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Renaturalisation and macrozoobenthos - a case study at the River Bünz

SEMESTERARBEIT

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Zusammenfassung

Über die letzten zwei Jahrzehnte ist klar geworden, dass die Gewässerkorrekturstrategien unter dem veralteten Wassermanagement nicht funktioniert haben und überholt sind. Vor Ende des letzten Jahrtausends kanalisierten und begradigten die Bauämter verschiedener europäischen Länder Flüsse in flachen, von Hochwasser bedrohten Gebieten. Die Grundidee war, Agrar- und Bauland zu schützen und zu vergrössern, um der zunehmenden Bevölkerung Rechnung zu tragen. In den letzten Jahren wurde aber realisiert, dass die systematische Kanalisierung ein Teil des Grundes für die grossen und zunehmenden Schäden durch Hochwasser ist. Dadurch werden nun grosse Anstrengungen unternommen, um die Gewässerkorrekturen wieder zu korrigieren. Von Regierungen, Naturschutz- und anderen Organisationen werden Revitalisierungsprogramme in Auftrag gegeben oder entwickelt, um Flüssen wieder mehr Platz zu gegeben und deren Ufer von ihrer Betoneinfassung zu befreien. Vermehrt werden in den letzten Jahren Studien durchgeführt, die den Erfolg von diesen Revitalisierungen messen. In der vorliegenden Studie wurde untersucht, ob die Revitalisierung eines Baches die Vielfalt und Menge an Individuen des Makrozoobenthos verbessert. Der Makrozoobenthos aus sechs verschiedenen Streckenabschnitten des Baches Bünz im Kanton Aargau wurde mit dem Makrozoobenthos einer degradierten Referenz im gleichen Bach verglichen. Der Makrozoobenthos wurde besammelt, bestimmt und gezählt. Zusätzlich wurden die physikalischen, chemischen und morphologischen Bacheigenschaften durch die Entnahme von Wasserproben und eine Standortbeurteilung jeder Strecke beschrieben. Die Resultate der vorliegenden Studie zeigen keine Verbesserung in der Anzahl oder der Diversität der Makrozoobenthosgesellschaft. Somit haben die an der Bünz unternommenen Revitalisierungen entweder noch keinen Effekt bewirkt oder sie sind in der Tat wirkungslos geblieben. Die Schlussfolgerung wäre eher, dass es für Makroinvertebraten kein Unterschied macht, ob sie in einem reich strukturierten Habitat oder in einem langweiligen, geraden und betonierten Kanal leben.

Abstract

Over the last two decades it became increasingly clear that the river management of the previous two centuries has failed. At the end of the last millennium Civil Engineering Offices of many European Nations tended to straighten every flowing current in midland plains to prevent potential flooding. The idea was to increase and protect arable land and space for a growing population. Actually, the systematic canalisation is part of the reason for the extent of the damage caused by floods. As a result local governments and NGOs have started rehabilitation projects to improve the course and the structuring of the rivers in the Midlands. The rivers were given more space; the banks were loosened from their corset. In recent years studies were encouraged by governmental and non-governmental organisations to measure the actual success of such rehabilitations. The present study investigated whether the macroinvertebrate community of a river showed any improvement after rehabilitations have been conducted. The macroinvertebrates of six stretches with different rehabilitation stages of the River Bünz in the canton of Aargau were compared with a straightened stretch. The macrozoobenthos was sampled, identified and counted. In addition, water samples were chemically analysed, physical properties of the river were measured and a habitat assessment was conducted for

every stretch. The restorations undertaken at the river Bünz seem not to have had any effect on numbers in or diversity of the macroinvertebrate community. The conclusion would rather be that it makes no difference to macroinvertebrates whether they have a rich and structured habitat or a boring and straight channel of concrete.

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1 Introduction

In the large fields of Community Ecology and Conservation Biology the importance of studies on restoration efficiency and success is quickly growing. Restoration and rehabilitation efforts are nowadays undertaken in many countries by governmental (Federal Constitution of the Swiss Confederation, Art. 76.3; Agenda 21) and non-governmental organisations (NGOs) (Hostmann & Knutti, 2009). Unfortunately, these two terms are often wrongly used. But in order to compare between the different projects in place, a clear definition of both terms is needed. The term restoration is used for changes made to an ecosystem in its former condition (Williams et al, 1997). Rehabilitation is an improvement of important aspects of an ecosystem without coming back to the original state (Williams et al, 2007). Therefore, almost any change in an ecosystem is a rehabilitation, as restoring the natural or initial state is almost impossible, e.g. because of the dense population in the Swiss valleys (Woolsey et al, 2005).

In the 19^{th} and 20^{th} century, a trend was established to canalise Midland rivers to prevent flooding and to give more space to arable land due to a growing population (Vischer, 2003). Major floods in the late 20^{th} century showed that the canalising activities could not successfully protect settlements and agricultural land, like the flood in 1993 in Brig where a part of the city has been destroyed (Gemeinde Brig-Glis). Actually, the systematic canalisation is part of the reason for the extent of the damage caused by these floods. As a result local governments and NGOs started rehabilitation projects to improve the course and the structuring of the rivers in the Midlands. The rivers were given more space; the banks were loosened from their corset. Over the past years a big part of the Swiss population shows a growing desire for close-to-nature recreation areas. People want to spend more time in a natural surrounding (Junker et al, 2007, Junker & Buchecker, 2008), which enforces nature-orientated restorations of deteriorated landscapes by governments and other organisations, like it was done in Müntschemier, where an networking project between different marshes in the agricultural landscape was successfully created (Mühlethaler, 2007).

The diversity of the macrozoobenthos in a river is a good indicator of the success of the revitalisation efforts. Many species, mainly benthic insects, e.g. Ephemeroptera, Plecoptera and Trichoptera in the macrozoobenthos are very good indicators for water quality (Smith et al, 1999) and environmental changes (Hawkins et al, 2000). They are widely used as indicators of short- and long-term environmental changes in running water (Smith et all, 1999). Taxonomic richness of aquatic insects is strongly influenced by natural disturbances (Rosenberg & Resh, 1993) and anthropogenic activities on stream ecosystem (Resh & Jackson, 1993).

The River Bünz is a small midland river that flows in the region of Aargau, Switzerland. It's source is in Lindenberg and flows into the river Aare in Wildegg, 25 km away from there and descends 500 m in altitude. Before the 19^{th} century, the Bünz was meandering freely, using a lot of space for its riverbed and changing its way depending on the amount of water it was transporting (Burger, 2007). In the 1930s, as the population grew and more agricultural fields were needed, important modifications were undertaken and most of the Bünz lost its former state: the river was canalised and straightened almost along its whole length, and the land around it was drained (Burger, 2007). In the 1990s, two floods occurred and it became clear that the former measures of flood protection were neither timely nor sufficient anymore. In addition, the population wanted more space in the nature for recreation. The canton decided to radically change the river morphology and thus respond to the flooding problem as well as the demand of the people. These changes should also bring an improvement to the ecological value of the landscape (Wernli, 2005).

