Clean 2008, *36* (1), 84 – 91

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Research Article

Biodiversity in the Benthic Diatom Community in the Upper River Töss Reflected in Water Quality Indices

Biodiversity in benthic diatom communities was determined to assess the ecological state and to evaluate changes in water quality in time and space in the prealpine part of the river Töss (Switzerland). One site upstream and three sites downstream from the inlet of a communal waste water treatment plant (WWTP) were analyzed during 1996/97. In total, 67 diatom species were detected and the relative abundance of each taxon determined. The Shannon Diversity Index and the Saprobic Index were calculated and related to the newly developed Swiss Trophic Diatom Index. Dominant species belonged to the genera *Achnanthes*, *Amphora*, *Cymbella*, *Diatoma*, *Gomphonema*, *Navicula*, and *Nitzschia*. The species composition and the abundance of the diatom species present varied over the seasons, but changes in the chemical parameters or the flow regime had little effect. The Shannon Index gave evidence of biodiversity variations over the seasons and some differences between sampling sites. The Saprobic Index oscillated within a small band, indicative for oligo-mesosaprobic conditions. It could not identify significant changes in water quality between sampling sites and over the seasons. The Swiss Trophic Diatom Index differentiated better between sampling sites and seasons and gave values corresponding to a β-mesosaprobic state. Preliminary data from 2005 and 2006 give no evidence of a change in water quality during the last decade.

Keywords: Töss; Biodiversity; Swiss Trophic Diatom Index; Saprobic Index; Shannon Diversity Index; Wastewater Treatment Plant

Received: May 22, 2007; *revised:* September 7, 2007; *accepted:* October 17, 2007

DOI: 10.1002/clen.200700053

1 Introduction

Biomonitoring is the use of organisms to assess or monitor environmental conditions. The response of a population to changes in an ecosystem is mostly reflected by the species composition and their abundance. In rivers with varying impacts from agriculture and urban pollution and a highly variable flow regime, the organic and inorganic substances often rapidly undergo massive fluctuations; thus, common planned physical and chemical monitoring will only show a momentary state of the water body and cannot reflect the current highly dynamic environmental situation, which strongly determines the water organisms present. In contrast, the response of the biota to environmental factors summarizes both short- and long-term influences [1]. Biomonitoring techniques have been known for 100 years [2] and have been used in running waters to obtain information on the effects of pollution by waste waters or from the runoff from fertilized agricultural land on the biota. The results allow planning investment priorities for water conservation rules for the disposal of sewage effluents to fresh-waters.

Benthic biofilms are dominant riverine biota and relatively stable communities. They summarize the response of biota to physical factors (e.g., runoff, temperature) and the means as well as the extremes of the pollutants occurring in rivers over time [1, 3]. A variety of taxonomic groups may be used as in situ biomonitors in rivers. Such organisms should be simple in structure, easy to recognize and to determine. The species of a favorable taxonomic group occupy all water covered substrates of the river and are present during the whole year. Some of them should react sensitively to changes in concentrations of inorganic plant nutrients as well as of organic pollutants [1]. Diatoms fulfill these prerequisites, they are ubiquitous in lakes and rivers and frequent in the euphotic benthic zone throughout the year. Diatoms are abundant and the most species-rich primary producers in rivers, living in almost all habitats from the source to the mouth [1, 4]. They have a short lifecycle and rapidly follow environmental changes. Due to their siliceous cell wall, they are easily sampled and preserved, hence providing a permanent record which allows the assessment of short or long term changes. Furthermore, an excellent literature is available for species determination. Several studies have clearly demonstrated that diatom communities change with increasing concentrations of both organic and inorganic load of substances, making them the preferred organismic group for in situ biomonitoring studies in Europe, the US and Asia [5 – 16].

To quantify water quality conditions, various indices have been calculated on the basis of nutrient preferences and relative frequencies of the full range of diatom species present, such as the Swiss Trophic Diatom Index [14, 15], the Generic Diatom Index (GDI) [17], and the Saprobic Index [18]. All these indices have been found to be

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Abbreviations: a.s.l., above sea level; **DI-CH**, Swiss Trophic Diatom Index; **SI**, Saprobic Index; **WWTP**, waste water treatment plant good measures to quantify the changes in saprobity or trophy along a river [11, 19, 20]. Transfer functions relate community data to measured environmental physical and chemical factors. They include the tolerance of a species towards specific stressors. It has been pointed out that diatom-based water quality indices and the corresponding transfer functions seem to be geographically restricted and inaccurate in other regions, furthermore, species distribution between rivers may differ [21]. Thus for Swiss rivers, the Swiss Trophic Diatom Index [22] has been established over the last decade. This is the first published work using it and comparing it with other quality measures.

