Spatial-temporal Distribution of Periphyton in the lower parts of the River Thur: The Influence of Morphology, Hydraulics and Hydrology

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Contents

1 Summary

This study describes at revealing the distribution of periphyton in the lower parts of the River Thur, a prealpine gravelbed-river in north-eastern Switzerland. Its main focus was on the relationship between hydraulic condition and periphyton biomass at different spatial and temporal scales.
Field measurements were conducted on 9 sample sessions from May to August 2003. During this time, Switzerland experienced an exceptionally hot summer with almost no rainfall. Ten reaches between Pfyn, a village close to the city of Frauenfeld, and the confluence with the Rhine were sampled, including one in the tributary Murg. Channelisation in this section made the Thur a rather morphologically uniform flume; yet a number of rehabilitation-projects were completed in the last 20 years. Sampling reaches, therefore, were chosen in both channelised and rehabilitated sections.

Field measurements included the assessment of 1) *Chl. a* and *AFDM* for periphyton biomassdetermination, 2) shear velocity for characterisation of the hydraulic condition, and 3) water temperature, conductivity, photosynthetic active radiation (PAR), water chemistry, pH and grain size. Further, data on discharge and water temperature were provided by the Federal Office for Water and Geology (BWG) and the National River Monitoring Station (NADUF).
A strong relation between shear velocity and periphyton was not found. 1) High values of periphyton biomass occurred in all reaches. *AFDM* was the only parameter showing a significant difference between rehabilitated and channelised reaches. However, this was only aparent during two sample sessions with a constantly low discharge of around $10m^3/s$ (longterm average $47.2m^3/s$). An increase in *Chl. a* some 3 months after the last bed-moving spate was observed in all reaches.
2) Shear velocity was low to intermediate for most sample sessions with higher values although nonsignificant in channelised parts and a broader spectrum in rehabilitated ones. It was believed that the low discharge was responsible for the similar conditions in both rehabilitated and channelised reaches.
3) Nutrients were well-above limiting conditions. The exceptionally hot and dry environmental situation was reflected in a very low discharge almost throughout the whole sample period with only one bed-moving spate occurring in this period and very warm water temperatures. Light availablity was high with the exception of a short-lasting spate on 3 June.

Under these conditions of low discharge and, thus, shear velocities within a small bandwidth, periphyton abundance seemed influenced by other factors. It is proposed that biological processes such as senescence and grazing may have dominated.

2 Introduction

Periphyton refers to the biotic community that grows on substrata, and includes algae, bacteria and fungi embedded in a polysaccharide matrix. In lotic ecoystems, periphyton can be an important energy source supporting heterotrophic communities; its contribution to the biologically mediated energy flow varies along the river continuum and across climatic regions. Biomass and growth of periphyton is influenced by a variety of factors such as light availability, substratum stability, nutrients, hydraulic conditions, and temperature. These factors vary in space and time at quite different scales. For example, hydraulic conditions change along the river continuum (scale, 10–1000 km), within reaches (pool-riffle sequences, 10–100 m) or microhabitats (rocks, 1–100 cm). Hydraulic conditions may change within hours (spates) or be subject to relatively predictable seasonal variations (e.g. glacier fed streams, very large rivers). This spatio-temporal variability in factors of influence result in a corresponding spatio-temporal variation in periphyton distribution, and thus enhances habitat diversity with respect to biologically available energy.
Human impacts such as the elimination of riparian vegetation, enhanced nutrient inputs, or modification of the flow regime can result in prolific periphyton growth that impairs water quality and recreational value of a stream or river. The channelisation of rivers creates relatively uniform hydraulic conditions and thus leads to a loss of hydraulically diverse habitats. In Switzerland, almost every medium or large-sized river has been channelised by the end of the 19th century, mainly to protect the adjacent land from flood hazards. In the past 15 years, an increasing number of rehabilitation projects have been realized. However, many of these projects were restricted to reaches of a few hundred meters in length, and the effect of such measures has rarely been documented.

This investigation of the periphyton in the Thur River is part of the Rhône-Thur project supported by several federal research institutions and the Federal Agency for Environment, Forest and Landscape, and aimed to provide conceptual support of rehabilitation projects in the Thur and Rhône Rivers. The lower River Thur, originally a meandering stream with a relatively flashy flow regime, was channelised at the end of the 19th century. The failure of the artificial levée during a high magnitude flood in 1978 resulted in a proposal to enhance flood protection by enlarging levées and increasing the channel capacity by removing fluvial deposits from the forelands between the levées, thereby widely neglecting ecological issues. However, a continuing discussion about ecological aspects and the limits of classical flood protection measures finally resulted in a hydraulic engineering project that also considered ecological issues. In roughly 8 km of the lower Thur River a rehabilitation projects have been in operation since about 1980.

The objectives of this study were 1) to investigate the relation between hydraulic conditions and periphyton biomass, and 2) to evaluate the distribution of periphyton biomass in channelised and rehabilitated reaches of the lower Thur River. Based on the results of several studies, it was expected that periphyton biomass would be correlated with hydraulic parameters such as shear stress and current velocity. Rehabilitated reaches were assumed to be more diverse with respect to hydraulic conditions than channelised reaches, and be reflected by a more patchy periphyton distribution.

3 Study reach

The River Thur is a major tributary of the upper Rhine (Fig. 1). The headwaters are in the alpine region of north-eastern Switzerland (highest elevation in the catchment is 2502 m a.s.l). Major parts of the upper catchment are in the prealpine zone, where elevations range from 600 to 1800 m a.s.l. The catchment area is 1723 km^2. About 25% of the area is forested, 61% fields, orchards and pastureland, and 8% urban.

Figure 1: Location of the River Thur in north-eastern Switzerland

Between the lower end of the prealpine zone (river km 76) and its confluence with the Rhine (river km 0.0), the Thur has been channelised, and thus, is rather morphologically uniform except for some reaches that have been rehabilitated. In the channelised parts, banks of the low-water channel are stabilized by stone rip-rap and by short wing dams at a few sites. The study reach is located in the lower Thur River between river km 1.2 and 33.2 (elevation=345-400 m a.s.l., average channel slope=0.17%). The width of the wetted channel averages 35 m at low flow (15 m^3/s). Bed sediments mainly consist of gravel. The mean annual discharge at river km 10.1 (location of the gauging station) is 47.2 m^3/s [7]. Initiation of sediment movement occurs at flows exceeding 150 m^3/s and disruption of the surface layer starts at flows above 350 m^3/s. In the study area, the river is open-canopied with only minor valley shading.

The investigation also included one reach in the River Murg, a major tributary of the lower Thur, with a mean annual discharge of 4.25 m^3/s [7]. The Murg site was located about 110 m upstream of the confluence with the River Thur, where the river is channelised and open canopied.

4 Methods

The sampling sites were located in channelised and rehabilitated reaches:

- sites in which the river is able to move freely or in which artificial groyns induced a certain dynamic.
  - *Andelfingen, (A'fingen)*, rehabilitated, channel width 55m, km 7.3, Appendix A.2
  - *Gütighausen, (G'hausen)*, rehabilitated, channel width 40m, km 17.1, Appendix A.3
  - *Niederneunforn1, (N'forn1)*, rehabilitation finished in 2003, channel width 50m, km 18.4, Appendix A.4
  - *Niederneunforn2, (N'forn2)*, rehabilitated, channel width 70m, km 19.5, Appendix A.5
  - *Warth*, slightly rehabilitated, channel width 45m, km 27.8, Appendix A.7
  - *Felben*, slightly rehabilitated, channel width 50m, km 32.1, Appendix A.8
- parts that are channelised
  - *Flaach*, channel width 60m, km 1.2, Appendix A.1
  - *Niederneunforn3, (N'forn3)*, channel width 50m, km 20.4, Appendix A.6
  - *Pfyn*, channel width 45m, km 33.2, Appendix A.9
- site in the tributary Murg/Frauenfeld
  - *Murg*, channel width 10m, confluence at km 28.1, Appendix A.10

A map with the sample reaches can be found in Appendix D.
The reaches were selected in coordination with a macrozoobenthos research program of the Thur by the company "Limex", Zurich. This should facilitate to link the results of both programs in order to evaluate how the rehabilitation changed the ecology of the river.

Sampling took place at intervals of 1–3 weeks on 9 dates between May 15 and August 8, 2003. In Appendix E us the complete sampling schedule. The design of the study is illustrated in Figure 2.

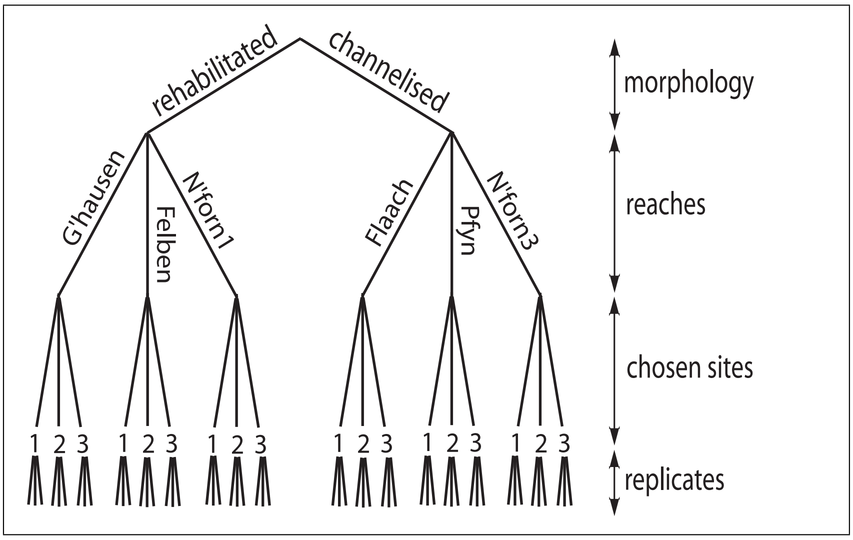

Figure 2: Design of the study

4.1 Discharge

Discharge data of the Thur River (gauging stations: Halden at river km 51, and Alten at river km 5.5, map in Appendix C) and the Murg river were provided by the Federal Office of Water and Geology.

4.2 Grain size distribution

To assess the grain size distribution of the rocks forming the surface layer of the bed sediments at the sampling sites photographs of the river bed were taken with a digital camera (Digicam HP photosmart 320, Hewlett Packard, Palo Alto, USA) either using a plexiglass frame to smooth the water surface or a plastic underwater camera bag (Appendix B.6). To calibrate the photos a ruler was placed on the sediment surface. The computer program Image Pro Plus 4.4.1.29 (Media Cybernetics, Silver Spring, USA) was used to determine the length (a-diameter) of the rocks photographed (*average stone length*) and standard deviation.

4.3 Temperature

During sampling, water temperature was measured at each site with the temperature probe of the LF323 conductivity meter (WTW, Weilheim, Germany, Appendix B.2). Temperature records of the National River Monitoring Station (NADUF) were provided by the Federal Office of Water and Geology.

4.4 Light, turbidity and conductivity

An underwater quantum sensor LI-190SA connected to a LI-1000 data logger (LI-COR Inc., Lincoln, Nebraska, Appendix B.4) was used to measure the vertical distribution of photosynthetically active radiation (PAR). The vertical PAR attenuation coefficent ε (m^{-1}) was obtained by linerar regression of log(PAR) with depth. Relative PAR in % of PAR at the air-water interface (I_0) was calculated using specific vertical PAR attenuation and depth. Turbidity was measured with a Cosmos turbidity meter (Züllig AG., Rheineck, Switzerland, Appendix B.3) in nephelometric turbidity units (NTU), and specific conductance (reference temperature at 20°C) with a LF323 conductivity meter (Appendix B.2).

4.5 Water chemistry

Surface water was collected 4 times during the investigation in 1-liter glass bottles and filtered through pre-ashed glass fibre filters (Whatman GF/F) to separate dissolved and particulate matter. Soluble reactive phosphorus (SRP) was determined with the molybdenum blue method. Total dissolved phosphorus (TDP) and particulate phosphorus were digested with $K_2S_2O_8$ at 121°C and determined as SRP. Nitrate (NO_2-N) was spectrophotometrically measured after diazotizing with sulfanilamid and coupling with N-(-1-naphtyl)-ethylendiamine [22]. Ammonium and nitrate were measured with the indophenyl-blue method and hydrazin reduction [14], respectively. Total dissolved nitrogen(TDN) was obtained by oxidizing all dissolved nitrogen forms to nitrate with $K_2S_2O_8$ at 121°C and subsequent nitrate determination. Particulate nitrogen (PN) was measured as nitrate after oxidation with $K_2S_2O_8$ at 121°C. Particulate organic carbon was determined according to [18]. Total inorganic carbon (TIC) was measured with a TOC-5000A total organic carbon analyzer (Shimadzu TOC-5000A Analyser, Japan). On a few occasions, pH was measured with a 330/Set1 pH-meter (WTW, Weilheim, Germany, Appendix B.5).

4.6 Periphyton

In each reach, 3 rocks were collected at random from three sites: 1) near the left bank, 2) near the right bank, and 3) in the thalweg. Exceptions were made in Niederneunforn 1 & 2, where site 3 was located in a hydraulically more interesting place, and in Pfyn where an additional site 4 was sampled (see Appendix A for more information). Periphyton biomass was determined as chlorophyll a (*Chl. a*) and ash-free dry mass (*AFDM*). Each rock was transported in a separate plastic bag to the laboratory in a cooler. A brass wire brush was used to remove the biofilm from each rock into a bucket filled with tapwater. The main axes (a and b) of each rock was measured with calipers. Aliquots of the algal suspension were filtered on pre-ashed glass fiber filters (Whatman GF/F). *Chl. a* was extracted and analyzed according to [1]. To determine ash-free dry mass, filters were dried at 60°C for 24 h and ashed at 500°C. *Chl a* and $AFDM$ were normalized on the cross-section area of each rock. The rock cross section was calculated from width and breadth according to [19].

4.7 Hydraulic conditions

A vertical velocity profile was measured with a Mini-Air2 propeller anemometer (Schildknecht, Gossau, Switzerland, Appendix B.1) above each rock that was collected for the determination of periphyton biomass (see below). Current velocities were measured in 10 cm intervals from 1 cm below the air-water interface to 1 cm above the rock surface. Shear velocities V^* were calculated according to Prandtl's "universal velocity-distribution law"

$$\frac{\nu}{V*} = \frac{1}{\kappa}\left(\frac{yV*}{\nu}\right) + B$$

with ν [m/s] as the velocity, y [m] the distance away from the solid surface, $V*$ [m/s] the shear velocity, κ Karman's universal constant with a empirical value of around 0.40 and B also as an empirical constant.

The shear velocity can be expressed as

$$V* = \frac{b}{5.75}$$

where b is the slope of the logarithmic velocity profile (velocity versus log(depth), Figure 3) in the logarithmic layer. ([11],[15], [12], [16], [8], [2], [4], [17]). However, the upper parts often deviated from the logarithmic velocity-depth model as described in [16]. Therefore, shear velocities were calculated a) by considering data from the entire profile (V*all*), and b) by considering data only from those parts of the profile that fitted the logarithmic velocity-depth model (V*fitted*). The shear-force τ, thereafter, can easily be calculated according to

$$\tau = \rho(V*)^2$$

with τ $[N/m^2]$ being the shear-force and ρ $[kg/m^3]$ the density of water;

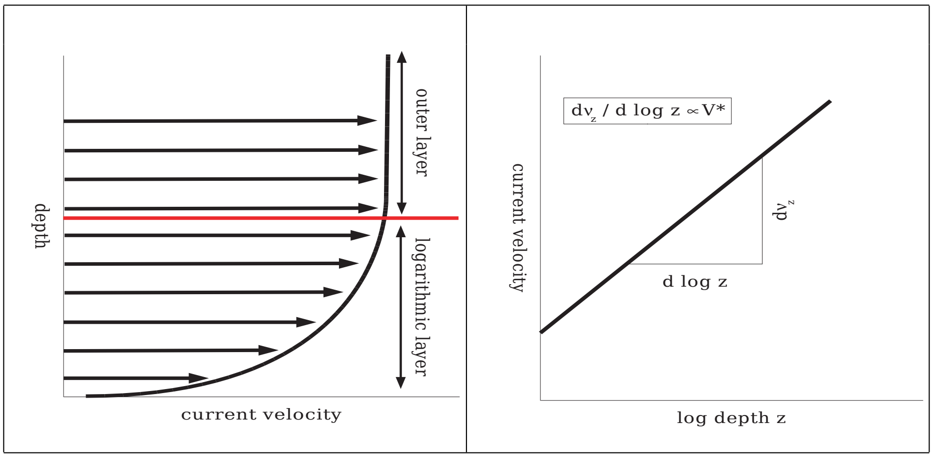

Figure 3: *Velocity - depth* and *velocity - log(depth)* diagrams with logarithmic layer

this was only calculated for comparison with cited studies.

4.8 Statistical analyses

Descriptive statistics were used to characterise periphyton and hydraulic conditions as well as temperature and conductivity. Analysis of variance (ANOVA) and t-tests were used to test for effects of site on periphyton biomass and hydraulic parameters after the data were transformed (log(x+1)) to improve normality. Effects were considered significant when $p<0.05$. Relationships between chemo-physical parameters and periphyton biomass were examined using correlation and regression analysis. Correlation and regression models were assumed to be significant when $p<0.05$. All statistics were computed with Statistica 6.0 (StatSoft, Tulsa, USA) and OpenOffice 1.1.0 (opensource, http://www.openoffice.org).

5 Results

5.1 Discharge

Summer 2003 was exceptionally hot and dry. The discharge at the gauging-station Alten (Figure 4) exceeded $150 m^3/s$ only once, which contrasts with the long-term average (1974-1999) of 6.2 spates >150 m^3/s (May-August). The time between sample sessions 5-8 was characterised by extreme and unusually low waterlevels with a minimal discharge of $5.43 m^3/s$ on 15 July and an average discharge of $31.74 m^3/s$ for the whole sample period compared to the long-term average of $47.2 m^3/s$.

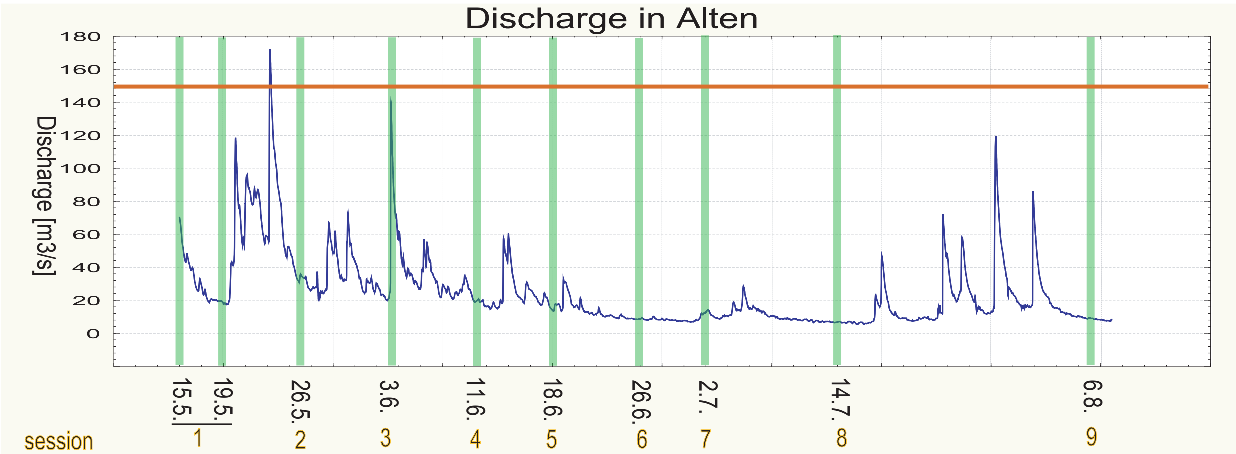

Figure 4: Discharge at the gauging-station Alten during the sample period. The horizontal red line indicates the limit for sediment-moving spates, the vertical green lines the sampling dates.