The present study investigated the macroinvertebrate community in order to answer the question whether the rehabilitations undertaken had improved the River Bünz. The macro-invertebrates of 6 stretches that had undergone rehabilitation or hadn't been touched at all were compared with a straightened stretch used as a degraded reference. In the seven stretches of the river the macrozoobenthos were sampled, identified and counted. In addition, water samples were chemically analyzed, physical properties of the river were measured and a habitat assessment was conducted for every stretch.

2 Material and methods

2.1 Research area

The River Bünz is 30 km long and flows through the canton of Aargau. Its source is in the South-Eastern part of the Canton close to Beinwil am Lindenberg at around 800 m above sea level. Before the Bünz joins with the River Aare it passes many villages and agricultural fields. The following map shows the seven investigation stretches (Fig. 1).

In the Canton Aargau a lot of work and money has been invested into revitalisations of rivers (Burger, 2007). On its whole length, the Bünz shows different types of hydro-morphology due to the use of the river and its canalisation, as well as the rehabilitation projects. In 1999, a flood occurred and the stretch of the river close to Möriken (AUE, see map Fig. 1) was transformed into a flood plain, which is now a protected area of national importance (BUWAL, 2005). Other rehabilitation projects are planned in Othmarsingen or already ongoing in Murimoos (Burger, 2007). Due to these different rehabilitations situations along the Bünz it is ideal for long-term studies on the effectiveness and efficiency of restoration measures.

To investigate the success of the rehabilitation, 6 representative stretches of the river that are different from each other were chosen and the macroinvertebrate community compared to a 7th one, a degraded reference (Fig. 2). Their lengths were > 1km, and the sampling was done on a representative stretch of 100 meters. The degraded reference, which represents the worst-case scenario of a river correction, was chosen in order to compare it with the restored sites and thus decide of the success of restoration.

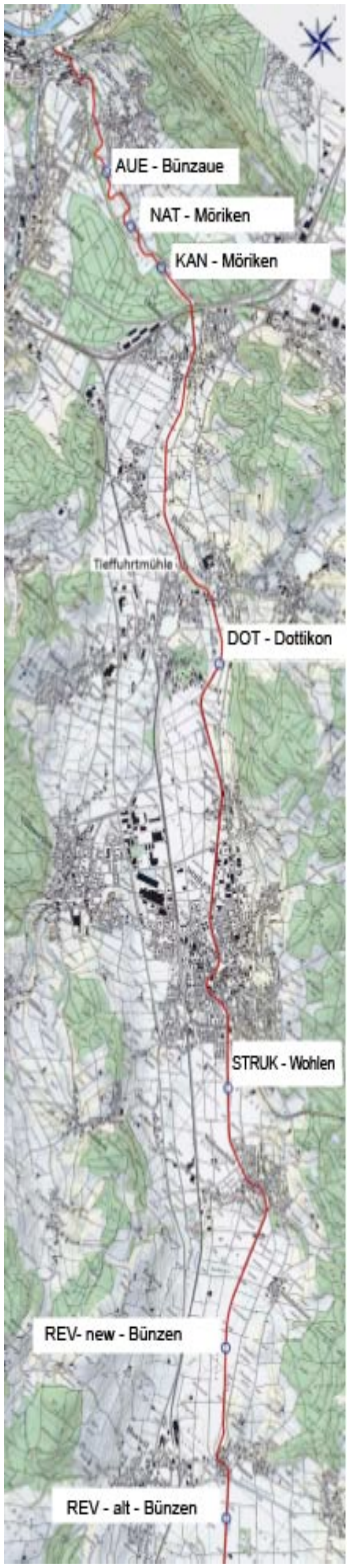

Figure 1: The seven investigated stretches at the Bünz.

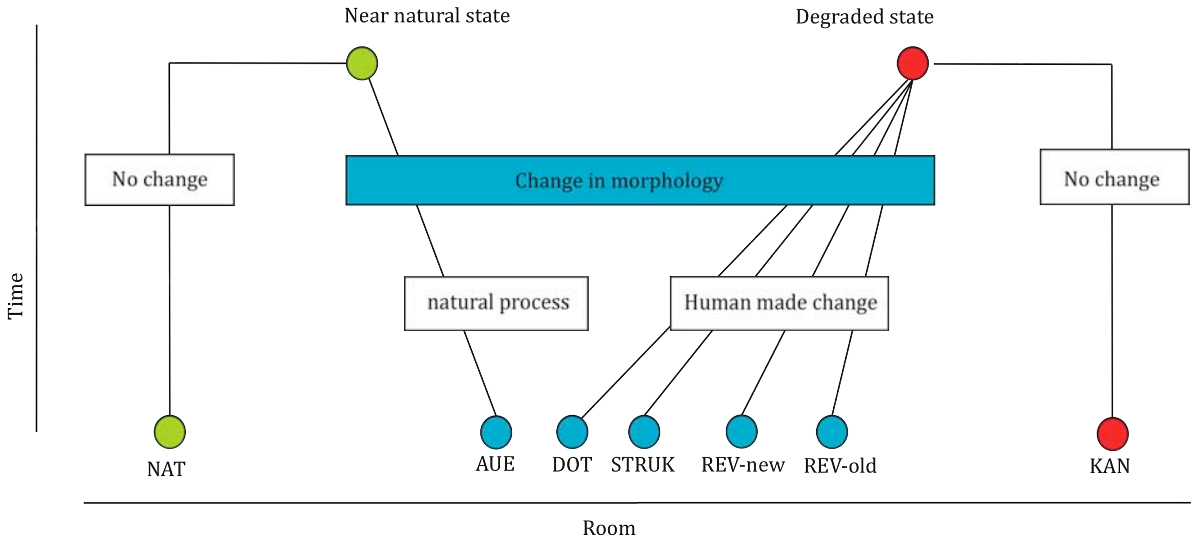

Figure 2: Experimental design - comparison of the investigated stretches at the river Bünz.

2.1.1 Bünzaue – near natural state (AUE)

Figure 3: Bünzaue (AUE)

In 1999 a flood occurred (Burger, 2007). Bünzaue was naturally transformed into a floodplain, which is nowadays registered as a floodplain of national relevance and thus protected. In 2007, another flood happened. The river was stabilised afterwards. Now it's in a stage of early floodplain vegetation and the different sizes of stones, the free way of the riverbed and the small channels of water have created a dynamic stretch.

2.1.2 Möriken – semi-natural state (NAT)

Figure 4: Möriken (NAT)

This stretch of the Bünz was never straightened. The riverbed has been stabilised poorly in the 1930s but nothing ever since (Burger, 2007). The river always had space to meander; the vegetation is in an early stage of development and is monotonous.