This report describes the analyses of the diatom population from a one-year sampling period 10 years ago in the prealpine river Töss near a waste water treatment plant (WWTP) to study the water quality within a relative short distance during the self-purification process. The variation of the diatom population between sites and seasons is quantified by calculating different indices to evaluate their value for monitoring the relatively clean water of the river Töss.

2 Material and Methods

2.1 Study Site

The Töss is a prealpine river without retention basins within the drainage area, and therefore, with a highly variable flow regime. High flow rates are usually the result of snow melting in spring and long lasting rainfall in late autumn. Low flow periods occur both in summer and in winter. Because of a permeable gravel-bed and a low ground water table in the area of sampling, large parts of the stream water infiltrate. The riverbed was regulated at the beginning of the 20th century to protect the valley from flooding. Gravel banks narrow the channel and lead to an average low flow width of 15 m. The sampling region was near Saland-Bauma about 25 km northeast of Zürich, Switzerland, at 621 m a.s.l. In this region, the Töss collects the effluent from the local waste water treatment plant (WWTP) and occasionally becomes polluted by combined sewer overflows from the villages of Bauma and Saland. The inlet site of the WWTP is at the Swiss coordinates 707′740/247′960 (Schweiz. Landeskarte). The WWTP went into operation in 1969 and additional purification steps were added 1996. It is an activated sludge plant (5000 inhabitant equivalents), nitrifying nearly completely during high temperature periods but only partially in winter.

Diatoms were sampled at 4 sites: sampling station 1 (= 0 m) just upstream of the inlet of the WWTP); station 2 (= 300 m downstream); station 3 (=900 m downstream) and station 4 (= 1500 m downstream). Water quality was monitored automatically at station 2 and station 4. Sampling and monitoring of the physical and chemical parameters were performed between 1996 and 1997 by Jancarkova [23]. The environmental conditions change along the 4 sites. Stations 1 and 2 are exposed and receive full sunlight during the whole day. Between stations 2 and 4 the valley narrows and trees at the riverside limit the exposure of the riverbed to the sun. Station 4 stays in the shadow nearly the full day, except for a short time in the morning. The water velocity is similar at the 4 sampling sites.

2.2 Sample Collection and Preparation of Slides

Diatoms were sampled by scraping the upper surface of selected rocks from riffle sections of the river with a toothbrush and the resulting suspensions collected and preserved in 4% formaldehyde [10, 22, 24]. The cleaning of diatom frustules from organic material and mounting the residues on slides was done as described by Krammer and Lange-Bertalot [25]. About 500 valves per slide were counted using 100 × oil immersion, yielding a 95% confidence for the data on species composition [10, 24, 26]. Diatoms were identified using standard literature [25, 27 – 30].

2.3 Data Analysis

On the basis of the quantitative data obtained and the indicator value of each species the Shannon Diversity Index, H' [31], the Saprobic Index, SI [18], and the Swiss Trophic Diatom Index, DI-CH [22] were calculated. While the Shannon Diversity Index H' and the Saprobic Index SI are widely present in the literature, this is the first report on a monitoring using the DI-CH. The Swiss law for the protection of waters (Gewässerschutzgesetz, GSchG) of 1991 and the corresponding decree for the protection of waters (Gewässerschutzverordnung, GSchV) of 1998 ask for a full protection of the waters and their manifold functions as well as their sustainable use. To evaluate running waters in Switzerland, the DI-CH has been developed on the basis of over 1600 biologically and chemically characterized samples by the Federal Office for the Environment. In 2002, a first draft was published on the Internet (www.umwelt-schweiz.ch/imperia/md/content/gefisch/oberflaech/diatomeen_d.pdf), and a printed version is expected in 2007 (www.modul-stufen-konzept.ch/download/diatomeen_d.pdf). From the indicator value D_i (not polluted to highly polluted water, or nutrient poor to high nutrient concentration), species specificity G_i and relative frequency H_i of each species i, DI-CH for a diatom community of a study site is calculated as:

$$DI\text{-}CH = \frac{\sum_{i=1}^{n} D_i G_i H_i}{\sum_{i=1}^{n} G_i H_i} \qquad (1)$$

The values are correlated to the known trophic and saprobic classes, respectively (see Tab. 1).