The gauging-station Halden measured a maximum discharge of $188.41 m^3/s$ on 23 May and a minimum discharge of $2.88 m^3/s$ on 15 July. Average discharge during the investigation was $25.35 m^3/s$. The critical value of $150 m^3/s$ was exceeded two times during the sample period. However, Halden is about 18 kilometres upstream of the upper most sample reach, therefore, it is uncertain whether sediments mobilised moved in the study reaches on 3 June, when flow exceeded $150 m^3/s$ in Halden but not in Alten. Discharge in Halden can be found in Appendix F.1.

Discharge in the River Murg did not exceed $9.54 m^3/s$ (22 July). Mean flow during the sample period was $1.39 m^3/s$, with a minimum flow of $0.62 m^3/s$ on

28 June and 16 July (discharge curve of the Murg River is in Appendix F.2)

The gauging stations Alten and Halden show the same pattern (Appendix F.3) but the variation in discharge is higher in Halden than Alten. A flow peak took about 6 hours to travel from Halden to Alten.

5.2 Chemo-physical parameters

Refer to Appendix F.4 for further information about the following subsections.

5.2.1 Grain size distribution

Rock length averaged 3.0 cm +/-1.5 cm. Rocks were significantly larger in reach Warth than in Niederneunforn 1-3, but no significant differences could be found among the other reaches.

5.2.2 Temperature

During the first three sessions temperature varied between 12-15°C and increased to 22-24°C in the later sessions (Table 1, Appendix F.7). The continuous temperature record at the gauging station Andelfingen showed minimum temperatures on 22 May (9.9°C) and maximum temperatures on 5 August (27.5°C, Figure 5). Diel temperature variations were in the range of 1-4°C. From May to August, monthly mean temperatures deviated between +2.4 (May) and +6°C (June) from the corresponding long-term averages (1974-2000).

Session	Ave. Temp [°C]	N	Std. Dev.
1	14.9	34	2.7
2	12.5	44	0.4
3	15.0	3	0.3
4	22.1	30	3.1
5	21.5	75	2.2
6	24.2	39	2.9
7	19.8	51	1.6
8	23.6	82	2.3
9	24.7	79	3.4

Table 1: Average temperature during sampling in the Thur River

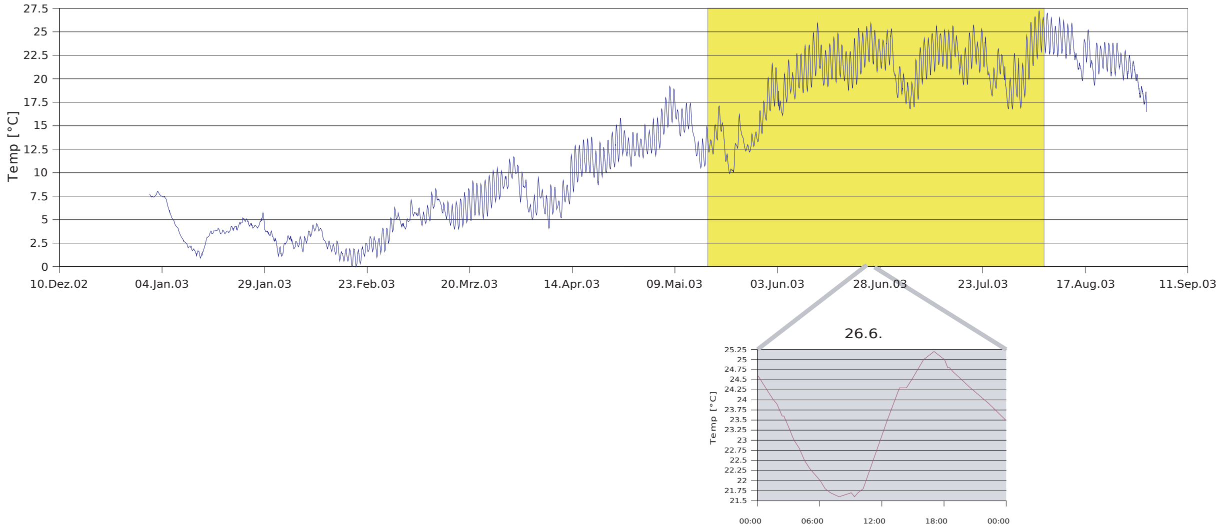

Figure 5: Temperature curve at the gauging station Andelfingen. The insert shows diel temperature variation on 26 June.

5.2.3 Conductivity

Conductivity usually was between 300-400 μS/cm (max. 499μS/cm, min. 209μS/cm, average 388μS/cm, excluding Gütighausen Site 3, Warth Site 1 and Murg) over all sites and all sampling-dates (Figure 36 in Appendix F.4). High values of *conductivity* occurred in the Murg and at site 1, reach Warth (further investigated in section 5.5) and in reach Gütighausen Site 3 which was cut off before this time from the main channel in *Mid-June*, although it had standing water.

5.2.4 Light and turbidity

Vertical attenuation coefficients ε of the photosynthetically active radiation (PAR) ranged from -0.53m^{-1} to -3.27m^{-1}, except on 3 June at higher discharge. *Turbidity* followed the same temporal pattern, and thus both parameters were correlated (r=-0.95; without session 3 the correlation diminishes to r=-0.46). Table 2 gives an overview. (Individual scatter-plots for each sample session: Figures 37 and 39 in Appendix F.4)

Apart from 3 June, usually between 60-100% of PAR measured directly below the air-water interface reached the river bottom. Figure 6 shows a histogram of the relative PAR.

Session	Ave. Turbidity [NTU]	Max.	Min.	Ave. Light ext. ε [m^{-1}]	Max.	Min.
3	1400	2565	667	-34.12	-39.74	-30.18
all without 3	8.44	64.9	0.43	-1.30	-3.27	-0.53

Table 2: Turbidity and light-extinction for session 3 and the other sessions)

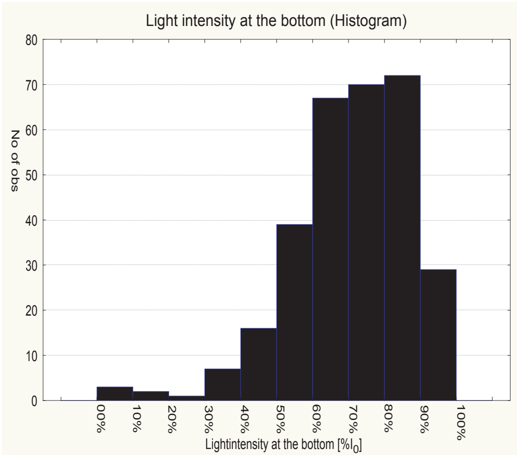

Figure 6: Histogram of the relative PAR intensity at the river bottom using all available data

5.2.5 Water chemistry

Concentrations of the major nutrients were high in both the River Thur and River Murg, reflecting discharge from sewage treatment facilities and diffuse input from agriculture. Soluble reactive phosphorus (SRP, P-PO_4) and nitrate + nitrite (N-NO_3+N-NO_2) averaged 27.3 μg P l^{-1} and 2.0 mg N l^{-1} in River Thur, and 12.8 μg P l^{-1} and 2.1 mg N l^{-1} in River Murg (all measured water-chemistry data are in Appendix F.8). In the River Thur, pH averaged 8.42 +/-0.17.

5.3 Hydraulic conditions

The parameters used to describe the hydraulic conditions (*V*, V*fitted, v_max,* and *v_bottom*) are all closely related and significantly correlated (Table 3 and Appendix F.9). For further characterisation of the hydraulic condition, only *V*fitted* was used as a representative parameter.

The relation between discharge and *V*fitted* was strong. Discharge at the gauging station Alten and *V*fitted* was normalised with their mean value for comparison. In Figure 7 the correlation between normalised discharge in Alten and *V*fitted* of the nearby reach Flaach is given ($r=0.99$, $p<0.01$).

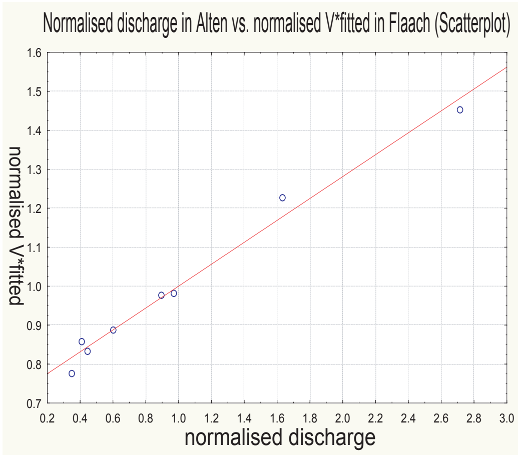

Figure 7: Normalised discharge in Alten vs. normalised V*fitted in Flaach

	V*all	V*fitted	v_max		range of values
V*all					0.00-0.15
V*fitted	$R^2=0.87$ $p<0.01$ $n=446$				0.00-0.36
v_max	$R^2=0.80$ $p<0.45$ $n=441$	$R^2=0.95$ $p<0.23$ $n=441$			0.00-1.65
v_bottom	$R^2=0.24$ $p<0.00$ $n=438$	$R^2=0.52$ $p<0.05$ $n=438$	$R^2=0.58$ $p<0.06$ $n=438$		0.00-1.65

Table 3: Correlation analysis of the calculated parameters for the hydraulic condition, including the range of values [m/s]

The location of the reaches within the lower Thur River had no significant effect (One-Way ANOVA) on *V*fitted*. Differences between channelised and rehabilitated reaches also were non-significant (ANOVA), as shown in Table 4. When looking at the different sample sessions individually, and thus ruling out time-effects, a trend can still be found with channelised reaches having slightly higher *V*fitted*.

Morphology	1	2	Parameter
1			
2	0.07		V*fitted
3	0.95	0.94	

Table 4: All data sorted by 1:revitalised 2:channelised 3:Murg (One-Way ANOVA, probability of Post-Hoc-Tuckey for unequal N, significant differences highlighted)

It appears that rehabilitated reaches, on the other hand, offered a greater spectrum of shear velocity, with a standard deviation in rehabilitated reaches of 0.09 compared to 0.07 in channelised ones (Figure 8), but these differences were non-significant (p=0.07). Sites with low *V*fitted* are more frequent in rehabilitated sites. About 39% of *V*fitted* values were <0.05$\frac{\mathrm{m}}{\mathrm{s}}$, compared to 25% in channelised sites.

5.4 Periphyton

5.4.1 Spatial-temporal distribution

The parameters for periphyton biomass, *Chl. a* and *AFDM*, were not correlated (r=0.15).
Chl. a averaged 397mg/m^2 and *AFDM* 7437mg/m^2 (Table 5).

Figure 9 illustrates the change in biomass along the lower Thur River. *Chl. a* seemed to slightly increase toward the upstream reaches. The River Murg had a clearly higher mean value than all reaches in the Thur. *AFDM* showed no consistent pattern.

Some sites in rehabilitated reaches (Gütighausen site 1 & 3, Niederneunforn1 site1, Niederneunforn2 site3) with low current velocities, deposits of seems build up and impaired periphyton accrual (Appendix F.15).

Temporal variability in periphyton was characterised by an increase in mean *AFDM* from 20 June to 28 June. This reflects the discharge profile with high mean *AFDM* values with low discharge. Mean *Chl.a*, on the other

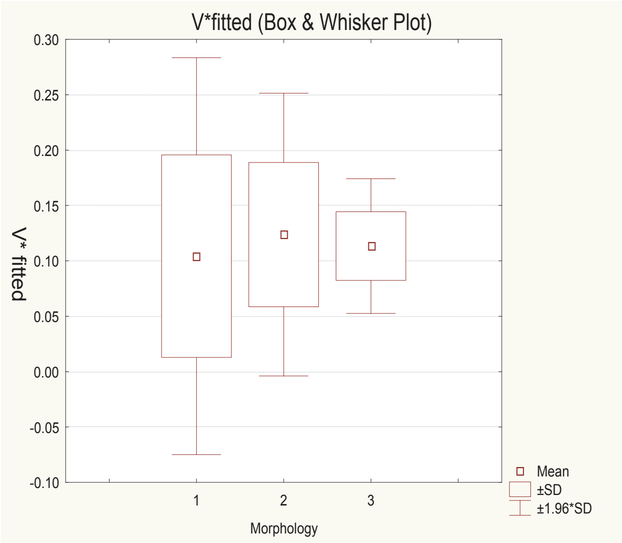

Figure 8: Standard deviation of V*fitted by morphology; 1:rehabilitated 2:channelised 3:Murg

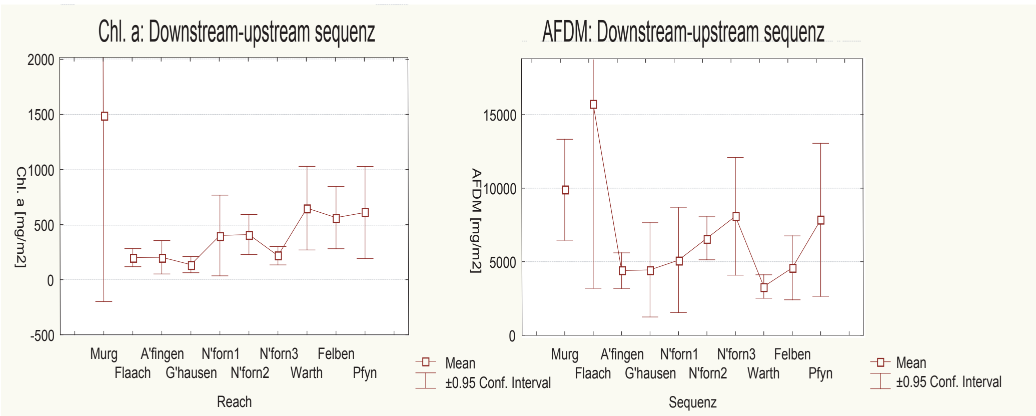

Figure 9: Mean Chl. a & AFDM in a downstream-upstream sequence. Murg is out of the sequence.

	Chl. a [mg/m^2]	AFDM [mg/m^2]	Autotrophic Index (AI)
max.	10982	353992	5138
min.	0	0	0
mean	397	7437	110
median	81	3661	51
std. dev.	1033	23207	324
n	325	226	

Table 5: Descriptive statistics of Chl. a, AFDM and the autotrophic index (AI) for all data-sets combined

hand, was low during the drought period (18. June-18. July). Once mean discharge rose (Mid-July), *Chl. a* increased. It seems that higher than minimum discharge supports this process, since the values only increase once the period of very low waterlevels ends.

Figure 10 contains plots of discharge in Alten, overall *Chl.a* and *AFDM*. Appendix F.16 also illustrates the same relations individually for reach Gütighausen (rehabilitated) and Flaach (channelised) which are in accordance with the plots of means for all sites.

AFDM was significantly higher in channelised than in rehabilitated reaches ($p<0.05$ for *ln(AFDM)*). Differences in *Chl. a* between the two morphologies were not significant ($p=0.37$ for *ln(Chl. a)*) (Figure 11).

5.4.2 Influence of V*fitted and light

Neither *Chl. a* or *AFDM* correlated with *V*fitted* (Chl. a: $R=0.06$, $p=0.20$; AFDM: $R=0.00$, $p=0.91$ Figure 12). Eliminating the influence of reach and date, no relation between biomass and *V*fitted* was evident (Appendix F.14).

Regression analysis revealed no significant relationship between grain size distribution and *Chl. a* ($R=0.003$, $p=0.72$) and *AFDM* ($R=0.08$, $p=0.33$), respectively.

Except for 6/7 August, *Chl. a* and AFDM were unrelated to the relative PAR intensity at the bed surface (with data from 6/7 August, Chl. a: $R^2=0.16$, $p=0.001$; AFDM: $R^2=0.03$, $p=0.167$)

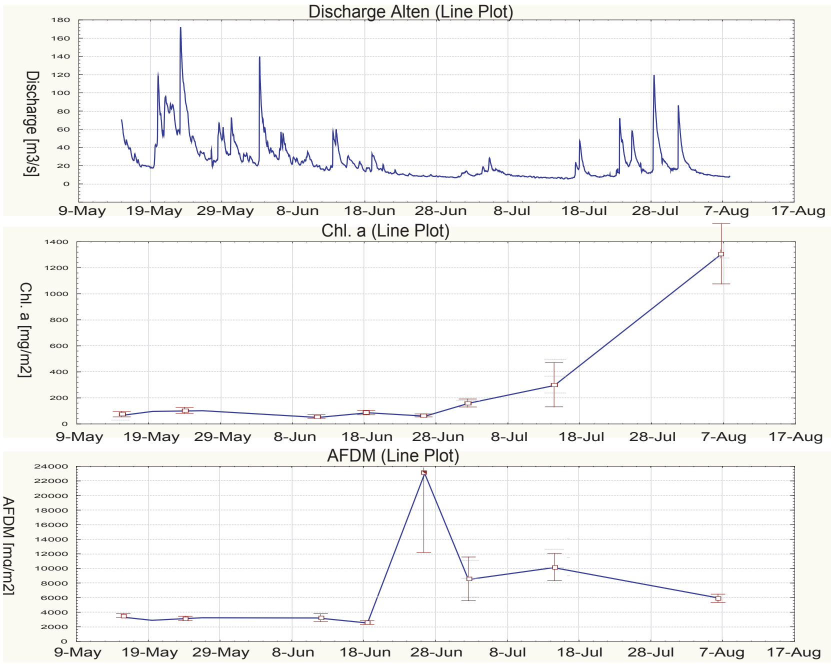

Figure 10: Multiple Line Plots for discharge in Alten, Chl. a and AFDM (all reaches)

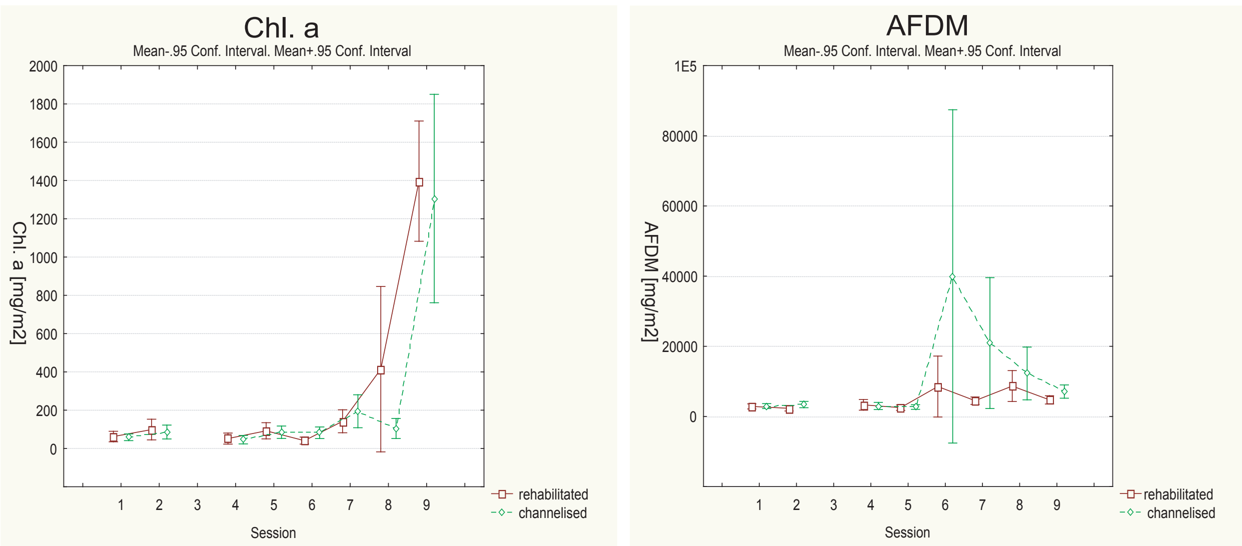

Figure 11: Temporal development of Chl. a and AFDM for rehabilitated and channelised reaches. For better visual distinction, datapoints for channelised morphology are shifted slightly to the right.

