Macroinvertebrate species diversity comparison among a restored and an unrestored part in the Sege River, Sweden

Sarah Kerle, Saghar Khandan, Xi Yang
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Supervisor: Cecilia Lyddby

Abstract

Restoration ecology has become more and more of interest in the last decades as streams and rivers in Europe are highly affected through diffuse pollution and physical degradation (EU Commission, 2007). Sege's basin is located in the southwest of Scania and restoration measures have been undertaken in 2008 within the Sege Project (2000-2021).To increase habitat-heterogeneity stones, rocks and boulders have been added in the river bed to modify the otherwise homogeneous conditions in the stream. Additionally trees have been planted to create shading conditions. As an increase in different habitat should promote species diversity (Ricklef &Schulter, 1993) we expected to find a higher diversity in macroinvertebrates in the restored part than in the unrestored part of the Sege River section. Through kick-sampling we investigated macroinvertebrates species diversity in the restored area as well as in the unrestored area, within a section of the Sege River. Contrary to our hypothesis we didn't find any significant difference in macroinvertebrate species diversity among the two different parts. Though, our results are not surprisingly when comparing with previous studies (Palmer et al., 2010).

Introduction

Restoration ecology has become more and more of interest in the last decades as streams and rivers in Europe are highly affected through diffuse pollution and physical degradation (EU Commission, 2007). One example for undertaken restoration measures illustrates the Sege River.

Sege's basin is located in the southwest of Scania. The catchment area of the river is mainly characterized by agricultural land except the catchment area around the lakes in the south-east part of the drainage area which consist of some forest. The Sege mainstream is approximately 46 km and starts from Börringesjön and flows towards Oresund (Segeå jordbrukså i backlandskap, 2011).

Since 2000, the Sege restoration project has started and the aim of this action work is to increase the water storage pond, to increase biodiversity in the aquatic environment and in the catchment area, and to enhance the right of common property area.

By restoring rivers and streams, the environmental conditions could be improved such as water quality (i.e. reduction of pollutant in streams and rise dissolved oxygen levels) (Gilmann et al., 2009) and biological habitats. Some of these restoration measures have effect on aquatic assemblages, especially the grain size of the bottom sediments, which is one of the most effective parameters that determine the composition of benthic communities (Culp et al., 1983; Rempel et al., 2000). Coarse substrate is suitable for some taxa, fine substrate is necessary for others. (Arthur V. Brown & Peter P. Brussock, 1991). Also creating riffles and pools and increasing aquatic macrophytes, which can provide distinct habitat for invertebrates provides better ecological conditions. (Humphries 1996). Disturbance, frequency, severity and intensity are different between riffles and pools and therefore have significant impact on invertebrates' community structures (Resh et al., 1988). Invertebrates use aquatic macrophytes as a direct food source, shelter from predators, spawning area and feeding on the attached periphyton growing on their surface (Papa, 2007). These measures will probably reduce the amount of nitrogen and phosphorus in aquatic environments (Segeå jordbrukså I backlandskap, 2011) and the catchment area, which could have positive effect of reducing the eutrophication. The presence of a variety of invertebrate species shows a sustainable healthy river system. Moreover, invertebrates play an important role in the natural flow of energy and nutrients (Rivers & Streams, 2011). Invertebrates have a long life cycle of one to three years (Invertebrate Pollution Tolerance , 2010) and allow ecologists to investigate the effect of past pollution events such as pesticide spills and illegal dumping on environmental quality.

(Freshwater Benthic Macroinvertebrates, Useful Indicators of Water Quality, 2011) For example scrapers or collectors are indicators of increasing organic nutrient pollution and if they become more common in the river an enhancement of algae growth is expected (Invertebrate Pollution Tolerance, 2010). There are three categories of aquatic macroinvertebrates which can be grouped on their sensitivity to pollution and can be used for classifying the water quality (Water Quality Monitoring, 2005).

Class 1 Organisms are pollution sensitive. They cannot stand pollution well and are just observed when good water quality is present, like *Caddisfly larva, Stonefly larvae and Mayfly larva*. (The biotic index, 1975) (Water Quality Monitoring, 2005).