2.1.3 Möriken – canalised state (KAN)

Figure 5: Möriken (KAN)

This part of the Bünz has been canalised in the 1930s and therefore has been in that condition for a long time. The straightening was done with the Turnherr system: ground plates were installed in the riverbed and the riverbanks were anchored with concrete or big stone blocks. There are no existing structures, i.e. no stones or vegetation to provide shelter for insects or fish, the river goes straight. This stretch was chosen as the reference stretch for our study. Its degraded situation is ideal to be compared to the other more natural stretches.

2.1.4 Dottikon – rehabilitated state (2005/2006) (DOT)

Figure 6: Dottikon (DOT)

The stretch in Dottikon has been rehabilitated along 1.5 km in 2005/2006. The river was given more width and structure and the trees were left to grow. Boulders and trunks were placed in the river and small islands were created.

2.1.5 Wohlen – revitalised state (1995) (STRUK)

Figure 7: Wohlen (STRUK)

This part of the Bünz is the first of the investigated sites which had been restored – this being done in 1995. The structure of the Bünz has been upgraded: the Turnherr canalising system was removed; the riverbed was given more profile. Big stones were put in the river in order to slow down the water and give structures.

2.1.6 Bünzen – revitalised state (2007/2008) (REV-new)

Figure 8: Bünzen (REV-new)

This part of the Bünz in Bünzen is the latest revitalised stretch: in 2007/2008, the riverbed has been enlarged and it serpentines now along small islands. The vegetation is on its early stadium of succession.

2.1.7 Bünzen – revitalised state (2005/2006) (REV-old)

Figure 9: Bünzen (REV-alt)

In Bünzen the river has been revitalised in 2005/2006. The riverbed is rather narrow, and few structures exist. The bank is steep. The riparian zone has a dense and diverse vegetation cover.

2.2 Sampling methods

Habitat assessment

On the 16th of March, the habitat of all seven sampling stretches was characterised. In addition, several physical measures of the water were taken. Over a distance of 50m the riverbed width was measured every 5 meters and the river depth was measured on transects of 50 meters every 5 meters. In addition, one stone was taken out of the water every 5 meters parallel to the shoreline on a stretch of 50 meters and its longest diameter was measured to the nearest cm. The water velocity was measured at the same places by putting the sensor into the stream at half its water depth. Turbidity, the measure of diffused light at an angle of 90° (WTW LF 340, Weinheim, Deutschland), conductivity (Cosmos, Züllig AG, Schweiz) and temperature were measured as well by putting its sensor in water until the value was stable. Temperature, turbidity and conductivity were measured in order to make sure that no other factors other than the hydromorphological differences would differ between the sampling sites.

Macrozoobenthos

Macroinvertebrates were collected according to the method described by the Federal Office for Environment (FOEN; BUWAL, 2005). The procedure was changed a bit. At every stretch, the ground of the river was kicked during 1 minute and the whirled material was collected in a net (kick-sampling method). At every stretch two samples were taken from two different places and pooled. The samples were immediately preserved in ethanol 70% for subsequent sorting and identification in the laboratory, where they were separated from large debris with rinsing them with water over a sieve (mesh size: 0.02 mm) and then spread out in a plate. The samples were identified to the family level and not to species level due to the short time range of this semester thesis. As Furse et al. (1984) describe, family level is sufficient to detect the important environmental gradients related to the sites. For identification, standard identification literature and a stereomicroscope were used. The benthic macro-invertebrates were collected on two days in late winter, 23rd of February 2009, and early spring, 6th of April. Samples later in the year, as proposed by the protocol of the FOEN, were not collected because of the short time of this semester thesis. Thus, it has been decided to still take two samples as far apart in time as possible.

Water chemistry

On every field day (23.02.2009, 16.03.2009, 6.04.2009), water samples were collected on all 7 stretches and given to the AuA Laboratory of EAWAG for analysis, where dissolved organic carbon (DOC), particular organic carbon (POC), ortho-phosphate (o-P), particular phosphate (PP), Nitrate and particular nitrate (PN) were measured. In addition, the total inorganic carbon (TIC) was calculated. The pH was also measured on every field day.

2.3 Data analysis

To compare the different sites to each other three parameters were calculated from the macro-zoobenthos data: (1) the taxonomic richness, i.e. total number of families found in each stretch, (2) the abundance of individual animals, i.e. total number of individuals found per stretch to investigate changes or alternations that could have taken place in the biotope and (3) the Simpson's Index ($D=\Sigma\ p_i^2$, where p_i is the proportion of total number of individuals in the ith taxa) (Simpson, 1947). The Simpson's Index is a measure of dominance: the lower the value the less is a stretch influenced by any one taxa. A value of one means that only one taxon was found. Additionally, a principal component analysis (PCA; Burnham & Anderson, 2002) was done for the most abundant taxa at the order level to explain the species composition of the macroinvertebrates. In a first step, the variables were reduced: the factors that correlated strongly (r ≥ 0.5) were eliminated. The number of taxa was log-transformed and analysed with STATISTICA (StatSoft, Tulsa 1988). The chemical properties were also compared with the physical properties in a PCA.

3 Results

3.1 Habitat assessment

The width of the river decreases from 10.8m in Bünzaue to 5.60m in the old restored stretch in Bünzen (REV-alt), with the exception in Dottikon (DOT) and Wohlen (STRUK), where the river has been enlarged during the restorations (Tab. 1). The depth has no clear trend, but the deepest parts of the river have been measured in the channel part in Möriken (KAN, 61.50m), and in Dottikon (DOT, 61.80 m). The lowest water depth has been measured in the stretch at Möriken (NAT).

The biggest stones were measured at the end of the river, the smallest at the higher part of the Bünz.

Table 1: Measurements of habitat assessment (16.03.2009). Average, in brackets standard deviations. No stones could be collected from the channel (KAN) because of difficulty to go into the water.

	Width (m)	Depth (cm)	Stones diameter (cm)
AUE	10.08 (1.65)	40.95 (5.05)	7.55 (2.28)
NAT	6.12 (1.00)	28.85 (8.51)	8.00 (1.84)
KAN	5.00 (0)	61.50 (7.00)	n.a
DOT	8.10 (2.0)	61.80 (15.73)	4.94 (2.90)
STRUK	6.82 (0.51)	53.40 (9.42)	4.45 (3.60)
REV-new	5.02 (0.40)	63.56 (8.41)	3.06 (1.72)
REV-alt	5.60 (1.27)	47.40 (10.90)	2.00 (1.29)

The water flow measured was the highest in the Bünzaue (AUE) with 1.40 m^3/s (Tab. 2). The lowest was measured in Wohlen (STRUK). The measured turbidity augmented upstream. The temperature (data 16.03.2009) was increasing upstream. The conductivity was decreasing as the river flowed downstream. The pH was increasing but not in STRUK, where the highest pH (5.839) was measured. The turbidity had high values in Bünzen, at both sites (REV-alt and REV-new), and lower values in the other sites.

Table 2: Turbidity, velocity, conductivity, pH and temperature measured the 16.03.2009. The numbers in brackets are the standard deviations.

