. Protistenkunde 104:515-526.

Schumacher, G.I. & L.A. Whitford 1965. Respiration and p-32 uptake in various species of freshwater algae as affected by a current. - J. Phycol. 1:78-80.

Sheath, R.G., Havas, M., Hellebust, J.A. & T.C. Hutchinsson 1982. Effects of long-term natural acidification of the algal communities of tundra ponds at the Smoking hills, N.W.T. Canada. - Can. J. Botany 60:58-72.

Stevenson, R.J. 1983. Effects of current and conditions simulating autogenically changing microhabitats on benthic diatom immigration. - Ecology 64:1514-1524.

Stevenson, R. J. and Y. Pan. 1999. Assessing ecological conditions in rivers and streams with diatoms. In: E. F. Stoermer and J. P. Smol, eds. The Diatoms: Applications to the Environmental and Earth Sciences. Pp. 11-40. Cambridge University Press, Cambridge, UK.

Stockner, J.G. & K.R.S. Shortreed 1976. Autotrophic production in Carnation Creek, a coastal rainforest stream on Vancouver Island, British Columbia. - J. Fish. Res. Board Can. 33:1553-1563.

Welsh, P.S. 1952. Limnology 538 pp. New York

Whitford, L.A. 1969. The current effect and growth of freshwater algae. - Trans. Am. Microscope. Soc. 79:302-39.

Whitford, L.A. & G.D. Schumacher 1961. Effect of current on mineral uptake and respiration by freshwater alga. - Limnol. Oceanogr. 6:423-425.

Whitford, L.A. & G.J. Schumacher 1964. Effect of a current on respiration and mineral uptake in Spirogyra and Oedogonium. - Ecology 45:168-170.

Skyfallsmodellering i Fluidit Storm och MIKE+ – En jämförande studie av de två programvarorna

Cloudburst modeling in Fluidit Storm and MIKE – A comparative study of the two software

Frida Wistfors
Hållbar utveckling, miljövetenskap och teknik, Skolan för arkitektur och samhällsbyggnad (ABE), KTH

Sammanfattning

Denna studie presenterar en jämförande analys av skyfallsmodelleringsprogrammen MIKE+ och Fluidit Storm, med fokus på deras hydrauliska resultat, ekvationer och numeriska lösningar. Båda programvarorna genererar dynamiska skyfallsmodeller, men deras metoder för ytavrinning skiljer sig avsevärt. MIKE+ använder "Shallow Water Equations" där massa och rörelsemängd bevaras, medan Fluidit Storm tillämpar en cellular automata-metod baserad på Mannings och kritiska flödesekvationer. För 1D-flöde använder båda programmen St. Venants ekvationer och ger liknande resultat.

Jämförelsen mellan modellerna gjordes för tre studieområden varav två presenteras i denna artikel. Betydande variationer i vattendjup och hastighetsfördelning noterades, där MIKE+ uppvisade mer koncentrerade hastighetsmönster och snabbare vattenrörelse, medan Fluidit Storm visade på mer utspridda hastigheter och där en större mängd vatten fanns kvar i modellområdet efter simuleringen slut. Studien tyder på att skillnaderna i resultat beror på ekvationerna och de numeriska metoderna de två programvarornas använder.

MIKE+ ger mer fysikaliskt representativa flödesvägar, medan Fluidit Storm kan användas för snabba, dynamiska översvämningsbedömningar med lägre beräkningskostnader. Valet mellan de två programvarorna bör därför baseras på modellens syfte och den önskade nivån av hydraulisk detaljering.

Nyckelord: Skyfallsmodellering, ytavrinning, dagvattenledningsnät, ekvationer och numeriska lösningar

Abstract

This study presents a comparative analysis of the cloudburst modeling software MIKE+ and Fluidit Storm, focusing on their hydraulic results, governing equations and numerical solutions. Both software simulate dynamic cloudburst events, but their approaches to 2D overland flow modeling differ significantly. MIKE+ employs shallow water equations that account for mass and momentum, whereas Fluidit Storm utilizes a cellular automata method based on Manning's and critical flow equations. For 1D pipe flow, both software apply the St. Venant equations, leading to similar results.

The comparison, conducted across three study areas, whereas two are presented in this article, revealed