Class 2 Organisms moderate pollution tolerant. They tolerate water pollution better than Class 1 organisms. When the water quality ranges from good to moderate a significant abundance of these animals can be expected. *Water penny (Coleoptera), Crayfish, Aquatic Sowbug, Rifle beetle larva, Clam or mussels* are examples of these organisms (The biotic index, 1975) (Water Quality Monitoring, 2005).

Class 3 Organisms are pollution tolerant. They are tolerant to even higher levels of pollution than Class 2 Organism. When these animals dominate, poor water quality has to be expected. Examples are *Leech, Lunged snails, Black fly and Midge fly larva*. (The biotic index, 1975) (Water Quality Monitoring, 2005).

Dpending on the food resource in the Rivers there are different functional groups, shredders (like *Gammarus sp.*), grazers (like *Baetis sp.*), collectors (like *Simuliidae*), and predators (like *Tanypus sp.*). Abundance or loss of a specific group can be an indicator of changing in the ecological status of the stream or river. The representatives of each functional feeding group; mean the ideal 'healthy' aquatic habitat (How to use the online Bug Guide, 2011).

The aim of this study is to investigate if there is a difference in the assemblage of benthic macroinvertebrates between two parts in a Sege River-Section, one restored and one unrestored part.

Material and Methods

Benthic Macroinvertebrates samples were collected between the 8th and the 9th of November 2011. The study area was a section of the small-sized lowland Sege River, placed in the municipality of Svedala (Scania), Sweden, (Fig.1).

Nine sample sites were chosen, five in the restored (R) reach of the river, located upstream, and four in the unrestored (UR) reach of the river, located downstream, within a range of 1km (Fig.1). Within each section, two samples were taken, one in the bank and one in the middle site of the river (unit 25 cm²), except of sample site R3 (only one sample in the middle was taken due to lack of habitat difference between bank and middle part of the river).

The aim was to find comparable sites between the restored part and the unrestored part concerning bottom substrate, water flow rate and surrounding vegetation.

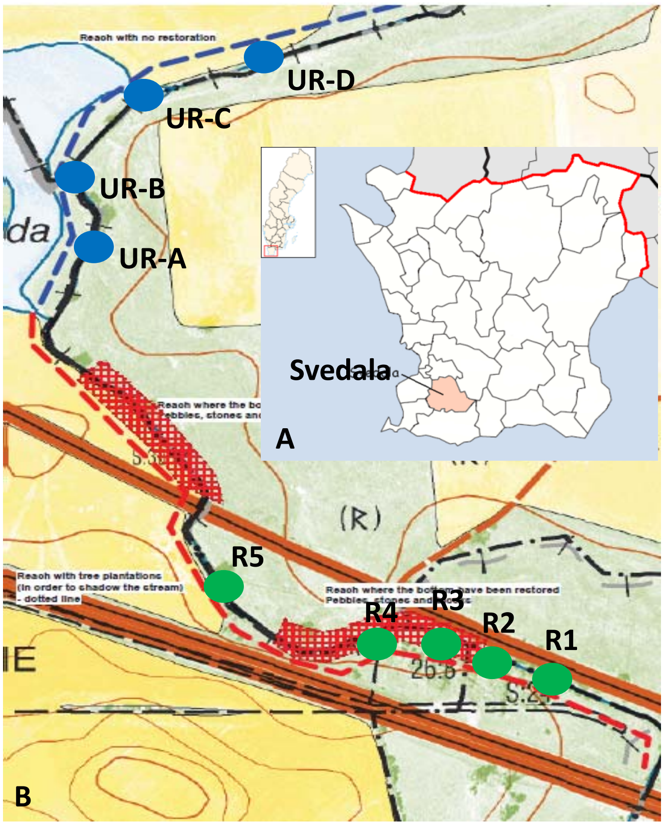


Figure 1: A: Map of Southern Sweden, Skåne (Wikipedia, 2011); B: Sege-River-Section near Oxie with sample sites (green = restored area; blue = unrestored area) (Segeåns Vattendragsförbund and Vattenråd, 2011)


Figure 2. Kick-Sampling: Hand-net placed on river bed against river flow direction and area around disturbed through kicking.