3 Results

3.1 Ecological Description of the Sampling Sites

In the region of Saland, the riverbed of the Töss has a width of 8 to 12 m. The 4 sampling sites were exposed to heterogeneous light conditions as described in Section 2 "Material and Methods". Figure 1 shows the runoff (flow rates) during the period 1996/97. In dry weather periods, the flow rate can be as low as 0.1 m^3/s (November 12th, 1995) but can reach up to 20 m^3/s a few days later (November 17th, 1995). At high rainfall events in the catchment area, values of up to 30 m^3/s were occasionally observed (September 28th, 1995, July 8th, 1996). During the sampling period between September 1996 and August 1997, except for short peak periods during rainfall, the flow remained below 10 m^3/s. Such flow rates have no influence on the benthic biofilms, but those greater than about 18 m^3/s resulted in a massive loss of biofilm biomass as the gravel in the river bed started moving downstream [23]. Such an event occurred only once during the sampling period, on July 6th. The 10 m^3/s mark was reached several times, especially frequently in June and July.

Table 1. Comparison between the Swiss Trophic Diatom Index (DI-CH) and the Saproby Classes [15, 18], adapted from [22].

Class	Scale of the Swiss Diatom Index (DI-CH, [22])		Scale of the Saprobic Index , SI [15, 18]		Description of the pollution
1	1.0 – 1.49	zero to slightly polluted	<1.3	oligosaprobic	None
2	1.5 – 2.49		1.4 – 1.7	oligo-β-mesosaprobic	little
3	2.5 – 3.49		1.8 – 2.1	β-mesosaprobic	moderate
4	3.5 – 4.49	moderately polluted	2.2 – 2.5	α-β-mesosaprobic	fair
5	4.5 – 5.49	obviously polluted	2.6 – 3.0	α-mesosaprobic	obvious
6	5.5 – 6.49	heavily to massively polluted	3.1 – 3.4	α-meso-polysaprobic	heavy
7	6.5 – 7.49		>3.5	polysaprobic	strong to very strong
8	7.5 – 8.0				

Table 2. Semi-quantitative characterization of the biofilm composition at station 2 (bright light) and station 4 (shadow). The frequency of individual species has been estimated visually as: x- low, xx- middle, xxx- high, xxxx- very high density (from [23]).

	Algal community at station 2	Frequency	Algal community at station 4	Frequency
31.10.1996	*Cladophora glomerata*	xxxx	Diatom biofilms	xx
	Cocconeis and *Achnanthes*, both epiphytic on *Cladophora*	x	*Cladophora glomerata*	x
			Homoeothrix sp.	xxx
27.01.1997	*Cladophora glomerata*	xxx		
	Cocconeis and *Achnanthes*, both epiphytic on *Cladophora*	xxx		
	Diatom biofilms	xxx		
	Bacterial filaments (epiphytic)	xxx		
	Homoeothrix sp.	xx/x		
	Phormidium sp.	x		
	Hydrurus foetidus	x		
21.04.1997	*Vaucheria* sp.	xxxx	Diatom biofilms	xx/x
	Diatom biofilms	xxx	*Hydrurus foetidus*	xxx
	Cladophora glomerata	xx	*Phormidium autumnale*	x
	Phormidium autumnale	xx	*Homoeothrix sp.*	xx/x
11.06.1997	Diatom biofilms	xxx	Diatom biofilms	xx
	Cladophora glomerata	xxxx	*Cladophora glomerata*	x
	Chamaesiphon sp. (epiphytic)	xx	*Chamaesiphon sp. (epiphytic)*	xx/x

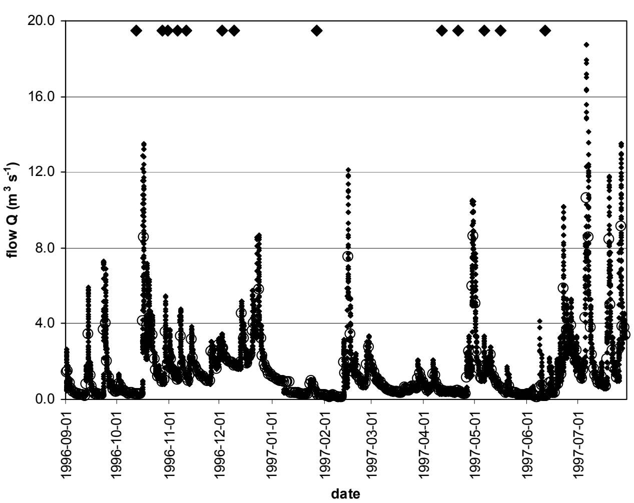

Figure 1. Hydrology (flow rate) of the Töss river during the sampling period 1996/97. Data show 30 min interval measurements (closed small squares) and daily mean values (open circles). Sampling days are marked on the top (closed squares).