	Turbidity (FNU)	Velocity (m/s)	Conductivity (uS/s)	pH	Temperature (°C)
AUE	8.65	1.40 (0.32)	574	5.675 (0.275)	5.9
NAT	3.59	0.90 (0.43)	581	5.721 (0.290)	6.0
KAN	3.89	0.85 (0.14)	581	5.727 (0.314)	6.2
DOT	4.95	0.56 (0.24)	553	5.784 (0.235)	6.0
STRUK	3.61	0.41 (0.28)	562	5.839 (0.283)	6.3
REV-new	44.3	0.45 (0.21)	562	5.724 (0.281)	6.9
REV-alt	34.7	0.64 (0.24)	548	5.478 (0.299)	7.9

3.2 Macro-invertebrates

Taxonomic richness

The number of taxonomic families found at the different sampling sites varied between 7 and 17 (Fig. 10). The most taxa were found in Möriken (NAT), and the number varied between the two dates (Fig. 10). Similar to the abundance data, the Bünzaue had the smallest number of families (Fig. 10). The four restored sites varied between each other in the number of taxonomic families (Fig. 10). For comparison, the same insect taxa were found on every sampling site.

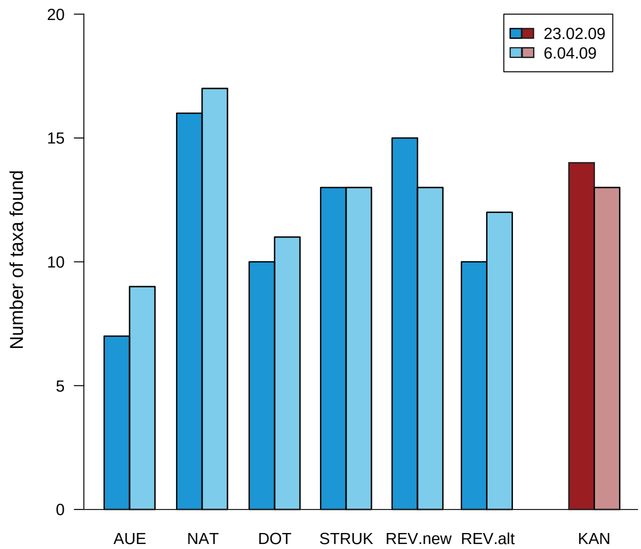

Figure 10: Taxonomic richness. The bars in blue show the number of taxa found at each site for both sampling dates. The bars in red show the degraded reference (KAN) for both sampling dates.

Abundance

The number of individuals over all families found was quite different between the sample sites. The most individuals (n=441) were found in the second stretch, Möriken (NAT) (Fig. 11). At the Bünzaue (AUE), the abundance was unexpectedly low (n=123, n=131), but constant at the two dates (Fig. 11). The four restored stretches showed a difference in their abundance between the two sampling dates (Fig. 11). Also the canalised stretch (KAN) differed in abundance between the sampling days (Fig. 11). The two untouched stretches (NAT, KAN) had the most individuals on the 23rd February. In Dottikon (DOT), as well as in the old restored stretch in Bünzen (REV-alt), very few individuals were found on the first sampling day. In general, the most abundant family was the Chironomidae (see Appendix).

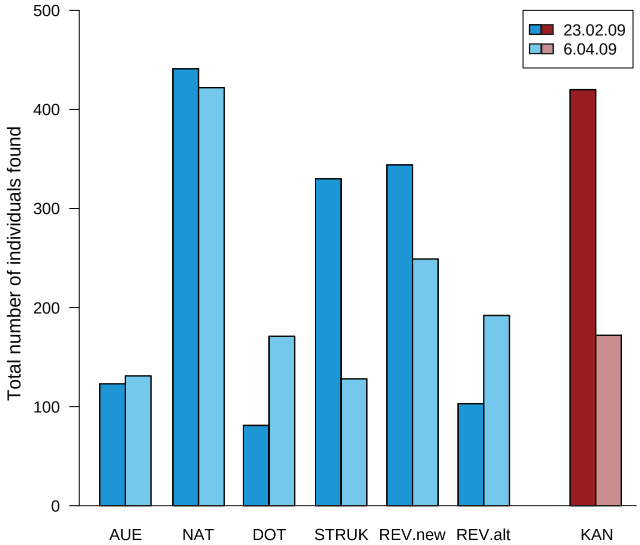

Figure 11: Abundance (number of individuals) for each stretch. In blue the restored sites and in red the degraded reference (KAN) for both sampling dates.

Chironomids seem to dominate the stretches at Bünzaue (AUE) (70% of all individuals found on the first sampling date), Wohlen (as well 70%), and at Bünzen. Trichoptera were found on all stretches, with at least one individual (Fig. 12). The most taxa (5, total) were found in the second stretch, with 69 individuals (16%) for the first sampling and 52 for the second one (12%). In the canalised stretch, four taxa were found in February (n=46, 11%) and three in April (n=19, 12%). In the other stretches, very few individuals were found.