As sample method the kick-sampling technique (Naturvårdsverket, 2010) (Fig. 2) was performed using a hand-net with 1 mm mesh size. The net was placed in the river bed against flow direction and the area around the net was disturbed for 30 seconds through kicking. The collected sample material was filled in a trail. Macroinvertebrates were hand-picked with tweezers, stored in closable cubs and fixed with 70% Ethanol for transportation and laboratory analyses. In the laboratory the organisms were identified with microscopes (Nikon SMZ-1) mainly to genus or species level according to Mandahl-Barth (1941) and Stenroth (2001), with selected species only to family level (species listed in Appendix A).

The water flow rate of each sample spot was measured to calculate the water speed using the "orange-technique". A meter stick was located above the water surface. Then the orange was dropped and time was taken how long it took the orange to travel one meter. Additionally data on river depth and river width were recorded in pre-made protocols (Naturvårdsverket, 2003, Appendix B), as well as bottom substrate-type, bank structure, submerged and surrounding vegetation and nearby land-use as potential influencing factors on macroinvertebrates diversity.

Statistical Analyses

Shannon-Weaver Index (Species Diversity)

The Shannon-Weaver Index (Shannon & Weaver, 1949) was calculated order to investigate the biodiversity of macroinvertebrates.

$$H_n = -\sum (p_i \ln p_i) \quad \text{Pi} = \text{ni/N}$$

Pi *(relative abundance of each species)* = **ni** *(number of individuals in each species)/* **N** *(total number of all individuals)*

ASPT-Index (Ecological quality)

The ASPT-Index (Average Score per Taxon) (Armitage et al., 1983) was calculated in order to investigate the state of pollution of the river by using invertebrates as sensitivity indicators. In this Index macroinvertebrate families are scored from 1 to 10 depending on their sensitivity to organic pollution. Families with a high sensitivity to organic pollution contribute a high indicator value (ASPT = 10, high sensitivity on organic pollution, Table 3). The ASPT is defined as the summation of indicator values divided by number of input taxa.

The Danish-Stream-Fauna-Index (Impact of pollution)

The Danish-Stream-Fauna-Index (Skriver et al., 2001) was additionally used to detect organic pollution. All macroinvertebrates taxa act as indicators by being either sensitive or tolerant towards an oxygen level and assigned to seven quality classes, ranging from fauna class 7 (not affected) to fauna class 1 (very strongly affected). The index was calculated by firstly classing the sampled taxa to either positive or negative groups (Table 1) and secondly determine the value by using a key groups table (Table 2).

Table 1: Diversity Groups (Miljöstyrelsen, 1998)

Diversity Groups	
Positive	**Negative**
Tricladida	*Oligochaeta ≥100*
Gammarus	*Helobdella*
Plecoptera	*Erpobdella*
Ephemeroptera	*Asellus*
Elmis	*Sialis*
Limnius	*Psychodidae*
Helodes	*Chironoms*
Rhyacophilidae	*Eristalis*
Trichoptera	*Sphaerium*
Ancylus	*Lymnaea*

Table 2: Key-Groups (Miljöstyrelsen, 1998)

Keygroups (KG)	**Number diversity groups**	**≤ +2**	**+1 - 3**	**4 - 9**	**≥10**
Keygroup1: Brachyptera, Capnia, Leutra, Isogenus, Isoperla Isoptena, Perlodes, Protonemura, Siphonoperla Ephemeridae Limnius Glossosomatidae, Sericostomatidae	≥ 2 groups	-	5	6	7
	1 group	-	4	5	6
Keygroup 2: Amphinemura, Taeniopteryx Ametropdidae, Ephemerellidae Heptageniidae, Leptophlebiidae, Siphlonuridae Elmis, Helodes Rhyacophilidae, Goeridae Ancylus if Asellus ≥5 tested KG3 if Chironomus ≥5 tested KG 4		4	4	5	5
Keygroup 3: Gammarus ≥10		3	4	4	4

Caenidae other Tricoptera than those specified above ≥5 if Chironomus ≥ 5 tested KG 4					
Keygroup 4: Gammarus ≥10, Asellus Caenidae Sialis Other Tricoptera	≥ 2 groups 1 group	3 2	3 3	4 3	- -
Keygroup 5: Gammarus Baetidae Simuliidae ≥25 if Oligochaeta ≥ 100 tested KG5, 1 group if Eristalis ≥ 5 tested KG 6	≥ 2 groups	2	3	3	-
	1 group or Oligochaeta ≥ 100	2	2	3	-
Keygroup 6: Tubificidae Psychodidae Chironomidae Eristalis		1	1	-	-