Various algae covered rocks and gravel in the riverbed, forming extended biofilms. Table 2 gives a semi-quantitative overview of the dominant phototrophic organisms. The visually most dominant algal species at sites receiving high light was the filamentous green alga *Cladophora glomerata*, forming green patches on large rocks. Brown diatom biofilms fully covered the upper side of small rocks and gravel, but also lived epiphytically on *Cladophora* filaments [23]. The most frequent diatom genera in the Töss were *Achnanthes* sp. and *Gomphonema* sp. (see Tab. 3). These diatoms dominated in all samples of all 4 sites. Based on ash-free dry weight, the biomass at station 2 was estimated to be about 11 times higher than at station 4, due to the different light input. Such differences between the sites became even more pronounced during a two-month low-flow period starting at the beginning of May 1997 [23].

3.2 Physico-Chemical Parameters and Nitrogen Concentrations in the River Töss

Monthly mean values of the 6 parameters measured at station 2 and station 4 resulted in small fluctuations for pH and conductivity. The pH stayed within 8.4 and 8.7, the conductivity between 475 and 525

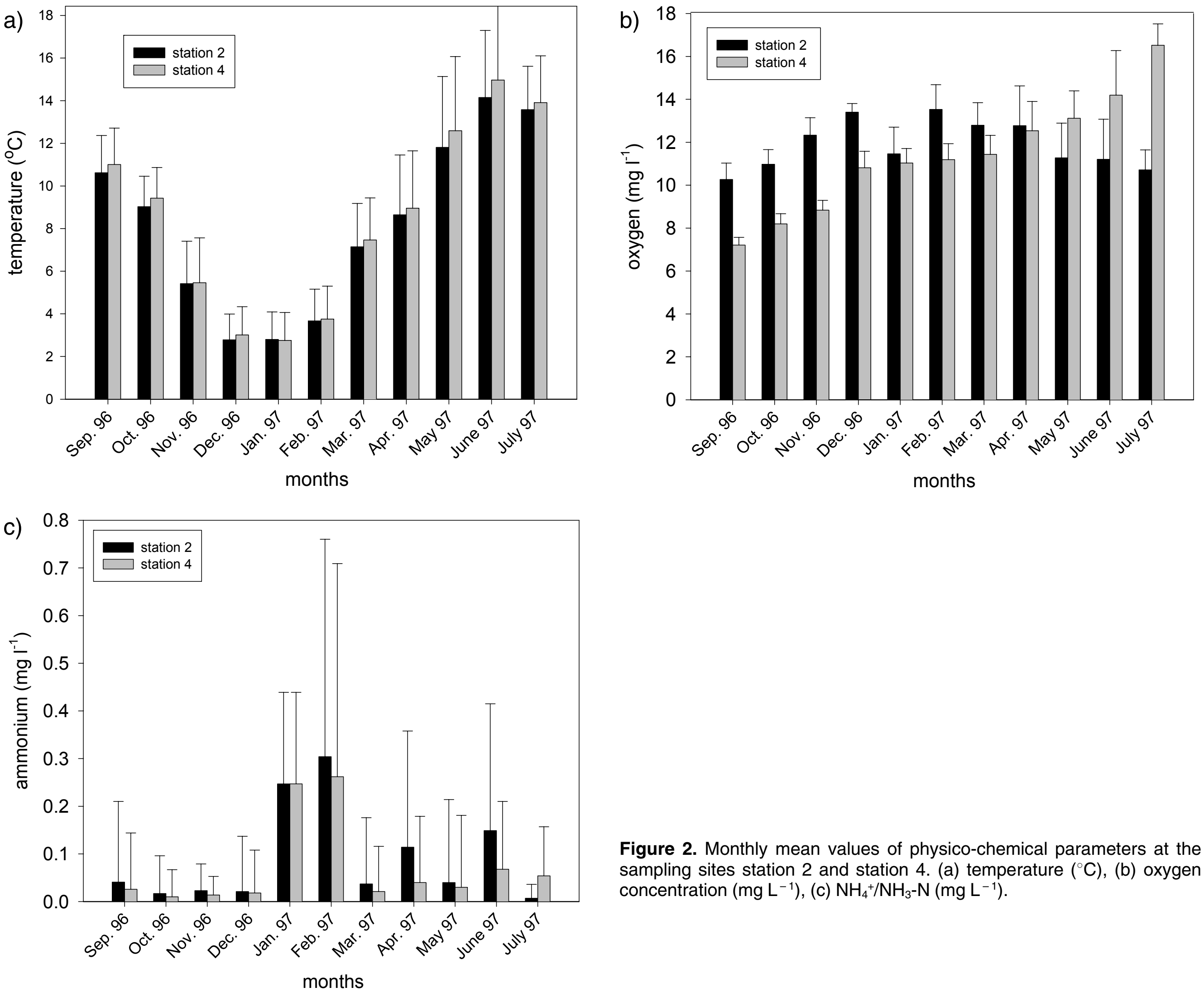

Figure 2. Monthly mean values of physico-chemical parameters at the sampling sites station 2 and station 4. (a) temperature (°C), (b) oxygen concentration (mg L^{-1}), (c) NH_4^+/NH_3-N (mg L^{-1}).

