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Report – review of existing information on key taxa and functional groups relevant to the eight study catchments

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Integrated Project to evaluate the Impacts of Global Change on European Freshwater Ecosystems

WP2: Climate-hydromorphology interactions

Task 2 Hydromorphological changes and aquatic and riparian biota

Subtask 2.1 Review and data collation

Deliverable No. 13

Report – review of existing information on key taxa and functional groups relevant to the eight study catchments

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Partners 26 (MasUniv, Czech Republic), 6 (ALTERRA, The Netherlands), 15 (BOKU, Austria), 3 (NERC, United Kingdom), 16 (CNR-IRSA, Italy), 11 (SLU, Sweden), 4 (UDE, Germany), 31 (UNIBUC-ECO, Romania) and 17 (CNRS-UPS, France)

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1. Subtask description and detailed workplan

The main aim of this subtask is to review existing information on key taxa or functional groups identified in the study catchments. Data relating to the distribution in space and time of characteristics taxa (mainly macroinvertebrates) were collated. This biological data will be use in subtasks 2.2, 2.3, 2.4 and 2.5.

Data sources as existing literature, other ecological studies, data collected by water authorities and other organization were evaluated. The analysis, which were jointly performed, aimed at clarification of main questions:

What are the relations between hydrology/hydromorphology and species composition?

Which species or biological parameters are good indicators for changes in hydrology/hydromorphology?

Detailed workplan – Activities (with participants listed)

Month(s)	Activity No.	Description of activity	Partners Involved
1	1	Review of existing literature and linkage to reviews of other projects (REBECCA)	MasUniv, Alterra, BOKU, NERC-CEH, CNR, SLU, UDE, UNIBUC-ECO
1	2	Collection of historical and present day biological data	Alterra, BOKU, MasUniv, NERC-CEH, CNR, SLU, UDE, UNIBUC-ECO
6	3	Data analysis	Alterra, BOKU, MasUniv, NERC-CEH, CNR, SLU, UDE, UNIBUC-ECO
12	4	Report	MasUniv, Alterra, BOKU, NERC-CEH, CNR, SLU, UDE, UNIBUC-ECO

Milestones (relate to activities)

Milestone	Activity No.	Month
review	1	18
data collation	2	9
data analysis	3	12
report	4	18

Deliverable (relate to activities)

Deliverable	Activity No.	Month
Report – review of existing information on key taxa and functional groups relevant to the eight study catchments	4	18

2. Relation to Subtask 1.1 – Climate-hydromorphology interactions through changes in land-use and discharge: review of information relating selected study catchment across Europe

Our subtask 2.1 supplements the subtask 1.1 which was finished at the end of first year of project duration. Regarding climatic/discharge scenarios and in view of the information from the report for subtask 1.1 it is expected an increase in temperature, a decrease in summer and an increase in autumn-winter precipitations and an increase of extreme daily precipitation. Consequently, discharge will show a more dynamic regime, due to increases in extreme daily precipitation and in severity of droughts.
The alternative key hypotheses are:

- **Global change may cause hydromorphological deterioration through intensification of land-use or through a more variable discharge regime that results in habitat modification and losses.**
- **Alternatively, global change may cause significant improvement if, for example, human disturbance are withdrawn from floodplains due to more frequent flood events or as a result of floods that generate a near-natural habitat structure.**

Regarding land-use scenarios there is the lack of information on the combined effects of climate-discharge-hydromorphology in the selected catchments, land-use scenarios are mainly based on the actual land-use and on historical reconstruction of its general trend.
To main conclusions of subtask 1.1 belong:

- Evidence a relationship between drainage measures and the mobility of sandy substrates (BOKU).
- A stream-size specific relationship between land-use and hydromorphology (UDE).
- The multivariate analysis evidenced that the land-use data often cannot be used to really predict/calculate the hydromorphological state.
- Catchment scale land-use may be related to depositional/erosional activity at site scale and may influence microscale characteristics of current velocities and substrates (CNR-IRSA).
- The importance of in-stream meso/microhabitat characteristics of substrate/channel vegetation and as the most important explanatory variables were shading along the banks of the river or stream, the mean depth and whether of not the stream were meandering (SLU).
- Confirmation the importance of in-stream vegetation, evidencing its association with land-use (NERC).

According to the preliminary results of subtask 1.1, several issues (released in conclusions of the subtask 1.1 report) could be of interest in Task 2, e.g.:

- The impact of hydromorphological stress on aquatic insects and test whether the effects of this stressor differed in different habitat types as riffles, pools and banks.
- The relationship between aquatic community structure, species richness, colonization strategies, *r* and *k* strategy and the hydromorphological state in terms of river stability/instability (macroscale-mesoscale).

- Aquatic community in more stable conditions with vegetated substrates, various habitat types and food resources should be compared with aquatic communities in unstable conditions.
- The study of riparian zones as terrestrial-wetland ecotones and how they can affect both the adjacent benthic and terrestrial communities in relation to land-use and river reach stability/instability.
- Considerations could be extended to a stream typology following a question if there are any differences between stream types.

3. Work progress

A report on subtask 2.1 is indicated for Delivery in Month 12 in the list of deliverables. However, this task was originally planned to be completed in month 18 and therefore this deliverable was re-scheduled for month 18.

What was done during first six months:

UNIBUC-ECO: A review of existing biological data from literature and other research projects had been performed. Field trips to collect additional samples to describe (assess) the present situation were organized. Data on water chemistry were collected from the regional water agency and previous UNIBUC-ECO research projects.

ALTERRA: A review of the existing historical and present data took place. A questionnaire was sent out to water managers with the aim of providing an overview of restoration and rehabilitation projects relating to lowland streams. A workshop was held to compile a metadatabase on the Vecht catchment. Historical, environmental and biological data were collected for larger streams and rivers in the study area.

SLU: Biological variables were collected, including fish and benthic macroinvertebrates and, for some sites, phytobenthos and macrophytes.

NERC: Existing biotic data for River Lambourn had been collating (macroinvertebrate and macrophyte data). Analyses were focussing on the relationship between macroinvertebrate communities, macrophyte assemblage structure and cover and substratum characteristics. Furthermore the influence of long-term climatic cycles such as the North Atlantic Oscillation on these relationships was being investigated.

UDE: The review of existing literature and links to other projects and the collection of historical and present via the Cause-Effect-Chains work in WP7 Task 1.

CNR: A bibliography search started and preliminary data collection had been undertaken.

First year:

Collection of historical and present day biological data was under way. A literature review on effects of hydromorphological pressures was acquired from the REBECCA project. A questionnaire was circulated to obtain information on the progress of data collation by individual partners.

During the Eurolimpacs WP2, 7 and 8 meeting hold in Wageningen, Netherlands was decided:

a. The data from the eight model catchments has been extended to cover the French Garonne catchment (CNRS-UPS).

b. A list of common hydromorphology variables will be provided by Andrea Buffagni (it is a part of the report on subtask 1. 1).
c. Analysis for each catchment will be done by the respective partners (a chapter for each partner).
d. As the data from the AQEM and STAR projects provide more information than those from the study catchments, these data can be included in the analysis.
e. Additional data from other catchments can be used.

<u>Months 12-18:</u>
An overview of our activities done and planned within subtask 2.1 (see Annex 1) was compiled and sent to the partners. The part of this overview was also a list of contributions that we need from the partners and a time schedule of works.
We compiled existing datasets relating to study catchments from the individual partners:

ALTERRA (Netherlands):

Metadata Vecht catchment (Dutch part)
Subcatchment Vecht

macroinvertebrates

macroinvertebrates	river Vecht
number of sites	8
number of samples	37

series (number of samples)	number	first year (min/max)	last year (min/max)
>=10	2	1984/1990	1999/2003
5-10	0	-	-
<5	6	1995	1995/2003

fish

fishes	river Vecht	years
number of sites	2	
number of samples	4	1999/2003

macrophytes

macrophytes	river Vecht	years
number of sites	9	
number of samples	25	1995/2003

series (number of samples)	number	first year (min/max)	last year (min/max)
5-10	1	1997	2003
<5	8	1995	1995/2003

diatoms

macrophytes	river Vecht	years
number of sites	5	
number of samples	9	1991/1995

discharge

	number	with macroinvertebrate samples	years
discharge stations	1	all	1950-now

Subcatchments Regge-West, Regge-East & Dinkel

macroinvertebrates

macroinvertebrates	subcatchments Regge & Dinkel
number of sites	627
number of samples	1410

series (number of samples)	number	first year (min/max)	last year (min/max)
>=20	4	1980/1982	2001/2003
>=10	9	1980/1987	1996/2003
5-10	41	1980/1995	1989/2003
<5	573	1979/2004	1979/2004

discharge

	number	with macroinvertebrate samples	number of years
discharge stations	37	19	up to 10

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macroinvertebrates

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discharge

	number	with macroinvertebrate samples	number of years
discharge stations	37	19	up to 10

BOKU (Austria):

Available Data on river Waldaist

Hydrological data

- 2 hydrological stations within the catchments
- 1st station (middle reach): discharge since 1984, 2nd (lower reach) discharge since 1976 (water level since 1937), 3rd 1976 (water level since 1956), we're trying to get handwritten data from earlier records
- temporal resolution is at least days
- study on bed load quantities in relation to land use

Morphological data

Morphological data is available for app. 80% of the river stretch (Austrian Method for ecomorphological evaluation according to Werth (1987) and Spiegler et. al (1989), including - degree of bank- and bed fixation, deviation of bed sediments, current and riparian vegetation from reference condition), detailed data on morphology from studies on Margaritifera – see below.

Biological data

Biological parameter	Catchment	No of streams/rivers sampled (no of sites in total)	No of years sampled (years)	Times per year (season)	Taxonomic resolution (main level)	Method no (describe below)
Benthic invertebrates	Waldaist	26 sites + 5	1994; 1996; 1998; 2000	irregularly	species	3
Fish	Waldaist	5 sites	1 (2000)	once	species	4
Algae	Waldaist	9 sites	1 (1996)	once	species	5
Ciliates	Waldaist	9 sites	1 (1996)	once	Mainly species	6

GIS data
Relevant GIS data are available from the catchment that can be used in the time-series analysis, such as land-use and geology. Datasource: **Upper Austrian GIS – System (DORIS: Digitales Oberösterreichisches Raum-Informations System)**

Chemistry data

Chemical parameter	Catchment	No of streams/rivers sampled (no of sites in total)	No of years sampled (years)	Times per year (season)
NO3-N,NO2-N, NH4-N, Total P,DOC, pH, O2	Waldaist	1 site additional sites	8 years (1997-2004) about 20	every 3. week every 3-4 year

Other information:

- Detailed study of Margaritifera margaritifera (distribution mapping, autecological studies) within the whole reach, including
- Detailed description of hydromorphology along the whole stretch
- investigations on macroinvertebrates on different sites along the stretch
- studies on the riparian vegetation along the river

NERC-CEH (UK):

Data type	Details	Source	Format
Daily rainfall	10 sites in the catchment with various temporal extents, the greatest being 1970-1999. Daily temperature record also for the Lambourn town site	Meteorological Office	.xls
Monthly catchment rainfall	Averaged monthly rainfall for catchment of 4 flow gauges from 1962/1966 to 2001	National Water Archive/Environment Agency	.xls
Abstraction	Annual volume abstracted from river at 2 sites from 1970-1982, monthly volumes abstracted from 1983-2002	Environment Agency	.xls
Hydrochemistry	Patchy coverage of P, ChlA, Ca, Bo, pH, Sus Sol, TON from 1972 to 2002 for 9 sites	Environment Agency	.mdb
Hydrochemistry	3 sites on Lambourn, weekly/fortnightly sampling from May 2002-Jan 2004, Temp, pH, EC, Alk, Sus Sol, SRP, TDP, TP, NH4, ChlA, F, Cl, NO2, NO3, SO4, TN, DOC, Si, Na, K, Ca, Mg, B, Mn, Co, Fe, Zn, Cr, Ni, Al.	LOCAR	.xls
Daily Discharge	Gauged discharge from 4 sites covering period 1962-1983 (2 sites) or 2004 (2 sites)	National Water Archive/Environment Agency	.xls
Daily Run-off	calculated from daily discharge data for the 4 sites, same temporal extent	National Water Archive/Environment Agency	.xls
River Habitat Survey	6 sites on Lambourn and 2 on Winterbourne, each surveyed once in mid 1990's	Environment Agency/CEH RHS database	.xls
River Habitat Survey	500m of every 1 km of river surveyed during 2002-2003	LOCAR/Environment Agency	.xls
1990 Land Cover map	The 1990 Land Cover Map of Great Britain is a digital dataset, providing classification of land cover types into 25 classes, at a 25m resolution. The data was derived from satellite data collected by Landsat 5's Thematic Mapper during 1988/89. Catchment land cover was determined for 14 sites along the Lambourn and Winterbourne watercourses.	NERC-CEH	.apr / .xls
2000 Land cover map	Land Cover Map 2000 (LCM2000) is a vector database of polygons or land parcels, with each parcel having a list of attributes attached to it. Catchment land cover was determined for the same 14 sites along the Lambourn and Winterbourne watercourses as for the 1990 map.	NERC-CEH	.apr / .xls
Macroinvertebrate	3 min kick sample, family level, 15 sites irregularly sampled between 1980 and 2004. Only 4 sites with substantial time series.	Environment Agency	.xls
Macroinvertebrate	3 min kick sample, species level, 4 sites irregularly sampled between 1998 and 2003. Only 1 site with reasonable time series.	Environment Agency	.xls
Macroinvertebrate	Lambourn sampler, family level, 2 sites (Lambourn @ Bagnor shaded & unshaded), macrophyte mesohabitats sampled separately, 1971-79 (2 sites) & 1997-2001 (1 site)	CEH	.mdb / .xls
Macroinvertebrate	3 min kick sample, species level, 8 sites sampled in summer 2003	LOCAR/CEH	.mdb / .xls
Macrophyte	Mean Trophic Rank survey, 8 sites surveyed in summer 2003	LOCAR/CEH	.mdb / .xls
Macrophyte	% cover data for macrophyte mesohabitats at 2 sites on Lambourn sampled between 1971-79 (2 sites) & 1997-2001 (1 site)	CEH	.mdb / .xls
Fish	EA electric fishing data over 15+ years, difficult to retrieve or modify to a useful form	Environment Agency	.xls

CNR-IRSA (Italy):

Data Category	Data type	Details	Source	Format
Climate				
	Daily rainfall and temperature	9 sites in the catchment with various temporal extents, the greatest being 1990-2004: 2 sites in Chiusella and 7 sites in Orco catchment. For the same sites also daily mean, maximum and minimum temperature are available.	Piedmont region, Meteorological Office	.xls
Hydrology				
	Daily Discharge	Gauged discharge from 3 sites: 2 in orco and 1 in Chiusella catchment, covering period 2000-2004. Data furnished by Piedmont Region.	Piedmont Region	.xls
	Daily Discharge	Discharge measures from sites where macroinvertebrates were sampled: available only for the macroinvertebrates sampling data (monthly from March/April 2005).	CNR-IRSA	.xls
	Hydrochemistry	Parameters included in National Method used for rivers quality class assessment, furnished by Piedmont region from 2000 to 2004. Data available for Orco river.	Piedmont Region	.xls
	Hydrochemistry	Parameters included in National Method used for rivers quality class assessment, measured by CNR-IRSA from March/April 2005. Data available for 4 monthly sampled sites in Orco and chiusella river.	CNR-IRSA	
Hydromorphology				
	River Habitat Survey South Europe	18 sites on Orco and 4 on Chiusella, each surveyed in Summer 2004 (July/August/September 2004)	CNR IRSA	.mdb
	River Habitat Survey South Europe	4 sites on Orco catchment and 6 in Chiusella catchmenmt, each surveyed in March/April 2005.	CNR IRSA	.xls
Catchment Land Cover				
	2000 Corine Land Cover	The 2000 Corine Land Cover Map of Italy is available as digital format, in Arcview 3.1. Spatial arrangement of catchment land cover was determined for 22 sites along the Orco and Chiusella watercourses, with Arcview 3.1.	CNR-IRSA	.apr / .xls
	300 m land cover	Land cover data referred to 300 m wide area along each river bank for Orco river reach comprised between Pont Canavese (around 500 m asl) and Chivasso (at Po confluence) are available. These data have been extracted from a GIS project furnished by Piedmon	Piedmont Region	.apr / .xls
Biota				
	Macroinvertebrate - literature data	National Method (IBE) samples from 6 sites in Orco catchment, collected by ARPA Piemonte since 2000	Piedmont Region	.xls
	Fish - literature data (to be checked)	Fish data referred to 2000, provided by Piedmont Region	Piedmont Region	.xls

Topics suitable for studying in Orco/Chiusella catchments

In North Western Italian Alps climatic/hydrologic scenarios indicate a tendency towards a temperature increase, change in timing of flows, an increase in hydrological instability due to more intense Summer droughts and more intense and frequent Summer-Autumn floods. In particular, a peculiar characteristics of river Orco and Chiusella is linked to the intensity of floods and the recent increase in their frequency (1993, 2000).

SLU (Sweden):

SLU	30 sites in River Eman catchment	macroinvertebrates, fish

UDE (Germany):

UDE	20 sites in Eder and 16 sites in Vechte catchment	macroinvertebrates, fish, macrophytes, AQEM/STAR variables
UDE	information from research reports are available	

UNIBUC-ECO (Romania):

Data Category	Data Type	Nr. of sites	Time span	Frequency	Resolution
Climatic	Precipitation	1	1994-2001	daily	
	Air temperature	1	1994-2001	daily	Tmed, Tmax, Tmin
	Relative humidity	1	1994-2001	daily	
	Wind velocity	1	1994-2001	daily	
	Hours of sunshine	1	1994-2001	daily	
	Soil temperature	1	1998-2001	daily	Tmed
Hydrology	Discharge	3	1996-2000	daily	
		5	1994-2003	monthly	
		1	1994-2003	seasonaly	
	Runoff	3	1996-2000		calculated
Water chemistry	pH, O2, SS, Cl^-, SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, CCO-Mn, N-NH_4^+,N-NO_2^-, N-NO_3^-, P-PO_4^{3-}, phenols, Fe, Mn	3	1994-2003	monthly	
	pH, O2, SS, N-NH_4^+,N-NO_2^-, N-NO_3^-, P-PO_4^{3-}, TN, TP	9	2001-2003	fortnightly	
Hydromorphology	River lengh, river slope, sinuosity	3			calculated based on maps from 1970/1990
Land cover	The land cover is in a digital dataset (based on maps with resolution 1/5000), and it provides many classess, which were grouped in 5 classes (agricultural, pastures and meadows, wetlands, rural/urban areas, forest). Catchment land cover was determined for 3 sites along the Neajlov watercourses. For the whole catchment the land cover was obtained from Corinne land cover.	3	1970/1990		
Biological data	Terrestrial arthropoda(riparian zones)	4	2001-2002	monthly	species (semiquantitative)
	Aquatic invertebrates	5 (complex sites, containing many sampling points along the course of several springs)	1960	~monthly	species(qualitative data)
	Aquatic invertebrates	1(complex site, containing many sampling points along the course of a spring, tributary of Neajlov - found in literature, 1962)	starting from 2004	monthly	species, quantitative

CNRS-UPS (France):

TIME SERIES	Number of sites	Years	Source	Details
Macroinvertebrates	*On request*	*Not yet available*	Regional Environment Agency (DIREN)	*Not yet available*
Fish	105	7 - 10 (1995 - 2004)	Conseil Supérieur de la Pêche	Taxonomic richness, Abundance, Density
Diatoms	*On request*	*Not yet available*	Adour-Garonne Water Agency	Taxonomic richness, Abundance
Hydrology	50	series > 10 yrs	Regional Environment Agency (DIREN)	Daily flow
Physico-chemistry	30	series > 10 yrs	Adour-Garonne Water Agency	T°, pH, Cond, O2 (mg/l & %), MES, BOD, COD, NH3, NH4, NO2, NO3, Ptot, PO4, HCO3, Cl, K, Na, SO4

SPATIAL SERIES	Number of sites	Years	Source	Details
Macroinvertebrates	*On request*	2005	Regional Environment Agency (DIREN)	*Not yet available*
Fish	105	2005	Conseil Supérieur de la Pêche	Taxonomic richness, Abundance, Density
Diatoms	105	2005	CNRS / UPS	Taxonomic richness, Abundance
Hydrology	50	2005	Regional Environment Agency (DIREN)	Daily flow
Physico-chemistry	35	2005	Adour-Garonne Water Agency	T°, pH, Cond, O2 (mg/l & %), MES, BOD, COD, NH3, NH4, NO2, NO3, Ptot, PO4, HCO3, Cl, K, Na, SO4
Morphology	105	2005	CNRS / UPS	width, depth, velocity, flow, bed sinuosity, valley form, Land-use surrounding, bank stability, profile and vegetation, shade of the bed, substrate composition, channel vegetation types, pollution
Land Use	105	2000	CNRS / UPS	Corine Land Cover

MasUniv (Czech Republic):

Data Category	Data Type	Nr. of sites	Years	Frequency	Resol.
Climatic	Precipitation	4	1978/79 - 2004	monthly sum	
		4	Jan 2005 - March 2005	daily sum	
	Air temperature	4	1978/79 - 2004, (one site 1987 - 2004)	monthly average	
		4	Jan 2005 - March 2005	daily average	
Hydrology	Discharge	4	Nov 1977 - Oct 2003	daily	
	Water level	4	Nov 1994 - Oct 2004	hourly	
Water physico-chemical parameters	BSK_5,$CHSK_{Cr}$, N-NH_4, N-NO_2, N-NO_3, NH_4, NO_2, NO_3, P_{TOTAL}	2	Feb 2001 or Jan 2002 - Feb 2005	monthly	
	Water temperature	4	Nov 1977 - Oct 2003	daily average	
		1	June 1999 - Dec 2004	hourly	
	pH, conductivity, water temperature, O_2 dissolved, O_2 saturation	Cernotin	Oct 2004 - July 2005	monthly	
		Osek	July 2004 - Oct 2004	three times	
Hydromorphology	For the comparison of sinuosity and channel character with the state of nature before the stream regulation, maps of the 2nd military mapping were used		1819-1858		1:28 800
Land cover	For the whole catchment of all the sampling sites Corine land cover was used		1990		1:100 000
	For riverine vegetation analysis of all the sampling sites orthofotomaps of 10m/pixel was used		2000-2002		10m/pixel
Biological data	Aquatic invertebrates	Osek	Oct 2004	once	
		Cernotin	Oct 2004, May 2005	twice	

4. Literature review – relationship between hydrology/hydromorphology and benthic macroinvertebrates

Introduction

We have prepared a literature overview presenting a compact text about main hydrological and hydromorphological factors influencing benthic macroinvertebrates with links to main literature source. From the project Rebecca we have also acquired an Endnote file with titles, abstracts and journal details of 11.705 papers relating to hydromorphology and biotic communities.

Spatial scale and habitat

An extensive literature explores the hierarchical nature of river systems, from the largest spatial scale of landscape or basin to successively smaller scales of the valley segment, channel reach, individual channel units (such as riffles and pools) and microhabitats (Allan, 2004).
To unify conclusions of stream community studies using different spatial scales Pardo and Armitage (1997) defined mesohabitats subjectively as visually distinct units of habitat within the stream, recognizable from the bank and with apparent physical uniformity. Results from the analysis of the mesohabitat data set show that spatial changes between mesohabitats, which are due to differences in faunal composition (in this study as reaction on stream regulation), are of greater importance than seasonal trends (Armitage and Pardo, 1995). Mesohabitats are supposed to detect the subtle effects of stream regulation in contrary to other methods and using biotic scores and indices.

Functional habitat

The functional habitat concept as a method which assess a habitat structure in a biologically meaningful way offers one of the approaches to integrating measures of the effects of physical and chemical processes upon river environment (Harper et al., 2000, Kemp et. al., 2000). The main goal in measuring ‘ecological integrity’ is integrating the scales so that recording at one scale provides valuable information about another.
In the study (Harper et al., 2000) was shown that an easily-measured physical variable – surface flow type – can be related to an easily-measured channel structural variable – functional habitat type/frequency – which is related to biodiversity. Kemp et al. established the link between ‘functional habitats’ (biologically defined habitat units) and flow ‘biotopes’ (hydraulically defined habitat units) using Froude number. Fifteen of the 16 functional habitats were found to be distributed with Froude number in a non-random fashion. This information can be applied to river rehabilitation projects. Hydraulic variables, such as Froude number, can be manipulated through changes to channel morphology, to maximize habitat heterogeneity and therefore biodiversity.

Current velocity and other hydraulic conditions

Many studies have examined the relative importance of different physical factors in structuring the benthic community (Statzner and Higler, 1986, Poff and Ward, 1990, Ward, 1992, Palmer and Poff, 1997, Rempel et al., 2000, Merigoux and Doledec, 2004). Hydraulic properties of streams can influence the quantity and quality of available habitats at all spatial scales, and many insects have anatomical and behavioral adaptations for living in slow or fast water habitats (Vinson and Hawkins, 1998, Statzner, 1988, Poff et al., 1991, Feld, 2002). Symposia and sections of textbooks have been devoted to organisms-substratum or organisms-velocity relationships of invertebrates in running waters (Statzner et al, 1988). Therefore we focused in this review to approaches that combine simple hydraulic characteristics.

Regarding water velocity a maximum in a straight section of stream channel is normally greatest at or near the surface of the water in the center of the stream with greatly diminished values along the edges and near the bottom. Ideally, velocity declines exponentially with depth, with the mean column velocity 0,6 of the distance from the surface to the bed (Ward, 1992). Flow in a natural channel is three-dimensional, i.e., each fluid particle may travel in upstream-downstream direction (longitudinally), from bank to bank (laterally), and from bottom to surface (vertically). The three-dimensional flow pattern commonly shifts with discharge changes (Statzner et al., 1988).

Some of recent studies have divided stream reaches into mesohabitats, such as areas with macrophytes, fine sediments, and gravels, each with similar substrates and water velocities (Armitage and Pardo, 1995, Beisel et. al., 1998). Faunal communities were found to be distinct and to vary significantly between mesohabitats, where average velocities can vary from 0 to 0,9 $m.s^{-1}$. Jowett (2003) found out that hydraulic conditions near or at the surface of the streambed may have a more direct influence on benthic invertebrates than either water depth or mean velocity in the water column above them (see also Statzner et al, 1988). Merigoux and Doledec (2004) related invertebrate assemblages to direct measurements of near-bed hydraulic conditions and recognized that nearly 70% of the taxa collected was significantly related to the hydraulic parameters assessed (see also Brooks et al., 2005). Shear stress (stress state where the shape of a material tends to change without particular volume change) and Froude number (indicate the influence of gravity on fluid motion) were the most important hydraulic parameters whereas substratum particle size and bed roughness (the standard deviation of the heights of graduated rods placed according to the roughness of the bottom) had less influence. In this study was also found out that the proportion of filter feeders and collector-gatherers was inversely related to shear stress.

We can say that most studies recognized that the primary components of the physical habitat in a stream are water depth, velocity and substrate size, and these appear to be the best predictors of benthic invertebrate distribution within a stream (Jowett, 2003, Ilmonen and Paasivirta, 2005, Doisy and Rabeni, 2001). Armitage (1997) also confirmed that water velocity and flow dynamics together with nature of the substratum influence the distribution of the benthic communities. Beisel et al. (1998) indicated substrate as a primary determinant of community structure and current velocity and water depth emerged as secondary factors. Rempel et al. (2000) observed that the density of collector-gatherers sharply declined with increasing water depth and also is positively correlated with CPOM and positively associated with mean grain size. It is obvious that mesohabitats differed in their physical structure and

hydraulic nature and that these functional habitats are partly inhabited by distinct invertebrate assemblages (Brunke et al., 2001).
There also exist some studies relating to flow regime in microhabitats. For example Bouckaert and Davis (1998) studied microflow regimes and the distribution of macroinvertebrates around stream boulders. They collected velocity data in three dimensions in front of and in the wakes of selected boulder in a riffle, where macroinvertebrates were also sampled. Despite the complex flow patterns inherent in natural streamflow, a large roughness element (boulder) appears to predominate in determining microflows within its immediate surroundings. The benthic macroinvertebrate fauna was significantly richer and more abundant in the wakes than at the front of boulders.

IFIM and PHABSIM

PHABSIM and IFIM are widely accepted as a basis for establishing acceptable flows to maintain the integrity of stream and river ecosystems (Bovee, 1988). The PHABSIM model [the evaluation tool within the Instream Flow Incremental Methodology (IFIM) (Bovee, 1988)] combines hydrological records (from gauging stations along the river), direct measurements of conditions at the site, and biological information on the flow-related habitat requirements of various aquatic species. The output of the model is a prediction of the gains and/or losses of habitat with changes in discharge or with a proposed regulated flow regime. The PHABSIM protocol ties hydrologic information (stage/discharge relationships and measured information on velocity, depth, and substrate) at typical stream reaches with biological information (habitat suitability) to predict changes in amounts and locations of available habitat over a range of discharges (Gore, 2002). This technique can be an aid in demonstrating the value of certain restoration structures during the rehabilitation planning proces (Gore, 1998).

Changes in stream flow regime relating to climate change

Anthropogenic climate change that alters dominant pattern of precipitation and run-off presents a real threat to the structure and function of aquatic ecosystems, including river, lakes, wetlands and coastal system (Meyer et al., 1999, Wright, 2004). Many examples in the literature show how individual species populations, whole communities and ecosystem processes are directly influenced by streamflow regime, a dominant environmental driver (Death et al, 1995, Bond et al., 2003, Fritz et al., 2004, Gasith et al., 1999, Poff, 2002). An important aspect of the streamflow regime is flooding. Floods belong to most evident consequences of the climate change.
Effects of floods on stream ecosystem depend on their frequency, intensity, timing and duration (Gasith et al., 1999).

The main hydromorphological affects of intensive floods are:

- Scouring of accumulated sediment and debris.
- Redistribution of streambed substrate and organic matter in the channel.
- Changing channel morphology and forming new erosional (riffle) and depositional (point and mid-channel bars, pools) zones.
- Washing away in-channel and encroaching riparian vegetation.
- Restoring channel connectivity.

- Homogenizing water quality conditions along the stream channel.

The response of benthic macroinvertebrates may be different: 1) some invertebrates may actively or passively move to habitats with low hydraulic stress (e.g. stream margins, hyporheic zone, other patches protected from high flow); 2) some invertebrates may remain on relatively stable habitats where their drift-thresholds velocities are not reached under flooding conditions; 3) other invertebrates may be washed downstream from reach (Imbert et al., 2005).

For minimization of negative effects of floods are important substrate stability and presence of refuges. Hyporheic zone provides important refuge for surface invertebrates from floods and also from droughts, predation and deterioration in surface water (Boulton et al., 1998). This stable environment also generates relatively protected conditions for eggs, pupae, and diapausing stages of invertebrates and can therefore play an important role in a phase of recovery after floods. Fritz (2004) recognized that the time required for recovery to pre-flood conditions (richness and density) was about 27 days for perennial site and 76 days for intermittent sites (see also Fisher et al., 1982). Colonization of intermittent sites was a function of distance from upstream refuge. Contrary to this observation Ward (1992) speaks about 2 or 3 months for recovery of spring brook populations and Collier and Quinn (2003) about 5-7 months for recovering taxa numbers and densities to preflood levels (28-year flood). It is also obvious that severe floods greatly reduce population size of organisms that are entirely aquatic (e.g. snails, ostracods, some hemipterans, Oligochaeta), while those with terrestrial aerial stages (e.g. most aquatic insects) rapidly recolonize these streams (Gasith et. al., 1999).

Imbert et al. (2005) studied influence of inorganic substrata size, leaf litter and woody debris removal on benthic invertebrates resistance to floods. They determined *Baetis* spp., Simuliidae, *Protonemura* spp. and *Echinogammarus* as the most resistant taxa to floods. Oligochaeta was always the least resistant. Lack of statistically significant effect of woody debris removal may imply that the composition and stability of inorganic substrata have more influence on invertebrate resistance to floods than woody debris at the reach scale in these headwater streams dominated by relatively stable substrata.

Bond and Downes (2003) tested in eight artificial streams whether high suspended-sediment concentrations influenced the short-term response of benthic invertebrate fauna to increases in flow. Flow increases caused large increases in the number and diversity of drifting animal, the addition of sediments alone had little effect on the fauna. The results suggest that flow increases alone can disturb benthic fauna, and that neither substrate movement nor suspended sediment increases are necessary for floods and spates to disturb benthic assemblage. However the effects of flow increases are likely to be contingent upon the presence or absence of local flow refugia.

Habitat types – riffle and pool

The most common habitat delineations in stream studies were pools (depositional habitats) and riffles (erosional habitats) (Vinson and Hawkins, 1998). In many rivers, the riffle-pool sequence structures the mesoscale physical habitat environment and is recognized as a primary determinant of in-channel flow patterns (Emery et al., 2003). Studies on differencies between macroinvertebrates communities of riffle and pool were also a first step to

development of sampling techniques focused not only on sampling in relatively shallow riffle areas which are easily accessible by wading but also in the deeper, slower flowing reaches of rivers.
Differences in the fauna between these habitats have been attributed to a number of abiotic factors such as: (1) differences in substratum size and substratum heterogeneity (Percival and Whitehead, 1929); (2) the presence of organic matter; (3) disturbance intensity and disturbance frequency (Brown and Brussock, 1991); and (4) human impact. Carter (2001) pointed out that the community structure of riffles and pools was a function of habitat, reach gradient, and discharge and was taxon specific. In years below average peak diacharge, riffles had higher taxon richness than pools but richness was similar between habitats during a year of average discharge. Collector-gatherers were only one functional feeding group whose density was significantly higher in pools than in riffles.
Also Logan and Brooker (1983) who examined 17 studies from North America and United Kingdom reported that significantly higher mean total densities were detected in riffles compared to pools. Overall the composition of the fauna, by major taxonomic group, from all studies was generally similar, probably reflecting the upland location of the study sites. However, ephemeropteran densities were significantly higher in riffles than in pools, although density differences were not detected in other groups. Additionally, *Ephemeroptera* appeared proportionally more abundant in riffles whilst Diptera formed a higher proportion of the fauna in pools than riffles.

Role of the substrate

Stream ecologists have spent considerable effort studying the effect that substrate has on benthic macroinvertebrates. Many stream ecologists generally assume biological richness will be correlated with environmental heterogeneity (Vinson and Hawkins, 1998); however, the empirical evidence supporting this generality for stream substrates is not clear.
The substrate of running water is largely structured by physical processes related to the unidirectional flow of water interacting with basin geology and allochthonous organic debris. It is convenient to consider the mineral and organic substrates separately, although most sediments are mixtures of both components (Ward, 1992). The close association of a particular species with a given substrate may reflect current preferenda, requirements for shelter, respiratory needs, or food habits, rather than directly indicating an affinity for a specific bottom type (Ward, 1992). According to Ward (1992) we can distinguish following insect associations on the general substrate categories with examples of species occuring at these habitats:

Lithophilous fauna – rocky streams, large size classes of mineral particles, ample water movement, high levels of dissolved oxygen, relatively silt-free interstices, absence or paucity of higher aquatic plants, mosses and algae may be well developed on rock surfaces.
Ephemeroptera – *Ecdyonurus lateralis*, *Baetis tenax*, *Baetis vernus*, *Rhithrogena* sp.
Plecoptera – *Isogenus* sp., *Nephelopteryx* sp., *Leuctra inermis*, *Dictyopterys mortoni*, *Isopteryx torrentium.*
Trichoptera – *Rhyacophila obliterata*, *Agapetus fuscipes*, *Silo nigricornis*, *Apatania fimbriata*, *Hydropsyche angustipennis*, *Mesophylax impunctatus*, *Hydroptila* sp., *Brachycentrus* sp.
Diptera – *Simulium latipes*, *Dixa maculata*, *Clinocera* sp., *Deuterophlebia* sp., *Simulium* sp.

Psephophilous fauna – gravel substrate. In these substrates are the best developed hyporheic habitats colonized by many lotic insects at least during their early instars, and provide a refuge from droughts, floods, and other adverse surface conditions.
Ephemeroptera – *Ephemera danica* (larger nymphs prefer gravel to sand) , *Serratella deficiens*.

Psammophilous fauna - sand, instable habitats, low organic content.
Ephemeroptera – *Siplonurus* sp., *Behningia* sp.
Odonata – *Gomphus plagiatus.*
Coleoptera – *Haliplus* sp., *Laccobius* sp.
Megaloptera – *Sialis* sp.
Chironomidae – *Stenochironomus macateei*, *Polypedilum* sp., C*ryptochironomus* sp., *Paracladopelma* sp., *Rheosmittia* sp.
Other Diptera – *Stratiomyia* sp., *Tabanus* sp., *Chrysops* sp.

Pelophilous fauna – mud-dwellers, herpobenthic forms associated with sediments in which silt- and clay-sized particles predominate
Ephemeroptera – *Caenis* spp. (dorsally positioned gills, a pair of sclerotized opercular gills covers the remaining gills and protect them from silt deposition)
Megaloptera – *Sialis* sp.
Plecoptera – *Leuctra nigra.*

Xylophilous fauna – on or within submerged wood that provides food, living space, oviposition and attachment substrate, refuge from predators, protection from adverse abiotic conditions, and emergence sites for aquatic insects.
Trichoptera – *Lepidostoma* sp. (some species pupate in wood crevices).
Diptera – *Brillia* sp. (one of the first insects to bore into new wood when it first enters stream), *Lipsothrix* sp. (Tipulidae), *Stenochironomus* sp.

Phytophilous fauna - associated with living aquatic macrophytes.
Representatives of the moss fauna:
Ephemeroptera - *Baetis rhodani*, *Ephemerella ignita*.
Plecoptera - *Amphinemura sulcicollis*, *Nemurella picteti*, *Protonemura hrabei*.
Trichoptera – *Ithytrichia lamellaris*, *Crunoecia irrorata*, *Hydroptila* sp.
Coleoptera – *Limnius tuberculatus.*
Diptera – *Orthocladius* sp., *Pericoma* sp., *Limonia* sp.

Pardo and Armitage (1997) characterized in their study mesohabitat groups by abundance and frequency indicator species as follows:

Group I Ranunculus ‚fast' and ‚slow'- *Baetis buceratus, Baetis muticus* (mobile species, able to occupy high current areas temporarily), *Simulium gr.equinum, Simulium posticatum, Simulium gr.ornatum* (sessile species attached Ranunculus leaves, trapping food particles under high velocities).

Groups IIa and IIb Sandy mesohabitats – *Limnodrilus hoffmeisteri, Limnodrilus claparedeanus*, *Chironomus* sp., *Cryptochironomus* sp., *Prodiamesa olivacea* (all of them burrow in sandy habitats feeding on deposited detritus or small prey).
Groups IIIa and IIIb Silted mesohabitats – characterised by a high number of frequency indicators (23 species)

Species feed mainly on plant detritus – *Crangonyx pseudogracilis*, *Halesus radiatus*, *Limnephilus lunatus*.

Species feeding on algae, detritus and bacteria deposited on macrophyte stems – *Oulimnius major*.

Burrower which collects fine organic particles from the surface of the sediment – *Aulodrilus pluriseta*

Organic particle filterers – Ostracoda, *Pisidium* spp., *Sphaerium corneum*.

Group IV Gravel mesohabitats – *Ephemera danica*, *Hydropsyche contubernalis*, *Ancylus fluviatilis*, *Leuctra fusca*, *Orthocladius* (E.) *rivulorum*, *Stylodrilus heringianus*, *Cladotanytarsus* sp., *Cheumatopsyche lepida*.
Group V Macrophyte – *Physa fontinalis*, *Anisus vortex*, *Metriocnemus* sp., *Gyraulus albus*, *Baetis* gr.*scambus*, *Ephemerella ignita*, *Rheotanytarsus* sp., *C*. (*Isocladius*) spp., *Simulium* gr.*angustitarse*, *Ithytrichia* sp.

Beisel et al. (2000) established a relationships between community structure and substrate heterogeneity. The faunal richness was higher in a heterogeneous environment composed of numerous substrates, an elevated patchiness and with high perimeters. Such a mosaic potentially offers a great number of niches for invertebrates. A reduced distance between two types of substrate favours exchange of species. At the opposite, a very homogeneous mosaic offers a low variety of niches and shelters fewer taxa and in these habitats one or two particular taxa dominated the community, probably because competition with taxa coming from neighbouring patches was reduced. He also determined invertebrates having an inherent need for current or well adapted to shear stress (*Hydropsyche*, Simuliidae or Heptageniidae), taxa requiring sheltered microhabitats in a fast-flowing environment (*Eriocera* or *Atherix*) and taxa adapted to low current velocity and uncohesive substrates (Tabanidae or *Ephemera danica*).
Buffagni et al. (2000) distinguished in his study on Italian river five functional habitats characterised by high abundances of these species: I) margin with macrophytes – *Centroptilum luteolum* ; II) margin without macrophytes – *Sphaerium* sp. ; III) backwater – *Leuctra* sp.; IV) run-riffle – *Ephemerella ignita*, Hydropsychidae, *Leuctra* sp.; V) macrophytes in the flow – *Ephemerella ignita*, *Baetis liebenauae,* Simuliidae.
Huryn and Wallace (1987) studied an annual production of functional feeding groups in relation to three principal habitats: bedrock-outcrop, riffle and pool. Annual production of collector-filterers was highest in the bedrock-outcrop (ash-free dry mass 1920 mg/m²), shredders in pools (2616 mg/m²), scrapers in the riffle habitat (905 mg/m²) and engulfing predators in the pool habitat (2313 mg/m²).
Ilmonen and Paasivirta (2005) defined five habitat types in the studied springs according to water flow and benthic substrate characteristics. Using Indicator Species Analysis identified following indicator species:

Minerogenic brooks (a substrate dominated by sand and gravel) – *Baetis rhodani*, *Potamophylax nigricornis*, *Brillia bifida*, *Simulium* indet., *Agabus guttatus*.
Organogenic brooks (deeper with stronger flow, course detritus substrate and some large bitter-cress and bryophytes) – *Nemoura cinerea*, *Trissopelopia longimana*, *Orthocladius rubicundus*, *Micropsectra bidentata*.
Helocrene habitats (very little open water area, the water seeping through the substrate, covered by mud and mosses) – no significant indicator species.
Floating moss carpets (the edges of brooks, in pools were usually dominated either Fontinalis antipyretica or Calliergon giganteum) – *Asellus aquaticus*, *Limnephilus ignavus*, *Metriocnemus fuscipes*, *Anopheles claviger*.
Limnocrene pools (no or few mosses, a bottom dominated by fine and course detritus) – *Procladius* (*Holotanypus*) indet., *Prodiamesa olivacea*, *Micropsectra fusca.*

Some studies were also performed on artificial substrates to recognize a relationship between substrate composition, current velocity and benthic macroinvertebrates. Cummins and Lauff (1969) tested eight particle size categories of both silted and non-silted subtrates to find substrate microhabitat preferences of ten species of benthic macroinvertebrates and compared it with preliminary field data. Minshall (1977) used trays filled with stones or pebbles placed to pool or riffle. Reice (1980) placed replicate baskets of three different substrata in a single riffle. Half the baskets had leaf packs attached to their upper surfaces. He recognized that animals showed substratum preferences even when velocity differences were eliminated. Hawkins et al. (1982) also placed trays of rubble embedded 0, 25, 75 and 100% with sand in areas of three different current velocity (0, 15, 30 cm/s). Comparison of differences of specific taxa showed that embedding the trays with sand generally caused a decline in density of the dominant taxa. Downes et al. (1998) used clay bricks and manipulated three sources of habitat structure: large surface pits and craks (low density/high density); small pits caused by variation in surface texture (rough/smooth); and the abundance of macroalgae (begun with algae, begun without algae). The bricks were sampled for both fauna and epilithon on days 14 and 28 of colonization.

The role of riparian vegetation

The presence or absence of trees on land adjacent to stream channels is shown to significantly affect the structure and function of macroinvertebrate communities (Sweeney, 1993). Streamside forests affect food quality and quantity for macroinvertebrates directly through inputs of particulate food (leaf litter, soils, wood, etc.) and indirectly by affecting the structure and productivity of the microbial (algae, bacteria) food web through shading and modifying the levels of dissolved organic carbon and nutrients (Reed and Carpenter, 2002). Deforestation eliminates shading and can result in a 2-5°C warming of small streams which is shown to greatly affect important life history characteristics of macroinvertebrates (e.g. growth rate, suvivorship, adult size and fecundity, timing of reproduction). Also many land-use practises increase a input of sediments and inorganic nutrients from terrestrial sources.
It is quite clear that macroinvertebrates communities in streams respond to changes in land-use which can modify streamside vegetation and also the character of surficial sediments. However, because populations are concominantly influenced by both factors it is often difficult to specify the causal mechanisms underlying observed patterns of community

structure (Hawkins et al., 1982). In view of results of his detailed study Hawkins supposed that canopy type was more important than substrate character in influencing total abundance and guild structure. Open streams had higher abundances in the collector-gatherer, filter feeder, herbivore shredder and piercer, and predator guilds. Contrary to expectations, shredders were no more abundant in shaded streams than in streams lacking a riparian canopy. On the other hand, Bis et al. (2000) found out that an increase of incident radiation enhanced algal productivity and significantly affected the occurrence of scrapers (Gastropoda, Elmidae) in the studied river sections with list of invertebrate taxa and groups of taxa significantly responsing to clear-cutting (see also Gurtz and Wallace, 1984 and Sabater et al., 1998).

Not only width and structure of riparian vegetation but also bank profile are important factor in influencing benthic communities and in planning of restoration projects. Armitage et al. (2001) examined changes in macroinvertebrate communitites in four different bank types and discussed the implications of these funding to management activities and restoration procedures. He recognized that total abundances were five to six times greater in the shallow vegetated sites compared with the steeply sloped and artificial banks (see also Clarke and Wharton, 2000).

Regarding land-use Sponseller et al. (2001) suggested that differences in macroinvertebrate assemblage structure can be explained by land-cover pattern when appropriate spatial scales are employed. In his study the 200 m sub-corridor scale was most closely related to macroinvertebrate indices. Land-use studies are not so easy because of the difficulty of finding catchments that can be used as replicates and because land-use effects may be obscured by sources of variance acting over spatial scales smaller than the catchment.

We can also say to this topic that studies focusing on relationships biological parameters and changes in river morphology (Lorenz et al., 2004, Balestrini et al., 2004, Feld, 2004, papers in press relating to project STAR) revealed significant correlations between structure of macroinvertebrates communities and mainly these morphological parameters: shading of the channel, width and percentage of shoreline vegetation, width and percentage of natural floodplain vegetation, land-use in floodplain, average width of woody riparian vegetation and shoreline covered with woody riparian vegetation.

Woody debris

Wood plays a major role in creating multiple invertebrate habitats in small stream and large rivers. In small streams, woody debris dams are instrumental in creating a step and pool profile of habitats, enhancing habitat heterogeneity, retaining organic matter, and changing current velocity. Benke and Wallace (2003) highlighted that re-introduction of wood in streams and rivers is becoming an important aspect of restoration and management strategies around the world, as attempts are made to increase biodiversity and refuges both for fishes and their invertebrate prey.

Palmer et al. (1996) recognized that removal of woody debris from the stream did not prevent faunal recovery throughout the channel; however, the presence of woody debris dams did confer greater resistance of fauna to floods (as measured by no degrease in abundance during flooding).

Warmke and Hering (2000) studied the macroinvertebrate community inhabiting woody debris in low-order mountain streams. They observed Amphipoda, Plecoptera and Diptera to be the most important taxa. Futhermore they found out that the microhabitat is colonized by xylophagous taxa (*Lype reducta*, *Lipsothrix* sp., *Symposiocladius lignicola*, *Potamophylax cingulatus*) as well as taxa of other feeding types. They did not find a correlation between the abundance of specimens and density of wood, tree species, bark cover, consistency class, and surface structure.

Brooks et al. (2004) created 20 engineered log jams in gravel-bed river that has been desnagged and had most of its riparian vegetation removed to test the effectiveness of reintroducing woody debris as a mean of improving channel stability and recreating habitat diversity. This experiment demonstrated that even in the face of these gross geomorphic changes, the rehabilitation of channel geomorphology is possible over very short timeframes.

Johnson et al. (2003) observed that 86% a 95% of the total taxa encountered at study sites were found in wood habitats. The presence of wood in a site increased the average taxa richness by 15 a 10 taxa in Michigan and Minessota, respectively.

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5. Contribution by Alterra

Selection of indicators for hydrology and morphology in Dutch lowland streams

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Introduction

General introduction

The key research question in Workpackage 2, task 2 is: “What is the effect of climate and land-use changes on hydromorphology and species composition and indicator species?”
In task 1.1 we evaluated the relationships of land use and hydromorphology. It turned out that the impact of land-use change on lowland streams was very indirect. The major hydromorphological changes took place at discrete moments in time, when streams were channellised, normalised and regulated. These water management measures were taken to improve the agricultural land-use practices but the measures themselves had large impact on the stream ecosystems.
Thus, at first it is most important to focus on the relationship between hydromorphology and stream ecosystems.
The major questions for this task are:

- What are the relations between hydrology and morphology, and species composition?
- Which species are good indicators for changes in hydrology and morphology?

The latter question is dealt with in this study.

Indicator definition and selection criteria

Each organism group occupies its own niche in space and time. For example, a diatom inhabits a surface of a few square millimetres while a fish moves around in stretches of kilometres (Figure 1). The scale of each organisms biotope affects the organisms response to a stressor. At the scale of time, the life span and survival strategy of different organism groups differ. This also affects the organisms’ response to a stressor. It is not always easy to separate spatial and temporal scale but, in general, the response of macroinvertebrates and fish is related to a scale of the habitat to a stream stretch and a time span of weeks to years. Algae respond fast and at micro-scale while macrophytes respond slowly at stretch scale.
The use of a taxon as indicator not only depends on response time but also on other criteria, like available knowledge, ease to collect and identify.

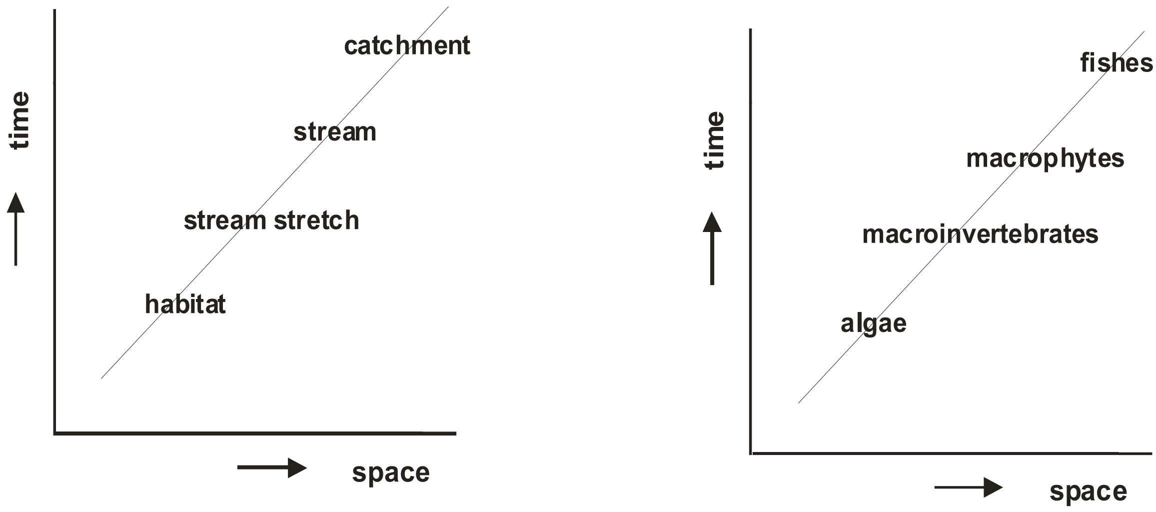

Figure 1. Position of spatial units and organism groups in space and time (after Frisell et al., 1986, Habersack, 2000)

The basic idea behind a biological indicator is that it provides information about its niche. An indicator is selected based on its sensitivity to a particular environmental variable, next the indicator is assessed to make inferences about that variable. Three kinds of indicators can be distinguished (Robertson & Davis, 1993):

- pressure indicators: measures of pressures on the environment caused by human activities.
- state indicators: measures of the quality of the environment and the quality and quantity of natural resources.
- response indicators: measures that demonstrate how and how much society is doing to respond to environmental changes and issues.

Ideally, each indicator included in an assessment system should meet a series of criteria designed to ensure high and consistent quality of the assessment result. Robertson & Davis (1993) and Hellawell (1978) listed a number of criteria to select indicators (Tables 1 and 2).

Table 1. Overview of some indicator selection criteria (altered after Robertson & Davis, 1993).

criteria	***definition***
scientific validity	
measurable	measures a direct feature of the environment over time
quantitative	has a numerical scale that can be quantified simply using standard methodologies with a known degree of accuracy and precision
sensitivity (scale)	responds to a broad range of conditions or perturbations within an appropriate timeframe and geographic scale
sensitivity (trend)	should show reliability over time, bringing to light a representative trend
sensitivity (disturbance)	sensitive to potential impacts being evaluated
resolution/discriminatory power	is able to distinguish meaningful differences in environmental conditions with an acceptable degree of resolution (high signal : noise ratio). Small changes in the indicator show measurable results
integrator effects/exposures	integrates effects or exposures over time and space and responds to the cumulative impacts of multiple stressors. It is broadly applicable to many stressors and sites
validity/accuracy	is a relevant and powerful measure of some environmental conditions/processes and is related or linked unambiguously to an

	endpoint in an assessment process
reproducible	reproducible within defined and acceptable limits for data collection over time and space
representative	changes in the indicator are highly correlated to trends in the other parameters or systems they are selected to represent
scope/applicability	responds to changes on a geographic and temporal scale appropriate to the goal or issue
reference value	has a reference condition or benchmark against which to measure progress
data comparability	the data supporting an indicator can be compared to existing and past measures of conditions to develop trends and define variation
anticipatory	is capable of providing an early warning of environmental change
practical considerations	
cost effective/availability	the information for an indicator is available or can be obtained with reasonable cost and effort and provides maximum information per unit effort
level of difficulty	ability to obtain expertise to monitor
measurable	ability to find (easily detected), identify, and interpret
accepted	accepted methods available
safe	sampling produces minimal environmental impact
goal oriented	
relevance	should be relevant to a desired significant policy goal, issue, legal mandate, or agency mission that provides information of obvious value that can be easily related to the public and decision makers
coverage	uses a suite of indicators that encompasses major components of the ecosystem over the range of environmental conditions that can be expected
understandable	should be simple and clear, and sufficiently non-technical to be comprehensible to the general public with brief explanation; should lend itself to effective and appealing display and presentation

Table 2. Indicator selection criteria (after Hellawell, 1978).

1. economic interest as source (e.g., fish) or as nuisance or plague
2. availability of a large amount of ecological information
3. wide distribution (global/European)
4. reliable accumulator of toxic substances
5. ease to collect/measure
6. geographical constancy in habitat preference
7. limited genetic variability
8. ease to rear in the laboratory
9. under certain circumstances abundant

From all the above listed criteria the actual use of an indicator in this study depends on:
- √ the frequency of occurrence or coverage of the indicator,
- √ the potential to represent a trend in time,
- √ the possibility to be monitored,
- √ the ease to be identified,
- √ the reliability,
- √ the indicative value (positive or negative) for hydrology and/or morphology disturbance.

These criteria are taken into account during the process of selecting indicators for hydrology and morphology.

Indicator tolerance range and rarity

Species are adapted to their environments in that, to survive and reproduce, they must meet their environment's conditions for existence (Pianka, 1978). Adaptation includes simultaneously the various components of the environment, such as physical conditions, competitors and predation. Species are adapted by genetic, physiological, behavioral and developmental means. To be adapted the species must cope with conflicting demands of the various environmental components, as such this requires compromises in its adaptations to each. Highly adapted species with narrow tolerance limits will suffer greater losses in fitness due to environmental deterioration than do generalists. This means that specialists will be better indicators then generalists, who can survive in many different environments. Species can not simply be grouped in specialists and generalists. All stages in between are present.
Niche width is determined through the width of the tolerance range along one or more niche dimensions. Often, specialists have very specific habitat requirements, and as a result they may not be very abundant. In contrast, generalists with broad tolerance ranges have flexible habitat requirements, and are usually more common. Thus, specialists are often rare while generalists are more abundant. A rare species may, however, frequently occur in a clump, so that its local density can be high. Rarity is either defined by the species abundance or the species distribution range (Gaston 1994). Nijboer & Schmidt-Kloiber (2004) showed that species with small distribution ranges appeared to be indicative for ecological quality. In this study rare species are defined as species with small distribution ranges using the classes of Nijboer & Verdonschot (2004). Rarity can be due to different causes:

1. natural causes

- the indicator, even under natural conditions, only occurs in low numbers;
- the indicator lives in interaction with another species that is rare;
- the indicator occurs on the edge of its geographical distribution area;
- the indicator has a low dispersal capacity.

2. human interference

- the indicator depends on very specific environmental conditions or a very specific habitat that only rarely occurs either through natural or human induced causes;
- the indicator can not survive certain types of degradation, e.g. eutrophication, organic pollution or hydromorphological degradation and therefore only rarely occurs. Probably, these species were widely distributed in the past when habitats were still pristine.

In this study, those rare species that were more common in the past but became rare through human interference (group 2), especially hydromorphological degradation, are preferred as indicators. Such indicators really reflect degradation and not other types of rarity. Those which are rare (have a small distribution range) but have high abundances at the sites where they occur are even better suited.

Positive and negative indicators

Ecosystem disturbance can sometimes cause a decrease in diversity, a dominance of pollution tolerant taxa and/or a change in taxon abundances. All available assessment systems use these response types. There is a huge number of indices or metrics available to assess streams, on the level of the specimen, species or community. Johnson (2002) summarized all approaches in three categories:

1. indices that use a single organism group and are based on biodiversity and/or tolerance;
2. indices (multimetrics) that are composed of single indices and/or several organism groups, such as diatoms, macroinvertebrates and fishes;
3. indices that use the community as a whole and for example are based on species richness, evenness and distribution of abundances.

Other classifications are of course possible but the most important issue is the use of certain features of taxa or groups of taxa by each of the approaches. Nijboer (2004) separated five groups of indicators each related to either:

1. environmental circumstances;
2. biological processes and interactions;
3. communities;
4. rarity;
5. dominance;

Nijboer & Verdonschot (1999) showed that indicators can be composed of features of species or of communities that indicate environmental circumstances under reference conditions (positive indicators) or that emphasize the degraded environmental conditions (negative indicators) (Table 3, Figure 2).

Table 3. Key features of indicator approaches.

<table>
<tr><th>feature</th><th>ecosystem</th><th colspan="2">quality gradient</th></tr>
<tr><td>environment (water type)</td><td>system conditions</td><td>reference</td><td>degraded</td></tr>
<tr><td>taxon indicators for:</td><td>– hydrology
– morphology
– chemistry
– biology</td><td>species with positive scores</td><td>species with negative scores</td></tr>
<tr><td>community indicators for:</td><td>– communities
– relationships</td><td>– indices with positive scores
– assemblages with positive score</td><td>– indices with negative scores
– assemblages with negative score</td></tr>
</table>

Hydrology and morphology both are environmental circumstances optimally developed under reference conditions but degraded by human interference and affected through climate change. The most suitable set of indicators would include:

- positive dominance indicators: indicators present under reference and good ecological conditions in high numbers and with a high frequency of occurrence;
- negative dominance indicators: indicators present under moderate to bad (degraded) ecological conditions in high numbers and with a high frequency of occurrence;
- positive characteristic indicators: indicators present under reference ecological conditions, more often in lower numbers;
- negative characteristic indicators: indicators present under bad ecological conditions, more often in lower numbers ;
- indicators for rarity: this category is discussed in the next paragraph.

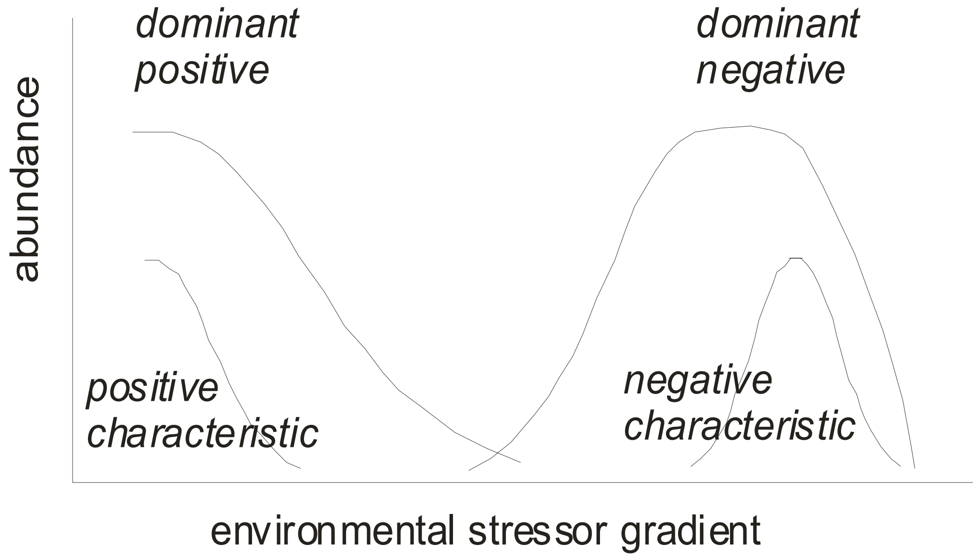

Figure 2. Response of positive and negative dominants and characteristic indicators.

Indicator selection: sources of information

To select indicators for hydrology and morphology we started with an extensive list of general stream indicators drawn up for the Dutch National Nature Policy Plan implementation (Verdonschot, 2000). This list was based on available data and expert knowledge. The indicator values for hydrological and morphological disturbance were added by using the literature as listed in Table 4 and included macroinvertebrates, macrophytes and fishes..