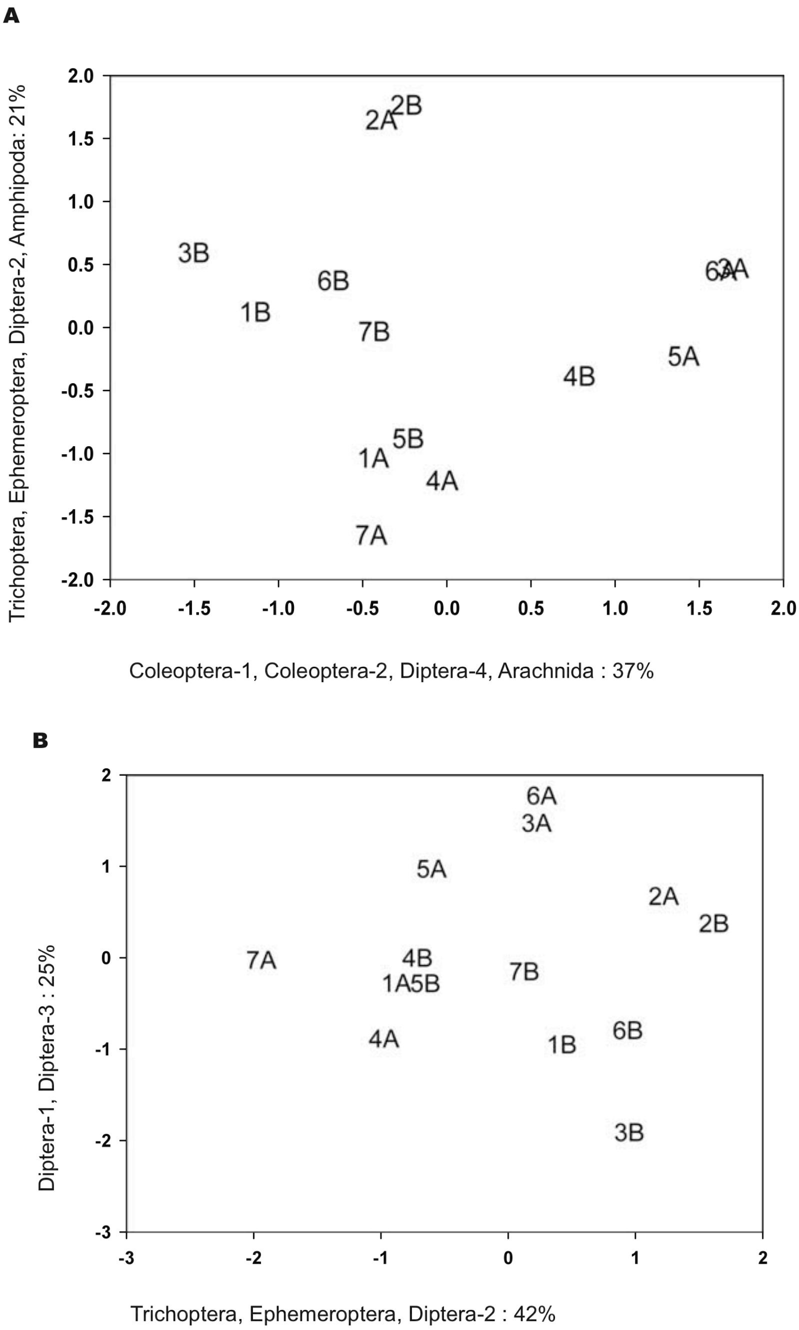

Figure 12: PCA for the most found macroinvertebrates. **A**: with all the taxa (Trichoptera, Coleoptera, Ephemeroptera, Diptera, Arachnida, Amphipoda) except the low abundant ones. Note that the taxa are here only in the order level. **B**: 7 most abundant arthropods taxa found (Trichoptera, Ephemeroptera, Diptera, Amphipoda). The stretches are numbered from 1 to 7. A are samples from the 23.2.09, B from 6.7.09.

Simpson's Index

The biodiversity was measured with the Simpson's Index. The index ranges from zero to one. A low index value means high diversity and a value of 1 means that only one taxa was found. The highest diversity with 0.2 was found in the channel in Möriken (KAN), followed by Möriken (NAT) (Fig. 13). The recently restored sites Bünzen (REV-new), Bünzaue (AUE), Dottikon (DOT), Wohlen (STRUK) and the oldest restoration site Bünzen (REV-alt) showed different values between sampling days. A value of 0.7 would mean that the system is dominated by few taxa, which is not the case here. For all stretches the diversity is high (Fig. 13).

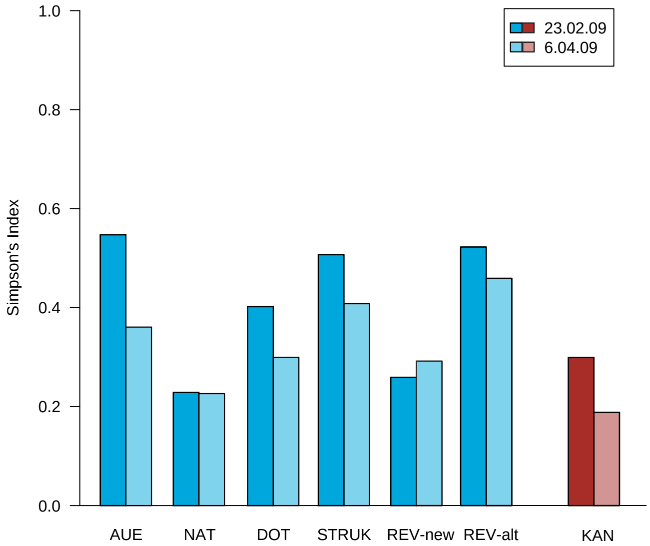

Figure 13: Simpson's Index of the different stretches. In blues the restored stretches, in red the degraded reference (KAN).

3.3 Water chemistry

The different sites were compared in a PCA for their water properties with their chemical properties. Nitrate and Phosphorous, which were explained to 33%, were compared with the conductivity, the temperature and the velocity, which were explained to 40% (Fig. 14). The stretches in Dottikon (DOT), and the two ones in Möriken (NAT, KAN) were similar. In the old restored stretch in Bünzen (REV-alt), a high level of Phosphorous and a low level of nitrate were measured, as well as a high conductivity and velocity, and a low temperature. It makes this stretch different of the other ones. In Bünzaue (AUE), a high level of Nitrate was found and a low one of Phosphorous (Fig. 14).

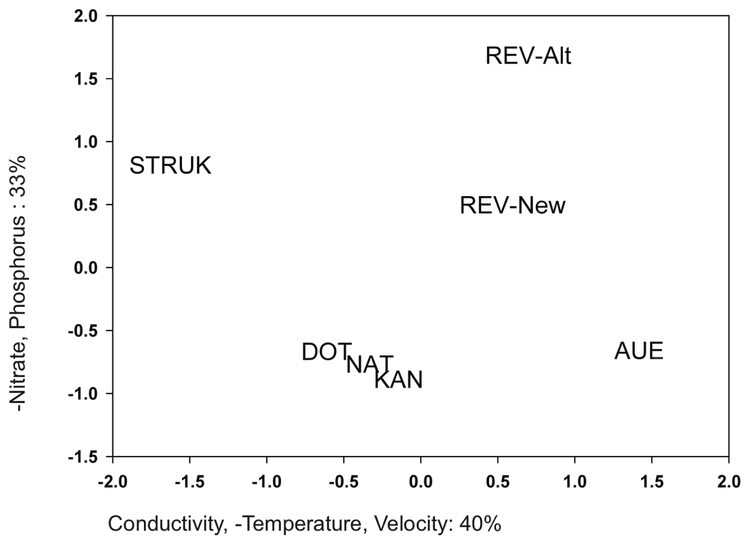

Figure 14: PCA of the most relevant properties of water for the seven stretches.

The DOC, pH, TIC, Nitrate, PN and POC showed a low variation between the stretches (Table 3). The ortho-Phosphate had a low value in Dottikon (DOT, 14.033), and a high value in Wohlen (STRUK, 45.967) and even bigger in the first stretch in Bünzen (REV-alt, 55.367). But to notice are the high values of their standard deviations. The particular Phosphate also showed variations and high standard deviations. The highest measure was found in the Bünzaue (AUE, 36.728), followed by both Möriken sites (KAN, 22.742, NAT, 33.901).

Table 3: Water chemistry, data from 23.02.2009, 16.03.2009 and 6.04.2009. In brackets: standard deviations. Abbreviations: POC (particular organic carbon), DOC (dissolved organic carbon), TIC (total inorganic carbon), o-P (ortho-phosphate), PP (particular phosphate), PN (particular nitrate).