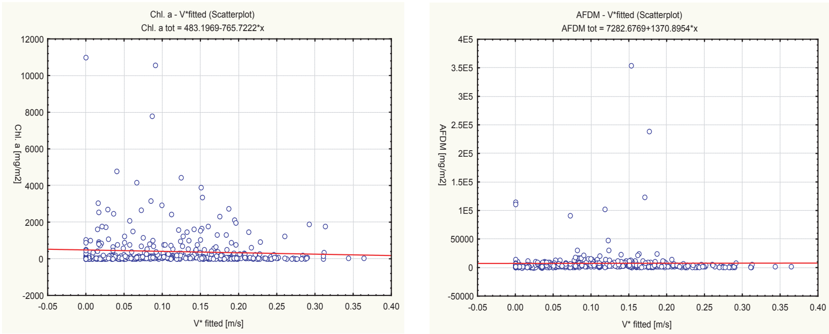

Figure 12: Chl. a & AFDM versus V*fitted

5.5 Murg

The Murg River differs from the Thur in some respects. Table 6 and Figure 60 in Appendix F.18 show an overview of chemo-physical parameters according to a t-test, although a satisfying databases existed only for temperature and conductivity. Temporal effects could be viewed by looking at the data sorted by sample session. Appendix F.19 shows this for conductivity.

Variable	Thur Mean	Murg Mean	p	Thur Valid N	Murg Valid N	Thur Std.Dev.	Murg Std.Dev.
Temp	21.1	19.9	0.4	437	12	4.6	3.5
Conductivity	399.6	568.8	0.0	433	12	57.4	128.6
Turbidity	24.7	3.8	0.7	430	11	168.6	4.0
pH	8.4	8.7	0.0	116	5	0.2	0.1
Lightext. ε	-1.6	-2.3	0.7	321	3	3.2	0.0
Average stone-length	0.03	0.03	0.46	149	8	0.02	0.01

Table 6: Overview over the chemo-physical parameters for the rivers Thur and Murg with significant differences highlighted

The inflow of the River Murg into the Thur takes place some 240m above the sampling-location Warth. As can be expected by the significant difference in conductivity between the two rivers, at the location Warth site 1 (at this side of the river the Murg flows into the Thur) also had a significant increase in conductivity compared to site 2 and 3 which were the same. (Figure 13, Appendix F.20)

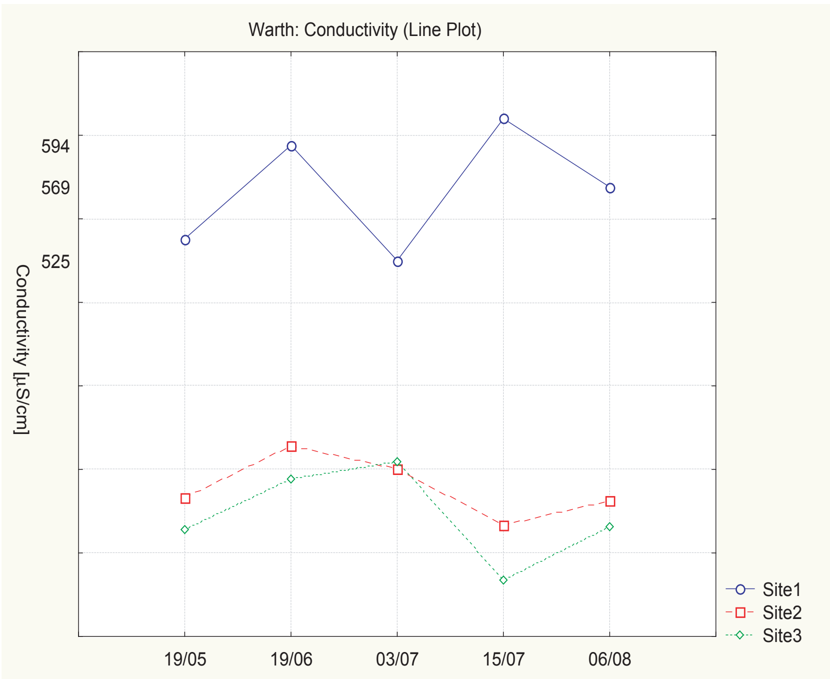

Figure 13: Line-plot of the temporal variation in conductivity for sites 1, 2 and 3 at location Warth

6 Discussion

The results of this study demonstrated a minor influence of changes in channel morphology on hydraulic conditions and periphyton biomass in the Thur River. The variability in shear velocity was higher in rehabilitated than in channelised reaches but differences between both reach types were non-significant. Ash-free dry mass was significantly higher in rehabilitated reaches, but chlorophyll a did not significantly differ between rehabilitated and channelised reaches during the entire investigation. The lack of any significant relation between hydraulic parameters such as shear velocity, near bottom velocities or maximum velocity, and periphyton biomass was striking.

During the study, nutrient concentrations were high; agricultural runoff and discharge of treated sewage raised nutrients far above limiting concentrations, particularly during the extended period of low discharge ([20], [10]). Light availability was high at all sites because of low depths and high water transparency. There was some evidence that periods of high light attenuation were restricted to spates and, thus, relatively short. Temperatures were unusually high, especially during the second part of the study, compared to temperatures measured in other years [21]. Environmental conditions similar to those observed in the Thur River during summer 2003 are considered to enhance periphyton growth ([11], [10], [4]). Potential factors limiting periphyton accrual are hydraulic forces (shear stress) and biotic processes such as senescence of biofilms or grazing by invertebrates. During an average year, the relatively frequent bed-moving spates also affect invertebrates and, thus, presumably reduce the grazing impacts on periphyton. In summer 2003, the lack of major floods may have enhanced the grazing pressure and, as a consequence, confounded hydraulic influences. As shown by [3] the successional stage of periphyton and its species composition also have major effects on its response to increased shear velocities.

The lack of significant differences in hydraulic conditions (shear velocity) between channelised and rehabilitated reaches may also result from the particular flow conditions of summer 2003; hydraulic parameters such as shear velocity and near bottom velocity were low and within a relatively narrow range in all reaches and sampling dates. In the prealpine river Necker, a tributary of the upper Thur River, near bottom shear-forces range from 0.00 to 30.2N/m^2 [9] compared to 0.00-0.13N/m^2 during this study. Channelised reaches developed habitats such as backwater or disconnected water bodies which are typical for rehabilitated reaches under normal discharge. Nevertheless, hydraulic conditions were more variable in rehabilitated reaches (although not significant).

7 Outlook

The results derived in this study showed little differences in rehabilitated and channelised reaches with respect to periphyton biomass and hydraulic conditions. But it must be stressed that these results were gained during an extreme and unusual hot and dry summer. In order to get information on periphyton biomass and hydraulic conditions, further studies should include "normal" flow conditions.

The results of this study may be of some importance considering the impact of global climate change. A study focussing on the influence of climate change for the Thur River [6] expects an increase in low-water events during summer and an average decrease of 10% (-20-30% during summer, +10-20% during winter) in overall discharge.

To transfer the results of this study to the River Rhône is problematic, especially in the face of flow variation that is induced by power plant operations that alter not only hydraulics but also temperature, light (turbidity) and nutrient regime [5], [13].

8 Acknowledgements

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Dr. Urs Uehlinger, who gave me the opportunity for this work, supported me with many hints and tips and was even available during his holidays to answer questions and help me with this report!
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Lorenz Meier
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BWG for the provision of detailed discharge-data,
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A Sampling-Sites

A.1 Flaach

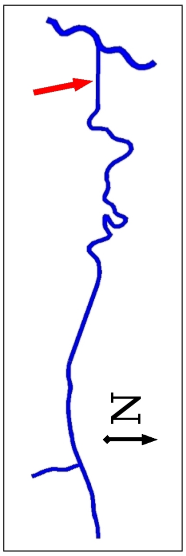


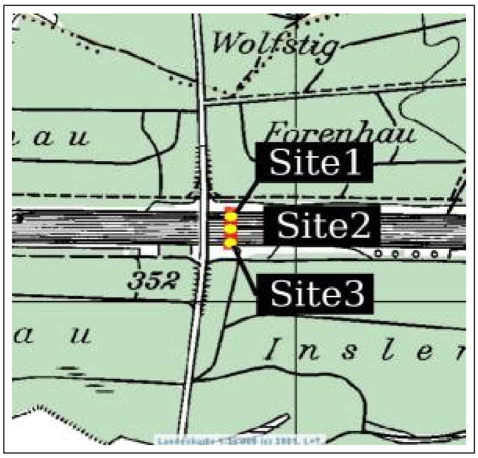
Figure 14: *Impression* and *geographical position* of the site Flaach

Flaach is **channelised**.
(CH-Coordinates: 687856, 272172)

Site1 Bigger stone-structures would show up when low waterlevel was present reducing current to almost nothing.

Site2 In the second half of the sampling-period waterlevel was very low and a great algae-mat developed some 50m above the site, reducing current.

Site3 Remarkebly deeper the the rest of the transect it also showed the greatest current.



A.2 Andelfingen

Figure 15: *Impression* and *geographical position* of the site Andelfingen

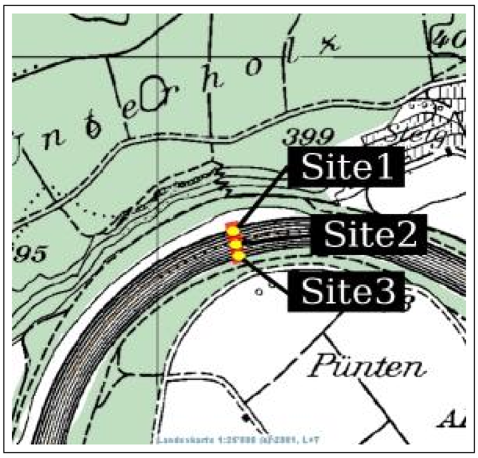
Andelfingen is **revitalised**.
(CH-Coordinates: 692236, 273729)

Site1 At the most forwarded point of the wing-dams, quite deep with low current.

Site2 High current, intermediate depth.

Site3 Low depth, bigger stone-structures reduced velocity.

Andelfingen was only samples in session 8 & 9.



A.3 Gütighausen

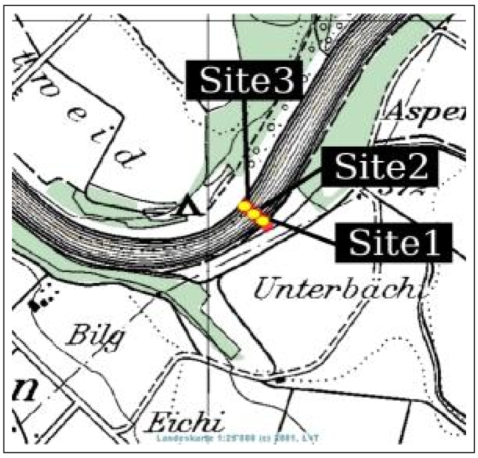
Figure 16: *Impression* and *geographical position* of the site Gütighausen

Gütighausen is **revitalised**.
(CH-Coordinates: 698049, 271705)

Site1 Behind wing-dams, quite deep with very low current but turbulent.

Site2 At the left side of the main-channel with high current, steep.

Site3 Backwater, no current, lots of slick, very little periphyton. Was cut of from the main-channel for the 2nd half of the sampling-period.



A.4 Niederneunforn1

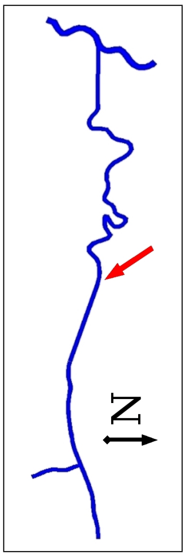


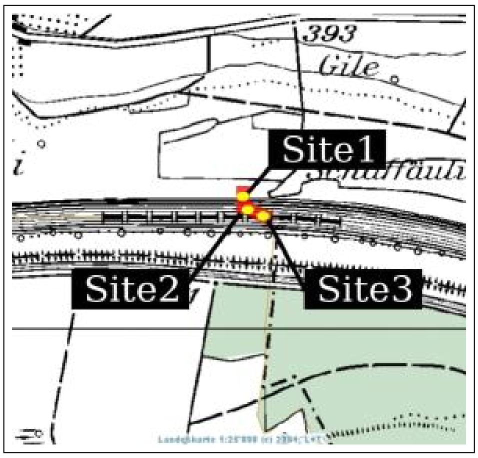
Figure 17: *Impression* and *geographical position* of the site Niederneunforn1

Niederneunforn1 is **revitalised**.
(CH-Coordinates: 699887, 272195)

Site1 Inflow of sidechannel, low current. Lots of slick and periphyton, underground sandy. Temperature lower than main-channel. Behind sandbank.

Site2 Intermediate current, low depth.

Site3 Middle of main-channel with verly low depth but high current.



A.5 Niederneunforn2

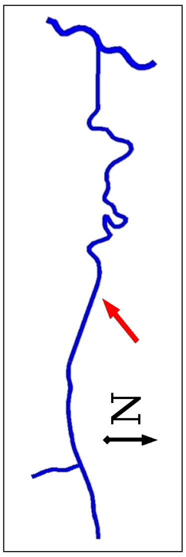


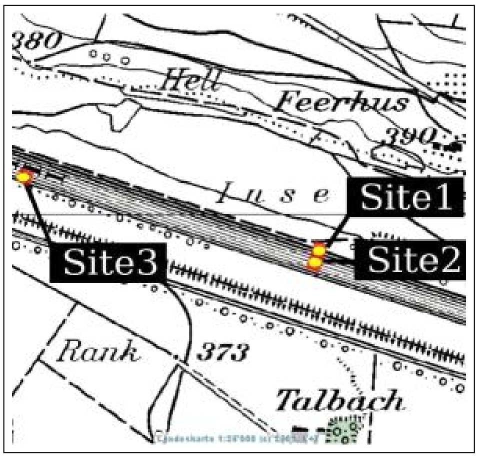
Figure 18: *Impression* and *geographical position* of the site Niederneunforn2

Niederneunforn2 is **revitalised**.
(CH-Coordinates: 700614, 271936)

Site1 Low current, intermediate depth. High amount of algae developed in the 2nd half of the sampling-period.

Site2 Intermediate current, intermediate depth. High amount of algae developed in the 2nd half of the sampling-period.

Site3 Backwater behind sandbank with no current, lots of slick and very little periphyton.



A.6 Niederneunforn3

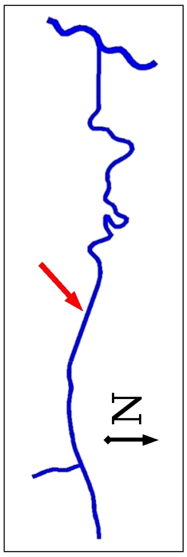


Figure 19: *Impression* and *geographical position* of the site Niederneunforn3

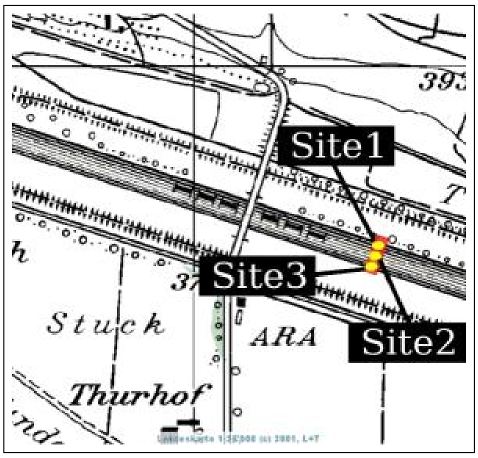
Niederneunforn3 is **channelised**.
(CH-Coordinates: 701157, 271733)

Site1 Intermediate current, deep. Big stone-structures behind site reduce current. Trees cover site.

Site2 High current, intermediate depth. In the middle of the main-channel.

Site3 High current, intermediate depth.

Site 2 & 3 are very uniform.



A.7 Warth

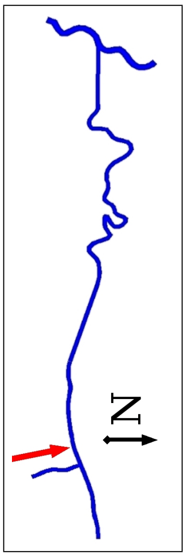


Figure 20: *Impression* and *geographical position* of the site Warth

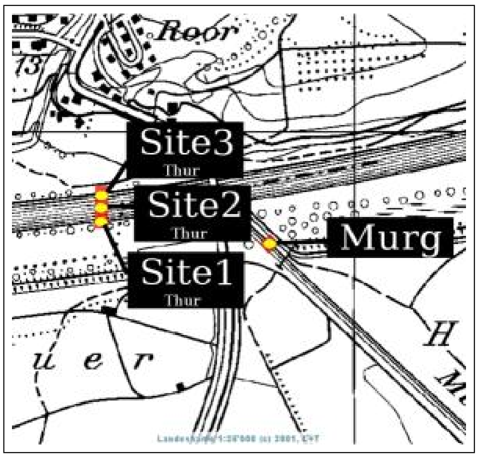
Warth is **revitalised**.
(CH-Coordinates: 708519, 270840)

Site1 At the hight of the top of wing-dams. Very low depth, low current.

Site2 High current, deep. In the middle of the main-channel.

Site3 High current, intermediate depth.

At Site 1 the influence of the Murg is apparent.



A.8 Felben

Figure 21: *Impression* and *geographical position* of the site Felben

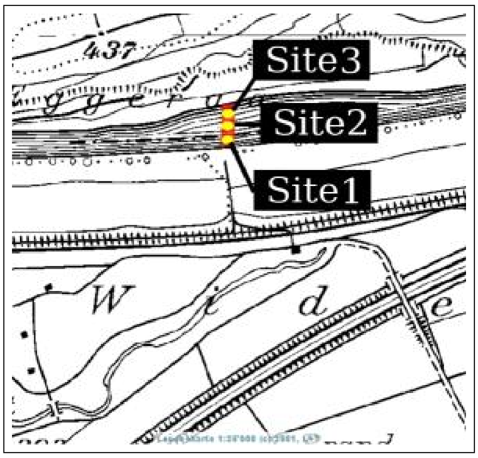
Felben is **revitalised**.
(CH-Coordinates: 712415, 271824)

Site1 Intermediate current, low depth.

Site2 Very high current, deep. In the middle of the main-channel.

Site3 Intermediate current, low depth.

Felben was only sampled three times.



A.9 Pfyn

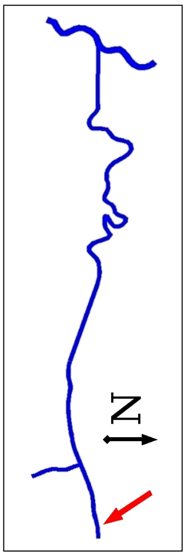


Figure 22: *Impression* and *geographical position* of the site Pfyn

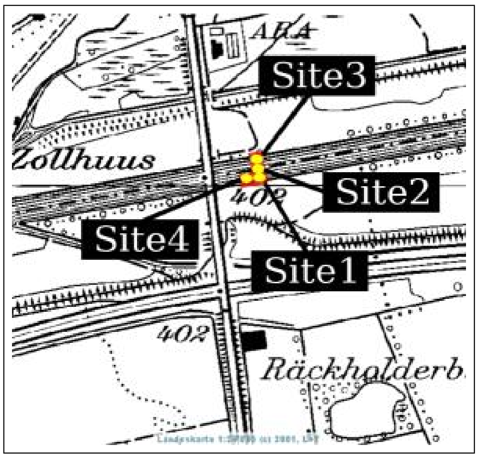
Pfyn is **channelised**.
(CH-Coordinates: 713554, 272002)

Site1 Intermediate current, intermediate depth.

Site2 Intermediate current, intermediate depth. In the middle of the main-channel.

Site3 Intermediate current, intermediate depth.

Site4 Behind big stone-structures. Low current, intermediate depth. Was cut off the main channel in the last sessions and the developed very high amount of algae.