Value-Ranges for Shannon-Weaver-, Danish-Stream-Fauna- and ASPT-Index

In Table 3 the value-ranges of the calculated indices are presented and assigned to five classes (1=very high; 5=very low)

Table 3: Assessment criteria for benthic bottom fauna (Naturvårdsverket, 2007)

Class	Appellation	Shannon-Weaver-Index	Danish-Stream-Fauna-Index	ASPT-index
1	very high	>3,71	7	> 6,9
2	high	2,97-3,71	6	6,1-6,9
3	intermediate	2,22-2,97	5	5,3-6,1
4	low	1,48-2,22	4	4,5-5,3
5	very low	≤1,48	≤3	≤4,5

Statistics:

To test if the values are normal distributed the Kolmogorov-Smirnov test was done, as well as the Levene-Test to test for equal variances (SPSS 17.0).

Since the values were normal distributed an independent t-test was conducted in SPSS 17.0 in order to the test for significance. Results are presented with mean values and standard errors.

Results

Shannon-Weaver Index and ASPT Index

The results of Shannon-Weaver index show higher species diversity in the restored area comparing to the unrestored area (Fig. 3), (t =-0.41, df =7, p =0.968). In the restored area, a higher ASPT was achieved comparing to the unrestored area (Fig. 4), (t = -1.09, df = 7, p = 0.855).

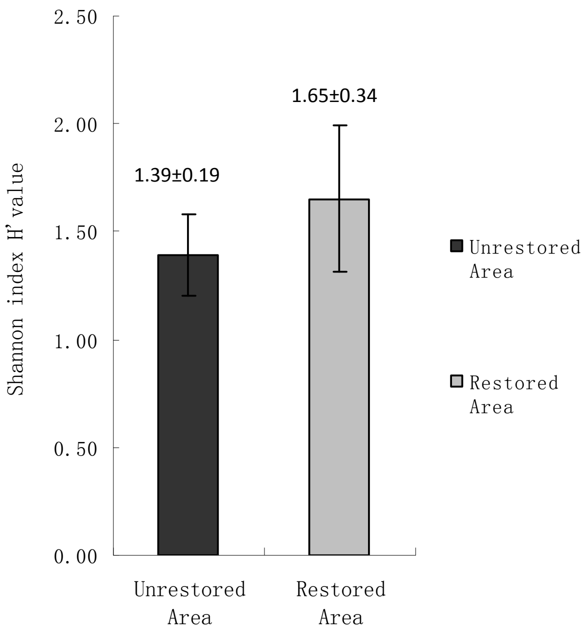


Figure 3: The Shannon weaver index indicates higher species diversity in the restored area comparing to the unrestored area. The H' values of unrestored and restored area are 1.65 and 1. 39, respectively.