	POC (mg/l)	DOC (mg C/l)	TIC (mg C/l)	o-P (µg P/l)	PP (µg/l)	Nitrate (mg N/l)	PN (mg/l)
AUE	2.067(1.325)	2.822(0.213)	68.096(3.301)	25.333(16.308)	36.728(37.556)	4.921(0.121)	0.343(0.255)
KAN	1.395(0.388)	2.916(0.383)	68.648(3.475)	25.467(15.458)	22.742(14.859)	5.010(0.116)	0.306(0.281)
NAT	1.801(1.602)	2.772(0.307)	68.720(3.766)	28.767(19.325)	33.901(46.929)	5.029(0.154)	0.228(0.128)
DOT	0.725(0.193)	2.741(0.327)	69.408(2.816)	14.033 (9.843)	4.811 (2.959)	4.774(0.109)	0.116(0.055)
STRUK	0.841(0.445)	3.201(0.416)	70.064(3.396)	45.967(24.416)	9.370 (8.565)	4.697(0.240)	0.112(0.048)
REVnew	1.120(0.835)	3.212(0.372)	68.688(3.373)	34.133(24.373)	13.633(15.486)	4.593(0.310)	0.127(0.059)
REV-alt	0.937(0.519)	3.083(0.291)	65.736(3.592)	55.367(28.958)	10.293(10.483)	4.102(0.277)	0.124(0.049)

4 Discussion

In this study, seven stretches were investigated in their occurrence of macroinvertebrates and the composition of the macroinvertebrate community. Six stretches, which have been rehabilitated (see Fig.1, Fig.2), were compared to a degraded reference because no data before the restorations are available. All rehabilitations at the river Bünz were undertaken between 1995 and 2006.

Habitat assessment

The results for the habitat assessment were as expected, the river widens the more downstream one goes. The higher values in DOT and STRUK are explained by the rehabilitations that were conducted. At these places the river has been enlarged. The river is deepest in the straightened (KAN) part of the Bünz, followed by the stretch that has been rehabilitated first (STRUK).

The increasing velocity from REV-alt to AUE follows the principles of river continuum concept (Vannote et al., 1980). The further downstream one goes the more the river increases in width and depth. The temperature was negatively correlated to the current and the river depth. The turbidity also decreased from REV-alt to AUE. The high values of turbidity could be explained by the close vicinity to agricultural fields in Bünzen, what leads to an eventual growth of phytoplankton (Koseff et al., 1993).

Taxonomic richness

If the taxonomic richness of the restored sites is compared to the degraded reference, there seems to be no difference between the sites. For the first sampling day, the highest values reach 16 taxa for the nature-close (NAT) stretch, and 17 for the second sampling day. The next stretch to have as many taxa is the REV-new, with 15 (February) and 13 (April). The degraded reference (KAN) has 14 taxa for the first sampling day, 13 for the second. Expected was that the number of taxa would be much higher in the rehabilitated sites than in the canalised part.

Among the taxa found, there are three very important ones, i.e. Ephemeroptera, Plecoptera and Trichoptera. These are good indicators of water quality (Smith et al. 1999) and therefore important for the assessment of the success of a rehabilitation (Rosenberg & Resh, 1993; Resh & Jackson, 1993). Most individuals of these taxa were found in NAT, where 69 individuals from 5 different families of the order Trichoptera, 14 Ephemeroptera (2 families) were found for the first sampling day. On the second day, 52 Trichoptera (5 families) and 31 Ephemeroptera (2 families) were found. Similarly, in KAN, 46 Trichoptera (4 families) and 17 Ephemeroptera (1 family) were found in February, and additionally 47 Plecoptera of the same family were collected. On April 19 Trichoptera (3 families) and 40 Ephemeroptera (2 families) were found. In Bünzen, REV-new, 36 Trichoptera (3 families) the first time, 2 (1 family) the second, 22 and 69 Ephemeroptera (2 and 1 families) and 6 and 4 Plecoptera (1 and 2 families) were found. The differences between the two sampling days might suggest seasonality in the presence of those three taxa. Probably, a mature hatching event occurred between the two sampling days in the trichopteran larvae in the stretches NAT, KAN and REV-new, for the ephemeropteran larvae a later start of development (Coleman & Hynes, 1970). The seasonality was also observed when looking at the number of indivuduals.

No taxon was found in KAN that was not found in the other stretches. On the contrary, 8 taxa were not found in KAN that were found in the other stretches: 2 families of Trichoptera, 1 family of Plecoptera, Hirudinea, Oligochaeta, Gastropoda, Isopoda and Bivalvia. These taxa were also the rarest overall, e.g. only 1 individual of Bivalvia was found in REV-alt.

Abundance

The overall number of individuals was expected to be the highest in any of the restored stretches. But the highest numbers were found in the channel (KAN) and in the close to natural state (NAT). A low numbers of animals were found in the floodplain (AUE), Dottikon (DOT), and Bünzen (REV-alt). The low number of individuals in AUE could be explained by the poor habitat. In addition, the current was quite strong on the sampling days and the samples were taken in the middle of the river. If the current is strong there might be less suitable or sufficient shelters for insects. Therefore, fewer individuals would be found in high currents (Erman & Erman, 1983). The low number in REV-alt seems to be contrary to the fact that the high turbidity in REV-alt suggests a high phytoplankton biomass and therefore high resource availability for macro-invertebrates. Additionally, the current is not strong and the river has a complex structuring, which makes it an even more suitable habitat (Hynes, 1970). The PCA (Fig.14) reveals that the site in Bünzen (REV-alt) is different from the other sites in its how Nitrate level and high Phosphorus level and its low conductivity and velocity and high temperature.

Simpson's Index

The highest macrozoobenthos diversity was found in the stretch that remained untouched (NAT) since the 1930s. The channel (KAN) showed for the second sampling date a value of 0.19, which means a high diversity. Interestingly, the highest diversities were found where no changes have been made over the last 70 years (KAN, NAT). Even compared to the first restored stretch (STRUK), with Simpson's Index between 0.5 and 0.4 (February and April) KAN and NAT still have higher diversity. The diversity of the most recently restored site (REV-new) is only slightly higher than in NAT. Either the diversity of the macro-invertebrates was already high before the restoration, or the community has recovered very fast. Overall, these findings either suggest that the macroinvertebrate community needs more than 13 years to recover or that the channel (KAN) is better than previously assumed.

Water chemistry

The water quality was very similar among the stretches, which is confirmed by the principal component analysis (fig.7). Figure 7 shows that there is a group of quite similar habitats (see the bottom of the graph, i.e. DOT, NAT, KAN) where the nitrate concentration is higher than in the other stretches, and phosphorous is lowest.

Synthesis

To resume, the rehabilitations undertaken at the river Bünz seem not to have had any effect on numbers in or diversity of the macroinvertebrate community. The conclusion would rather be that it makes no difference to macroinvertebrates whether they have a rich and structured habitat or a boring and straight channel of concrete.