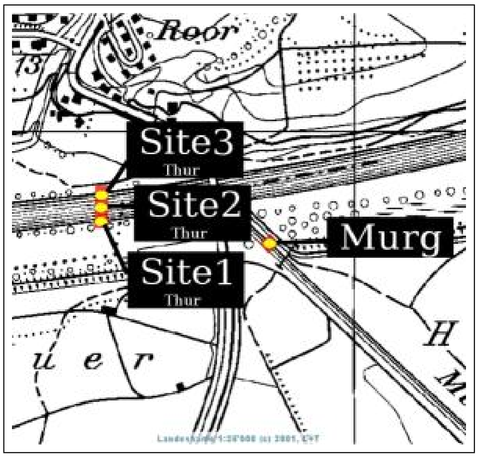


Pfyn is very uniform with exception of site 4.

A.10 Murg

Figure 23: *Impression* and *geographical position* of the site Murg

Murg is **channelised**.
(CH-Coordinates: 708839, 270809)
It is a tributary of the Thur with lower discharge (~1/15 during the sampling-period) and different water-characeristics (high values of nutrients, high cunductivity, see section 5.5). Reach is very uniform and was taken as one site with a sample taken at each bank and one in the middle. Current was intermediate and depth low.



B Materials & Methods

B.1 Velocity Meter

Figure 24: Velocity meter Mini-Air2 by Schiltknecht

Mini-Air2 by Schiltknecht (Figure 24).
Head-Dimensions: 22 x 28mm
Range: 0.4-20m/s

B.2 Conductivity Meter

Figure 25: Conductivity meter LF323 by WTW

Conductivity meter LF323 by WTW, Weinheim, Germany (Figure 25).
Conductivity-range: 0 to 500mS/cm
Temperature-range: -5 to +99.9°C

B.3 Turbidity Meter

Figure 26: Turbidity meter Cosmos by Züllig

Turbidity meter Cosmos by Züllig (Figure 26).

B.4 Light-Probe and Data-Logger

Figure 27: Light-probe and data-logger

Light-probe from Lambda Instr. Corp and the attached data logger LI-1000 by LiCor Inc. (Figure 27).

B.5 pH Meter

Figure 28: pH meter 330/Set1, WTW

pH meter 330/Set1 by WTW, Weinheim, Germany (Figure 28).

B.6 Picture of river-bed stones

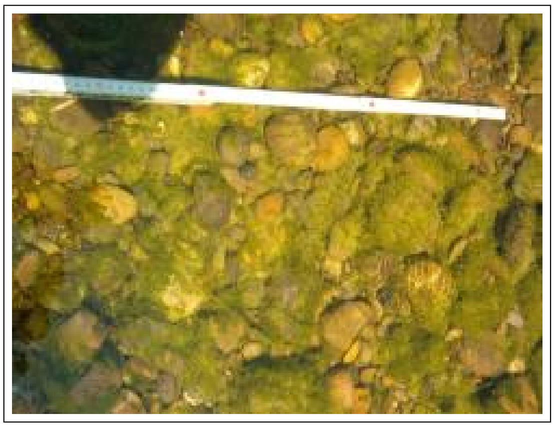


Figure 29: Picture of river-bed stones, Pfyn, site1, July 15. 2003

Figure 29 shows a sample-picture of the riverbed, which was used to measure the mean diameter of the sediment-building stones.

C Geographical location of the gaugin-stations

Figure 30 shows the geographical location of the gaugingstations Alten and Murg and the NADUF-station in Andelfingen. Station Halden is further away and therefore not given in the graph.

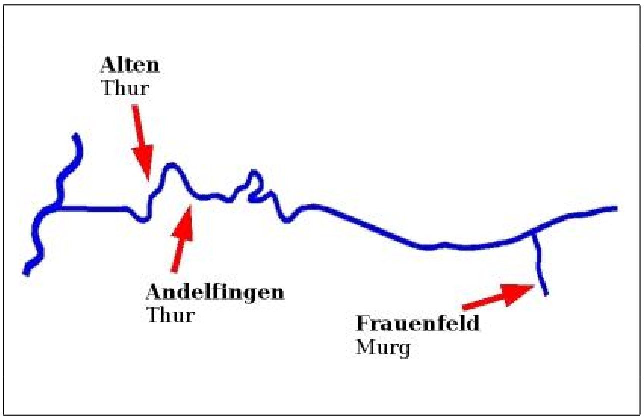


Figure 30: Location of the gauging-stations in the lower part of the rivers Thur and Murg

D Geographical location of the sampling reaches

The locations of the sampling reaches are given in Figure 31

Figure 31: Sampling reaches

E Sampling schedule

Site Session	15./19.5. 1	26./27.5. 2	3.6. 3	11.6. 4	18./19.6. 5	26.6. 6	2./3.7. 7	14./15.7. 8	6./7.8. 9
Flaach	X	X+	(X)+l	Xl	Xl	Xl	Xl	Xl	X+l
A'fingen								Xl	X+l
G'hausen	X+	X+	(X)+l	Xl	Xl	Xl	Xl	Xl	X+l
N'forn1	X	X+	(X)+l	Xl	Xl	Xl	Xl	Xl	X+l
N'forn2	X	X+		Xl	Xl	X	X	X	X+
N'forn3	X	X+			Xl	Xl	X	Xl	X+l
Warth	X+	(X)+	(X)+		Xl		Xl	X	X+
Murg	X+		(X)		X		Xl	Xl	X+l
Felben					Xl			Xl	X+l
Pfyn	X+		(X)+		Xl			Xl	X+l

Table 7: The schedule of the sampling

Tabel 7 shows when samples were taken. The coding is as follows:

X	periphyton-sample was taken in at least 1 site
(X)	it was not possible to take a periphyton-sample
+	nutrients were measured
l	light-extinction was measured

F Statistics

F.1 Discharge in Halden

Discharge at the gauginstation Halden (Figure 32)

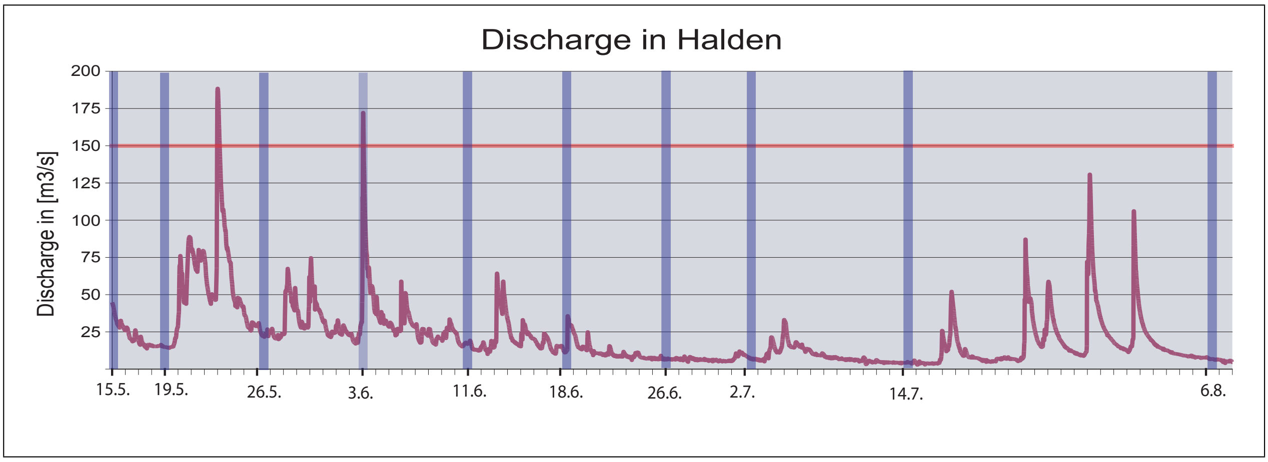


Figure 32: Discharge at the gaugingstation Halden; the blue bars indicate the sampling-dates, the red bar the beginning of sedminet-moving discharge.

F.2 Discharge of River Murg

Figure 33 shows discharge at the River Murg.

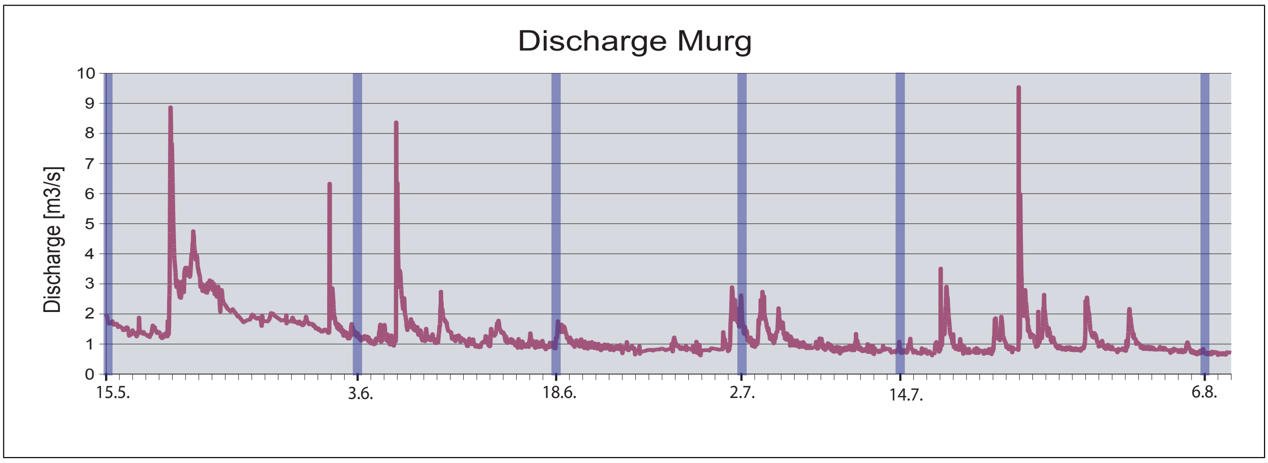


Figure 33: Discharge at the gaugingstation Murg; the blue bars indicate the sampling-dates.

F.3 Discharge of Alten, Halden and Murg

Figure 34 shows discharge in Alten, in Halden and at the River Murg.

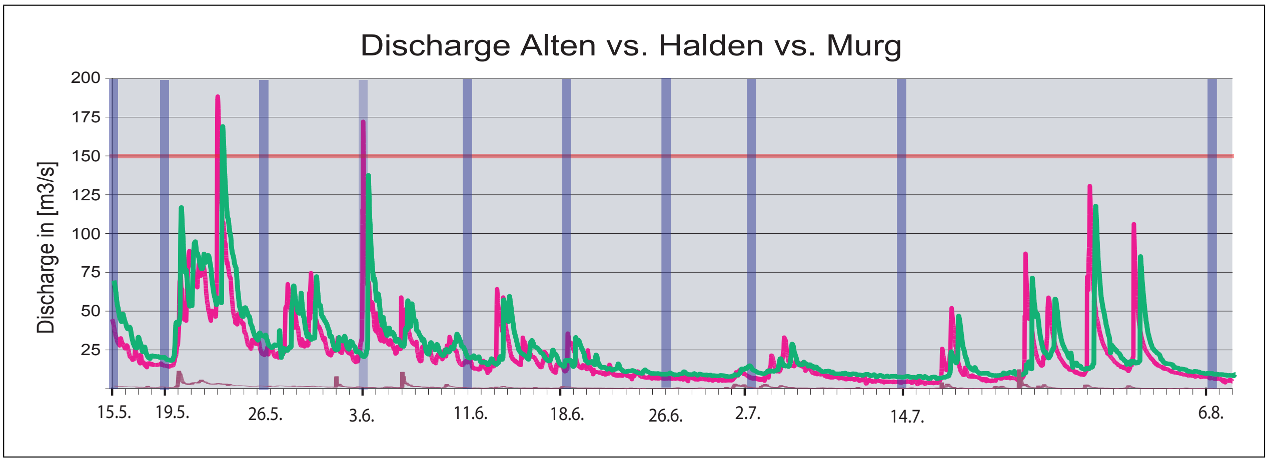


Figure 34: Discharge at the gaugingstations Alten (green), Halden (pink) and Murg-Frauenfeld (bordeaux); the blue bars indicate the sampling-dates, the red bar the beginning of sedminet-moving discharge.

F.4 Scatterplots of temperature, conductivity, turbidity, pH, light-extinction, average stone length

Scatterplots for *temperature* (fig. 35), *conductivity* (fig. 36), *turbidity* (fig. 37), *pH* (fig. 38), *lightextinction* (fig. 39) and *average stone-length* (fig. 40) categorised for locations and sessions.