Table 4. Sources of information to extract stressor information for macroinvertebrates, macrophytes and fishes.

information source	organism group	water type	remark
literature			
Verdonschot, 1990	macroinvertebrates	all	
Verdonschot et al., 1992	macroinvertebrates	all	
Buskens, 2001	macroinvertebrates	peat ditches and streams	
Weeda et al. 1994	macrophytes	all	autecological information
Bloemendaal & Roelofs 1988	macrophytes	all	autecological information
Haslam et al. 1975	macrophytes	all	autecological information of British waterplants
Schaminee et al., 1995	macrophytes	all	plant communities
Zuidhoff et al., 2002	macrophytes	peat pits, peat ditches, streams and fens	
Verdonschot, 2000	all	streams	
RIVM 2003	fishes	peatpits	
Crombachs et al., 2002	fishes	all	province of Limburg
De Nie, 1996	fishes	all	Atlas
data sets Alterra			
	macroinvertebrates, macrophytes	streams	
	macroinvertebrates, macrophytes	ditches	
	macroinvertebrates	streams	province of Limburg
	macroinvertebrates, macrophytes	all	province of Overijssel
	macroinvertebrates	streams	water management area Vallei & Eem/Veluwe
	macroinvertebrates	streams and ditches	Gelderland
	macroinvertebrates, macrophytes	dune waters	

Table 5 illustrates the construction of the indicator table. All results are listed according to this structure.

For each indicator the organism group is listed, the stream type, the stressor, the ease to identify the organism to species level and the reliability of the taxonomical status. The stressor is classified according to a weight:

+ the indicator decreases with an increase of stress (positive indicator)
- the indicator increases with an increase of stress (negative indicator)

The score 1, 2 or 3 indicates the strength of the response;
1 = weak response;
2 = moderate response;
3 = strong response.

Table 5. Example of the (transposed) table of indicators.

		indicator	
		Baetis rhodani	***Chrysosplenum sp.***
organism group	macroinvertebrates	x	
	macrophytes		x
	vis		
stream type	a		
	b		x
	c		
	d	x	x
	….	x	x
stressor	hydrological degradation	-3	
	morphological degradation	-3	-3
	drought	-3	
identifiability	identification possible	2	3
reliability	reliability of taxonomic status	0	3

Ease to identify and reliability

Macroinvertebrates

To establish the ease and reliability to identify macroinvertebrates to species level, a number of criteria were used. In general, three basic criteria were taken as a starting-point:

- √ the criteria were established, based on experiences and developments since about 1980 ;
- √ the identifier is supposed to have more then 5 years of experience;
- √ the criteria only apply to the relevant aquatic stages.

Next, the following three categories were distinguished:

Difficult to identify (score 1):

- √ the identification features between related taxa show strong overlap;
- √ the identification features are hard to interpret;
- √ the taxonomical status of the taxon is unclear;
- √ the identification key is long and complicated (large error risk);
- √ representatives within one taxonomical group can only be identified through the use of different keys that include different combinations of taxa;
- √ one or only a few stages of the taxa are well identifiable (e.g., only the adult or the male) while the other stages are difficult to identify or not identifiable (e.g., the female or the juveniles);
- √ identification of the aquatic stage of the taxon is impossible.

Moderately identifiable (score 2):

- √ the identification is possible for well developed specimens (e.g., the last instars);

√ the identification is possible but sometimes important features can lack;
√ the majority of the stages can be identified (adults, males, females, fully grown instars) but some are difficult (e.g., juveniles).

Easy to identify (score 3):

√ all features are easy to recognize;
√ it is easy to recognize and separate species;
√ the identification key is clear and different keys use the same features.

The reliability of the taxonomical and biogeographical status of macroinvertebrates is based on the following criteria:

Low reliability (score 1):

√ the taxonomical status is unclear;
√ identification is difficult and misidentifications often occur (=category 'difficult to identify');
√ many synonyms are known;
√ the nomenclature has changed;
√ the taxon is recently split;
√ the taxonomical literature is until recent less developed;
√ often, the taxon is not identified

moderate reliability (score 2):

√ sometimes misidentification takes place due to the use of less clear features (=category 'moderately identifiable');
√ the taxon reached the Netherlands in the last 20 years;
√ taxonomical literature was changed at some points.

high reliability (score 3):

√ the taxon name did not change;
√ identification is clear and easy (=(=category 'easy to identify');
√ the taxon occurs in the Netherlands for more then 20 years;
√ taxonomical literature did not change over the last 20 years;
√ the identification is easy and often performed.

The identifiability and reliability is based on the expert judgement of experienced identifiers.

Macrophytes

The identifiability of macrophytes is established by examining the available data sets. Genera that more often were not split further down to species were labeled 'difficult to identify'. Genera of which species are difficult to separate but that were identified more often were labelled 'moderately identifiable'. The reliability was not coded for macrophytes. Macrophytes in general were much more identifiable in comparison to macroinvertebrates.

Fishes

Fishes were considered to be well identifiable and reliable.

Results and discussion

The results of the listing of potential indicators for hydrological and morphological disturbance (including drought, water inlet and current) are given in appendices 1 (macroinvertebrates), 2 (macrophytes) and 3 (fishes).

The indication of rarity was added to the macroinvertebrates. Very common and common macroinvertebrates are considered as less suited indicators. Their wide distribution strongly decreases the indicative reliability, on the other hand such taxa can be negative indicators for certain stressors.

In total, for macroinvertebrates, 444 indicators for hydrological disturbance, 419 for morphological disturbance, and 16 for drought are available. For macrophytes 32 indicators for hydrological disturbance, 14 for morphological disturbance, 25 for inlet water, 65 for drought and 41 for current were listed. For fishes 33 indicators for hydrological disturbance, and 35 for morphological disturbance, were listed.

The selection of indicators presented is based on a review of easily available literature and large datasets. The selection is not yet validated by specific stressor response studies. Therefore, the use of these indicators should take these restrictions into consideration.

1. Next, it is of great importance to validate the most suited indicators by either experiments or detailed literature.
2. It would be even better to list indicators per water type.

In tasks 3.1 of WP2 the selection of indicators to perform experiments takes place.

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Appendix 1. Macroinvertebrate indicators of hydrology and morphology (codes: rarity: u=extinct, vr=very rare, r=rare, u=uncommon, c=common, vc=very common, a=abundant: stressor: 1=decrease, 2=strong decrease, 3=disappearence, -1=increase, -2=strong increase, -3=mass increase.: ease to identify: 1=difficult, 2=moderate, 3=easy: reliability: 1=low, 2=moderate, 3=high).

taxon name	hydrological disturbance	morphological disturbance	drought	ease to identify	reliability	rarity	remark
Adicella filicornis	3			3	3	vr	
Adicella reducta		3		3	3	r	
Aedes cantans	1			3	3	-	
Aedes communis	1			3	3		
Aedes punctor	1			3	3	vc	
Aedes sp	1			3	3	a	
Agabus biguttatus	3	3		2	2	vr	
Agabus chalconatus	3			1	1	u	
Agabus guttatus	3	2		2	2	r	
Agabus melanarius	3			2	2	vr	
Agabus paludosus		1		1	1	c	
Agabus uliginosus	3			1	1	r	
Agapetus fuscipes	3	3		3	3	u	
Agapetus ochripes	3	3		3	1	vr	
Alderia modesta	3			0	0	x	marine, no key
Allogamus auricollis	3			3	3	vr	
Ametropus fragilis		3		3	3	ex	
Amphichaeta leydigii	1			2	2	r	
Amphichaeta sannio	1			2	2	u	
Amphinemura standfussi	3	2		1	1	r	
Amphinemura sulcicollis	3	2		1	1	r	
Anabolia nervosa	-3	-3		2	2	vc	
Annitella obscurata	3	3		1	1	vr	
Antocha vitripennis	1			2	2	-	
Apatania fimbriata	3	3		3	3	vr	
Aphelocheirus aestivalis	2	3		3	3	r	
Apsectrotanypus trifascipennis	-2	-2		2	2	vc	
Aquarius najas	1	3		3	3	r	
Arrenurus cylindratus	2	2		1	1	u	
Assiminea grayana	1			3	3	-	
Astacus astacus		3		3	3	vr	
Atherix sp		3		3	3	r	
Athripsodes albifrons	3	3		2	2	vr	
Athripsodes cinereus		1		2	2	c	
Baetis buceratus		3		2	2	vr	
Baetis digitatus	3	3		3	3	ex	
Baetis fuscatus	2	2		2	2	r	
Baetis lutheri		3		3	3	vr	
Baetis muticus	3	3		2	2	vr	
Baetis niger	3	3		2	2	vr	
Baetis rhodani	2			3	3	c	
Baetis scambus	3	3		2	2	r	

taxon name	hydrological disturbance	morphological disturbance	drought	ease to identify	reliability	rarity	remark
Baetis sp	1	1		3	3	-	
Baetis vernus	1	1		3	3	vc	
Balanus improvisus		1		2	2	-	
Bathyporeia pilosa	1			0	0		
Batracobdella verrucata	3	3		3	3	vr	
Beckidia zabolotskyi		2		1	1		
Beraea maura	3			2	3	r	
Beraea pullata	3	2		2	3	u	
Beraeodes minutus	2	2		3	3	u	
Beris sp	1			3	3	-	
Boophthora erythrocephala	1			1	1		
Brachycentrus subnubilus		3		3	3	vr	
Brachycercus harrisella		3		3	3	vr	
Brachyptera braueri	3	3		3	3	ex	
Brachyptera risi	3	3		3	3	ex	
Brillia flavifrons	1			3	3	c	
Brychius elevatus	3	3		3	3	vr	
Caenis macrura		2		3	3	u	
Caenis pseudorivulorum	3	3		3	3	r	
Caenis rivulorum	3	3		3	3	vr	
Calopteryx virgo		3		3	3	r	
Cardiocladius fuscus	3	3		2	2	vr	
Ceraclea alboguttata	3	3		3	3	vr	
Ceraclea annulicornis	3	3		3	3	vr	
Ceraclea dissimilis	2	3		3	3	r	
Ceraclea fulva	2	3		3	3	r	
Ceraclea nigronervosa	2	3		3	3	vr	
Ceraclea riparia	3	3		3	3	ex	
Ceraclea senilis	2			3	3	u	
Cercion lindenii		3		3	3	r	
Chaetocladius gr vitellinus	3	3		3	3	vr	
Chaetocladius laminatus	3	3		1	1	vr	
Chaetocladius melaleucus agg	3	3		3	3	vr	
Chaetocladius sp	3	3		3	3	-	
Chaetogaster langi		2		2	2	r	
Chaetopteryx villosa		2		1	1	c	
Chernovskiia orbicus		3		3	2	x	
Cheumatopsyche lepida		3		3	3	vr	
Chimarra marginata	1	3		3	3	ex	
Chloroperla tripunctata	3	3		3	3	ex	
Choroterpes picteti	3	3		3	3	ex	
Chrysogaster sp	3			3	3	-	
Chrysops relictus	3	3		2	2	-	
Cladotanytarsus mancus	1	1		1	1	c	
Cladotanytarsus pallidus		3		1	1	vr	
Cnetha costata	2	2		1	1	r	
Cnetha cryophila	2	2		1	1	r	

taxon name	hydrological disturbance	morphological disturbance	drought	ease to identify	reliability	rarity	remark
Cnetha latipes	2			1	1	u	
Conchapelopia melanops	1	1		2	2	c	
Cordulegaster boltonii	3	3		3	3	vr	
Cordylophora caspia	3			0	0	-	
Corophium insidiosum	3			3	3	r	
Corophium multisetosum	2			3	3	u	
Corynoneura lobata	2	2		3	3	u	
Crenobia alpina	3			3	3	vr	
Cricotopus gr tibialis	3	3		3	3	vr	
Cricotopus tremulus	3	3		1	1	vr	
Cricotopus triannulatus	1	1		1	1	u	
Cricotopus trifascia	2	2		1	1	r	
Crunoecia irrorata		3		3	3	r	
Cryptochironomus rostratus	2	2		1	1	r	
Cryptotendipes usmaensis	3	3		1	1	vr	
Cystobranchus respirans	3	3		3	3	vr	
Dendrocoelum boettgeri	3			0	0		
Deronectes latus		3		3	3	u	
Deronectes platynotus	3	3		3	3	vr	
Dicranomyia sp	1			3	3	-	
Dicranota bimaculata	1	1		1	1	-	
Dinocras cephalotes	3	3		3	3	ex	
Dixa dilatata	3			2	2	r	
Dixa gr maculata	1	1		3	3	u	
Dixa maculata	1	1		2	2	u	
Dixa nubilipennis	3	3		2	2	vr	
Drusus annulatus	3	3		3	3	vr	
Drusus trifidus	3	3		3	3	vr	
Dugesia gonocephala	2			3	3	r	
Ecdyonurus affinis	3	3		1	1	ex	
Ecdyonurus aurantiacus	3	3		1	1	ex	
Ecdyonurus dispar	3	3		1	1	ex	
Ecdyonurus insignis	3	3		1	1	vr	
Ecdyonurus lateralis	2	2		1	1	r	
Ecdyonurus torrentis	3	3		1	1	vr	
Ecdyonurus venosus	3	3		1	1	vr	
Echinogammarus berilloni	3	3		3	3	r	
Ecnomus tenellus		2		3	3	vc	
Electra crustulenta		1		0	0	-	
Elmis aenea	1	2		1	1	u	
Elmis maugetii	3	3		1	1	vr	
Elmis obscura	3	3		1	1	vr	
Elmis sp	3	3		2	2	-	
Elodes minuta	1	1		2	1	-	
Elodes sp	1	1		2	2	-	
Endochironomus tendens	-1	-1		3	3	a	
Enoicyla pusilla	-1			3	3	vc	

taxon name	hydrological disturbance	morphological disturbance	drought	ease to identify	reliability	rarity	remark
Ephemera danica	2	2		3	3	u	
Ephemera glaucops	2			3	3	vr	
Ephemera lineata	2	2		3	3	r	
Ephemera vulgata	1	1		3	3	u	
Ephemerella ignita	2	2		3	3	r	
Ephemerella sp	2	2		2	3	-	
Ephoron virgo	3	3		3	3	r	
Epoicocladius ephemerae	2	2		3	2	-	E. flavens (Malloch, 1915)
Epoicocladius flavens	3	3		3	3	vr	
Eriopterinae	-3			3	3	x	
Ernodes articularis	3	3		3	3	vr	
Erotesis baltica		2		3	3	r	
Esolus angustatus	3	3		3	3	vr	
Esolus parallelepipedus	3	3		3	3	vr	
Esolus pygmaeus	3	3		3	3	vr	
Esolus sp	3	3		2	2	-	
Eteone longa	2			0	0	-	
Eukiefferiella brevicalcar	2	2		1	1	r	
Eukiefferiella calvescens	2	2		1	1	r	
Eukiefferiella claripennis	1			1	1	u	
Eukiefferiella claripennis agg	1			3	3	c	
Eukiefferiella discoloripes	-1	-1		1	1	c	
Eukiefferiella gr discoloripes	1			3	3	c	
Eukiefferiella ilkleyensis	3	3		1	1	vr	
Eukiefferiella verralli	3	3		1	1	vr	
Euleuctra geniculata	3	3		1	1	ex	
Eusimulium angustipes	1			1	1	-	
Eusimulium aureum	1			1	1	-	
Eusimulium sp	1			1	1	x	
Eylais koenikei	1	1		1	1	u	
Eylais setosa	-1	-1		1	1	vc	
Feltria armata	3	3		1	1	vr	
Forelia variegator	-1	-1		2	2	c	
Glossosoma conformis	3	3		3	3	vr	
Glyphotaelius pellucidus	1	1		3	3	c	
Goera pilosa	1	1		3	3	u	
Gomphus flavipes	3	3		2	2	vr	
Gomphus vulgatissimus	3	3		2	2	vr	
Gordius setiger	3	3		0	0	-	
Grammotaulius submaculatus	3	3		3	3	vr	
Graptodytes pictus	-3	-3		3	3	a	
Gyraulus albus	-3	-3		3	3	a	
Gyrinus marinus	-1			3	3	vc	
Habroleptoides modesta	3	3		3	3	ex	
Habrophlebia fusca	2	2		3	3	r	
Habrophlebia lauta	3	3		3	3	vr	
Haementeria costata		1		3	3	u	

taxon name	hydrological disturbance	morphological disturbance	drought	ease to identify	reliability	rarity	remark
Hagenella clathrata			3	3	3	vr	
Halesus digitatus	3	3		2	2	vr	
Halesus radiatus	1	1		2	2	c	
Halesus radiatus/digitatus	1	1		3	3	c	
Halesus tessellatus	3	3		2	2	vr	
Haliplus flavicollis	-1	-1		2	2	c	
Haliplus fluviatilis	-2	-2		2	2	vc	
Haliplus laminatus	-1	-1		2	2	c	
Haliplus wehnkei	-1	-1		1	1	c	
Haplotaxis gordioides	3	3		3	3	vr	
Harnischia curtilamellata	3	3		1	1	vr	
Heleniella ornaticollis	2	2		3	3	r	
Helophorus arvernicus	2	2		1	1	r	
Helophorus flavipes	2	2		1	1	r	
Helophorus pumilio	2			1	1	r	
Hemerodromia sp			2	3	3	-	
Heptagenia coerulans	3	3		1	1	ex	
Heptagenia flava	3	3		1	1	vr	
Heptagenia fuscogrisea	3	3		1	1	vr	
Heptagenia longicauda	3	3		1	1	vr	
Heptagenia sp	3	3		2	3	-	
Heptagenia sulphurea	2	2		1	1	r	
Heteromastus filiformis	1			3	3	-	
Heterotanytarsus apicalis	2	2		3	3	r	
Heterotrissocladius marcidus	1	1		3	3	u	
Homochaeta naidina	3	3		3	3	vr	
Hydatophylax infumatus	3	3		3	3	vr	
Hydraena assimilis	3	3		1	1	vr	
Hydraena belgica	3	3		1	1	vr	
Hydraena excisa	3	3		1	1	vr	
Hydraena gracilis	3	3		1	1	vr	
Hydraena melas	3	3		1	1	vr	
Hydraena minutissima	3	3		1	1	-	
Hydraena pulchella	3	3		1	1	vr	
Hydraena riparia	1			1	1	u	
Hydraena testacea		1		3	3	c	
Hydrobaenus pilipes			3	2	2	vr	
Hydrobius fuscipes	-3			3	3	a	
Hydrochus ignicollis	2			3	2	r	
Hydroporus discretus	1	1		1	1	u	
Hydroporus longulus	3	3		1	1	vr	
Hydroporus nigrita			1	1	1	u	
Hydroporus planus			-3	1	1	a	
Hydroporus pubescens			-2	1	1	vc	
Hydropsyche bulgaromanorum	1	1		3	3	u	
Hydropsyche contubernalis	1	1		2	2	c	
Hydropsyche dinarica	3	3		2	2	vr	

taxon name	hydrological disturbance	morphological disturbance	drought	ease to identify	reliability	rarity	remark
Hydropsyche exocellata	3	3		2	2	vr	
Hydropsyche fulvipes	3	3		2	2	vr	
Hydropsyche instabilis	2	2		2	2	r	
Hydropsyche modesta	3	3		2	2	vr	
Hydropsyche ornatula	3	3		2	2		
Hydropsyche pellucidula	1	1		3	3	u	
Hydropsyche saxonica	2	2		2	2	r	
Hydropsyche siltalai	2	2		3	3	r	
Hydroptila cornuta	3	3		2	2	ex	
Hydroptila dampfi	3	3		2	2	ex	
Hydroptila pulchricornis	3	3		2	2	vr	
Hydroptila sparsa	2	2		2	2	r	
Hygrobates fluviatilis	2	2		3	3	r	
Hygrobates longipalpis	-2	-2		3	3	vc	
Hygrobates nigromaculatus	-2	-2		3	3	vc	
Hygrotus inaequalis	-3	-3		3	3	a	
Ironoquia dubia	1	1		3	3	u	
Isogenus nubecula	3	3		3	3	ex	
Isonychia ignota	3	3		3	3	ex	
Isoperla grammatica	3	3		2	2	ex	
Isoperla obscura	3	3		2	2	ex	
Isoptena serricornis	3	3		3	3	ex	
Ithytrichia lamellaris	3	3		2	2	ex	
Kloosia pusilla	2	2		1	1	r	
Krenopelopia sp	1	1		3	3	u	
Laccobius atratus	3	3		2	2	vr	
Laccobius obscuratus	3	3		2	2	vr	
Laccobius sinuatus	2	2		2	2	r	
Laccobius striatulus	2	2		2	2	r	
Lasiocephala basalis	3	3		3	3	vr	
Lebertia minutipalpis	2	2		1	1	r	
Lebertia porosa	3	3		1	1	vr	
Lepidostoma hirtum	3	3		3	3	vr	
Leptocerus interruptus	3	3		2	2	vr	
Leptophlebia marginata	2	2	2	3	3	r	
Leuctra fusca	3	3		2	2	ex	
Leuctra nigra	3	3		2	2	vr	
Limnebius truncatellus	1	1		3	3	u	
Limnephilus bipunctatus			2	2	2	vc	
Limnephilus centralis			2	2	2	r	
Limnephilus coenosus			3	2	2	vr	
Limnephilus decipiens	-1	-1		2	2	c	
Limnephilus elegans	3	3	3	2	2	vr	
Limnephilus extricatus			1	2	2	u	
Limnephilus fuscicornis	3	3		2	2	vr	
Limnephilus griseus	3	3		2	2	vr	
Limnephilus ignavus	3	3		2	2	vr	

taxon name	hydrological disturbance	morphological disturbance	drought	ease to identify	reliability	rarity	remark
Limnephilus lunatus	-3	-3		2	2	a	
Limnephilus stigma			2	2	2	r	
Limnephilus subcentralis	2	2		2	2	r	
Limnius opacus	3	3		3	3	vr	
Limnius perrisi	3	3		3	3	vr	
Limnius volckmari	2	2		3	3	r	
Limnophila sp	2	2		3	3	-	
Limnophora riparia	2	2		1	1	-	
Lipiniella araenicola	1	1		1	1	u	Shilova, 1961
Lipiniella moderata	3	3		1	1	vr	
Lithax obscurus	3	3		3	3	vr	
Macronychus quadrituberculatus	3	3		3	3	vr	
Macropelopia notata	3	3		1	1	vr	
Macroplea sp	3	3		2	2	-	
Marthamea selysii	3	3		3	3	ex	
Melampophylax mucoreus	3	3		3	3	vr	
Mercuria confusa	3			1	1	vr	
Metreletus balcanicus	3	3		3	3	vr	
Metriocnemus hygropetricus agg	2	2		2	2	r	
Micrasema minimum	3	3		3	3	ex	
Micronecta poweri	3	3		3	1	vr	
Micropsectra bidentata	2	2		1	1	r	
Micropsectra notescens	1	1		1	1	u	
Micropsectra roseiventris	3	3		1	1	vr	
Micropterna lateralis	1	1		2	2	u	
Micropterna sequax	1	1		2	2	u	
Microtendipes pedellus agg	-1	-1		2	2	c	
Mystacides azurea	-2	-2		2	2	vc	
Nais alpina	1	1		1	1	u	
Nais bretscheri	1	1		3	3	u	
Nanocladius rectinervis	2	2		3	2	r	
Nanocladius rectinervis agg	2	2		3	2	r	
Nemoura avicularis	3	3		3	3	vr	
Nemoura cambrica	2	2		1	1	r	
Nemoura dubitans	3	3		2	2	vr	
Nemoura marginata	3	3		1	1	vr	
Nemurella pictetii	1	1		3	3	u	
Neozavrelia sp	1	1		3	3	u	
Neumania imitata	3	3		1	1	vr	
Neureclepsis bimaculata	1	1		3	3	u	
Niphargus aquilex	3			1	1	r	
Niphargus schellenbergi	2			1	1	r	
Notidobia ciliaris	2	2		3	3	r	
Ochthebius bicolon	2	2		3	3	r	
Ochthebius exsculptus	3	3		3	3	vr	
Ochthebius gibbosus	3	3		3	3	vr	

taxon name	hydrological disturbance	morphological disturbance	drought	ease to identify	reliability	rarity	remark
Ochthebius metallescens	3	3		3	3	vr	
Odontocerum albicorne	3	3		3	3	vr	
Oecetis notata	3	3		2	2	vr	
Oecetis tripunctata	3	3		2	2	ex	
Oemopteryx loewii	3	3		3	3	ex	
Oligoneuriella rhenana	3	3		3	3	-	
Oligoneuriella sp	3	3		3	3	-	
Oligoplectrum maculatum	3	3		3	3	ex	
Onychogomphus forcipatus	3	3		3	3	-	
Ophiogomphus cecilia	3	3		2	2	-	
Orectochilus villosus	2	2		3	3	r	
Oreodytes sanmarki	3	3		3	3	vr	
Orthocladius fuscimanus	3	3		1	1	vr	
Orthocladius rivulorum	3	3		1	1	vr	
Orthocladius rubicundus	3	3		1	1	vr	
Orthocladius thienemanni	3	3		1	1	vr	
Orthotrichia sp	1	1		3	3	u	
Osmylus fulvicephalus	2	2		3	3	r	
Oulimnius troglodytes	3	3		3	3	vr	
Oxyethira falcata	3	3		2	2	vr	
Palingenia longicauda	3	3		3	3	ex	
Panisus torrenticolus	3	3		1	1	-	
Parachiona picicornis	3	3		3	3	vr	
Parachironomus gr vitiosus	-1	-1		3	3	c	
Paracladius conversus agg	-1	-1		3	3	-	
Paracladopelma camptolabis	1	1		1	1	u	
Paracladopelma laminata agg	-1	-1		3	3	c	
Paracladopelma nigritula	-1	-1		1	1	c	
Paraleptophlebia cincta	3	3		3	3	vr	
Paraleptophlebia submarginata	3	3		3	3	vr	
Parametriocnemus stylatus	1	1		3	3	u	
Paratanytarsus tenuis	1	1		1	1	u	
Paratendipes gr albimanus	-2	-2		3	3	-	
Paratendipes intermedius	2	2		1	1	r	
Pedicia rivosa	2	2		3	1	r	
Pedicia sp	2	2		3	3	-	
Peloscolex velutinus	2	2		1	1	r	
Perla burmeisteriana	3	3		3	3	ex	
Perlodes microcephala	3	3		3	3	vr	
Phaenopsectra sp	-2	-2		3	3	vc	
Phagocata vitta	3	3		3	3	vr	
Phryganea bipunctata	-2	-2		2	2	vc	
Physa acuta	-3	-3		3	3	a	
Physa fontinalis	-3	-3		3	3	a	
Pisidium pseudosphaerium	1	1		1	1	u	
Platycnemis pennipes	-1	-1		3	3	c	
Polycelis felina	1	1		3	3	u	

taxon name	hydrological disturbance	morphological disturbance	drought	ease to identify	reliability	rarity	remark
Polycentropus flavomaculatus	3	3		3	3	vr	
Polycentropus irroratus	2	2		3	3	r	
Polypedilum gr bicrenatum	-2	-2		2	2	vc	new key available
Polypedilum laetum	1	1		2	1	u	new key available
Polypedilum laetum agg	1	1		2	2	u	new key available
Polypedilum pedestre	2	2		2	2	r	new key available
Polypedilum scalaenum	1	1		2	1	u	new key available
Potamanthus luteus	3	3		3	3	vr	
Potamophilus acuminatus	3	3		3	3	vr	
Potamophylax cingulatus	2	2		2	1	r	
Potamophylax latipennis	2	2		2	1	r	
Potamophylax luctuosus	3	3		2	1	vr	
Potamophylax nigricornis	2	2		3	3	r	
Potamothrix hammoniensis	-2	-2		1	1	vc	
Potamothrix moldaviensis	-2	-2		1	1	vc	
Potamothrix vejdovskyi	2			1	1	r	
Potthastia gaedii	3	3		2	2	vr	
Potthastia longimana	-1	-1		2	2	c	
Proasellus cavaticus	3	3		3	3	vr	
Proasellus meridianus	-3	-3		2	2	a	
Procladius sp	-3	-3		3	3	a	
Procloeon bifidum	2	2		3	3	r	
Protonemura meyeri	3	3		2	2	vr	
Protonemura nitida	3	3		2	2	ex	
Protzia eximia	3	3		3	3	vr	
Protzia invalvaris	3	3		3	3	ex	
Pseudanodonta complanata	3	3		3	3	vr	
Pseudosmittia sp	2	2		2	2	r	
Pseudosmittia virgo	2	2		1	1	r	
Psychomyia pusilla	3	3		3	3	vr	
Ptilocolepus granulatus	3	3		3	3	vr	
Pyrrhosoma nymphula			-2	3	3	vc	
Radix peregra	-3	-3		1	1	-	
Raptobaetopus tenellus	3	3		3	3	ex	
Rheocricotopus atripes	3	3		1	1	vr	
Rheocricotopus fuscipes	1	1		1	1	c	
Rheocricotopus gr fuscipes	1	1		3	3	c	
Rheopelopia ornata	1	1		1	1	u	
Rheotanytarsus photophilus	2	2		1	1	r	
Rheotanytarsus rhenanus	2	2		1	1	r	
Rheotanytarsus sp	-2	-2		3	3	vc	
Rhithrogena diaphana	3	3		1	1	ex	
Rhithrogena iridina	2	2		1	1	r	
Rhithrogena semicolorata	2	2		1	1	r	
Rhithrogena sp	2	2		2	3	-	
Rhyacophila fasciata	2	2		2	2	r	
Rhyacophila nubila	3	3		2	2	-	

taxon name	hydrological disturbance	morphological disturbance	drought	ease to identify	reliability	rarity	remark
Rhyacophila vulgaris	3	3		2	2		
Riolus cupreus	3	3		3	3	vr	
Riolus subviolaceus	3	3		3	3	vr	
Robackia demeyerei	3	3		3	3	vr	
Roederiodes juncta	2	2		0	0	-	
Scarodytes halensis	3	3		3	3	vr	
Sericostoma flavicorne	3	3		3	3	ex	
Sericostoma personatum	1	1		3	3	c	
Setodes argentipunctellus	3	3		2	2	vr	
Setodes punctatus	3	3		2	2	vr	
Setodes viridis	3	3		2	2	ex	
Sialis fuliginosa	1	1		3	3	u	
Sigara distincta	-2	-2		2	1	vc	
Sigara hellensi	3	3		3	3	vr	
Sigara nigrolineata	-1	-1		3	3	c	
Sigara striata	-3	-3		3	3	a	
Silo nigricornis	3	3		3	3	r	
Silo pallipes	3	3		3	3	r	
Silo piceus	3	3		3	3	-	
Silo sp	3	3		3	3	-	
Simulium morsitans	3	3		1	1	vr	
Simulium vernum	1	1		1	1	u	
Siphlonurus aestivalis	3	3		3	3	ex	
Siphlonurus armatus	3	3		3	3	vr	
Siphlonurus lacustris	3	3		3	3	ex	
Siphonoperla burmeisteri	3	3		3	3	ex	
Siphonoperla torrentium	3	3		3	3	ex	
Sisyra fuscata	3	3		3	3		
Somatochlora metallica	1	1		2	2	u	
Specaria josinae	2	2		3	3	r	
Sperchon clupeifer	2	2		2	2	r	
Sperchon glandulosus	2	2		1	1	r	
Sperchon setiger	2	2		3	3	r	
Sperchon squamosus	1	1		3	3	u	
Sperchonopsis verrucosa	3	3		3	3	vr	
Sphaerium rivicola	1	1		3	3	u	
Sphaerium solidum	1	1		3	3	u	
Stempellina sp	2	2		2	2	r	
Stempellinella brevis	3	3		1	1	vr	
Stenophylax permistus	3	3		2	2	vr	
Stenophylax sp	2	2		2	2	-	
Stictotarsus duodecimpustulatus	-1	-1		3	3	c	
Symposiocladius lignicola	3	3		3	3	vr	
Synorthocladius semivirens	1	1		3	3	u	
Taeniopteryx nebulosa	3	3		3	3	ex	
Tanytarsus bathophilus	1	1		1	1	u	

taxon name	hydrological disturbance	morphological disturbance	drought	ease to identify	reliability	rarity	remark
Tanytarsus ejuncidus	3	3		1	1	vr	
Tanytarsus lestagei	3	3		1	1	vr	
Tanytarsus striatulus	3	3		1	1	vr	
Thalassosmittia thalassophila	2			1	1	r	
Thienemanniella flaviforceps	1	1		1	1	u	
Tinodes assimilis	2	2		2	2	r	
Tinodes pallidulus	3	3		2	2	vr	
Tinodes unicolor	3	3		2	2	vr	
Torrenticola amplexa	3	3		3	3	vr	
Triaenodes simulans	3	3		3	3	vr	
Trissopelopia longimana	3	3		2	2	vr	
Unio crassus	3	3		3	3	vr	
Unio crassus nanus	3	3		3	3	vr	
Unionicola intermedia	2	2		1	1	r	
Valvata piscinalis	-3	-3		3	3	a	
Velia saulii	3	3		3	3	vr	
Wettina podagrica	2	2		3	3	r	
Wormaldia occipitalis	3	3		3	3	vr	
Wormaldia subnigra	3	3		3	3	vr	
Xanthoperla apicalis	3	3		3	3	ex	
Xenopelopia nigricans			-3	1	1	a	
Zavrelimyia sp			-1	3	3	c	

Appendix 2. Macrophyte indicators (type; w = water, t=terrestrial, m=moss: stressor; 1=decrease, 2=strong decrease, 3=disappearence, -1=increase, -2=strong increase, -3=mass increase; extra drought 0=tolerates temporary periods of drought: ease to identify: 1=hard, 2=moderate, 3=easy: reliability: 1=low, 2=moderate, 3=high).

taxon name	**type**	**hydrological disturbance**	**morphological disturbance**	**inlet water**	**drought**	**current**	**ease to identify**	**reliability**	**remark**
Alisma gramineum	w					1	2		
Alisma plantago-aquatica	w			0	-2	0	2		
Alopecurus aequalis	w				-2		2		
Apium inundatum	w				0		2		
Butomus umbellatus	w			-3	0		3		
Callitriche hermaphroditica	w				3		1		
Callitriche obtusangula	w				0		1		
Callitriche platycarpa	w				0		1		
Callitriche stagnalis	w				-2		1		
Caltha palustris subsp. araneosa	w	-3					3		prefers strong waterlevel fluctuation
Carex acuta	w				-2		1		
Carex elata	w				-2		1		prefers strong waterlevel fluctuation
Carex lasiocarpa	w				-1		1		
Carex limosa	w	3					1		
Carex oederi subsp. oederi	w				3		1		indicator of drought, winter aquatic, summer dry
Carex rostrata	w	3					1		intolerant to waterlevel fluctuation
Ceratophyllum submersum	w	2					3	2	intolerant to waterlevel fluctuation
Chara contraria	w		-2				1		
Chara vulgaris	w		-2				1		
Chara vulgaris var. papillata	w		-2				1		
Chrysosplenium alternifolium	w		3				3		
Chrysosplenium oppositifolium	w		3				3		
Cladium mariscus	w				1		3		
Deschampsia setacea	w	3			0/ 3		2		need flooding in winter
Echinodorus ranunculoides	w				0		2		
Echinodorus repens	w				0		2		
Elatine hexandra	w				0		3		
Eleocharis acicularis	w				0		1		
Eleocharis multicaulis	w				0		1		
Eleocharis palustris	w	-2			0		1		prefers strong waterlevel fluctuation
Eleogiton fluitans	w		-2		0	0	2		
Elodea canadensis	w	-1		2			3		tolerant to discharge

taxon name	type	hydrological disturbance	morphological disturbance	inlet water	drought	current	ease to identify	reliability	remark
									peaks
Elodea nuttallii	w		-3	-3			3		
Enteromorpha intestinalis	a			-3					
Enteromorpha sp	a			-3					
Eriophorum angustifolium	w				0		2		
Glyceria fluitans	w				0		3		intolerant to inundation
Glyceria maxima	w				0		3		intolerant to wave action
Glyceria notata subsp. declinata	w				0		1		
Groenlandia densa	w			-3		1	2		
Hottonia palustris	w			2			3		
Hydrocharis morsus-ranae	w				3		3		
Hydrocotyle vulgaris	w	0					3		tolerant to waterlevel fluctuation
Hypericum elodes	w			3	0		2		
Lemna gibba	w			-3			1		
Littorella uniflora	w				0		3		
Lycopodium inundatum	w				0		3		winter flooding
Lythrum portula	w				0		3		
Menyanthes trifoliata	w			3			3		indicative for seepage
Montia fontana	w				0	0	3		restricted to flowing wtaer
Myosotis palustris	w				0		3		
Myriophyllum verticillatum	w				0		2		indicative for seepage
Najas marina	w			-3			3		
Narthecium ossifragum	w				0/3		3		
Nitella capillaris	w		-3				1		
Nitella flexilis	w		-2			0	1		
Nymphaea alba	w				0	3	3		
Nymphoides peltata	w					0	3		
Oenanthe aquatica	w				0		3		germination during drought
Phalaris arundinacea	w	-3			0	0	3		in dynamic environments
Phragmites australis	w				0	0	3		
Pilularia globulifera	w	3			0		3		needs waterlevel fluctuation
Polygonum amphibium	w	-3				0	3		tolerant to waterlevel fluctuation and peak flows
Polygonum hydropiper	w				3		3		
Potamogeton acutifolius	w			3		0	1		
Potamogeton alpinus	w	0	-2			0	1		tolerant to peak flows

taxon name	type	hydrological disturbance	morphological disturbance	inlet water	drought	current	ease to identify	reliability	remark
Potamogeton berchtoldii	w	1		3		0	1		
Potamogeton coloratus	w				0		1		seepage
Potamogeton compressus	w			3		0	1		
Potamogeton crispus	w			-2	0	0	2		positive influence waterlevel fluctuations
Potamogeton lucens	w	-2					2		resistant to wave action
Potamogeton mucronatus	w					0	1		
Potamogeton natans	w	2		3		0	2		stable environment, no water level fluctuation or wave action
Potamogeton nodosus	w	2					1		intolerant to water level fluctuation
Potamogeton obtusifolius	w					0	1		
Potamogeton pectinatus	w	-3		-3	0	0	2		
Potamogeton perfoliatus	w	0				0	1		tolerant to sudden water movement
Potamogeton polygonifolius	w				0	0	2		
Potamogeton pusillus	w			0	0	0	1		
Potamogeton trichoides	w	3	-3	-3		0	1		intolerant to water movement
Potentilla palustris	w			3			3		indicator for seepage
Ranunculus aquatilis	w				0	0	2		
Ranunculus aquatilis var. diffusus	w			1			1		
Ranunculus circinatus	w					0	2		
Ranunculus flammula	w			3	0		3		
Ranunculus fluitans	w	3				1	2		in running waters
Ranunculus hederaceus	w				0	0	3		
Ranunculus lingua	w	3			3		3		in running waters
Ranunculus peltatus	w					0	2		
Ranunculus peltatus var. heterophyllus	w		-3			0	1		in channalised streams
Ranunculus sceleratus	w				0		2		
Ranunculus tripartitus	w				0		2		
Rhynchospora alba	w				0/3		3		
Rorippa microphylla	w					0	2		
Rorippa nasturtium-aquaticum	w					0	2		
Ruppia cirrhosa	w	3	-3				2		intolerant to wave action
Ruppia maritima	w	0					2		somewhat tolerant to wave action/water movement
Sagittaria sagittifolia	w			2			3		indicator for seepage
Scheuchzeria palustris	w				3		3		

taxon name	type	hydrological disturbance	morphological disturbance	inlet water	drought	current	ease to identify	reliability	remark
Scirpus lacustris	w	3			2	0	3		
Scirpus maritimus	w				0		3		
Scirpus triqueter	w	3					3		
Senecio paludosus	w	3			0	0	2		
Sium latifolium	w					0	3		
Sparganium emersum	w	-3				0	3		
Sparganium erectum	w	-3			0	0	3		indicator for wave action in winter
Sparganium natans	w		-2		1		3		
Spirodela polyrhiza	w					0	3		
Stratiotes aloides	w			3	3		3		
Typha angustifolia	w	-3				0	3		tolerant to wave action
Typha latifolia	w	3			0		3		intolerant to wave action
Utricularia minor	w				0		2		
Veronica beccabunga	w	2				0	3		little water level fluctuation
Zannichellia palustris subsp. palustris	w	0			1	0	2		
Zannichellia palustris subsp. pedicellata	w				0		2		
Zostera marina	w				0		3		
Zostera noltii	w				-1		3		tolerant to strong water level fluctuation

Appendix 3. Fish indicators (codes: stressor; 1=decrease, 2=strong decrease, 3=disappearence, -1=increase, -2=strong increase, -3=mass increase; extra drought 0=tolerates temporary periods of drought: ease to identify: 1=hard, 2=moderate, 3=easy: reliability: 1=low, 2=moderate, 3=high).

taxon name	**hydrological disturbance**	**morphological disturbance**	**ease to identify**	**reliability**	**remark**
Alburnus alburnus	1	2	3	2	
Umbra pygmaea	1	2	3	3	
Perca fluviatilis		1	3	3	
Barbus barbus	2	2	3	3	
Salmo trutta fario	2	3	3	3	migrating specimens alike Salmo salar
Lampetra planeri	3	3	3	3	larvae alike L. fluviatilis
Barbatula barbatulus	1	2	3	3	
Rhodeus sericeus	1	1	3	3	
Platichthys flesus	1		3	3	
Gasterosteus aculeatus	2	2	3	3	
Alosa alosa	3	3	1	2	alike A. fallax
Phoxinus phoxinus	2	2	3	3	
Alosa fallax	3	3	1	2	alike A. alosa
Alburnoides bipunctatus	2	3	3	2	
Misgurnus fossilis	2	1	3	3	
Coregonus oxyrinchus	3	3	3	2	
Cyprinus carpio	1	1	3	3	
Cobitis taenia	1	2	3	3	
Leuciscus cephalus	2	3	2	2	confused with L. idus
Lota lota	2	2	3	3	
Silurus glanis		1	3	3	
Anguilla anguilla	1	1	3	3	
Cottus gobio	1	2	3	3	
Gobio gobio	1	1	3	3	
Lampetra fluviatilis	1	2	3	2	larvae alike L. planeri
Rutilus erythrophthalmus	1		3	2	alike R. rutilus
Leuciscus leuciscus	2	2	2	2	alike R. rutilus
Chondrostoma nasus	2	2	2	2	
Esox lucius	1	1	3	3	
Acipenser sturio	2	3	3	3	
Leucaspius delineatus	1	1	1	2	often unidentified
Thymallus thymallus	2	3	3	3	
Leuciscus idus	1	3	2	2	alike L. cephalus
Salmo salar		2	1	1	alike S. trutta
Salmo trutta	2	2	1	2	alike S. salar
Tinca tinca		1	3	3	
Petromyzon marinus	1	2	3	3	

6. Contribution by BOKU

T. Ofenböck, W. Graf & A. Schmidt-Kloiber

Task 2: *Hydromorphological changes and aquatic and riparian biology*

Subtask 2.1 Review and data collation

Subtask leader: *Masaryk University - MasUniv (Libuse Opatrilova)*

Hypothesis / Questions

- *What are the relations between land use, hydrology and hydromorphology and habitat composition?*
- *What are the relations between habitat and species composition?*
- *Which species or biological parameters are good indicators for changes in hydrology/hydromorphology?*

1. Introduction

1.1. Investigated Area

Upper Austria and the catchment of the river Waldaist has a long history of land use change associated with human occupation. In Middle Ages the human population was higher and the land use (agriculture) as well as the water use for mills was quite intensive (Kammerer et al., 1997). Nowadays human population density is comparatively low (31 inhabitants/km²) and agrarian economy is mainly based on forestry and grassland for cattle breeding: the share of forested areas is about 49 %, only about 15 % is used as crop land and 30.5 % is used as grassland (see figure 1). Figure 2 shows that cropland is not relevant at all in riparian properties. The stand density of productive livestock is very low as well (0,47 cattle units) (Amt d. Oberösterr. Landesregierung, 1996).

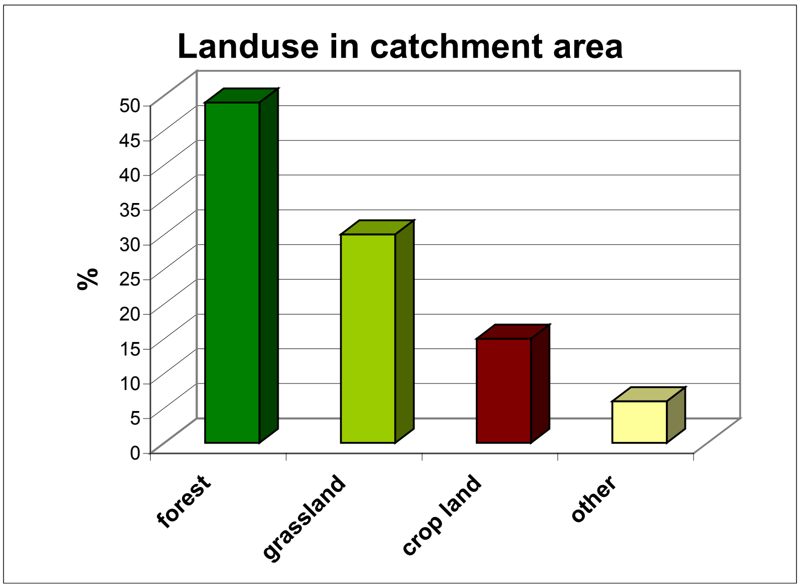


Figure 1: Landuse within the catchment area (Amt d. Oberösterr. Landesregierung, 1996).

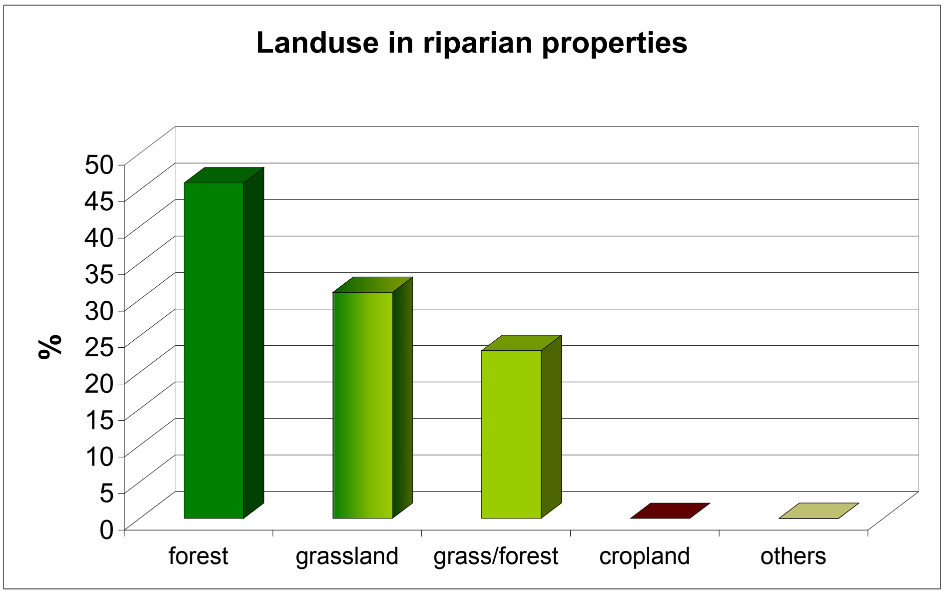


Figure 2: Landuse within riparian properties (Ofenböck 1997).

Agricultural land use (cropland) decreases since decades and cropland and grassland were continuously substituted by forests. Naturally occuring deciduous and mixed forests and fens are more and more replaced by monocultures of coniferous trees (*Picea abies*) under suboptimal conditions.

The river Waldaist was chosen as study site, because a drastic loss of specimens as well as an dramatic overaging of populations of the freshwater-pearl mussel *Margaritifera margaritifera* was observed during earlier investigations. The negative effects of unstable fine sediments on more or less sessile organisms could clearly be documented in the field and led to a substantial interest in the problem of sedimentation.

In the river Waldaist as well as in many rivers in bioregion *Austrian Granite and Gneiss Region* (ecoregion 9) the natural river bed is nearly entirely smothered with fine sediments leaving only streches of higher slope gradient untangled. Contrary to other findings which link erosion rather with deforestation and changes from woodland to rural areas, afforestation with spruce did increase erosional effects. Due to sensitivity of the trees to soil-moistness the forests are artificially drained, thus creating a steady source of fine sediments (sandy deposits and fine to medium sized gravel) which are transported into the rivers. Though the term siltation is linked with deposition of finer substrates like sand and mud we use it nevertheless as it describes the eco-morphological processes and implications.

1.2. Siltation

Siltation can be defined as the deposition of fine sediment either on the surface of the stream bed or within a gravel substrate. Under natural conditions the balance of erosion and sedimentation creates a diversity of sediment patches over the riverbed, which is vital for the maintenance of good habitat diversity and to the different life stages of some species. Problems arise through high deposition rates, smothering of coarser patches with finer sediments, and ingress of finer materials that may deplete oxygen levels either through a reduction in throughflow rates or, in the case of organic particulates, by their own use of oxygen (e.g. Buddensiek 1991, 1992, Buddensiek und Ratzbor 1995, Buddensiek et al. 1997 Richards & Bacon 1994).

By reviewing the literature it became obvious that siltation is a major topic in riverine ecology. It is widely recognised that anthropogenic activities such as agriculture (e.g. Walling 1990; Richards et al., 1993), forestry (e.g. Scrivener and Brownlee, 1989; Murphy and Milner, 1997), groundwater abstraction (e.g. Bickerton *et al*., 1993) and periodic in-channel management activities (e.g. Brookes, 1986; Hearne and Armitage, 1993; Doeg and Koehn, 1994) can result in significant changes to in-channel deposition, storage and erosion of fine sediments.

The ecological consequences of siltation comprehends the following topics:

- substrate composition
- substrate stability
- quantity, quality and availability of food resources
- clogging of hyporheos

Fine sediment suspension and deposition affects benthic invertebrates in four ways (Wood and Armitage, 1997): (1) by altering substrate composition and changing the suitability of the substrate for some taxa (Erman and Ligon 1988, Richards and Bacon 1994); (2) by increasing drift due to sediment deposition or substrate instability (Culp and others 1985, Rosenberg and Wiens 1978); (3) by affecting respiration due to the deposition of silt on respiration structures (Lemly 1982) or low oxygen concentrations associated with silt deposits (Eriksen 1966); and (4) by affecting feeding activities by impeding filter feeding due to an increase in suspended sediment concentrations (Aldridge and others 1987), reducing the food value of periphyton (Cline and others 1982, Graham 1990) and reducing the density of prey items (Peckarsky 1984). A holistic overview of the effects of fine sediments in the lotic ecosystem (Wood & Armitage, 1997) is given in figure 3.

According to Wood & Armitage (1997) these changes result in

- an impairment of filter-feeding and reduced metabolic rate of mussels;
- reduced density, abundance, and diversity;
- change in community structure;
- reduced diversity and biomass;
- decline in abundance of emerging insects;

Both suspended solids and condition of the substrate, particularly with regard to siltation, are important for many of the species. For example, high suspended solids concentrations can affect the feeding and health of individual species either indirectly through increased turbidity of the water, or directly through clogging of gills. Siltation is a potential problem both with regard to access to suitable substrate – for example, for the establishment of the freshwater pearl mussel (*Margaritifera margaritifera*) – and with regard to egg and fry survival in populations of salmonid fishes. Additionally we propose a decrease of grazers due to the lack of coarse stable substrates.

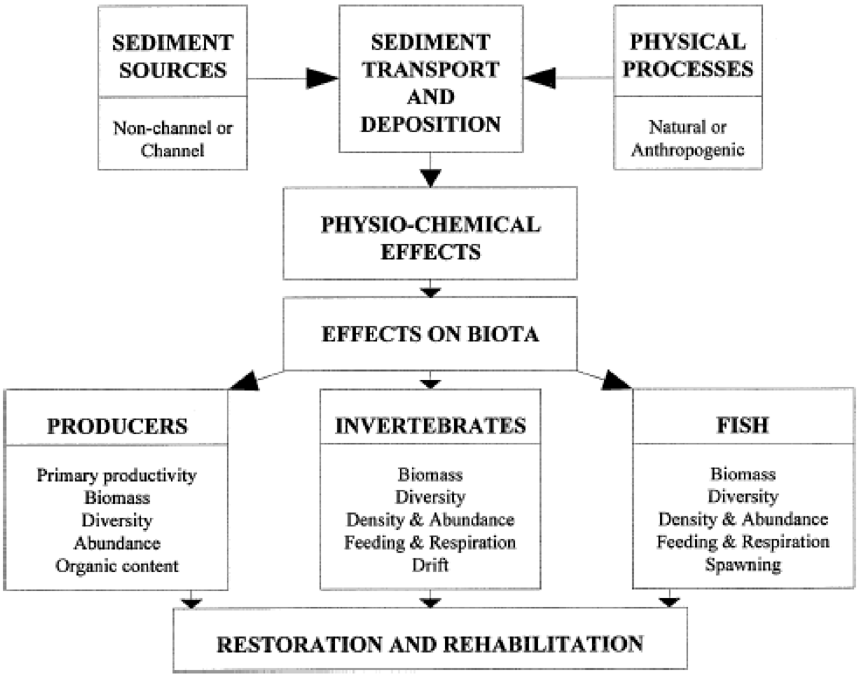


Figure 3**:** A holistic overview of fine sediment in the lotic ecosystem (Wood & Armitage, 1997).

Sediments affect the nature of the hyporheic habitat directly (Brunke & Gonser, 1997). Sediment factors are of importance in determining the vertical distribution of the hyporheos including porosity (Maridet et al. 1992) and the amount of fine material (Maridet et al., 1992; Richards & Bacon, 1994). However, by interacting with vertical hydrological exchange (Vaux, 1968) sediment features may indirectly affect the hyporheic community by altering interstitial physicochemical conditions such as temperature, concentrations of oxygen and nutrients through changes in water residence time (Jones & Holmes, 1996; Sobczak & Findlay, 2002). Sediment factors (including the proportion of fine sediments) have been suggested to be important determinants of the distribution of hyporheic invertebrates in other studies (Maridet et al., 1992; Richards & Bacon, 1994). Sediment may have direct effects on invertebrates study by altering habitat characteristics (such as pore size) or by restricting their ability to feed, respire or move.

An additional question is sediment quality. This is important in relation to both phosphorus and contaminants (heavy metals and organic compounds). Phosphorus plays a key role in eutrophication of surface waters. Elevated phosphorus concentrations in rivers have been linked to increasing rates of plant growth, changes in species composition and proliferation of planktonic, epiphytic and epibenthic algae, resulting in shading of higher plants. A key element governing phosphorus levels is the uptake and release by riverine sediments. The presence of contaminants in the fine fraction of aquatic sediments can also lead to acute or chronic toxicity to both sediment-dwelling and feeding organisms, and, through re-suspension of the sediment or release of the contaminants, organisms inhabiting the water column. Key factors are both the presence of the contaminant and its bioavailability.

1.3. Indicators

Many species of aquatic invertebrates have a clear preference for one substrate type or another. Such cases are generally due to the specific requirements associated with feeding habits, respiratory needs or shelter (Minshall, 1984; Ward, 1992). Some of the species with marked preferences are those showing specific morphological adaptations. This is the case with fauna considered as lithophilous, e.g. characterised by different species of *Brachycentrus*, Blephariceridae, Heptageniidae, *Rhyacophila*, Glossosomatidae and Simuliidae, or species of *Taeniopteryx* and *Micrasema*, which live amongst mosses, or burrowers living in gravel or sand (some species of Leuctridae, Ephemeridae and Chloroperlidae as well as the rare sand dweller *Isoptena serricornis*) (Zwick & Hohmann, in print), or in mud (e.g. species of the genus *Caenis*) (Elliot, 2002).

When considering whether a given species prefers one type of substrate or another, it must be borne in mind that it may change its preference according to its stage of development. For the same insect which shows an aerial stage, one must distinguish the substrate used by the aquatic larvae, the pupae (when applicable) and the egg-laying zones used by the adults. Much information is available to support such changes in preference in the same species.

During recent decades substantial research in lotic ecology has been carried out to elucidate the link between physical features and macroinvertebrate communities (e.g. Statzner and Higler, 1986; Brown and Brussock, 1991). Studies have mainly focused on the effects of current velocity and shear stress (Erdington, 1968; Bouchardt and Statzner, 1990), and substrate composition (Beisel et al. 2000, Percival and Whitehead, 1929; Minshall, 1984; Reice, 1980) on the structure, function and diversity of macroinvertebrate communities.

Work has primarily concentrated on analysing the influence of high discharges on unstable and erosion-dominated environments in upland streams (Matthaei, et al., 2000; Death, 1996; Matthaei and Townsend, 2000; Townsend et al., 1997). Effects of erosion and deposition on the macroinvertebrates have been studied in riffles and pools (Scarsbrook and Townsend, 1993). Furthermore, several investigations have addressed the relative importance of physical features compared to biotic interactions in determining e.g. the realised niche of stream invertebrates.

The decisive role played by the physical environment in the composition and dynamics of fluvial benthic macroinvertebrate communities is well known and has been described in numerous studies. There are different ways of approaching this relationship, either from the perspective of individuals or of the entire communities, or assessing the implication of an isolated physical factor or of more complex structures (habitat, mesohabitat, etc.).

1.4. Expected cause-effect chain and relation to climate change

A change in climatic conditions will lead to changes in land use and hydrology. Siltation rates may change through intensification or extensification of land-use or a change of landuse. A change in discharge regime (more frequent flood events or as a result of floods that generate a near-natural habitat structure) as well could have effects on habitat composition and sediment transport rates in time and space. The hypothetical cause-effect chain expected is shown in figure 4.

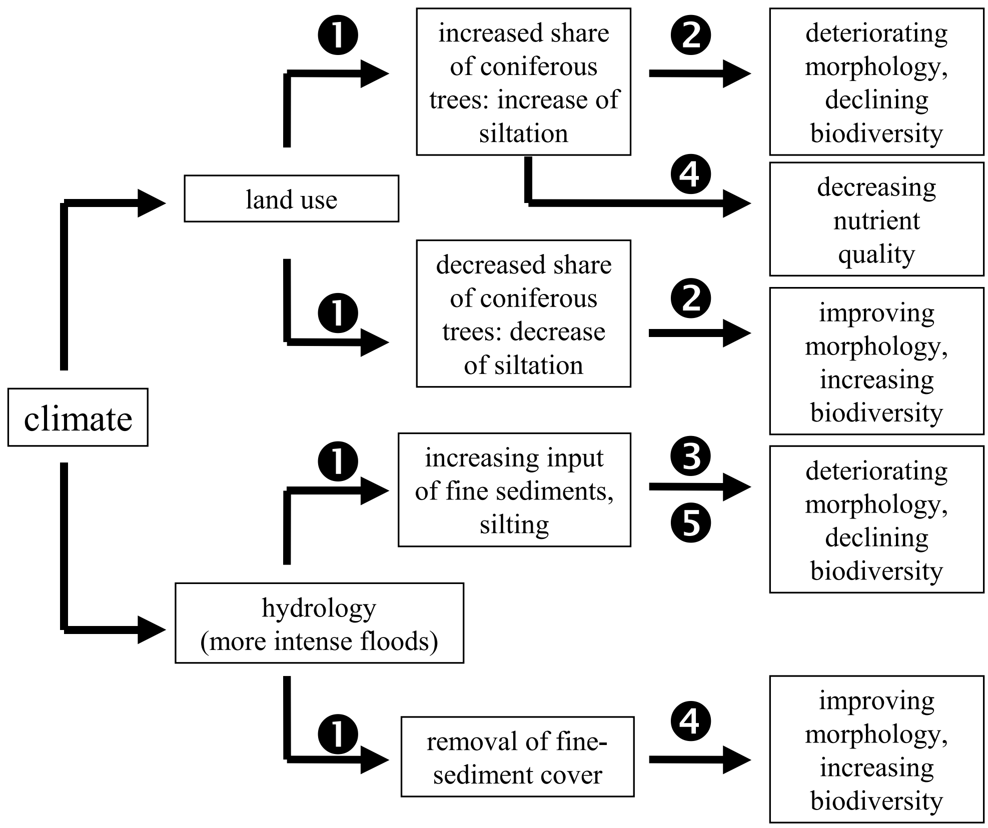


Figure 4: Expected hypothetical cause-effect chain.

Changes in land use and flood dynamics will change the (fine) sediment transport dynamics and may lead to dramatic changes in habitat composition and habitat quality. As shown in WP 2, Task 1, where land use data were correlated with the calculated transport rates in proportion to discharge there is a clear relationship between land use and the mobility of sandy substrates in the catchment area. Drainage measures within the catchment area seem to be the major resource for siltation processes.

Sections with (mobile) sandy deposits are hostile to several sensitive species (e.g. *M. margaritifera*) and will therefore lead to a loss species and biodiversity. Instream sandy deposits overlays also lead to changes in chemistry of the hyporheic interstices (e.g. Buddensiek 1991, 1992; Buddensiek et al. 1990 Richards & Bacon 1994) The expected cause- effect-chain results therefore in changes of the species composition.

2. Data collation

2.1. Review of existing literature

Available literature concerning geology, soil typology and chemistry, morphology, vegetation, riverine vegetation, historic and recent land use, climate, discharge, hydropower use, water chemistry, sediment dynamics and biology within the catchment area was collected as well as literature about sediment dynamics, siltation, land use / sediment. Furthermore, papers on the autecology of species occuring in the investigated area as a basis for the selection of key species . The literature list is appended as EndNote ® file.