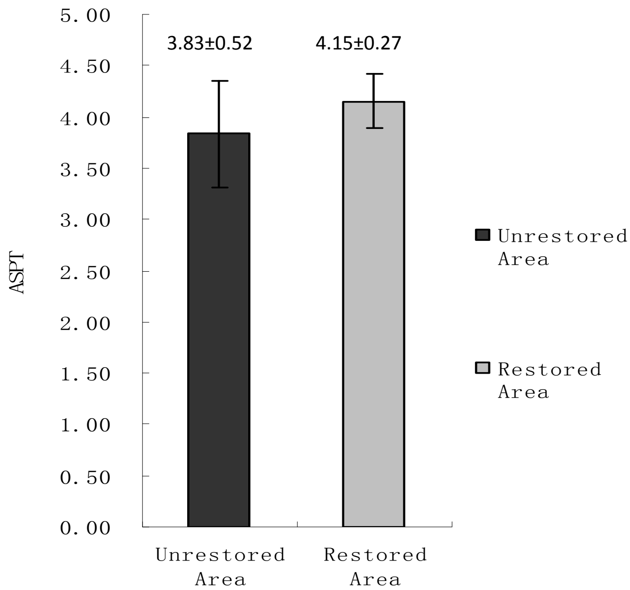


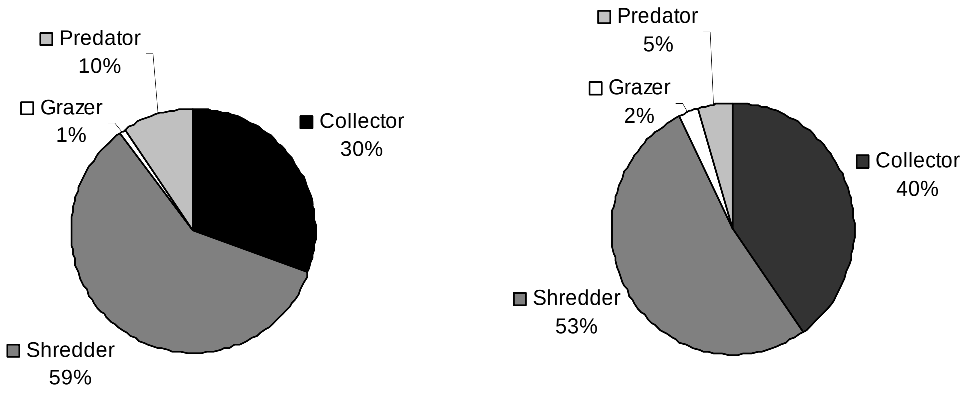
Figure 4: ASPT indicates higher water quality in the restored area comparing to the unrestored area. The ASPT of unrestored and restored area are 3.83 and 4.15, respectively.

Danish Stream Fauna Index

The results of Danish stream fauna index (DVFI) of unrestored and restored area showed no differences, with DVFI values of 3 in both areas (Table 3).

Functional Groups

The results of functional group in unrestored and restored area show differences on the ratios of different groups within unrestored and restored area. The ratio of predator, collector, shredder and grazer is 10:30:59:1 in unrestored area while 5:40:53:2 in restored area (Fig.5).



a b

Figure 5: Functional group abundance in unrestored (a) and restored (b) area.

Table 4: Mean depth, mean width, substrate type and flow speed of all sample sites.

Sites	Mean Depth (cm)	Mean Width (m)	Substrate Type(middle)	Substrate Type(bank)	Flow Speed *
Unrestored A	53	4.3	Clay/Gravel	Clay	gently flowing
Unrestored B	45	4	Clay/Cobbles	Clay	rapid flowing
Unrestored C	54	5.5	Clay/Gravel	Clay	slow flowing
Unrestored D	41	3.9	Clay/Cobbles	Clay	slow flowing
Restored 1	30	3.5	Cobbles	Cobbles	gently flowing
Restored 2	26	4	Cobbles/Boulders	Cobbles	rapid flowing
Restored 3	60	4.2	Cobbles/Boulders	Boulders	gently flowing
Restored 4	22	4.2	Cobbles/Boulders	Boulders	rapid flowing
Restored 5	67	4	Cobbles	Cobbles	slow flowing

* slow flowing (<0.2m/s), gently flowing (≥0.2m/s, ≤0.7m/s), rapid flowing (>0.7m/s)

Aquatic environment

The bottom substrates of unrestored area are mainly clay dominated, combined with scattered gravels or cobbles, while in restored area, substrates of cobbles and boulders are found. The mean depths of the sampling sites range from 26cm to 67cm, while there are no notable differences on the mean widths of the sampling sites, range from 3.5m to 5.5m. The flow speed differs among the sample sites, from speed lower than 0.2m/s to speed higher than 0.7m/s (Tab. 4).

Discussion

The aim of the study was to see if the arrangement of Sege River Project had any impact to restored area concerning the assemblage of the benthic fauna. We also wanted to do a comparison between the restored and unrestored area concerning the assemblage of the benthic fauna. To cover different areas in our section of Sege River, we used both abiotic and biotic methods. We also did an investigation both in the restored and unrestored areas concerning the surroundings, bottom substrates and aquatic environment to see if there were any differences between the areas. The biotic factors and abiotic factors can tell us about the past time and present time, respectively. In the end of the discussion there will be a conclusion of the biotic and abiotic factors.