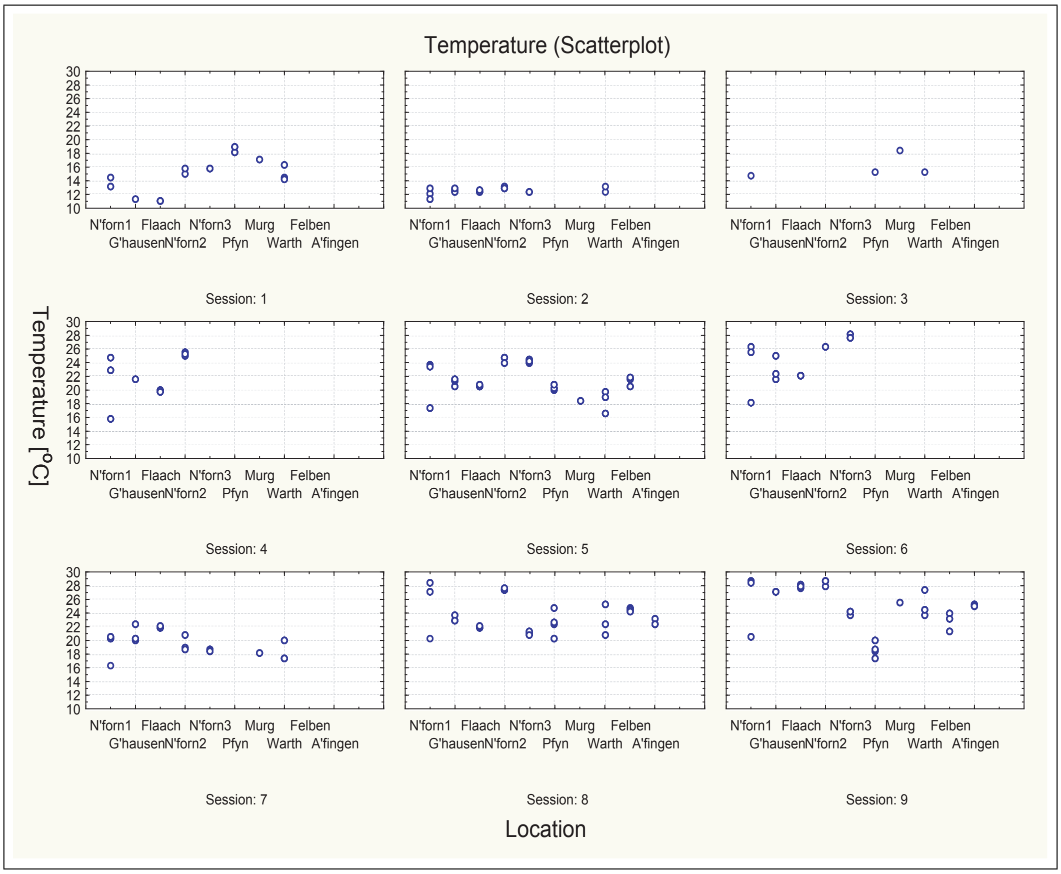


Figure 35: Scatterplots of temperature

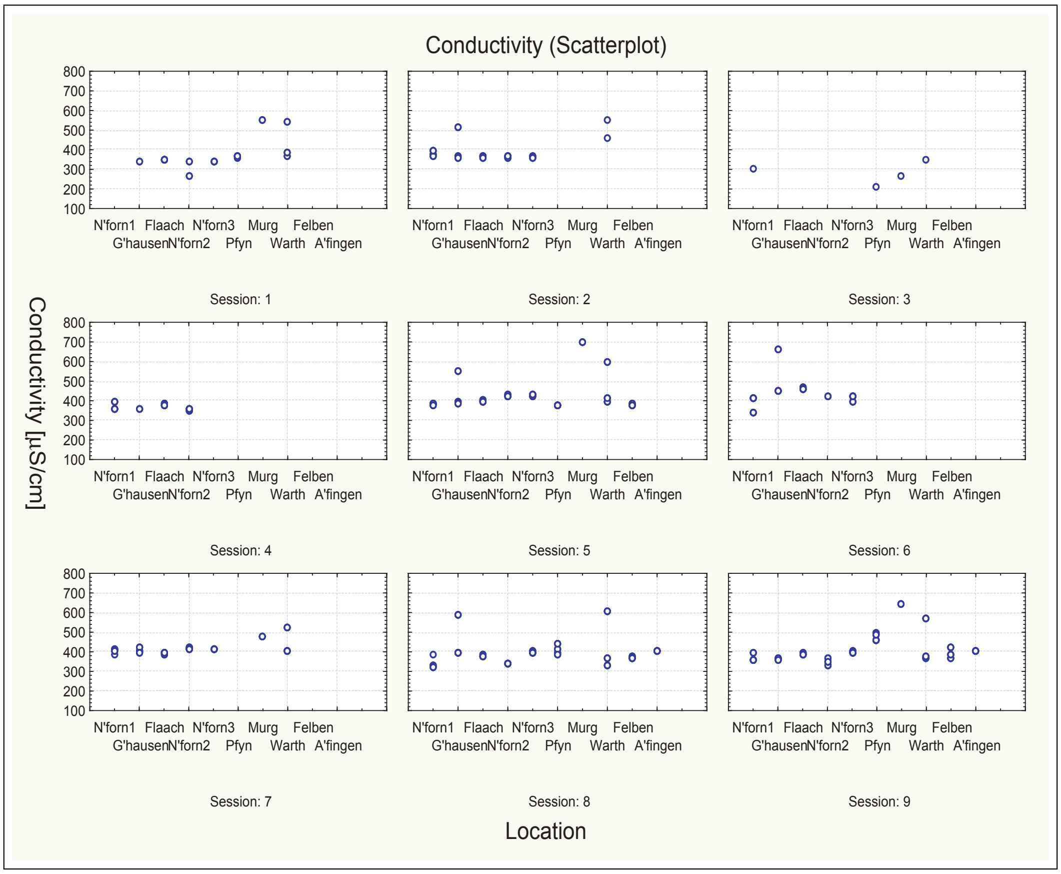


Figure 36: Scatterplots of conductivity

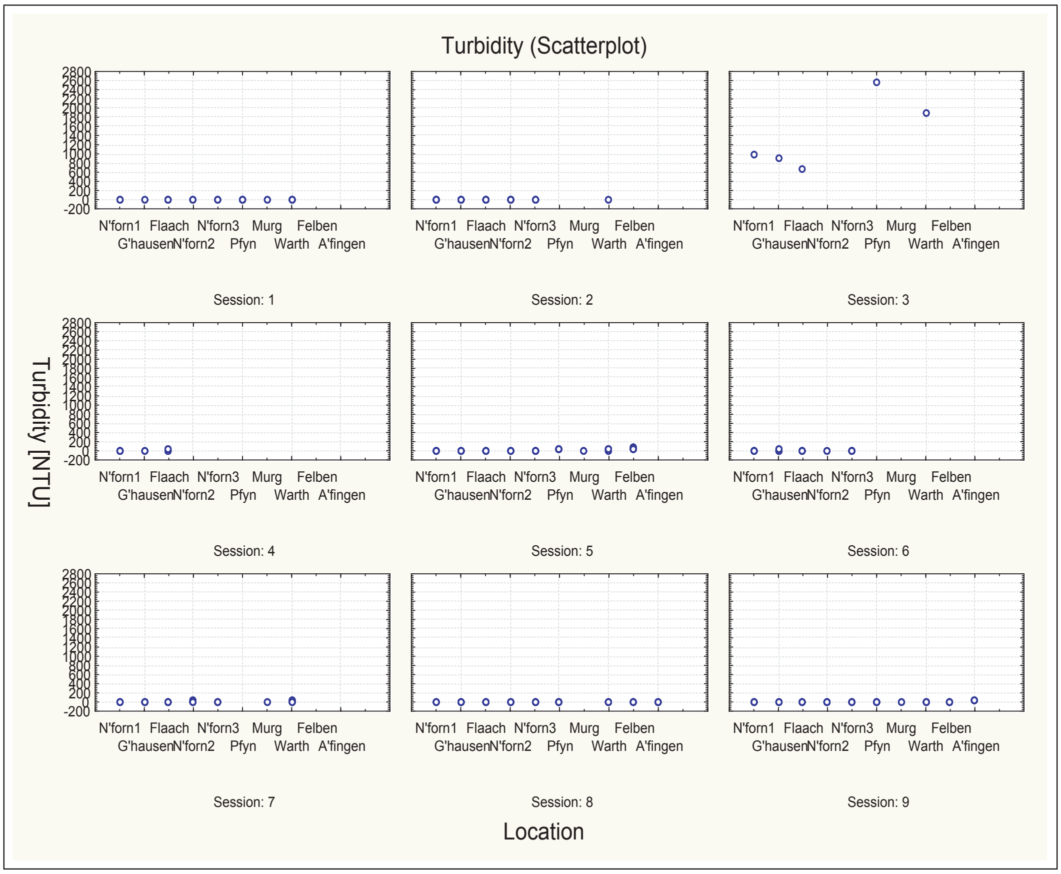


Figure 37: Scatterplots of turbidity

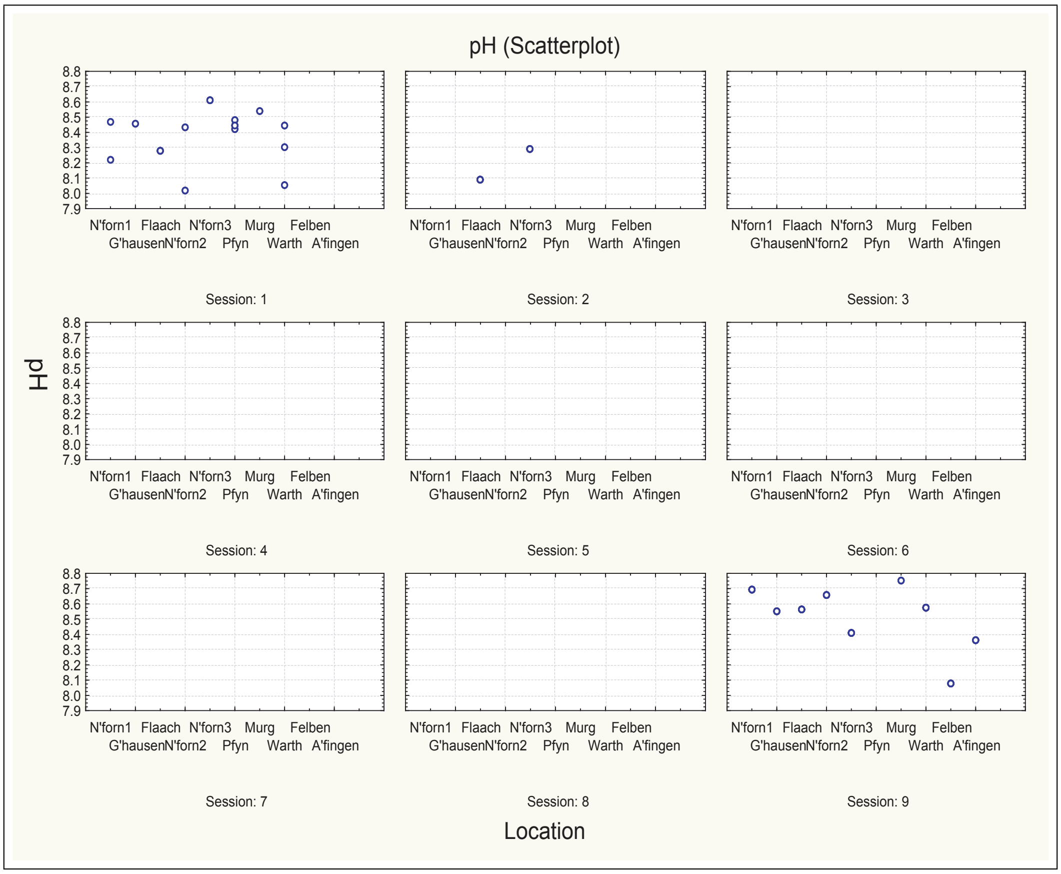


Figure 38: Scatterplots of pH

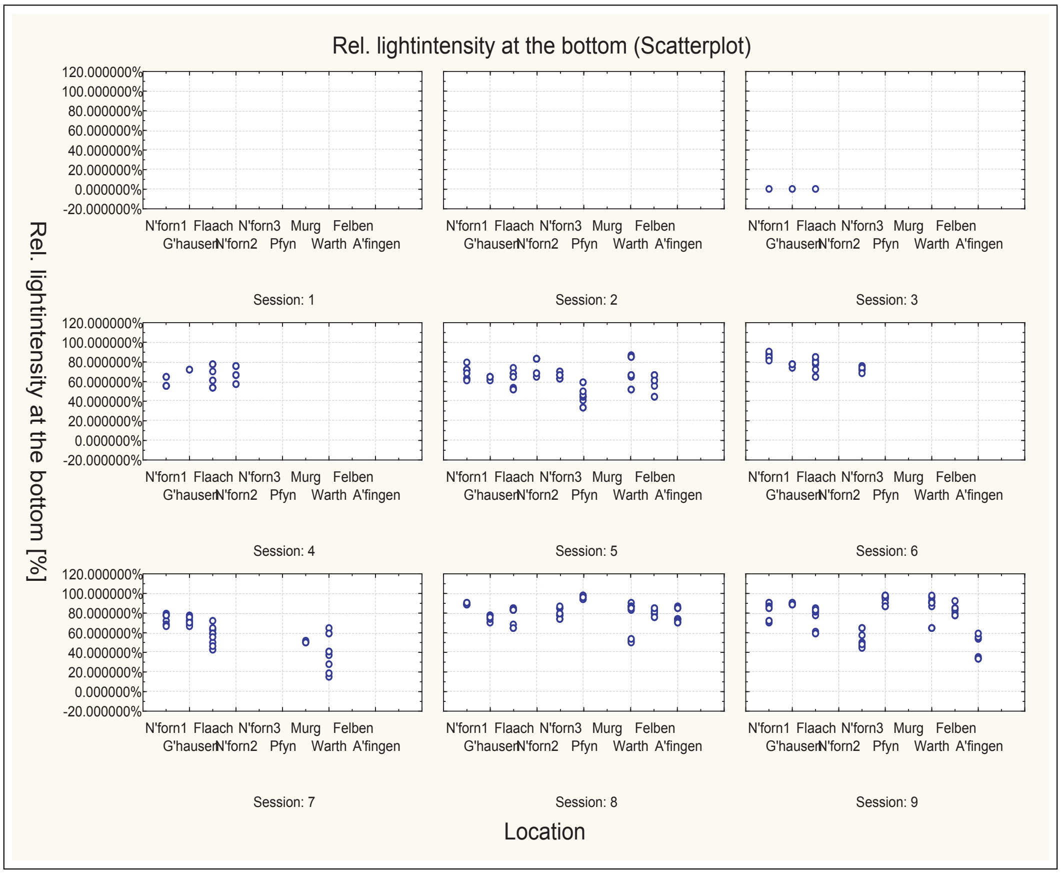


Figure 39: Scatterplots of lightextinction

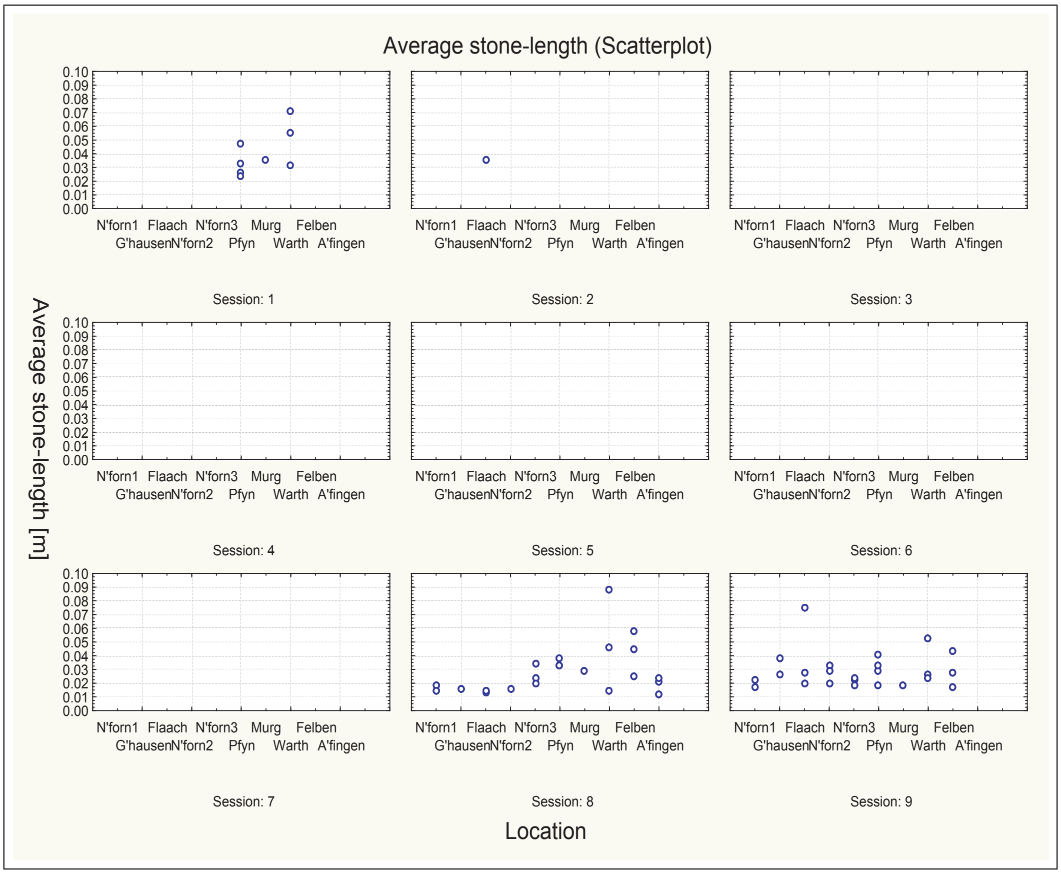


Figure 40: Scatterplots of average stone-length

F.5 Plots sorted for further parameters

Box & Whisker Plots sorted by revitalised and channelised for the parameters *conductivity, depth, lightextinction, pH, average stone-length, temperature* and *turbidity* can be found in figure 41.

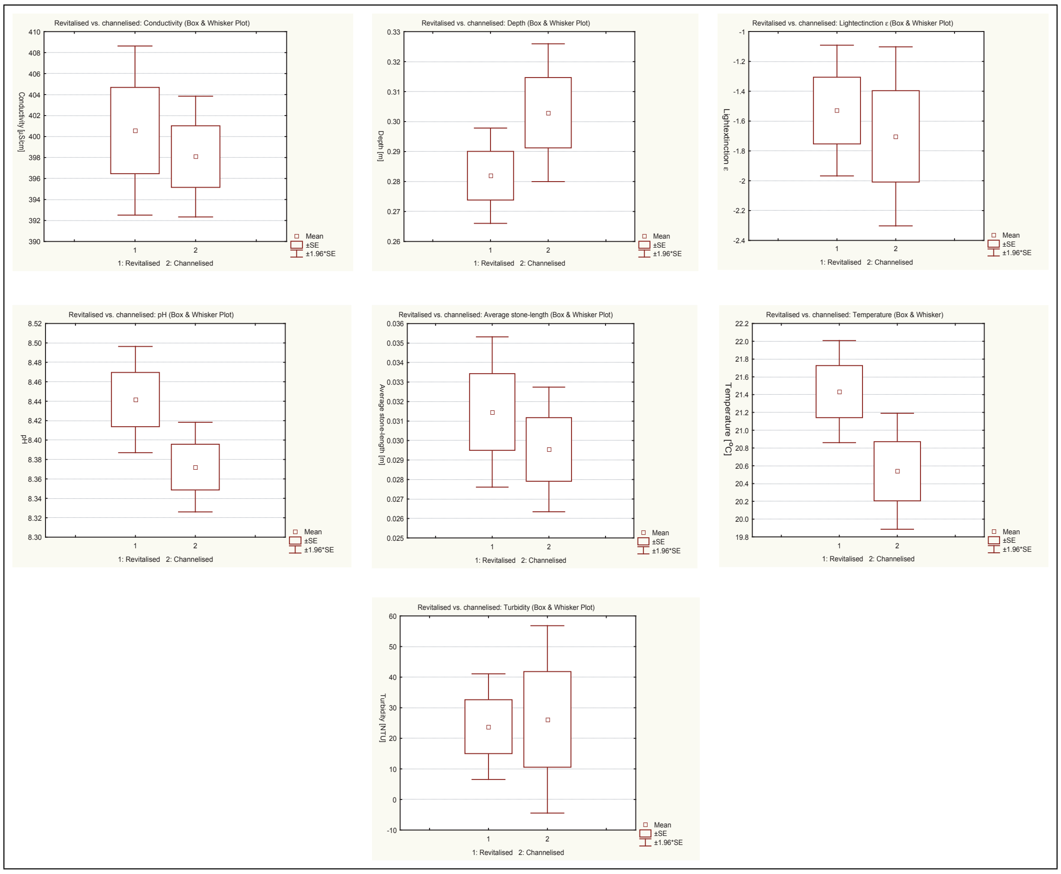


Figure 41: Box & Whisker Plots sorted by revitalised and channelised for conductivity, depth, lightextinction, pH, average stone-length, temperature and turbidity

F.6 Average stone-length in spatial sequence

For session 8 & 9 *average stone-lenth* is plotted in downstream-upstream sequence in Figure 42.

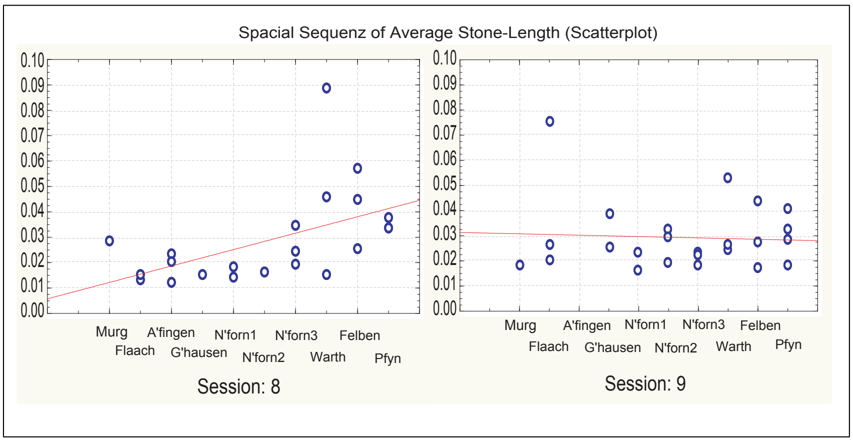


Figure 42: Average stone-length in spatial sequence for session 8 & 9

F.7 Temperature: Box & Whisker Plot for all sessions & fit of my own data with gauging-station Andelfingen

Figure 43 shows a Box & Whisker Plot for all sessions.
The temperature-data taken during the sample sessions fits well with the temperature-profile taken at the gauginstation Andelfingen. As an example data of reach Flaach are plotted against the data in Andelfingen in Figure 44.

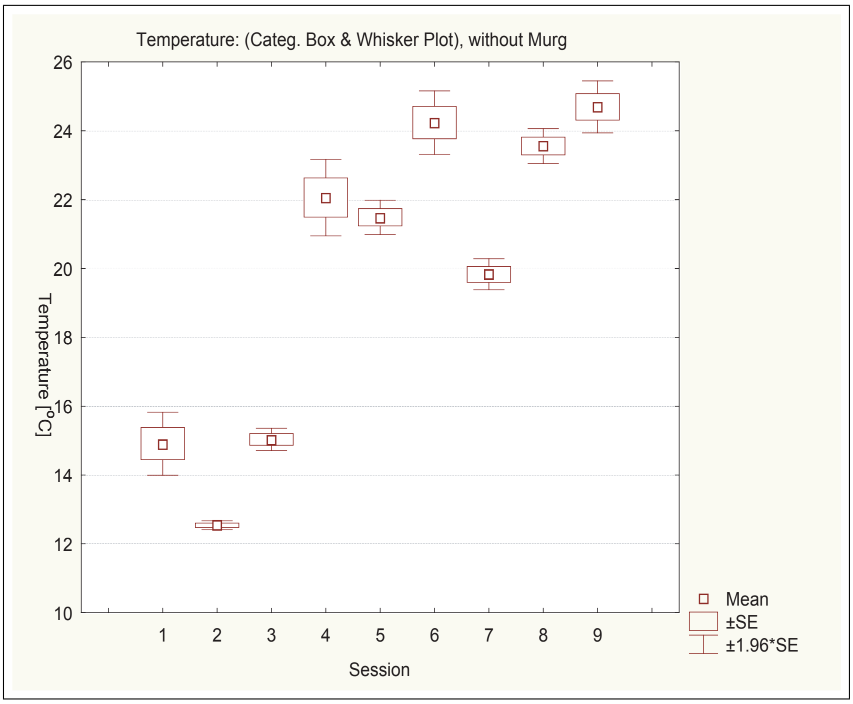


Figure 43: Box & Whisker Plot of the temperature for all sessions (without location Murg)

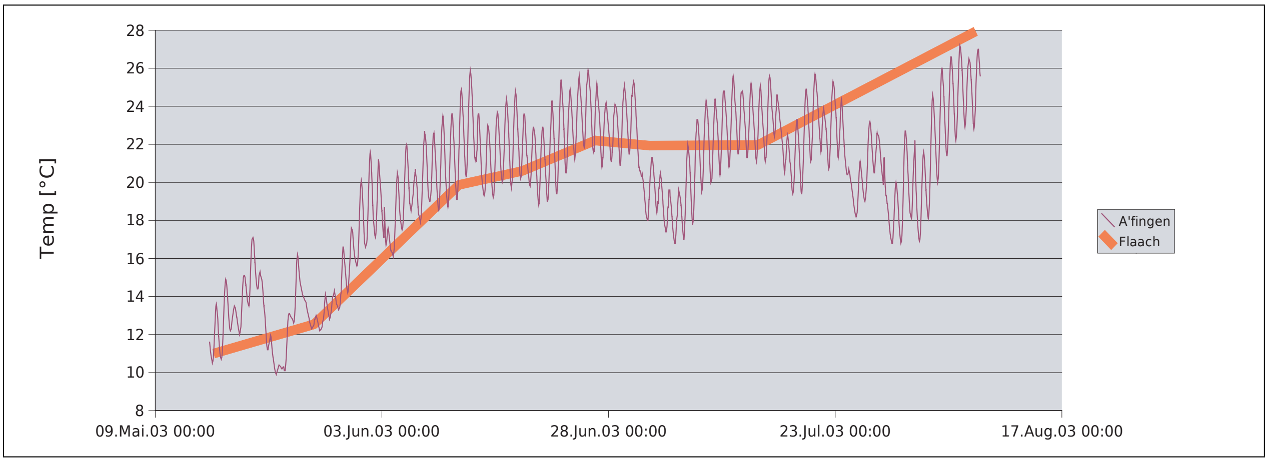


Figure 44: Fit of temperature-data in Flaach with data at gauginstation Andelfingen)

F.8 Nutrients: Table

Table 8 shows the parameters of the water-chemistry.