2.2. Collection of historical and present day biological data

Available biological data from different sources were collected. The biological data comprehend species lists from 6 federal monitoring sites (2 occasions, data on macroinvertebrates, phytobenthos, chemical data, site characteristics, ciliates), and 9 additional sites from further investigations (only macroinvertebrates). The location of sites within the catchment area is shown in figure 5.

Additionally, GIS data is available from the catchment including land use data (GIS-DORIS - Digitales Oberösterreichisches Raum-Informations-System), precipitation data and temperature data (3 Stations, 1971-2004), discharge records and water temperature (2 stations 1976-2004), obtained from the Upper Austrian Government (Hydrographischer Dienst). Furthermore data on bed sediment grading and mobility rates of sandy substrates from four of the main tributaries of the River Waldaist (KILLINGSEDER 1998) were collated.

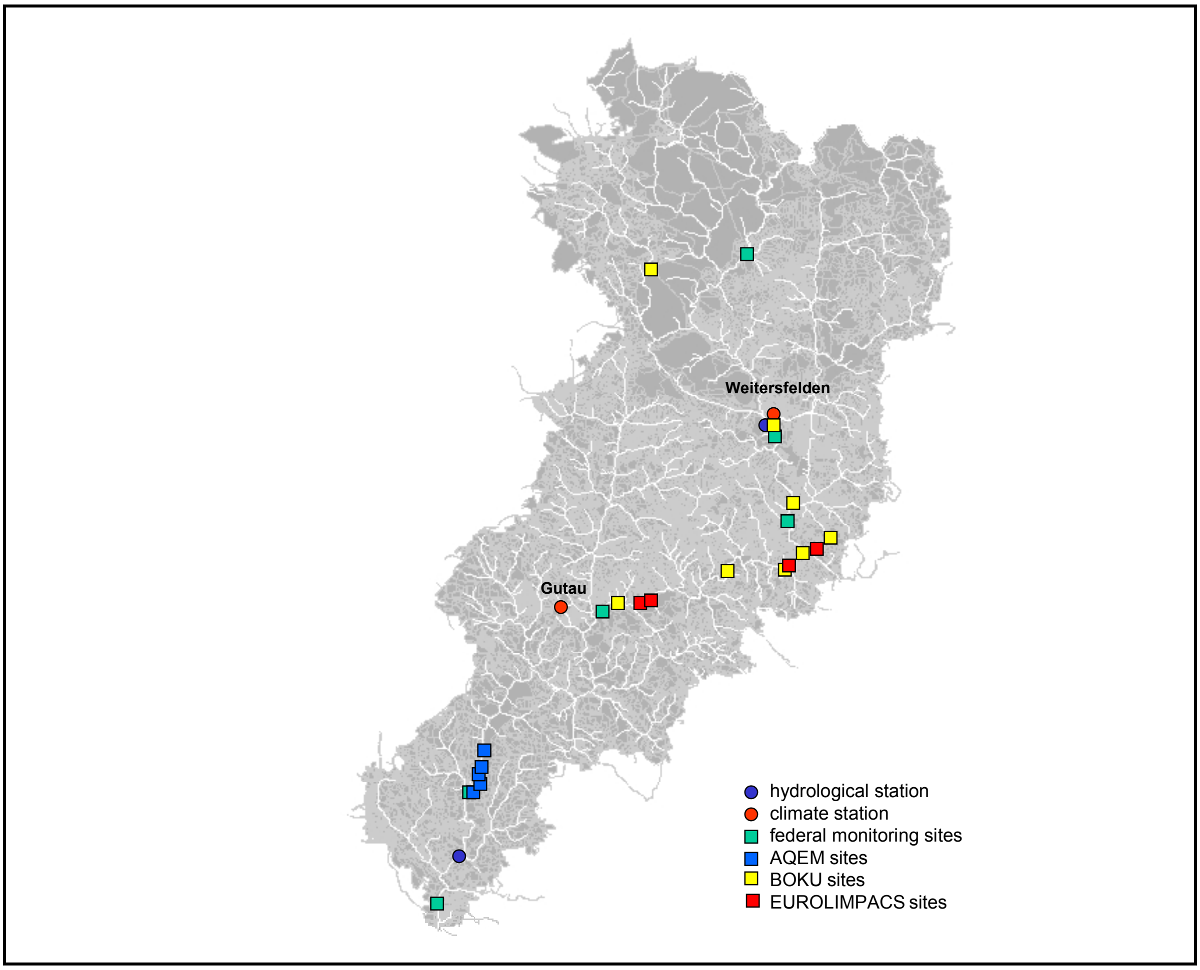


Figure 5: Location of hydrological and meteorological stations and sampling sites in the catchment area.

3. Data analysis

3.1 Relations between land use / hydrology / hydromorphology and habitat composition

The main stressor in the catchment area is siltation caused by intense land use (Picea abies-crops), leading to considerable degradation of instream habitat-structures. The huge input of silty bedloads originate from surface runoff in the forests. Also drainage measures to enable coniferous forestry in ,amy parts of the catchment seem to be a major resource for siltation processes. This sandy deposits create unstable and hostile conditions for several aquatic invertebrates.

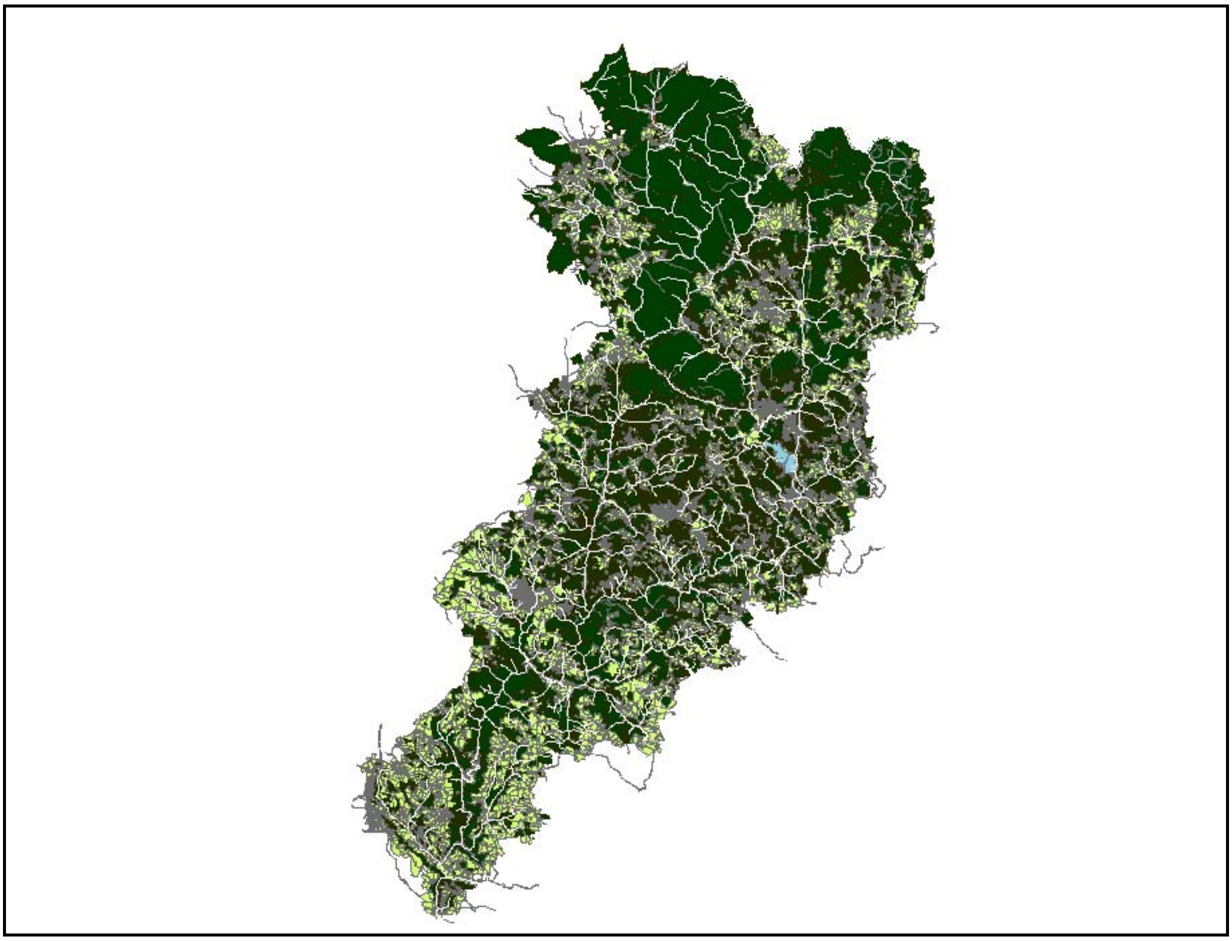


Figure 6: Land use in the catchment area (dark green: forest, light green: grassland).

Data on bed sediment grading and mobility rates of sandy substrates from four of the main tributaries of the River Waldaist (Killingseder 1998) were available. The study clearly demonstrated that the huge amount of mobile sandy substrates is mostly caused by surface runoff and drainage measures in coniferous forests. Using grain-size distribution curves, channel attributes and discharge data the mobility of bed load in relation to discharge was estimated.

For the analysis of the land use within the catchment area (this was already carried out in WP2, task 1.1.) GIS data from Upper Austria (DORIS) was used. The GIS database contains different land use categories, but the most important ones in the investigated area are: forests, different kinds of grassland and crop land (figure 6). These categories were used for the analysis.

The GIS - land use data (share of forested areas) were correlated with the calculated transport rates in proportion to discharge. Although the mobility also strongly depends on the topology and slope of the river corridor the correlation indicates a relationship between land use and the mobility of sandy substrates in the catchment area (r =0.64).

3.1. Microhabitat and stretch scale

Approach A (a posteriori selection of indicators):

- identification of key processes (stressors) in the catchment
- documentation of existing habitats (habitat mapping)

3.1.1. Preselection of potential indicator taxa or biological parameters

As a first step for preselecting potential indicators for siltation effects all available taxalists from the catchment were pooled and a combined taxalist for the whole catchment was created. Available literature about the occuring species was collected and reviewed. Also existing classification schemes (AQEM/STAR database, FAA (Moog et al., 1995)) for this species concerning substrate, current and feeding preferences were regarded.

Interrelation between substrate composition and benthic communties

Methods

To demonstrate whether there is an interrelation between substrate composition and benthic invertebrate assemblages, 24 samples from the study catchment were analysed. The samples were taken during the AQEM project and treated following the AQEM manual. Invertebrates were sampled using the Multi-Habitat-Sampling approach.

The substrate composition was estimated in 5%-steps in the field. For data analysis purposes the substrates were then organised in three groups, summarising mega- and macrolithal, meso- and microlithal as well as akal and psammal. Each sites was assigned to one class according to its dominant (> 50%) substrate type. These classes were used for scatter plot overlay in Figure 7.

Species tables were taxonomically adjusted and ln(x+1)-transformed.

Non-metric multidimensional scaling (NMS) (Kruskal 1964) was used as ordination method for analysing the data. Ordination analysis is a means of reducing the complexity of multivariate data so that it can be visualized graphically, and examined with other, more conventional, exploratory analyses. NMS develops an ordination from any distance or similarity matrix. The procedure is to rank the distances in the original matrix, and then attempt to display those ranks of distances in a specified number of dimensions, usually 2 or 3. In effect, NMS reproduces a map of the entities from the distances among the sites. The goodness-of-fit of the estimated distances is measured by the stress statistic. The computational procedure is a numerical approximation, beginning with an arbitrary configuration and reducing the stress statistic in each successive approximation. When plotted in ordination space, sites with similar species composition will be close together. Ordination plots are thus often used to verify or falsify an *a priori* classification hypotheses. NMS is relatively robust for species composition data, and has been applied frequently in recent years to benthic macro-invertebrate data (e.g., Reynoldson et al., 1995; Barbour et al., 1996). The Soerensen/Bray-Curtis coefficient was used as the distance measure and a 2-dimensional solution strived for.

To identify benthic invertebrate species that may serve as indicators for different substrate types an Indicator Species Analysis (ISA) according to Dufrêne & Legendre (1997) was used. The method combines information on the concentration of species abundance in a particular group and the faithfulness of occurrence of a species in a particular group. It produces indicator values for each species in each group. These are tested for statistical significance using a Monte Carlo Test. The relative abundance and the relative frequency of a species in a group are calculated. The indicator value is then calculated by multiplying these two values. Indicator values range from 0 (no indicator) to 100 (perfect indicator)

NMS and ISA were performed with PC-ORD 4.1 (McCune & Mefford, 1999).

Results

Main channel

For the NMS analysis a 2-dimensional solution is chosen. The ordination of the sampling sites is illustrated in a scatter plot (figure 7). Each item in the plot represents the species composition of a sampling site, showing sites with similar species inventory close together. The overlay shows the dominant substrate at a site (squares: mega-/macrolithal, circles: meso-/microlithal, diamonds: akal/psammal). The result of the NMS analysis is presented as joint plot to show the relationship between the estimated substrates and the species composition. The angle and length of the line tell the direction and strength of the relationship.

Although samples analysed here were taken for another purpose than substrate analyses a clear relationship can be seen between the macro-invertebrate community and the substrate composition. Samples belonging to the substrate group mega-/macrolithal and substrate group meso-/microlithal are displayed in the top left corner. The gradient of decreasing substrate size is indicated by the line leading to the “akal/psammal” substrate group in the right bottom corner of the NMS analysis (Figure 7).

These results are the basis for the next analysis step. Using Indicator Species Analysis (ISA) indicator species for the three substrate groups are examined. Species (taxa) with indicator values greater than 40 are displayed in Table 1.

Based on the available data most indicator species are identified for the mega-/macrolithal group, showing the caddisflies *Micrasema minimum* (indicator value (IV): 79), *Silo piceus* (71) and *Agapetus ochripes* (69), the mayfly *Epeorus sylviola* (73), the beetles *Elmis maugetii* (73) and *Hydraena gracilis* (62), the non biting midges *Cricotopus lygropis* (73), the worms *Haplotaxis gordioides* (67), *Nais stolci* (63) and *Cognettia sphagnetorum* (60) as good indicators (IV >= 60) for this substrate group.

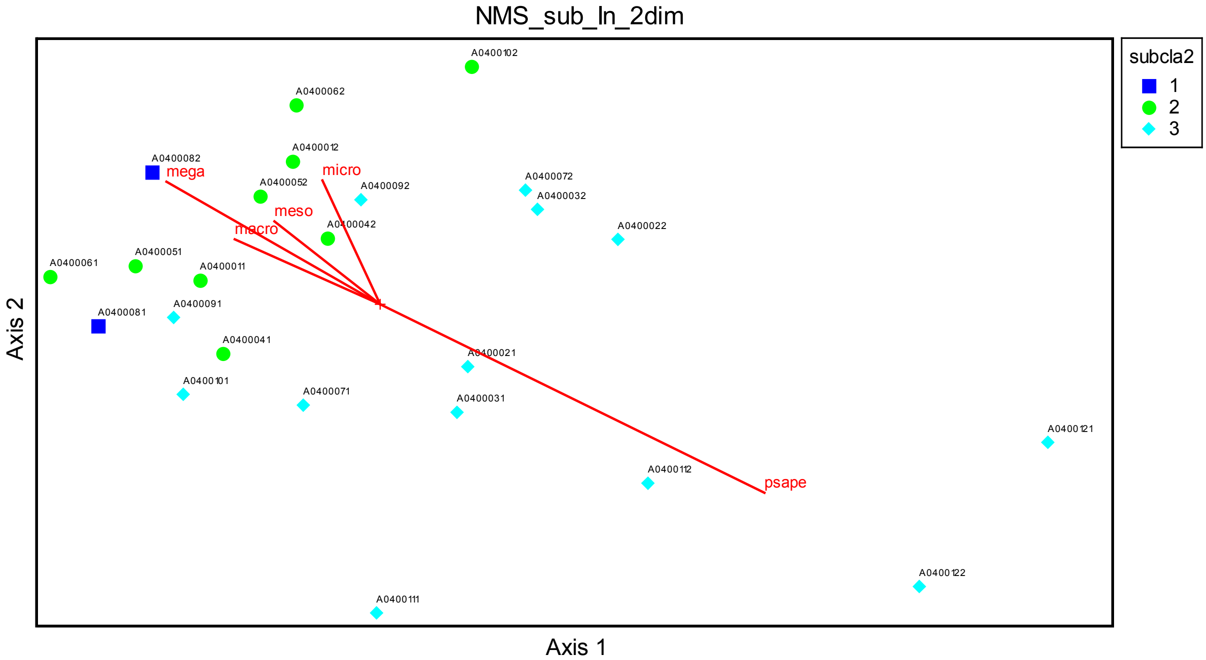


Figure 7: Scatter plot of a NMS analysis of AQEM samples in the subjected catchment; the overlay shows dominant substrate classes at a given site (squares: mega-/macrolithal, circles: meso-/microlithal, diamonds: akal/psammal); the lines show the relationship between benthic assemblages and substrates; stress: 7.85

For the meso-/microlithal group the indicator values are not greater than 54. Best indicators (IV >=40) for the group are the Trichoptera *Lepidostoma hirtum* (54), *Hydropsyche silfvenii* (49), *Odontocerum albicorne* (49), *Hydropsyche siltalai* (46), *Silo pallipes* (45), the chironomids *Micropsectra atrofasciata*-Agg. (46), *Synothocladius semivirens* (42), *Tvetenia verrallii* (42), the beetle *Limnius perrisi* (40) and other Diptera like *Chelifera* sp. (44), *Ibisia marginata* (43).

Indicators (IV >= 40) for the akal/psammal substrate group were identified as the Oligochaetes *Aulodrilus japonicus* (60), *Limnodrilus hoffmeisteri* (46), the mayfly *Centroptilum luteolum* (53), the chironomids *Polypedilum laetum* (49), *Prodiamesa olivacea* (47), *Cladotanytarsus vanderwulpi* (45) and *Microtendipes chloris*-Gr. (40) as well as the alderfly *Sialis lutaria* (47).

Table 1: Results of the ISA, showing indicator values above 40 for the three groups of dominant substrates

	Akal/ Psammal	Meso- Microl.	**Mega- /Macrol.**
Micrasema minimum	3	1	**79**
Epeorus sylvicola	1	13	**73**
Elmis maugetii	0	11	**73**
Cricotopus lygropis	4	1	**73**
Silo piceus	1	9	**71**
Agapetus ochripes	5	1	**69**
Haplotaxis gordioides	1	15	**67**
Nais stolci	1	13	**63**
Hydraena gracilis	0	25	**62**
Hemerodromia sp.	1	18	**61**
Cognettia sphagnetorum	0	27	**60**
Eukiefferiella clypeata	1	18	**60**
Alainites muticus	3	14	**58**
Eukiefferiella similis	3	20	**58**
Antocha sp.	4	20	**57**
Paracricotopus niger	6	20	**53**
Hydropsyche pellucidula	4	20	**51**
Dugesia lugubris	0	0	**50**
Stylodrilus heringianus	11	19	**50**
Baetis alpinus	0	0	**50**
Hydraena pygmaea	0	0	**50**
Rhyacophila tristis	0	0	**50**
Cardiocladius capucinus	0	0	**50**
Eurycnemus crassipes	0	0	**50**
Polypedilum convictum	11	19	**50**
Simulium degrangei	0	0	**50**
Blephariceridae Gen. sp.	0	0	**50**
Tipula saginata	0	0	**50**
Lasiocephala basalis	6	27	**48**
Rheosmittia spinicornis	11	19	**48**
Tabanidae Gen. sp.	0	0	**48**
Oligoneuriella rhenana	0	1	**47**
Dicranota sp.	10	34	**47**
Propappus volki	8	33	**46**
Elmis rioloides	10	36	**46**
Tvetenia calvescens	7	35	**45**
Polypedilum pedestre	1	0	**43**
Atherix ibis	6	32	**43**
Baetis rhodani	6	39	**42**
Corynoneura sp.	22	23	**42**
Thienemanniella sp.	9	34	**42**
Orthocladius rivicola-Gr.	0	2	**41**
Parametriocnemus stylatus	14	32	**41**
Rhyacophila dorsalis	0	2	**40**
	Akal/ Psammal	**Meso- Microl.**	Mega- /Macrol.
Lepidostoma hirtum	12	**54**	0
Hydropsyche silfvenii	1	**49**	0
Odontocerum albicorne	6	**49**	14
Hydropsyche siltalai	2	**46**	16
Micropsectra atrofasciata-Agg.	3	**46**	0
Silo pallipes	3	**45**	0
Chelifera sp.	0	**44**	0
Ibisia marginata	5	**43**	0
Synorthocladius semivirens	14	**42**	0
Tvetenia verralli	1	**42**	20
Limnius perrisi	1	**40**	0

	Akal/ Psammal	Meso- Microl.	**Mega- /Macrol.**
Aulodrilus japonicus	**60**	3	0
Centroptilum luteolum	**53**	2	0
Polypedilum laetum	**49**	7	0
Sialis lutaria	**47**	1	0
Prodiamesa olivacea	**47**	14	0
Limnodrilus hoffmeisteri	**46**	0	0
Cladotanytarsus vanderwulpi	**45**	40	3
Microtendipes chloris-Gr.	**40**	12	0

The ISA is a valuable tool for getting a first impression which species may serve as indicator species for a certain pre-defined group, but one has to be aware of the limitations of the method. Analysis based on only a limited dataset may not always reflect nature. In the study at hand the analysis is based on 24 MHS samples that were collected for detecting human impacts on stream communities, but not exclusively designed for habitat analysis. For statistical analysis the sampling sites were arranged in three arbitrary defined substrate groups according the dominant substrate type at the site. This approach may influence the results which may reflect some artefacts.

Generally the temporal and spatial distributions of freshwater organisms are tightly connected to aspects of zoogeography as well as their physiological and behavioural responses to varying levels of environmental factors. The key factors, such as water temperature, flow velocity, oxygen balance, food composition and the availability and quality of habitat are regarded as the main predictors of the community composition and distribution of benthic invertebrates. All these factors build up a complex network of interrelations and each of them may influence the ISA (or other statistical analysis) and has therefore to be considered as part of the overall result.

The results of the ISA are cross-checked by experts. The caddisfly *Micrasema minimum*, the mayfly *Epeorus sylvicola* and the chironomid *Cricotopus lygropis* for example were also classified to the mega-/macrolithal substrate group by expert judgement. Other species classified as typical for that group by the ISA may also occur in other (smaller sized) lithal-substrates, like *Silo piceus* or *Agapetus ochripes*. Other species were completely mis-classified by the ISA based on the available dataset. This is true for *Polypedilum convictum* or *Rheosmittia spinicornis* that prefer finer substrates. Also species inhabiting rare habitats may be classified into an inadequate group as the groups where only defined on dominant substrates and do not consider rare ones. Examples are *Lasiocephala basalis* and *Lepidostoma hirtum*, both occurring mainly on wood. On the other hand euryoecious species may be classified into a certain group although they occur in all different substrates (but have lower IVs there), e.g. *Synorthocladius semivirens*.

All ISA indicators of the akal/psammal group were put in this group also by expert opinion, with the exception of *Centroptilum luteolum*, which is not bound to a specific substrate.

Species clearly indicating mega-/macrolithal or meso-/microlithal may be sensitive to increasing siltation and may decrease regarding such a scenario. Species preferring akal/psammal according to the ISA may increase if siltation increases which would mean a clear shift in the whole communitiy-composition. The ISA therefore is seen as a base for gaining a indicator list of organisms sensitive or not sensitive to finer substrates.

The output list was set up by expert consultation with the help of statistical queries of species in the target area. Indicator values from 1 to 4 were assigned to the species, indicating 1 to 3 being sensitive to siltation and 4, being an indicator for finer substrate types (see table 2). All Oligochaeta and Chironomidae species that are indicators of akal/psammal on the base of the ISA were also assigned 4 by expert judgment. Similar results are true for both of the lithal-groups. Only Oligochaetes were mainly classified into the “wrong” group using the ISA instead of expert opinion.

Table 2: Explanation of indicator group keys and the number of pre-classified taxa.

Indicator group	Explanation	number of pre-classified taxa
1	sensitive to siltation, living preferably on stony substrates (mes-megalithal)	169
2	sensitive to siltation, living preferably on stable and aerated fine substrates (psammal-akal)	11
3	sensitive to siltation, living in the interstices of bed sediments	11
4	not sensitive to siltation, possibly benefiting from siltation	62

In Table 6 the list of taxa from the investigated catchment is summarised regarding the function as potential indicators for siltation.

Expert judgment and ISA have both proved as valuable tools to find out a species’ habitat preference. As a next step to evaluate possible siltation effects habitat specific samples will be investigated as well as existing data will be further analysed. The complete taxa list as well as the preliminary ratings are shown in table 6 (Appendix).

Wetlands

River-floodplain systems are complex ecosystems depending on hydrological dynamics. During the last two decades theoretical and applied limnological research more and more focused on the investigation of floodplain rivers. Due to the pressures on riverine systems, such as regulation and damming, these spots of biodiversity belong to most threatened ecosystems.

Along the banks of the river Waldaist some temporary pools and wettened areas created by autumnal spates can be found, which are of special interest as they may be classified as key habitats. Their existence indicate a unimpacted functioning flood plain systems. The invertebrate community found there is exceptional and highly specialised to astatic waterbodies. Especially Trichoptera-species are numerous as they have evolved a wide range of physiological, morphological and behavioural adaptations, allowing them to colonise the wide range of lotic, lentic and standing waterbodies, groundwater springs, spring brooks and temporary waters typically present in functioning flood plain systems by distinct species inventories. Species like *Limnephilus vittatus*, *L. griseus*, *L. fuscicornis*, *L. auricula*, *Trichostegia minor*, *Oligostomis reticulata* and *Ironoquia dubia* are rare and characteristic elements of wetlands which dry out within late spring and early summer.

3.1.2. Biological Parameters

Additionally biological parameters could be adequate measures for a decrease of habitat quality and diversity caused by sand input. To test the principal applicability of such metrics, the AQEM – dataset was analyzed. As mentioned above the samples were taken during the AQEM project and treatment followed the AQEM manual. Invertebrates were sampled using the MHS approach. The percentage of fine substrates (sand and silt, as recorded in the field protocol) as well as the variance of substrate types were correlated with some common metrics. The result of the best fitting metrics is given in table 3 and 4. Although the sampling design within AQEM was not specifically fitted to the addressed question, the results are quite promising. Several taxa-richness-measures as well as some functional metrics seem to be quite good candidate indicators for substrate variability and substrate composition. Siltation and overbank sedimentation leads to a decline of sediment variability and a loss of habitats. Therefore primarily a decrease in the number of taxa can be observed. Moreover diversity measures and some functional measures seem to be candidates for adequate parameters. Some examples of metrics response to substrate composition is given in figures 8 and 9).

Table 3: Correlation between some common metrics and the proportion of fine sediments. n=25

Metric	% fine substrates r^2
# of total families	*0.71*
# of total taxa	*0.68*
# of EPT-taxa	*0.65*
Structure-Score	*0.65*
# of Trichoptera taxa	*0.64*
# of total genera	*0.61*
Index of biocoenotic region	*0.59*
# of Diptera families	*0.58*
# of EPT-genera	*0.58*
# of EPT-families	*0.57*
# of Trichoptera genera	*0.56*
% mesolithal preferences	*0.56*
# of Trichoptera families	*0.55*
% of detritivorous	*0.54*
Diversity (Margalef)	*0.50*
# of Ephemeroptera taxa	*0.50*
% psammal preferences	*0.49*
# of Plecoptera genera	*0.46*
# of Plecoptera taxa	*0.44*
log10 abundance of selected EPT-Taxa	*0.43*
% grazers	*0.41*
# of Trichoptera families	*0.41*
% EPT-taxa	*0.40*
% macrolithal preferences	*0.40*
RETI	*0.39*
% psammo-pelal preferences	*0.38*

Diversity (Whilm & Dorris)	*0.37*
Diversity (Shannon & Weaver)	*0.37*
# of Diptera taxa	*0.35*
% EPT-genera	*0.35*
% akal preferences	*0.28*
# of Ephemeroptera families	*0.27*
% microlithal preferences	*0.25*
# of Ephemeroptera genera	*0.25*
# of Diptera genera	*0.24*
% pelal preferences	*0.17*
# of Chironomidae taxa	*0.16*
# of EPT-families	*0.13*
% shredder	*0.07*
# of Chironomidae genera	*0.06*
% megalithal preferences	*0.06*
% parasites	*0.05*
1-GOLD	*0.03*

Table 4: Correlation between some common metrics and the variance of substrates. n=25

Metric	variance of substrates r^2
Structure-Score	*0.55*
# of total families	*0.53*
log10 abundance of selected EPT-Taxa	*0.52*
Index of biocoenotic region	*0.51*
% grazers	*0.50*
% psammo-pelal preferences	*0.50*
RETI	*0.49*
% of detritivorous	*0.48*
% mesolithal preferences	*0.48*
# of total taxa	*0.48*
% microlithal preferences	*0.48*
# of total genera	*0.48*
# of EPT-genera	*0.46*
# of EPT-families	*0.46*
# of EPT-taxa	*0.44*
# of Trichoptera families	*0.42*
% psammal preferences	*0.41*
# of Ephemeroptera taxa	*0.40*
Diversity (Margalef)	*0.40*
% EPT-genera	*0.38*
# of Trichoptera taxa	*0.37*
% EPT-taxa	*0.37*
# of Trichoptera genera	*0.36*
# of Ephemeroptera genera	*0.36*
# of Diptera families	*0.35*
# of Ephemeroptera families	*0.35*
# of Plecoptera genera	*0.31*
Diversity (Whilm & Dorris)	*0.29*
# of Plecoptera taxa	*0.29*
Diversity (Shannon & Weaver)	*0.29*

# of Diptera taxa	*0.25*
# of EPT-families	*0.24*
% pelal preferences	*0.23*
# of Trichoptera families	*0.23*
% macrolithal preferences	*0.18*
# of Diptera genera	*0.17*
% shredder	*0.15*
# of Chironomidae taxa	*0.13*
% akal preferences	*0.10*
1-GOLD	*0.09*
# of Chironomidae genera	*0.05*
% megalithal preferences	*0.02*
% parasites	*0.01*

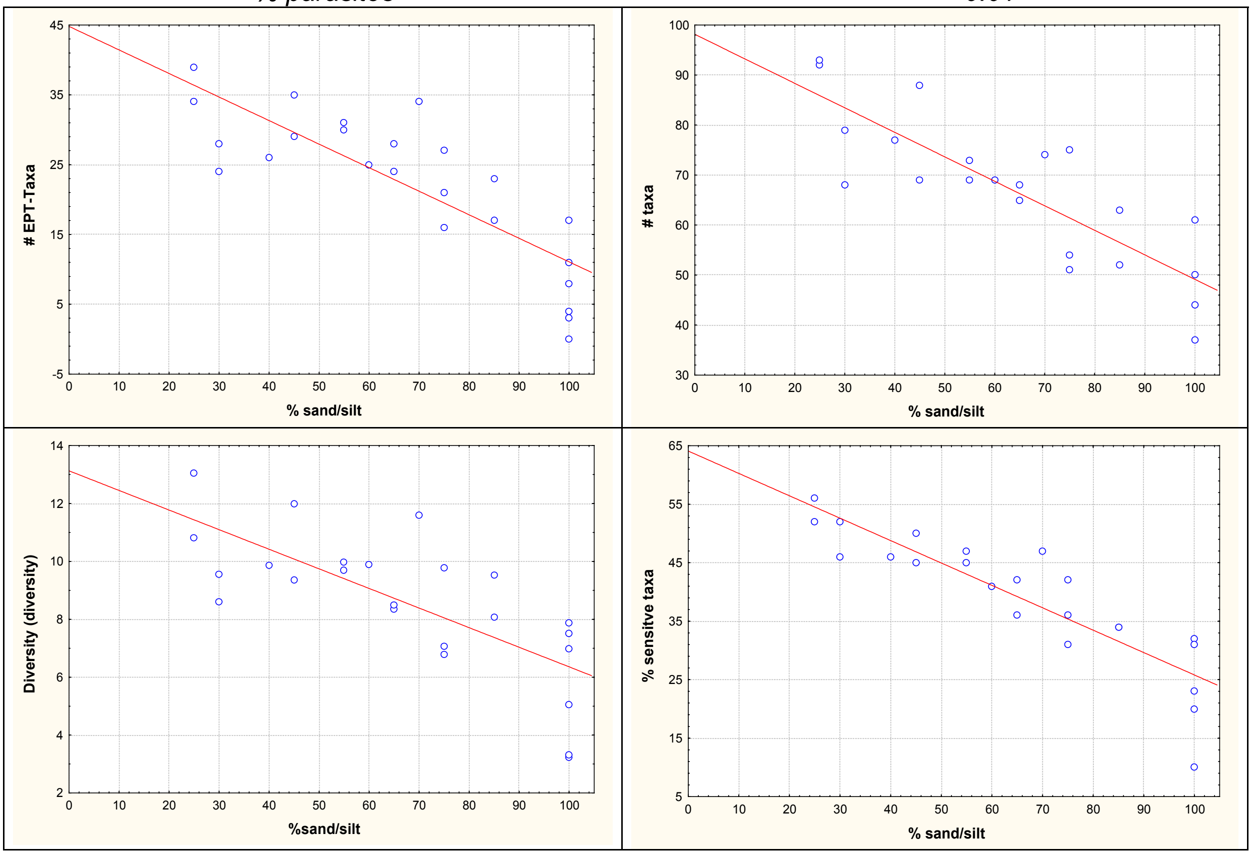
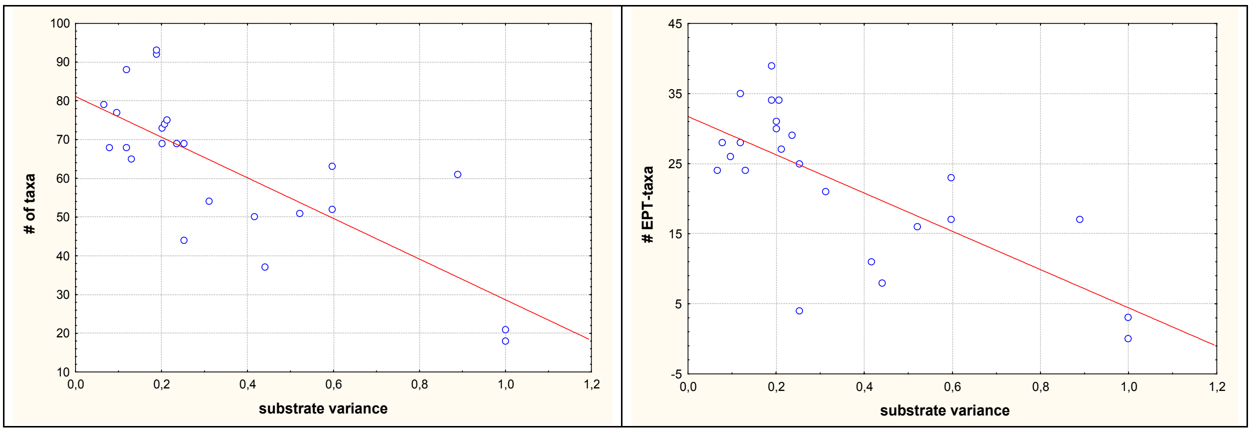


Figure 8: Examples of the response of metrics to increasing proportion of fine substrates.



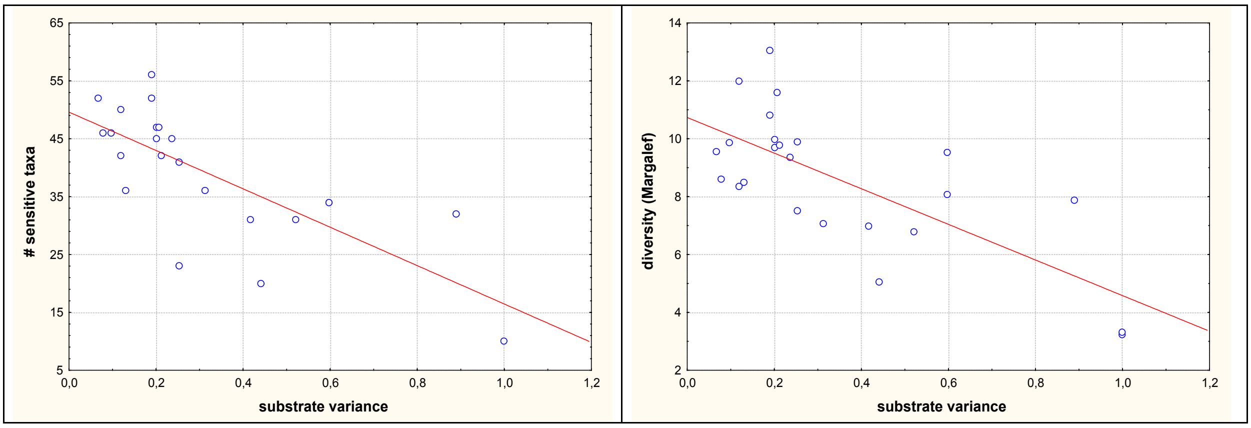


Figure 9: Examples of the response of metrics to increasing habitat diversity.

4. Sampling

4.1. Sampling Design

The sampling was designed to be able to reflect properly different key-habitat characteristics as well as habitat-indicator interaction.

Special emphasis was given on:

- covering all microhabitats at a given sampling site (the whole river corridor)
- aquatic – terrestrial transition zones as they reflect hydromorphological dynamics, faunal refugia as special habitats for adapted organism or stages and serve as linkages between organic (roots, woody debris) and anorganic (lithal) components
- lateral habitats which can increase the overall biodiversity as the fauna will select adequate niches along the cross section of river corridor, (temporal) side branches (arms) with different substrate/flow and temperature characteristics as well as backwaters like pools and springs within the flood-plain are of special interest
- wetland habitats like temporary water bodies, which are in close connection with hydromorphological dynamics in the sense of lateral connectivity and sedimentation-erosion –phenomena.
- any other special habitat

During the WP 2, 7, 8 - meeting in Wageningen, the Netherlands (22.-24.11.2004) it was agreed to build up the sampling design on existing and already tested protocols:

- AQEM sampling protocol (http://www.aqem.de) and
- CEN prEN Multihabitat (CEN, 2004: New work item "Water quality – Guidance on pro rata Multi-Habitat-Sampling (MHS) of benthic invertebrates from wadeable rivers")

Within WP2, task 2.1. we focus on indicators on species level. To reach this goal sampling frequency must be rather high (at least three times a year).

Habitats are frequently characterised as substrate composition, hydraulic conditions and food availability (Minshall & Minshall, 1977, Statzner et al. 1988; Drake 1984, Hildrew &

Townsend, 1976, Brooks et al. 2005, Downes et al. 2000; Heino et al. 2004). Consequently habitats are practically defined in the field as a combination of range of current velocity, substrate type and coverage of organic layers (biotic substrate, as algae or mosses can provide not only food resources but also be structural habitats; for definitions of substrates see below) as well as water depth.

Sampling was designed as follows:

- sampling has to be based on key-(micro)habitat scale (AQEM sampling protocol (http://www.aqem.de) and CEN prEN Multihabitat (CEN, 2004); with major modifications, Single Habitat Sampling-method,
- each sampling unit has to be stored separately, i.e. the collected samples are not pooled to a "site sample"
- for each sampling unit several features have to be documented: substrate type (mineral/organic habitat according to AQEM/STAR, CEN prEN Multihabitat); water depth; current velocity at different depths;
- in the sense of documenting all species and studying their distribution within a range of microhabitats at a sampling site the microhabitats don't have to be necessarily sampled proportionally according to their presence within a sampling reach.
- the overall number of sample units for a given site is not restricted to 20
- at least three replicates of each habitat (if possible) have to be taken for statistical reasons
- special emphasis has to be given to backwaters of different typological characteristics as potential key habitats for wetland faunas
- if backwaters show different habitat types (macrophytes, woody debris, sandy bottom etc.), each of them have to be sampled and are to be stored and analysed separately
- as special focus is given to indicators at species level at least two sampling seasons according to different life cycles of organisms are recommended.

Habitats were defined using the following attributes:

- Current velocity
- Substrate type
- Substrate roughness
- Shear stress
- Water depth
- Sediment stability
- Embeddedness

The following attributes were documented for each sample using the following equipment:

Water velocity

For measuring water current velocity a magnetic-inductive flow meter was used. Velocity was measured 5 cm above the sediment surface, 3 cm below water surface and additionally in the middle depth.

Substrate type

For the purpose of this European Standard, the following terms and definitions were applied. The scientific background for the selection of habitats is based on the principle that each habitat is colonized by a habitat-specific benthic assemblage (Austrian Standards M 6232):

Akal
Fine to medium-sized gravel; grain-diameter > 0.2 cm to 2 cm
Argyllal
Silt, loam, clay
CPOM
Deposits of particulate organic matter, Coarse Particulate Organic Matter as e.g. fallen leaves
Debris
Organic and inorganic matter deposited within the splash zone area by wave-motion and changing water levels
Emergent macrophytes
Emergent (parts of) macrophytes (e.g. *Typha, Carex* and *Phragmites* species)
FPOM
Deposits of particulate organic matter, Fine Particulate Organic Matter
Hygropetric sites
Thin water layer on solid (rocky) substrates
Living parts of terrestrial plants
Fine roots, floating riparian vegetation
Macro-algae
Three-dimensional filamentous algae, algal tufts
Macrolithal
Coarse blocks, cobbles, gravel and sand; grain-diameter > 20 cm to 40 cm
Megalithal
Upper sizes of large cobbles, boulders and blocks, bedrock; grain-diameter > 40 cm
Mesolithal
Fist to hand-sized cobbles with a variable percentage of gravel and sand; grain-diameter > 6 cm to 20 cm
Micro-algae
Two-dimensional algal cover
Microlithal
Coarse gravel (size of a pigeon egg to child's fist) with variable percentages of medium to fine gravel; grain- diameter > 2 cm to 6 cm
Pelal
Mud and sludge; grain-diameter < 0.06 mm
Psammal
Sand; grain-diameter 0.06 mm to 2 mm
Psammopelal
Sand and mud
Sewage bacteria and -fungi
e.g. *Sphaerotilus, Leptomitus*, sulfur bacteria (e.g. *Beggiatoa, Thiothrix*), sludge
Submerged macrophytes
Totally immersed macrophytes, including water mosses, water ferns and Characeae
Xylal
Tree trunks (dead wood), branches, roots

Substrate roughness

Substratum roughness was measured by using a substratum profile sampler (Gore, 1978; Statzner, 1981; Statzner et al. 1988, see Figure 9). The substratum profile sampler we constructed uses six rows, each containing six steel rods, which are allowed to fall freely to the bottom. The position of the rods is measured, the variability of values indicates substrate roughness.

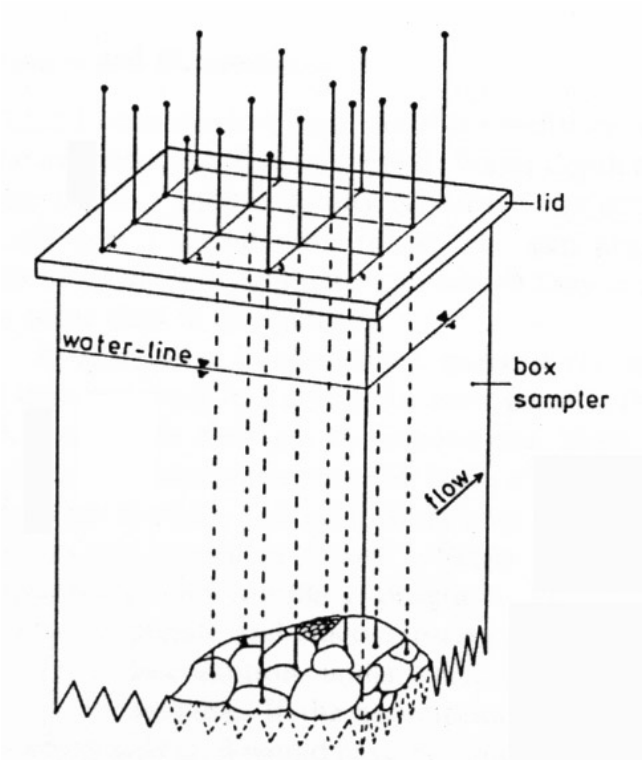


Figure 9: substratum profile sampler

Shear stress

The shear-, shearing- or tangential stress is the stress component tangential to a given plane. It is the force which the water exerts on the wetted perimeter of a channel because of the motion of water – it is not the force on a single particle but on a certain area of the bed or banks. In rivers the shear stress depends on water density (ρ), gravity (g), hydraulic radius (R) and hydraulic gradient (I) ($\tau_R = \rho\ g\ R\ I$). Bed load transport starts by exceeding a defined level of shear stress, which depends on the density and the grain size of the material. **Standard FST hemispheres** (figure 10) – bottom near velocities only were used.

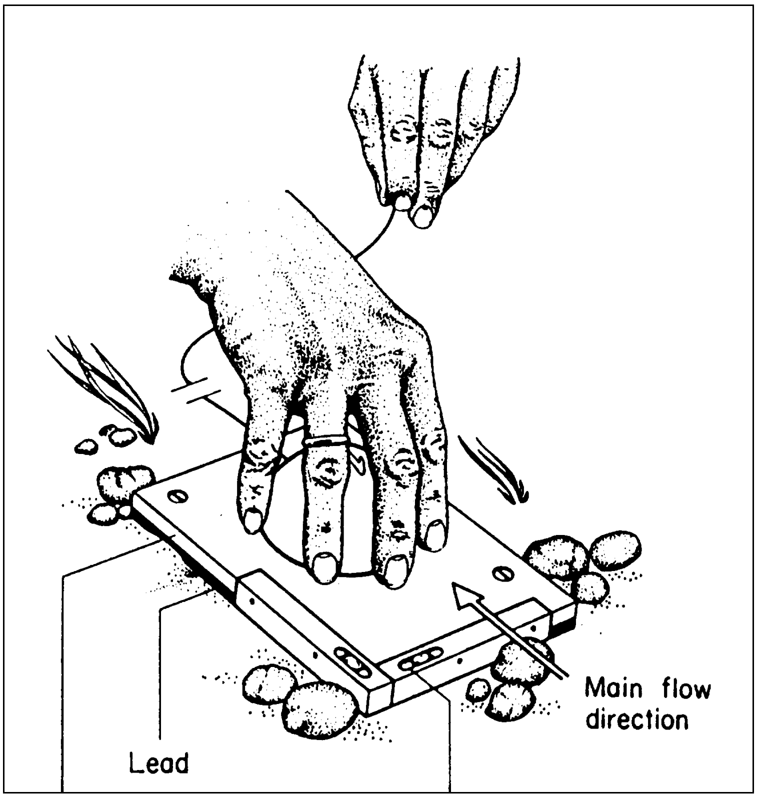


Figure 10: FST - hemispheres.

Water depth

Water depth was measured as the distance between undisturbed substrate and water surface.

Embeddedness

Embeddedness is a substrate attribute reflecting the degree to which larger particles are surrounded or covered by fine sediment such as sand, silt, or clay. Fine sediments can fill the interstitial spaces between larger particles and block water flow important for quality substrate habitat to support benthic macroinvertebrates.

Using the criteria in table 5 the embeddedness of a habitat was roughly estimated although the visual assessment is not highly accurate. The technique is intended to approximate the condition of the substrate relative to fine sediment impacts.

Table 5: Embeddedness rating for stream channel material (Platts et al., 1983). Fine sediment includes material less than 2 mm in diameter: sand, silt, and clay.

Level of embeddedness	Description
Negligible	Gravel, pebble, cobble, and boulder particles have >5% of their surface covered by fine sediment
Low	Gravel, pebble, cobble, and boulder particles have >5-25% of their surface covered by fine sediment

Moderate	Gravel, pebble, cobble, and boulder particles have >26-50% of their surface covered by fine sediment
High	Gravel, pebble, cobble, and boulder particles have >51-75% of their surface covered by fine sediment
Very high	Gravel, pebble, cobble, and boulder particles have >75% of their surface covered by fine sediment

Sediment stability

Especially sediment stability cannot be easily measured as it changes on a spatial and temporal axis according to hydrologic conditions. One simple possibility to estimate the dynamic of sediment transports is to install scour-chains (Laronne, 1992). These chains are implemented vertically, and enable studies on erosional-sedimentary processes within a given period (see figure 11). This method was only applied for selected locations.

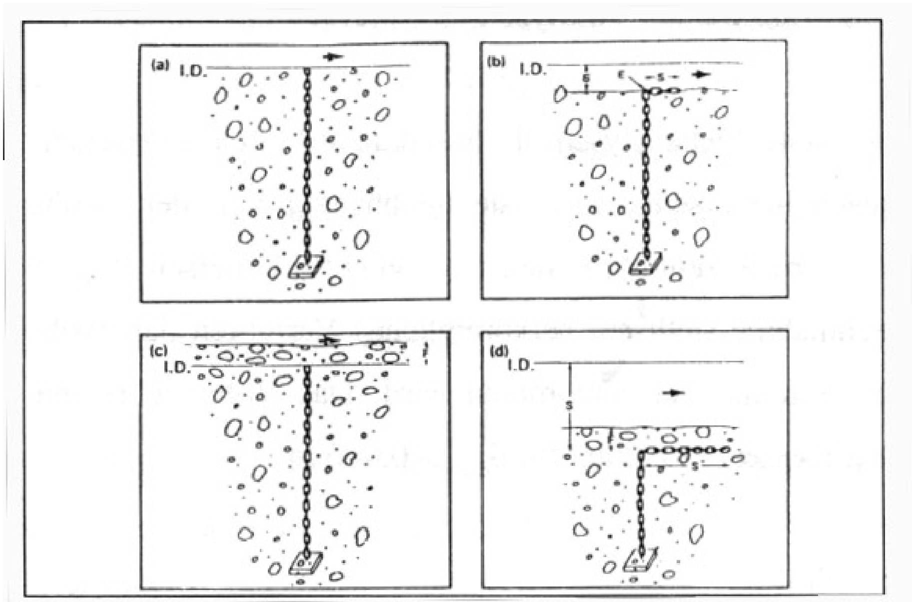


Figure 11: Erosion or scour chains

4. Outlook:

Additional samples will be taken in autumn and spring. Further analysis using the single-habitat samplings will primarily focus on:

a) Substrate specific species composition and the relation between the degree of siltation and species / community composition. Habitat distribution and availability will be linked to ecological requirements of the biota (habitat preference, feeding strategies).

b) Identification of relations between biological characteristics and physical parameters of habitat. Diversity measures, species traits characteristics, community structure and indices based on sensitive taxa will be analysed together with hydraulic and substrate parameters (grain size, substrate roughness, degree of embeddedness, velocity).
c) Preference curves of selected taxa along environmental characteristics representing various spatial scale levels will be generated, regression analysis – relationship of abundances and environmental variables, cluster analysis, discriminant analysis, multidimensional scaling will be also used for data evaluation.
d) Macroinvertebrate response to habitat heterogeneity and existence of rare habitats (analysis of the macroinvertebrate community with and without rare habitats or variable habitat composition) to select key habitats.

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Appendix

Table 6: List of taxa known from the investigated catchment and their function as potential indicators for siltation (Indicator-key values: 1: sensitive to siltation, living preferably on stony substrates (meso- megalithal); 2: sensitive to siltation, living preferably on stable and aerated fine substrates (akal-microlithal); 3: sensitive to siltation, living in the interstices of bed sediments; 4: not sensitive to siltation, possibly benefit from siltation).

Family	Genus	Species	Indicator-key
NAIDIDAE	*Nais*	*alpina*	
NAIDIDAE	*Nais*	*barbata*	
NAIDIDAE	*Nais*	*bretscheri*	
NAIDIDAE	*Nais*	*communis*	
NAIDIDAE	*Nais*	*elinguis*	
NAIDIDAE	*Nais*	*pardalis*	4
NAIDIDAE	*Nais*	*stolci*	
NAIDIDAE	*Chaetogaster*	*diastrophus*	
AEOLOSOMATIDAE	*Aeolosoma*	*sp.*	
TUBIFICIDAE	*Aulodrilus*	*pluriseta*	4
ENCHYTRAEIDAE	*Cognettia*	*sphagnetorum*	
LUMBRICIDAE	*Eiseniella*	*tetraedra*	
ENCHYTRAEIDAE	Enchytraeidae	Gen. sp.	4
ENCHYTRAEIDAE	*Fridericia*	*sp.*	
HAPLOTAXIDAE	*Haplotaxis*	*gordioides*	4
TUBIFICIDAE	*Limnodrilus*	*claparedeianus*	4
TUBIFICIDAE	*Limnodrilus*	*hoffmeisteri*	4
TUBIFICIDAE	*Limnodrilus*	*profundicola*	4
TUBIFICIDAE	*Limnodrilus*	*sp.*	4
TUBIFICIDAE	*Limnodrilus*	*udekemianus*	4
LUMBRICIDAE	Lumbricidae	Gen. sp.	4
LUMBRICULIDAE	*Lumbriculus*	*variegatus*	4
ENCHYTRAEIDAE	*Marionina*	*argentea*	
ENCHYTRAEIDAE	*Mesenchytraeus*	*armatus*	
NAIDIDAE	Naididae	Gen. sp.	
NAIDIDAE	*Ophidonais*	*serpentina*	
NAIDIDAE	*Paranais*	*frici*	
NAIDIDAE	*Pristina*	*foreli*	4
NAIDIDAE	*Pristina*	*longiseta*	
NAIDIDAE	*Pristinella*	*sp.*	
PROPAPPIDAE	*Propappus*	*volki*	4
TUBIFICIDAE	*Psammoryctides*	*barbatus*	4
TUBIFICIDAE	*Rhyacodrilus*	*coccineus*	
LUMBRICULIDAE	*Rhynchelmis*	*limosella*	
LUMBRICULIDAE	*Rhynchelmis*	*sp.*	
NAIDIDAE	*Slavina*	*appendiculata*	
NAIDIDAE	*Specaria*	*josinae*	
TUBIFICIDAE	*Spirosperma*	*ferox*	4
NAIDIDAE	*Stylaria*	*lacustris*	
LUMBRICULIDAE	*Stylodrilus*	*heringianus*	4
LUMBRICULIDAE	*Stylodrilus*	*sp.*	
TUBIFICIDAE	*Tubifex*	*ignotus*	
TUBIFICIDAE	*Tubifex*	*tubifex*	4

Family	Genus	Species	Indicator-key
TUBIFICIDAE	Tubificidae	Gen. sp.	
NAIDIDAE	*Vejdovskyella*	*comata*	
NAIDIDAE	*Pristinella*	*bilobata*	4
LUMBRICULIDAE	Lumbriculidae	Gen. sp.	
NAIDIDAE	*Pristinella*	*jenkinae*	
TUBIFICIDAE	*Aulodrilus*	*japonicus*	4
ENCHYTRAEIDAE	*Cernosvitoviella*	*atrata*	
LUMBRICULIDAE	*Stylodrilus*	*brachystylus*	
LUMBRICULIDAE	*Trichodrilus*	*tenuis*	
LUMBRICULIDAE	*Bythonomus*	*lemani*	
ENCHYTRAEIDAE	*Cognettia*	*sp.*	
GLOSSOSCOLECIDAE	Glossoscolecidae	Gen. sp.	
ENCHYTRAEIDAE	*Henlea*	*sp.*	
APHELOCHEIRIDAE	*Aphelocheirus*	*aestivalis aestivalis*	2
GERRIDAE	*Gerris*	*sp.*	
LEBERTIIDAE	*Lebertia*	*sp.*	
TORRENTICOLIDAE	*Torrenticola*	*anomala*	
SPERCHONIDAE	*Sperchonopsis*	*verrucosa*	
ATURIDAE	*Aturus*	*sp.*	
ATURIDAE	*Aturus*	*scaber*	
SPERCHONIDAE	*Sperchon*	*clupeifer*	
SPERCHONIDAE	*Sperchon*	*sp.*	
HYDRYPHANTIDAE	*Protzia*	*sp.*	
HYGROBATIDAE	*Hygrobates*	*sp.*	
HYGROBATIDAE	*Atractides*	*sp.*	
HYGROBATIDAE	*Hygrobates*	*fluviatilis*	
HYGROBATIDAE	*Hygrobates*	*calliger*	
HYDRYPHANTIDAE	*Protzia*	*invalvaris*	
ELMIDAE	*Elmis*	*aenea*	1
ELMIDAE	*Elmis*	*latreillei*	1
ELMIDAE	*Elmis*	*maugetii*	1
ELMIDAE	*Elmis*	*rietscheli*	1
ELMIDAE	*Elmis*	*rioloides*	1
ELMIDAE	*Elmis*	*sp.*	1
ELMIDAE	*Esolus*	*parallelepipedus*	
ELMIDAE	*Esolus*	*sp.*	1
HYDRAENIDAE	*Hydraena*	*dentipes Ad.*	
HYDRAENIDAE	*Hydraena*	*gracilis Ad.*	
HYDRAENIDAE	*Hydraena*	*truncata Ad.*	
ELMIDAE	*Limnius*	*opacus*	1
ELMIDAE	*Limnius*	*perrisi*	1
ELMIDAE	*Limnius*	*sp.*	1
ELMIDAE	*Limnius*	*volckmari*	1
ELMIDAE	*Oulimnius*	*sp.*	1
ELMIDAE	*Oulimnius*	*tuberculatus*	1
DYTISCIDAE	Dytiscidae	Gen. sp.	
GYRINIDAE	*Gyrinus*	*sp.*	
DYTISCIDAE	Hydroporinae	Gen. sp.	
DYTISCIDAE	*Hydroporus*	*sp.*	
GYRINIDAE	*Orectochilus*	*villosus*	
DYTISCIDAE	*Oreodytes*	*sanmarkii*	
DYTISCIDAE	*Platambus*	*maculatus*	

Family	Genus	Species	Indicator-key
HYDRAENIDAE	*Hydraena*	*belgica*	1
HYDRAENIDAE	*Hydraena*	*dentipes*	1
HYDRAENIDAE	*Hydraena*	*gracilis*	1
HYDRAENIDAE	*Hydraena*	*melas*	1
HYDRAENIDAE	*Hydraena*	*pygmaea*	1
HYDRAENIDAE	*Hydraena*	*sp.*	1
DUGESIIDAE	*Dugesia*	*gonocephala*	
DUGESIIDAE	*Dugesia*	*lugubris*	
DUGESIIDAE	*Dugesia*	*sp.*	
PLANARIIDAE	*Planaria*	*sp.*	
TAENIOPTERYGIDAE	*Brachyptera*	*risi*	1
TAENIOPTERYGIDAE	*Brachyptera*	*seticornis*	1
TAENIOPTERYGIDAE	*Brachyptera*	*sp.*	1
NEMOURIDAE	*Amphinemura*	*sp.*	
NEMOURIDAE	*Amphinemura*	*sulcicollis*	
LEUCTRIDAE	*Leuctra*	*braueri*	3
LEUCTRIDAE	*Leuctra*	*fusca*	3
LEUCTRIDAE	*Leuctra*	*hippopus*	3
LEUCTRIDAE	*Leuctra*	*inermis*	3
LEUCTRIDAE	*Leuctra*	*nigra*	3
LEUCTRIDAE	*Leuctra*	*sp.*	3
NEMOURIDAE	*Nemurella*	*pictetii*	
NEMOURIDAE	*Protonemura*	*auberti*	
NEMOURIDAE	*Protonemura*	*hrabei*	
NEMOURIDAE	*Protonemura*	*intricata*	
NEMOURIDAE	*Protonemura*	*meyeri*	
NEMOURIDAE	*Protonemura*	*sp.*	
CAPNIIDAE	*Capnia*	*nigra*	3
CAPNIIDAE	*Capnia*	*sp.*	3
CAPNIIDAE	*Capnopsis*	*schilleri*	2
PERLODIDAE	*Perlodes*	*sp.*	1
TAENIOPTERYGIDAE	*Rhabdiopteryx*	*navicula*	1
CHLOROPERLIDAE	*Chloroperla*	*sp.*	3
CHLOROPERLIDAE	Chloroperlidae	Gen. sp.	3
PERLIDAE	*Dinocras*	*cephalotes*	1
PERLIDAE	*Dinocras*	*sp.*	1
PERLODIDAE	*Isoperla*	*oxylepis*	
PERLODIDAE	*Isoperla*	*rivulorum*	
PERLODIDAE	*Isoperla*	*sp.*	
PERLIDAE	*Perla*	*burmeisteriana*	1
PERLIDAE	*Perla*	*marginata*	1
PERLIDAE	*Perla*	*sp.*	1
CHLOROPERLIDAE	*Siphonoperla*	*sp.*	3
CHLOROPERLIDAE	*Siphonoperla*	*taurica*	3
CHLOROPERLIDAE	*Siphonoperla*	*torrentium*	3
PERLIDAE	Perlidae	Gen. sp.	1
PERLODIDAE	*Dictyogenus*	*sp.*	1
NEMOURIDAE	*Nemoura*	*sp.*	
TAENIOPTERYGIDAE	Taeniopterygidae	Gen. sp.	1
TAENIOPTERYGIDAE	*Taeniopteryx*	*auberti*	1
TAENIOPTERYGIDAE	*Taeniopteryx*	*hubaulti*	1
NEMOURIDAE	Nemouridae	Gen. sp.	