µS/cm, with a standard deviation of about 8 to 10% of the monthly mean value (not shown). The temperature varied between 22°C in summer and 0°C in winter, with minor differences between the station 2 and station 4 monitoring sites. The mean temperature was up to 0.8°C higher at station 4 (see Fig. 2a) except for the winter months. A decrease of the oxygen concentration was observed between station 2 and station 4 from September 1996 to April 1997 due to consumption, while from May 1997 to July 1997, the section between the two sites was highly productive, yielding oversaturation of oxygen mainly at station 4 (see Fig. 2b). Oxygen consumption might be due to biofilm respiration at low light in winter or infiltration of oxygen poor groundwater.

Monthly mean concentrations of ammonium- and nitrite-nitrogen ranged between 0.01 and 0.30 mg/L for ammonium and 0.004 and 0.060 mg/L for nitrite, with single peaks of 4.0 mg/L for ammonium and 0.31 mg/L for nitrite (see Fig. 2c for ammonium). As a consequence of these large fluctuations, the standard deviation was often greater than the mean value. High ammonium concentrations pertained to the period before spring 1996, after which the nitrification efficiency of the WWTP was improved. Both nitrogen compounds attained maximum values at high rainfall, when the overflow from pre-treatment released waste water into the river, and when in winter 1996/1997 low temperatures caused a collapse of the nitrification in the WWTP. High levels of ammonium and nitrites indicate a high degradation rate of the organic material and reducing conditions combined with insufficient nitrification in the WWTP. The differences between station 2 and station 4 indicate self purification (ammonia oxidation) within a distance of around 1 km (see Fig. 2c).

3.3 Characteristics of the Diatom Community 1996/97

A total of 68 different diatom species were found at all 4 sites during the 1996/97 sampling. The most frequent species are listed in Tab. 3. Pennates with 64 species were strongly dominant compared to Centrics (complete counting results are given as Supporting Information). *Achnanthes minutissima Kützing,* described as a tolerant species [32], was present in all samples; it furthermore often dominated, with up to 52% of the total number of valves counted (July 1997).

Table 3. The most abundant diatom species in the river Töss, 1996/97.

Species	*D*	pres%	Relative Frequency, p%	Maximum Relative Frequency			
				Site 0 m	Site 300 m	Site 900 m	Site 1500 m
Achnanthes biasolettiana GRUNOW	2.0	97	0–38.0	38.0	28.4	29.3	30.5
Achnanthes minutissima KÜTZING	3.0	100	17.0–51.7	29.6	51.7	42.6	46.3
Amphora pediculus (KÜTZING) GRUNOW	5.0	63	0–5.3	2.4	5.3	1.1	1.1
Cymbella affinis KÜTZING	2.0	97	0–8.0	8.0	7.1	6.7	5.7
Cymbella minuta HILSE	2.5	100	0.4–24.7	8.4	15.4	24.7	14.3
Diatoma moniliformis KÜTZING	2.0	63	0–7.7	0.4	3.4	3.6	7.7
Diatoma vulgaris BORY	4.5	50	0–11.7	11.7	5.6	1.6	3.2
Gomphonema olivaceum (HORNEMAN) BREBISSON	3.0	82	0–42.5	5.6	7.9	10.4	42.5
Gomphonema pumilum (GRUNOW) LANGE-BERTALOT&REICHARDT	2.5	100	1.1–46.2	5.6	11.4	17.3	46.2
Gomphonema tergestinum (GRUNOW) FRICKE	2.5	79	0–8.1	3.2	3.1	8.1	7.1
Navicula cryptotenella LANGE-BERTALOT	3.5	82	0–8.6	0.7	8.6	2.4	5.7
Navicula reichardtiana LANGE-BERTALOT	4.0	89	0–6.9	4.0	6.0	4.9	6.9
Navicula tripunctata (O.F.MÜLLER) BORY	4.0	82	0–4.7	2.4	4.5	2.6	4.7
Nitzschia dissipata (KÜTZING) GRUNOW	3.5	84	0–11.4	6.2	9.9	3.6	11.4
Nitzschia fonticola GRUNOW	4.0	97	0–24.0	4.7	24.0	15.9	17.0

pres% = abundance of each species in all 38 samples collected, relative frequency range (percentiles p%) of each species in all samples collected, maximum relative frequency of each species at sites 0 m, 300m, 900m and 1500 m.
D = indicator value for each species according to the DI-CH (between 1 = not polluted by community waste water or low concentration of algal nutrients, and 8 = heavily polluted or high nutrient concentration [22]).