Shannon-Weaver Index

Our investigation has shown that there is no significant difference in macroinvertebrates biodiversity between the restored and the unrestored part of the Sege River-Section. One reason might be that the recovery time was too short, as the restoration was conducted in 2008 giving a recovery period for three years until now, supported by previous studies (Sundermann et al., 2011); however, according to Palmer et al. (2010) only two studies out of 78, of which many have been sampled several years after restoration, have shown a significant difference in biodiversity of macroinvertebrates. We also have to be conscious that mechanical restoration can have damaging short-term effects and might even lead to a decrease in biodiversity (Muotka et al., 2002).

ASPT Index and Danish Stream Fauna index

The calculated ASPT and Danish-Stream-Fauna-Index indicated low ecological status and bad water quality of Sege River, possibly due to impact of nearby agriculture. This could be another reason for the poor response of macroinvertebrates to the restoration (Sundermann et al., 2010).

Functional Group

The dominance of shredders and collectors in both areas is one of the features of small size streams or headwaters of larger rivers (Vannote et al., 1980). The larger abundance of shredders could be taken as an evidence of relatively more coarse particles in the stream (Vannote et al., 1980). On the other hand, the sufficient coarse organic matter provided by the vegetation along the stream banks which can be taken as food source by the shredders could be an explanation of the relative high abundance. The difference on the ratios of grazer might have been due to the differences of the substrates in the two areas, since in the restored part the cobbles and rocks on the bottom are providing relatively more suitable condition for the growth of periphyton which are fed on by grazers like snails, while in unrestored part, scattered gravels in the mud provide less space for the attaching of periphyton (Allan, 1995). The low abundance of grazers in both areas could be an evidence of low ratio of gross primary production to respiration within the certain part of the stream (Vannote et al., 1980). The difference on the ratio of predators might also have been due to the differences of the types of substrate in unrestored and restored area. In the certain stream section, vertebrate and invertebrate predators are feeding on the same source of preys (Soluk & Collins, 1988). The muddy substrates could have affected negatively on vertebrate predators like fish in the interspecies competition on food with invertebrate predators since vertebrate predators depends relatively more on visual hunting, thus structuring the community with more abundant invertebrate predators (Allan, 1995). However, the abundances of functional groups are also determined by the seasonal changes of food (Allan, 1995), sampling work within a year other than late autumn should be done in order to get more comprehensive results.

The surroundings, bottom substrate and aquatic environment of the sampling points

Habitat-heterogeneity promotes biodiversity (Ricklef & Schulter, 1993) but streams and rivers present a multifactorial system and many other stressors, such as agriculture, urbanisation, invasive species etc. may have a strong impact on the assemblages of macroinvertebrates. The nearby land-use of the Sege å -River, farmland and road, could have a greater impact then heterogeneity of habitat within the stream. The planted trees, one measure of the restoration, for shading the river, are still too small to have a greater impact. Although we didn’t examine habitat-heterogeneity in our project we were clearly able to see that we have more diverse habitats through restoration measures in the restored part. We had different substrate types, like gravel, cobbles and small boulders and also faster flowing areas, which we couldn't find in the unrestored part. The unrestored part was more homogenous with more or less muddy banks and fine grains in the middle parts. This might also be a reason that we found mussels of the species *Anodonta sp.* only in the unrestored part. These mussels are clearly filter feeders and their preferred habitats are muddy grounds (Dillon, 2000).

Conclusions

Concluding it can be said that our results are not surprisingly and agree with many other studies who have reported no significant difference in biodiversity of macroinvertebrates after restoration (Palmer et al., 2010). Maybe more needs to be done to improve ecological conditions of streams and rivers than increasing habitat-heterogeneity. The focus of restoration should be expanded on a larger scale and therefore including as well the surroundings of rivers like making changes in forestry and agriculture practices and conservation of nearby land and riparian vegetation (Palmer et al., 2010). Though success of restoration can be defined by different parameters, objective and subjective ones, and is a question of view (Jaehnig et al., 2011).