Family	Genus	Species	Indicator-key
PERLODIDAE	Perlodidae	Gen. sp.	
PLANORBIDAE	*Ancylus*	*fluviatilis*	
PLANORBIDAE	*Gyraulus*	*albus*	
PLANORBIDAE	*Gyraulus*	*sp.*	
HYDROBIIDAE	*Potamopyrgus*	*antipodarum*	
LYMNAEIDAE	*Radix*	*sp.*	
VALVATIDAE	*Valvata*	*piscinalis piscinalis*	
LYMNAEIDAE	Lymnaeidae	Gen. sp.	
SUCCINEIDAE	*Succinea*	*putris*	
SIALIDAE	*Sialis*	*fuliginosa*	
SIALIDAE	*Sialis*	*lutaria*	
SIALIDAE	*Sialis*	*sp.*	
SIALIDAE	*Sialis*	*nigripes*	
BLEPHARICERIDAE	Blephariceridae	Gen. sp.	1
CHIRONOMIDAE	*Cricotopus*	*lygropis*	1
BLEPHARICERIDAE	*Liponeura*	*sp.*	1
BLEPHARICERIDAE	*Liponeura*	*decipiens/vimmeri*	1
CHIRONOMIDAE	*Cricotopus*	*annulator*	1
CHIRONOMIDAE	*Cricotopus*	*similis*	1
CHIRONOMIDAE	*Eukiefferiella*	*brevicalcar*	1
CHIRONOMIDAE	*Eukiefferiella*	*brevicalcar/tirolensis*	1
CHIRONOMIDAE	*Eukiefferiella*	*coerulescens*	1
CHIRONOMIDAE	*Eukiefferiella*	*devonica*	1
CHIRONOMIDAE	*Eukiefferiella*	*fuldensis*	1
CHIRONOMIDAE	*Eukiefferiella*	*devonica/ilkleyensis*	1
CHIRONOMIDAE	*Eukiefferiella*	*lobifera*	1
CHIRONOMIDAE	*Eukiefferiella*	*minor*	1
CHIRONOMIDAE	*Eukiefferiella*	*fittkaui/minor*	1
CHIRONOMIDAE	*Eukiefferiella*	*similis*	1
CHIRONOMIDAE	*Eukiefferiella*	*sp.*	1
CHIRONOMIDAE	*Paracricotopus*	*niger*	1
CHIRONOMIDAE	*Tvetenia*	*bavarica*	1
CHIRONOMIDAE	*Orthocladius*	*rivicola*	1
CHIRONOMIDAE	*Corynoneura*	*sp.*	1
CHIRONOMIDAE	*Cricotopus*	*tremulus*	1
CHIRONOMIDAE	*Cricotopus*	*triannulatus*	1
CHIRONOMIDAE	*Diamesa*	*sp.*	1
CHIRONOMIDAE	*Eukiefferiella*	*claripennis*	1
CHIRONOMIDAE	*Eukiefferiella*	*clypeata*	1
CHIRONOMIDAE	*Eukiefferiella*	*gracei*	1
CHIRONOMIDAE	*Orthocladius*	*frigidus*	1
CHIRONOMIDAE	*Orthocladius*	*ashei*	1
CHIRONOMIDAE	*Paratrichocladius*	*skirwithensis*	1
CHIRONOMIDAE	*Tvetenia*	*calvescens*	1
CHIRONOMIDAE	*Tvetenia*	*sp.*	1
CHIRONOMIDAE	*Tvetenia*	*verralli*	1
CHIRONOMIDAE	*Tvetenia*	*discoloripes*-Gr.	1
CHIRONOMIDAE	*Paratrichocladius*	*veronicae*	1
CHIRONOMIDAE	*Cricotopus*	*bicinctus*	1
CHIRONOMIDAE	*Cricotopus*	*trifascia*	1
CHIRONOMIDAE	*Diamesa*	*insignipes*	1
CHIRONOMIDAE	*Paratrichocladius*	*rufiventris*	

Family	Genus	Species	Indicator-key
CHIRONOMIDAE	*Potthastia*	*gaedii*	
CHIRONOMIDAE	*Thienemanniella*	*sp.*	4
CHIRONOMIDAE	*Cardiocladius*	*capucinus*	1
CHIRONOMIDAE	*Cardiocladius*	*fuscus*	1
CHIRONOMIDAE	*Cardiocladius*	*sp.*	1
CHIRONOMIDAE	*Nanocladius*	*bicolor*	
CHIRONOMIDAE	*Rheocricotopus*	*chalybeatus*	1
CHIRONOMIDAE	*Corynoneura*	*lobata*	1
CHIRONOMIDAE	*Orthocladius*	*oblidens*	
CHIRONOMIDAE	*Orthocladius*	*rubicundus*	
CHIRONOMIDAE	*Orthocladius*	*wetterensis*	
CHIRONOMIDAE	*Phaenopsectra*	*sp.*	4
CHIRONOMIDAE	*Potthastia*	*longimana*-Gr.	1
CHIRONOMIDAE	*Synorthocladius*	*semivirens*	
CHIRONOMIDAE	*Orthocladius*	*obumbratus*	
CHIRONOMIDAE	*Potthastia*	*longimana*	
CHIRONOMIDAE	*Chaetocladius*	*sp.*	4
LIMONIIDAE	Limoniinae	Gen. sp.	
CHIRONOMIDAE	*Nanocladius*	*rectinervis*	
CHIRONOMIDAE	*Rheocricotopus*	*fuscipes*	1
CHIRONOMIDAE	*Tanytarsus*	*brundini*	
CHIRONOMIDAE	*Tanytarsus*	*eminulus*	
CHIRONOMIDAE	*Virgatanytarsus*	*arduennensis/triangularis*	
CHIRONOMIDAE	*Virgatanytarsus*	*arduennensis*	
CHIRONOMIDAE	*Cladotanytarsus*	*vanderwulpi*	4
CHIRONOMIDAE	*Cladotanytarsus*	*vanderwulpi*-Gr.	4
CHIRONOMIDAE	*Krenosmittia*	*sp.*	
CHIRONOMIDAE	Micropsectra	atrofasciata-Agg.	
CHIRONOMIDAE	*Paracladius*	*conversus*	4
CHIRONOMIDAE	*Parametriocnemus*	*stylatus*	
CHIRONOMIDAE	*Parametriocnemus*	*sp.*	
CHIRONOMIDAE	*Micropsectra*	*atrofasciata*	
CHIRONOMIDAE	*Cladopelma*	*viridula*	4
CHIRONOMIDAE	*Micropsectra*	*sp.*	
CHIRONOMIDAE	*Microtendipes*	*pedellus*-Gr.	
CHIRONOMIDAE	*Paracladopelma*	*nigritula*	
CHIRONOMIDAE	*Paracladopelma*	*sp.*	
CHIRONOMIDAE	*Paratendipes*	*albimanus*	
CHIRONOMIDAE	*Paratendipes*	*sp.*	
CHIRONOMIDAE	*Polypedilum*	*scalaenum*-Gr.	4
CHIRONOMIDAE	*Polypedilum*	*laetum*	4
CHIRONOMIDAE	*Polypedilum*	*nubeculosum*	4
CHIRONOMIDAE	*Polypedilum*	*pedestre*	4
CHIRONOMIDAE	*Polypedilum*	*pullum/scalaenum*	4
SIMULIIDAE	*Prosimulium*	*rufipes*	1
SIMULIIDAE	*Prosimulium*	*sp.*	1
CHIRONOMIDAE	*Rheotanytarsus*	*curtistylus*	1
CHIRONOMIDAE	*Rheotanytarsus*	*rhenanus*	1
CHIRONOMIDAE	*Rheotanytarsus*	*sp.*	1
CHIRONOMIDAE	*Saetheria*	*reissi*	4
CHIRONOMIDAE	*Polypedilum*	*aegyptium*	4
CHIRONOMIDAE	*Micropsectra*	*bidentata*	

Family	Genus	Species	Indicator-key
LIMONIIDAE	*Antocha*	*sp.*	
CHIRONOMIDAE	*Apsectrotanypus*	*trifascipennis*	4
ATHERICIDAE	*Atherix*	*ibis*	4
ATHERICIDAE	*Ibisia*	*marginata*	4
ATHERICIDAE	*Atherix*	*sp.*	4
CERATOPOGONIDAE	*Bezzia*	*sp.*	
CHIRONOMIDAE	*Brillia*	*bifida*	4
CERATOPOGONIDAE	Ceratopogonidae	Gen. sp.	
EMPIDIDAE	*Chelifera*	*sp.*	
CHIRONOMIDAE	Chironomidae	Gen. sp.	
CHIRONOMIDAE	Chironominae	Gen. sp.	
CHIRONOMIDAE	Chironomini	Gen. sp.	
CHIRONOMIDAE	*Chironomus*	*acutiventris*	4
CHIRONOMIDAE	*Chironomus*	*bernensis*	4
CHIRONOMIDAE	*Chironomus*	*sp.*	4
CHIRONOMIDAE	*Cladotanytarsus*	*sp.*	4
CHIRONOMIDAE	*Conchapelopia*	*pallidula*	4
CHIRONOMIDAE	*Conchapelopia*	*sp.*	4
CHIRONOMIDAE	Cricotopus	sylvestris-Gr.	
CHIRONOMIDAE	Cricotopus	tremulus-Gr.	1
CHIRONOMIDAE	*Cryptochironomus*	*sp.*	
CHIRONOMIDAE	*Demicryptochironomus*	*vulneratus*	
CHIRONOMIDAE	*Diamesa*	*dampfi*-Gr.	1
PEDICIIDAE	*Dicranota*	*sp.*	4
CHIRONOMIDAE	*Diplocladius*	*cultriger*	
DIXIDAE	*Dixa*	*sp.*	
EMPIDIDAE	*Dolichocephala*	*sp.*	
EMPIDIDAE	Empididae	Gen. sp.	
CHIRONOMIDAE	*Heleniella*	*ornaticollis*	1
CHIRONOMIDAE	*Heleniella*	*sp.*	1
EMPIDIDAE	*Hemerodromia*	*sp.*	
CHIRONOMIDAE	*Heterotrissocladius*	*marcidus*	4
LIMONIIDAE	*Hexatoma*	*sp.*	
MUSCIDAE	*Limnophora*	*riparia*	
CHIRONOMIDAE	*Limnophyes*	*sp.*	
CHIRONOMIDAE	*Macropelopia*	*nebulosa*	4
CHIRONOMIDAE	*Macropelopia*	*notata*	4
CHIRONOMIDAE	*Macropelopia*	*sp.*	4
CHIRONOMIDAE	Macropelopiini	Gen. sp.	
CHIRONOMIDAE	*Micropsectra*	*notescens*-Gr.	
CHIRONOMIDAE	*Natarsia*	*sp.*	
CHIRONOMIDAE	*Neozavrelia*	*sp.*	1
CHIRONOMIDAE	*Nilotanypus*	*dubius*	2
CHIRONOMIDAE	*Odontomesa*	*fulva*	4
CHIRONOMIDAE	Orthocladiinae	Gen. sp.	
CHIRONOMIDAE	*Orthocladiini*	*COP*	
CHIRONOMIDAE	*Orthocladius*	*sp.*	
CHIRONOMIDAE	*Parakiefferiella*	*sp.*	4
CHIRONOMIDAE	*Paratanytarsus*	*sp.*	
CHIRONOMIDAE	*Paratrissocladius*	*excerptus*	4
CHIRONOMIDAE	Pentaneurini	Gen. sp.	
CHIRONOMIDAE	*Polypedilum*	*albicorne*	4

Family	Genus	Species	Indicator-key
CHIRONOMIDAE	*Polypedilum*	*convictum*	
CHIRONOMIDAE	*Polypedilum*	*cultellatum*	
CHIRONOMIDAE	*Polypedilum*	*sp.*	4
CHIRONOMIDAE	*Procladius*	*choreus*	
CHIRONOMIDAE	*Procladius*	*sp.*	
CHIRONOMIDAE	*Prodiamesa*	*olivacea*	4
CHIRONOMIDAE	*Psectrocladius*	*sp.*	
CHIRONOMIDAE	*Pseudodiamesa*	*branickii*	
CHIRONOMIDAE	*Rheocricotopus*	*sp.*	1
CHIRONOMIDAE	*Rheopelopia*	*sp.*	
CHIRONOMIDAE	*Rheosmittia*	*spinicornis*	2
SIMULIIDAE	Simuliidae	Gen. sp.	1
SIMULIIDAE	*Simulium*	*argyreatum*	1
SIMULIIDAE	*Simulium*	*reptans*	1
SIMULIIDAE	*Simulium*	*sp.*	1
SIMULIIDAE	*Simulium*	*variegatum*	1
CHIRONOMIDAE	*Stictochironomus*	*sp.*	
TABANIDAE	*Tabanus*	*sp.*	
CHIRONOMIDAE	Tanypodinae	Gen. sp.	
CHIRONOMIDAE	Tanytarsini	Gen. sp.	
CHIRONOMIDAE	*Tanytarsus*	*sp.*	
CHIRONOMIDAE	*Thienemannia*	*sp.*	4
CHIRONOMIDAE	*Thienemannimyia*	*carnea*	
CHIRONOMIDAE	*Thienemannimyia*	*sp.*	
CHIRONOMIDAE	Thienemannimyia	Gr., Gen. indet.	
TIPULIDAE	*Tipula*	*saginata*	
TIPULIDAE	*Tipula*	*sp.*	
CHIRONOMIDAE	*Virgatanytarsus*	*sp.*	
EMPIDIDAE	*Wiedemannia*	*sp.*	
CHIRONOMIDAE	*Zavrelimyia*	*sp.*	
CHIRONOMIDAE	*Cryptotendipes*	*sp.*	4
LIMONIIDAE	*Ormosia*	*sp.*	
CHIRONOMIDAE	*Brillia*	*flavifrons*	4
CHIRONOMIDAE	*Chironomus*	*acutiventris/obtusidens*	4
CHIRONOMIDAE	*Cricotopus*	*sp.*	
DIXIDAE	*Dixa*	*puberula*	
ATHERICIDAE	Athericidae	Gen. sp.	4
CHIRONOMIDAE	*Metriocnemus*	*obscuripes*	1
SIMULIIDAE	*Simulium*	*cryophilum*	1
SIMULIIDAE	*Simulium*	*vernum*	1
SIMULIIDAE	*Simulium*	*ornatum*	1
SIMULIIDAE	*Simulium*	*degrangei*	1
SIMULIIDAE	*Simulium*	*trifasciatum*	1
SIMULIIDAE	*Simulium*	*lineatum*	1
CHIRONOMIDAE	*Dratnalia*	*potamophylaxi*	
CHIRONOMIDAE	*Epoicocladius*	*flavens*	4
CHIRONOMIDAE	*Eurycnemus*	*crassipes*	1
CHIRONOMIDAE	*Parakiefferiella*	*triquetra*	4
CHIRONOMIDAE	*Demicryptochironomus*	*neglectus*	4
CHIRONOMIDAE	*Stictochironomus*	*pictulus*	
CHIRONOMIDAE	*Rheotanytarsus*	*pentapoda*	1
CHIRONOMIDAE	*Telopelopia*	*fascigera*	4

Family	Genus	Species	Indicator-key
CHIRONOMIDAE	*Ablabesmyia*	*longistyla*	
TABANIDAE	Tabanidae	Gen. sp.	
TIPULIDAE	Tipulidae	Gen. sp.	
PSYCHODIDAE	Psychodidae	Gen. sp.	
CHIRONOMIDAE	*Orthocladius*	*lignicola*	
CHIRONOMIDAE	*Ablabesmyia*	*sp.*	
CHIRONOMIDAE	*Demicryptochironomus*	*sp.*	
PTYCHOPTERIDAE	Ptychopteridae	Gen. sp.	
CHIRONOMIDAE	*Paracladopelma*	*nigritula*-Gr.	
CHIRONOMIDAE	*Orthocladius*	*rivicola*-Gr.	
CHIRONOMIDAE	*Rheotanytarsus*	*pellucidus*	1
LIMONIIDAE	*Eloeophila*	*sp.*	
SIMULIIDAE	*Simulium*	*ornatum*-Gr.	1
SIMULIIDAE	*Simulium*	*variegatum*-Gr.	1
CHIRONOMIDAE	*Cryptochironomus*	*denticulatus*	
CHIRONOMIDAE	*Stempellinella*	*brevis*-Gr.	4
CHIRONOMIDAE	*Cryptochironomus*	*psittacinus*-Gr.	
CHIRONOMIDAE	*Polypedilum*	*albicorne/cultellatum*	4
OSMYLIDAE	*Osmylus*	*fulvicephalus*	
HYDRIDAE	*Hydra*	*sp.*	
MARGARITIFERIDAE	*Margaritifera*	*margaritifera*	2
PISIDIIDAE	*Pisidium*	*casertanum casertanum*	
PISIDIIDAE	*Pisidium*	*obtusale*	
PISIDIIDAE	*Pisidium*	*personatum*	
PISIDIIDAE	*Pisidium*	*sp.*	
PISIDIIDAE	*Pisidium*	*subtruncatum*	
PISIDIIDAE	*Pisidium*	*tenuilineatum*	
PISIDIIDAE	Pisidiidae	Gen. sp.	
AESHNIDAE	*Aeshna*	*cyanea*	
CALOPTERYGIDAE	*Calopteryx*	*splendens*	
CALOPTERYGIDAE	*Calopteryx*	*virgo*	
CORDULEGASTRIDAE	*Cordulegaster*	*boltoni*	
GOMPHIDAE	*Ophiogomphus*	*cecilia*	
GAMMARIDAE	*Gammarus*	*fossarum*	
GAMMARIDAE	*Gammarus*	*roeselii*	
GAMMARIDAE	*Gammarus*	*sp.*	
GAMMARIDAE	*Niphargus*	*sp.*	
BERAEIDAE	*Beraeodes*	*minuta*	
HYDROPTILIDAE	*Ithytrichia*	*lamellaris*	
GOERIDAE	*Goera*	*pilosa*	1
GOERIDAE	Goeridae	Gen. sp.	1
GOERIDAE	*Silo*	*nigricornis*	1
GOERIDAE	*Silo*	*pallipes*	1
GOERIDAE	*Silo*	*piceus*	1
GOERIDAE	*Silo*	*sp.*	1
GLOSSOSOMATIDAE	*Agapetus*	*ochripes*	1
GLOSSOSOMATIDAE	*Agapetus*	*sp.*	1
LIMNEPHILIDAE	*Ecclisopteryx*	*dalecarlica*	1
LIMNEPHILIDAE	*Ecclisopteryx*	*guttulata*	1
GLOSSOSOMATIDAE	*Glossosoma*	*boltoni*	1
GLOSSOSOMATIDAE	*Glossosoma*	*conformis*	1
GLOSSOSOMATIDAE	*Glossosoma*	*sp.*	1

Family	Genus	Species	Indicator-key
PSYCHOMYIIDAE	*Lype*	*reducta*	
GLOSSOSOMATIDAE	*Synagapetus*	*sp.*	1
PSYCHOMYIIDAE	*Tinodes*	*rostocki*	1
PSYCHOMYIIDAE	*Tinodes*	*sp.*	1
PSYCHOMYIIDAE	*Lype*	*sp.*	
PSYCHOMYIIDAE	*Tinodes*	*waeneri*	1
LIMNEPHILIDAE	*Anomalopterygella*	*chauviniana*	1
PSYCHOMYIIDAE	*Psychomyia*	*pusilla*	
LEPIDOSTOMATIDAE	*Lasiocephala*	*basalis*	1
LEPIDOSTOMATIDAE	*Lepidostoma*	*hirtum*	1
BRACHYCENTRIDAE	*Micrasema*	*longulum*	1
BRACHYCENTRIDAE	*Micrasema*	*minimum*	1
ODONTOCERIDAE	*Odontocerum*	*albicorne*	1
LEPTOCERIDAE	*Adicella*	*reducta*	
LIMNEPHILIDAE	*Anabolia*	*furcata*	
LIMNEPHILIDAE	*Annitella*	*obscurata*	
BRACHYCENTRIDAE	*Brachycentrus*	*montanus*	1
BRACHYCENTRIDAE	*Brachycentrus*	*sp.*	1
BRACHYCENTRIDAE	*Brachycentrus*	*subnubilus*	1
LIMNEPHILIDAE	*Chaetopterygopsis*	*maclachlani*	
LIMNEPHILIDAE	*Chaetopteryx*	*fusca*	
LIMNEPHILIDAE	*Chaetopteryx*	*sp.*	
LIMNEPHILIDAE	*Chaetopteryx*	*villosa*	
HYDROPSYCHIDAE	*Hydropsyche*	*angustipennis*	1
HYDROPSYCHIDAE	*Hydropsyche*	*bulbifera*	1
HYDROPSYCHIDAE	*Hydropsyche*	*contubernalis*	1
HYDROPSYCHIDAE	*Hydropsyche*	*dinarica*	1
HYDROPSYCHIDAE	*Hydropsyche*	*instabilis*	1
HYDROPSYCHIDAE	*Hydropsyche*	*pellucidula*	1
HYDROPSYCHIDAE	*Hydropsyche*	*saxonica*	1
HYDROPSYCHIDAE	*Hydropsyche*	*silfvenii*	1
HYDROPSYCHIDAE	*Hydropsyche*	*siltalai*	1
HYDROPSYCHIDAE	*Hydropsyche*	*sp.*	1
LIMNEPHILIDAE	Limnephilidae	Gen. sp.	
LEPTOCERIDAE	*Mystacides*	*azurea*	
LEPTOCERIDAE	*Mystacides*	*nigra*	
LEPTOCERIDAE	*Mystacides*	*sp.*	
BRACHYCENTRIDAE	*Oligoplectrum*	*maculatum*	1
LIMNEPHILIDAE	*Potamophylax*	*cingulatus*	
LIMNEPHILIDAE	*Potamophylax*	*latipennis*	
LIMNEPHILIDAE	*Potamophylax*	*luctuosus*	
LIMNEPHILIDAE	*Potamophylax*	*rotundipennis*	
LIMNEPHILIDAE	*Potamophylax*	*sp.*	
LIMNEPHILIDAE	*Pseudopsilopteryx*	*zimmeri*	
HYDROPSYCHIDAE	*Hydropsyche*	*incognita*	1
HYDROPSYCHIDAE	Hydropsychidae	Gen. sp.	1
LIMNEPHILIDAE	*Chaetopteryx*	*fusca/villosa*	
HYDROPSYCHIDAE	*Hydropsyche*	*incognita/pellucidula*	1
LIMNEPHILIDAE	*Halesus*	*digitatus*	
LIMNEPHILIDAE	*Halesus*	*radiatus*	
LIMNEPHILIDAE	*Halesus*	*sp.*	
LEPTOCERIDAE	*Athripsodes*	*bilineatus*	2

Family	Genus	Species	Indicator-key
LEPTOCERIDAE	*Athripsodes*	*commutatus*	2
LEPTOCERIDAE	*Athripsodes*	*sp.*	2
BRACHYCENTRIDAE	Brachycentridae	Gen. sp.	1
LEPTOCERIDAE	*Ceraclea*	*dissimilis*	
POLYCENTROPODIDAE	*Cyrnus*	*trimaculatus*	
HYDROPTILIDAE	*Hydroptila*	*forcipata*	
HYDROPTILIDAE	*Hydroptila*	*sparsa*	
HYDROPTILIDAE	*Hydroptila*	*sp.*	
LEPIDOSTOMATIDAE	Lepidostomatidae	Gen. sp.	1
LEPTOCERIDAE	Leptoceridae	Gen. sp.	
LIMNEPHILIDAE	Limnephilinae	Gen. sp.	
LEPTOCERIDAE	*Oecetis*	*notata*	
SERICOSTOMATIDAE	*Oecismus*	*monedula*	
PHILOPOTAMIDAE	Philopotamidae	Gen. sp.	1
PHILOPOTAMIDAE	*Philopotamus*	*ludificatus*	1
PHILOPOTAMIDAE	*Philopotamus*	*montanus*	1
PHILOPOTAMIDAE	*Philopotamus*	*sp.*	1
POLYCENTROPODIDAE	*Polycentropus*	*flavomaculatus*	
PSYCHOMYIIDAE	Psychomyiidae	Gen. sp.	
RHYACOPHILIDAE	*Rhyacophila*	*dorsalis*	
RHYACOPHILIDAE	*Rhyacophila*	*fasciata*	
RHYACOPHILIDAE	*Rhyacophila*	*nubila*	
RHYACOPHILIDAE	*Rhyacophila*	*obliterata*	
RHYACOPHILIDAE	*Rhyacophila*	*sp.*	
RHYACOPHILIDAE	*Rhyacophila*	*tristis*	
RHYACOPHILIDAE	*Rhyacophila*	*vulgaris*	
RHYACOPHILIDAE	*Rhyacophila*	*vulgaris*-Gr.	
RHYACOPHILIDAE	Rhyacophilidae	Gen. sp.	
SERICOSTOMATIDAE	*Sericostoma*	*flavicorne*	
SERICOSTOMATIDAE	*Sericostoma*	*personatum*	
SERICOSTOMATIDAE	*Sericostoma*	*sp.*	
BRACHYCENTRIDAE	*Micrasema*	*setiferum*	1
HYDROPTILIDAE	Hydroptilidae	Gen. sp.	
RHYACOPHILIDAE	Rhyacophila	s. str. sp.	
POLYCENTROPODIDAE	Polycentropodidae	Gen. sp.	
LIMNEPHILIDAE	Drusinae	Gen. sp.	1
SERICOSTOMATIDAE	Sericostomatidae	Gen. sp.	
SERICOSTOMATIDAE	*Sericostoma*	*flavicorne/personatum*	
GLOSSOSOMATIDAE	Glossosomatidae	Gen. sp.	1
SCIRTIDAE	*Elodes*	*minuta*	
PSEPHENIDAE	*Eubria*	*palustris*	
SCIRTIDAE	*Elodes*	*sp.*	
SCIRTIDAE	*Elodes*	*marginata*	
ICHNEUMONIDAE	*Agriotypus*	*armatus*	
MERMITHIDAE	Mermithidae	Gen. sp.	
HEPTAGENIIDAE	*Epeorus*	*sp.*	1
HEPTAGENIIDAE	*Epeorus*	*sylvicola*	1
HEPTAGENIIDAE	*Rhithrogena*	*beskidensis*	1
HEPTAGENIIDAE	*Rhithrogena*	*carpatoalpina*	1
HEPTAGENIIDAE	*Rhithrogena*	*gratianopolitana*	1
HEPTAGENIIDAE	*Rhithrogena*	*savoiensis*	1
HEPTAGENIIDAE	*Rhithrogena*	*semicolorata*	1

Family	Genus	Species	Indicator-key
HEPTAGENIIDAE	*Rhithrogena*	*semicolorata*-Gr.	1
HEPTAGENIIDAE	*Rhithrogena*	*sp.*	1
HEPTAGENIIDAE	Rhithrogena	diaphana-Gr.	1
BAETIDAE	*Baetis*	*alpinus*	1
BAETIDAE	*Baetis*	*alpinus*-Gr.	1
BAETIDAE	*Baetis*	*fuscatus*	1
BAETIDAE	*Baetis*	*fuscatus/scambus*	1
BAETIDAE	*Baetis*	*lutheri*	1
BAETIDAE	*Baetis*	*melanonyx*	1
BAETIDAE	*Baetis*	*muticus*	1
BAETIDAE	*Baetis*	*niger*	1
BAETIDAE	*Baetis*	*rhodani*	1
BAETIDAE	*Baetis*	*scambus*	1
BAETIDAE	*Baetis*	*sp.*	1
BAETIDAE	*Baetis*	*vernus*	1
BAETIDAE	*Centroptilum*	*pennulatum*	
BAETIDAE	*Cloeon*	*dipterum*	
HEPTAGENIIDAE	*Ecdyonurus*	*macani*	1
HEPTAGENIIDAE	*Ecdyonurus*	*picteti*	1
HEPTAGENIIDAE	*Ecdyonurus*	*sp.*	1
HEPTAGENIIDAE	*Ecdyonurus*	*venosus*	1
HEPTAGENIIDAE	*Ecdyonurus*	*venosus*-Gr.	1
EPHEMERELLIDAE	*Ephemerella*	*ignita*	
EPHEMERELLIDAE	*Ephemerella*	*major*	1
EPHEMERELLIDAE	*Ephemerella*	*mucronata*	1
EPHEMERELLIDAE	*Ephemerella*	*sp.*	
HEPTAGENIIDAE	*Heptagenia*	*sp.*	1
HEPTAGENIIDAE	*Heptagenia*	*sulphurea*	1
EPHEMERELLIDAE	Ephemerellidae	Gen. sp.	
BAETIDAE	*Baetis*	*lutheri/vardarensis*	1
CAENIDAE	*Caenis*	*beskidensis*	
CAENIDAE	*Caenis*	*luctuosa*	
CAENIDAE	*Caenis*	*pseudorivulorum*	
CAENIDAE	*Caenis*	*rivulorum*	
CAENIDAE	*Caenis*	*sp.*	
HEPTAGENIIDAE	*Epeorus*	*assimilis*	1
EPHEMERIDAE	*Ephemera*	*danica*	2
EPHEMERIDAE	*Ephemera*	*sp.*	
EPHEMERIDAE	*Ephemera*	*vulgata*	
LEPTOPHLEBIIDAE	*Habroleptoides*	*confusa*	3
LEPTOPHLEBIIDAE	*Habrophlebia*	*lauta*	3
HEPTAGENIIDAE	Heptageniidae	Gen. sp.	1
OLIGONEURIIDAE	*Oligoneuriella*	*rhenana*	1
LEPTOPHLEBIIDAE	*Paraleptophlebia*	*sp.*	3
LEPTOPHLEBIIDAE	*Paraleptophlebia*	*submarginata*	3
SIPHLONURIDAE	*Siphlonurus*	*lacustris*	
LEPTOPHLEBIIDAE	Leptophlebiidae	Gen. sp.	3
BAETIDAE	*Centroptilum*	*luteolum*	
ERPOBDELLIDAE	*Erpobdella*	*octoculata*	1
ERPOBDELLIDAE	Erpobdellidae	Gen. sp.	1
HAEMOPIDAE	*Haemopis*	*sanguisuga*	

7. Contribution by CEH

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1 Review

CEH has considerable experience of assessing the relationship between physical habitat, flow conditions and macroinvertebrates and macrophytes in streams. During the 1970s detailed work was undertaken by John Wright and colleagues on assessing impacts of reduced flows on the biotic communities in the Lambourn and Kennet chalk streams (Wright *et al*. 1981, Wright & Berrie 1987, Wright 1992, Wright *et al*. 1994, Wright & Symes 1999). This work was revisited again in the late 1990s (Wright et al. 2000, 2002a, 2002b, 2003, 2004). During both periods the sites experienced sustained low-flow episodes (1976, 1997) and during the latter period there was also a phase of prolonged exceptionally high flows (2000/01). These data, therefore, are very suitable for determining links between discharge dynamics and biotic community responses. The previous work has addressed this to a certain extent. Drought events appeared to have a more deleterious impact on macroinvertebrates than high flow events but in both cases the communities recovered within a year or less. Taxa such as Simuliidae, Baetidae, Caenidae, Glossosomatidae and Planorbidae were often less abundant in drought years. Conversely Ephemerellidae, Hydroptilidae and Chironomidae seemed to be tolerant of long-lasting low-flow conditions. Much of these responses were influenced by the changes in substrate composition and coverage of macrophyte beds in the river. The current work will undertake more detailed analysis of these existing data to identify potential indicator taxa for use by Tasks 2.2 and 3.

2 Data Collation

We have collated biological data of sufficient quality and quantity from the Environment Agency, CEH data holdings and the NERC LOCAR research programme. We have gathered macroinvertebrate & macrophyte data for a number of sites along the catchment and in the neighbouring Kennet catchment (Fig. 1 & 2). We also have supporting hydromorphological, hydrochemical, land cover (Fig. 3) and some hydrological data (Fig. 4).

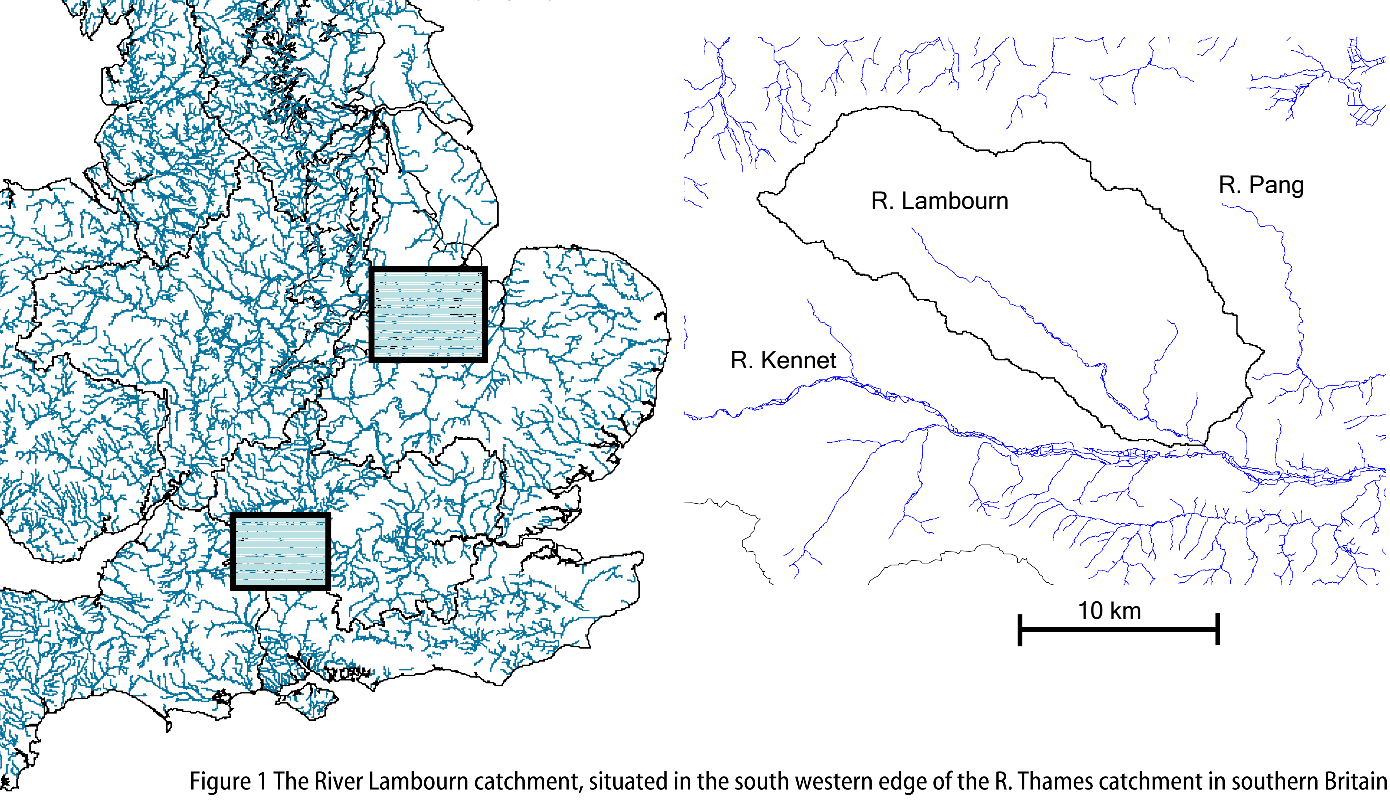

Figure 1 The River Lambourn catchment, situated in the south western edge of the R. Thames catchment in southern Britain.

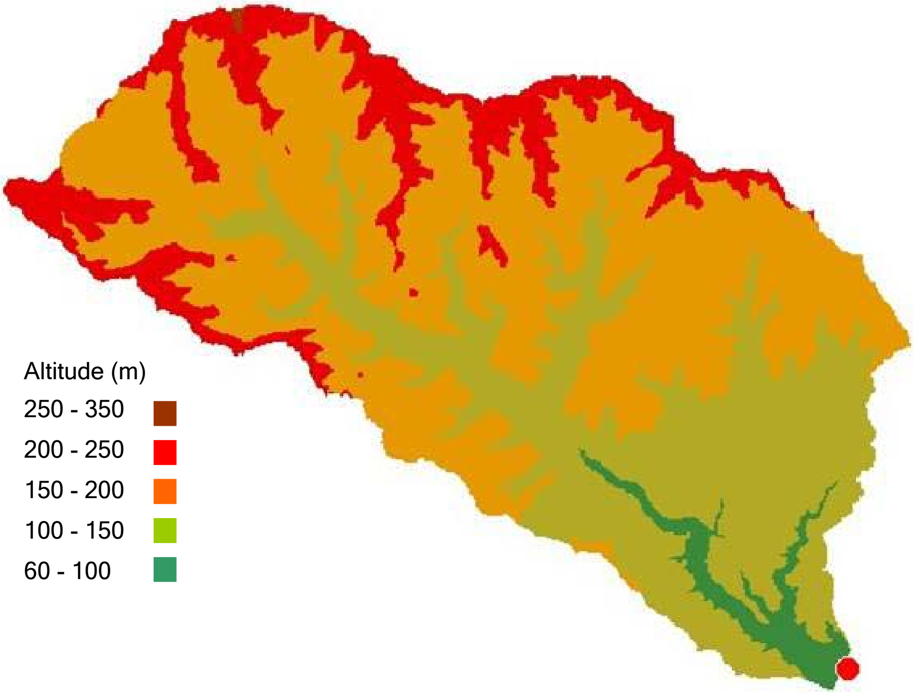

Figure 2 Elevation contours of the R. Lambourn catchment upstream of Shaw, north of Newbury town.

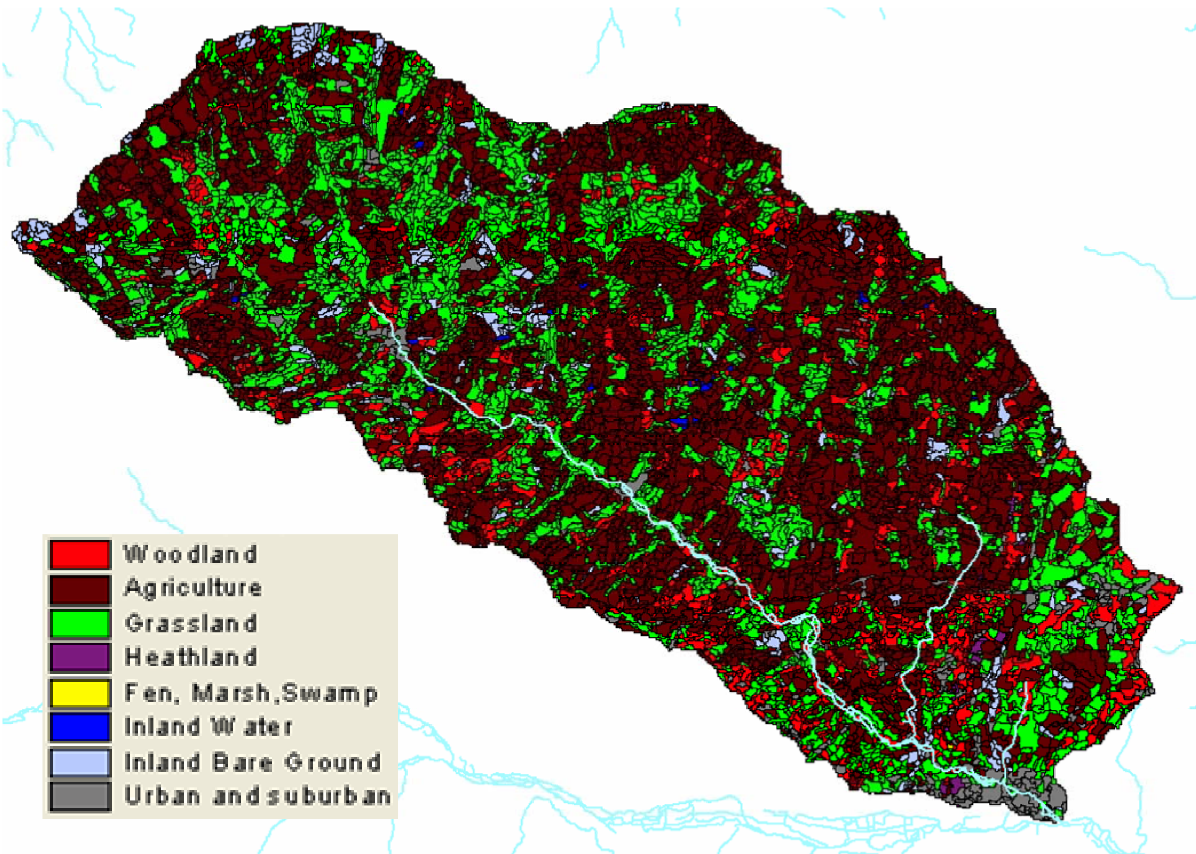

Figure 3 Land cover within the R. Lambourn catchment upstream of the A4 road bridge, according to the Countryside Survey 2000 Land Cover Map, converted to Level 1 EUNIS habitat categories.

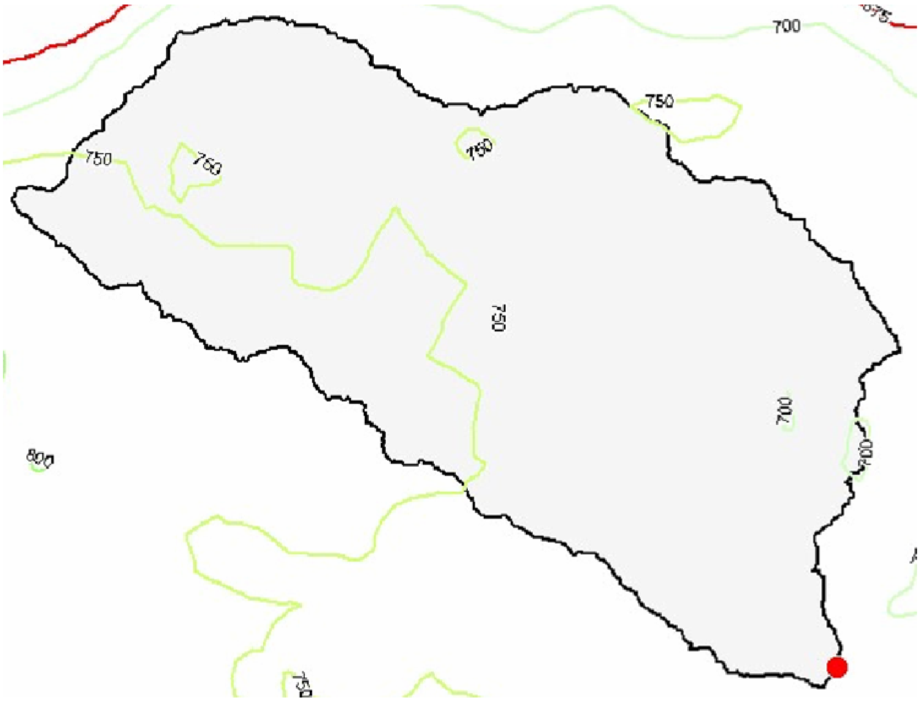

Figure 4 Rainfall map for the R. Lambourn catchment at Shaw, based on the Standard Annual Average Rainfall 1961-1990 (derived from Met Office rain gauge data).

We have not collated fish data for the catchment. The fish data are not in an easily retrievable form and the consistency of the data are uncertain. Therefore we took the decision to drop this element from our analysis. We have also gained some extra data from the LOCAR research programme in the form of mesohabitat-specific macroinvertebrate samples from 8 sites along the Lambourn, sampled in 2003.

2.1 Hydromorphology

During the summer of 2003 the hydromorphological features of 500m of every 1km of the R. Lambourn was surveyed using the standard River Habitat Survey (RHS) method (Anon 2003). These surveys records over 150 variables either from spot-checks at 10 equidistant transects or as part of sweep-up of features over the entire 500m survey reach. The information is recorded in categorical, ordinal and continuous form. Unfortunately categorical data cannot be applied to multivariate ordination. Also, there is some replication of information between the spot-checks and the sweep-up. For our analysis the spot-check data was presented in a way that gave the prevalence (as a % of its maximum possible frequency of occurrence) of each of 96 separate features. The sweep data is a combination of counts (20), measurements (4), 3-class ordinal (67) or 6-class ordinal (1) across the 92 features recorded. The spot-check and sweep-up data were combined by including all spot-check data and any extra elements recorded only in the sweep up, to produce a final dataset of 92 features that occurred across the 25 sites.

2.2 Macrophyte

Using the Mean Trophic Rank (MTR) field methodology (Holmes et al. 1999) the macrophyte community was surveyed at 8 sites along the R. Lambourn, from its source to the confluence with the R. Kennet, below Newbury town. The presence and cover of all macrophyte and bryophyte species was recorded on a 9-point scale over a 100m reach.

2.3 Macroinvertebrate

The macroinvertebrate community was sampled at the reach level using the standard RIVPACS methodology (Murray-Bligh 1999). A 3-min active kick sample (1mm mesh net) was taken with all habitats within each of the 8 sites sampled in 2003. Effort was distributed among habitats according to their coverage. A 1-min hand search of areas poorly covered by the kick sampling was also undertaken where necessary. The samples was fixed in 4% formalin and returned to the laboratory where all animals were sorted from the sediment and detritus, identified to species level or lowest practicable level.

The macroinvertebrate community was semi-quantitatively sampled at the mesohabitat level for the LOCAR programme by kick-sweeping through discrete patches of each mesohabitat. Four mesohabitats were sampled; bare gravel substrates, channel margins, *Ranunculus* beds, and sand and silt substrates.

The quantitative mesohabitat samples collected by J.F. Wright and co-workers during the 1970s and late 1990s were obtained by a stratified random sampling procedure. A total of 7 different mesohabitats were sampled; *Berula* beds, *Callitriche* beds, emergent vegetation, bare gravel substrates, *Ranunculus* beds, *Schoenoplectus* stands and silt substrates. A standard 0.05 m^2 area was disturbed to a depth of about 6 cm. The same method was applied to the both mineral and macrophyte mesohabitats, with the underlying substrate included in the sample in the case of the latter.

All mesohabitat samples was fixed in 4% formalin and returned to the laboratory where all animals were sorted from the sediment and detritus, and identified to BMWP-family level (LOCAR data) or to actual family level (JFW data) and counted.

3 Data Analysis

For the purposes of this sub-task we defined a sub-set of sites and time-matched data for the different elements that allowed us to quantify the variation in biotic community across the catchment and relate this variation to elements of the physical environment.

We carried out this analysis at two spatial scales:

(i) Reach Scale: We related the hydromorphological condition of a 500m stretch of river to elements of the biological community it supports. We used the LOCAR macroinvertebrate, macrophyte data collected at 8 sites and River Habitat Survey data collected at 25 sites in 2003 for this purpose. Principal component analysis (PCA) amalgamated the multi-dimensional RHS data to 4 orthogonal axes defining the most significant hydromorphological gradients across the 25 sites. PCA was carried out on the correlation matrix (species scores centred and standardised), with inter-species scaling so that the species scores could be interpreted as correlations between the environmental variables and each PC axis. The most important variables related to each PCA axis were considered those with correlations >0.5. The PCA axis scores for the 8 sites with matching macrophyte and macroinvertebrate data were then used to relate variation in biotic assemblages to hydromorphological features. A separate PCA was undertaken, with Channel Vegetation data omitted, for the purposes of relating the PCA axes scores to the macrophyte data.

(ii) Mesohabitat Scale: We identified associations between the macroinvertebrate community, and macrophyte and substrate-based mesohabitats. We analysed the LOCAR mesohabitat data for 8 sites in the Lambourn and then separately existing CEH macroinvertebrate mesohabitat data from 1970s and late 1990s from 4 sites on the R. Kennet and R. Lambourn. Detrended correspondence analysis (DCA) and Kruskal-Wallis tests were used to determine the strength of associations between taxa and particular mesohabitats. Applying existing knowledge on variation in the prevalence of mesohabitats with flow allowed us to identify taxa and mesohabitats indicative of certain flow and hydromorphological conditions.

4 Results

4.1 Reach Scale

The major hydromorphological gradient along the R. Lambourn, as defined by the first axis of the PCA (accounting for14.3% of the variation), separates more deeply cut-in sites with a lot of riffles and exposed bars (Sites La004-La007) from wider and deeper sites featuring more submerged, free-floating macrophytes and emergent reeds and sedges, and riparian woodland and scrub (Sites La013-014, La018, La020) (Figs. 5 & 6). The second most important gradient (11.9%) distinguishes sites with simple bank-top vegetation structure, with continuous or semi-continuous tree cover, a lot of over hanging boughs and reinforced banks (Sites La026, La029, La032, La033) from sites with earthen banks, uniform bank-face and bank-top vegetation structure, improved grassland in the riparian corridor and more emergent herbs in the river channel (Sites La008-La010, La022). Site La002 is more distinct from the others due to the presence of a culvert at the site and the increased prevalence of tipped debris, and wood piling along its banks (Figs. 5 & 6).

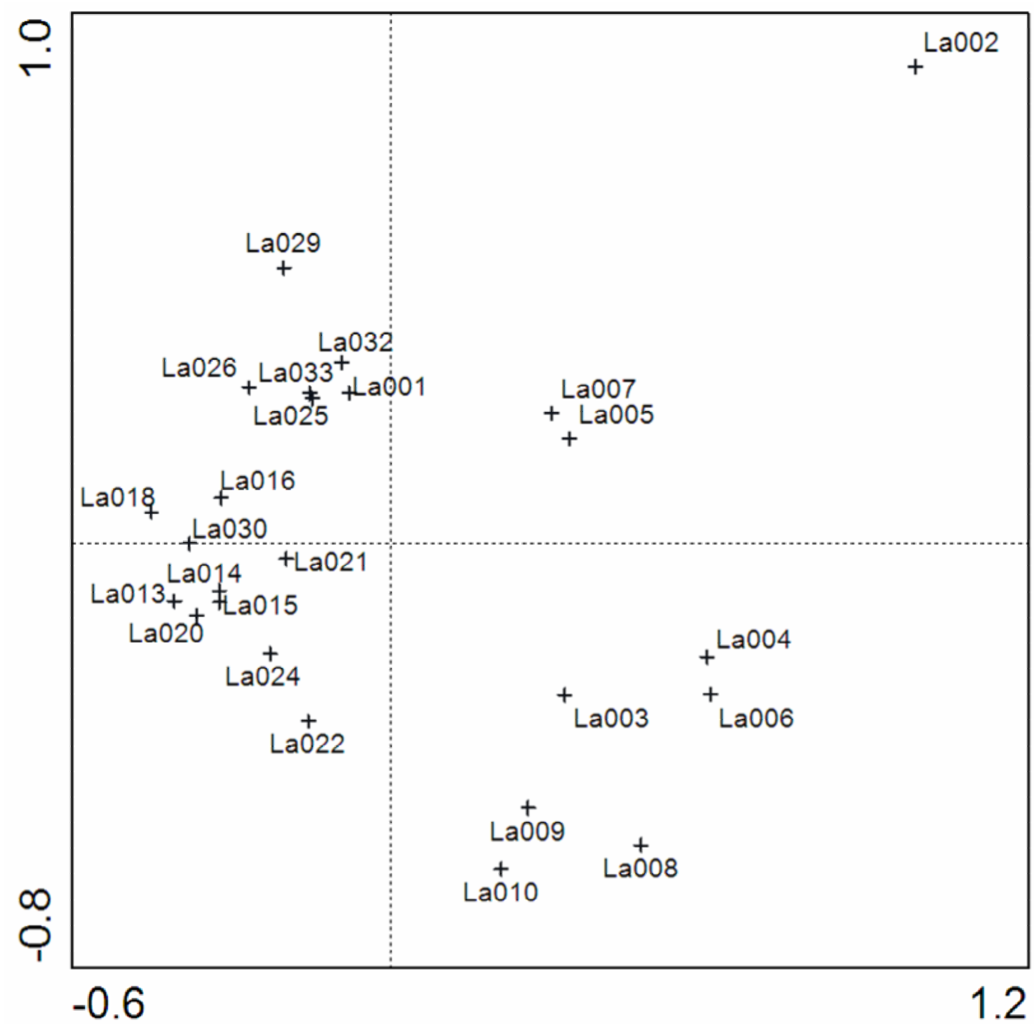

Figure 5 PCA ordination plot of 25 500m survey reaches based on their hydromorphological features. Sites are labelled La001 to La030 in an upstream to downstream direction.

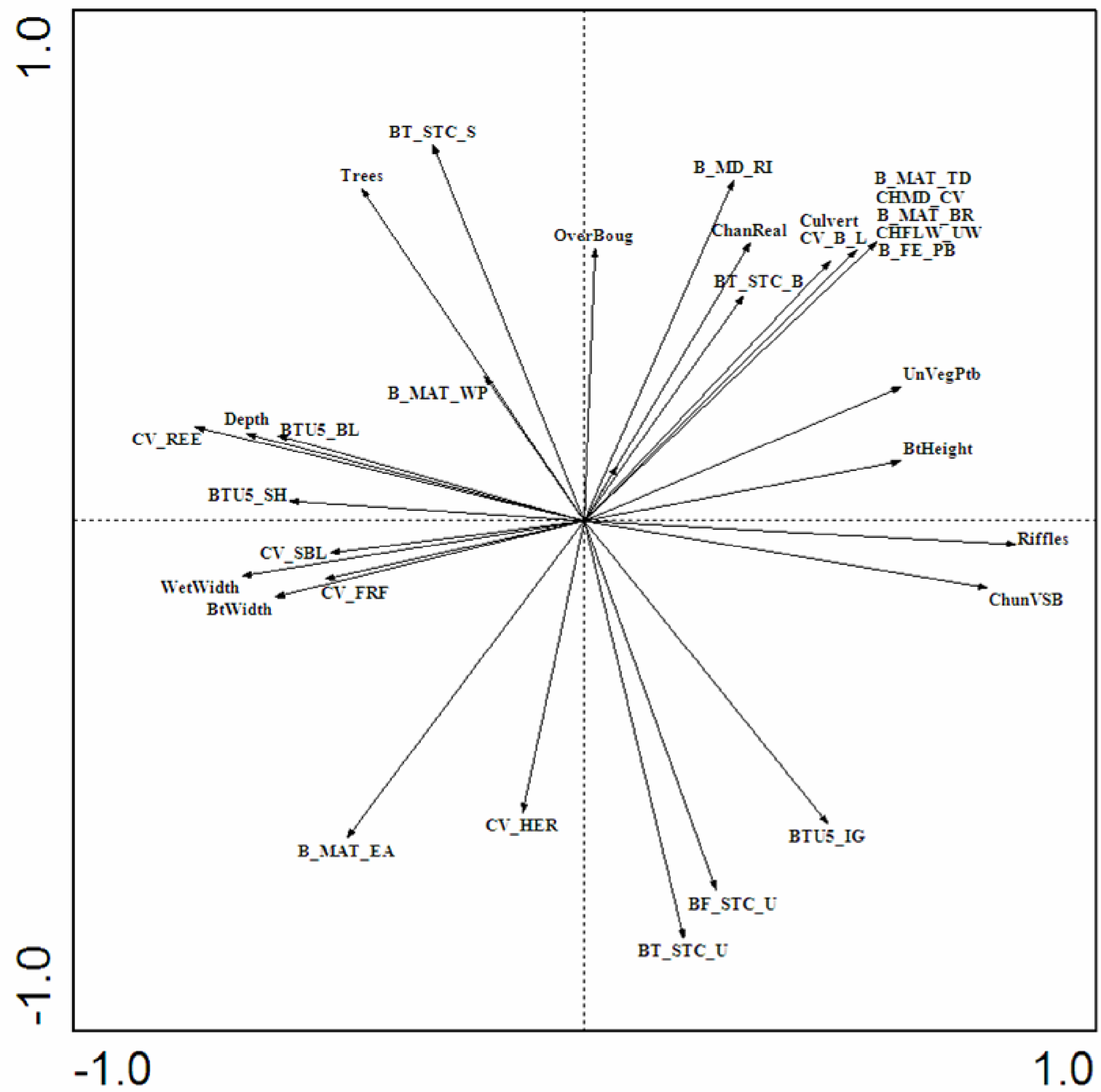

Figure 6 PCA ordination plot illustrating the direction of greatest variation for each of the variables most strongly aligned with axes 1 and 2 only. Other variables have been omitted for ease of interpretation of the plot. See Appendix 1 for explanation of abbreviations.

We then related the PCA axes scores (axes 1-4) for the sites with matching macrophyte and macroinvertebrate data to test for any significant relationships between the biological communities at these sites and their hydromorphological structure.

A DCA on the macrophyte data showed that the gradient length across the 8 site was 2.1, so an RDA was used to relate the biological data to the RHS PCA score variables. The RDA found that only PCA1 could account for a significant portion of the variation in macrophyte community composition across the 8 sites, and this relationship was only just statistically significant (P<0.049).

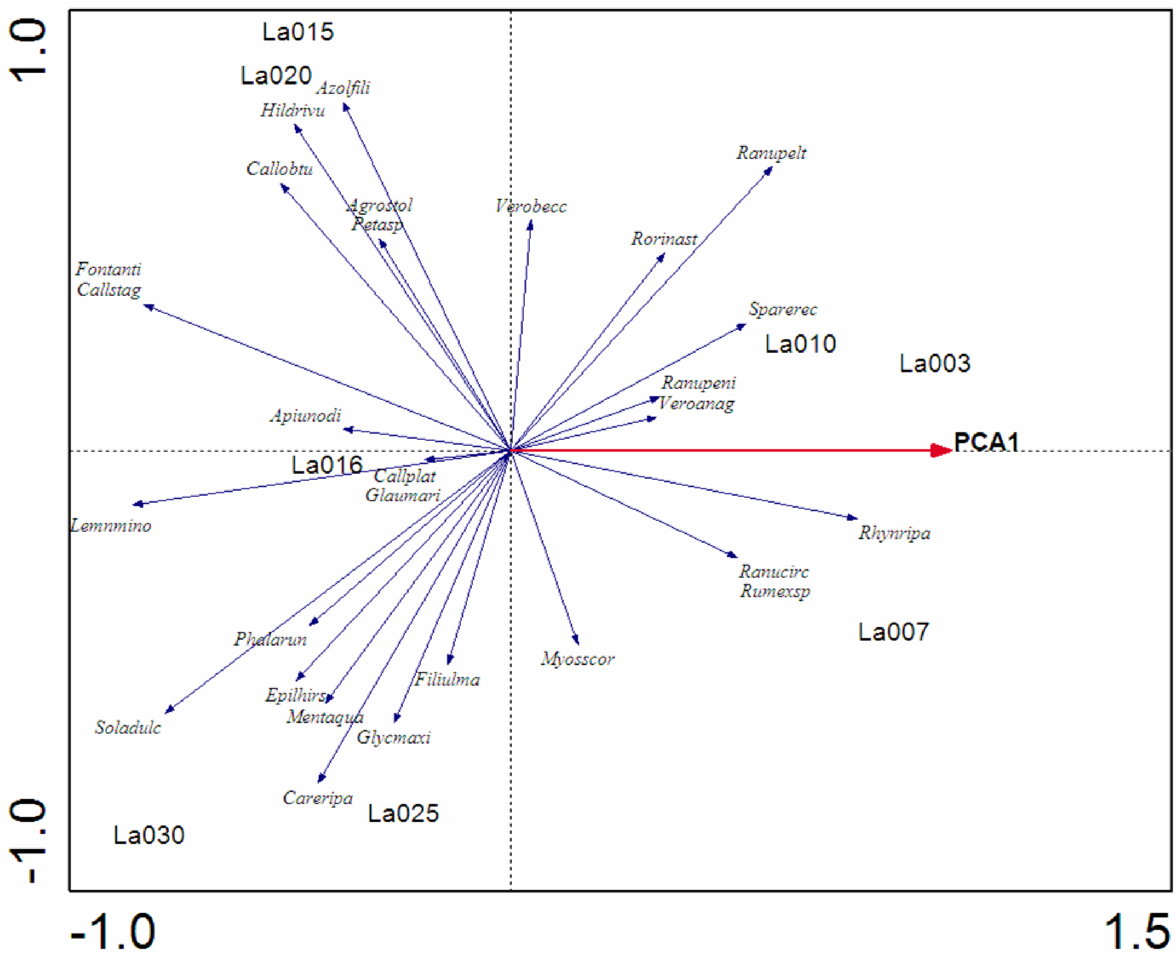

Figure 7 RDA ordination tri-plot of macrophyte community variation across the 8 R. Lambourn sites and its relation to the hydromorphological variable PCA1. Species labels are derived by combining the first four letters of the genus and species names (except for *Rumex* sp.).

The dominant gradient through the data is that separating the upstream sites La003-010 from the more mid-catchment and downstream sites La015-030 (Fig. 7). This gradient is aligned with PCA1 scores, thus distinguishing more deeply cut-in sites with a lot of riffles, shallow waters and exposed bars from wider and deeper sites with more riparian woodland and scrub. The upstream sites were characterised by *Rhynchostegium riparioides*, *Ranunculus circinatus*, *Rumex* sp. and *Sparganium erectum*. The other sites were split into two main groups on the basis of their macrophyte assemblages. The mid-catchment sites were distinguished from the downstream sites on the basis of *Azolla filiculoides, Hildenbrandia rivularis, Callitriche obtusangula, Solanum dulcamara, Carex riparia, Mentha aquatica* and *Epilobium hirsutum* (Fig. 7). The increased prevalence of marginal species such as *S. erectum*, *Rumex* sp. could indicate an increased tendency towards low-flows and reduced water surface area within the channel. These are potential indicator species.

We related RHS PCA scores (with the channel vegetation information included) to the species-level macroinvertebrate community at the 8 sites. An initial DCA on the macroinvertebrate data found that the taxa-turnover gradient was quite short across the 8 sites (1.715). Therefore an RDA was used to relate the RHS info to the biological data. None of the RHS PCA axes were significantly related to variation in the macroinvertebrate community across the 8 sites.

So in conclusion, the RHS data collected over a 500m reach scale does not relate very strongly to either the macrophyte (sampled over 100m) or macroinvertebrate communities (sampled over 50m). A weak relationship was found between the RHS data and the macrophyte data and some tentative suggestions were drawn on potential reach-scale indicator species.

4.2 Mesohabitat Scale

A total of 53 taxa were recorded across the 27 LOCAR mesohabitat samples from 8 sites along the R. Lambourn. DCA plots revealed that the different mesohabitats appeared to be distinct from one another in terms of their macroinvertebrate assemblages, but with some degree of overlap (Figs. 8 & 9).