Earlier in the year it reached between 42.6% and 46.3% of the diatom populations at stations 3 and 4. Other species surmounting the 10% level of the population were *Achnanthes biasolettiana* with 38% upstream the inlet of the WWTP at sampling station 1, *Gomphonema pumilum* with 46.2% and *Gomphonema olivaceum* with 42.5%, both at sampling station 4, *Nitzschia fonticola* with 24% and *Nitzschia dissipata* with 11.4%, both at sampling station 2. *Cymbella minuta* also reached 15 to 25% at sampling stations 2, 3 and 4. The large number of additional species had lower abundance, never reaching the 10% level, and most were not regularly found during the sampling period.

3.4 Shannon Diversity Index H′

The Diversity Index H′ ranged between 2.1 and 3.7 (see Fig. 3). Not surprisingly, biodiversity was highly correlated with the number of species. Higher diversity values were observed during winter. Towards spring, H′ dropped gradually to low values in May–June. The various high water days, with flow rates higher than 10 m^3/s (see Fig. 1), had no significant influence on the diversity. Low values of H' were the result of a small number of genera and a high abundance of a few common species. While until late fall 1996 and in spring 1997 station 2 had a higher biodiversity than station 4, the two values were rather similar between December and April.

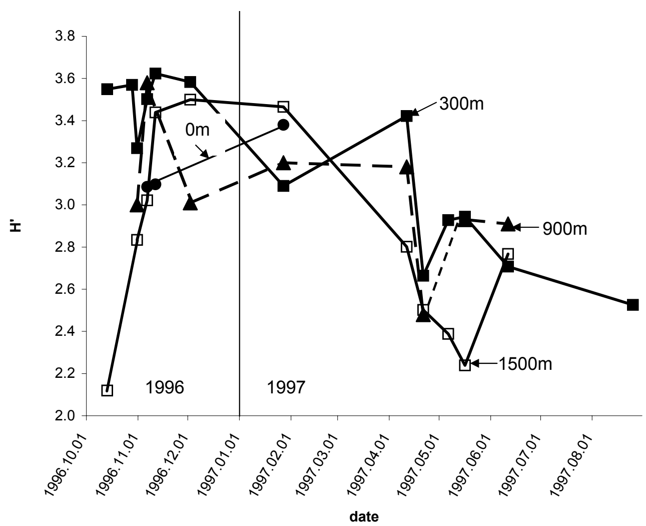

Figure 3. Shannon Diversity Index H′ at the 4 sampling sites at sampling days 1996/97. Closed spheres = station 1 (0 m), closed squares = station 2 (300 m), closed triangles = station 3 (900 m), open squares = station 4 (1500 m).

3.5 Swiss Trophic Diatom Index DI-CH and Saprobic Index SI

Indices like the Trophic Index [33], the Swiss Trophic Diatom Index DI-CH [22] and the Saprobic Index SI [18] are excellent tools for water qualification (see Figs. 4 and 5). While the values of the DI-CH Index for station 1 were below 2.4, they mostly exceeded 2.5 during winter at sites 2 to 4, indicating a more eutrophic state downstream from the WWTP inlet. However, chemical data during winter 1996/97 did not parallel the DI-CH (see Fig. 2c). Elevated nitrogen concentrations in January and February did not increase the Diatom Index.

The Saprobic Index values ranged from 1.5 to 1.8, with smaller fluctuations than the DI-CH. This suggests a water quality for this section of the river to be of oligo- to β-mesosaprobic state. Both indices, DI-CH and SI, confirm that the upper part of the river Töss (from the source to Saland) is only marginally polluted, even at the site 300 m below the inlet of the WWTP. Variations over the year in these values, mainly from variations in the number of species present as well as the composition of the diatom population (the

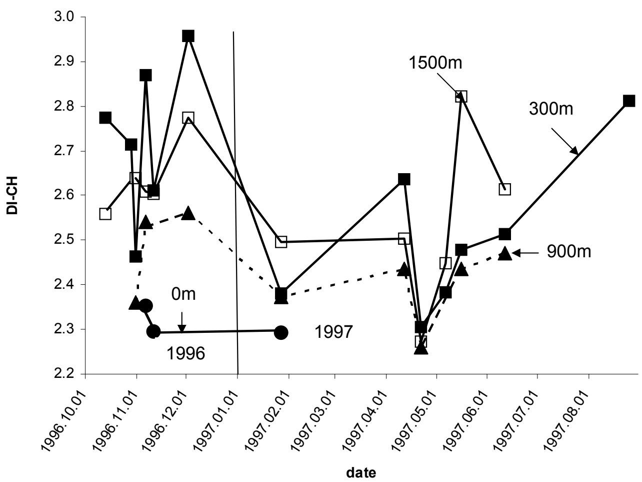

Figure 4. Swiss Diatom Trophic Index DI-CH at the 4 sampling sites at diatom sampling days 1996/97. Closed spheres = station 1 (0 m), closed squares = station 2 (300 m), closed triangles = station 3 (900 m), open squares = station 4 (1500 m).