Ort	Datum	Session	NH_4-N mg/l	NO_2-N mg/l	NO_2-N + NO_3-N mg/l	DN mg/l	PN mg/l	PO_4-P µg/l	DP µg/l	PP µg/l	DOC mg/l	TIC mg/l	POC mg/l
Murg	19.05.03	1	0.11	0.07	3.81	4.6	0.07	14.02	39.91	9.91	3.05		0.57
G'hausen	15.05.03	1	0.02	0.02	1.61	2.03	0.07	27.83	46.04	10.42	2.36		0.72
Warth	19.05.03	1	0.12	0.08	4.43	4.87	0.06	22.16	43.42	8.12	2.98		0.39
Pfyn	19.05.03	1	0.01	0.02	1.53	2	0.06	24.63	44.22	9.38	2.31		0.45
Flaach	26.05.03	2	0.02	0.02	1.5	2	0.04	43	65	6.5	3.25	45.49	0.4
G'hausen	26.05.03	2	<0.01	0.02	1.4	1.9	0.04	32	56	6.5	2.5	43.93	0.34
N'forn1	26.05.03	2	0.03	0.02	1.3	1.8	0.04	32	54	5.7	3.52	44.4	0.4
N'forn2	26.05.03	2	0.03	0.03	1.5	2	0.04	33	60	6	3.03	42.7	0.37
N'forn3	27.05.03	2	0.01	0.03	1.8	2.4	0.06	39	63	8.1	2.61	44.34	0.39
Warth	27.05.03	2	<0.01	0.04	4.3	4.8	0.08	87	137	10.8	3.99	62.33	0.84
Flaach	03.06.03	3	0.01	0.03	1.48	2.05	1.76	37.04	65.43	524.26	2.89		14.03
G'hausen	03.06.03	3	0.06	0.03	1.32	1.72	0.48	39.24	61.34	60.38	3.31		42.28
N'forn1	03.06.03	3	0.05	0.02	1.19	1.52	0.44	33.74	55.4	55.38	2.68		41.66
Warth	03.06.03	3	0.04	0.02	1.75	2.16	0.54	32.16	59.97	150.55	3.42		45.32
Pfyn	03.06.03	3	0.04	0.02	0.88	1.24	0.87	25.76	46.87	263.92	4.7		62.07
Murg	06.08.03	9	0.02	0.02	2.47	2.87	<0.01	11.51	139.69	1.24	3.15	53.74	1
Flaach	07.08.03	9	<0.01	0.09	2.28	2.55	<0.01	9.92	34.73	1.47	2.01	40.66	0.79
A'fingen	07.08.03	9	<0.01	0.01	2.03	2.85	0.01	11.45	37.39	3.54	2.04	41.83	2.41
G'hausen	06.08.03	9	<0.01	0.01	2.29	2.45	0.15	14.82	40.99	108.27	2.06	44.34	0.66
N'forn1	06.08.03	9	<0.01	0.01	2.63	2.64	¡0.01	10.31	34.87	<1	2.11	43.02	0.85
N'forn2	06.08.03	9	0.02	0.01	2.44	2.46	0.08	9.12	33.1	13.63	2.16	42.21	0.92
N'forn3	07.08.03	9	<0.01	0.01	2.53	2.52	0.08	7.57	31.93	12.67	2.34	42.09	0.94
Warth	06.08.03	9	<0.01	0.02	1.42	2.77	0.07	49.38	93.13	11.33	2.67	48.41	0.62
Felben	06.08.03	9	<0.01	0.01	2.33	2.54	0.17	6.74	22.88	106.86	1.81	44.27	0.8
Pfyn	06.08.03	9	<0.01	0.01	1.73	1.93	0.03	5	10.4	5.84	1.18	45.05	0.4

Table 8: Table of water-chemistry

F.9 Correlation shear-force parameters

In figure 45 the correlation between V*all, v_bottom, v_max with V*fitted can be seen.

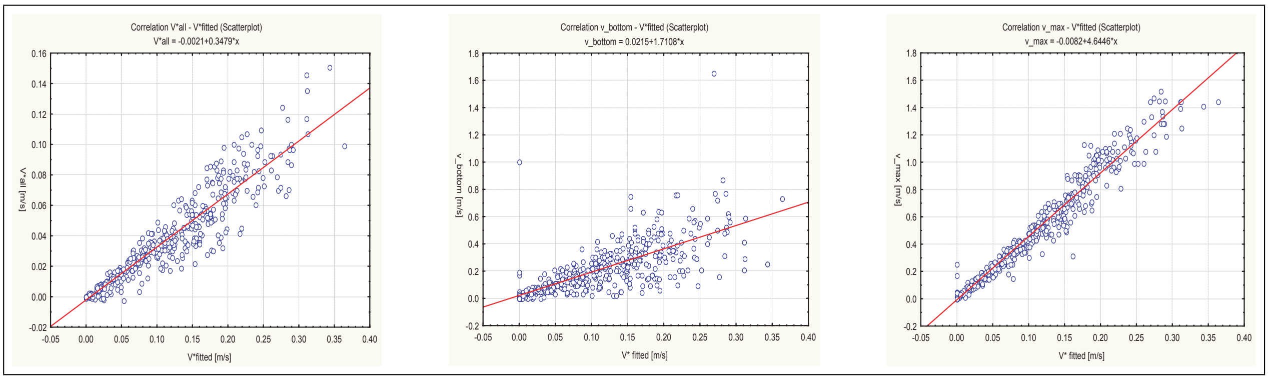


Figure 45: Correlation between V*all, v_bottom, v_max with V*fitted

F.10 V*fitted: spatial distribution of shear velocity during sessions 1, 5, 8 and 9

Figure 46 gives an overview of the spatial distribution of *V*fitted* in a downstream-upstream sequence for session 1, 5, 8 and 9. Table 9 shows the according descriptive statistics and table 10 the results of a Post-Hoc Tuckey test for unequal N.

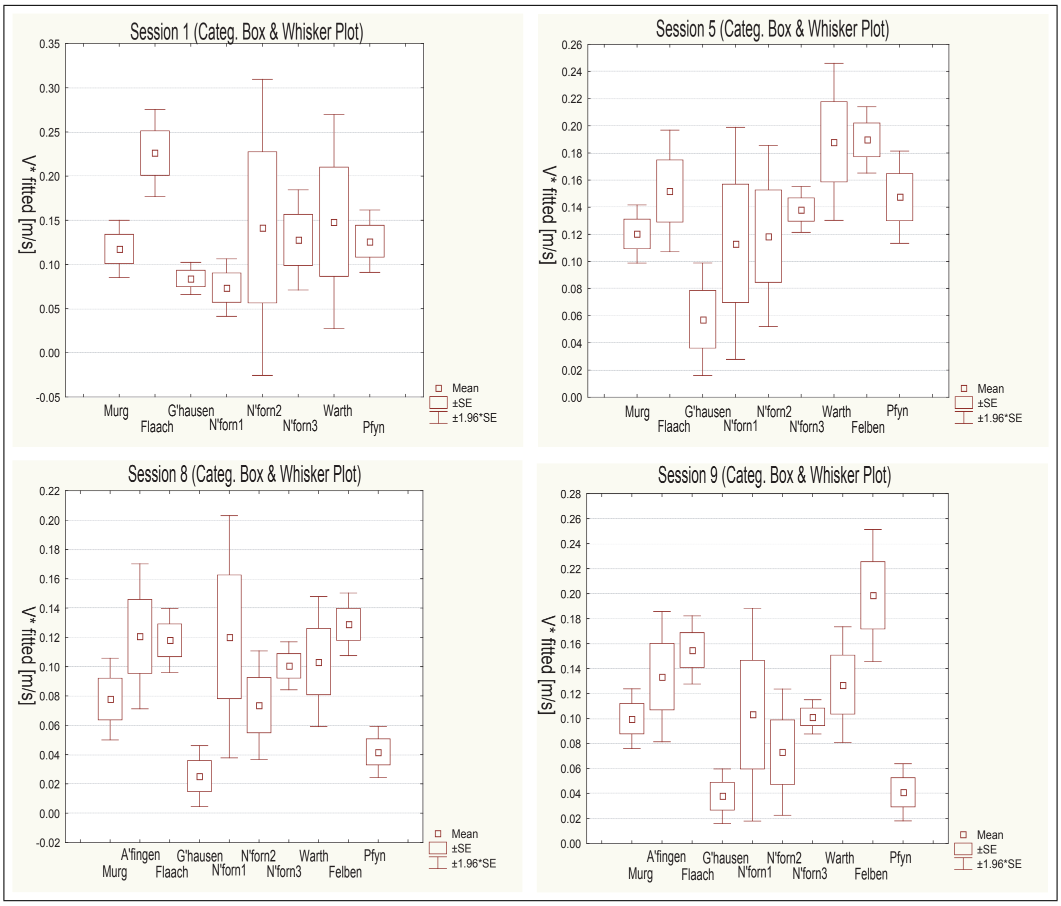


Figure 46: Spatial distribution of V*fitted for session 1, 5, 8 and 9; Murg is out of sequence.

Reach	mean V*fitted	N	Std. Dev.
Session 1			
Murg	0.12	2	0.02
Flaach	0.23	6	0.06
G'hausen	0.08	2	0.01
N'forn1	0.07	4	0.03
N'forn2	0.14	4	0.17
N'forn3	0.13	4	0.06
Warth	0.15	6	0.15
Pfyn	0.13	8	0.05
Session 5			
Murg	0.12	3	0.02
Flaach	0.15	9	0.07
G'hausen	0.06	9	0.06
N'forn1	0.11	9	0.13
N'forn2	0.12	9	0.10
N'forn3	0.14	9	0.03
Warth	0.19	9	0.09
Felben	0.19	9	0.04
Pfyn	0.15	12	0.06
Session 8			
Murg	0.08	3	0.02
Flaach	0.12	9	0.08
A'fingen	0.12	9	0.03
G'hausen	0.03	9	0.03
N'forn1	0.12	7	0.11
N'forn2	0.07	9	0.06
N'forn3	0.10	9	0.03
Warth	0.10	9	0.07
Felben	0.13	9	0.03
Pfyn	0.04	12	0.03
Session 9			
Murg	0.10	3	0.02
Flaach	0.13	9	0.08
A'fingen	0.15	6	0.03
G'hausen	0.04	6	0.03
N'forn1	0.10	9	0.13
N'forn2	0.07	9	0.08
N'forn3	0.10	9	0.02
Warth	0.13	9	0.07
Felben	0.20	9	0.08
Pfyn	0.04	12	0.04

Table 9: Descriptive statistics for spatial distribution of V*fitted

Session 1

	Murg	Flaach	G'hausen	N'forn1	N'forn2	N'forn3	Warth		
Flaach	0.94								
G'hausen	1.00	0.81							
N'forn1	1.00	0.35	1.00						
N'forn2	1.00	0.91	1.00	0.97					
N'forn3	1.00	0.82	1.00	0.99	1.00				
Warth	1.00	0.84	1.00	0.95	1.00	1.00			
Pfyn	1.00	0.62	1.00	0.99	1.00	1.00	1.00		

Session 5

	Murg	Flaach	G'hausen	N'forn1	N'forn2	N'forn3	Warth	Felben	
Flaach	1.00								
G'hausen	0.98	0.20							
N'forn1	1.00	0.98	0.83						
N'forn2	1.00	0.99	0.75	1.00					
N'forn3	1.00	1.00	0.40	1.00	1.00				
Warth	0.98	0.99	0.02	0.51	0.61	0.90			
Felben	0.97	0.98	0.01	0.48	0.58	0.89	1.00		
Pfyn	1.00	1.00	0.26	0.99	1.00	1.00	0.97	0.96	

Session 8

	Murg	Flaach	A'fingen	G'hausen	N'forn1	N'forn2	N'forn3	Warth	Felben
Flaach	0.99								
A'fingen	1.00	1.00							
G'hausen	0.97	0.01	0.02						
N'forn1	0.99	1.00	1.00	0.05					
N'forn2	1.00	0.72	0.78	0.69	0.85				
N'forn3	1.00	1.00	1.00	0.12	1.00	0.99			
bed-moving Warth	1.00	1.00	1.00	0.09	1.00	0.98	1.00		
Felben	0.98	1.00	1.00	0.01	1.00	0.51	0.98	0.99	
Pfyn	1.00	0.09	0.11	1.00	0.20	0.96	0.42	0.35	0.04

Session 9

	Murg	Flaach	A'fingen	G'hausen	N'forn1	N'forn2	N'forn3	Warth	Felben
Flaach	1.00								
A'fingen	0.99	1.00							
G'hausen	0.99	0.38	0.14						
N'forn1	1.00	1.00	0.96	0.85					
N'forn2	1.00	0.73	0.61	1.00	1.00				
N'forn3	1.00	0.99	0.95	0.87	1.00	1.00			
Warth	1.00	1.00	1.00	0.48	1.00	0.84	1.00		
Felben	0.79	0.64	0.99	0.01	0.14	0.01	0.12	0.51	
Pfyn	0.99	0.17	0.17	1.00	0.70	0.99	0.73	0.25	0.00

Table 10: Post-Hoc Huckey-test after One-Way ANOVA for spatial distribution of V*fitted; singificant results are highlighted.

F.11 ln(Chl. a), ln(AFDM) and V*fitted according to the revitalisation status

Figure 47 shows the categorized One-Way-ANOVA-output of ln(Chl. a), ln(AFDM) and V*fitted.

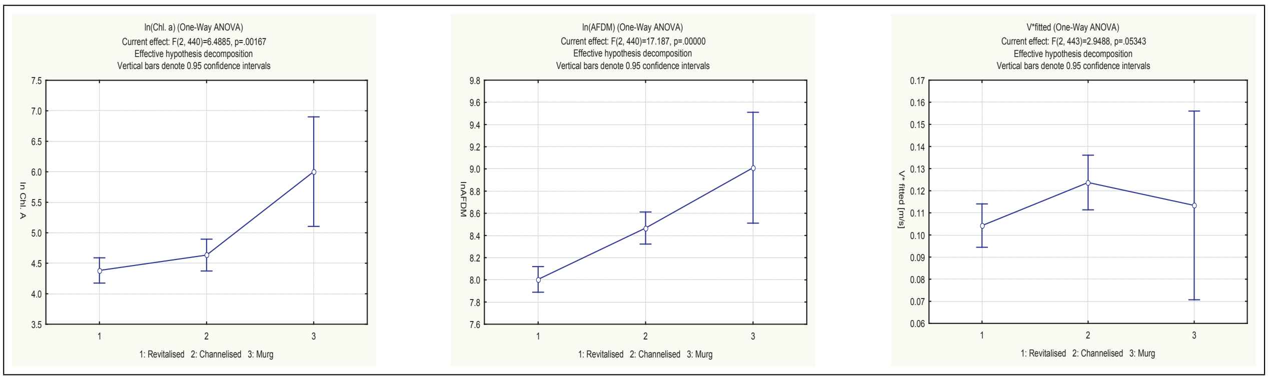


Figure 47: ln(Chl. a), ln(AFDM) and V*fitted categorized, 1:revitalised 2:channelised 3:Murg

F.12 Standard deviation for different sessions for Chl. a, AFDM and V*fittted

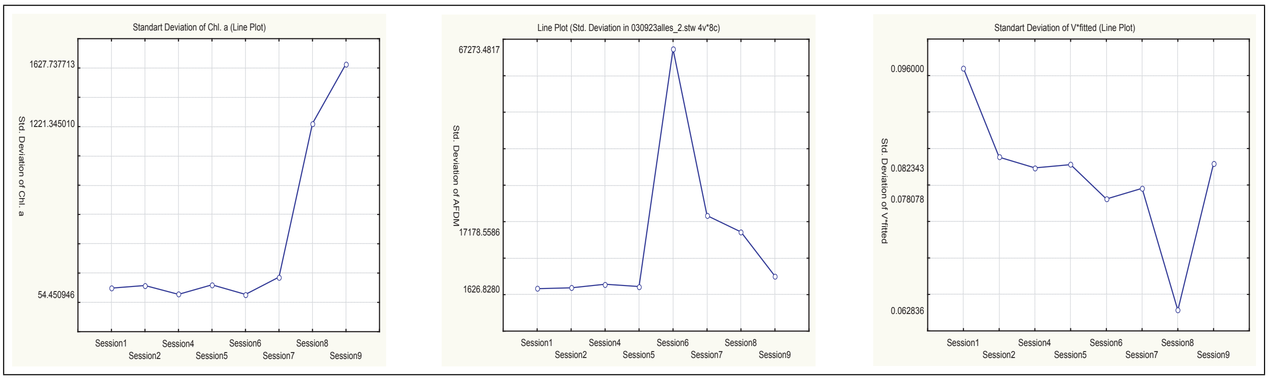


Figure 48: Change of std. deviation for Chl. a, AFDM and V*fittted

Standart deviation for different sessions for *Chl. a*, *AFDM* and *V*fittted* are plotted in Figure 48.

F.13 Q-Q-Plots for periphyton parameters: Chl. a, ln(Chl. a), AFDM, ln(AFDM)

Figure 49 with Q-Q-plots of *Chl. a*, *ln(Chl. a)*, *AFDM* and *ln(AFDM)* shows that the ln-transformed data better fits normal distribution.

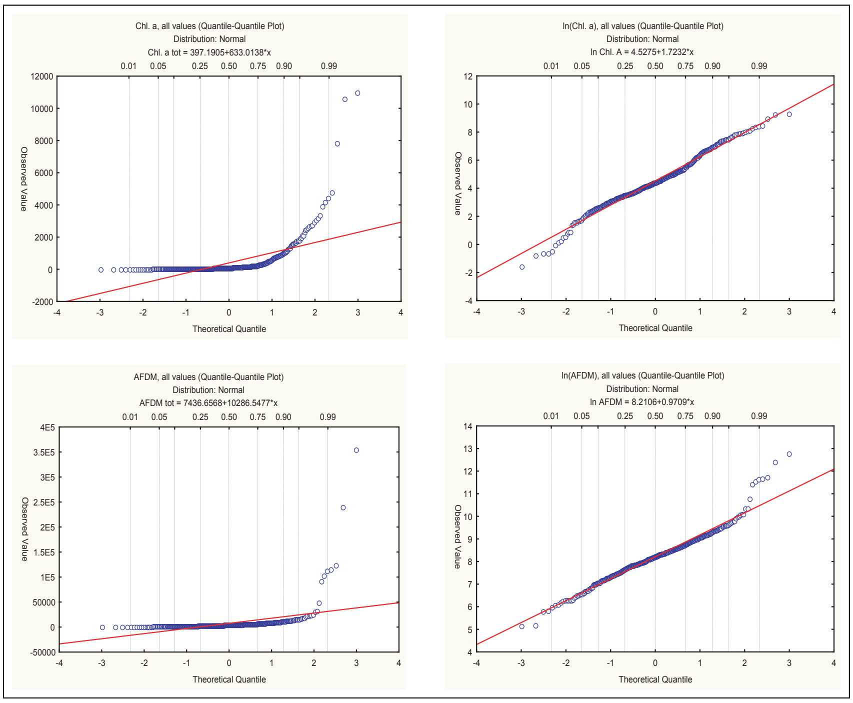


Figure 49: Q-Q-Plots of Chl. a, ln(Chl. a), AFDM, ln(AFDM)

F.14 Correlation periphyton - shear velocity

Figures 50 and 51 show the correlation of periphyton-parameters and *V*fitted*, split up in location and sample session.