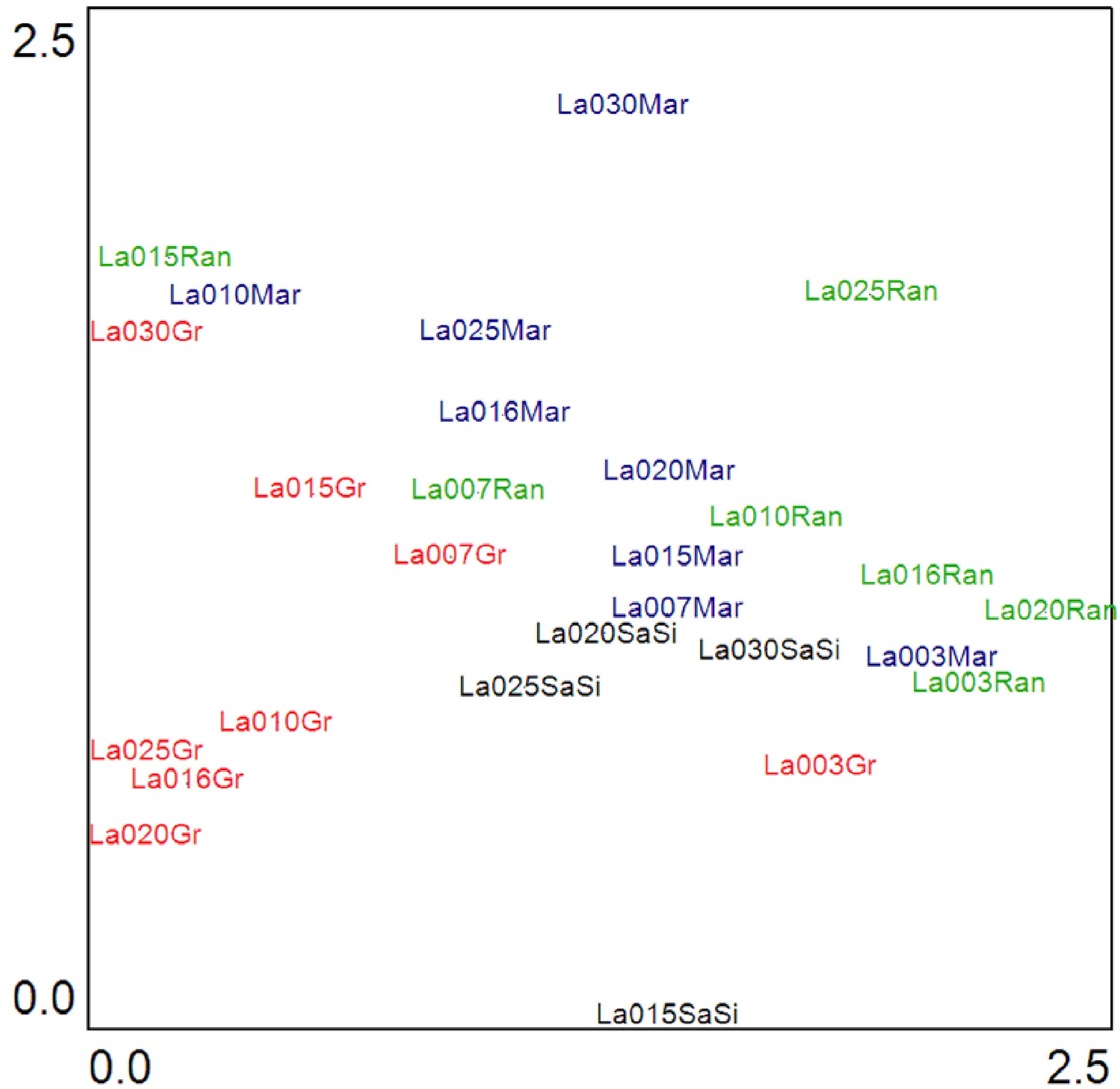

Figure 8 DCA ordination plot of mesohabitat samples (Gravel (Gr), Margin (Mar), *Ranunculus* (Ran) and Sand and Silt) from sites La003, La007, La010, La015, La016, La020, La025 & La030.

Gravel samples supported greater numbers of Hydropsychidae, Goridae, Tipulidae and Rhyacophilidae (Glossosomatidae) than other mesohabitats. Simuliidae and Lymnaeidae were more associated with *Ranunculus* beds while Corixidae and Hydrobiidae were most often found in marginal habitat (Figs. 8 & 9).

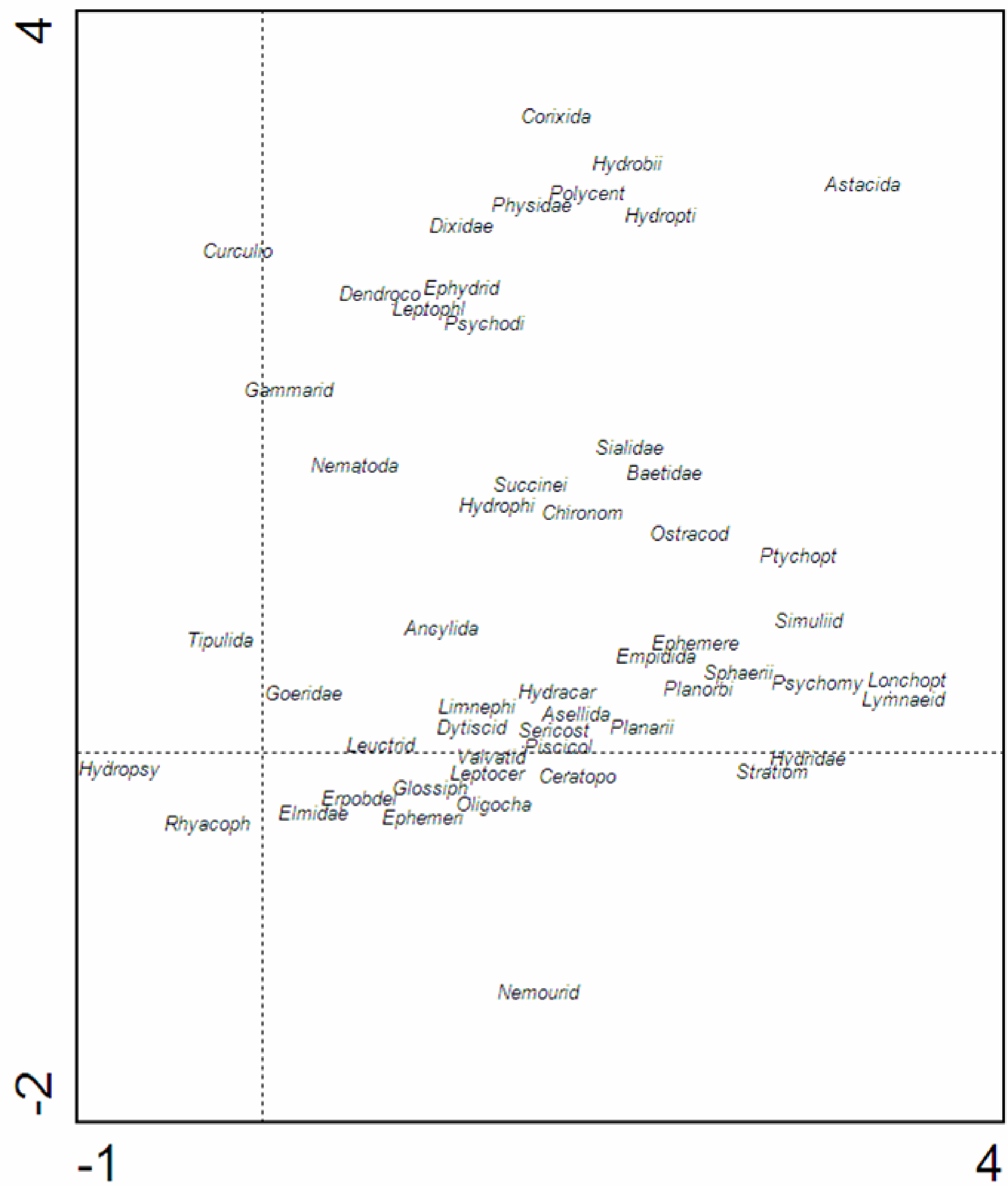

Figure 9 DCA ordination plot of macroinvertebrate BMWP families scores from mesohabitat samples. Taxa names are abbreviated to their first 8 letters.

To more formally test for differences between the 4 mesohabitats I carried out Kruskal-Wallis tests. There was no significant difference between the four mesohabitats in terms of their taxon richness ($F_{26,3}$=1.34, P<0.287) but a marginal difference in the number of individuals

(H_3= 8.29, P =0.04) (Fig. 10). *Ranunculus* had the most individuals and the margins and Sand/Silt the lowest. Among the 8 most commonly occurring taxa in the mesohabitat dataset the strongest results were the associations between Baetidae and Ranunculus, Gammaridae and Gravel, Oligochaeta and Sand/Silt, and Rhyacophilidae/Glossosomatidae and Gravel (Table 1).

By plotting the variation in the abundance of these 4 taxa across the DCA ordination space we illustrated more clearly their affinity to given mesohabitats as well as sites (Fig. 11). The Gammaridae plot is misleading as it gives the impression that the taxon is strongly associated with Ranunculus, when in fact their preference is more consistently for Gravel. There was one Ranunculus sample from La015 that had very large numbers of Gammarus, but the other Ranunculus samples had low numbers (Fig. 11).

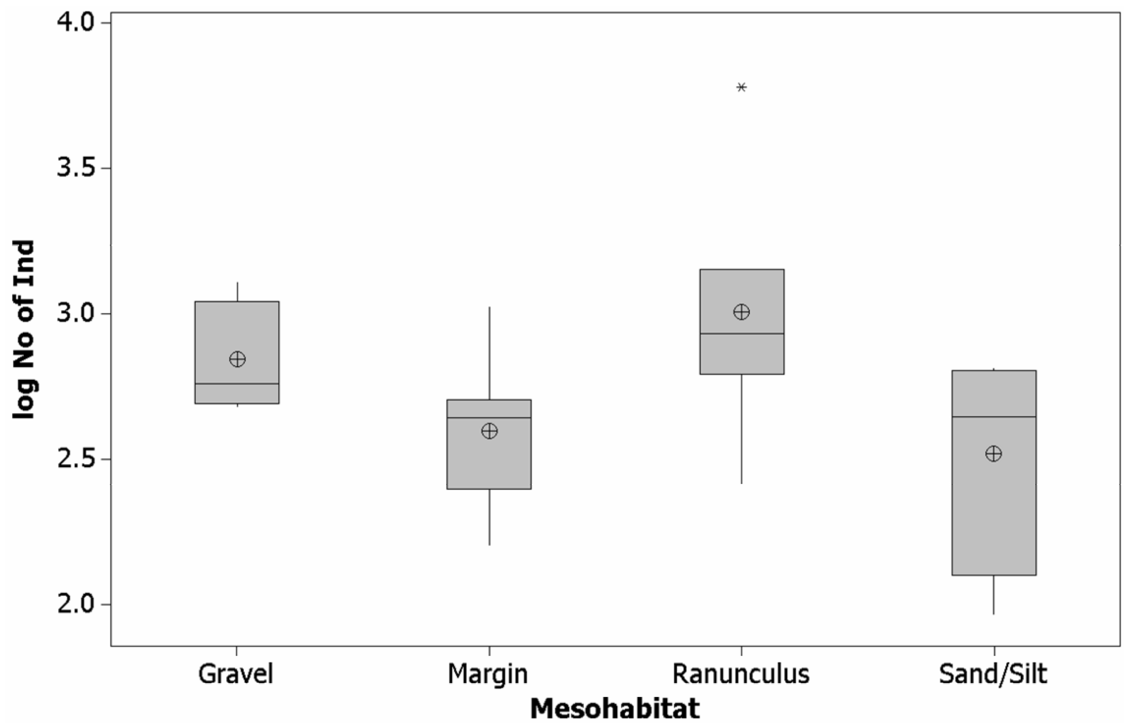

Figure 10 Variation in the abundance of macroinvertebrates found in samples from each of the four mesohabitats.

Table 1 Macroinvertebrate associations with mesohabitats as determined from Kruskal-Wallis tests.

	GRAVEL	MARGIN	*RANUNCULUS*	SAND/SILT
CHIRONOMIDAE	*	*	*	*
BAETIDAE			****	
GAMMARIDAE (INCL. CRANGONYCTIDAE & NIPHARGIDAE)	***	*		
OLIGOCHAETA	*			***
EPHEMERELLIDAE	*	*	**	
HYDRACARINA	*	*	*	*
ANCYLIDAE (INCL. ACROLOXIDAE)	**		**	
RHYACOPHILIDAE (INCL. GLOSSOSOMATIDAE)	***		*	

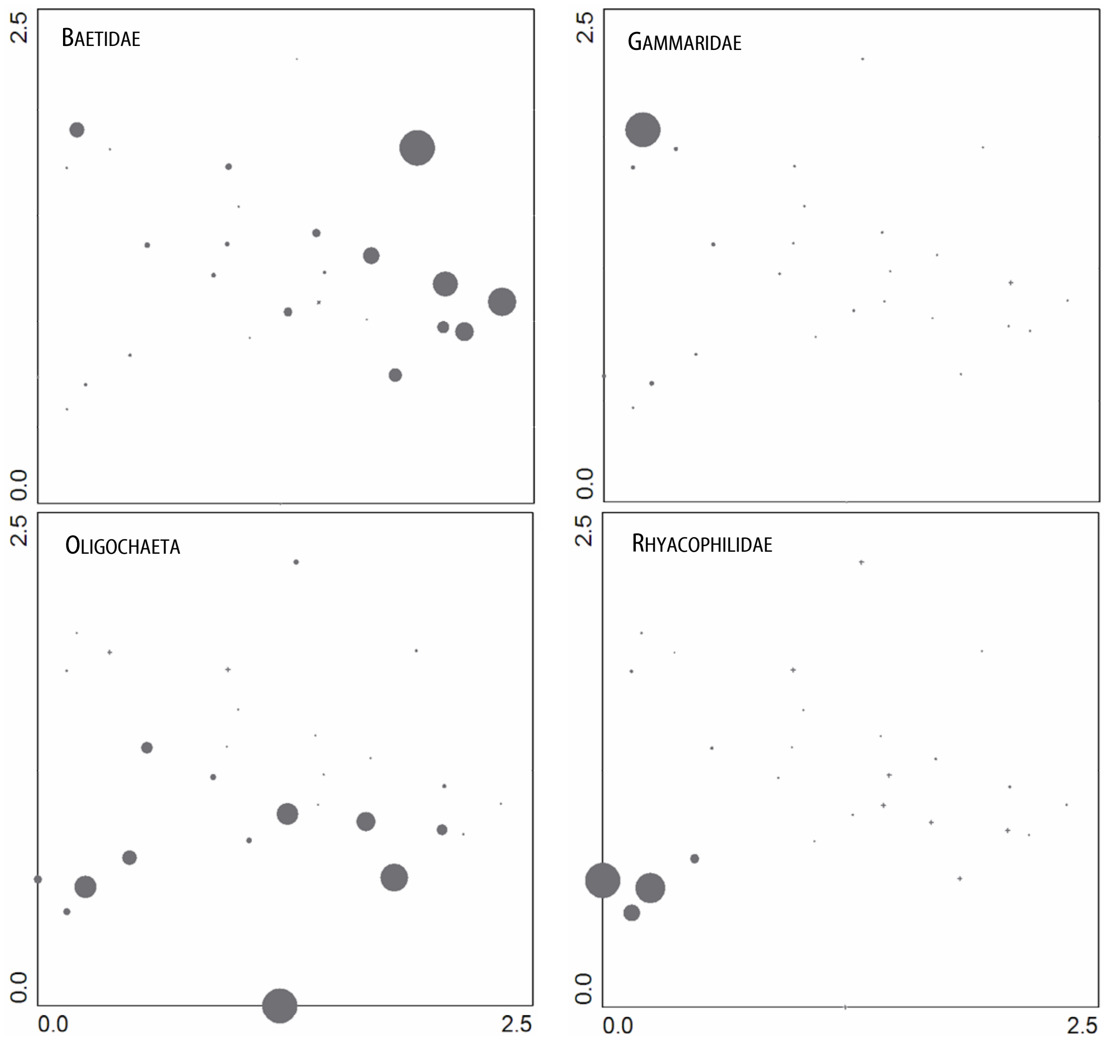

Figure 11 Relative abundance of taxa across DCA ordination space (axes 1 & 2). The larger the circle the more abundant the taxon was in that sample. Refer to Figs. 8 & 9 for samples labels.

A more comprehensive quantitative dataset of 189 samples into one of 7 mesohabitats (*Berula*, *Callitriche*, *Ranunculus*, *Schoenoplectus*, Emergent Vegetation, Gravel, and Silt) was compiled from the work of J.F. Wright on the R. Lambourn and R. Kennet during the 1970s and 1990s. From these data we analysed mesohabitat preferences of chalk stream macroinvertebrate families. There was uneven replication across the 7 groups. Using DCA we looked for consistent associations between invertebrate families and mesohabitats having first excluded from any analysis, taxa that occurred in less than 5% of the samples, leaving 55 taxa.

The most distinct difference is between Gravel and the others (Fig. 12). Silt is generally within the range of variation of the other macrophyte habitats. There does not appear to be a strong differentiation between the vegetation types in terms of the macroinvertebrate assemblages they support. Glossosomatidae, Goeridae, Gyrinidae and Heptageniidae were more abundant in Gravel, while Ephemerellidae, Chironomidae and Corixidae were more closely associated with macrophyte habitats (Fig 12).

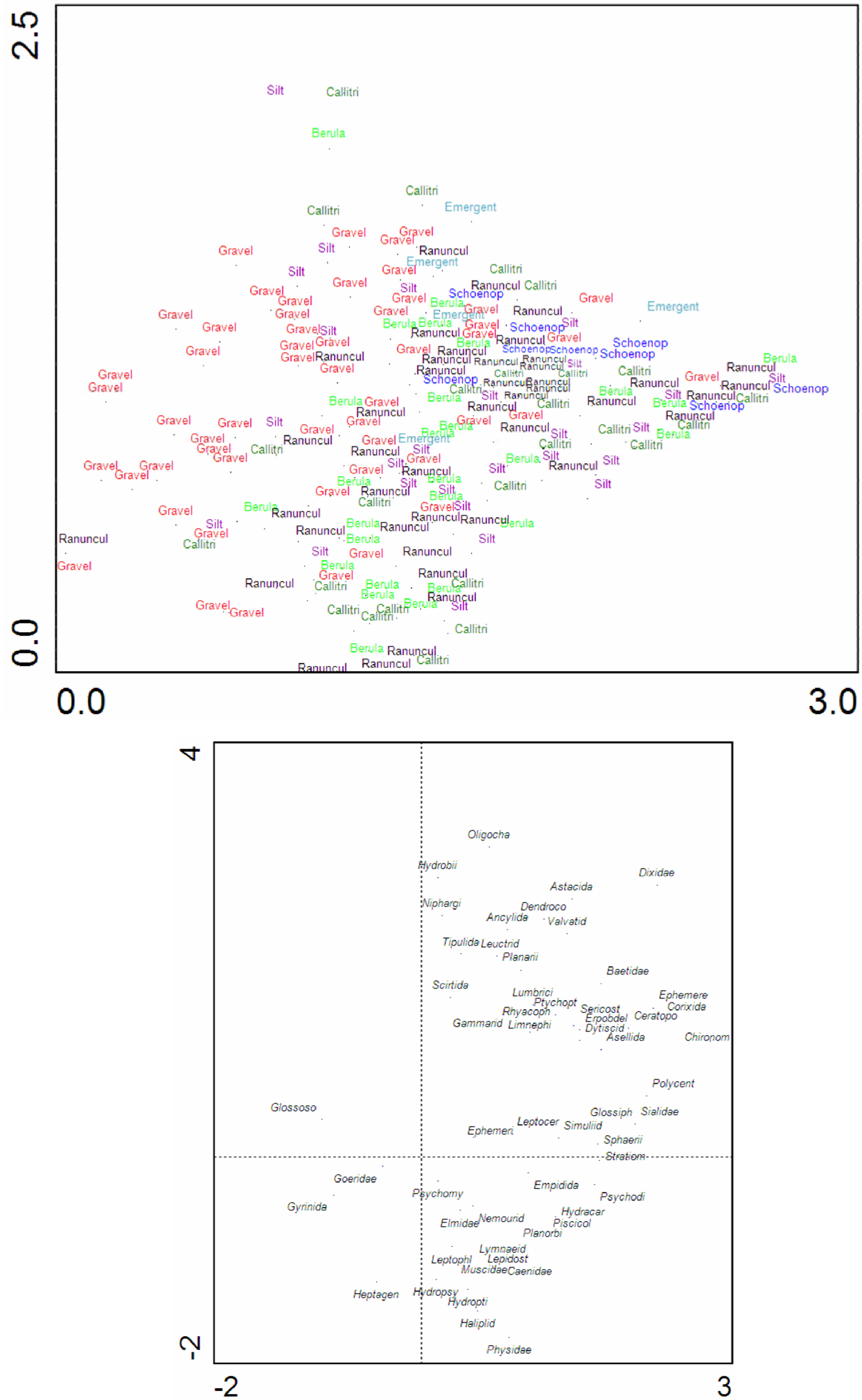

Figure 12 DCA ordination plots of mesohabitat sample scores and taxon scores. Taxa names are abbreviated to their first 8 letters.

Kruskal-Wallis was then applied to assess the extent of these apparent differences in the density of individuals between mesohabitats for the 33 most frequently occurring taxa (taxa less common than this had a less than 50% chance of being in a sample).

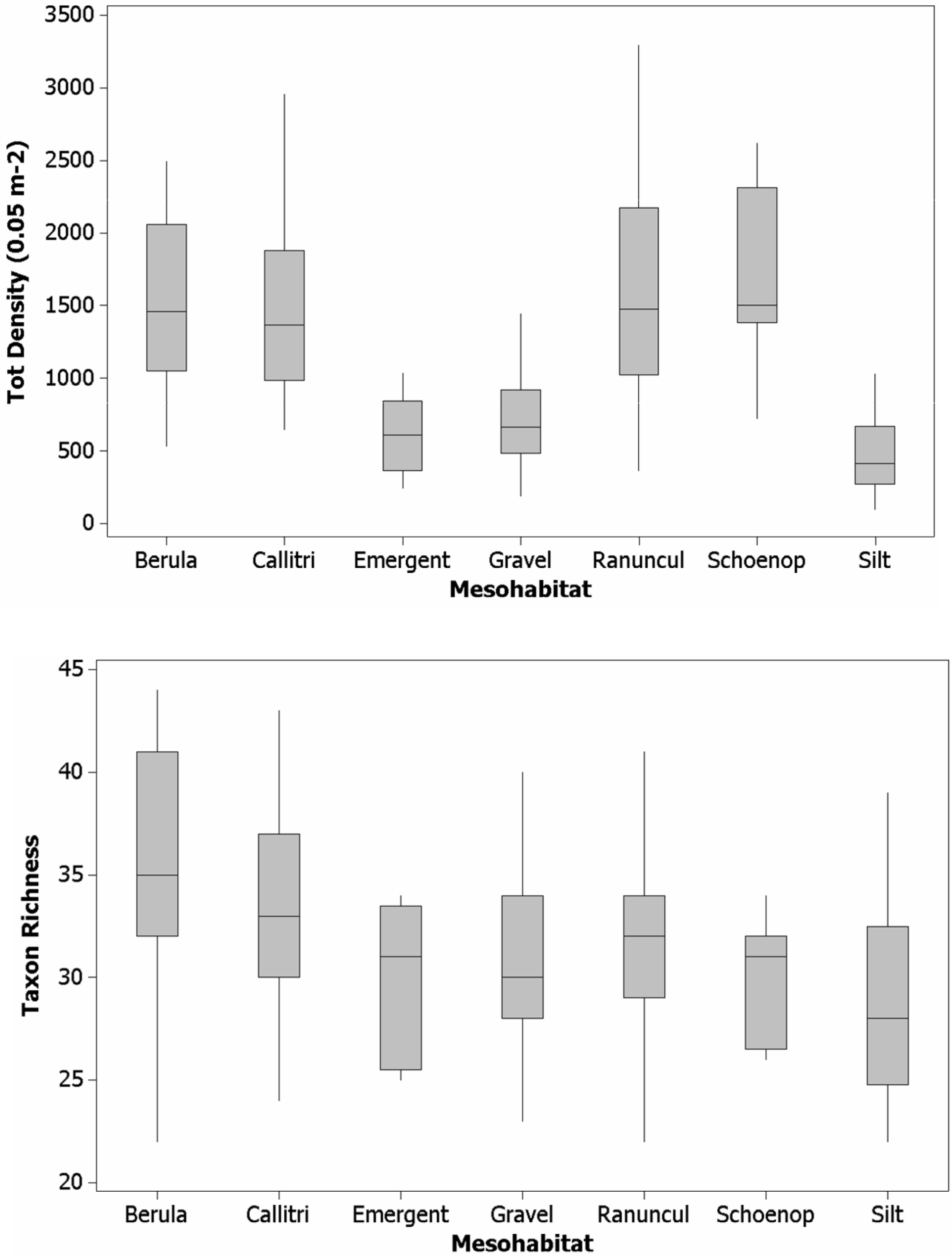

Figure 13 Variation in density and taxon richness across seven mesohabitats.

There was a significant difference between the seven mesohabitats in terms of their taxon richness (H_6=27.8, P<0.001) and the density of individuals they maintained (H_6= 89.47, *P*<0.001) (Fig. 13). The four in-stream macrophyte habitats held more individuals than the bare substrates and emergent vegetation habitats. *Berula* and *Callitriche* supported the greatest number of families, with Silt and Gravel having the lowest median taxon richness (Fig. 13). Most taxa tested did differ in their densities between the mesohabitats. Only the mobile beetle Dytiscidae was equally distributed across all habitats.

Table 2 Macroinvertebrate associations with mesohabitats as determined from Kruskal-Wallis tests.

	Berula	*Callitriche*	Emergent	Gravel	*Ranunculus*	*Schoenoplectus*	Silt
Chironomidae	*	**			*	***	
Gammaridae	**			*	***	*	
Baetidae	*	*			****	*	
Elmidae	***	**			**		
Ceratopogonidae	***	***	*				
Ephemerellidae	**	**			***		
Sphaeriidae	*	***				*	**
Hydracarina	***	**			**		
Limnephilidae	**	**	**		*		
Erpobdellidae	*	*			*	****	
Glossiphoniidae	**	**			*	**	
Leptoceridae	**			***		**	
Simuliidae	**				****	*	
Caenidae	***	**			**		
Glossosomatidae	**			****	*		
Asellidae	*	***	*			**	
Tipulidae	*		**	***			*
Lumbricidae	**			**	***		
Planariidae	**	*			*	***	
Empididae	****	**			*		
Piscicolidae	*	***			***		
Polycentropodidae	**	*			*	***	
Hydrobiidae	*		****				**
Ancylidae				****	**	*	
Hydroptilidae	***	***					*
Rhyacophilidae	*			**	****		
Planorbidae	**	***			**		
Ephemeridae	***	**					**
Goeridae	*			*****	*		
Dytiscidae	*	*	*	*	*	*	*
Physidae	***	***			*		
Lepidostomatidae	***	**			**		
Hydropsychidae	**			**	***		

Berula had strong associations with Elmidae, Empididae, Ceratopogonidae, Hydracarina, Caenidae, Ephemeridae, Physidae, Lepidostomatidae and Hydroptilidae. *Callitriche* was most consistently associated with Ceratopogonidae, Asellidae, Piscicolidae, Hydroptilidae, Sphaeriidae, Planorbidae and Physidae. Hydrobiidae was strongly associated with Emergent Vegetation, while Gravel was the preferred mesohabitat for Goeridae, Leptoceridae, Glossosomatidae, Tipulidae and Ancylidae. Most taxa were found in relatively low densities in Silt though some, such as Sphaeriidae, Hydrobiidae and Ephemeridae, did have a certain affinity for the habitat. *Ranunculus* had strong associations with Gammaridae, Baetidae, Ephemerellidae, Simuliidae, Rhyacophilidae and Hydropsychidae. Chironomidae, Erpobdellidae, Planariidae and Polycentropodidae were most often associated with *Schoenoplectus* stands.

Previous studies in these rivers have shown a positive link between discharge and the extent of *Ranunculus* cover in the channel (Ham et al. 1981, Wright & Berrie 1987, Wright et al. 2002). In drought years *Ranunculus* and *Schoenoplectus* tend to be restricted due to smothering by epiphytic algae and silt. *Callitriche* and other marginal emergent vegetation can replace the Water Crowfoot as the dominant vegetation under such conditions. It is likely therefore that the increased incidence of warmer, drier summers for this region over the next 80 years will lead to changes in the macroinvertebrate community via changes in the availability of preferred habitat. Taxa that are particularly dependent on *Ranunculus* and *Schoenoplectus* e.g. Baetidae, Simuliidae, Rhyacophildae and Erpobdellidae would be expected to decline, while Sphaeriidae, Physidae, Ephemeridae, Asellidae and Hydroptilidae may become more prevalent.

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Appendix I: Key to RHS abbreviations

RHS code	Explanation
B_MAT_BI	Bank Material-bioengineering
B_MAT_BR	Bank Material-brick/laid stone
B_MAT_CC	Bank Material-concrete
B_MAT_EA	Bank Material-earth
B_MAT_GS	Bank Material-gravel/sand
B_MAT_SP	Bank Material-sheet piling
B_MAT_TD	Bank Material-tipped debris
B_MAT_WP	Bank Material-wood piling
B_MD_BM	Bank Modification-artificial berm
B_MD_EM	Bank Modification-embanked
B_MD_PC	Bank Modification-poached
B_MD_RI	Bank Modification-reinforced
B_MD_RS	Bank Modification-resectioned (reprofiled)
B_FE_EC	Bank Feature-eroding cliff
B_FE_PB	Bank Feature-unvegetated point bar
B_FE_SB	Bank Feature-unvegetated side bar
B_FE_SC	Bank Feature-stable cliff
B_FE_VS	Bank Feature-vegetated side bar
CHSB_CO	Channel substrate-cobble
CHSB_EA	Channel substrate-earth
CHSB_GP	Channel substrate-gravel/pebble
CHSB_GPG	Channel substrate-predominantly gravel/ some pebble
CHSB_GPP	Channel substrate-some gravel/ predominantly pebble
CHSB_SA	Channel substrate-sand
CHSB_SI	Channel substrate-silt
CHFLW_DR	Channel flow-dry channel
CHFLW_NP	Channel flow-no perceptible flow
CHFLW_RP	Channel flow-rippled
CHFLW_SM	Channel flow-smooth
CHFLW_UW	Channel flow-unbroken standing waves
CHMD_CV	Channel modification-culvert
CHMD_RS	Channel modification-resectioned
BTU5_BL	Bank top land use (5m)-broadleaf/mixed woodland
BTU5_BP	Bank top land use (5m)-broadleaf/mixed plantation
BTU5_IG	Bank top land use (5m)-improved grassland
BTU5_OW	Bank top land use (5m)-natural open water
BTU5_PG	Bank top land use (5m)-parkland/garden
BTU5_RP	Bank top land use (5m)-rough grassland
BTU5_SH	Bank top land use (5m)-scrub/shrub
BTU5_SU	Bank top land use (5m)-suburbs/urban
BTU5_TH	Bank top land use (5m)-tall herb/rank vegetation
BTU5_TL	Bank top land use (5m)-tilled land
BTU5_WL	Bank top land use (5m)-wetland
BT_STC_B	Bank top vegetation structure- bare
BT_STC_C	Bank top vegetation structure- complex
BT_STC_S	Bank top vegetation structure- simple
BT_STC_U	Bank top vegetation structure- uniform
BF_STC_B	Bank face vegetation structure- bare
BF_STC_C	Bank face vegetation structure- complex
BF_STC_S	Bank face vegetation structure- simple
BF_STC_U	Bank face vegetation structure- uniform
CV_B_L	CHANNEL VEG - Liverworts/mosses/lichens
CV_HER	CHANNEL VEG - Emergent broad-leaved herbs
CV_REE	CHANNEL VEG - Emergent reeds/sedges/rushes
CV_FOL	CHANNEL VEG - Floating-leaved (rooted)
CV_FRF	CHANNEL VEG - Free-floating
CV_AMP	CHANNEL VEG - Amphibious
CV_SBL	CHANNEL VEG - Submerged broad-leaved
CV_FIA	CHANNEL VEG - Filamentous algae
CV_FIN	CHANNEL VEG - Submerged fine leaved
CV_LL	CHANNEL VEG - Submerged linear leaved
Riffles	No of Riffles
Pools	No of Pools
UnVegPtb	No of Unvegetated point-bars
WeirSlui	No of Wiers/sluices
Culvert	No of Culverts
Bridge	No of Bridges
Outfall	No of Outfalls/Intakes
Ford	No of Fords
Deflect	No of Deflectors/Groynes/Croys
OthFeat	No of Other artificial features
ChanReal	Channel realigned
Chandeep	Channel over-deepened
WaterImp	Water impounded
Trees	Trees
ShadChan	Shading of channel
OverBoug	Overhanging boughs
ExpRoot	Exposed bankside roots
UnWatRts	Underwater tree roots
FallTree	Fallen trees
CWD	Coarse woody debris
ErodClif	Eroding cliff
StabClif	Stable cliff
ChunVmCB	Unvegetated mid-channel bar(s)
ChVmCB	Vegetated mid-channel bar(s)
ChunVSB	Unvegetated side bar(s)
ChVSB	Vegetated side bar(s)
ChunVSD	Unvegetated silt deposit(s)
BtHeight	Banktop Height (m)
BtWidth	Channel Banktop width (m)
Depth	Channel Water depth (m)
WetWidth	Channel Water width (m)

8. Contribution by CNR-IRSA

1. Collation of existing information on key taxa or functional groups identified in the study catchment. More regionally oriented overview.

Existing data

Macroinvertebrate data from 6 sites in Orco catchment collected with Italian National Method (IBE) at family or genus level. Data have been collected by local authorities from 2000 to 2004, with a seasonal frequency (data collected every three month, therefore 4 times a year). For Orco catchment are available fish data too, furnished by Piedmont Region.
Moreover, data additionally collected within the AQEM project in the Northern Apennine area will be used, to support the description of the relationships between selected hydromorphological features and invertebrates data. The studied river sites were mainly affected by morphological degradation. These data includes River Habitat Survey and macroinvertebrates data collected in different microhabitats according to the AQEM sampling protocol.

2. Analytical methods and approaches

Analyses will combine hydro-morphological and biological data, also considering data collected for task 1.1.
Information on microhabitat composition and distribution obtained from Italian AQEM and SE_RHS (on 500 and 100 m reaches) will be compared. Moreover, hydromorphological and microhabitat characteristics data recorded in main and secondary channels will be compared. The aim is to compare:

- ✓ data on microhabitat characteristics and hydromorphological features recorded at different spatial scales;
- ✓ data on microhabitat characteristics and hydromorphological features recorded in main and secondary channels.

Moreover, natural and artificial channels will be compared to evidence the differences among them in terms of microhabitat and hydromorphological features.
Existing macroinvertebrates data collected with National method (IBE) from 2000 to 2004 and fish data (to be checked) will be used to interpret the differences among natural and artificial river reaches from a biological point of view.
Macroinvertebrates data newly collected with Italian AQEM and *BIOLIMPACS* sampling protocols will be related to hydromorphological data collected at different spatial scales (SE_RHS on 500 and 100 m reaches) and in the main/secondary channel to complete the results obtained from IBE data analysis and to give a more detailed description of biota present condition in the selected catchments. These analyses will be supported with analyses done on AQEM additional data from Northern Apennines rivers. In particular, with the *BIOLIMPACS* protocol the invertebrates data are collected not according to the proportionality of the observed habitats, but in fixed substrates types in relation to different erosional/depositional features.

Main methods of analysis will include: multivariate analysis and correlation/regression analysis. Land use data on different spatial scales will be included when available and correlated to hydro-morphological features.

3. Preliminary results

Data have not yet been analyzed.

9. Contribution by UDE

Assessing the impact of hydromorphological degradation on the macroinvertebrate fauna of four German stream types

Methods

Site selection and sampling

We investigated four stream types, two of which are located in the Northern German lowlands (ecoregion 14, according to Illies, 1978) and two of which are located in lower mountainous areas (ecoregion 9) (Table 1, Fig. 1).

For each stream type, 12 to 20 sites were selected (Table 1). The rationale behind this selection process was to cover a gradient from near-natural sites to heavily degraded sections for each of the stream types. The degradation of the sites was mainly caused by hydromorphological alterations, while the level of organic pollution was low or moderate in all cases according to official sources. With the help of simple parameters such as degree of bank- and bed-fixation we preliminary assigned morphological degradation classes to all sites ("pre-classification"). Consequently, sampling sites represented the situation of streams in Germany: low to moderate pollution and different degrees of morphological degradation.

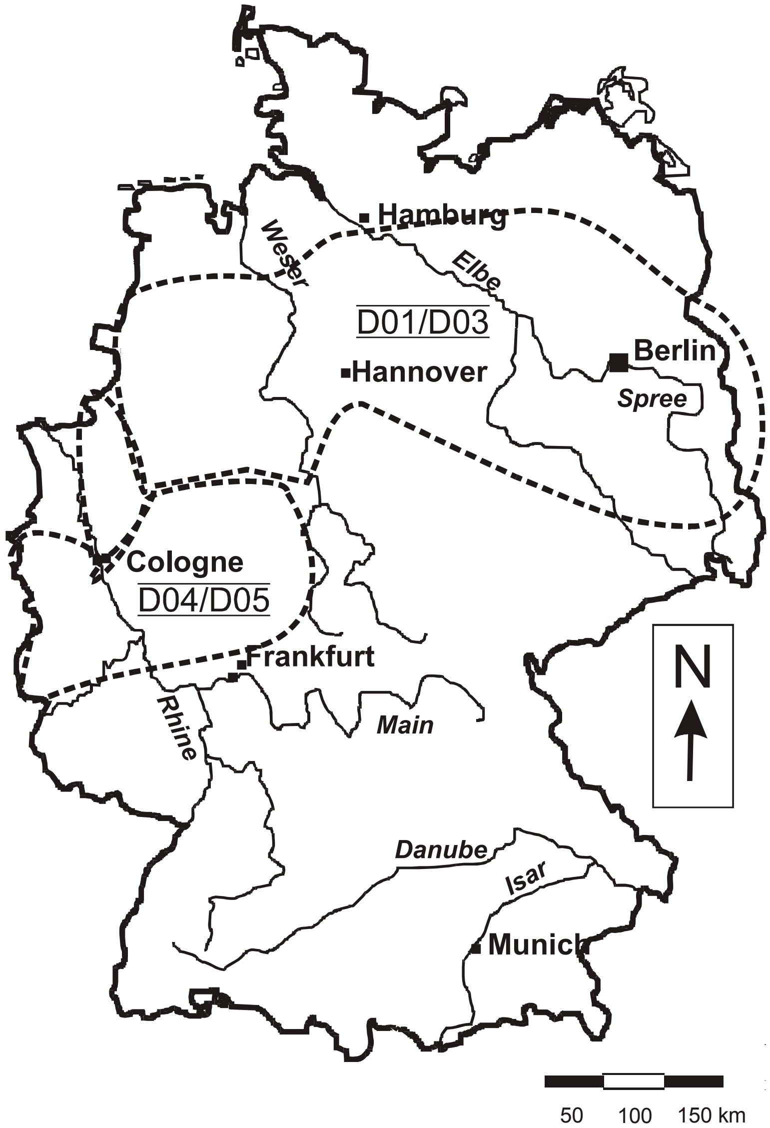


Fig. 1. **Distribution of stream types in Germany.**

We took a total of 174 samples in spring (March/April) and summer (June/July) 2000 using a multi-habitat sampling technique (Hering et al., 2004). Subsequent sample processing included a sieving process separating the samples into a coarse (> 2000 µm for mountain streams; > 1000 µm for lowland streams) and a fine fraction. Further analyses were limited to the coarse fraction.

We aimed for an identification to species level, with the exceptions of Oligochaeta (usually family level), Chironomidae (mixed level ranging from species to tribe), Simuliidae and Limoniidae (genus level), and Brachycera (family level).

Table 1. **Stream type characteristics.**

Stream type	abbreviation	Catchment geology	Ecoregion acc. Illies (1978)	Altitude [m a.s.l.]	Catchment area [km^2]	Main substrate	Sieving fraction [µm]	No. of sampling sites
Small sand bottom streams in the German lowlands	D01	Siliceous	14	0-200	10-100	Sand	>1000	12
Mid-sized sand bottom streams in the German lowlands	D03	Siliceous	14	0-200	100-1000	Sand	>1000	18
Small streams in lower mountainous areas of Central Europe	D04	Siliceous	9	200-500	10-100	Gravel	>2000	38
Mid-sized streams in lower mountainous areas of Central Europe	D05	Siliceous	9	200-500	100-1000	Gravel	>2000	20

Approximately 200 parameters describing morphology, chemistry, hydrology and catchment characteristics were recorded using a harmonised site protocol (Feld, 2004; Hering et al., 2004). These data were used to derive a hydromorphological classification of each site as a value ranging from 0 to 100 (“Structure Index”). The Structure Index was also used to describe “Structural Quality Classes” ranging from 5 (high structural status) to 1 (bad structural status). Since causes and effects of morphological degradation differ significantly between lowland and mountain streams and between stream sizes, different parameters of the site protocol have been used for the Structure Indices of the individual stream types (Table 2). In general, parameters have been selected, which discriminate between the unstressed and stressed sampling sites and which are likely to affect the benthic invertebrate fauna. The selected parameters were individually scored from 0 (degraded) to 100 (reference). For calculating the final index score the scores of the individual parameters were averaged, using weighting factors in selected cases. For stream type D03 the development process of the Structure Index is described in detail by Feld (2004).

Table 2. **Morphological parameters used to define the Structure Index for the stream types (for stream type abbreviations see Table 1).**

Stream type	Parameters
D01	Share of woody debris [%]
	Share of organic substrates [%]
	Shading of the channel [%]
	Width [m] and percentage of shoreline vegetation
	Width [m] and percentage of natural floodplain vegetation
	Land use in the floodplain
	Scouring [m]
	Presence and material of bank fixation
	Channel form and anthropogenic alterations
D03	Share of woody debris [%]
	Share of organic substrates [%]
	Shading of the channel [%]
	Width [m] and percentage of shoreline vegetation
	Width [m] and percentage of natural floodplain vegetation
	Land use in the floodplain
	Scouring [m]
	Presence and material of bank fixation
	Channel form and anthropogenic alterations
D04	Average width of woody riparian vegetation [m]
	Shoreline covered with woody riparian vegetation [%]
	Shading of the channel [%]
	No. of debris dams / no. of logs
	Presence and material of bank fixation
	Variance of the mineral substrates
D05	Channel form
	Width of the channel to width of the floodplain
	Current (flow) diversity
	Depth variation
	Share of woody debris [%]
	Positive and negative channel patterns (dams, backwaters)
	Presence of migration barriers

Selection and development of metrics

Approximately 200 metrics were derived from the fauna dataset and tested to identify calculation methods, with a close correlation to the Structure Index. This step was performed individually for each stream type. The selection of metrics suitable to assess the impact of hydromorphological degradation on the macroinvertebrate fauna was based on the following criteria: (1) the metric must decrease or increase with increasing Structure Index (tested through linear correlation). (2) all criteria defined by the Water Framework Directive for the assessment of the benthic invertebrate fauna (taxonomic composition, abundance, ratio sensitive/insensitive taxa, diversity) should be covered by the selected metrics. (3) there should be a theoretical rationale why the metric changes with hydromorphological degradation. (4) the metrics should not be redundant (tested by linear correlation of candidate metric results).

In addition, a new group of metrics was developed ("German Fauna Index"; one index for each stream type investigated), based on a stream type-specific list of indicator taxa. Although the selection of indicator taxa necessarily included a certain degree of expert judgement, the following criteria were defined to keep the selection process as transparent as possible: (1) the occurrence and/or abundance of an indicator taxon correlates, positively or negatively, with the Structure Index; thus, the taxon shows a preference for either reference sites or hydromorphologically degraded sites. Evaluation of the data was performed with the PC program IndVal (Dufrêne & Legendre, 1997) (details in Appendix 1). This criterion was used for both, positive and negative indicator taxa. (2) based on literature data, the taxon shows a preference for a certain habitat, either typical for the reference situation (e.g., coarse wood, lentic zones in the shore area of mountain streams) or for degraded section (e.g., stones used for bank fixation in sand bottom lowland streams). The literature data used are partly empirical and partly experimental (references are given in Appendix 1). The near-natural habitat composition of each stream type was taken into account in this step (derived from LUA NRW, 1999a, b, 2000, 2001); consequently, different indicator taxa and different scores were defined for the individual stream types. This criterion was used for both positive and negative indicator taxa. (3) the taxon historically occurs in a certain stream type. These taxa received a positive value, and (4) under near-natural conditions, the taxon shows a clear preference for the stream type. These taxa were mainly taken from LUA NRW (1999a, 1999b, 2000, 2001) and received positive values.

Four different scores (+2, +1, -1, -2) were assigned to the selected indicator taxa. The “German Fauna Index” is then calculated as:

$$German \quad Fauna \quad Index = \frac{\sum_{i}^{N} sc_i \cdot a_i}{\sum_{i}^{N} a_i}$$

(N = total number of indicator taxa; i = number of indicator taxa; sc_i = score of the i^{th} taxon; a_i = abundance class of the i^{th} taxon; abundance class defined as: 1-3 ind. = class 1; 4-10 ind. = class 2; 11-30 ind. = class 3; 31-100 ind. = class 4; 101-300 ind. = class 5; 301-1000 ind. = class 6; > 1000 ind. = class 7)

Ecological Quality Classes and Multimetric Index

For each selected metric, Ecological Quality Classes were defined ranging from 5 (high status) to 1 (bad status). In a first step, this scoring system was solely based on the samples taken throughout this study and which supposedly covered all stages of degradation. As a general rule, the class boundaries were taken from the index values achieved in a certain Structural Quality Class (defined by the Structure Index): if 25% of the investigated sites were assigned to structural class 5, then the 25% highest metric values were also assigned to quality class 5.

The scores of the individual metrics were summarised to a Multimetric Index, which ranges from 5 (high status) to 1 (bad status). The Multimetric Index is calculated as the average score of all metrics included; a weighting factor ensures that the German Fauna Index always contributes to 50% of the Multimetric Index. The procedure is presented for the stream type “mid-sized streams in lower mountainous areas of Central Europe” (D05) in the result chapter.

The validity of the assessment method was tested with data taken from other studies and which have been collected with comparable sampling methods. For the mid-sized mountain streams, data on 32 sampling sites from LUA NRW (2001) and Frenz & Hering (1999) were used.

Results

The “German Fauna Index”

The number of indicator taxa per stream type ranges between 122 (stream type D01, small sand bottom streams in the German lowlands) and 189 (stream type D04, small streams in lower mountainous areas of Central Europe) (Appendix 1).

We selected a similar number of positive and negative indicator taxa for small sand bottom lowland streams (D01); for mid-sized sand bottom lowland streams (D03) the number of positive indicator taxa is higher. The negative indicator taxa are generally restricted to the usually artificial lithal (stone) habitats or to stagnant sections upstream of dams. The positive indicator taxa comprise xylophagous species and taxa restricted to fast flowing sections.

There are only a comparatively small number of negative indicator taxa (39) in small streams of lower mountainous areas of Central Europe (D04). Most of these are restricted to stagnant conditions or indicate “potamalisation” (conditions usually present in large rivers, such as comparatively high temperatures and low current velocities). Some very common species, such as *Baetis rhodani* PICTET, are typically found in high densities in degraded sections, although they also inhabit near-natural sections but in lower numbers. In contrast to sand bottom lowland streams we could not find any taxa restricted to artificial substrates, since bank- and bed fixation is usually performed with autochthonous materials (stone plastering). Positive indicator taxa include species that predominantly occur in debris dams (e.g., *Philopotamus montanus* (DONOVAN)) in lentic zones near the shoreline (e.g., several Dytiscidae). Some/most of these are characterised by a comparatively long life cycle (e.g., *Perla marginata* PANZER).

Mid-sized streams in lower mountainous areas of Central Europe (D05) have only approximately half the number of negative (53 taxa) than positive indicator taxa (102). The latter include taxa from lentic zones near the shoreline (e.g., *Siphlonurus* sp.), taxa that indicate high current velocities (e.g., *Oligoneuriella rhenana* (IMHOFF)) or that prefer scarce habitats (*Ephemera danica* MÜLLER in sandy patches). Some of those negative indicator species, which are restricted to stagnant sections, received positive indicator values in stream type D04, where they generally occur in natural floodplain ponds.

Rationale of metric selection

The metric selection for mid-sized streams in lower mountainous areas of Central Europe (D05) can serve as an example to demonstrate the rationale for their choice. Four metrics, aiming to indicate additional characteristics of mid-sized mountain streams under reference conditions and correlated to the hydromorphological quality of the sites (Fig. 2), were selected to supplement the “German Fauna Index D05”:

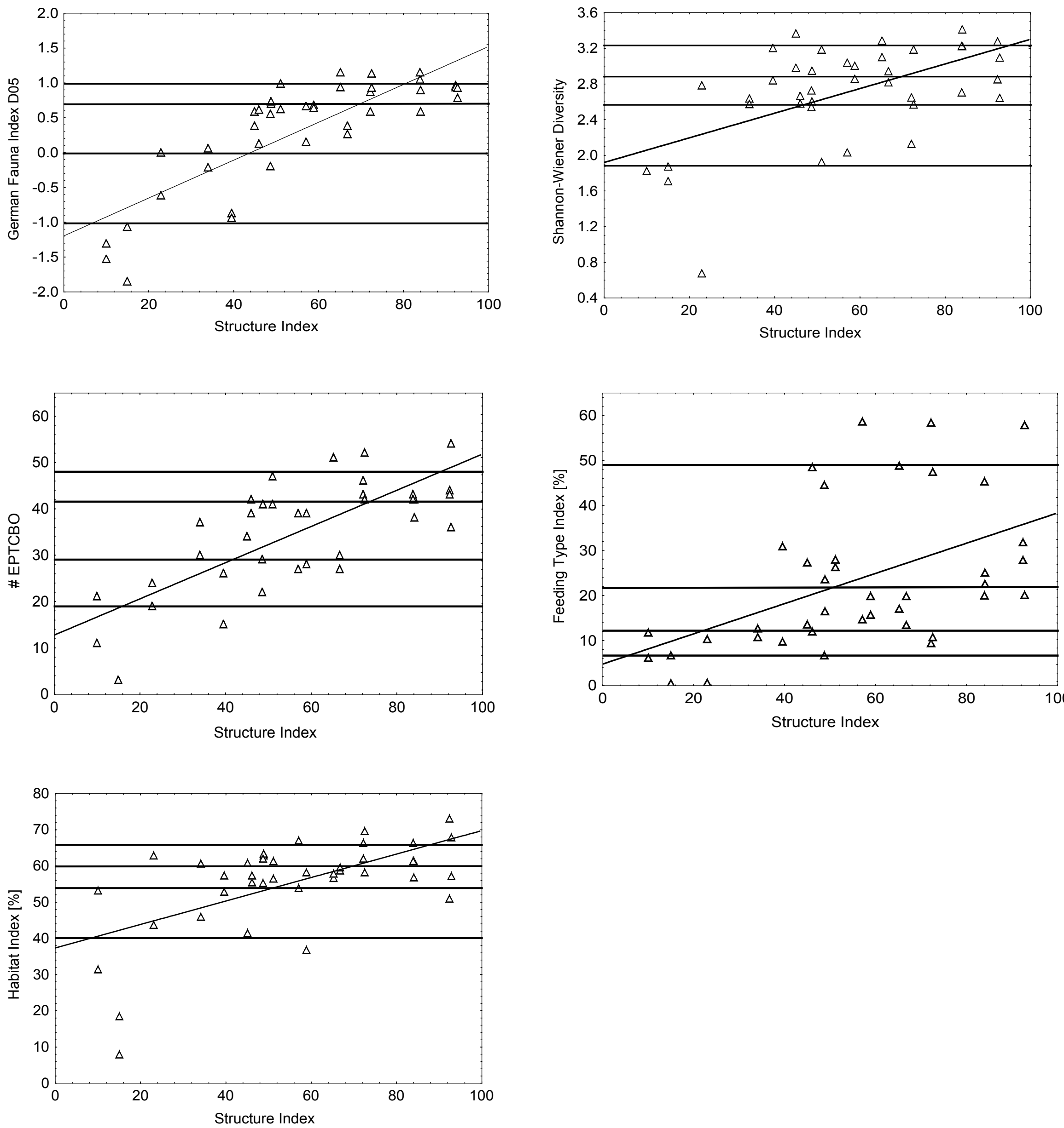
(1) Shannon-Wiener-Diversity (Shannon & Weaver, 1949);

(2) Number of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Odonata and Bivalvia (EPTCOB) taxa: although most mid-sized mountain streams are dominated by homogeneous stony substrates, they were formerly characterised by a high substrate diversity (LUA NRW, 2001, Ehlert et al., 2002), likely resulting in both a higher number of taxa and higher diversity of species.

(3) Percent xylophagous taxa, shredders, active filter feeders and passive filter feeders (“Feeding Type Index”): under reference conditions, the catchment is completely covered by natural woody vegetation and the river contains a high standing stock of woody debris (Hering et al., 2000). This debris traps other coarse organic material which results in a reference invertebrate fauna with a high percentage of xylophagous and shredder taxa, supplemented by filter feeders dependent on the fine particulate organic matter (FPOM) generated by the shredders.

(4) Percent akal (gravel), lithal (stone) and psammal (sand) preferences (“Habitat Index”): under reference conditions, the stream bed is dominated by stony and gravely substrates and in addition sandy patches are frequently found in lentic zones. Therefore, the reference invertebrate fauna is dominated by taxa with these habitat preferences.

***Figure** 2.* **Linear regression of the individual metrics and the "Structure Index" for stream type D05, including the boundaries of the Ecological Quality Classes: German Fauna Index D05 (r^2 = 0.81), Shannon-Wiener-Diversity (r^2 = 0.34), number of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Odonata and Bivalvia taxa (r^2 = 0.54), [%] xylophagous taxa, shredder, active filter feeders and passive filter feeders ("Feeding type Index") (r^2 = 0.24), [%] akal, lithal and psammal preferences ("Habitat Index") (r^2 = 0.35).**



The “German Fauna Index D05” and the additional metrics cover all criteria required for the assessment of the benthic invertebrate fauna according to the Water Framework Directive (Table 3).

The four metrics selected to supplement the “German Fauna Index D05” are only weakly correlated with each other, with the exception of the “Habitat Index” and number of EPTCBO taxa (r^2 = 0.51; Table 4). Although the correlation with the “German Fauna Index D05” is usually stronger, they are included into the Multimetric Index for stabilisation in case only a small number of indicator taxa of the “German Fauna Index D05” are found in a particular sample. The resulting Multimetric Index shows a clear correlation to the hydromorphological quality of the sites (Fig. 3).

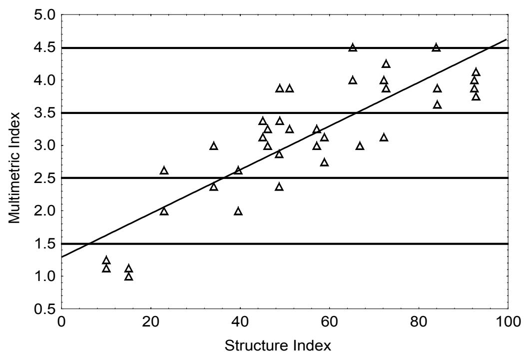
Table 3. **Metrics included into the Multimetric System. (For stream type abbreviation see Table 1). Criterion: Criterion of the Water Framework Directive for the assessment of benthic invertebrates addressed by the metric; abd = abundance; div = diversity; rat = ratio of sensitive and robust taxa; tax = taxonomic composition; r^2, p: Linear correlation of the metric (dependent variable) and the Structure Index describing the morphological degradation (independent variable); linear regression, separately given for the stream types; 100% = classified individuals: taxa, for which autecological information is lacking, have been excluded.**

Stream type	Metric	criterion	r^2	p
D01	German Fauna Index D01	tax; rat	0.88	< 0.001
	[%] Plecoptera	tax; abd	0.34	< 0.01
	[%] rheophilous preferences - calculated with classified taxa only	abd; rat	0.27	< 0.01
	[%] gatherers/collectors	abd; rat	-0.14	> 0.05
	[%] litoral preferences	abd; rat	-0.20	> 0.05
	[%] pelal preferences - calculated with classified taxa only	abd; rat	-0.03	> 0.05
D03	German Fauna Index D03	tax; rat	0.85	< 0.001
	[%] Trichoptera	tax; abd	0.26	< 0.01
	[%] rheophilous preferences - calculated with classified taxa only	abd; rat	0.60	< 0.001
	[%] gatherers/collectors	abd; rat	0.39	< 0.001
	[%] litoral preferences	abd; rat	-0.39	< 0.001
	[%] pelal preferences - calculated with classified taxa only	abd; rat	-0.36	< 0.001
D04	German Fauna Index D04	tax; rat	0.52	< 0.001
	BMWP	rat	0.44	< 0.001
	Shannon-Wiener-Diversity	div	0.29	< 0.001
	[%] akal preferences - calculated with classified taxa only	abd; rat	0.10	0.06
	[%] phytal preferences - calculated with classified taxa only	abd; rat	0.23	< 0.01
	[%] hyporhithral preferences - calculated with classified taxa only (spring samples)	abd; rat	0.44	< 0.01
	[%] hypocrenal preferences - calculated with classified taxa only (summer samples)	abd; rat	0.43	<0.01
D05	German Fauna Index D05	tax; rat	0.67	< 0.001
	number of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Odonata and Bivalvia taxa	tax	0.54	< 0.001

[%] xylophagous taxa, shredder, active filter feeders and passive filter feeders	abd; rat	0.24	< 0.01
[%] akal, lithal and psammal preferences	abd; rat	0.35	< 0.001
Shannon-Wiener-Diversity	div	0.34	< 0.001

Considering data on additional sampling sites the Multimetric Index for stream type D05 shows only "poor" or "bad" values for sections of the river Lenne, which are heavily degraded due to stagnant conditions or residual flow (Fig. 4), sections of several rivers in Northrhine-Westphalia, with a "moderate" morphological evaluation, were assessed as "poor", "moderate" or "good" using the Multimetric Index (Fig. 4).

***Figure 3*. Linear regression of the Multimetric Index and the Structure Index for stream type D05 (r^2 = 0.67).**



Between 5 and 6 additional metrics provide informative data for stream types D01 to D04 (Table 3).

The morphological degradation of sandy bottom lowland streams (D01 and D03) is caused by straightening, scouring and bank fixation, often supplemented by damming, stagnation and intensive agricultural land use of the riparian corridor. On a smaller scale, these alterations lead to homogeneous hydraulic and morphological conditions and, most importantly, the loss of certain habitats (woody debris, CPOM). Therefore, the metrics selected to supplement the "German Fauna Indices D01 and D03" indicate mainly loss of habitat and species diversity ([%] Plecoptera; [%] Trichoptera), stagnant conditions ([%] litoral preferences; [%] pelal preferences; [%] rheophilous preferences) and shifts in feeding type ([%] gatherers/collectors).

Morphological degradation in small mountain streams (D04) is mainly caused by straightening, bank fixation, and lack of woody vegetation in the floodplain and removal of woody debris. These impairments lead to a decrease in substrate and current diversity, increase in aquatic vegetation and a loss of lentic habitats. The metrics selected to supplement the "German Fauna Index D04" focus on the loss of habitat and species diversity (Shannon-Wiener Diversity, BMWP), the loss of lentic habitats ([%] akal preferences), the loss of woody riparian vegetation ([%] phytal preferences) and an indication of homogeneous flow conditions and increased water temperature ([%] hyporhithral preferences; [%] hypocrenal preferences). For the habitat types compare Hering et al. (2003).

Table 4. **Correlation matrix of the individual metrics included into the multimetric system for stream type D05, the Multimetric Index and the German Saprobic Index (DIN 38410); r^2 values, linear correlation. # EPTCBO = number of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Bivalvia and Odonata taxa; Feeding type Index = [%] xylophagous taxa, shredder, active filter feeders and passive filter feeders; Habitat Index = [%] akal, lithal and psammal preferences; DIN 38 410 = German Saprobic System; Multimetric Index D05 = composed of German Fauna Index D05 (50%), # EPTCBO, Shannon-Wiener-Diversity, Feeding type Index, Habitat Index.**

	# EPTCBO	Shannon-Wiener-Div.	Feeding type Index	Habitat Index	German Fauna Index D05	DIN 38 410	Multimetric Index D05
# EPTCBO							
Shannon-Wiener-Div.	0.28						
Feeding type Index	0.13	0.02					
Habitat Index	0.51	0.07	0.18				
German Fauna Index D05	0.77	0.36	0.21	0.42			
DIN 38 410	0.43	0.28	0.21	0.45	0.65		
Multimetric Index D05	0.80	0.38	0.28	0.48	0.88	0.54	

In general, the results of the “German Fauna Index” are strongly correlated with the results of the Structure Index of the stream types (e.g., D04: r^2 = 0.52; D01: r^2 = 0.81; Table 5). The correlation of the metrics selected for the individual stream types with the Structure Index is usually weaker (Table 3). However, the correlation of the individual metrics with each other is generally weak (e.g., Table 4 for D05), so that they indicate additional characteristics of the community. The correlation of the Multimetric Index and the hydromorphological quality is usually similar to the correlation of the “German Fauna Index” and the Structure Index (Table 5).