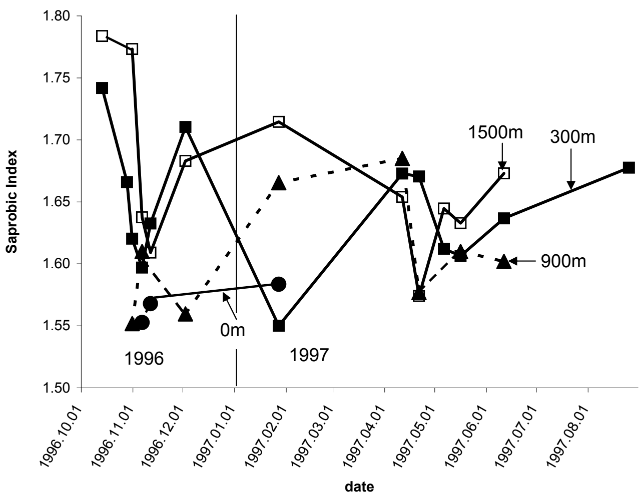

Figure 5. Saprobic Index SI at the 4 sampling sites at diatom sampling days 1996/97. Closed spheres = station 1 (0 m), closed squares = station 2 (300 m), closed triangles = station 3 (900 m), open squares = station 4 (1500 m).

quality and frequency of the species), point to only slight deviations in the trophic and saprobic state of this river section. In contrast, the chemical events occurred as pulses that only influenced the diatom community during short periods, however, without pronounced effects on the diatom community.

When the species are grouped into the eight classes according to the DI-CH, a Gaussian distribution with only small differences between the 4 sampling sites is observed. At station 2 (300 m below the WWTP), the distribution is slightly shifted towards higher pollution and contains a smaller percentage of marker diatoms for pollution classes 1 and 2 (species preferring unpolluted water; Fig. 6). A shift in the composition of the diatom population from station 1 to station 4 at 1500 m distance is suggested from the frequencies in the pollution classes 3, 7 and 8. The percentage of class 3 organisms increased with distance from the WWTP and the one of organisms belonging to the high pollution classes decreased, both indicating a

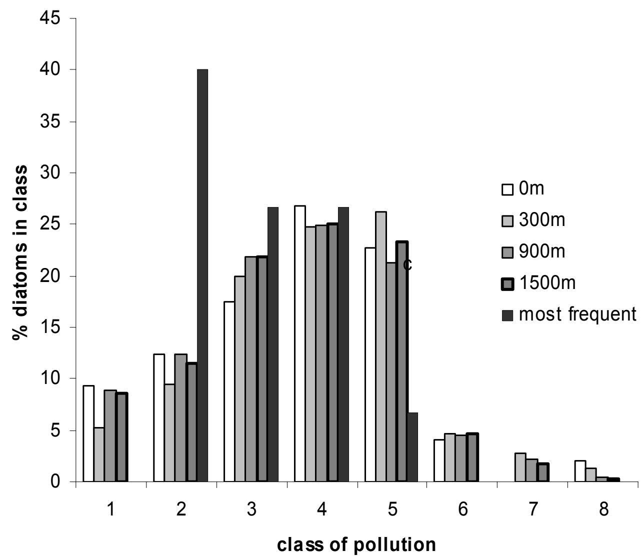

Figure 6. Distribution of benthic diatoms according to their class of pollution [18] at the 4 stations 1 (0 m), 2 (300 m), 3 (900 m) and 4 (1500 m) downstream the WWTP, and distribution of the most frequent diatoms in the Töss (from Tab. 3).

drop in pollution. Among the 15 most frequent diatom species (see Tab. 3) six of them are rated to class 2, four to class 3 and 4, all are indicators of little pollution. This results in a distribution of the most frequent diatom species among the 8 classes which is shifted towards lower pollution and is quite different from the one of all diatom species present.

Chemical data indicate that the WWTP worked satisfactorily since 1997, resulting in low values for the nitrogen species determined. In 2004/2005 ammonium was in the range between 0.01 and 0.1 mg/L in monthly samplings, with few peaks up to 0.76 mg/L until August 2005 (data for station 2 from AWEL). A total of 40 diatom species were found in August 2005 with the same most abundant diatom species as in 1996/97 and the three indices fit well within the distribution patterns of 1996/97.