A point that is often forgotten is that a restoration in the broad sense is not possible due to the fact that the growing population needs more and more space (Woolsey et al, 2005). Thus a river cannot be given its past course anymore. The macroinvertebrates will not find their former biotope after rehabilitation and hence they will never be found in the same diversity and richness as in an untouched river. The goal of the assessment of river management is nowadays not only to give more space to the river and thus reduce the danger of flood, but also to increase the biodiversity and to provide suitable recreation areas for people. Visually, these changes may have been achieved at the Bünz, but to make a concrete statement about the biodiversity, more indicators than just macroinvertebrates would be needed. Generally, long-term studies would be more suitable to decide about the success of restorations. In this way, the dynamics of the recovery of the macroinvertebrate community could be monitored more precisely.

River monitoring is still in its beginning and the establishment of suitable indicators for a successful river management strategy is notoriously hard as morphologies of water bodies differ tremendously between each other. It will still take some time and research funding to create a catalogue of suitable indicators for a complete and meaningful assessment of any restored ecosystem. Furthermore, to a river also belongs the riverbank and its vegetation, if not even most of the immediate area surrounding the river. Therefore, the scale does matter, meaning an ecosystem level approach will produce a better understanding of the lower levels, i.e. habitat and species levels. More insight will also be gained by putting together the results from studies conducted in different river ecosystems and different climate zones.

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Appendix

List of all taxa found in the seven stretches at the Bünz.

Bünzaue (AUE)

Sample	Date	Class	Order	Family	Genus	Species	Total Ind
1	23.3	Insecta	Trichoptera	1		Gen. sp.	1
	23.3	Insecta	Coleoptera	Dryopidae		Gen. sp.	1
	23.3	Insecta	Ephemeroptera	1		Gen. sp.	1
	23.3	Insecta	Diptera	Chironomidae		Gen. sp.	87
	23.3	Insecta		Simuliidae		Gen. sp.	5
	23.3	Insecta		Ceratopogonidae		Gen. sp.	26
	23.3	Insecta		other		Gen. sp.	2
	23.3	unknown					1
	6.4	Insecta	Trichoptera	1		Gen. sp.	6
	6.4	Insecta		5		Gen. sp.	1
	6.4	Insecta	Ephemeroptera	1		Gen. sp.	10
	6.4	Insecta	Diptera	Chironomidae		Gen. sp.	74
	6.4	Insecta		Ceratopogonidae		Gen. sp.	15
	6.4	Insecta		other		Gen. sp.	18
	6.4	Insecta	Plecoptera	2		Gen. sp.	1
	6.4	Crustacea	Amphipoda	Gammarus		Gen. sp.	5
	6.4	Clitellata	Oligochaeta			Gen. sp.	1
						Total:	255

Möriken (NAT)

Sample	Date	Class	Order	Family	Genus	Species	Total Ind
2	23.3	Insecta	Trichoptera	1		Gen. sp.	58
	23.3	Insecta		2		Gen. sp.	3
	23.3	Insecta		3		Gen. sp.	1
	23.3	Insecta		4		Gen. sp.	2
	23.3	Insecta		5		Gen. sp.	5
	23.3	Insecta	Coleoptera	Dryopidae		Gen. sp.	2
	23.3	Insecta	Ephemeroptera	1		Gen. sp.	13
	23.3	Insecta		2		Gen. sp.	1
	23.3	Insecta	Diptera	Chironomidae		Gen. sp.	170
	23.3	Insecta		Simuliidae		Gen. sp.	1
	23.3	Insecta		Ceratopogonidae		Gen. sp.	75
	23.3	Insecta		other		Gen. sp.	29
	23.3	Crustacea	Amphipoda	Gammarus		Gen. sp.	74
	23.3	Crustacea	Isopoda	Asellus		Gen. sp.	1
	23.3	Arachnida	Acari			Gen. sp.	5
	23.3	Gastropoda				Gen. sp.	1
	23.3	unknown					1
	6.4	Insecta	Trichoptera	1		Gen. sp.	38
	6.4	Insecta		2		Gen. sp.	3
	6.4	Insecta		4		Gen. sp.	7
	6.4	Insecta		5		Gen. sp.	1
	6.4	Insecta		6		Gen. sp.	3
	6.4	Insecta	Coleoptera	Dryopidae		Gen. sp.	4
	6.4	Insecta		other		Gen. sp.	2
	6.4	Insecta	Ephemeroptera	1		Gen. sp.	29
	6.4	Insecta		2		Gen. sp.	2
	6.4	Insecta	Diptera	Chironomidae		Gen. sp.	175
	6.4	Insecta		Ceratopogonidae		Gen. sp.	53
	6.4	Insecta		other		Gen. sp.	48
	6.4	Crustacea	Amphipoda	Gammarus		Gen. sp.	46
	6.4	Arachnida	Acari			Gen. sp.	6
	6.4	Gastropoda				Gen. sp.	1
	6.4	Clitellata	Oligochaeta			Gen. sp.	3
	6.4	Clitellata	Hirudinea			Gen. sp.	1
						Total:	864

Möriken channel (KAN)

Sample	Date	Class	Order	Family	Genus	Species	Total Ind
3	23.3	Insecta	Trichoptera	1		Gen. sp.	41
	23.3	Insecta		2		Gen. sp.	1
	23.3	Insecta		5		Gen. sp.	2
	23.3	Insecta		6		Gen. sp.	2
	23.3	Insecta	Coleoptera	Dryopidae		Gen. sp.	1
	23.3	Insecta		other		Gen. sp.	1
	23.3	Insecta	Ephemeroptera	1		Gen. sp.	17
	23.3	Insecta	Diptera	Chironomidae		Gen. sp.	213
	23.3	Insecta		Simuliidae		Gen. sp.	20
	23.3	Insecta		Ceratopogonidae		Gen. sp.	7
	23.3	Insecta		other		Gen. sp.	51
	23.3	Insecta	Plecoptera	1		Gen. sp.	47
	23.3	Crustacea	Amphipoda	Gammarus		Gen. sp.	11
	23.3	Arachnida	Acari			Gen. sp.	6
	6.4	Insecta	Trichoptera	1		Gen. sp.	10
	6.4	Insecta		2		Gen. sp.	4
	6.4	Insecta		5		Gen. sp.	5
	6.4	Insecta	Coleoptera	other		Gen. sp.	1
	6.4	Insecta	Ephemeroptera	1		Gen. sp.	37
	6.4	Insecta		2		Gen. sp.	3
	6.4	Insecta	Diptera	Chironomidae		Gen. sp.	57
	6.4	Insecta		Ceratopogonidae		Gen. sp.	14
	6.4	Insecta		other		Gen. sp.	5
	6.4	Crustacea	Amphipoda	Gammarus		Gen. sp.	17
	6.4	Arachnida	Acari			Gen. sp.	1
	6.4		Annelida			Gen. sp.	1
						Total:	575

Dottikon (DOT)