Figure 4. Multimetric Index for additional sampling sites of stream type D05 (mid-sized streams in lower mountainous areas of Central Europe). Group 1: Heavily degraded sections of the river Lenne (residual flow sections and stagnant sections) (data from Frenz & Hering, 1999); Group 2: Sections of the river Lenne with a degraded hydromorphology, but not dammed or effected by residual flow (data from Frenz & Hering, 1999); Group 3: Sections of several rivers in Northrhine-Westphalia; the morphology covers a wide range but was mainly estimated to be in a "moderate" condition (data from LUA, 2001).

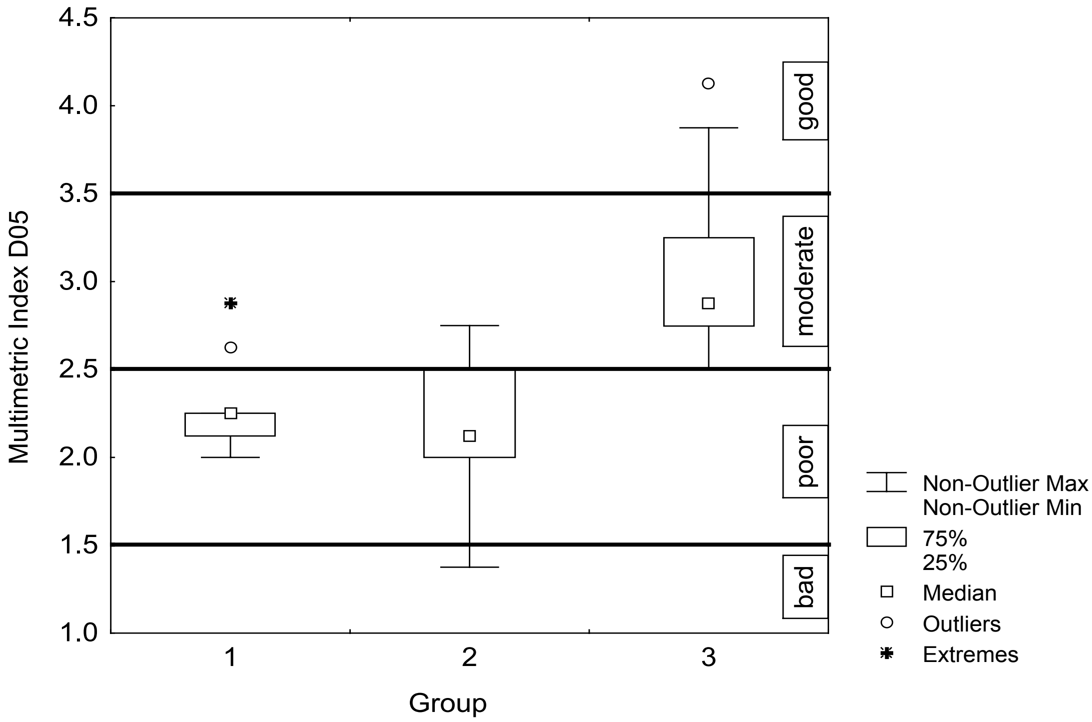


Table 5. **Correlation of the German Fauna Index and the Multimetric Index, respectively and the Structure Index describing the morphological degradation; linear regression, separately given for the stream types. (Stream type abbreviations: compare Table 1).**

	German Fauna Index		Multimetric Index	
Stream type	r^2	p	r^2	p
D01	0.81	< 0.001	0.65	< 0.001
D03	0.78	< 0.001	0.78	< 0.001
D04	0.52	< 0.001	0.51	< 0.001
D05	0.67	< 0.001	0.72	< 0.001

Discussion

Stressor-specific indices and assessment systems have been generated for organic pollution (amongst others AFNOR, 1985; Alba-Tercedor & Sanchez-Ortega, 1988; de Pauw & Vanhooren, 1983; DEV 1992; Moog et al., 1999), acidification (Braukmann, 2000; Henrikson & Medin, 1986; Rutt et al., 1990) and the impact of heavy metals (Paasavirta, 1990; Reynoldson et al., 1997). There are two reasons for stressor-specific assessment methods. Firstly, individual taxa may not be equally sensitive to all types of stressors (Chessman & McEnvoy, 1998), thus offering the opportunity to discriminate between different impairments. Secondly, it is often important for general monitoring programmes to have information about the cause of a possible degradation in addition to the overall Ecological Quality.

At present, the main stressor affecting Central European streams appears to be hydromorphological degradation and a multitude of methods have been developed to assess river morphology with abiotic protocols. A recent review (Birk & Hering, 2002) lists 21 protocols for hydromorphological assessment and classification, which are applied or are under development in several European countries (see also Maddock, 1999). According to the Water Framework Directive the direct assessment of hydromorphology can only be a supplementary measure for stream assessment in Europe. Therefore, there is a strong demand for evaluation methods based on the biotic communities, which evaluate the consequences of hydromorphological degradation.

In contrast to organic pollution or acidification, hydromorphological degradation affects the benthic community through a multitude of individual factors. Dams and impoundments alter flow conditions or temperature profiles (Ward & Stanford, 1979). The loss of riparian vegetation affects production (Bunn et al., 1999) and water temperature (Sponseller et al., 2001), processes and parameters with an imminent influence on the benthic community. Anthropogenic alteration of the channel and the river bed have a strong influence on microhabitat composition (Kemp et al., 1999), which has been argued as the primary factor influencing community structure and species richness (Beisel et al., 1998). Certain microhabitats are particularly affected by hydromorphological degradation and are inhabited by specialist taxa. For example, 103 benthic invertebrate taxa have a preference for woody debris in Central Europe (Hoffmann & Hering, 2000), and this debris is often removed from the main channel. Approaches to assess the impact of hydromorphological alterations on the invertebrate fauna include only some impacts, such as dams (Marchant & Hehir, 2002), reduced discharge (Brunke et al., 2001), habitat composition (Buffagni et al., 2001), fine sediment cover (Mebane, 1999) and logging (Fore et al., 1996).

Multimetric systems are summing up parameters integrating different spatial and temporal scales (Barbour et al., 1998; Karr, 1994; Karr & Chu, 1999). Therefore, multimetric systems seem to be well suited to detect the impact of hydromorphological degradation on the invertebrate fauna, which is usually composed of several factors. Sometimes, but not always, these factors are linked.

The Multimetric Index developed for mid-sized streams in lower mountainous areas of Central Europe (D05) aims for an integration of parameters potentially affected by different kinds of hydromorphological degradation. This is performed on two levels. Firstly, the "German Fauna Index", which includes taxa likely to respond to different components of morphological degradation, and secondly supplementary metrics, which cover additional parameters.

A crucial point for the development of assessment systems aiming to detect the effects of hydromorphological degradation is a profound knowledge on reference conditions. Particularly for stream types in the German lowlands and for medium-sized mountain streams no reference sites are available anymore. We used, therefore, additional information to define reference conditions, particularly historical information on river morphology and results of several national projects targeting on reference conditions, which are described in detail in LUA NRW (1999a, 1999b, 2000, 2001).

The multimetric system aims to assess the impact of hydromorphological degradation. However, the "German Fauna Index" appears also to be sensitive to organic pollution as both the "German Fauna Index D05" and the German Saprobic Index are strongly correlated (r^2 = 0.55; Table 4). The correlation of the "German Fauna Index D05" with the hydromorphological conditions is also strong (r^2 = 0.67), in contrast to the correlation of the Saprobic Index with the Structure Index (r^2 = 0.42). Consequently, the "German Fauna Index D05", although somewhat sensitive to organic pollution, appears to deliver additional information. Similar results have been found for the other stream types. The occurrence and abundance of most taxa is affected by several parameters and their interactions and therefore there is an inevitable overlap of taxa included into the Saprobic System and into the "German Fauna Index". Both metrics aim to utilise different characters of certain taxa: *Siphlonurus* sp. indicates high oxygen contents but also the presence of lentic sections and high stream dynamics. *Asellus aquaticus* LINNAEUS indicates low oxygen contents but also stagnation and low current velocities, which may also occur upstream of dams in unpolluted rivers. Furthermore, hydromorphological degradation and organic pollution often interact, e.g., in stagnant sections high BOD values may effect the community more seriously than in running sections. However, particularly in small mountain streams, the most serious effect of hydromorphological degradation is the loss of lentic habitats; taxa preferring low current velocities are therefore often good indicators for morphological reference conditions, despite a low saprobic value (Hering et al., 2001).

The impact of organic pollution can be assessed with a comparatively low taxonomic resolution, e.g., the ASPT system, which is based on family level identifications. Most metrics we used to assess the impact of hydromorphological degradation, however, are based on species level, since taxa occurring in certain habitats or preferring sites with a certain hydromorphological quality can be defined only on species level, while within genera or families the variability of habitat peferences is usually high (Appendix 1). This may indicate a general shift in stream assessment in Central Europe: organic pollution, which can easily be indicated by a large number of metrics, has widely disappeared, while the assessment of the remaining threats to aquatic biodiversity requires a high taxonomic resolution. While the saprobic assessment in Germany recently lead mainly to a "good" water quality class for the majority of streams, the assessment with the new Multimetric Index displays results from "bad" to "high" quality classes (Figs 2-4), thus better reflecting the present quality of Central European rivers. In conclusion, the new Multimetric Index works well in detecting the impact of morphological degradation on the macroinvertebrate fauna even with other datasets, which have a sufficient taxonomic resolution.

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Appendix 1. **List of scores of indicator taxa in stream type D01 to D05; "ref.": references, from which the index values were derived (Bi = Bivalvia; Co = Coleoptera; Cr = Crustacea; Di = Diptera; Ep = Ephemeroptera; Ga = Gastropoda; He = Heteroptera; Hi = Hirudinea; Me = Megaloptera; Od = Odonata; Ol = Oligochaeta; Pl = Plecoptera; Tc = Trichoptera; Tu = Turbellaria; A = IndVal analyses with the AQEM data; B = LUA NRW, 1999a, 1999b, 2000, 2001; C = habitat or current preferences taken from Schmedtje & Colling, 1996; D = feeding types or longitudinal zonation preferences taken from Moog, 1995; E = Feld et al., 2002; F = Zettler, 1999; G = Haybach, 1998; H = Sommerhäuser, 1998; X = expert judgement; n.a. = not applicable).**

Group	Taxon name	Author	D01	ref.	D03	ref.	D04	ref.	D05	ref.
Bi	Anodonta anatina	(LINNAEUS, 1758)	0	n.a.	0	n.a.	0	n.a.	1	B
Bi	Anodonta cygnea	(LINNAEUS, 1758)	0	n.a.	1	B	0	n.a.	0	n.a.
Bi	Dreissena polymorpha	(PALLAS, 1771)	0	n.a.	-2	C, X	0	n.a.	-2	C, X
Bi	Musculium lacustre	(O.F. MÜLLER, 1774)	0	n.a.	-1	A	0	n.a.	0	n.a.
Bi	Pisidium amnicum	(O.F. MÜLLER, 1774)	0	n.a.	2	A, B, F	0	n.a.	0	n.a.
Bi	Pisidium sp.	PFEIFFER, 1821	0	n.a.	0	n.a.	0	n.a.	2	A
Bi	Pisidium supinum	A. SCHMIDT, 1851	0	n.a.	-1	A, F	0	n.a.	0	n.a.
Bi	Pseudanodonta complanata	(ROSSMÄSSLER, 1835)	0	n.a.	1	B	0	n.a.	0	n.a.
Bi	Sphaerium sp.	SCOPOLI, 1777	-2	A	0	n.a.	0	n.a.	1	A
Bi	Unio crassus crassus	PHILIPSSON, 1788	0	n.a.	2	B	0	n.a.	2	B
Bi	Unio pictorum pictorum	(LINNAEUS, 1758)	0	n.a.	2	B	0	n.a.	0	n.a.
Bi	Unio tumidus tumidus	PHILIPSSON, 1788	0	n.a.	1	B	0	n.a.	0	n.a.
Co	Anacaena globulus Ad.	(PAYKULL, 1798)	0	n.a.	1	C	2	C	0	n.a.
Co	Anacaena globulus Lv.	(PAYKULL, 1798)	0	n.a.	1	C	2	C	0	n.a.
Co	Anacaena limbata Ad.	(FABRICIUS, 1792)	0	n.a.	1	C	2	B	0	n.a.
Co	Anacaena limbata Lv.	(FABRICIUS, 1792)	0	n.a.	1	C	2	A	0	n.a.
Co	Brychius elevatus Ad.	(PANZER, 1794)	0	n.a.	0	n.a.	2	A	-1	A
Co	Brychius elevatus Lv.	(PANZER, 1794)	0	n.a.	0	n.a.	2	A	-1	A
Co	Cyphon sp. Ad.		0	n.a.	0	n.a.	2	B	0	n.a.
Co	Cyphon sp. Lv.		0	n.a.	0	n.a.	2	B	0	n.a.
Co	Deronectes latus Ad.	(STEPHENS, 1829)	1	C	0	n.a.	2	A, D	0	n.a.
Co	Deronectes latus Lv.	(STEPHENS, 1829)	1	C	0	n.a.	2	A	0	n.a.
Co	Deronectes platynotus Ad.	(GERMAR, 1834)	0	n.a.	0	n.a.	2	A, B, D	0	n.a.
Co	Deronectes platynotus Lv.	(GERMAR, 1834)	0	n.a.	0	n.a.	2	A	0	n.a.
Co	Dryops sp. Ad.		0	n.a.	0	n.a.	2	A	2	A
Co	Dryops sp. Lv.		0	n.a.	0	n.a.	2	A	2	A
Co	Elmis aenea/maugetii Ad.		0	n.a.	1	C	1	A	1	A, B
Co	Elmis rioloides Ad.	KUWERT, 1890	0	n.a.	0	n.a.	0	n.a.	1	A
Co	Elmis sp. Lv.		0	n.a.	1	A, B	1	A	1	A
Co	Elodes marginata Ad.	(FABRICIUS, 1798)	0	n.a.	0	n.a.	2	A	0	n.a.
Co	Elodes marginata Lv.	(FABRICIUS, 1798)	0	n.a.	0	n.a.	2	A	0	n.a.
Co	Elodes minuta-Gr. Ad.		0	n.a.	0	n.a.	1	A	0	n.a.
Co	Elodes minuta-Gr. Lv.		2	H	1	A	1	A, C	0	n.a.
Co	Esolus angustatus Ad.	(MÜLLER, 1821)	0	n.a.	0	n.a.	2	A, B	-1	A
Co	Esolus angustatus Lv.	(MÜLLER, 1821)	0	n.a.	0	n.a.	2	B, D	-1	A
Co	Esolus parallelepipedus Ad.	(MÜLLER, 1806)	0	n.a.	0	n.a.	0	n.a.	2	A, B
Co	Esolus parallelepipedus Lv.	(MÜLLER, 1806)	0	n.a.	0	n.a.	0	n.a.	2	A, B
Co	Haliplus sp. Ad.		1	A	-1	C	0	n.a.	-2	A, C
Co	Haliplus sp. Lv.		1	A	-1	C	0	n.a.	-2	A, C
Co	Hydraena dentipes Ad.	GERMAR, 1844	0	n.a.	0	n.a.	2	B, D	1	A
Co	Hydraena gracilis Ad.	GERMAR, 1824	0	n.a.	1	C	1	A	1	B

Group	Taxon name	Author	D01	ref.	D03	ref.	D04	ref.	D05	ref.
Co	Hydraena gracilis Lv.	GERMAR, 1824	0	n.a.	1	C	0	n.a.	0	n.a.
Co	Hydraena minutissima Ad.	STEPHENS, 1829	0	n.a.	0	n.a.	2	A, C	0	n.a.
Co	Hydraena reyi Ad.	KUWERT, 1888	0	n.a.	0	n.a.	2	B, D	2	A
Co	Hydraena riparia Ad.	KUGELANN, 1794	0	n.a.	2	A	0	n.a.	0	n.a.
Co	Hydraena sp. Ad.		0	n.a.	1	C	1	B	1	X
Co	Hydraena sp. Lv.		0	n.a.	1	C	1	A	1	X
Co	Hydrocyphon deflexicollis Ad.	(MÜLLER, 1821)	0	n.a.	0	n.a.	2	A, C	0	n.a.
Co	Hydrocyphon deflexicollis Lv.	(MÜLLER, 1821)	0	n.a.	0	n.a.	2	A	0	n.a.
Co	Hygrotus inaequalis Ad.	(FABRICIUS, 1777)	0	n.a.	2	A	0	n.a.	0	n.a.
Co	Hygrotus inaequalis Lv.	(FABRICIUS, 1777)	0	n.a.	2	A	0	n.a.	0	n.a.
Co	Hygrotus versicolor Ad.	(SCHALLER, 1783)	0	n.a.	1	B	0	n.a.	0	n.a.
Co	Hygrotus versicolor Lv.	(SCHALLER, 1783)	0	n.a.	1	B	0	n.a.	0	n.a.
Co	Ilybius fuliginosus Ad.	(FABRICIUS, 1792)	1	A	1	C	0	n.a.	0	n.a.
Co	Ilybius fuliginosus Lv.	(FABRICIUS, 1792)	1	A	1	C	0	n.a.	0	n.a.
Co	Laccophilus hyalinus Ad.	(DE GEER, 1774)	0	n.a.	0	n.a.	0	n.a.	1	X
Co	Laccophilus hyalinus Lv.	(DE GEER, 1774)	0	n.a.	0	n.a.	0	n.a.	1	X
Co	Laccophilus minutus Ad.	(LINNAEUS, 1758)	0	n.a.	-1	C	0	n.a.	0	n.a.
Co	Laccophilus minutus Lv.	(LINNAEUS, 1758)	0	n.a.	-1	C	0	n.a.	0	n.a.
Co	Limnebius truncatellus Ad.	(THUNBERG, 1794)	0	n.a.	0	n.a.	2	A, C	0	n.a.
Co	Limnebius truncatellus Lv.	(THUNBERG, 1794)	0	n.a.	0	n.a.	2	A, C	0	n.a.
Co	Limnius opacus Ad.	MÜLLER, 1806	0	n.a.	0	n.a.	2	B, D	2	A, D
Co	Limnius opacus Lv.	MÜLLER, 1806	0	n.a.	0	n.a.	2	D	2	A, D
Co	Limnius perrisi Ad.	(DUFOUR, 1843)	0	n.a.	0	n.a.	2	A, B, D	0	n.a.
Co	Limnius perrisi Lv.	(DUFOUR, 1843)	0	n.a.	0	n.a.	2	B	0	n.a.
Co	Limnius volckmari Ad.	(PANZER, 1793)	0	n.a.	2	B	2	A	1	A, B
Co	Limnius volckmari Lv.	(PANZER, 1793)	0	n.a.	2	B	2	A	1	A, B
Co	Macronychus quadrituberculatus Ad.	MÜLLER, 1806	2	C	2	B, C	0	n.a.	0	n.a.
Co	Macronychus quadrituberculatus Lv.	MÜLLER, 1806	2	C	2	B, C	0	n.a.	0	n.a.
Co	Nebrioporus depressus Ad.	(FABRICIUS, 1775)	0	n.a.	-2	A	2	A	-2	A
Co	Nebrioporus depressus/elegans Ad.		0	n.a.	-2	A	2	A	-2	A
Co	Nebrioporus depressus/elegans Lv.		0	n.a.	-2	A	2	A	-2	A
Co	Nebrioporus elegans Ad.	(PANZER, 1794)	0	n.a.	-2	A	2	B	-2	A
Co	Nebrioporus sp. Ad.		0	n.a.	-2	A, X	2	B, D	-2	A
Co	Nebrioporus sp. Lv.		0	n.a.	-2	A, X	2	B, D	-2	A
Co	Orectochilus villosus Ad.	(MÜLLER, 1776)	0	n.a.	1	C, X	0	n.a.	1	A, B
Co	Orectochilus villosus Lv.	(MÜLLER, 1776)	0	n.a.	1	C, X	0	n.a.	1	A, B
Co	Oreodytes sanmarkii Ad.	(SAHLBERG, 1834)	0	n.a.	0	n.a.	1	A, B	0	n.a.
Co	Oreodytes sanmarkii Lv.	(SAHLBERG, 1834)	0	n.a.	0	n.a.	1	B, D	0	n.a.
Co	Platambus maculatus Ad.	(LINNAEUS, 1758)	0	n.a.	0	n.a.	2	A	0	n.a.
Co	Platambus maculatus Lv.	(LINNAEUS, 1758)	0	n.a.	0	n.a.	2	D	0	n.a.
Co	Rhantus frontalis Ad.	(MARSHAM, 1802)	0	n.a.	1	A	0	n.a.	0	n.a.
Co	Rhantus frontalis Lv.	(MARSHAM, 1802)	0	n.a.	1	A	0	n.a.	0	n.a.
Co	Stenelmis canaliculata Ad.	(GYLLENHÅL, 1808)	0	n.a.	0	n.a.	0	n.a.	2	A, B
Co	Stenelmis canaliculata Lv.	(GYLLENHÅL, 1808)	0	n.a.	0	n.a.	0	n.a.	2	A, B
Co	Stictotarsus duodecimpustulatus Ad.	(FABRICIUS, 1792)	0	n.a.	-2	A, C	2	D	0	n.a.
Co	Stictotarsus duodecimpustulatus Lv.	(FABRICIUS, 1792)	0	n.a.	-2	A, C	2	B, D	0	n.a.
Cr	Asellus aquaticus	(LINNAEUS, 1758)	-1	A	0	n.a.	-2	C	-2	A, C
Cr	Corophium curvispinum	SARS, 1895	0	n.a.	-1	C, D	0	n.a.	0	n.a.
Cr	Gammarus fossarum	KOCH in PANZER, 1836	1	A	0	n.a.	1	A, C	2	A
Cr	Gammarus pulex	(LINNAEUS, 1758)	0	n.a.	0	n.a.	-2	D	1	A
Cr	Gammarus roeselii	(GERVAIS, 1835)	-1	A	0	n.a.	0	n.a.	0	n.a.
Cr	Proasellus coxalis	(DOLLFUS, 1892)	0	n.a.	0	n.a.	-2	C	0	n.a.

Group	Taxon name	Author	D01	ref.	D03	ref.	D04	ref.	D05	ref.
Di	Atherix flavipes	(FABRICIUS, 1781)	0	n.a.	0	n.a.	2	A, C	0	n.a.
Di	Atherix ibis	(FABRICIUS, 1798)	0	n.a.	1	A, C	2	A, C	0	n.a.
Di	Atherix sp.		2	A	1	A, B	2	A	0	n.a.
Di	Atrichops crassipes	(MEIGEN, 1820)	2	A	1	B	0	n.a.	0	n.a.
Di	Blephariceridae Gen. sp.		0	n.a.	0	n.a.	2	A, C	1	A
Di	Brillia sp.		2	A	2	A	0	n.a.	0	n.a.
Di	Chironomus obtusidens-Gr.		-1	A	0	n.a.	0	n.a.	0	n.a.
Di	Chironomus plumosus-Gr.		-2	A	0	n.a.	0	n.a.	0	n.a.
Di	Chironomus thummi-Gr.		-2	A	-2	C	0	n.a.	0	n.a.
Di	Cryptochironomus sp.		-2	A	0	n.a.	0	n.a.	0	n.a.
Di	Dixa sp.		2	A	0	n.a.	2	A	0	n.a.
Di	Erioptera sp.	MEIGEN, 1803	1	A	0	n.a.	0	n.a.	0	n.a.
Di	Eutonia barbipes	(MEIGEN, 1804)	0	n.a.	0	n.a.	2	A	0	n.a.
Di	Ibisia marginata	(FABRICIUS, 1781)	1	A	1	A, C	1	A	1	A
Di	Idioptera sp.	MACQUART, 1834	0	n.a.	0	n.a.	2	A	0	n.a.
Di	Limonia sp.	MEIGEN, 1803	1	A	0	n.a.	0	n.a.	0	n.a.
Di	Liponeura brevirostris/decipiens/vimmeri		0	n.a.	0	n.a.	2	A, C	1	A
Di	Liponeura cinerascens cinerascens	LOEW, 1844	0	n.a.	0	n.a.	2	A, C	1	A
Di	Liponeura sp.		0	n.a.	0	n.a.	2	A, C	1	A
Di	Microtendipes pedellus	(DE GEER, 1776)	-2	A	0	n.a.	0	n.a.	0	n.a.
Di	Pedicia sp.	LATREILLE, 1809	1	A	-1	C	2	A	-1	A
Di	Prosimulium hirtipes	(FRIES, 1824)	0	n.a.	0	n.a.	2	A, C	1	A, B
Di	Prosimulium tomosvaryi	(ENDERLEIN, 1921)	0	n.a.	0	n.a.	0	n.a.	1	B
Di	Pseudolimnophila sp.	ALEXANDER, 1919	0	n.a.	0	n.a.	2	A	0	n.a.
Di	Ptychoptera sp.		1	A	2	A, C	0	n.a.	0	n.a.
Di	Ptychopteridae Gen. sp.		0	n.a.	2	A	0	n.a.	0	n.a.
Di	Rhabdomastix sp.	SKUSE, 1890	0	n.a.	0	n.a.	2	A	0	n.a.
Di	Rhagionidae Gen. sp.		-1	A	0	n.a.	-2	D	-1	X
Di	Rhypholophus sp.	KOLENATI, 1860	0	n.a.	0	n.a.	2	A	0	n.a.
Di	Simulium argyreatum	MEIGEN, 1838	-1	A, E	0	n.a.	1	A	0	n.a.
Di	Simulium costatum	FRIEDERICHS, 1920	0	n.a.	0	n.a.	0	n.a.	-1	A
Di	Simulium equinum	(LINNAEUS, 1758)	-2	A, E	0	n.a.	0	n.a.	0	n.a.
Di	Simulium erythrocephalum	(DE GEER, 1776)	-2	A, E	0	n.a.	2	A	0	n.a.
Di	Simulium lineatum	(MEIGEN, 1804)	-2	A, E	2	A, C, E	0	n.a.	0	n.a.
Di	Simulium ornatum	MEIGEN, 1818	-2	A, E	0	n.a.	0	n.a.	-1	A
Di	Simulium ornatum-Gr.		-2	A, E	0	n.a.	0	n.a.	-1	A
Di	Simulium paramorsitans	RUBZOV, 1956	0	n.a.	0	n.a.	0	n.a.	2	A
Di	Simulium urbanum	DAVIES, 1966	2	A, E	0	n.a.	2	A	0	n.a.
Di	Simulium vernum	MACQUART, 1826	2	A, E	0	n.a.	2	D	0	n.a.
Di	Tabanidae Gen. sp.		0	n.a.	1	A, C	2	A	0	n.a.
Di	Tipula maxima	PODA, 1761	1	A	1	A, C	-1	A	-2	A
Di	Tipula maxima-Gr.		1	A	1	A, C	-1	A	-2	A
Ep	Baetis alpinus	PICTET, 1843-1845	0	n.a.	0	n.a.	2	C	0	n.a.
Ep	Baetis buceratus	EATON, 1870	0	n.a.	1	B	0	n.a.	0	n.a.
Ep	Baetis fuscatus	(LINNAEUS, 1761)	-1	A	1	B	-1	A	1	B
Ep	Baetis lutheri	MÜLLER-LIEBENAU, 1967	0	n.a.	0	n.a.	0	n.a.	2	A, B
Ep	Baetis melanonyx	PICTET, 1843-1845	0	n.a.	0	n.a.	2	C	0	n.a.
Ep	Baetis rhodani	PICTET, 1843-1845	0	n.a.	0	n.a.	-2	A, C	0	n.a.
Ep	Baetis scambus	EATON, 1870	0	n.a.	0	n.a.	1	C	0	n.a.
Ep	Baetis vardarensis	IKONOMOV, 1962	0	n.a.	0	n.a.	0	n.a.	2	B
Ep	Baetis vernus	CURTIS, 1834	0	n.a.	0	n.a.	0	n.a.	0	n.a.
Ep	Brachycercus harisella	CURTIS, 1834	0	n.a.	2	B	0	n.a.	0	n.a.

Group	Taxon name	Author	D01	ref.	D03	ref.	D04	ref.	D05	ref.
Ep	Caenis beskidensis	SOWA, 1973	0	n.a.	0	n.a.	1	A	1	A
Ep	Caenis horaria	(LINNAEUS, 1758)	-2	A	-2	A	0	n.a.	0	n.a.
Ep	Caenis luctuosa	(BURMEISTER, 1839)	-1	A	-2	A	2	D	1	A
Ep	Caenis macrura	STEPHENS, 1835	0	n.a.	-1	A	0	n.a.	2	A, B
Ep	Caenis pseudorivulorum	KEFFERMÜLLER, 1960	0	n.a.	-1	C, D	0	n.a.	2	A, B
Ep	Caenis rivulorum	EATON, 1884	-1	A	-1	A, C, D	1	B, D	1	A, B
Ep	Caenis robusta	EATON, 1884	0	n.a.	1	B	0	n.a.	0	n.a.
Ep	Centroptilum luteolum	(MÜLLER, 1776)	-1	A	-1	A	0	n.a.	0	n.a.
Ep	Cloeon dipterum	(LINNAEUS, 1761)	-1	A	-2	A	0	n.a.	0	n.a.
Ep	Cloeon simile	EATON, 1870	-1	A	-2	A	0	n.a.	0	n.a.
Ep	Cloeon sp.		-1	A	-2	A	0	n.a.	0	n.a.
Ep	Ecdyonurus dispar	(CURTIS, 1834)	0	n.a.	0	n.a.	-1	D	0	n.a.
Ep	Ecdyonurus insignis	(EATON, 1870)	0	n.a.	0	n.a.	0	n.a.	2	B
Ep	Ecdyonurus macani	THOMAS & SOWA, 1970	0	n.a.	0	n.a.	0	n.a.	2	A, B
Ep	Ecdyonurus venosus	(FABRICIUS, 1775)	0	n.a.	0	n.a.	2	A, B	-1	A
Ep	Electrogena affinis	(EATON, 1886)	0	n.a.	1	B	0	n.a.	0	n.a.
Ep	Electrogena sp.		0	n.a.	0	n.a.	2	B, D	0	n.a.
Ep	Electrogena ujhelyii	(SOWA, 1981)	0	n.a.	-1	A, 9	0	n.a.	0	n.a.
Ep	Epeorus sylvicola	(PICTET, 1865)	0	n.a.	0	n.a.	0	n.a.	2	A, B
Ep	Ephemera danica	MÜLLER, 1764	1	B	1	A, B	2	A, C	1	A, B
Ep	Ephemera vulgata	LINNAEUS, 1758	0	n.a.	-1	C, D	0	n.a.	0	n.a.
Ep	Habroleptoides confusa	SARTORI & JACOB, 1986	0	n.a.	0	n.a.	1	A	0	n.a.
Ep	Habrophlebia fusca	(CURTIS, 1834)	1	A	1	C, D	0	n.a.	0	n.a.
Ep	Habrophlebia lauta	EATON, 1884	0	n.a.	0	n.a.	0	n.a.	1	A
Ep	Heptagenia flava	ROSTOCK, 1877	2	A	2	B, 9	0	n.a.	0	n.a.
Ep	Heptagenia longicauda	(STEPHENS, 1836)	0	n.a.	2	B, C, D, G	0	n.a.	0	n.a.
Ep	Heptagenia sulphurea	(MÜLLER, 1776)	1	A	1	B, C, D, G	0	n.a.	1	A
Ep	Kageronia fuscogrisea	(RETZIUS, 1783)	0	n.a.	2	B, X	0	n.a.	0	n.a.
Ep	Leptophlebia marginata	(LINNAEUS, 1767)	0	n.a.	1	C, D	0	n.a.	0	n.a.
Ep	Nigrobaetis niger	(LINNAEUS, 1761)	0	n.a.	0	n.a.	2	A	0	n.a.
Ep	Oligoneuriella rhenana	(IMHOFF, 1852)	0	n.a.	0	n.a.	0	n.a.	2	B
Ep	Paraleptophlebia submarginata	(STEPHENS, 1835)	1	A	0	n.a.	0	n.a.	0	n.a.
Ep	Potamanthus luteus	(LINNAEUS, 1767)	0	n.a.	0	n.a.	0	n.a.	2	B
Ep	Procloeon bifidum	(BENGTSSON, 1912)	0	n.a.	1	A, B	0	n.a.	0	n.a.
Ep	Rhithrogena hercynia	LANDA, 1969	0	n.a.	0	n.a.	2	B, D	2	A
Ep	Rhithrogena semicolorata-Gr.		0	n.a.	0	n.a.	1	A, B	0	n.a.
Ep	Siphlonurus aestivalis	(EATON, 1903)	0	n.a.	0	n.a.	0	n.a.	2	B
Ep	Siphlonurus lacustris	(EATON, 1870)	0	n.a.	0	n.a.	0	n.a.	2	B
Ga	Bithynia tentaculata	(LINNAEUS, 1758)	-1	A	-1	A, X	0	n.a.	0	n.a.
Ga	Gyraulus albus	(O.F. MÜLLER, 1774)	-1	A	0	n.a.	0	n.a.	-2	A
Ga	Gyraulus sp.	CHARPENTIER, 1837	-1	A	0	n.a.	0	n.a.	-2	A
Ga	Lymnaea stagnalis	(LINNAEUS, 1758)	0	n.a.	-1	C, D, X	0	n.a.	0	n.a.
Ga	Physa fontinalis	(LINNAEUS, 1758)	-1	A	-1	A, C, D, X	0	n.a.	0	n.a.
Ga	Physella acuta	(DRAPARNAUD, 1805)	-1	A	0	n.a.	-2	D	0	n.a.
Ga	Planorbarius corneus	(LINNAEUS, 1758)	-1	A	0	n.a.	0	n.a.	0	n.a.
Ga	Planorbis sp.	O.F. MÜLLER, 1774	-1	A	0	n.a.	0	n.a.	0	n.a.
Ga	Potamopyrgus antipodarum	(GRAY, 1843)	-2	A	-1	C, D, F	-2	A	-2	A
Ga	Potamopyrgus sp.	STIMPSON, 1865	0	n.a.	-1	A	-2	A	-2	A
Ga	Radix auricularia	(LINNAEUS, 1758)	0	n.a.	0	n.a.	-2	B, D	-2	A
Ga	Radix ovata	(DRAPARNAUD, 1805)	-1	A	0	n.a.	-2	A, C	-2	A, C

Group	Taxon name	Author	D01	ref.	D03	ref.	D04	ref.	D05	ref.
Ga	Radix ovata/peregra		-1	A	0	n.a.	-2	A, C	-2	A, C
Ga	Radix peregra	(O.F. MÜLLER, 1774)	-1	A	0	n.a.	-2	A, C	-2	A, C
Ga	Radix sp.	MONTFORT, 1810	-1	A	0	n.a.	-2	A, C	-2	A, C
Ga	Theodoxus fluviatilis	(LINNAEUS, 1758)	0	n.a.	1	A, B, C, D, X	0	n.a.	0	n.a.
Ga	Viviparus viviparus	(LINNAEUS, 1758)	0	n.a.	-1	C, D	0	n.a.	0	n.a.
He	Aphelocheirus aestivalis	(FABRICIUS, 1794)	0	n.a.	2	A, X	0	n.a.	1	X
Hi	Erpobdella nigricollis	(BRANDES, 1900)	0	n.a.	-1	A, C	-2	A	-2	A, C
Hi	Erpobdella octoculata	(LINNAEUS, 1758)	0	n.a.	-1	A, C	-2	A	-2	A, C
Hi	Erpobdella sp.		0	n.a.	-1	A, C	-2	A	-2	A, C
Hi	Erpobdella testacea	(SAVIGNY, 1822)	0	n.a.	-1	A, C	-2	A	-2	A, C
Hi	Erpobdella vilnensis	(LISKIEWICZ, 1925)	0	n.a.	-1	A, C	-2	A	-2	A, C
Hi	Erpobdellidae Gen. sp.		-1	A	-1	C, D	-2	A	-2	A
Hi	Glossiphonia complanata	(LINNAEUS, 1758)	-1	A	0	n.a.	-1	A, D	0	n.a.
Hi	Helobdella stagnalis	(LINNAEUS, 1758)	-2	A	-1	A, C, D	-2	A, C	-2	A, C
Me	Sialis fuliginosa	PICTET, 1836	1	A	0	n.a.	2	A	-2	A
Me	Sialis lutaria	(LINNAEUS, 1758)	-1	A	-1	A, C	0	n.a.	-2	A
Me	Sialis nigripes	PICTET, 1865	0	n.a.	0	n.a.	0	n.a.	-2	A
Od	Calopteryx splendens	(HARRIS, 1782)	-1	A	1	B	0	n.a.	1	B
Od	Calopteryx virgo	(LINNAEUS, 1758)	2	A	0	n.a.	2	A	1	B
Od	Cordulegaster boltonii	(DONOVAN, 1807)	2	B	0	n.a.	0	n.a.	0	n.a.
Od	Gomphus vulgatissimus	(LINNAEUS, 1758)	0	n.a.	1	B	0	n.a.	1	B
Od	Onychogomphus forcipatus	(LINNAEUS, 1758)	0	n.a.	0	n.a.	0	n.a.	2	B
Od	Ophiogomphus cecilia	(FOURCROY, 1785)	0	n.a.	2	B	0	n.a.	2	A
Ol	Eiseniella tetraedra	(SAVIGNY, 1826)	-1	A	0	n.a.	0	n.a.	0	n.a.
Ol	Lumbriculus variegatus	(MÜLLER, 1774)	-1	A	0	n.a.	0	n.a.	0	n.a.
Ol	Naididae Gen. sp.		-2	A	0	n.a.	-2	A, C	-2	A, C
Ol	Stylodrilus heringianus	CLAPAREDE, 1862	-1	A	0	n.a.	-1	A, D	0	n.a.
Ol	Tubificidae Gen. sp.		-1	A	-1	C, D	-1	A	-1	A
Pl	Amphinemura sp.		2	A	1	B, C	2	A	1	A, B
Pl	Amphinemura standfussi	(RIS, 1902)	0	n.a.	1	C	0	n.a.	0	n.a.
Pl	Brachyptera braueri	(KLAPALEK, 1900)	0	n.a.	2	C	0	n.a.	0	n.a.
Pl	Brachyptera monilicornis	(PICTET, 1841)	0	n.a.	0	n.a.	0	n.a.	2	B
Pl	Brachyptera risi	(MORTON, 1896)	0	n.a.	0	n.a.	1	A, B, D	0	n.a.
Pl	Brachyptera seticornis	(KLAPALEK, 1902)	0	n.a.	0	n.a.	1	A, D	0	n.a.
Pl	Chloroperla tripunctata	(SCOPOLI, 1763)	0	n.a.	0	n.a.	1	B, D	0	n.a.
Pl	Dinocras cephalotes	(CURTIS, 1827)	0	n.a.	0	n.a.	1	A, C	0	n.a.
Pl	Diura bicaudata	(LINNAEUS, 1758)	0	n.a.	0	n.a.	2	B, D	0	n.a.
Pl	Isogenus nubecula	NEWMAN, 1833	0	n.a.	2	B	0	n.a.	0	n.a.
Pl	Isoperla grammatica	(PODA, 1761)	0	n.a.	2	A, C	0	n.a.	0	n.a.
Pl	Isoperla sp.		2	A	2	A	0	n.a.	1	A, B
Pl	Isoptena serricornis	(PICTET, 1841)	0	n.a.	2	B, C	0	n.a.	0	n.a.
Pl	Leuctra braueri	KEMPNY, 1898	0	n.a.	0	n.a.	2	A	0	n.a.
Pl	Leuctra geniculata	(STEPHENS, 1836)	0	n.a.	0	n.a.	0	n.a.	1	A, B
Pl	Leuctra nigra	(OLIVIER, 1811)	2	B	1	A, C	2	A	0	n.a.
Pl	Leuctra sp.		2	A	1	A	1	A	0	n.a.
Pl	Nemoura cinerea	(RETZIUS, 1783)	0	n.a.	1	A	0	n.a.	0	n.a.
Pl	Nemoura sp.		1	A, H	1	A, B	1	A	1	A
Pl	Nemurella pictetii	KLAPALEK, 1900	1	A	0	n.a.	0	n.a.	0	n.a.
Pl	Perla burmeisteriana	CLAASSEN, 1936	0	n.a.	0	n.a.	0	n.a.	2	A, B
Pl	Perla marginata	(PANZER, 1799)	0	n.a.	0	n.a.	2	C, D	2	A, B
Pl	Perlodes dispar	(RAMBUR, 1842)	0	n.a.	2	A, C	0	n.a.	0	n.a.
Pl	Perlodes microcephalus	(PICTET, 1833)	0	n.a.	2	A, C	0	n.a.	1	B

Group	Taxon name	Author	D01	ref.	D03	ref.	D04	ref.	D05	ref.
Pl	Perlodes sp.		0	n.a.	2	B	0	n.a.	0	n.a.
Pl	Protonemura sp.		2	A	0	n.a.	2	A, B	1	A
Pl	Siphonoperla sp.		0	n.a.	1	B	1	A	0	n.a.
Pl	Siphonoperla torrentium	(PICTET, 1841)	0	n.a.	1	C	0	n.a.	0	n.a.
Pl	Taeniopteryx auberti	KIS & SOWA, 1964	0	n.a.	0	n.a.	2	A, C	0	n.a.
Pl	Taeniopteryx nebulosa	(LINNAEUS, 1758)	2	B	2	B	0	n.a.	0	n.a.
Tc	Agapetus delicatulus	McLACHLAN, 1884	0	n.a.	0	n.a.	2	A	0	n.a.
Tc	Agapetus fuscipes	CURTIS, 1834	2	A, H	0	n.a.	2	C	1	A
Tc	Agapetus ochripes	CURTIS, 1834	0	n.a.	0	n.a.	0	n.a.	1	A, B
Tc	Allogamus auricollis	(PICTET, 1834)	0	n.a.	0	n.a.	0	n.a.	1	A, B
Tc	Anabolia nervosa	(CURTIS, 1834)	-1	A	-1	A	0	n.a.	1	A
Tc	Annitella obscurata	(McLACHLAN, 1876)	0	n.a.	0	n.a.	0	n.a.	2	A
Tc	Anomalopterygella chauviniana	(STEIN, 1874)	0	n.a.	0	n.a.	0	n.a.	2	A, B
Tc	Athripsodes albifrons	(LINNAEUS, 1758)	0	n.a.	0	n.a.	2	A	1	A
Tc	Athripsodes aterrimus	(STEPHENS, 1836)	-1	A	0	n.a.	0	n.a.	0	n.a.
Tc	Athripsodes bilineatus	(LINNAEUS, 1758)	1	A	0	n.a.	2	A	-1	A
Tc	Athripsodes cinereus	(CURTIS, 1834)	-2	A	0	n.a.	0	n.a.	1	A
Tc	Brachycentrus maculatus	(FOURCROY , 1785)	0	n.a.	0	n.a.	0	n.a.	1	B
Tc	Brachycentrus subnubilus	CURTIS, 1834	2	A	2	A, B, C, X	0	n.a.	2	A
Tc	Ceraclea annulicornis	(STEPHENS, 1836)	0	n.a.	0	n.a.	0	n.a.	1	A
Tc	Ceraclea fulva	(RAMBUR, 1842)	0	n.a.	2	B	0	n.a.	0	n.a.
Tc	Ceraclea riparia	(ALBARDA, 1874)	0	n.a.	0	n.a.	0	n.a.	2	B
Tc	Chaetopteryx villosa	(FABRICIUS, 1789)	2	A	1	A	1	A, B, D	1	A
Tc	Cheumatopsyche lepida	(PICTET, 1834)	0	n.a.	0	n.a.	0	n.a.	2	A, B
Tc	Chimarra marginata	(LINNAEUS, 1767)	0	n.a.	0	n.a.	0	n.a.	2	A
Tc	Cyrnus trimaculatus	(CURTIS, 1834)	-2	A	-1	C	0	n.a.	0	n.a.
Tc	Drusus annulatus	(STEPHENS, 1837)	0	n.a.	0	n.a.	1	A	0	n.a.
Tc	Ecclisopteryx guttulata	(PICTET, 1834)	0	n.a.	0	n.a.	2	B, D	0	n.a.
Tc	Glossosoma conformis	NEBOISS, 1963	0	n.a.	0	n.a.	2	A	0	n.a.
Tc	Glyphotaelius pellucidus	(RETZIUS, 1783)	2	B	2	B, C	2	B, D	1	X
Tc	Goera pilosa	(FABRICIUS, 1775)	-2	A	0	n.a.	-2	B	0	n.a.
Tc	Halesus digitatus	(SCHRANK, 1781)	2	A, H	1	C	2	A	0	n.a.
Tc	Halesus radiatus	(CURTIS, 1834)	1	B, H	1	B	2	A, B, D	0	n.a.
Tc	Halesus sp.		1	A, B, H	1	C	2	B, D	0	n.a.
Tc	Halesus tesselatus	(RAMBUR, 1842)	1	A	1	C	2	B, D	0	n.a.
Tc	Hydatophylax infumatus	(McLACHLAN, 1865)	0	n.a.	0	n.a.	1	B	0	n.a.
Tc	Hydropsyche angustipennis	(CURTIS, 1834)	-2	A	0	n.a.	0	n.a.	0	n.a.
Tc	Hydropsyche contubernalis	McLACHLAN, 1865	0	n.a.	1	C	0	n.a.	0	n.a.
Tc	Hydropsyche dinarica	MARINKOVIC, 1979	0	n.a.	0	n.a.	2	A	1	A
Tc	Hydropsyche instabilis	(CURTIS, 1834)	0	n.a.	0	n.a.	1	A	2	A
Tc	Hydropsyche pellucidula	(CURTIS, 1834)	0	n.a.	1	B	0	n.a.	0	n.a.
Tc	Hydropsyche saxonica	McLACHLAN, 1884	1	B	0	n.a.	2	A	0	n.a.
Tc	Hydropsyche silfvenii	(ULMER, 1906)	0	n.a.	0	n.a.	2	A	0	n.a.
Tc	Hydropsyche siltalai	DÖHLER, 1963	0	n.a.	1	B	-1	A, D	0	n.a.
Tc	Hydroptila sp.		0	n.a.	1	C	0	n.a.	-1	X
Tc	Ithytrichia lamellaris	EATON, 1873	0	n.a.	2	B	0	n.a.	2	X
Tc	Lasiocephala basalis	(KOLENATI, 1848)	2	B	2	A, B	1	D	1	A, B
Tc	Lepidostoma hirtum	(FABRICIUS, 1775)	1	A	1	B	2	A	0	n.a.
Tc	Leptocerus tineiformis	CURTIS, 1834	0	n.a.	2	B	0	n.a.	0	n.a.
Tc	Limnephilus affinis	CURTIS, 1834	0	n.a.	1	A, B	0	n.a.	0	n.a.
Tc	Limnephilus decipiens	(KOLENATI, 1848)	0	n.a.	1	A, C	0	n.a.	0	n.a.
Tc	Limnephilus rhombicus	(LINNAEUS, 1758)	1	B	2	C	0	n.a.	0	n.a.

Group	Taxon name	Author	D01	ref.	D03	ref.	D04	ref.	D05	ref.
Tc	Lithax niger	(HAGEN, 1859)	0	n.a.	0	n.a.	2	A	0	n.a.
Tc	Lype phaeopa	(STEPHENS, 1936)	1	B, H	2	B, C, D	0	n.a.	2	B
Tc	Lype reducta	(HAGEN, 1868)	1	A	2	B, C, D	2	C	2	B
Tc	Lype sp.		1	n.a.	2	A, C	0	n.a.	2	X
Tc	Melampophylax mucoreus	(HAGEN, 1861)	0	n.a.	0	n.a.	2	B, D	1	X
Tc	Micrasema longulum	McLACHLAN, 1876	0	n.a.	0	n.a.	0	n.a.	2	A, B
Tc	Micrasema minimum	McLACHLAN, 1876	0	n.a.	0	n.a.	2	A, C	1	A, B
Tc	Micrasema setiferum	(PICTET, 1834)	0	n.a.	0	n.a.	-2	B, D	1	B
Tc	Micropterna sp.		2	A, H	0	n.a.	0	n.a.	0	n.a.
Tc	Molanna angustata	CURTIS, 1834	0	n.a.	-2	A	0	n.a.	0	n.a.
Tc	Mystacides azurea	(LINNAEUS, 1761)	-1	A	-2	A, C	-2	B	-1	A, C
Tc	Mystacides longicornis	(LINNAEUS, 1758)	-1	A	-2	A, C	-2	B	-1	A, C
Tc	Mystacides longicornis/nigra		-1	A	-2	A, C	-2	B	-1	A, C
Tc	Mystacides nigra	(LINNAEUS, 1758)	-1	A	-2	A, C	-2	B	-1	A, C
Tc	Mystacides sp.		-1	A	-2	A, C	-2	B	-1	A, C
Tc	Odontocerum albicorne	(SCOPOLI, 1763)	0	n.a.	2	A, C	2	A	1	A
Tc	Oecetis notata	(RAMBUR, 1842)	0	n.a.	2	B	0	n.a.	1	A
Tc	Oecetis testacea	(CURTIS, 1834)	0	n.a.	0	n.a.	0	n.a.	1	A
Tc	Oecismus monedula	(HAGEN, 1859)	0	n.a.	0	n.a.	2	A	0	n.a.
Tc	Philopotamus ludificatus	McLACHLAN, 1878	0	n.a.	0	n.a.	2	A, C, D	0	n.a.
Tc	Philopotamus montanus	(DONOVAN, 1813)	0	n.a.	0	n.a.	2	B, C, D	0	n.a.
Tc	Philopotamus variegatus	(SCOPOLI, 1763)	0	n.a.	0	n.a.	2	C, D	0	n.a.
Tc	Phryganea bipunctata	RETZIUS, 1783	0	n.a.	-1	A, C	0	n.a.	0	n.a.
Tc	Plectrocnemia conspersa	(CURTIS, 1834)	2	A	2	C	0	n.a.	0	n.a.
Tc	Plectrocnemia geniculata	McLACHLAN, 1871	0	n.a.	0	n.a.	2	C, D	0	n.a.
Tc	Polycentropus flavomaculatus	(PICTET, 1834)	0	n.a.	0	n.a.	-1	A	0	n.a.
Tc	Polycentropus irroratus	CURTIS, 1835	1	A	1	B, X	0	n.a.	0	n.a.
Tc	Potamophylax cingulatus	(STEPHENS, 1837)	1	B	0	n.a.	2	A, C	0	n.a.
Tc	Potamophylax latipennis	(CURTIS, 1834)	0	n.a.	2	C	0	n.a.	-1	X
Tc	Potamophylax luctuosus	(PILLER & MITTERPACHER, 1783)	1	B	1	A, C	2	D	0	n.a.
Tc	Potamophylax rotundipennis	(BRAUER, 1857)	-1	A	1	A, C	2	A, C	0	n.a.
Tc	Potamophylax sp.		0	n.a.	0	n.a.	2	A, C	0	n.a.
Tc	Psychomyia pusilla	(FABRICIUS, 1781)	0	n.a.	-1	A, C	0	n.a.	-1	X
Tc	Rhyacophila fasciata	HAGEN, 1859	0	n.a.	0	n.a.	2	A, D	0	n.a.
Tc	Rhyacophila nubila	(ZETTERSTEDT, 1840)	-1	A	0	n.a.	-2	A	0	n.a.
Tc	Rhyacophila obliterata	McLACHLAN, 1863	0	n.a.	0	n.a.	2	A	0	n.a.
Tc	Rhyacophila praemorsa	McLACHLAN, 1879	0	n.a.	0	n.a.	2	A, C	0	n.a.
Tc	Rhyacophila tristis	PICTET, 1834	0	n.a.	0	n.a.	2	A, D	0	n.a.
Tc	Sericostoma sp.		2	B	2	A	2	A	0	n.a.
Tc	Setodes punctatus	(FABRICIUS, 1793)	0	n.a.	0	n.a.	0	n.a.	2	B
Tc	Silo nigricornis	(PICTET, 1834)	2	A	2	B, C	0	n.a.	0	n.a.
Tc	Silo pallipes	(FABRICIUS, 1781)	0	n.a.	0	n.a.	1	A	0	n.a.
Tc	Silo piceus	(BRAUER, 1857)	0	n.a.	0	n.a.	0	n.a.	1	A, B
Tc	Synagapetus iridipennis	McLACHLAN, 1879	0	n.a.	0	n.a.	2	B	0	n.a.
Tc	Tinodes rostocki	McLACHLAN, 1878	0	n.a.	0	n.a.	2	A	0	n.a.
Tc	Tinodes waeneri	(LINNAEUS, 1758)	-2	A	-2	A, C	-2	D	-2	A
Tc	Trichostegia minor	(CURTIS, 1834)	0	n.a.	2	B, C	0	n.a.	0	n.a.
Tc	Wormaldia occipitalis	(PICTET, 1834)	0	n.a.	0	n.a.	2	C, B, D	0	n.a.
Tu	Dugesia gonocephala	(DUGES, 1830)	0	n.a.	0	n.a.	2	A	0	n.a.
Tu	Dugesia lugubris	(SCHMIDT, 1861)	0	n.a.	0	n.a.	2	A	0	n.a.
Tu	Dugesia lugubris/polychroa		0	n.a.	0	n.a.	2	A	0	n.a.
Tu	Dugesia polychroa	(SCHMIDT, 1861)	0	n.a.	0	n.a.	2	A	0	n.a.

Group	Taxon name	Author	D01	ref.	D03	ref.	D04	ref.	D05	ref.
Tu	Dugesia sp.		-1	A	0	n.a.	2	A	0	n.a.
Tu	Dugesia tigrina	(GIRARD, 1850)	0	n.a.	0	n.a.	2	A	0	n.a.
Number of indicator taxa			**122**		**165**		**189**		**155**	
positive indicator taxa			**62**		**110**		**150**		**102**	
negative indicator taxa			**60**		**55**		**39**		**53**	

10. Contribution by UNIBUC-ECO

Carmen Postolache

Catchment location and description

Neajlov catchment is a sub-basin of Arges River catchment, an important tributary of the Danube River. Its location is in the southern part of Romania, between 43^{0}56'00"N -44^{0}49'12"N latitude and 24^{0}14'30"E-26^{0}15'36"E longitude.

Climate, hydrological, land use and geomorphological characteristics at catchment scale

The relief is characteristic for Getic piedmont – a plain with low slope, covered by loess, with compacting micro-depressioned and large parallel valleys oriented to NW→ SE. The altitude is gradually decreassing from north (about 350 m) to south (about 50 m), as it can be observed in Figure 1.

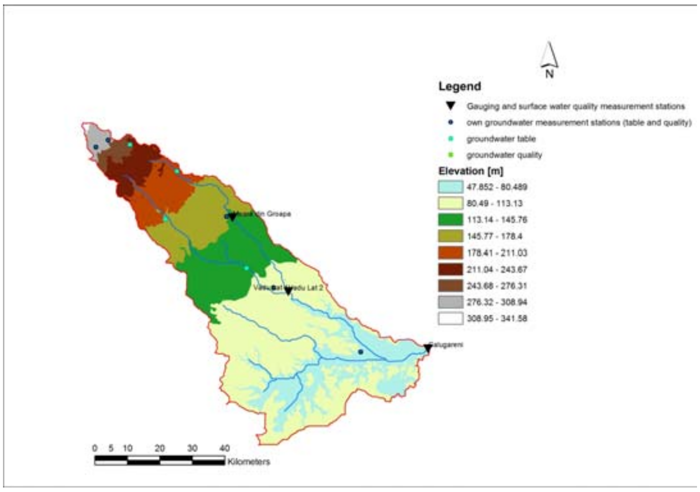

Figure 1. The elevation model for Neajlov catchment

The very gentle decrease of altitude is expressed in the extremely low slope, of 0.22% for the whole catchment and the subcatchments as well (all have slopes below 1%). The southern part of the basin is characterised by the lowest slopes and this is reflected by the increased sinuosity of the rivers (Cilnistea River) and the shalow aquifer in the region. In this part the extension of wetland zones is more evident (Comana lake and wetland).

The climate is temperate-continental, with transition influences from western and sub-mediteraneean to draughty eastern. Mean annual temperature is between 10^0 (in northen part) and 11^0 (in the south) and multiannual precipitation of 400-600 mm. Annual mean thermic amplitude is of 25-26^0, global radiation of 127 kcal/cm^2 and relative air humidity about 74%. The amount of multiannual precipitation in the catchment is between 400-600 mm/year.
The hydrographic network has a density of 0.3 km/km^2 and includes two main tributary rivers, Dambovnic and Calnistea (Figure 2). The catchment contains 45 sub-basins, with surfaces between 10 and 664 km^2.

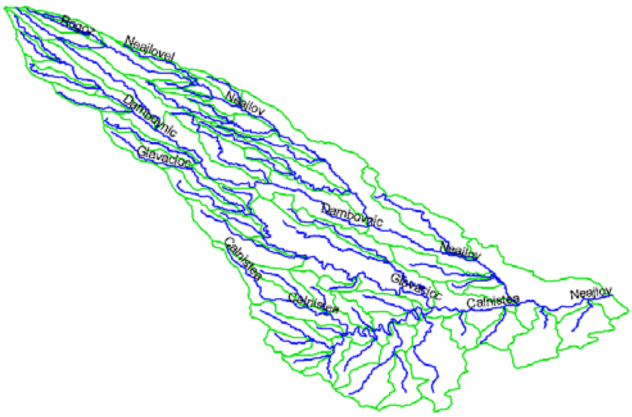

Figure 2. Sub-catchments and main tributaries of the Neajlov River.

It is covered by a non-uniform distribution of hydrographic network, with a density of 0.3 km/km^2. The mean water discharge of Neajlov River is about 8.45 m^3/s.

Base on existing climatic and hydrological data, the water balance for the whole catchment has been previous developed. Climatic data needed to compute water balance have been obtained from one meteorological station located within the basin (Videle).

The computed water balance shows a mean multiannual water yield value of 66 mm/year, from which the surface runoff into the surface waters is about 15 mm/year.

The hydrogeomorphological characteristics of River Neajlov and its main tributaries (Dambovnic and Calnistea) are presented in Table 1.

Table 1. Hydrogeomorphological characteristics of River Neajlov and its main tributaries

River name	Length (km)	Mean slope (‰)	Sinuosity
Neajlov	169.8957	1.70	1.32
Dambovnic	114.8280	2.06	1.40
Calnistea	104.7984	0.61	1.99

The geological formations of the Neajlov consist in unconsolidated rocks, covering all the surface of the basin. Parent material is loess, loess-like deposits and alluvial deposits. Soil types and characteristics have been defined according to the Romanian Soil Classification but further a correspondence between this classification and the FAO / UNESCO classification was performed. In accordance with the FAO soil classification the predominant soil classes at the catchment level are luvisols (61%), chernozems (9.5%), cambisols (7.8%), vertisols (6.2%), phaeozems (5%) and fluvisols (4%).

The geomorphologic features, hydrological characteristics, vegetation diversity and human interventions in the last 50 years explain the actual ecosystem composition in the catchment. The region is dominated by agro-systems, which represent 78.5% from total surface. In the category of semi-natural ecological systems secondary forests (10.4%) and pastures (4.3%) are dominant. Human-made systems cover 5.5% from the total surface area of the catchment (Figure 3).

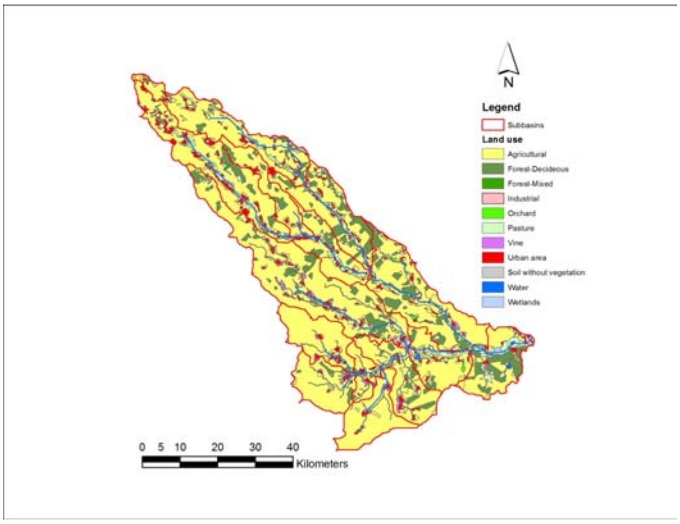

Figure 3. Land use in Neajlov catchmnet

Collection of historical and present day biological data

Stretch scale

Based on the literature review, we found that biological data exist only for few sites in the catchment (from 1960), from which the best represented is Izvoru site (previous named Corbii Ciungi) and Comana Marsh. Our team has obtained biological data from riparian zones during 2001-2002 in other three sites: Calugareni, Vadu-Lat and Furduiesti. Calugareni and Vadu-Lat are also the main monitored sites in the catchment (daily hydrological data). Taking into account the complexity the objectives of tasks 2.1, 2.2 and the availability of hydrological and biological data, we will focus on data from 3 monitoring stations located along the River Neajlov: Izvoru, Vadu-Lat and Calugareni (Figure 4).