4 Discussion

So far no biological index exists which fulfills all the requirements for judging the state of a running water system. For every scientific question the most suitable index has to be evaluated [34]. The Shannon Diversity Index is a good and widely used tool to compare organismic communities independent of pollution effects. The Saprobic Index [18, 19] and Trophic Indices [22, 33] describe, by definition, the capacity for two different biological processes, the degradation of organic material and the primary productivity, respectively. In case of aquatic systems with low organic load, as a result of an efficiently working WWTP, the Swiss Trophic Index is better suitable for river classification since plant nutrients, e. g., nitrogen and sulfur compounds, are in their oxidized states. In contrast, the Saprobic Index SI classifies rivers based on the load of dissolved organic materials originating from untreated or insufficiently treated municipal wastewater. In the present study, the Trophic Index DI-CH and the SI follow similar trends (see Fig. 4 and 5). However, due to different ecological classification of certain species, some differences have to be expected. While H' oscillates within 25% of its scale

Table 4. Mean values (MV) and standard deviations (Stdev) of the number of species, Shannon Diversity Index H', Swiss Trophic Diatom Index DI-CH and Saprobic Index SI at the 4 sampling sites, 1996/97.

Sampling site	0 m		300 m		900 m		1500 m	
	MV	Stdev	MV	Stdev	MV	Stdev	MV	Stdev
Number of species N	24.3	3.5	21.1	4.1	17.6	2.2	17.5	4.6
Shannon Diversity Index H'	3.19	0.16	3.21	0.38	3.04	0.31	2.83	0.50
Swiss Trophic Diatom Index DI-CH	2.32	0.04	2.63	0.21	2.46	0.11	2.58	0.15
Saprobic Index SI	1.57	0.02	1.67	0.08	1.61	0.05	1.67	0.06

(from 0 to 6), DI-CH stays within 10% (range 1 to 8) and SI within 8% (range 1 to 4). This indicates relatively stable conditions concerning the organic and inorganic load of the water. As environmental agencies often reduce monitoring to one or two samplings per year, these data will give reliable values for DI-CH and SI, while for the diversity H' a higher time resolution is needed.

The time fluctuations of NH_4^+/NH_3-concentrations at the two sites, 2 and 4, indicate occasional pollution (see Fig. 2c). The decrease in NH_4^+/NH_3 concentrations downstream between these sampling stations indicates ongoing self-purification. This is also confirmed by the shift in the distribution of the diatom species present within the DI-CH classes (see Fig. 6). The relative amount of class 3 (low pollution) organisms increased downstream, while high pollution indicators in classes 7 and 8 (high pollution) decreased.

Although the months of January and February 1997 had a significantly higher pollution load, the Shannon Diversity index H′ showed no variation. In contrast, H′ dropped during the spring months, which might be due to high production and mass development of the dominant species *Achnanthes biasolettiana*, *Achnanthes minutissima*, *Cymbella minuta*, *Gomphonema olivaceum*, and *Gomphonema pumilum* (see Tab. 3). April and May samplings led to low H' values, especially at sampling station 4, 1500 m below the WWTP (see Fig. 3). At the end of May, the DI-CH values were similar to those collected upstream from the WWTP at station 1 (see Fig. 4). Both DI-CH and SI had a higher variation between successive sampling periods and sites compared to H′. This indicates that the structures of the communities reflect real environmental changes.

The flow in the prealpine river Töss is highly variable and strongly depending on the rainfall in the catchment. The 17 year monthly means are between 0.92 and 2.37 m^3/s, with single peaks reaching 126 m^3/s (May 1999). The period 1996/97 had several peaks exceeding 10 m^3/s. Neither the high water event of October 16th 1996 nor the one of April 29th 1997 had a significant effect on the Shannon Diversity H' or induced strong changes in the DI-CH and SI.

Table 4 shows the mean values and the corresponding standard deviations considering all samples of the 4 sampling sites. It is evident that there are no significant differences between the sampling sites within the period 1996/97, possibly with the exception that the mean DI-CH at sampling site 0 m above the inlet of the WWTP is lower than the other values. This indicates that this site had less nutrients than the sites downstream. The Shannon Diversity Index does not differ between station 1 and 2, but the diatom biodiversity seems to become lower downstream, while variations in the SI suggest some increase in organic load from the WWTP.

Acknowledgements

We are indebted to the DEZA, Berne, for financing the stay of L. K. in Switzerland. Species identification was carried out with the help of Dr. J. Hürlimann, AquaPlus, Zug. Chemical data for the 1996/97 period were taken from Jancarkova [22], recent data were supplied by Dr. Pius Niederhauser, AWEL, Zürich.

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