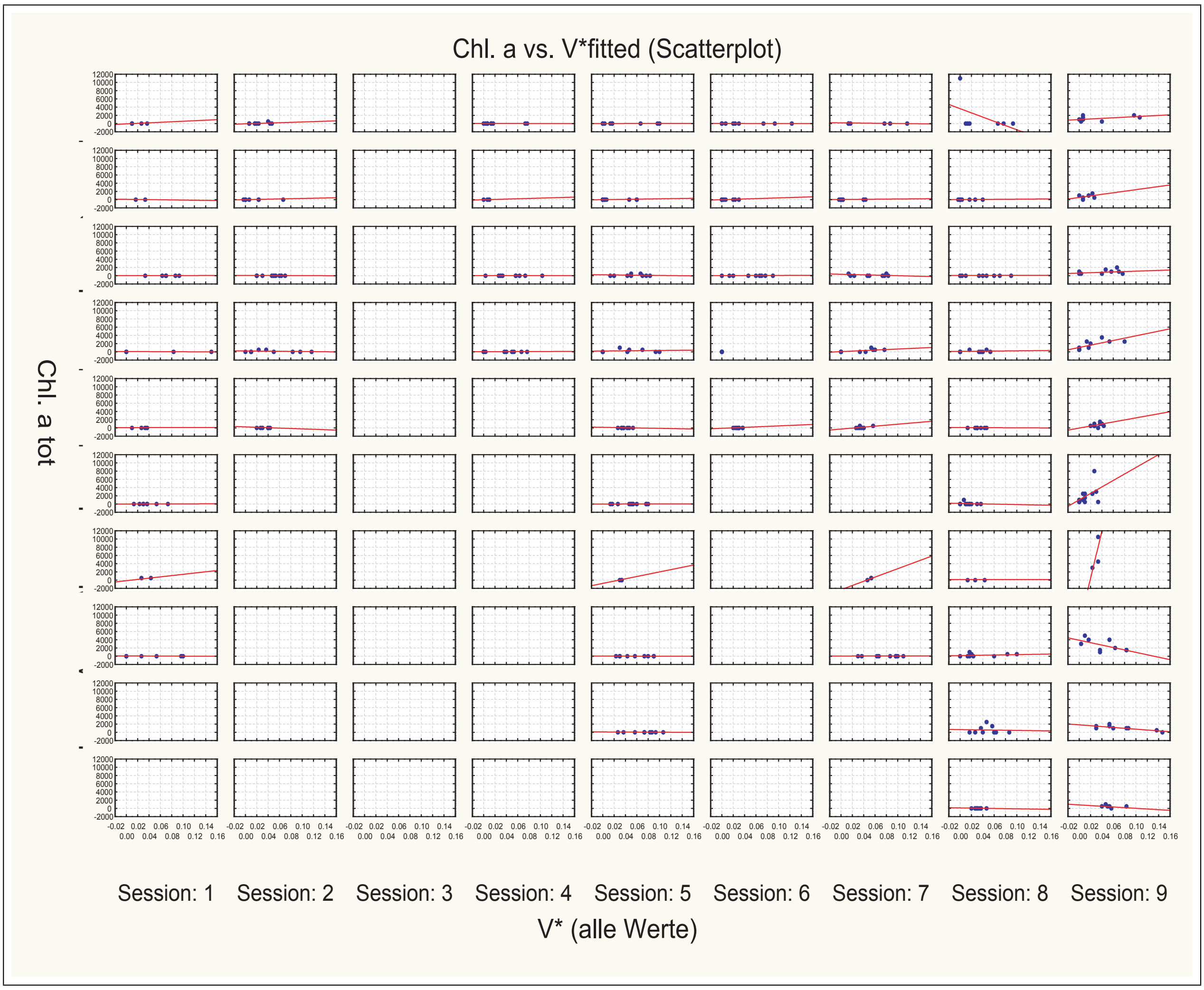


Figure 50: Correlation of Chl. a and V*fitted

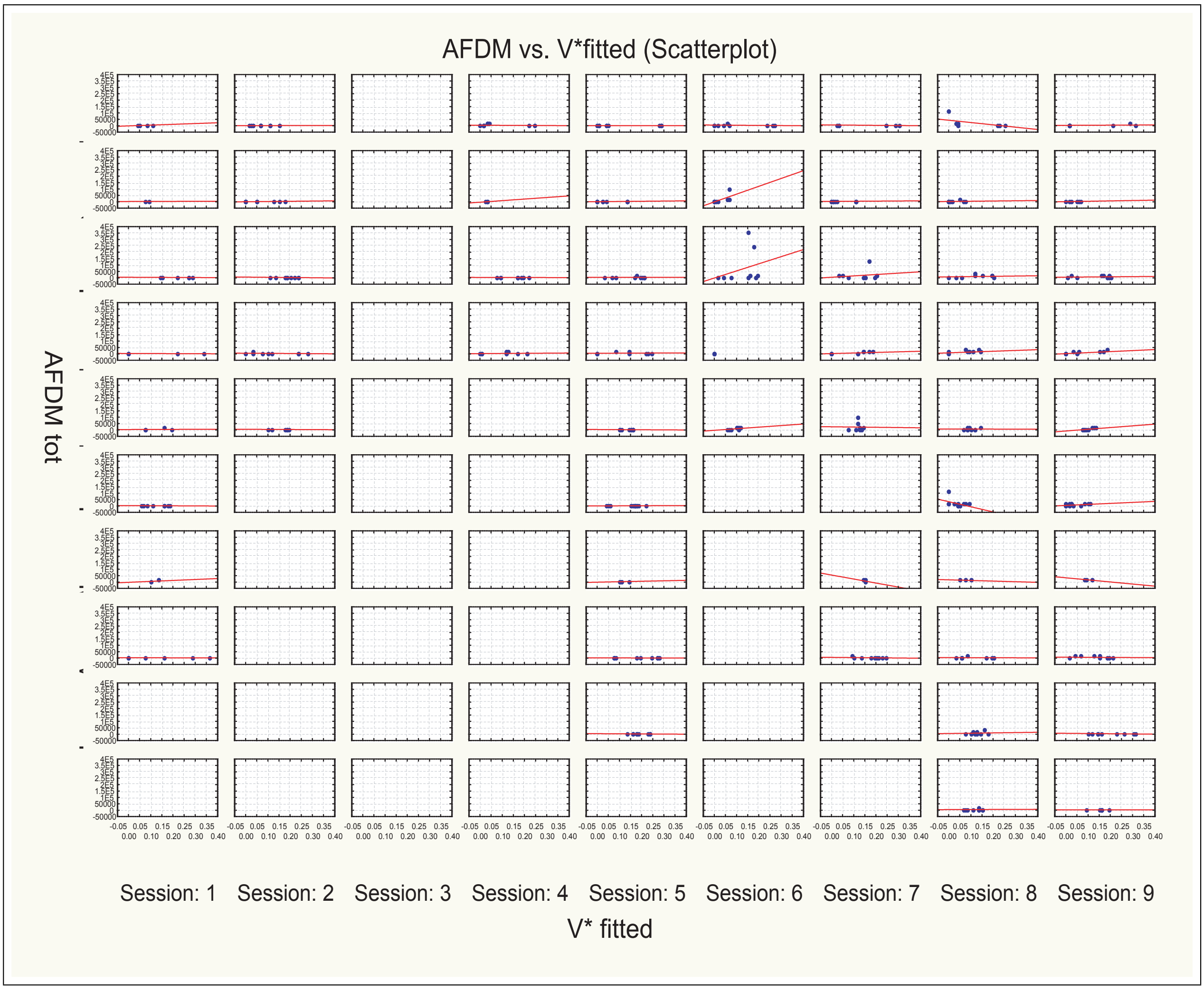


Figure 51: Correlation of AFDM and V*fitted

F.15 Influence: mud on periphyton biomass

Table 11 indicates the influence of mud on periphyton biomass. The sites of reach Andelfingen were only sampled rarely and therefore should not be taken into account. In Niederneunforn site1 filamentous algae could develop on top of the mud after some time of very low discharge.

Site	Chl. a Mean	Chl. a N	Chl. a Std.Dev.	Site	AFDM Mean	AFDM N	AFDM Std.Dev.	Site	V*fitted Mean	V*fitted N	V*fitted Std.Dev.
G'hausen, 3	19.48	15.00	14.10	G'hausen, 3	1949.87	15.00	1071.95	G'hausen, 3	0.00	15.00	0.00
A'fingen, 1	91.94	3.00	11.69	G'hausen, 1	2154.25	23.00	1480.26	N'forn2, 3	0.00	21.00	0.01
G'hausen, 1	104.59	23.00	217.16	Warth, 2	2519.38	14.00	1401.49	N'forn1, 1	0.02	18.00	0.01
A'fingen, 2	145.16	6.00	174.55	N'forn1, 3	2521.36	21.00	2085.34	Pfyn, 4	0.03	11.00	0.03
Flaach, 3	149.46	23.00	231.43	Felben, 3	3178.88	9.00	1418.30	G'hausen, 1	0.03	23.00	0.02
N'forn2, 3	161.21	21.00	203.48	Warth, 1	3547.33	14.00	2743.77	N'forn1, 2	0.05	23.00	0.02
N'forn3, 1	172.14	19.00	186.01	N'forn2, 3	3820.84	21.00	2420.69	Flaach, 1	0.07	23.00	0.05
Flaach, 1	183.54	23.00	262.77	A'fingen, 2	3826.40	6.00	1974.63	A'fingen, 1	0.08	3.00	0.01
Pfyn, 4	217.28	11.00	332.64	Warth, 3	3880.00	14.00	3158.59	Warth, 1	0.08	14.00	0.04
Felben, 2	217.53	9.00	393.75	N'forn3, 1	4005.32	19.00	1161.73	Pfyn, 3	0.09	11.00	0.06
N'forn3, 3	217.67	15.00	277.71	A'fingen, 3	4494.63	6.00	2893.78	N'forn2, 1	0.09	20.00	0.04
N'forn1, 3	250.75	21.00	553.48	Flaach, 1	4510.55	23.00	1826.96	N'forn3, 1	0.09	19.00	0.03
N'forn3, 2	260.95	20.00	406.97	Felben, 2	4512.61	9.00	7501.62	Pfyn, 1	0.09	11.00	0.07
N'forn1, 2	265.45	23.00	485.40	Pfyn, 1	4533.52	11.00	3653.45	G'hausen, 2	0.10	18.00	0.04
Flaach, 2	267.88	23.00	480.38	Flaach, 3	4657.87	23.00	3026.52	*All Grps*	*0.11*	*444.00*	*0.08*
G'hausen, 2	275.41	18.00	382.92	Pfyn, 3	4797.37	11.00	2869.85	N'forn3, 3	0.11	15.00	0.03
A'fingen, 3	317.72	6.00	388.89	A'fingen, 1	5345.68	3.00	538.63	Murg,	0.11	14.00	0.03
All Grps	*397.19*	*444.00*	*1032.66*	N'forn1, 2	5367.01	23.00	2901.46	Pfyn, 2	0.13	11.00	0.05
Warth, 2	435.60	14.00	661.86	Felben, 1	6060.65	9.00	5923.80	A'fingen, 3	0.13	6.00	0.03
N'forn2, 1	469.35	20.00	690.74	N'forn3, 2	6115.72	20.00	3730.76	Warth, 3	0.14	14.00	0.09
Pfyn, 1	533.31	11.00	853.36	*All Grps*	*7436.66*	*444.00*	*23206.84*	Felben, 1	0.14	9.00	0.03
Warth, 3	537.35	14.00	1097.98	N'forn1, 1	7790.36	18.00	25963.30	N'forn3, 2	0.14	20.00	0.03
N'forn2, 2	611.53	20.00	978.84	Pfyn, 2	7968.64	11.00	6737.91	Felben, 3	0.15	9.00	0.04
Pfyn, 3	616.15	11.00	1055.48	N'forn2, 1	8034.72	20.00	6388.75	A'fingen, 2	0.16	6.00	0.02
Felben, 1	674.44	9.00	858.07	N'forn2, 2	8072.62	20.00	6569.47	Flaach, 2	0.18	23.00	0.04
N'forn1, 1	750.91	18.00	2571.12	G'hausen, 2	9460.20	18.00	20500.11	N'forn2, 2	0.20	20.00	0.06
Felben, 3	797.51	9.00	740.78	Murg,	9895.11	14.00	5937.92	Flaach, 3	0.20	23.00	0.02
Warth, 1	974.71	14.00	1688.77	Pfyn, 4	14102.98	11.00	33543.84	Felben, 2	0.23	9.00	0.06
Pfyn, 2	1072.62	11.00	2397.84	N'forn3, 3	15887.56	15.00	26439.85	N'forn1, 3	0.23	21.00	0.08
Murg,	1490.95	14.00	2925.85	Flaach, 2	37967.27	23.00	87139.74	Warth, 2	0.23	14.00	0.06

Table 11: Descriptive statistics of all sites in the River Thur over the whole sampling-period; highlighted values were mud-covered.

F.16 Discharge in Alten vs. periphyton and shear velocity in Gütighausen and Flaach

In figures 52, 53, 54, 55, 56, 57 the periphyton-varaibles *Chl. a* and *AFDM* and the shear velocity in Gütighausen and Flaach are plotted against the discharge at the intermediate gaugingstation in Alten.