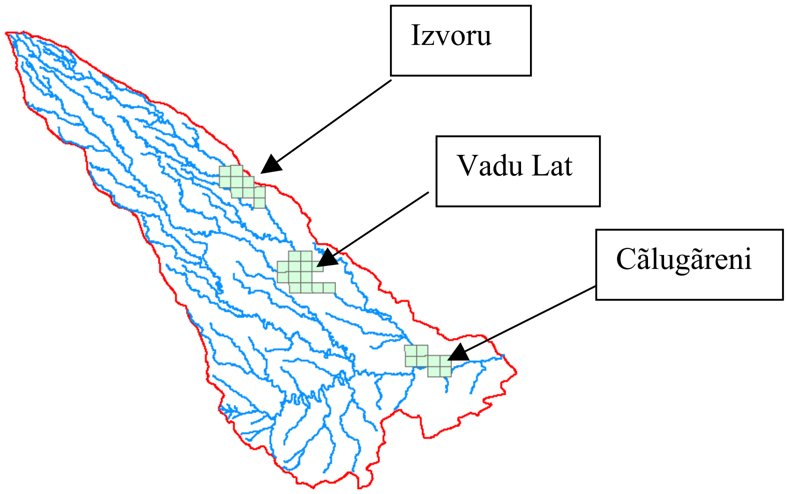

Figure 4. Location of selected sites for tasks 2.1, 2.2 in Neajlov catchment

Hydrogeomorphological characteristics at strech scale are presented below.

Izvoru site

The main hydrogeomorphological characteristics of Izvoru site have been obtained from maps with a resolution of 1:5000. They are presented in Table 2.

Table 2. Hydrogeomorphological characteristics of River Neajlov and its springs (Ip1andi Ip 2) in Izvoru site.

River name	Length (km)	Mean slope (‰)	Sinuosity
Neajlov	4.50	1.25	1.56
Ip1	1.12	7.23	1.20
Ip2	0.48	2.71	1.24

The land use is presented in Figure 5 and the percentages of main land use classes in Table 3**.**

Table 3. Land use in Izvoru site.

Id	LU code	Surface (ha)	Surface (%)
1	Agricultural	872.88	75.71
2	Pastures	163.12	14.15
3	Forests	4.70	0.41
4	Wetlands	5.79	0.50
5	Urban	76.53	6.64
6	Non-productive	29.82	2.59
Total		1152.88	100

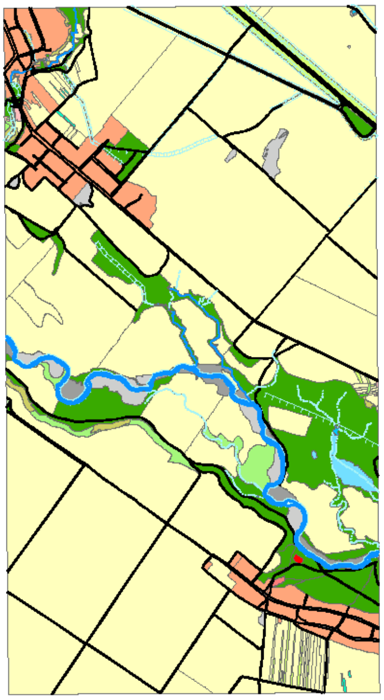

Figure 5. Land use in Izvoru site

Vadu-Lat site

The main hydrogeomorphological characteristics of Vadu-Lat site have been obtained from maps with a resolution of 1:5000. They are presented in Table 4.

Tabel 4. Hydrogeomorphological characteristics of River Neajlov and its tributary Dambovnic in Vadu-Lat site.

River name	Length (km)	Mean slope (‰)	Sinuosity
Neajlov	3.89	0.36	1.45
Dambovnic	2.12	2.07	1.79

The land use is presented in Figure 6 and the percentages of main land use classes in Table 5.

Table 5. Land use in Vadu-Lat site.

Id	LU code	Surface (ha)	Surface (%)
1	Agricultural	266.16	46.53
2	Pastures	66.29	11.59
3	Forests	122.58	21.43
4	Wetlands	1.45	0.25
5	Urban	111.15	19.43
6	Non-productive	4.39	0.77
	Total	572.05	100

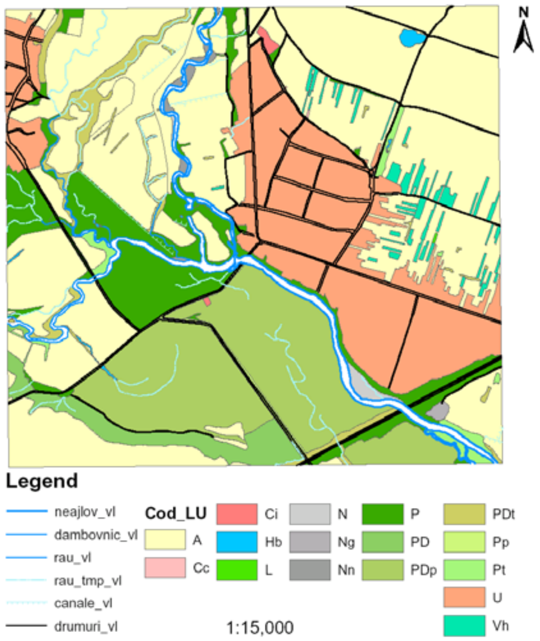

Figure 6. Land use in Vadu-Lat site

Calugareni site

The main hydrogeomorphological characteristics of Calugareni site have been obtained from maps with a resolution of 1:5000. They are presented in Table 6.

Table 6. Hydrogeomorphological characteristics of River Neajlov and its tributary Calnistea in Calugareni site.

River name	Length (km)	Mean slope (‰)	Sinuosity
Neajlov	3.1318	0.87	1.25
Calnistea	2.6984	0.42	1.34

The land use is presented in Figure 7 and the percentages of main land use classes in Table 7.

Table 7. Land use in Calugareni site.

Id	LU code	Surface (ha)	Surface (%)
1	Agricultural	651.81	57.48
2	Pastures	79.53	7.01
3	Forests	342.10	30.17
4	Wetlands	1.04	0.09
5	Urban	59.49	5.25
6	Non-productive	-	-
	Total	1133.99	100

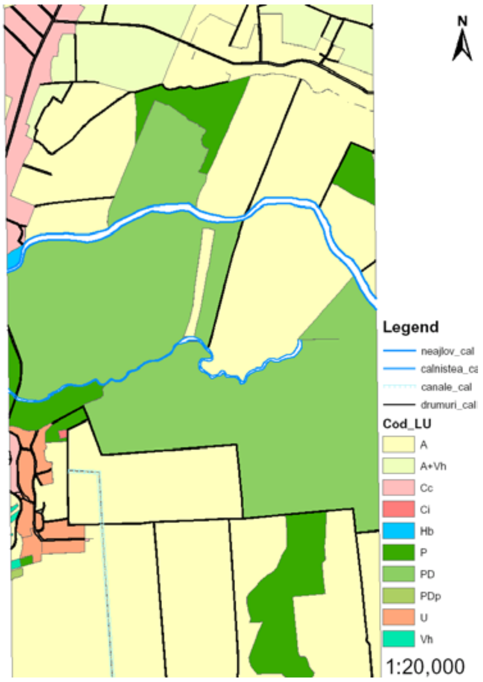

Figure 7. Land use in Calugareni site

Microhabitat scale analysis

Methodology

Studies on the structure of benthic fauna were carried out starting with October 2004 (with a pause during winter season). Startinf from April 2005, the sampling frequency was monthly.

Sites are located on River Neajlov at Izvoru and Vadu-Lat (Figure 4). River Neajlov receives a tributary in Izvoru (IP1) where our studies are focused and historical data exist. A number of 4 transects were established along IP1, from its spring to the confluence with River Neajlov, labeled from downstream to upstream as IP1-1 (at the confluence), IP1-2, IP1-3 and IP1-4 (the last two are reocrene springs)- Figure 8. The transects were choosen based on the diversity of riparian vegetation and microhabitat structure, but they also correspond to those mentioned in literature (1962).

The number of samples units took from River Neajlov varied between 3-6, in accordance with the substrate heterogeneity. Up to 10 sample units were taken from each transect, according to the microhabitat diversity. Sampling instrument was a Surber type, with the sampling surface of 300 cm^2. Mesh size was 230 µm.

Measures of river depth at each 20 cm were done and the river bed profile was drawn.

At each sampling date, the chemistry of water and sediments were determined - pH, oxygen, suspended solids, conductivity, main nutrients (nitrogen and phosphorous forms), organic matter.

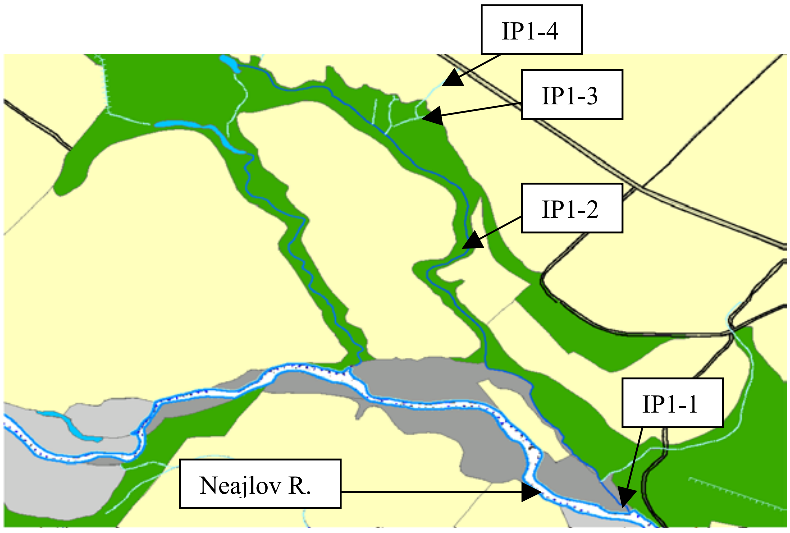

Figure 8. Spring IP 1 and selected transects (IP 1-1 – IP 1-4)

Preliminary results and discussion

An image of sampling site IP1-1 and the river bed profile are presented in Figures 9a and 9b.

9a **9b**

Figure 9. Image of microhabitats in transect IP 1-1 on a surface of 1 m^2 (May 2005)-**9a**
River bed profile of transect IP 1-1 on a 4m length (May 2005)-**9b**

Data on structure of benthic fauna from River Neajlov reveal the existence of 14 taxa of benthic organisms and a variation of densities between 1477 individuals/m^2 (Vadu-Lat, April 2005) and 29187 individuals/m^2 (Izvoru, May 2005), as it can be seen in Table 8. The groups of organisms with a constant presence are oligochaeta, gastropoda and diptera, which account for more than 80% from the total number of benthic components. The habitat heterogeneity (silt, rich in organic matter, sand, macrophyte substrate), as well as the relative reduced water flow were favourable conditions for some benthic groups (oligochaeta, chironomidae), which reach a high density (>10000 ind/ m^2).

Table 8. The structure (taxa), densities and abundances of benthic fauna in River Neajlov, between October 2004 – May 2005.

TAXA	VADU LAT						IZVORU			
	22.10.2004 (900 cm^2)		21.04.05 (1800 cm^2)		16.06.2005 (900 cm^2)		22.10.04 (900 cm^2)		05.05.05 (900 cm^2)	
	ind/m^2	A%	ind/m^2	A%	ind/m^2	A%	ind/m^2	A%	ind/m^2	A%
NEMATODA	**33**	**2.25**	**105**	**1.36**					**155**	**0.53**
OLIGOCHAETA	**900**	**60.9**	**3433**	**44.27**	**5155**	**39.66**	**1733**	**17.33**	**13267**	**45.45**
HIRUDINAE	**33**	**2.25**	**105**	**1.36**	**167**	**1.28**			**100**	**0.34**
GASTROPODA	**78**	**5.26**	**767**	**9.88**	**267**	**2.05**	**400**	**4**	**11**	**0.04**
LAMELLIBRANCHIA	**11**	**0.75**	**22**	**0.29**	**511**	**3.93**				
ACARINA			**17**	**0.21**					**244**	**0.84**
AMPHIPODA					**11**	**0.08**			**33**	**0.11**
Gammaridae					11				33	
ISOPODA			**5**	**0.07**			**33**	**0.33**	**11**	**0.04**
EPHEMEROPTERA	**67**	**4.51**	**111**	**1.43**	**633**	**4.87**	**33**	**0.33**	**1267**	**4.34**
ODONATA			**28**	**0.36**					**22**	**0.08**
HETEROPTERA	**22**	**1.5**	**44**	**0.57**			**200**	**2**	**78**	**0.27**
COLEOPTERA			**5**	**0.07**			**33**	**0.33**		
TRICHOPTERA			**11**	**0.14**	**244**	**1.88**			**55**	**0.19**
DIPTERA	**333**	**22.56**	**3100**	**39.97**	**6011**	**46.24**	**7333**	**73.38**	**13944**	**47.77**
Chironomidae	311		3061		6011		7267		13889	
Ceratopogonidae	22		39				67		55	
Total	**1477**		**7753**		**12999**		**9765**		**29187**	

The structure of benthic fauna in the tributary of Neajlov, IP1 revels a total of 14 taxa in transect IP1-1 and 9 groups in transect IP1-2, with high densities between 5099 - 32394 ind/ m^2 (IP1-1) and between 15866 - 43482 ind/ m^2 (IP1-2) – Tables 9, 10. It was observed that in microhabitats containing macrophytes, where stability is higher and food is more abundand, the density and diversity of zoobenthos is higher as compared to other microhabitats. Between 5-8 taxa were identified in sandy sediments and between 8-13 taxa in substrate covered by macrophytes. The dominant taxa (as number of individuals) are represented by amphipoda (gammaridae) and diptera (chironomidae), followed by oligochaeta and ephemeroptera. These four groups account all together 75% up to 95% of the total benthic organisms.

Table 9. The structure (taxa), densities and abundances of benthic fauna in the transect IP1-1 in April and May 2005.

TAXA	SAND				GRAVEL				MACROPHYTE			
	07.04.05 (600 cm^2)		05.05.05 (300 cm^2)		07.04.05 (2400 cm^2)		05.05.05 (900 cm^2)		07.04.05 (3000 cm^2)		05.05.05 (1500 cm^2)	
	ind/m^2	A%	ind/m^2	A%	ind/m^2	A%	ind/m^2	A%	ind/m^2	A%	ind/m^2	A%
NEMATODA	**83**	**0.7**			**17**	**0.2**	**78**	**0.66**	**147**	**0.67**	**53**	**0.16**
OLIGOCHAETA	**3383**	**28.5**	**1467**	**28.76**	**6112**	**57.4**	**3155**	**26.97**	**1547**	**7.05**	**907**	**2.79**
HIRUDINAE			**133**	**2.61**	**4**	**0.05**	**67**	**0.57**	**57**	**0.26**	**53**	**0.16**
GASTROPODA									**3**	**0.01**	**7**	**0.02**
LAMELLIBRANCHIA			**233**	**4.57**								
ACARINA									**13**	**0.06**	**33**	**0.1**
AMPHIPODA	**6150**	**51.9**	**667**	**13.07**	**652**	**7.55**	**1022**	**8.74**	**11990**	**54.63**	**19080**	**58.89**
Gammaridae	6150		667		652		1022		11990		19080	
ISOPODA									**10**	**0.04**		
EPHEMEROPTERA	**417**	**3.52**	**100**	**1.96**	**537**	**6.49**	**3289**	**28.11**	**560**	**2.55**	**1747**	**5.39**
ODONATA									**60**	**0.27**	**133**	**0.41**
HETEROPTERA									**17**	**0.07**	**7**	**0.02**
COLEOPTERA									**83**	**0.38**	**53**	**0.16**
TRICHOPTERA			**33**	**0.65**	**12**	**0.15**			**790**	**3.6**	**360**	**1.11**
DIPTERA	**1817**	**15.33**	**2466**	**48.37**	**2324**	**28.09**	**4078**	**34.95**	**6670**	**30.39**	**9961**	**30.76**
Chironomidae	1767		2033		2312		3878		6143		8833	
Ceratopogonidae	50		333		12		167		480		960	
Simuliidae			67				11				107	
Culicidae							22		10		47	
Ephydridae									27		7	
Stratiomyidae											7	
Tipulide			33									
Tabanidae									10			
Total	**11850**		**5099**		**9658**		**11689**		**21947**		**32394**	

Table 10. The structure (taxa), densities and abundances of benthic fauna in the transect IP1-2 in May 2005.

TAXA	SAND (300cm^2)		GRAVEL (900cm^2)		MACROPHYTE (600cm^2)	
	ind/m^2	A%	ind/m^2	A%	ind/m^2	A%
OLIGOCHAETA	**1917**	**5.71**	**1200**	**7.78**	**817**	**1.88**
HIRUDINAE			**11**	**0.07**		
LAMELLIBRANCHIA	**117**	**0.35**			**33**	**0.08**
ACARINA	**17**	**0.05**	**22**	**0.14**	**33**	**0.08**
AMPHIPODA	**24850**	**73.99**	**3300**	**21.4**	**14083**	**32.39**
Gammaridae	24850		3300		14083	
EPHEMEROPTERA	**2300**	**6.85**	**3567**	**23.13**	**4033**	**9.27**
COLEOPTERA	**250**	**0.74**			**183**	**0.42**
TRICHOPTERA	**450**	**1.34**	**11**	**0.07**	**867**	**1.99**
DIPTERA	**3683**	**10.97**	**7755**	**50.29**	**23433**	**53.89**
Chironomidae	3250		7311		18900	
Simuliidae	433		444		4533	
Total	**33584**		**15866**		**43482**	

The upstream transects (IP1-3 and IP1-4) are characterized mostly by a sandy and gravelly substrate - Table 11. The benthic fauna has a more simplified structure, represented by 5 to 8 taxa and densities between 6399 - 15700 ind/m^2.

Table 11. The structure (taxa), densities and abundances of benthic fauna in the transects IP1-3 and IP1-4 in May and June 2005.

TAXONS	IP1-3 (300cm^2)		IP1-3 (600cm^2)		IP1-4 (300cm^2)	
	05.05.2005		16.06.2005		05.05.2005	
	ind/m^2	A%	ind/m^2	A%	ind/m^2	A%
OLIGOCHAETA			**183**	**1.17**	**400**	**6.25**
HIRUDINAE			**33**	**0.21**		
AMPHIPODA	**1900**	**22.71**	**4717**	**30.04**	**3833**	**59.89**
Gammaridae	1900		4717		3833	
EPHEMEROPTERA			**67**	**0.42**		
COLEOPTERA	**100**	**1.19**			**133**	**2.08**
ISOPODA	**67**	**0.8**	**383**	**2.44**		
TRICHOPTERA	**5567**	**66.53**	**9067**	**57.75**	**133**	**2.08**
ODONATA			**17**	**0.11**		
DIPTERA	**733**	**8.76**	**1233**	**7.85**	**1900**	**29.69**
Chironomidae	733		1883		1900	
Ceratopogonidae			50			
Total	**8367**		**15700**		**6399**	

Dominant taxa are amphipoda and trichoptera (transect IP1-3) as well as gammaridae and chironomidae (transect IP1-4). These groups account for more than 80% from the total number of benthic organisms.

References

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Motaş, C., Botoăneanu, L., Negrea, Şt., 1962, Cercetări asupra biologiei izvoarelor şi apelor freatice din partea centrală a Cîmpiei Române, Ed. Academiei Republicii Populare Române.

11. Contribution by CNRS-UPS

Muriel Gevrey

Hypothesis

- *What are the relations between hydrology/hydromorphology and species composition?*
- *Which species or biological parameters are good indicators for changes in hydrology/hydromorphology?*

DETAILED WORKPLAN - ACTIVITIES

1. Review of existing literature and linkage to reviews of other project

We start to constitute a literature review related to our subtask hypothesis and to our basin. All the references collected are included in the endnote file: *BiblioEurolimpacs.enl*. This file is currently constituted of 90 references which are linked to these keywords: Adour-Garonne, database, catchment area, biogeography, undisturbed stations, community, environmental variables, ecohydrology, ecoregion, space and time evolution, fish assemblages, hydroecoregions, hydrology, hydromorphology, land-use, long-term ecological data, Midi-Pyrénées, physico-chemistry, regionalisation, spatial series, time series.

2. Collection of historical and present day biological data

Our data concerns mainly 105 selected sites (see figure 1) distributed all around the Adour-Garonne basin in the South West part of France.

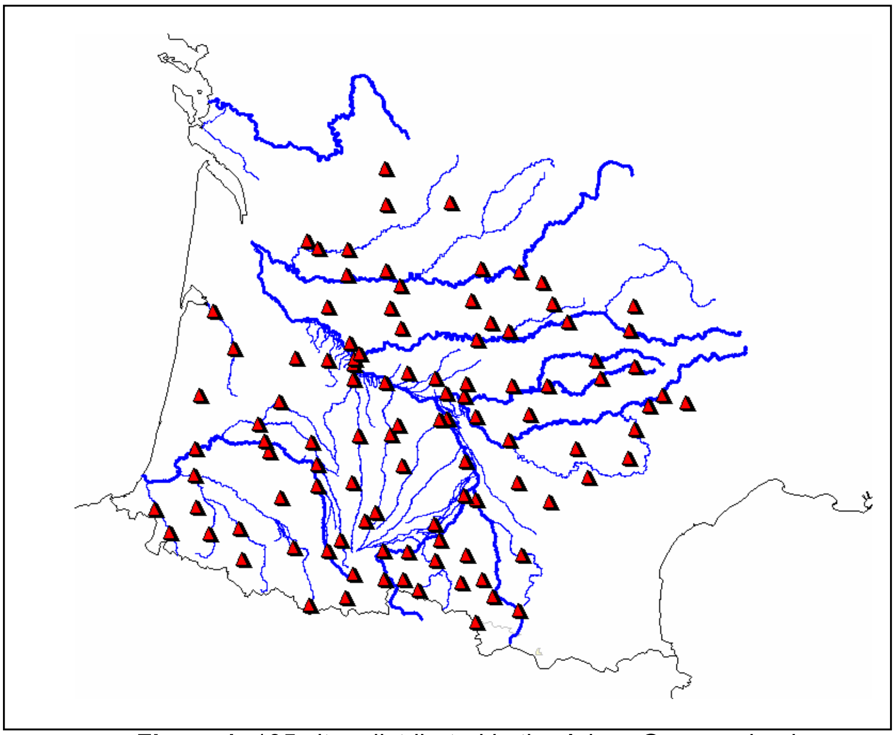


Figure 1: 105 sites distributed in the Adour-Garonne basin

Two different approaches are followed: time and spatial series studies.

Concerning the time series study, data for macroinvertebrates, fish and diatoms will be soon all available but probably not for all the 105 sites. The series available are also different according to the studied organism. Hydrology parameter (daily flow) is available for only 50 common sites with biological parameters and physico-chemistry parameters (ex: Temperature, pH, O2, NH4, NO2...) are available for at least 30 sites.

Concerning the spatial series study, for the 105 considered stations, fish, diatoms and macroinvertebrates data will be available. Hydrology and the physico-chemistry parameters are respectively available for 50 and 35 common sites with the biology. Morphology parameters and land-use characteristics are available for the 105 sites.

After collection of all the missing data, a large work has to be done to organise the data and make them usable for the analyses. Database is organised using softwares Excel, Access, Mapinfo and Arcview9. Several matrices will be created in order to link the environmental variables to the organisms. The organisms could be studied at different level: abundance, density, frequency... For the time series data, the same years has to be used for the environmental variables and the organisms. Several matrices will be also created according to the years available.

3. Data analyses

First artificial neural network techniques will be used to analyse the data: the Self-Organizing Map (SOM) and the multi-layer perceptron (MLP) with backpropagation learning algorithm. Later, other models will be developed as combination of different methods, as classical multivariate methods with artificial intelligence methods...

Several analyses will be realised, and there will be dependent of the data matrices created. In general, SOM could be used on organisms' matrix to determine community types (fish, macroinvertebrates and diatoms). Using the environmental parameters on the map obtained, it would be possible to see if there are some relations between the environmental parameters and the species composition. Then the MLP will be applied for the prediction of these community types using the environmental parameters. The results will help us to confirm the existing relations. Then methods applied on MLP results, called contribution methods, will give us the influence of the environment on the species composition. These results could help to define if species or biological parameters are good indicators for changes in hydrology/hydromorphology. Times series and spatial series will be both used with the neural networks methods.

Most of the preliminary analyses realised in this task will be then used in the subtask 2.4 in which will go deeply in the development of powerful models.

4. Preliminary results if there are some.

There are not yet any results at this time.

12. Contribution by SLU

The testing of biological indicators of hydromorphological stress
A case study from the Emå Catchment

Leonard Sandin

Study area

Geography

The Emå catchment is situated in the south-eastern part of Sweden (Fig. 1). It is the largest river in this part of the country, with a catchment area of 4472 km^2. It flows from west to east and the sources are found in the highland of Småland, just north of Storasjön, ca 10 km from the city of Nässjö. The main river then runs ca 220 km and enters the Baltic Sea in Em, at Kalmar sound. The river runs through eight municipalities on its way to the sea (starting from the sources) Nässjö, Eksjö, Sävsjö, Vetlanda, Hultsfred, Högsby, Mönsterås och Oskarshamn. Most of the river and catchment are found in the ecoregion of the "central and eastern south-swedish highland". At least six large lakes can be found in the main stem of the Emå river: Storasjön, Vallsjön, Tjurken, Grumlan, Norrasjön, and Flögen. The catchment consists of 19 subcatchments, where the main rivers are: Solgenån, Linneån, Silverån, Brusaån, Sällevadsån, Pauliströmsån, Gnyltån, Saljenån, Gårdevedaån, Marån, Morån, Nötån, Tjustaån, and Lillån.

Fig.1. The Emå catchment in south-eastern Sweden.

Water quality

The water quality in the Emå catchment is dependent both of diffuse input from e.g. agriculture and waste water, but also from point sources, such as paper mills and metal industries within the catchment. The recipient control of the water quality in the Emå catchment has been going on since 1992 (http://www.emans-vattenforbund.com). The transport of nitrogen and phosphorous has increased by between 16% and 100% in different parts of the catchment during this period.

The phosphorous and nitrogen levels in the lakes are generally “high” in the downstream parts of the catchment according to the Swedish Environmental Quality Criteria (Swedish Environmental Protection Agency, 2000), and in the upper parts “moderately high” or “low”. The pH are “almost neutral” or “midly acid” in the whole catchment. The extent of water color is “extremely intense” or “very intense” in large parts of the catchment (especially in the south-west). The oxygen level is “abundant” or “moderate” in almost all of the catchment, whereas the extent of turbidity of the water is “moderate” or “significant” in most cases. The concentration of metals in the water are in most cases “very low” or “low”, but in some areas of the catchment increasing significantly from 1999 to 2003 (Emåförbundet 2003), especially for aluminum, cadmium, and lead, but there are also decreases in metal concentrations in certain streams/rivers.

Climate and hydrology

The mean January temperature is between -4 and -2 °C and the mean July temperature is between 14 and 18 °C (National Atlas of Sweden, 1995). The mean yearly precipitation is between 500 near the coast and 700 mm in the western higlands. The growing season is 180 to 210 days. The mean discharge just upstream of the river mouth is 30 m^3/s (mean value from 1926-1975), the lowest discharge being 2 and the highest 270 m^3/s. The large difference is due to the fact there are no larger lakes or other water magazines in the lower part of the river. The monthly discharge between 1996 and 2003 varied between 5.5 in September of 2002 and 96.7 m^3/s in July 2003 (Fig. 2).

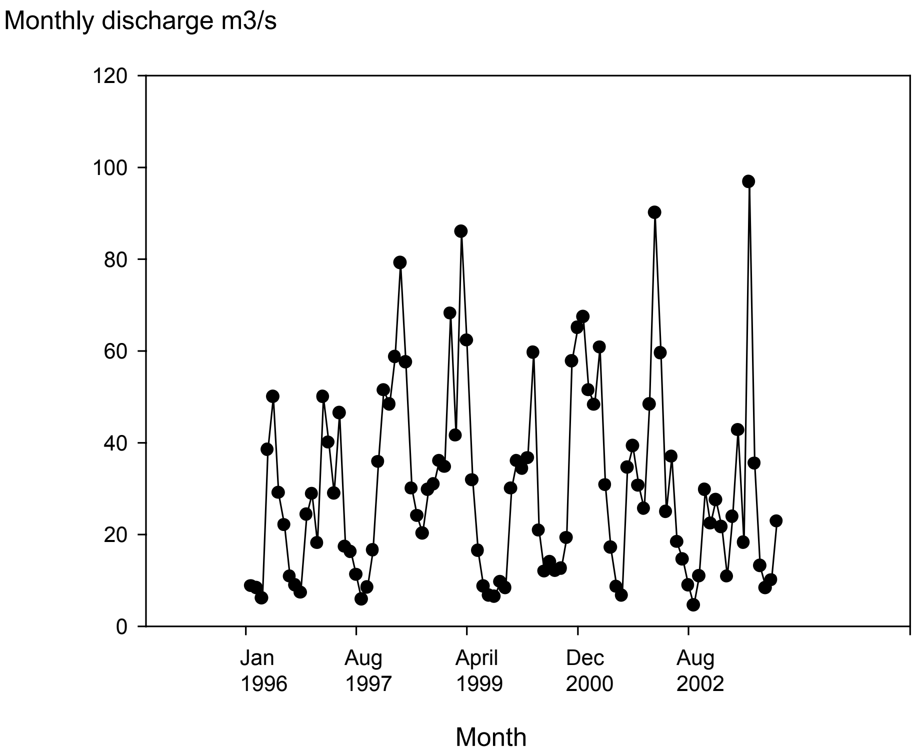


Fig. 2. Monthly discharge at Em, near the mouth of the Emå river. Discharge calculated using the Swedish Meteorological and Hydrological HBV/Pulse model.

Land-use

Forest is by far the most common land use type within the Emå catchment (74%) (see Fig. 3). The Emå valley has, however, been used for agriculture for a very long time (see history). The forests in the catchment are dominated by pine and spruce, but there are also important areas with deciduous forests. The lake area of the catchment only comprises 6% of the total area, where the total lake area is ca 300 km^2.

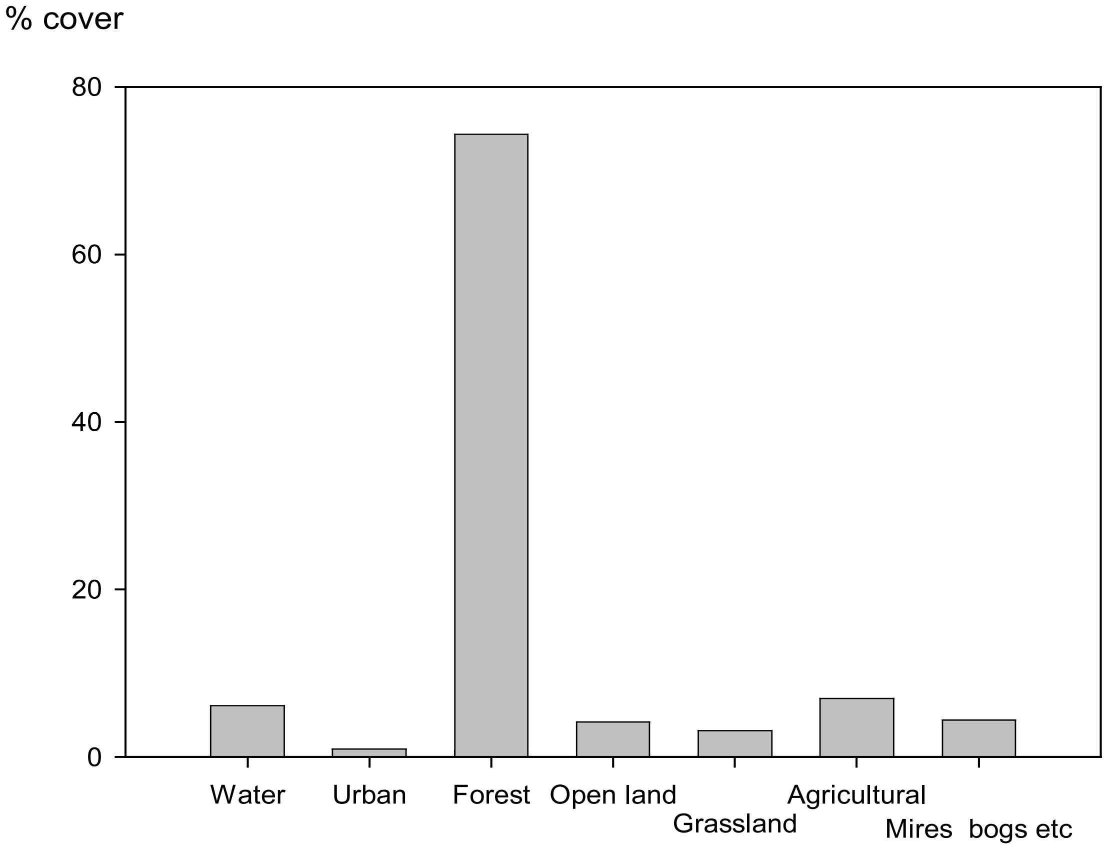


Fig. 3. Land-cover in the Emå catchment.

Climate scenarios

According to the climate scenarios for the south-eastern Sweden, where Emån is situated, there will be less frequent floods, and less total discharge in the rivers (Andréasson et al., 2004). More of the water will come into the system during winter and less during summer.

Stream morphology

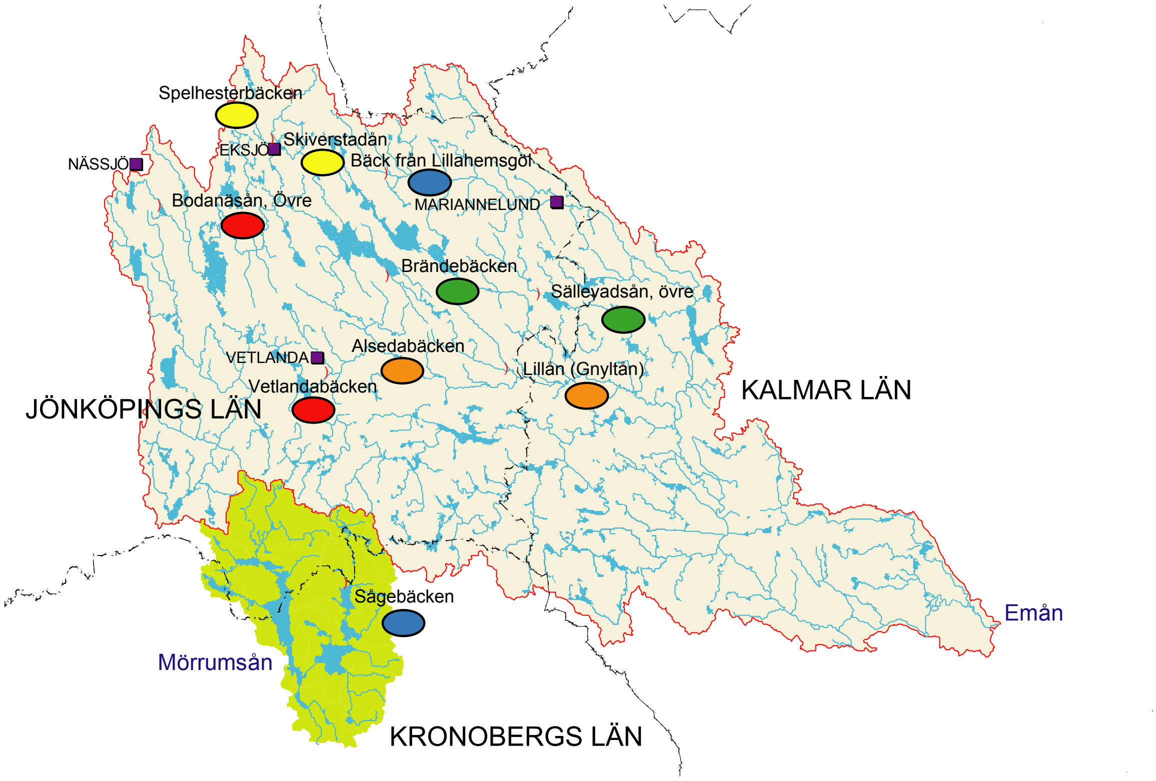
The larger streams/rivers within the Emå catchment were mapped using the biotope inventory method (Swedish Environmental Protection Agency, 2003). A total of 1624 river stretches were inventoried for e.g. bottom substratum type, vegetation in the stream, water velocity, near stream vegetation, and transverse structures. A total of 762.313 meters of stream length were mapped in this way, within the 19 subcatchments. The mapped lengths within each subcatchment differed from 100.478 meters (13.2% of the total length) in the subcatchment consisting of the lower parts of the main stem of the Emå catchment, to 11.561 meters (1.5%) in the Torsjöå subcatchment. The stream velocity of each stretch were divided into four categories, from slow flowing (<0.2 m/s) to (>0.7 m/s) the % of stream length within each stream section were scored into one of four categories from 0 = no cover to 3 = =>50% cover. Almost all (except five stretches and < 0.5% of the stream length did not have one stream category scored as a "3" i.e. with a total cover =>50% of the area.

Aims of the case study

The aim of this case study was to:

- Test how well the four organism groups (fish, macrophytes, macroinvertebrates, and phytobenthos) could detect the pre-defined naturalness gradient
- Test whether or not the organism groups are correlated in their response to this stress gradient both in terms of diversity, community composition and index values
- Analyse which physical/chemical parameters best correlate with the community composition for the four organism groups

Description of the study catchments



Figur 4. Map of the ten samplied streams. The colour of the circle indicates the naturalness of the sampled site/stream (blue = very high natutralness, green = high naturalness, yellow = medium naturalness, orange = low naturalness, red = very low naturalness. All assessments based on the Swedish System Aqua Aqua (Swedish EPA 1999). Source: SMHI (aro), Lantmäteriet (GSD – Röda Kartan, dnr 507-98-4720).

All ten streams, except Sågebäcken are found in the Emå catchment. The streams are coded from EM1 to EM10, with low numbers indicating more natural watercourses, whereas higher numbers indicates more affected streams.

Naturalness and hydromorphological stress in the streams

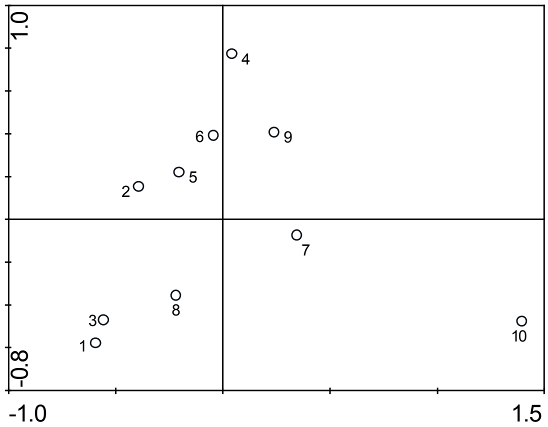
A natural system is here defined as a system free of human perturbation/stress. The degree of naturalness is assessed from the landscape to the object level.

Tabell 1. Sampling sites in the ten streams. At one site in each stream, all organism groups have been sampled, at the other sites only fish were sampled.

Code	Stream name	Site name	MASL	X-Coord	Y-Coord	Naturalness - stream	Naturalness - site	Samples
EM1	SÅGEBÄCKEN	UPPSTR BRON	213	633935	145975	**5**	**3**	All
EM1	SÅGEBÄCKEN	NEDAN BRON	212	633935	145980	**5**	**3**	Fish
EM1	SÅGEBÄCKEN	NEDAN KÖLJESJÖ	232	634160	145905	**5**	**4**	Fish
EM2	BÄCK FR LILLAHEMSGÖL	GAMMAL TRÄBRO	204	639100	146510	**5**	**4**	All
EM2	BÄCK FR LILLAHEMSGÖL	ÅVÄGEN	214	639170	146470	**5**	**4**	Fish
EM2	BÄCK FR LILLAHEMSGÖL	HYGGE NED MOSSEN	231	639220	146460	**5**	**4**	Fish
EM3	BRÄNDEBÄCKEN	BRÄNDEKVARN	245	637540	146840	**4**	**3**	All
EM3	BRÄNDEBÄCKEN	SANDLID	224	637635	146730	**4**	**2**	Fish
EM3	BRÄNDEBÄCKEN	HYGGET	220	637655	146695	**4**	**5**	Fish
EM4	SÄLLEVADSÅN	KARLSTORP	186	637650	148255	**4**	**2**	All
EM4	SÄLLEVADSÅN	GAMLA VÄGBRON	214	637995	147905	**4**	**1**	Fish
EM4	SÄLLEVADSÅN	KARLSTORP	187	637660	148260	**4**	**2**	Fish
EM5	SPELHESTERBÄCKEN	UPPSTR VÄGBRON	232	640090	145340	**3**	**2**	All
EM5	SPELHESTERBÄCKEN	UPPSTR KRAFTLEDNING	233	640102	145353	**3**	**4**	Fish
EM5	SPELHESTERBÄCKEN	UPPSTRÖMS VÄG 134	245	640070	145405	**3**	**4**	Fish
EM6	LILLÅN	BETESHAGEN	125	636645	147815	**3**	**4**	All
EM6	LILLÅN	VÄGTRUMMEBRON	131	636700	147675	**3**	**4**	Fish
EM6	LILLÅN	GAMLA STENBRON	137	636770	147525	**3**	**4**	Fish
EM7	ALSEDABÄCKEN	LASSABACKE	146	636560	146615	**2**	**1**	All
EM7	ALSEDABÄCKEN	NEDAN DAMM	144	636575	146630	**2**	**4**	Fish
EM7	ALSEDABÄCKEN	MEDERYD	194	636440	146290	**2**	**5**	Fish
EM8	SKIVERSTADÅN	MÖLLERYDSDAMM	228	639920	145215	**2**	**5**	All
EM8	SKIVERSTADÅN	KVARNDAMMEN	212	639860	145155	**2**	**1**	Fish
EM9	BODANÄSÅN	KVARNTORPET	297	638980	143380	**1**	**2**	All
EM9	BODANÄSÅN	MÅLEN SV	281	638775	143555	**1**	**2**	Fish
EM9	BODANÄSÅN	ISÅSA NV	286	638940	143440	**1**	**2**	Fish
EM10	VETLANDABÄCKEN	CYKELBRON	178	636600	145785	**1**	**4**	All
EM10	VETLANDABÄCKEN	NO ARVINGETORP	202	637115	145360	**1**	**1**	Fish
EM10	VETLANDABÄCKEN	LOCKABOLET	195	636980	145455	**1**	**4**	Fisk

Relationship among environmental variables

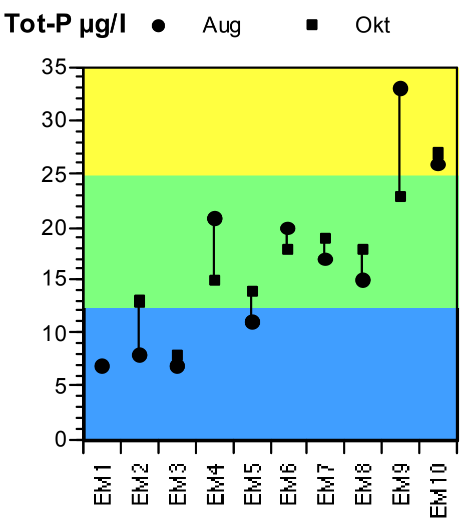
To be able to compare how similar the ten streams were in terms of environmental variables a PCA was done. It showed that the site in Vetlandabäcken (EM10), Cykelbron, clearly differs from the other nine sites (where all organisms were sampled).



Figur 5. Principal components analysis of all environmental variables in the ten streams (the integrated sampling sites).

There was a clear gradient from more natural streams (to the left) to less natural streams (to the right) in figure 5. This naturalness was positively correlated with altitude, amount of coarse woody debris, stream width, amount of detritus and oxygen content of the water. The naturalness was negatively correlated with the amount of open land in the catchment, the phosphorous, zink, and manganese content of the water. This gradient was uncorrelated with the naturalness of the sampling site (high at the bottom of figure 5 and low at the top). This second gradient was correlated with the amount of deciduous forest in the near stream zone and the amount of large stones in the stream. The naturalness of the site was negatively correlated with the water colour, TOC; aluminium, iron, and Si content of the water as well as the amount of fine sediment and sand in the streams.

There was a clear phosphorous gradient in the ten streams, strongly correlated with the naturalness gradient with phosphorous concentrations from 7 µg/l in Sågebäcken (EM1) to concentrations above 25 µg/l in Bodanäsån (EM9) and Vetlandabäcken (EM10) (Figur 6).



Figur 6. The total phosphorous concentration in August (●) and October (■) 2002.

Phytobenthos

IPS/IDG

This index is based on species determinations. At the sites EM1-EM9, the index value was high or very high. It was only lower at EM10 (Vetlandabäcken), the most affected stream.

IBD

This newer french index is based on 209 indicator taxa. Many of the clean water forms found in the Emå catchment is not part of this system (developed for French circumstances). Again Vetlandabäcken had a lowe index value than the other streams.

TDI

The UK index uses a combination of taxonomic levels for its indicators. All sites were classified into the very low classes (showing oligotrophic environments). Only Vetlandabäcken was close to class 2 (slightly affected).

Acidification

Only the stream Brändebäcken (EM3) ended up in the category ”episodically slightly acidic streams; pH smilar to type 2, but with rare pH depressions not <5,5”. All other streams was judged to be in the category ”permanently non-acidic streams; pH generally above 6,5, mostly at about 7, pH minimum never <6”.

Diversity and number of species

The diversity was highest in Sällevadsån (EM4) and Skiverstadån (EM8) and lowest in Bodanäsån (EM9) and Vetlandabäcken (EM10).

Calculated diatom indices at the ten sites from 12-14 augusti 2002.

	EM1	EM2	EM3	EM4	EM5	EM6	EM7	EM8	EM9	EM10
IPS	19,1	19,2	19,4	17,4	18,5	18,2	18,5	17,1	19,4	14,6
Class[1]	1	1	1	2	1	1	1	2	1	2
Class[2]	1	1	1	1	1	1	1	1	1	3
IDG	17,5	17,6	16,2	16,3	16,7	17,7	17,0	16,5	17,6	17,2
Class[1]	1	1	2	2	2	1	2	2	1	2
Klass[2]	1	1	2	2	2	1	1	2	1	1
IBD	17,5	17,6	20,0	17,2	17,3	18,0	17,3	15,5	17,9	17,9
Class[3]	1	1	1	1	1	1	1	2	1	1
TDI	4,5	4,5	2,8	4,2	5,2	5,3	5,5	5,2	4,9	6,6
Class[4]	1	1	1	1	1	1	1	1	1	1
%PT	0,5	0,7	0,0	0,2	1,0	0,2	1,2	3,1	0,0	1,7
Acidification	typ 2	typ 2	typ 3	typ 2	typ 2	typ 2	typ2	typ 2	typ 2	typ 2
Diversity	3,26	3,25	3,06	4,29	2,74	2,61	2,78	4,20	1,94	2,34
No of counted species	43	40	27	47	32	25	44	45	35	26

1 according to Swedish EPA Report 4913, 1999
2 according to Eloranta & Soininen 2002
3 according to Prygiel & Coste 2000
4 according to Eloranta & Soininen 2002
5 according toCoring 1996

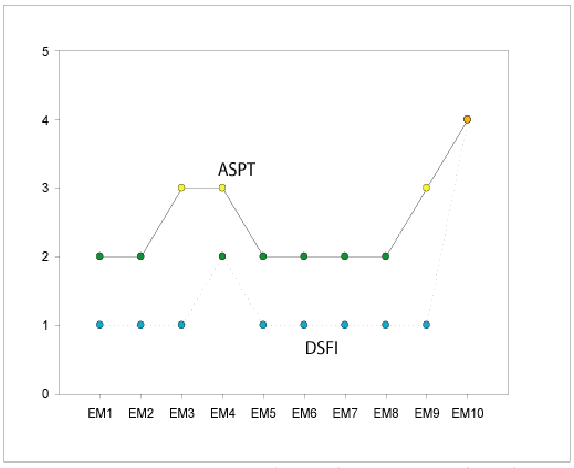
Macroinvertebrates

Diversity and number of taxa

A total of 114 macroinvertebrate taxa were captured at the ten sites. Eight taxa were found at all sites Ceratopogonidae, Tanypodinae, Tanytarsini, Orthocladiinae, Hydracarina, Oligochaeta, Sphaeriidae and *Polycentropus flavomaculatus*. The taxa with the highest abundances were Tanytarsini (1708), *Leuctra hippopus* (1682), Sphaeriidae (1536), *Caenis horaria* (1200). The most species rich streams were Sällevadsån (EM4) with 54 taxa and Alsedabäcken (EM7) with 52 taxa. The most species poor streams were Bodanäsaån (EM9) with 36 and Vetlandabäcken (EM10) with 33 taxa. The highest diversity (Shannon-Wiener) was found in Alsedabäcken (EM7) and in Brändebäcken (EM3), while the lowest was found in Vetlandabäcken (EM10) and in Sällevadsån (EM4).

Acidification
Noíne out of the ten sites had an acidification index ≥7, the only sites with a lower value was Skiverstadån (EM8), with an index value of 6 (indicating a possible acid effect.

Eutrophication
All streams except two had an DSFI index value of 7, which indicates very clean conditions. The exceptions were Sällevadsån (EM4), with a value of 6 and Vetlandabäcken (EM10), with a value of 4. Six out of the ten sites had an ASPT-value >6, which is classified as a high index value. Brändebäcken (EM3), Sällevadsån (EM4) and Bodanäsån (EM9) had a medium high index value, whereas Vetlandabäcken (EM10) had a low ASPT-value.



Figur 7. Index values for ASPT and DSFI for the ten streams.

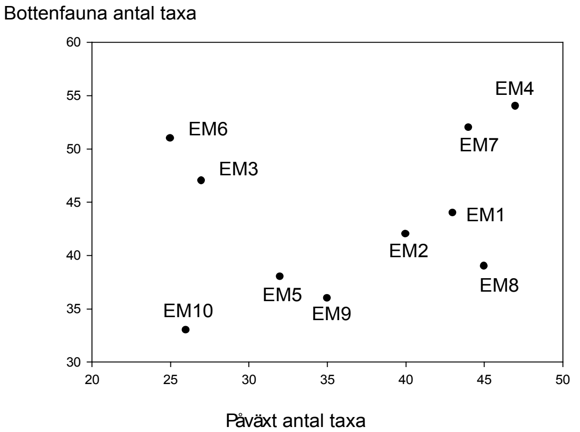
Macrophytes
Almost all the investigated streams were relatively oligotrophic with species such as *Juncus bulbosus*, *Menyanthes trifoliata*, *Potamogeton polygonifolius*, *Nuphar lutea*, *Carex rostrata*, *Eleocharis acicularis*, *Lysimachia thyrsiflora*, that are usually found in oligotrophic waters (Lohammar 1965) But the only true oligotrophic stream was Sågebäcken (EM1) while only Vetlandabäcken EM10 contained species indicative of eutrophic conditions with e.g. *Elodea canadensis*, (Wallsten och Solander, 1995), in low frequencies (2 %). According to the System Aqua assessment system all streams had a very low species diversity (class 0-2).

Fish
Brown trout was captured in 9 out of the 10 streams, but was the dominating species only in 6 streams and 12 sites. The highest concentration was found in Lillån (EM6) while Brändebäcken (EM3) did not contain brown trout. The highest species diversity was found in Lillån (EM6) and Bodanäsån (EM9) where 2,7 species were captured per site. The lowest diversity (1,0 species per site) was found in Brändebäcken (EM3). When doing a total assessment of the streams based on fish it was found that two sites in Brändebäcken (Sandlid and Brändekvarn), one site in Spelhesterbäcken (Uppströms kraftledningen) and one site in Vetlandabäcken (Arvingetorp) had a clear deviation from the expected value (class 3). A smaller deviation from the expected value

(class 2) were found in one site ach in the streams Alsedabäcken (Mederyd), Skiverstadsån, (Möllerydsdamm) and Bodanäsån (Kvarntorpet). Calculating a mean deviation for each stream (based on the three sampled sites in each) showed that only Brändebäcken (class 3) and Skiverstadsån (class 2) were classified as affected. All others showed no or an insignificant deviation from the expected value.

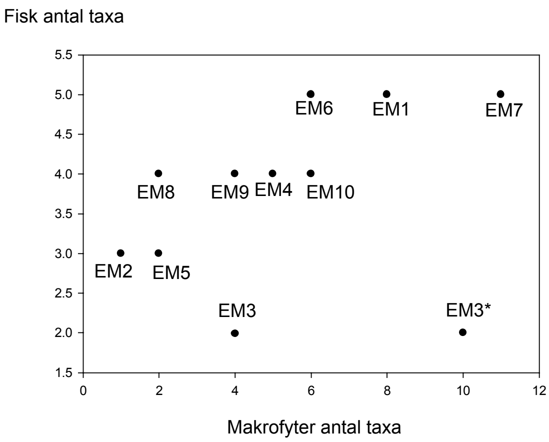
Comparisons of number of captured taxa among organism groups

There were no statistically significant relationship in number of captured taxa among the different organism groups. Despite this fact, the highest number of phytobenthos and macroinvertebrate taxa was found in Sällevadsån (EM4), while the lowest number of taxa was found in Vetlandabäcken (EM10).



Figur 8 Relationships among number of taxa of phytobenthos (x—axis) versus number of taxa of macroinvertebrates (y-axis) captured at the ten sites.

A similar relationship was found for fish and macrophytes, where the highest number of taxa was found in Alsedabäcken (EM7), while the lowest number of macrophytes was found in Bäck från Lillahemsgöl (EM2), where also the lowest but one number of fish taxa were captured (Figure 9).



Figur 9 Relationships among number of taxa of macrophytes (x—axis) versus number of taxa of fish (y-axis) captured at the ten sites.

Comparisons of the community composition for the different organism groups

To do a simple comparison of the community composition at the ten sites, the taxalists were analysed using Detrended Correspondence Analysis (DCA). What can clearly be seen from these analyses is that Vetlandabäcken (EM10) differs from all the other streams (least clear for macrophytes where Alsedabäcken (EM7) and Skiverstadån (EM8) have a taxa composition similar to Vetlandabäcken).For phytobenthos and macroinvertebrates it is also one other site that differ from the rest, i.e. Sällevadån (EM4).

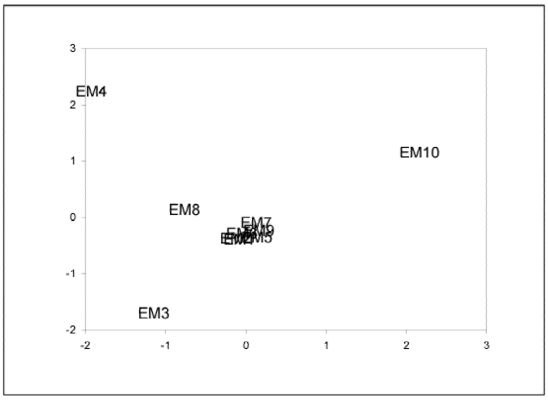


Figure 10. Community composition of phytobenthos.

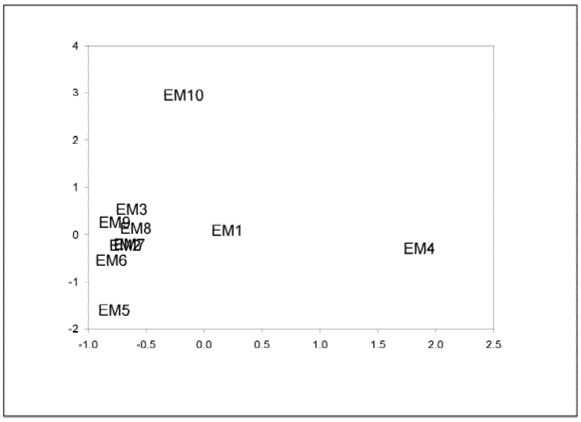


Figure 11. Community composition of macroinvertebrates.

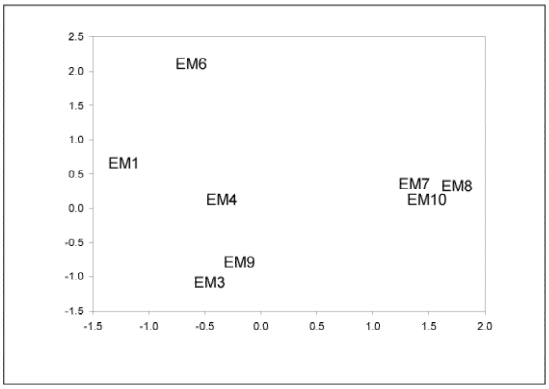


Figure 12. Community composition of macrophytes.

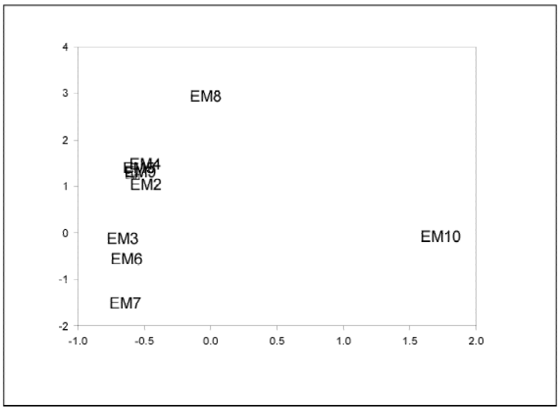


Figure 13. Community composition of fish.

The relationships between organisms and environmental variables

The most important environmental variables correlated with the phytobenthos community composition was conductivity, NO_2+NO_3, Na, SO_4, total N and amount of urban land in the catchment.

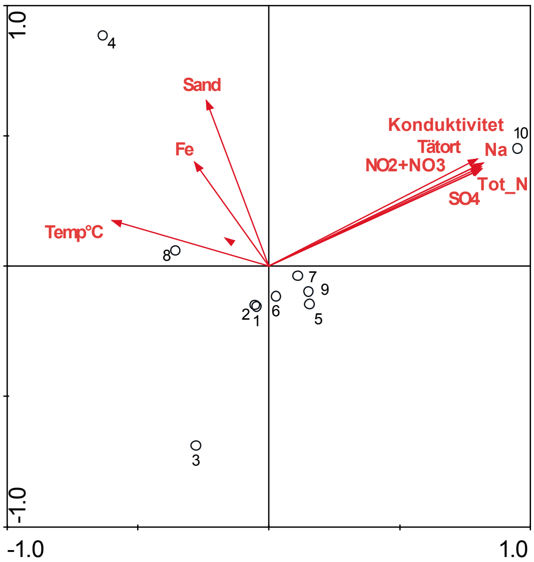


Figure 14. Correlation among the ten sampled sites and environmental variables in relation to phytobenthos community composition.

The most important variables for macroinvertebrates was the amount of sand in the stream and the water temperature. Less important (but significant) were the amount of emergent vegetation and the Si water content.

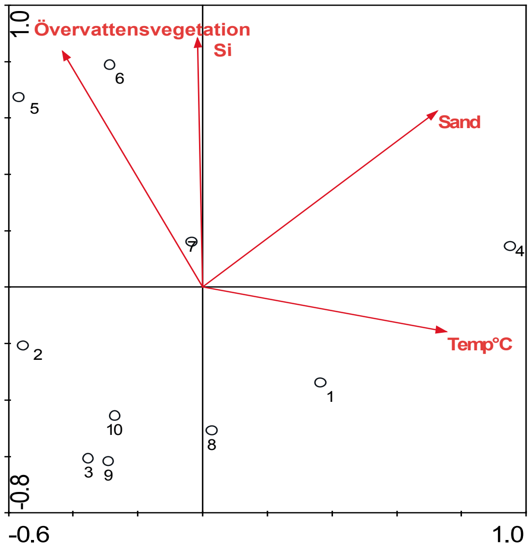


Figure 15. Correlation among the ten sampled sites and environmental variables in relation to macroinvertebrate community composition.

The environmental variables most strongly correlated with macrophyte composition were stream width, amount of suspended particles, As content, and pH.

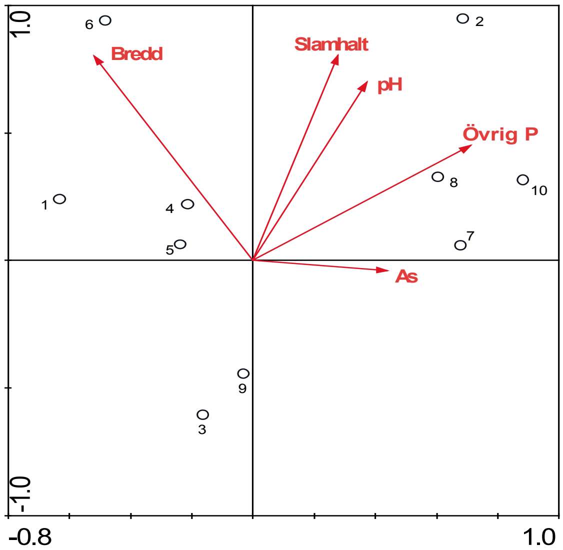


Figure 16. Correlation among the ten sampled sites and environmental variables in relation to macrophyte community composition.

For fish water colour, amount of coarse detritus, amount of agricultural land in the catchment and altitude the best environmental predictors.

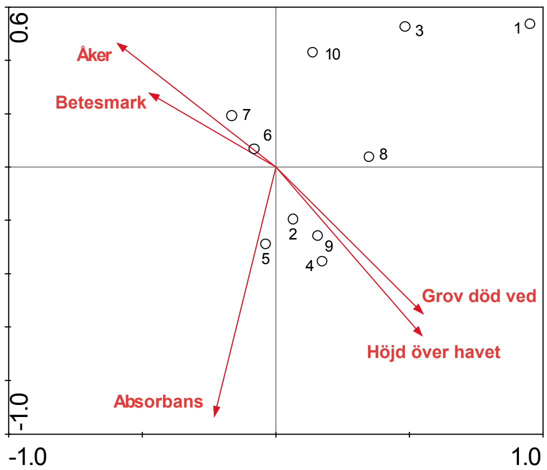


Figure 17. Correlation among the ten sampled sites and environmental variables in relation to fish community composition.