One disadvantage of our project was that the sampling points were spatial close to each other and may have not been independent between the restored and the unrestored part. Also the unrestored part was located downstream and the samples could have been influenced by the restored part. It was hard to find comparable sample spots between the sites. In further studies, more samples at more sampling spots should be taken in order to gain more comprehensive results. Also, it's necessary to investigate and study if the restoration had created new microhabitats which could encourage the colonization of invertebrates (Lepori et al., 2005).

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Appendix A: Species list

Restored Part	**Unrestored Part**
Hydropsyche sp.	*Hydropsyche sp.*
Gammarus sp.	*Gammarus sp.*
Polycentropus sp.	*Erpobdella octoculata*
Planaria larva	*Baetis sp.*
Erpobdella octoculata	*Asellus aquaticus*
Baetis sp.	*Simuliidae*
Asellus aquaticus	*Tanypus sp.*
Ceratopogonidae	*Oligochaeta*
Simuliidae	*Erpobdella testacea*
Haliplus sp.	*Calopteryx virgo*
Tanypus sp.	*Chironomus sp.*
Oligochaeta	*Gyrinidae*
Elmidae	*Anodonta sp.*
Erpobdella testacea	*Psidium sp.*
Chironomidae	*Tabanidae*
Mesostoma tetragonum	*Lymnaea peregra*
Calopteryx virgo	
Sphaerium sp.	
Chironomus sp.	
Limnophilus bipunctatus	

Appendix B: Field Protocols

Survey protocol	Protocol **A** Water biotope	Watercourse

A1. Survey Organisation: [ ]

Surveyors: [ ] Date: [- -]

A2. Site information Main watercourse: [ ] Watercourse: [ ]

Stretch nr: [ ] Photo: [ ] Topo map: [ ] Eko map: [ ]

Length(m): [ ] Width(m): Max [ ] Min [ ] Mean [ ]

Area (m ^{2}): [ ] Water depth(m): Max [ ] Mean [ ]

A3. Substrate
0 or empty box= missing, 1=<5%, 2=5-50%, 3=>50%

- Coarse detritus: [ ]
- Fine detritus: [ ]
- Clay: [ ]
- Sand: [ ]
- Gravel: [ ]
- Cobbles: [ ]
- Boulders: [ ]
- Bed rock: [ ]

A4.Water vegetation
0 or empty box=missing, 1=<5%, 2=5-50%, 3=>50%

- Total coverage: [ ] (interval must be specified)
- Rooted emersed vegetation: [ ]
- Floating leafed and/or freely floating vegetation: [ ]
- Submersed vegetation (whole leafed): [ ]
- Submersed vegetation (finger leafed): [ ]
- Submersed non vasular plants: [ ]
- Filamentous algae: [ ]
- Other periphyton: [ ]
- Fontinalis or similar species (mosses): [ ]
- Other mosses: [ ]

Eg. species
underline dominant species

Freshwater fungi (interval as above) [ ]

A5. Current
0 or empty box=missing, 1=<5%, 2=5-50%, 3=>50%

- Slow flowing (<0,2m/s): [ ]
- Gently flowing: [ ]
- Flowing: [ ]
- Rapid flowing >0,7m/s): [ ]

A6. Shading 0=non-existent, 1= <5%, 2=5-50%, 3=>50% [ ]

A7. Dead wood 0=missing, 1=<6 logs/100m, 2=6-25 logs/100m, 3= >25 logs/100m [ ]

A8. Flow/course

- Estimated (m³/s): [ ]
- Interval(1=<0,05 m ^{3}, 2=0,05-0,5 m ^{3}, 3=0,5-1,0 m ^{3}, 4=1,0-3,0 m ^{3}, 5=>3,0 m ^{3}) [ ]
- Low/Medium/High (L/M/H): [ ]
- Straight(x): [ ]
- Turning(x): [ ]
- Meandering (x): [ ]

A9. Dredged/modified

- Dry river bed(x): [ ]
- (UF) Filling (x): [ ]
- Culvert (x): [ ]
- Dam (x): [ ]
- Embankment (x): [ ]
- Dredged(0-3): [ ]

0= not,1=carefully, 2=heavily, 3=constructed

A10. Trout habitat (0-3)

- Spawning area: [ ]
- Nursery habitat: [ ]
- Available resting spots: [ ]