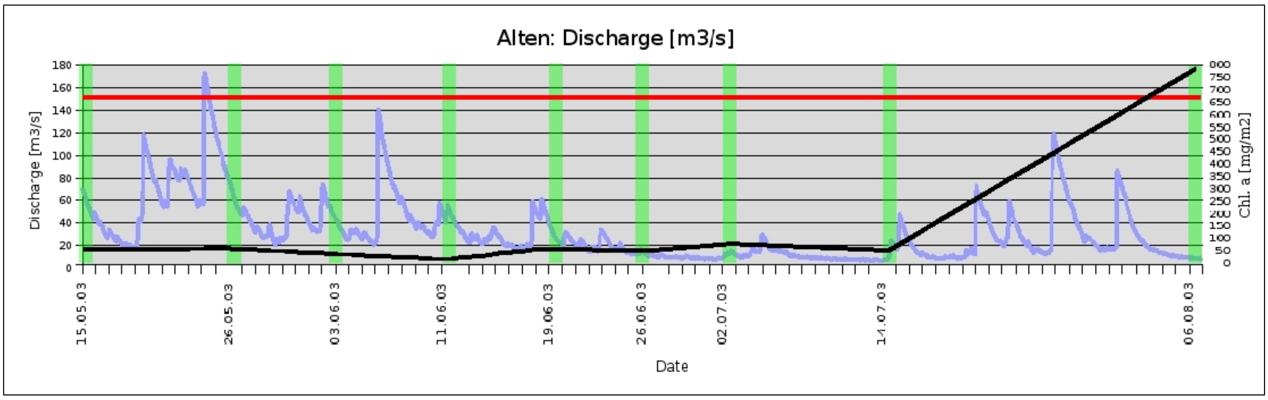


Figure 52: Gütighausen: Chl. a vs. discharge at the gaugingstation Alten

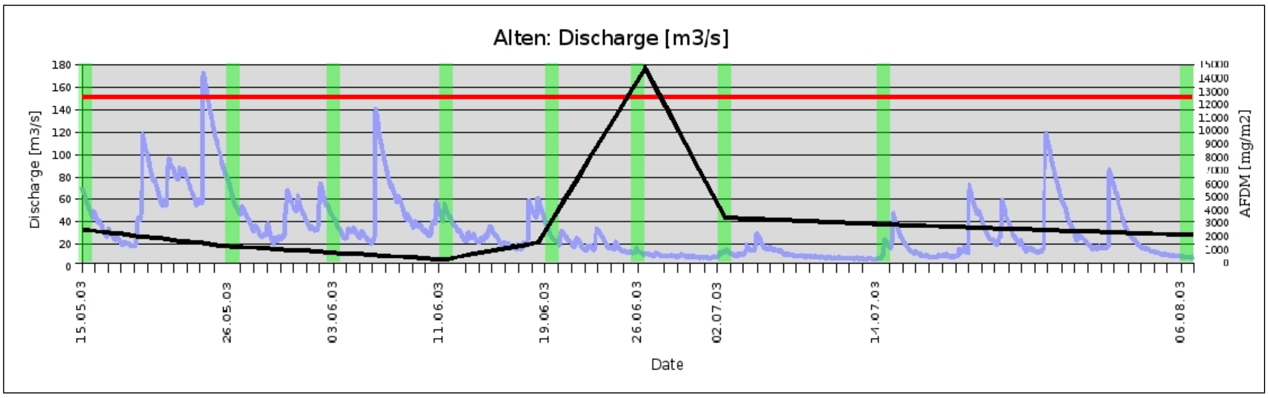


Figure 53: Gütighausen: AFDM vs. discharge at the gaugingstation Alten

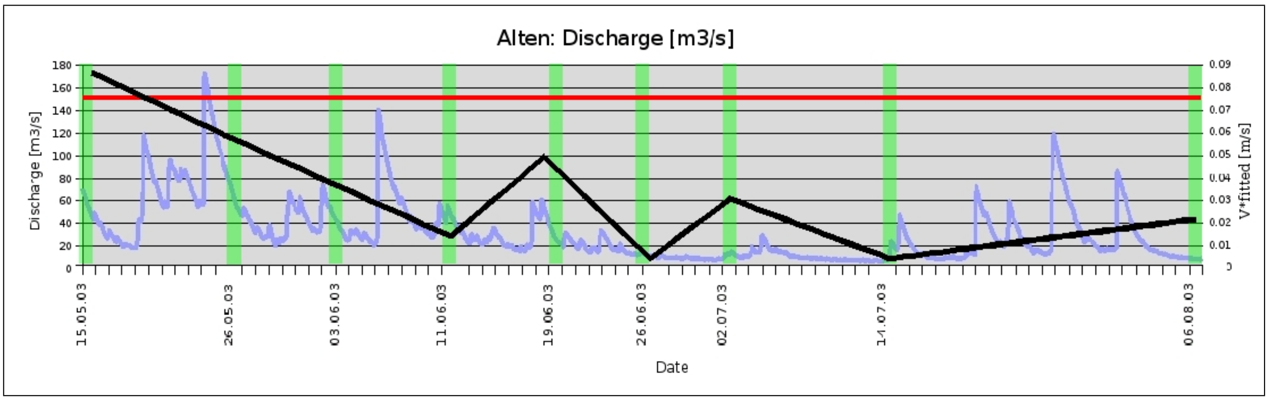


Figure 54: Gütighausen: V*fitted vs. discharge at the gaugingstation Alten

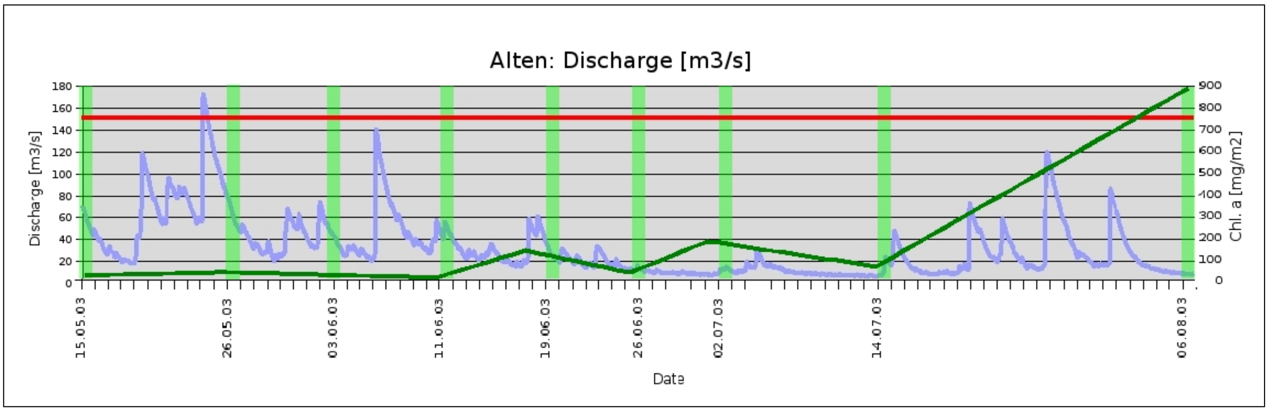


Figure 55: Flaach: Chl. a vs. discharge at the gaugingstation Alten

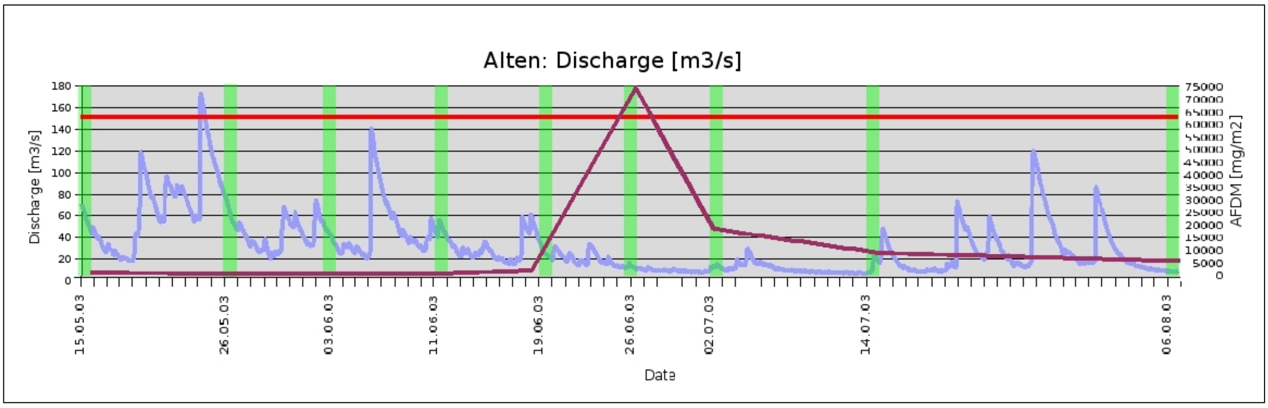


Figure 56: Flaach: AFDM vs. discharge at the gaugingstation Alten

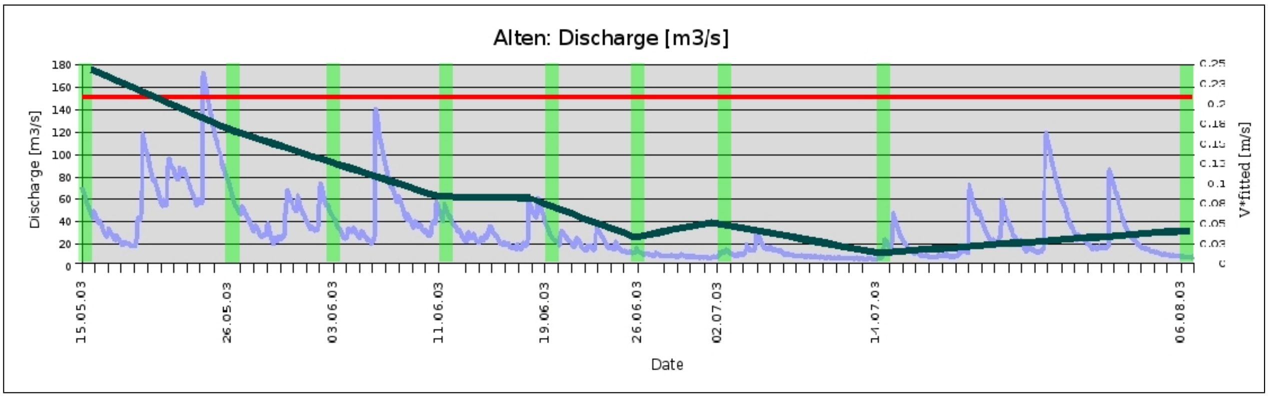


Figure 57: Flaach: V*fitted vs. discharge at the gaugingstation Alten

F.17 Relative photosynthetical radiation PAR: the relation to Chl. a and AFDM split by sample session

Figure 58 shows for each sample session individually the relation between *Chl. a* and rel. PAR, figure 59 for *AFDM* and rel. PAR.

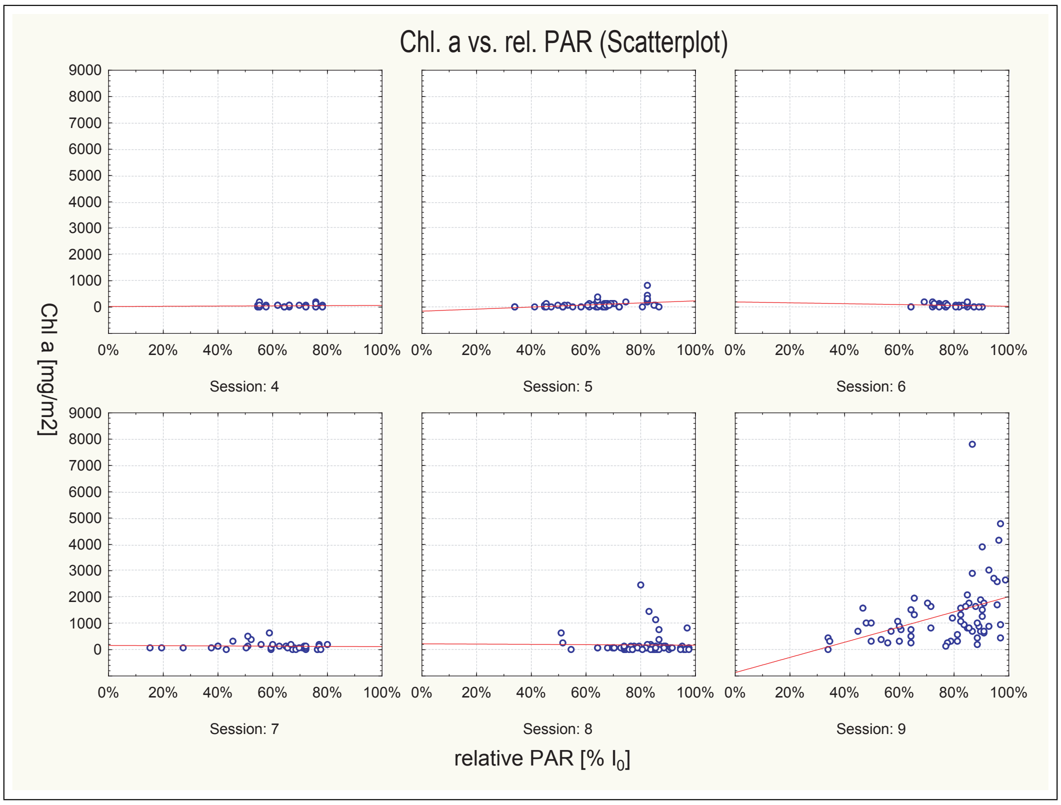


Figure 58: Relation between Chl. a and rel. PAR split up in sample sessions

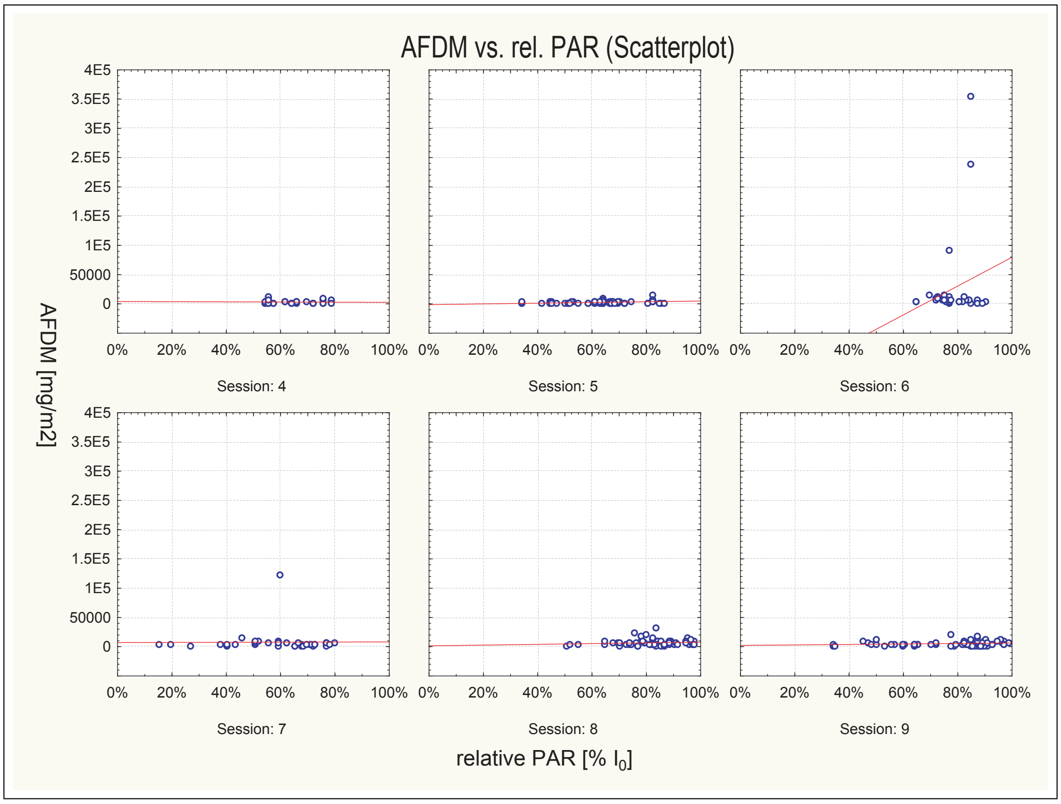


Figure 59: Relation between AFDM and rel. PAR split up in sample sessions

F.18 Discharge in Alten vs. periphyton and shear velocity in Gütighausen and Flaach

In figure 60, Box & Whisker plots give a overview over the chemo-physical parameters temperature, conductivity, turbidity, pH, lightextinction ε and average stone-length for the rivers Thur and Murg is given.

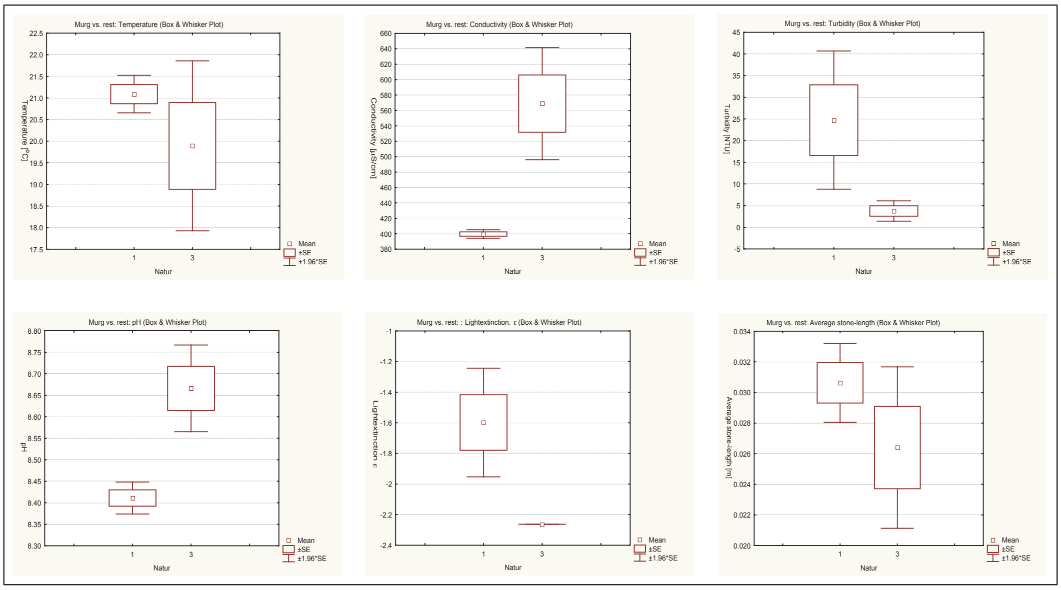


Figure 60: Overview over the chemo-physical parameters temperature, conductivity, turbidity, pH, lightextinction ε and average stone-length for the rivers Thur and Murg

F.19 Murg vs. Thur: Conductivity plotted individually for each sample session

As displayed in figure 61 conductivity in the River Murg is higher than in the River Thur. Comparison was only possible for session 1, 5, 7 & 9.

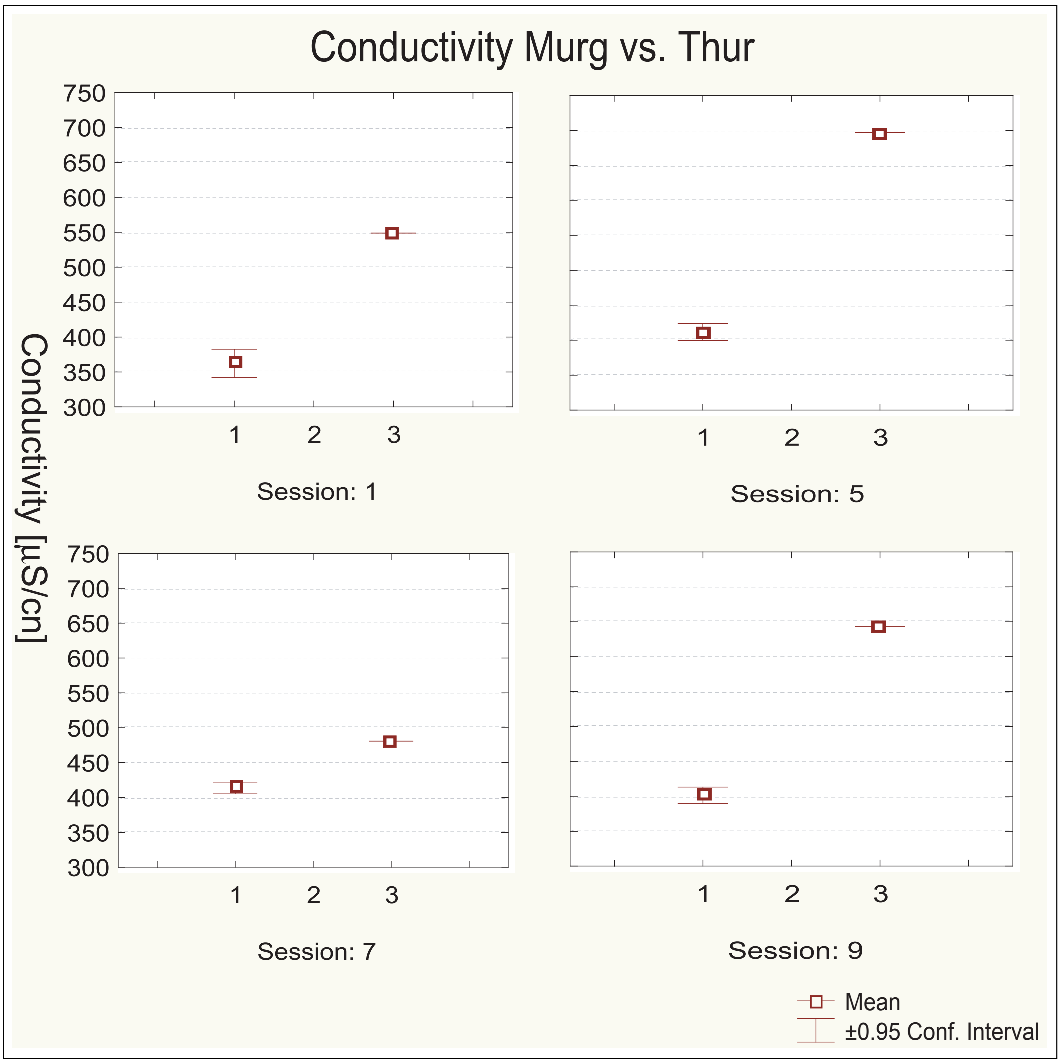


Figure 61: Conductivity for Murg and Thur split up by sample session (Means with Confidential Intervals); 1:Thur 3:Murg

F.20 Significance of conductivity amongthe different sites in location Warth

Table 12 gives a overview of significance in conductivity between the different sites in location Warth according to a t-test.

Site	Mean [1]	Mean [2]	p	Std.Dev.	Std.Dev.
1 vs. 2	567.2000	389.0000	0.000009	36.00972	18.23458
1 vs. 3	567.2000	372.6000	0.000012	36.00972	27.90699
2 vs. 3	389.0000	372.6000	0.303306	18.23458	27.90699

Table 12: Table of significance in conductivity between the different sites in location Warth according to a t-test. Significances are highlighted

F.21 Tukey table of temporal variability for shear velocity and periphyton biomass

Table 13 shows the Tuckey-table of temporal variability for shear velocity and periphyton. Significant values are highlighted.

Session	1	2	4	5	6	7	8
			ln (AFDM)				
1							
2	0.762						
4	0.999	0.990					
5	0.624	1.000	0.981				
6	0.000	0.000	0.000	0.000			
7	0.027	0.000	0.007	0.000	0.840		
8	0.000	0.000	0.000	0.000	1.000	0.752	
9	0.071	0.000	0.018	0.000	0.384	0.998	0.177
			ln(Chl. a)				
1							
2	0.257						
4	0.281	1.000					
5	1.000	0.125	0.173				
6	0.984	0.830	0.808	0.978			
7	0.124	0.000	0.000	0.016	0.004		
8	0.543	0.000	0.000	0.167	0.044	0.945	
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000
			V*fitted				
1							
2	0.864						
4	0.716	1.000					
5	1.000	0.802	0.635				
6	0.043	0.604	0.926	0.011			
7	0.973	1.000	0.990	0.962	0.269		
8	0.033	0.676	0.973	0.003	1.000	0.262	
9	0.399	0.999	1.000	0.189	0.823	0.939	0.892

Table 13: Tuckey-table of temporal variability for shear velocity and periphyton

F.22 Table of significance between locations in an upstream-downstream sequence

In table 14 one can find significant differences between locations (highlighted) for *ln(Chl. a)*, *ln(AFDM)* and *V*fitted* according to a One-Way ANOVA Post-Hoc Tuckey-test.

ln(Chl. a)

sequence	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
1-Murg									
2-Flaach	0.0541								
3-A'fingen	0.3971	1.0000							
4-G'hausen	0.0002	0.2347	0.7101						
5-N'forn1	0.0002	0.2689	0.7539	1.0000					
6-N'forn2	0.5393	0.7843	0.9985	0.0015	0.0016				
7-N'forn3	0.2688	0.9952	1.0000	0.0305	0.0352	0.9995			
8-Warth	0.3944	0.9859	1.0000	0.0315	0.0367	1.0000	1.0000		
9-Felben	0.8234	0.8185	0.9947	0.0125	0.0147	1.0000	0.9972	0.9997	
10-Pfyn	0.2246	0.9997	1.0000	0.0973	0.1131	0.9968	1.0000	1.0000	0.9910

ln(AFDM)

sequence	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
1-Murg									
2-Flaach	0.8130								
3-A'fingen	0.5023	0.9880							
4-G'hausen	0.0003	0.0001	0.6928						
5-N'forn1	0.0003	0.0001	0.7017	1.0000					
6-N'forn2	0.6634	1.0000	0.9987	0.0014	0.0010				
7-N'forn3	0.7767	1.0000	0.9952	0.0009	0.0006	1.0000			
8-Warth	0.0016	0.0029	0.8582	1.0000	1.0000	0.0164	0.0102		
9-Felben	0.0452	0.2820	0.9985	0.9713	0.9746	0.5215	0.4142	0.9972	
10-Pfyn	0.2189	0.8551	1.0000	0.1862	0.1792	0.9769	0.9379	0.4656	0.9893

V*fitted

sequence	[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
1-Murg									
2-Flaach	0.7067								
3-A'fingen	0.9995	0.9936							
4-G'hausen	0.0503	0.0000	0.0014						
5-N'forn1	1.0000	0.0030	0.9108	0.0008					
6-N'forn2	0.9994	0.0008	0.8243	0.0031	1.0000				
7-N'forn3	1.0000	0.2064	0.9996	0.0000	0.9769	0.9033			
8-Warth	0.8607	1.0000	0.9992	0.0000	0.0441	0.0180	0.5596		
9-Felben	0.3059	0.9802	0.8116	0.0000	0.0014	0.0005	0.0550	0.9585	
10-Pfyn	0.9690	0.0001	0.5031	0.1278	0.9830	0.9982	0.4865	0.0027	0.0001

Table 14: Table of significance between locations in upstream-downstream-sequence for ln(Chl. a), ln(AFDM) and V*fitted