Sample	Date	Class	Order	Family	Genus	Species	Total Ind
4	23.3	Insecta	Trichoptera	1		Gen. sp.	1
	23.3	Insecta		6		Gen. sp.	1
	23.3	Insecta	Coleoptera	Dryopidae		Gen. sp.	3
	23.3	Insecta		other		Gen. sp.	1
	23.3	Insecta	Ephemeroptera	1		Gen. sp.	3
	23.3	Insecta	Diptera	Chironomidae		Gen. sp.	49
	23.3	Insecta		Simuliidae		Gen. sp.	6
	23.3	Insecta		Ceratopogonidae		Gen. sp.	3
	23.3	Insecta		other		Gen. sp.	13
	23.3	Arachnida	Acari			Gen. sp.	1
	23.3	other					1
	6.4	Insecta	Trichoptera	1		Gen. sp.	17
	6.4	Insecta	Coleoptera	Dryopidae		Gen. sp.	6
	6.4	Insecta		other		Gen. sp.	4
	6.4	Insecta	Ephemeroptera	1		Gen. sp.	2
	6.4	Insecta	Diptera	Chironomidae		Gen. sp.	85
	6.4	Insecta		Ceratopogonidae		Gen. sp.	5
	6.4	Insecta		other		Gen. sp.	32
	6.4	Crustacea	Amphipoda	Gammarus		Gen. sp.	8
	6.4	Arachnida	Acari			Gen. sp.	8
	6.4	Gastropoda				Gen. sp.	1
	6.4	Clitellata	Hirudinea			Gen. sp.	3
						Total:	253

Wohlen (STRUK)

Sample	Date	Class	Order	Family	Genus	Species	Total Ind
5	23.3	Insecta	Trichoptera	1		Gen. sp.	1
	23.3	Insecta		2		Gen. sp.	1
	23.3	Insecta		3		Gen. sp.	1
	23.3	Insecta	Coleoptera	Dryopidae		Gen. sp.	2
	23.3	Insecta		other		Gen. sp.	3
	23.3	Insecta	Ephemeroptera	1		Gen. sp.	3
	23.3	Insecta	Diptera	Chironomidae		Gen. sp.	231
	23.3	Insecta		Ceratopogonidae		Gen. sp.	12
	23.3	Insecta		other/unknown		Gen. sp.	22
	23.3	Insecta		Simuliidae		Gen. sp.	28
	23.3	Insecta	Plecoptera	1		Gen. sp.	1
	23.3	Crustacea	Amphipoda	Gammarus		Gen. sp.	6
	23.3	Arachnida	Acari			Gen. sp.	19
	6.4	Insecta	Trichoptera	1		Gen. sp.	2
	6.4	Insecta		7		Gen. sp.	1
	6.4	Insecta	Coleoptera	Dryopidae		Gen. sp.	2
	6.4	Insecta		other		Gen. sp.	1
	6.4	Insecta	Ephemeroptera	1		Gen. sp.	2
	6.4	Insecta	Diptera	Chironomidae		Gen. sp.	78
	6.4	Insecta		Ceratopogonidae		Gen. sp.	7
	6.4	Insecta		other/unknown		Gen. sp.	22
	6.4	Insecta		Simuliidae		Gen. sp.	2
	6.4	Insecta	Plecoptera	1		Gen. sp.	1
	6.4	Insecta		2		Gen. sp.	1
	6.4	Gastropoda				Gen. sp.	3
	6.4	Clitellata	Oligochaeta			Gen. sp.	6
						Total:	458

Bünzen new (REV-new)

Sample	Date	Class	Order	Family	Genus	Species	Total Ind
6	23.3	Insecta	Trichoptera	1		Gen. sp.	29
	23.3	Insecta		2		Gen. sp.	6
	23.3	Insecta		6		Gen. sp.	1
	23.3	Insecta	Coleoptera	Dryopidae		Gen. sp.	5
	23.3	Insecta		other/unknown		Gen. sp.	2
	23.3	Insecta	Ephemeroptera	1		Gen. sp.	20
	23.3	Insecta		2		Gen. sp.	2
	23.3	Insecta	Diptera	Chironomidae		Gen. sp.	161
	23.3	Insecta		Simuliidae		Gen. sp.	18
	23.3	Insecta		Ceratopogonidae		Gen. sp.	32
	23.3	Insecta		other/unknown		Gen. sp.	45
	23.3	Insecta	Plecoptera	1		Gen. sp.	6
	23.3	Crustacea	Amphipoda	Gammarus		Gen. sp.	2
	23.3	Arachnida	Acari			Gen. sp.	14
	23.3	Crustacea	Isopoda			Gen. sp.	3
	6.4	Insecta	Trichoptera	1		Gen. sp.	2
	6.4	Insecta	Coleoptera	other		Gen. sp.	1
	6.4	Insecta		other		Gen. sp.	1
	6.4	Insecta	Ephemeroptera	1		Gen. sp.	69
	6.4	Insecta	Diptera	Chironomidae		Gen. sp.	109
	6.4	Insecta		Ceratopogonidae		Gen. sp.	33
	6.4	Insecta		other/unknown		Gen. sp.	16
	6.4	Insecta		Tipulidae		Gen. sp.	1
	6.4	Insecta	Plecoptera	1		Gen. sp.	1
	6.4	Insecta		2		Gen. sp.	3
	6.4	Crustacea	Amphipoda	Gammarus		Gen. sp.	1
	6.4	Arachnida	Acari			Gen. sp.	2
	6.4	Clitellata	Oligochaeta			Gen. sp.	9
	6.4	Clitellata	Hirudinea			Gen. sp.	1
						Total:	595

Bünzen old (REV-alt)

Sample	Date	Class	Order	Family	Genus	Species	Total Ind
7	23.3	Insecta	Trichoptera	1		Gen. sp.	1
	23.3	Insecta	Diptera	Chironomidae		Gen. sp.	72
	23.3	Insecta		other/unknown		Gen. sp.	18
	23.3	Insecta		Simuliidae		Gen. sp.	1
	23.3	Insecta		Tipulidae		Gen. sp.	1
	23.3	Insecta	Plecoptera	1		Gen. sp.	1
	23.3	Arachnida	Acari			Gen. sp.	1
	23.3	Crustacea	Isopoda			Gen. sp.	2
	23.3	Bivalvia				Gen. sp.	1
	23.3	Clitellata	Oligochaeta			Gen. sp.	5
	6.4	Insecta	Trichoptera	1		Gen. sp.	2
	6.4	Insecta		4		Gen. sp.	1
	6.4	Insecta		2		Gen. sp.	1
	6.4	Insecta	Coleoptera	other		Gen. sp.	1
	6.4	Insecta	Ephemeroptera	1		Gen. sp.	6
	6.4	Insecta	Diptera	Chironomidae		Gen. sp.	126
	6.4	Insecta		Ceratopogonidae		Gen. sp.	15
	6.4	Insecta		other/unknown		Gen. sp.	27
	6.4	Crustacea	Amphipoda	Gammarus		Gen. sp.	1
	6.4	Arachnida	Acari			Gen. sp.	5
	6.4	Clitellata	Oligochaeta			Gen. sp.	5
	6.4	Clitellata	Hirudinea			Gen. sp.	2
						Total:	295