Discussion

For most of the ten sites, the number of taxa of phytobenthos and benthic fauna correlated well, i.e. if there are few taxa of phytobenthos there are also few taxa of macroinvertebrates. Two sites differ from the others were Brändebäcken (EM3) and Lillån (EM6), both with relatively low number of phytobenthos taxa and relatively many benthic macroinvertebrate taxa. The only thing special about these sites is quite high suspended solids in the water at august sampling (when the phytobenthos samples were taken). A similar pattern were found for fish and macrophytes, where a high macrophyte taxon richness correlated with a low fish diversity. Macrophytes are also special since a site which is good for sampling of macrophytes (with a high diversity) generally contains few species of the other organism groups. The community composition were similar for phytobenthos and macroinvertebrate, where Vetlandabäcken (EM10) and Sällevadsån (EM4 differs from the other streams. Vetlandabäcken has the highest total P content, while Sällevadsån had a very high diversity of both phytobenthos and macroinvertebrates. For all organism groups except macrophytes, it is clear that Vetlandabäcken (EM10) differs from the other streams in terms of community composition. Phytobenthos was clearly best correlated with the naturalness/phosphorous gradient found among the ten streams.

Aknowledgement
Sampling and primary data analyses in this study were funded by the Swedish Environmental Protection Agency. The study was performed by Leonard Sandin (project leader), Berta Andersson and Mikael Östlund (macrophytes), Björn Bergquist and Magnus Dahlberg (fish), Jens Fölster (chemistry), Jakob Bergengren and Ola Broberg (biotope inventory) and Amelie Jarlman (phytobenthothos).

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13. Contribution by Masaryk University

Relationship between hydromorphology and biota

V. Syrovatka, K. Brabec, O. Hajek, H. Kvardova, L. Opatrilova & K. Petrivalska

Large rivers (catchment area of more than 1000 km^2) in the Czech Republic are impaired by impoundments, regulations, channelization, bank stabilization and pollution. In that conditions it is not possible to collect and analyze dataset representing gradient of hydromorphological degradation within this type of water bodies. Therefore we analyzed at first relationships between hydromorphological and biological parameters using existing high standard data from small streams. Results of that analyses provide knowledge about general response of benthic communities to river habitats patterns at reach scale. Subsequently the first preliminary data collected at microhabitat scale were evaluated.

1. **reach scale**
    - scale-dependent effect of catchment landuse and riparian zone characteristics on the water chemistry and benthic macroinvertebrates
    - links between habitat quality components and biota
    - biological indicators of habitat quality

2. **habitat scale**
    - identification of key habitats endangered by impairment being studied in the pilot catchment
    - analyses of relationships between structure of macroinvertebrate communities and environmental characteristics of habitats

1. REACH SCALE

DATA

The analyzed dataset consists of 30 samples taken at 14 sites representing various magnitude of organic pollution/eutrophication and 10 sites representing a range of magnitude of hydromorphological degradation. The stream type designated for evaluation of biological response to organic pollution is based on more general catchment geology typology than morphological subset. All sites are located on small streams in altitude 200-500 m a.s.l., their size can be characterized by Strahler order 2-4 or catchment area 16-51 km^2. The samples collected in the spring period between March 25 and April 18 2003 were included. Multihabitat design of sampling and laboratory procedures are described in Brabec et al. (in prep.).

RESULTS

LANDUSE

We tested effect of landuse within subcatchments and buffer zone on the water chemistry, phytobenthos and macroinvertebrate metrics. Data from spring sampling done within STAR project were analyzed.

Catchment of every site was devided into sub-catchments delineated by points distributed along main stream in 2-km interval. The Pearson correlation coefficients between land use within indivudual subcatchments and parameters recorded at studied sites were calculated (N=29, for site located in Slovak Republic were not available land use data).

Nutrient concentration at studied sites was significantly correlated with cropland proportion in the whole catchment upstream that site and in sub-catchment limited by closure point located 2 km upstream from site. Nitrates were significant at level $p < 0.001$ for both areas but total phosphates only for whole catchment ($p < 0.01$). Gradual increasing of correlation significance was evident in case of chlorides ($p < 0.05$ at 4 km upstream, $p < 0.01$ at 2 km upstream and $p < 0.001$ for the entire catchment.

Phytobenthos response to landuse cover within catchment was documented by correlation with indices, predominantly based on diatoms sensitivity to nutrients concentration:

Czech Saprobic index based on counts of diatom frustules (Marvan, unpublished revised valences) .

Specific Pollution Sensitivity Index (IPS, Coste 1987)

Trophic index (Rott et al., 1999)

The statisticaly significant response to cropland areas was detectable in sub-catchment with closure point located 0-6 km upstream the sites whereas forest areas operated at point 0-2 km. It means that phytobenthos communities are mostly influenced by sub-catchment landuse of last 6 km (cropland) and 2 km (forest) of stream above sampled site.

Macroinvertebrates exhibited weak relationships to landuse in catchment, but extensive number of metrics were significantly correlated with landuse within floodplain or more generaly defined buffer zone of certain width following channel trajectory (Tab 2). For the small streams 400 m wide buffer zone were used (within 1km long stretch upstream the sampling site).

Table 2. Biological parameters correlated with proportion of forest/cropland within a buffer zone (Pearson correlation coefficients)

CODE	biological parameter	FOREST	CROPLAND
B245	EPT/Diptera - number of taxa	0,825	-0,715
B122	Rhithron Typie Index	0,802	-0,714
B85	Number of sensitive taxa (Austria)	0,793	-0,688
B146	Stone-dwelling taxa (Braukmann, with abundance classes	0,79	-0,685
B76	German Fauna Index D04	0,769	-0,6
B243	EPT taxa	0,763	-0,64
B250	EPTCOB taxa (Eph., Ple., Tri., Col., Odo., Bivalv.)	0,749	-0,631
B160	[%] Xyloph. + Shred. + ActFiltFee. + PasFiltFee	0,736	-0,607
B36	Biological Monitoring Working Party	0,735	-0,587
B244	EPT/OL taxa	0,726	-0,613
B249	EP-Taxa	0,723	-0,603
B48	IBE	0,714	-0,607
B269	Plecoptera abundance	0,706	-0,677
B324	Plecoptera+Trichoptera taxa	0,698	-0,597
B38	Average score per Taxon	0,688	-0,531
B230	Plecoptera taxa	0,683	-0,597
B44	DSFI	0,682	-0,614
B73	German Fauna Index D01	0,675	-0,525
B236	Coleoptera taxa	0,669	-0,619
B144	[%] Type Aka+Lit+Psa (scored taxa = 100%)	0,662	-0,673
B234	Trichoptera taxa	0,637	-0,538
B272	Megaloptera abundance	0,633	-0,527
B207	EPT-Taxa [%]	0,591	-0,524
B138	[%] Type Aka + Lit + Psa	0,555	-0,539
B239	Chironomidae - number of taxa	-0,621	0,583
B79	r/K relationship	-0,63	0,586
B34	Czech Saprobic Index	-0,716	0,601
B163	[%] Gatherers/Collectors (scored taxa = 100%)	-0,743	0,586
B287	Index of Biocoenotic Region	-0,746	0,686
B26	German Saprobic Index (new version)	-0,792	0,63
B5	Saprobic Index (Zelinka & Marvan)	-0,796	0,774
B246	OD-Taxa [%] (Austria)	-0,821	0,694
B248	OD/Total-Taxa	-0,821	0,694

$p < 0.001$ (green)
$p < 0.01$ (orange)

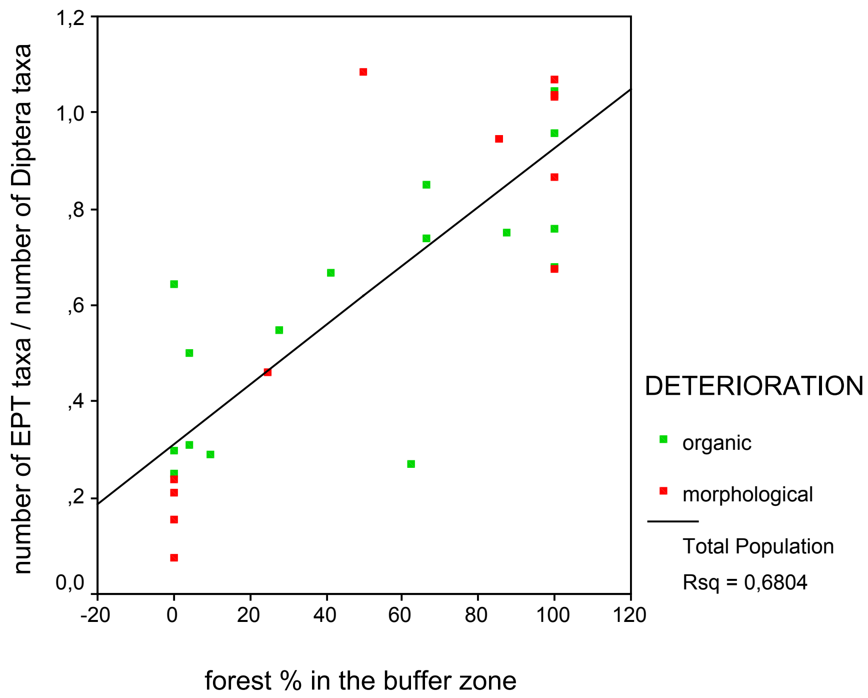

Fig. 5. Ratio of taxa richness of EPT and Diptera is one of biotic parameters positively correlated with forest landuse within buffer zone (p < 0.001).

<u>RIPARIAN ZONE</u>

The role of landuse characteristics in forming structure of stream invertebrate fauna was described in previous chapter. Here we have focused on shading, coverage of bank line by tree vegetation and its width. These features were positively related to taxa richness of Coleoptera, Plecoptera, Oligochaeta, EPT taxa, abundance of shredders (all $p < 0.001$) and many other metrics.

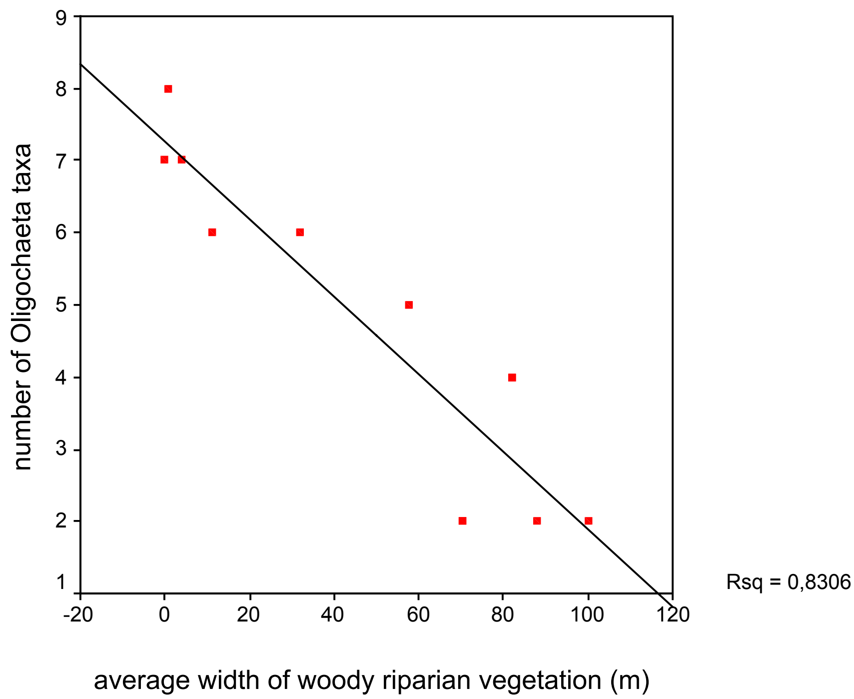

Fig. 6. Scatter plot of Oligochaeta taxa richness and average width of riparian vegetation within reach 1 km long upstream of the site. Width values higher than 100 m were assigned to value 100 m. Correlation coefficient is significant at level p < 0.001.

HYDROMORPHOLOGY

The biological response to hydromorphological conditions was studied using three types of characteristics of macroinvertebrate communities – all taxa, selected taxa recognized to be sensitive to impairment gradient and metrics/indices derived from taxonomic or functional structure of community. River Habitat Survey was applied to describe habitat quality or results of its modification. Survey results can be stratified into Habitat Quality indices arising from flow types (HQAFLOW), channel substrates (HQASUB), other channel features, bank features (HQABANK), bank vegetation (HQABVEG), in-stream channel vegetation, floodplain land use, trees (HQATREE) and associated features. The Habitat Quality Assessment score (HQASCOR) represents all above mentioned components. Physical degradation is assesed by Habitat Modification Score (HMSSCOR).

Community structure – multivariate analysis

The similarity of taxonomic composition (Bray-Curtis index) combined with Multidimensional Scaling (MDS) method allowed to extract simple score representing response to dominant stressor occuring within study dataset in various intensity. It has been found that sample scores of dimension 1 are significantly related to environmental measures of morphological degradation ($p < 0.001$; Fig. 7).

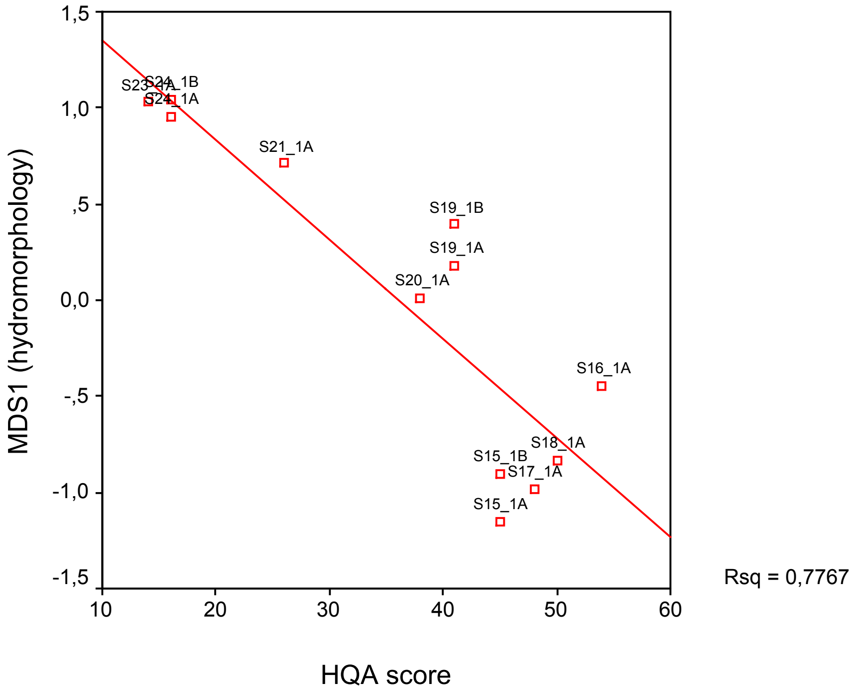

Fig. 7. Relationship between Habitat Quality Assessment score and multidimensional scaling scores of dimmension 1.

Community characteristics - metrics

General links between hydromorphological features and characteristics of stream macroinvertebrates were analyzed focusing on separate features of channel, banks and riparian zone. There are many biological characteristics correlated significantly with both summary indices (HQA, HMS), score arising from substrate and bank features (see Tab 3,4). These results show that aquatic fauna inhabiting this type of small streams responded to intensive interactions between in-stream and riparian habitats. Although it is expected that such relationships can operate in different way in condition of large river we obtained list of community characteristics being in relation to hydromorphology.

Only few biological metrics were significantly correlated with channel features of Habitat Quality score (e.g. ratio of number of EPT taxa/number of Oligochaeta taxa, R^2=0.59, $p < 0.01$; relative abundance of Xylophagous taxa + Shredders + Active filter feeders + Passive filter feeders, R^2=0.58, $p < 0.01$).

*Table 3. List of macroinvertebrate characteristics having highly significant Spearman correlation coefficient (N=12) with scores of River Habitat Survey (biotic metrics were calculated by ASTERICS available at **www.aqem.de** or **www.eu-star.at**, there is also description of metrics).*

code	biological parameter	HQAFLOW	HQASUB	HQABANK	HQABVEG	HQATREE	HQASCOR	HMSSPOT	HMSSCOR
B249	- EP-Taxa	0,137	0,001	0,001	0	0,016	0	0,003	0,004
B26	German Saprobic Index (new version)	0,006	0,001	0,001	0,006	0	0	0,001	0,001
B122	Rhithron Typie Index	0,007	0,013	0,005	0,001	0	0	0,02	0,018
B85	Number of sensitive taxa (Austria)	0,013	0,001	0,002	0	0,004	0	0	0
B319	- Sel_Trichoptera	0,014	0,005	0,002	0,001	0	0	0,005	0,004
B246	- OD-Taxa [%] (Austria)	0,022	0	0,001	0,003	0,003	0	0	0
B248	- OD/Total-Taxa	0,022	0	0,001	0,003	0,003	0	0	0
B5	Saprobic Index (Zelinka & Marvan)	0,015	0	0	0,001	0,002	0	0,001	0,001
B76	- German Fauna Index D04	0,024	0,004	0,001	0,003	0	0	0,004	0,004
B194	- Plecoptera [%]	0,025	0	0	0,001	0,002	0	0	0
B269	- Plecoptera	0,041	0	0	0,002	0,015	0	0	0
B320	- Leuctra_Calopteryx	0,083	0,009	0,002	0,002	0,066	0,001	0,051	0,071
B243	- EPT-Taxa	0,017	0,002	0,004	0,001	0,008	0,001	0	0
B230	- Plecoptera	0,128	0,001	0,001	0	0,039	0,001	0,001	0,002
B300	- Plecoptera_taxa	0,128	0,001	0,001	0	0,039	0,001	0,001	0,002
B44	DSFI	0,283	0	0,001	0,001	0,001	0,001	0,001	0,001
B287	Index of Biocoenotic Region	0,018	0,002	0,002	0	0,014	0,001	0	0
B245	- EPT/Diptera	0,029	0,004	0,004	0,008	0	0,001	0,005	0,003
B244	- EPT/OL	0,396	0	0	0,009	0,052	0,001	0	0
B250	- EPTCOB (Eph., Ple., Tri., Col., Odo., Bivalv.)	0,012	0,007	0,009	0,002	0,004	0,002	0,002	0,001
B36	Biological Monitoring Working Party	0,015	0,005	0,007	0,002	0,007	0,002	0,001	0,001
B324	- PleTri_taxa	0,02	0,007	0,008	0,003	0,007	0,002	0,001	0,001
B236	- Coleoptera	0,014	0,018	0,012	0,003	0,006	0,003	0,023	0,018
B171	- [%] burrowing/boring	0,02	0,005	0,01	0,003	0,009	0,003	0,001	0
B314	- Sel_Plecoptera_M	0,043	0,002	0,004	0,035	0,002	0,003	0	0
B136	- [%] Type Oth	0,028	0,004	0,009	0,002	0,007	0,004	0	0
B200	- Coleoptera [%]	0,018	0,071	0,032	0,008	0,001	0,005	0,089	0,084
B303	- Amphinemura_Protonemura	0	0,019	0,021	0,021	0,017	0,005	0,004	0,002
B46	BBI	0,602	0,003	0,004	0,005	0,004	0,006	0,008	0,009
B169	- [%] swimming/skating	0,065	0,079	0,033	0	0,038	0,007	0,08	0,102
B153	- [%] Gatherers/Collectors	0,11	0	0,005	0,024	0,048	0,007	0	0
B323	- Tubificidae	0,828	0,002	0,002	0,059	0,066	0,009	0,07	0,092
B275	- Coleoptera	0,039	0,073	0,037	0,02	0,001	0,009	0,106	0,094
B321	- Elmidae	0,043	0,071	0,036	0,018	0,001	0,009	0,096	0,085
B208	- EPT/OL [%]	0,002	0,01	0,017	0,118	0,159	0,01	0,009	0,009
B133	- [%] Type Lit	0,265	0,002	0,005	0,027	0,024	0,01	0,007	0,006
B73	- German Fauna Index D01	0,082	0,041	0,027	0,024	0	0,01	0,027	0,023
B306	- Leptophlebiidae	0,914	0	0,001	0,043	0,068	0,012	0,012	0,017
B198	- Trichoptera [%]	0,045	0,049	0,041	0,034	0,007	0,013	0,035	0,032
B234	- Trichoptera	0,06	0,034	0,035	0,027	0,014	0,015	0,015	0,014
B299	- Trichoptera_taxa	0,06	0,034	0,035	0,027	0,014	0,015	0,015	0,014
B228	- Ephemeroptera	0,538	0,007	0,009	0,005	0,028	0,015	0,026	0,024
B139	- [%] Type Pel (scored taxa = 100%)	0,643	0,002	0,005	0,106	0,052	0,018	0,026	0,028
B130	- [%] Type Arg	0,676	0,008	0,007	0,201	0,028	0,018	0,072	0,091
B48	IBE	0,122	0,033	0,04	0,002	0,029	0,019	0,009	0,008
B52	IBE Aqem	0,122	0,033	0,04	0,002	0,029	0,019	0,009	0,008
B144	- [%] Type Aka+Lit+Psa (scored taxa = 100%)	0,627	0,028	0,017	0,049	0,006	0,019	0,089	0,104
B38	Average score per Taxon	0,201	0,115	0,06	0,005	0,001	0,02	0,12	0,113
B203	Chironomidae	0,377	0,001	0,008	0,033	0,039	0,02	0	0
B129	- [%] Type Pel	0,586	0,003	0,006	0,156	0,068	0,023	0,035	0,037
B120	Rheoindex (Banning, with abundance classes)	0,668	0,016	0,021	0,075	0,009	0,024	0,026	0,033
B267	- Ephemeroptera	0,004	0,165	0,116	0,071	0,033	0,026	0,147	0,139
B146	Stone-dwelling taxa (Braukmann, with abundance classes	0,08	0,041	0,064	0,016	0,031	0,03	0,011	0,008
B304	- A.Muticus + N.digitatus	0,843	0,004	0,006	0,091	0,121	0,031	0,033	0,043
B293	- [%] Gatherers/Collectors	0,159	0,003	0,026	0,092	0,155	0,033	0	0
B160	- [%] Xyloph. + Shred. + ActFiltFee. + PasFiltFee	0,735	0,001	0,008	0,066	0,106	0,033	0,001	0,001
B224	- Oligochaeta	0,594	0,005	0,014	0,206	0,236	0,039	0,025	0,036
B34	Czech Saprobic Index	0,509	0,004	0,022	0,054	0,187	0,04	0,003	0,003
B283	Number of Families	0,059	0,103	0,102	0,014	0,01	0,043	0,038	0,026

p < 0.001
p < 0.01
p < 0.05

Table 4. Number of biological metrics significantly correlated with River Habitat Survey scores. Total number of calculated biological metrics was 224.

hydromorphological parameter	code	< 0.05	< 0.001
HQA Flow types	HQAFLOW	64	1
HQA Channel substrates	HQASUB	109	15
HQA Channel features	HQACHAN	31	0
HQA Bank features	HQABANK	105	7
HQA Bank vegetation	HQABVEG	96	9
HQA Channel vegetation	HQARVEG	8	0
HQA Land-use within 50 m	HQALAND	7	0
HQA Trees and Associated features	HQATREE	101	12
Habitat Quality Assessment Score	**HQASCOR**	**103**	**15**
Habitat Modification Score at spot checks	HMSSPOT	111	16
Habitat Modification Score not at spot checks	HMSNSPOT	1	0
Habitat Modification Score of the site	HMSSITE	47	2
Habitat Modification Score	**HMSSCOR**	**106**	**17**

Sensitive taxa

Biological indication of hydromorphological structures at level of individual taxa close to species level is based on their ecological requirements, preferences and tolerances. We can find taxa inhabiting preferably certain type of habitats or certain habitat pattern driving distribution of macroinvertebrate taxa across spatial scales. Empirical investigation resulted in identification of taxa tolerant/sensitive to morphological degradation. Austrian list of sensitive taxa is based on taxa, which can be determined in the field (Moog et al., 1999). Number of such taxa is a metric indicating stream degradation also in conditions of running waters studied in the Czech Republic. Statistically significant relation to flow conditions, substrate, bank features, bank vegetation and overall Habitat Quality score were found within small streams studied in the STAR project (www.eu-star.at, Brabec et al., in prep). However this metric is also correlated with environmental indicators of organic pollution and eutrophication (nitrite, $p < 0.001$).

STAR project dataset allowed analyses of indicator taxa based on final classification using multimetric assessment system. Five ecological quality classes were merged to three groups combining high and good classes and poor and bad classes. The Indicator Species Analysis was performed in PC-ORD with log(x+1) transformed data. Viewing Table 2 it is obvious that only positive indicators associated with high habitat quality (and not tolerant to conditions at degraded sites) are relevant result of this evaluation.

Table 5. List of indicator species (taxa related to degraded sites are in yellow and taxa associated with sites of high or good ecological status are marked in green)

taxon	Maxgrp	Value (IV)	Mean	S.Dev	p *
Paratrichocladius rufiventris	21	81,2	53,8	10,12	0,0065
Rheocricotopus fuscipes	21	97,2	81,3	7,31	0,0072
Tvetenia calvescens	21	84,4	64,8	9,64	0,0076
Amphinemura sulcicollis	54	97,5	61,4	14,14	0,0109
Anomalopterygella chauviniana	54	96,7	68,7	14,98	0,0109
Glossosoma conformis	54	98,4	68,2	13,39	0,0109
Orthocladius wetterensis	21	89,4	59,7	12,8	0,0117
Orthocladius rubicundus	21	97,1	82,2	9,96	0,0144
Esolus sp.	54	91	75,4	9,47	0,0169
Sericostoma sp.	54	84,7	59,6	11,95	0,0213
Elmis sp.	54	63,9	47,8	7,66	0,0284
Nais elinguis	21	90,8	60,3	13,37	0,0302
Halesus digitatus	54	77,3	61,2	8,68	0,0356
Tubifex sp.	21	99,2	94,4	3,46	0,0452

This example of identification of biological indicators of hydromorphological status is aplicable for the pilot catchment of Becva River studied in general terms only. It has to be considered differences related to typology of running waters (size, altitude, etc.) and distribution patterns of indicator taxa independent on degradation magnitude. The main component of morphological degradation in evaluated small streams was channel streightening, bank and riparian zone modifications. The lateral conectivity, floodplain characteristics, habitat patterns, bank fixation, meandering and braiding of channel are main hydromorphological features which we will concentrate on within sites of Becva River pilot catchment.

For the pilot catchment seems to be highly appropriate approach of the „Floodplain Index“ proposed by Waringer et al., (in prep.). This is a new method developed for assessment of ecological status of river/floodplain systems using indicator groups (molluscs, caddisflies, dragonflies, amphibians, and fish). It was developed and tested for large braided river systems. Habitat preferences of indicator taxa were linked to five habitat types (Tab 6). In order to describe the species' habitat preferences numerically, 10 valency points were distributed among five habitat types (Tab 4).

Table 6. Description of the habitat types (according to Ward & Stanford 1995, Chovanec & Waringer 2001).

Habitat type	Characterisation
H1	Hydrologically dynamic water bodies, connected with the main channel at both ends at mean water discharge; in case of connectivity high water velocities; no macrophyte communities in the open water; open banks or *Phalaridetum* stands in the littoral area; sand and gravel substrate are dominating.
H2	Water bodies which lack unidirectional current, connected only at the downstream end at mean water levels; only few macrophytes (e.g. *Phalaridetum*); high proportion of sand and gravel substrates

H3	No connectivity with the main channel at mean water levels; terrestrialisation processes; coverage of open water areas by macrophytes does not exceed 20% of open water area; dominating macrophyte communities: *Phragmitetum, Typhetum, Sagittario-Sparganietum, Myriophyllo-Nupharetum, Magnocaricetum*; increased degree of sedimentation
H4	No connectivity with the main channel at mean water levels; terrestrialisation processes; coverage of open water areas by macrophytes exceeds 20% of open water area; dominating macrophyte communities: *Phragmitetum, Typhetum, Sagittario-Sparganietum, Myriophyllo-Nupharetum, Magnocaricetum*; high degree of sedimentation
H5	Temporary pools, water level primarily dependent on ground water levels; dominating macrophyte communities: *Phragmitetum, Typhetum, Sagittario-Sparganietum, Magnocaricetum*; terrestrial vegetation

2. HABITAT SCALE

LOCALITIES (PILOT STUDY SITES)

Two sites, the Cernotin and the Osek on the Becva river were selected as our pilot sites. At each site two reaches (regulated and restored) are being studied.
Osek is an opened river reach with sporadic riparian vegetation, whereas both sides of the river at Cernotin are forested. Both sites are characterized by gravel bars; dominant substrate is mesolithal. The channel width at both sites varies between approx. 25-35 m at low discharges.

We have compared the proportion of different channel shapes (anastomosed, braided, meandered and straight) on the Becva river and its two main tributaries (Roznovska Becva and Vsetinska Becva) obtained during the 2nd military mapping (1819-1858) with the present situation. Whereas the proportion of the straight reaches on Becva river accounted of only 25% during the 2nd military mapping, at present only straight reaches can be found there. As the consequence of the straightening, the river was shortened to only 64% of its original length.

River	Reaches (km) - year 1858					year 2004	**short cut (km)**
	Anastomosed	braided	meandered	straight	total	only straight reaches	
Roznovska Becva	0.4 (1%)	6.7 (17%)	0 (0%)	31.5 (82%)	38.6	37.4	**1.2 (3%)**
Vsetinska Becva	5 (8%)	19.8 (32%)	4.7 (8%)	31.5 (52%)	61	58.6	**2.4 (4%)**
Becva	17.4 (18%)	7.8 (8%)	47.6 (49%)	23.9 (25%)	96.7	61.6	**35.1 (36%)**

Also on both tributaries only straight reaches can be found nowadays, but, contrary to the Becva river, both main tributaries were shortened to a little extend (3% and 4%). It is likely because Roznovska Becva and Vsetinska Becva flow throw narrow valleys and naturally there weren't many meanders to be cut short.

DISCHARGE AND TEMPERATURE CHARACTERISTICS

Becva catchment belongs to the areas of strongly variable runoff (GEOGRAFICKY USTAV CSAV, 1971). In this area floods frequently alternate with periods of low discharges. The water discharge, when increased to about 25 – 30 $m^3.s^{-1}$, causes the dominant particles (size 6 – 20 cm, mesolithal) of substratum to move. After periods of high discharges, the algae cover is abraded and a well visible siltation can be observed.

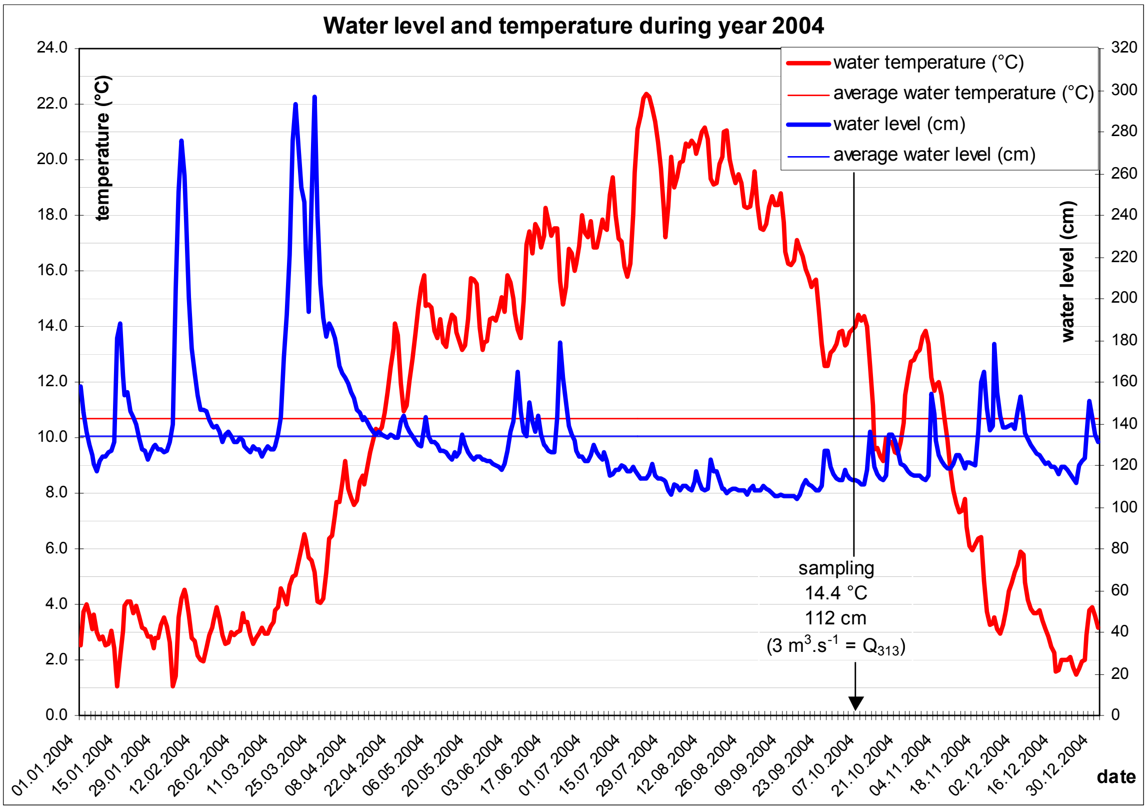

Fig. 1. The relation between the water level and the water temperature in year 2004.

The water level and temperature data from the hydrological station Dluhonice (located at the closing site of Becva catchment) were analyzed.

The mean annual water level in the calendar year 2004 was 134 cm (which equals to discharge of 12 $m^3.s^{-1}$), the lowest was 104 cm (= 2 $m^3.s^{-1}$) in September and the highest 297 cm (= 142 $m^3.s^{-1}$) during the spring flood in March. There was a 3 months period of low discharges before our sampling (see fig.1).

The mean annual water temperature in 2004 was 10.7°C, the lowest was 1°C in January and the highest 22.4°C in July. Fig. 1 shows the short-term relation between the discharge (water level) and the water temperature: an increasing discharge in winter season causes a rise of the temperature and on the contrary in summer season, a fall of the temperature. The water temperature before our sampling date had a decreasing tendency but in the date of our sampling there was a local peak of higher temperatures.

In comparison with time series since 1978, the discharge and water temperature pattern in 2004 were representative.

DATA COLLATION

In October 2004 both sites near Cernotin and the restored reach of Osek site were sampled in agreement with the AQEM project method.

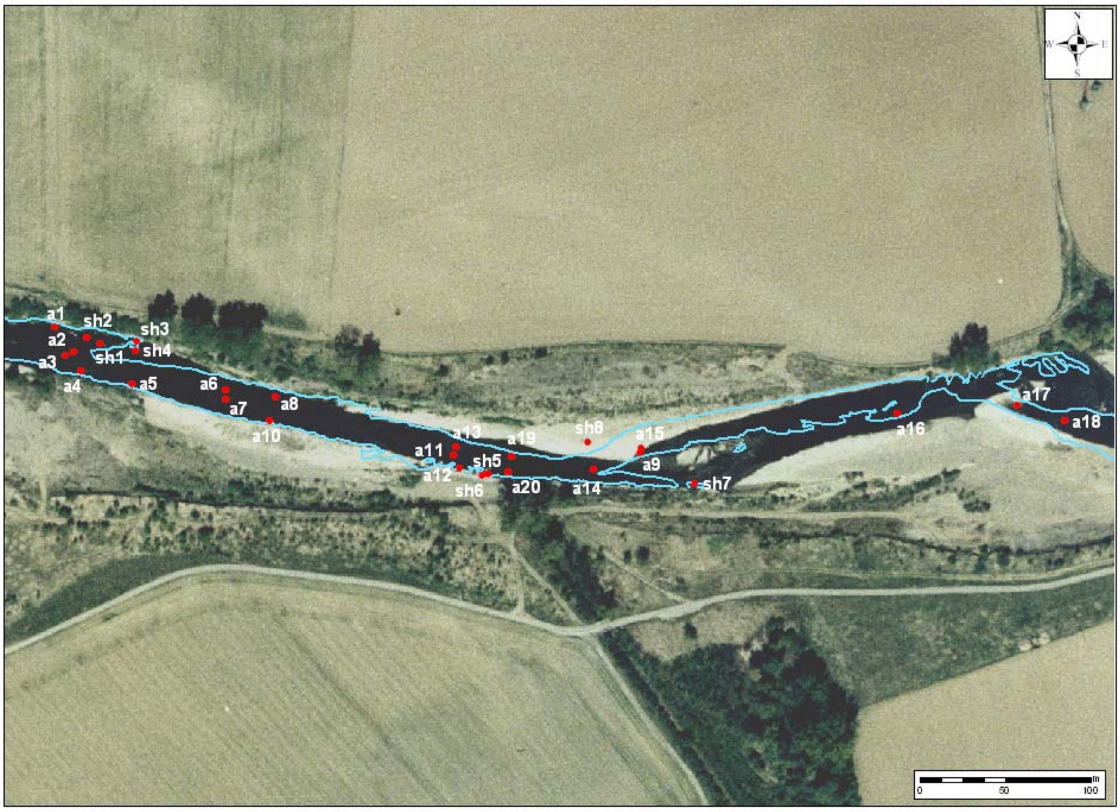

Fig. 3. The restored site at Osek, a1-20 = basic sampling units, sh1-8 = samples of rare habitats.

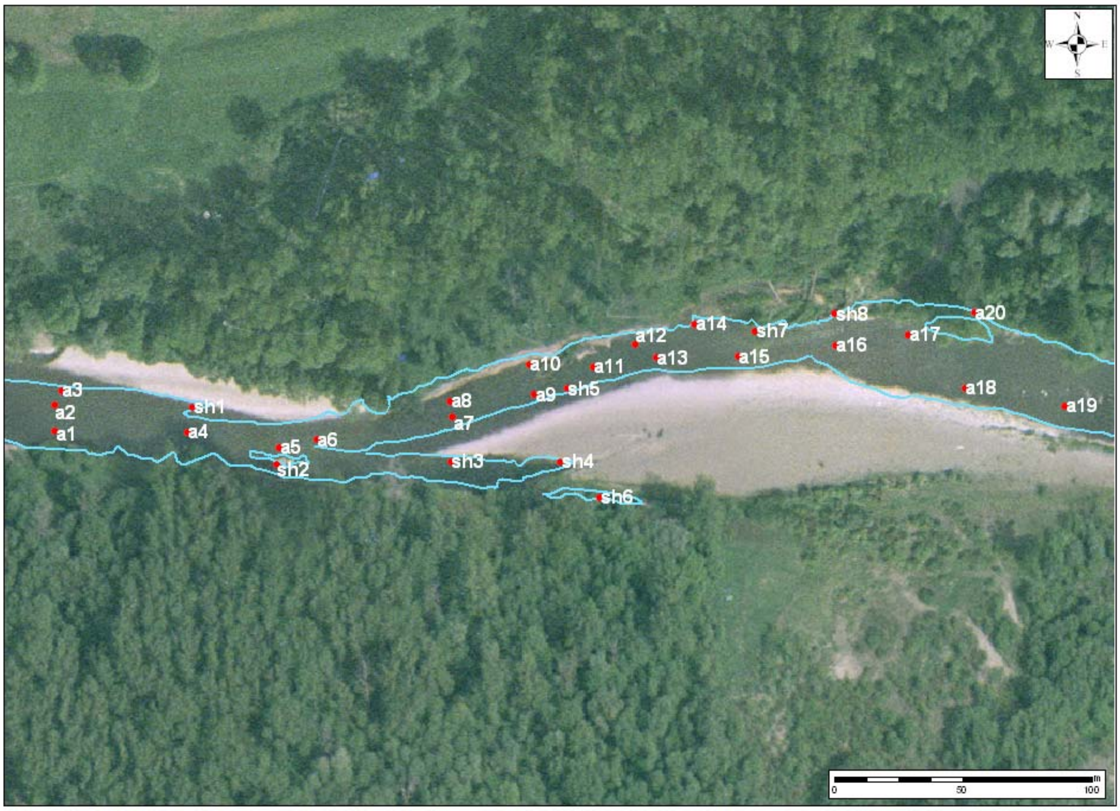

Fig. 4. The restored site at Cernotin, a1-20 = basic sampling units, sh1-8 = samples of rare habitats

20 basic „sampling units" (mesh size 250 µm) were distributed according to the share of microhabitats and in addition rare habitats were sampled on each site (HERING et al. 2004). Distribution of sampling points shows the Figures 3 and 4. Samples were stored and processed separately. All macroinvertebrates were sorted from the sediment and identified to species or the lowest practicable level.

At each sampling point the dominant and subdominant substrate were estimated, and depth, current velocity (in 40% of water column above the sediment surface) and some physico-chemical characteristics (pH, conductivity, dissolved oxygen concentration and saturation) were measured. The ranges of the measured parameters are listed in Table 1.

Table 1. The range of parameters measured at study sites.

	The restored reach at Cernotin			The restored reach at Osek		
	Minimum	Median	Maximum	Minimum	Median	Maximum
depth (m)	0.05	0.25	0.99	0.09	0.26	0.64
current velocity ($m.s^{-1}$)	0	0.19	0.80	0	0.02	0.98
Froude number	0	0.12	0.64	0	0.02	0.67
water temperature (°C)	12.40	16.05	16.70	10.50	14.20	15.70
dissolved O_2 ($mg.l^{-1}$)	0.76	12.89	14.20	1.74	8.57	10.27
O_2 saturation (%)	7.80	135.85	147.70	16.60	88.15	126.00
pH	8.17	9.31	9.77	6.20	7.77	9.54
conductivity ($mS.cm^{-1}$)	0.24	0.44	0.48	0.44	0.49	0.69

STATISTICAL ANALYSIS

Because only three samples from the regulated reach of Cernotin have been processed so far, only data from both (Cernotin and Osek) restored reaches were used for statistical analyses. These data contain macroinvertebrate and environmental data from 56 (28+28) samples/sampling points.

INDICATOR SPECIES ANALYSIS

Methods

The benthic invertebrates of the two sites were analyzed separately. For each site, samples were grouped according to the substrate type and hydraulic conditions (here we divided habitats using the Froude number (according to Jowet, 1993) in (a) Fr = 0 – **pools**, (b) 0 < Fr < 0.23 – **glides**, and (c) 0.23 < Fr – **riffles**) - the mesohabitat classification was used. At each site, three or four groups of 3-8 samples (major habitat types) were identified. During the grouping, those habitats that were markedly different and represented by only one sample were excluded from the analysis (e.g. habitats with very low oxygen concentration).

In the next step, the Indicator Species Analysis was performed (Dufrêne and Legendre, 1997) to identify benthic invertebrate species that may serve as indicators for these habitat types. Indicator Species Analysis combines information on the concentration of species abundance in a particular group and the faithfulness of occurrence of a species in a particular group. First it calculates proportional abundance of a particulate species in a particulate group relative to the abundance of that species in all groups (the mean abundance of the species in a particulate group divided by the sum of mean abundances of the species in all groups) and the proportional frequency of the species in each group (proportion of sample units in each group containing that species). The indicator value of the species is the multiple of these two proportions. This indicator value (IV) is computed for each species for all particulate groups and the highest IV obtained is selected. Then the statistical significance of the indicator value is evaluated by Monte Carlo method. Sample units are randomly reassigned to groups 10000 times and each time the IV is calculated. The probability of type I error is the proportion of times that the indicator value from the randomized data set equals or exceeds the indicator value from the actual data set.

For the Indicator Species Analysis the species abundances were log(x+1) transformed.

Generally, we could distinguish two kinds of indicator species (taxa). Those, that were relatively common, often occurring in all or most of habitats, but reaching higher abundances on a particular habitat type. And those that were relatively scarce and occurred only at a single habitat type (or few similar habitat types) and even in this specific habitat type not reaching high abundances. When making decision on the value of an indicator species, the kind of indication was considered too. Further only those taxa of both high indicator and low p values were regarded as good indicators due to the computational procedure leading to the indicator and associated p value, especially when considering the important role of average abundances of the potential indicator species in the particular groups of samples.

Results

At Osek, habitats with standing water (pools) were dominant (12) among the sampled habitats. Futhermore 10 glide habitats (habitats with flowing water and Froude number < 0.23) and 8 riffle habitats (Froude number > 0.23) were sampled. At Cernotin, 6 pools, 16 glides and 6 riffles were sampled.

Habitat types

Cernotin

Pool – habitats with standing water. This group contains isolated pools as well as marginal habitats which differ in substrate (algae, FPOM, lptp) and water depth, therefore this group is fairly heterogeneous.

Glide – habitats with slowly flowing water (Froude number < 0.23). The mineral substrate of these habitats (mesolithal, microlithal, akal) was often covered with filamentous algae and/or FPOM.

Riffle – habitats with fast flowing water and mineral substrate (mesolithal, microlithal), according to the Froude number classified as riffles.

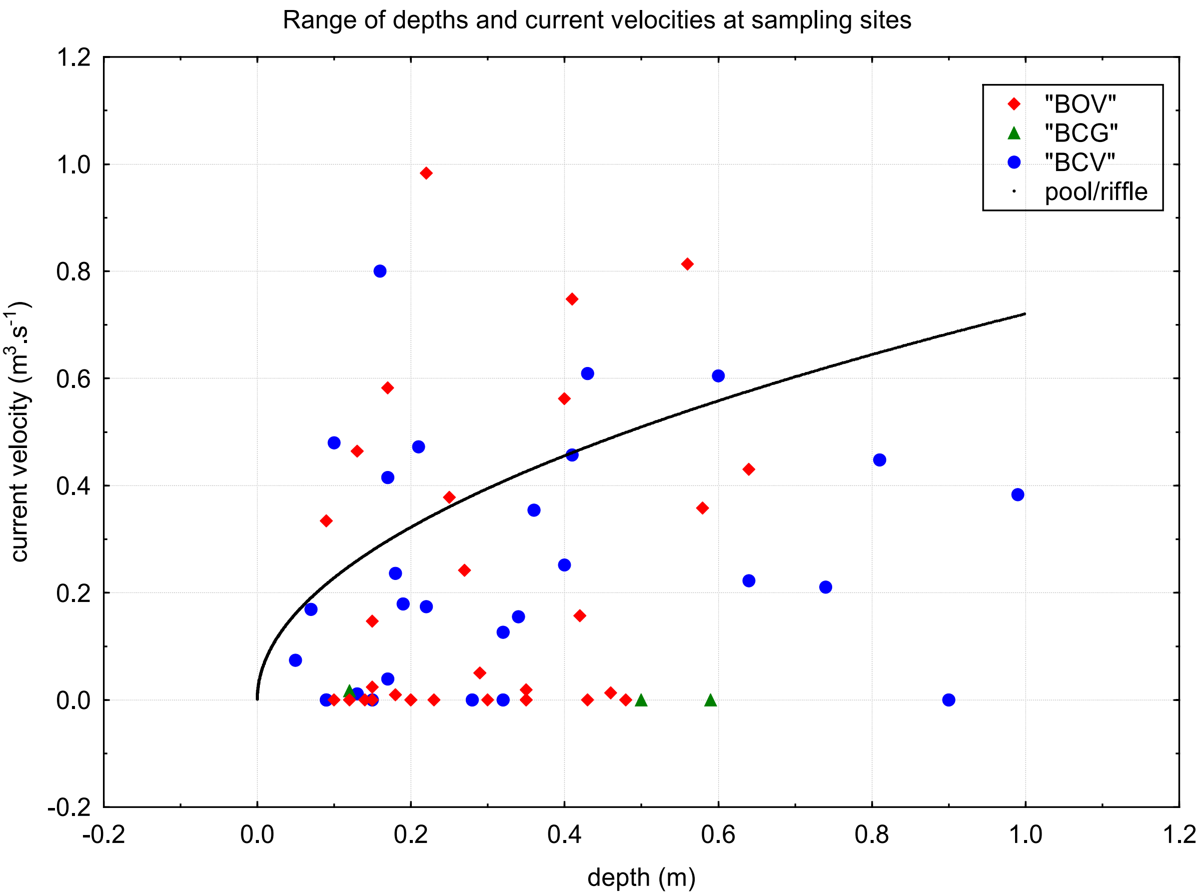

Fig. 2. BOV = the restored reach at Osek, BCG = the regulated reach at Cernotin, BCV = the restored reach at Cernotin. Curve shows the border between pool (Froude no < 0.23) and riffle (Froude no > 0.23) habitats (JOWETT 1993).

Osek

Pool – isolated pools and marginal habitats with standing water and mineral substrate. This group is similar to that of Cernotin, however contains only habitats, where mineral substrate dominates.

Org – marginal habitats with standing water and organic substrates (xylal, CPOM, living parts of terrestrial plants).

Glide – habitats with slowly flowing water (Froude number < 0.23) and mineral substrate (microlithal, mesolithal, megalithal).

Riffle – mid-channel habitats with fast flowing water (Froude number higher than 0,23) and mineral substrate (microlithal, mesolithal, megalithal).

Indicator Species

All statistically significant indicator species (taxa) obtained by the Indicator Species Analysis for defined habitat types are listed in the tables 1 and 2 for Cernotin and Osek separately. The most significant and potentially most important indicators are also mentioned in the text.

Cernotin

For **pools** only four species (taxa) were identified to be statistically significant indicators. This may be due to high heterogeneity of this group. The best indicator of this group was *Stictochironomus* sp. (Chironomidae) and this taxon was found to be the best indicator of pools at Osek too. The next indicators of pool habitats were chironomids *Chironomus* sp., *Procladius* sp. and the Crustacean *Gammarus roeselli*.

Out of the 19 statistically significant indicators of the **glide** habitats, *Nais* b*retscheri* (Oligochaeta) acted as the best indicator. This species occurred in all samples of this group and only in three other samples with abundance of 1 specimen. The second-best indicator were water mites (Hydrachnidia) that occurred in almost all glide (with one exception) and only in two other samples. The other good indicators of this group were *Pristina rosea* (Oligochaeta) and *Cryptochironomus* sp. (Chironomidae).

For **riffle**s 22 statistically significant indicators were identified but generally their statistical significances were lower than those of glide habitats. *Tvetenia calvescens* (Chironomidae) was found to be the best indicator of this group and it occurred in all samples of this group. Additionally it was found in five glide samples but with lower abundances. The caddisfly *Hydropsyche incognita* was recorded in most of glide habitats, but was found to be the most dominant species in a half of riffles. Similarly, other caddisflies *Hydropsyche contubernalis* and *Hydropsyche bulbifera* as well as the mayflies *Baetis lutheri* and *Potamanthus luteus*, chironomid *Syonrthocladius semivirens*, and the larvae of Elmid beetles *Esolus parallelepipedus* and *Elmis maugetii* were found in many or most of glide samples but reached higher abundances in riffles. On the other hand, not very abundant chironomids *Cricotopus trifascia*, *Eukiefferiella devonica*/*ilkleyensis*, *Eukiefferiella gracei* and *Eukiefferiella lobifera* occurred almost only in riffles.

CERNOTIN / TAXON	IndVal	p	POOL (6 samples) Min	LQ	Med	UQ	Max	GLIDE (14 samples) Min	LQ	Med	UQ	Max	RIFFLE (6 samples) Min	LQ	Med	UQ	Max
Stictochironomus sp.	77.8	0.0003	0	2	30	65	109	0	0	0	0	12	0	0	0	0	0
Chironomus sp.	66.7	0.0020	0	0	2	3	4	0	0	0	0	0	0	0	0	0	0
Procladius sp.	50.0	0.0145	0	0	1	5	6	0	0	0	0	0	0	0	0	0	0
Gammarus roeselii	45.7	0.0221	0	0	1	8	80	0	0	0	0	4	0	0	0	0	0
Nais bretscheri	88.0	0.0001	0	0	0	1	1	1	3	10	24	416	0	0	0	0	1
Hydrachnidia Gen. sp.	84.6	0.0001	0	0	0	0	1	0	6	9	16	60	0	0	0	0	1
Pristina rosea	78.2	0.0001	0	0	0	0	4	0	2	15	32	1760	0	0	0	0	0
Cryptochironomus sp.	73.3	0.0001	0	0	0	1	7	0	2	5	10	26	0	0	0	0	0
Tanytarsus brundini	64.7	0.0001	0	0	0	1	3	1	4	10	17	40	0	0	2	5	5
Microtendipes pedellus-Gr.	64.6	0.0001	0	0	2	4	47	5	18	88	150	872	0	1	3	3	5
Microtendipes pedellus-Gr. sp.A	55.9	0.0001	0	0	0	0	1	0	1	2	3	8	0	0	0	0	0
Tanytarsus sp.	62.8	0.0003	0	1	3	14	18	2	10	20	41	320	0	1	2	4	6
Caenis rivulorum	48.6	0.0007	0	0	0	0	2	0	6	13	16	64	0	0	2	5	9
Thienemannimyia Gr., Gen. indet.	71.4	0.0012	0	0	1	5	26	6	49	59	80	147	4	10	28	48	49
Paratrichocladius rufiventris	70.4	0.0016	0	0	0	0	0	0	0	1	2	32	0	0	0	0	0
Enchytraeidae Gen. sp.	67.5	0.0023	0	0	0	0	1	0	0	6	25	352	0	0	0	0	0
Caenis sp.	48.6	0.0026	0	1	6	10	452	43	65	201	571	24244	5	47	75	113	128
Hydroptila sp.	59.4	0.0035	0	0	0	0	9	0	5	14	35	196	0	0	1	14	24
Athripsodes sp.	59.4	0.0069	0	0	0	0	5	0	2	8	14	26	0	0	0	2	7
Tanypodinae Gen. sp.	47.8	0.0205	0	0	0	1	2	1	4	10	14	59	4	4	7	18	25
Limnodrilus sp.	52.0	0.0210	0	3	7	27	268	2	6	32	168	2336	0	0	1	2	38
Bothrioneurum vejdovskyanum	54.2	0.0319	0	0	0	0	2	0	0	2	8	304	0	0	1	1	1
Orthocladius obumbratus	45.9	0.0414	0	0	2	3	3	4	6	18	49	380	2	7	25	33	60
Tvetenia calvescens	84.6	0.0001	0	0	0	0	0	0	0	0	2	4	1	2	12	27	68
Hydropsyche incognita	70.5	0.0002	0	0	0	0	3	0	0	4	10	17	3	3	156	628	653
Hydropsyche contubernalis	67.3	0.0002	0	0	0	0	0	0	2	4	8	60	8	13	30	53	86
Baetis lutheri	80.2	0.0004	0	0	0	0	0	0	0	1	2	33	1	6	48	116	178
Cricotopus trifascia	77.3	0.0004	0	0	0	0	0	0	0	0	0	4	0	1	4	14	16
Synorthocladius semivirens	52.6	0.0010	0	0	0	1	2	4	6	17	39	64	20	22	27	50	70
Potamanthus luteus	61.8	0.0017	0	0	0	0	0	0	1	4	5	64	1	9	11	23	40
Hydropsyche bulbifera	60.2	0.0020	0	0	0	0	2	0	3	7	22	57	1	3	53	107	124
Esolus parallelepipedus Lv.	56.6	0.0020	0	0	0	0	1	0	4	6	8	91	4	4	11	26	37
Eukiefferiella devonica/ilkleyensis	53.5	0.0066	0	0	0	0	0	0	0	0	0	4	0	0	3	5	6
Eukiefferiella gracei	59.6	0.0077	0	0	0	0	0	0	0	0	0	2	0	0	1	10	14
Eukiefferiella lobifera	47.3	0.0112	0	0	0	0	0	0	0	0	0	1	0	0	1	6	8
Elmis aenea/maugetii Lv.	59.5	0.0129	0	0	0	0	1	0	0	1	2	18	1	1	2	4	30
Dicranota sp.	50.9	0.0131	0	0	0	0	0	0	0	0	0	4	0	0	1	3	3
Esolus parallelepipedus Ad.	50.0	0.0132	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
Cricotopus festivellus	53.3	0.0140	0	0	0	0	1	0	0	0	0	6	0	0	3	6	16
Orthocladius rivicola-Gr.	50.0	0.0144	0	0	0	0	0	0	0	0	0	0	0	0	1	2	4
Cricotopus sp.	51.7	0.0199	0	0	0	0	1	0	2	8	18	48	2	3	12	16	60
Baetis scambus	50.6	0.0258	0	0	0	0	1	0	0	1	4	9	0	2	3	10	13
Orectochilus villosus Lv.	42.7	0.0302	0	0	0	0	1	0	0	0	0	0	0	0	1	3	6
Hydropsyche pellucidula	51.4	0.0379	0	0	0	0	1	0	0	1	3	7	0	0	38	156	165
Orthocladius rubicundus	49.1	0.0483	0	0	0	0	1	1	3	7	23	88	1	2	12	19	70

Osek

Only two taxa were identified to be statistically significant indicators for **pool** habitats of Osek. Out of these only *Stictochironomus* sp. (Chironomidae) acted as a good indicator. It occurred in all pool samples and in low abundances in only three other samples. The second species, *Bothrioneurum vejdovskyanum* (Oligochaeta) was commonly found in all habitat types but reached highest abundances in pools.

Twelve taxa were found to be statistically significant indicators for the group **org**. Among these the highest indicator value had the damselfly *Platycnemis pennipes* that occurred in all samples of this group and in one sample of group glide (marginal habitat with low water velocity). *Glyptotendipes* sp. (Chironomidae) was a common taxon for all habitat types but reached the highest abundances in org habitats. The mayfly *Cloeon dipterum* was recorded in all org samples but in some pools too. Generally it occurred only in habitats that were at least partly separated from the main channel.

No taxon was statistically significant indicator for group **glide** at this site.

For **riffle**s, 19 indicator taxa were identified. Among these the mayfly *Baetis fuscatus* and the caddisflies *Psychomyia pusilla*, *Hydropsyche modesta* and *Hydropsyche bulbifera* were the best indicators, although these species were common in glide habitats too.

Conclusions

Although the two study sites aren't more than 25 km far between and look very similar, the communities of benthic invertebrates at these sites slightly. This probably caused, that (at least in part) different indicator species were found for identical habitats at these sites.

Only *Stictochironomus* sp. was the best indicator of **pool**s at both sites. This taxon occured at some other habitats, generally with very low water velocity and it seems to be a good indicator of pools and marginal habitats with standing or very slowly flowing water at both sites. The next indicator of pools at Cernotin – *Chironomus* sp. – was recorded in low abundances only in pools, however at Osek this taxon was found in all types of habitats in equal abundances. This taxon is regarded as potential indicator of pools.

The indicational potential of the damselfly *Platycnemis pennipes* for **marginal habitats** (group **org** at Osek) needs to be evaluated in subsequent studies. Although this species was found in four marginal habitats (three of the group org and one of the group glide) at Osek, at Cernotin it was recorded at a riffle habitat only.

OSEK / TAXON	IndVal	p	POOL (7 samples)					ORG (3 samples)					GLIDE (7 samples)					RIFFLE (8 samples)				
			Min	LQ	Med	UQ	Max	Min	LQ	Med	UQ	Max	Min	LQ	Med	UQ	Max	Min	LQ	Med	UQ	Max
Stictochironomus sp.	61.4	0.0079	2	3	14	52	81	0		0		32	0	0	0	1	8	0	0	0	0	1
Bothrioneurum vejdovskyanum	41.9	0.0139	6	14	62	188	282	1		3		60	2	2	4	21	56	0	1	4	7	15
Glyptotendipes sp.	62.3	0.0005	0	0	1	5	6	13		40		428	0	1	2	6	9	0	0	1	2	4
Platycnemis pennipes	94.7	0.0006	0	0	0	0	0	2		33		43	0	0	0	0	2	0	0	0	0	0
Cricotopus sylvestris-Gr.	59.4	0.0027	0	0	0	0	0	0		3		16	0	0	0	0	0	0	0	0	1	1
Gammarus roeselii	68.9	0.0041	0	0	1	5	5	1		25		57	0	0	1	1	3	0	0	0	0	0
Cloeon dipterum	70.4	0.0049	0	0	1	4	13	1		5		25	0	0	0	0	0	0	0	0	0	0
Vejdovskiella sp.	68.0	0.0067	0	0	0	1	8	1		1		40	0	0	0	2	4	0	0	0	0	0
Centroptilum luteolum	66.7	0.0095	0	0	0	0	0	0		1		2	0	0	0	0	0	0	0	0	0	0
Nais communis	52.7	0.0188	0	0	0	0	6	0		6		8	0	0	0	0	0	0	0	0	0	1
Enchytraeidae Gen. sp.	53.7	0.0233	0	0	0	0	0	0		1		4	0	0	0	0	1	0	0	0	0	1
Paratanytarsus sp.	50.3	0.0254	0	0	0	1	9	0		2		16	0	0	0	0	0	0	0	0	0	0
Aulodrilus pluriseta	50.2	0.0313	0	0	0	0	2	0		2		12	0	0	0	0	2	0	0	0	0	1
Parachironomus sp.	46.3	0.0383	0	0	0	0	8	0		4		8	0	0	0	0	2	0	0	0	0	1
Baetis fuscatus	69.5	0.0001	0	0	0	0	0	0		0		1	0	0	1	4	13	4	7	14	23	49
Psychomyia pusilla	63.8	0.0001	0	0	0	0	1	0		0		1	0	0	1	11	18	3	6	13	22	48
Hydropsyche modesta	67.9	0.0006	0	0	0	0	0	0		0		0	0	0	0	3	3	0	1	3	5	16
Orthocladius rubicundus	50.2	0.0006	0	0	0	3	6	0		0		0	0	1	3	12	24	6	7	7	11	18
Hydropsyche bulbifera	63.3	0.0007	0	0	0	0	0	0		0		0	0	0	0	7	25	0	9	15	35	71
Tanypodinae Gen. sp.	44.4	0.0007	0	0	1	8	9	0		4		16	1	3	21	50	70	30	34	52	75	212
Potamanthus luteus	55.3	0.0008	0	0	0	1	2	0		0		0	0	1	4	10	13	1	3	7	20	26
Rheotanytarsus sp.	54.8	0.0008	0	0	0	0	4	0		0		8	0	0	5	12	20	6	13	18	19	32
Thienemannimyia Gr., Gen. indet.	38.3	0.0009	1	2	3	17	32	0		5		56	8	15	39	80	142	49	58	82	160	220
Cricotopus sp.	45.5	0.0012	0	0	0	2	3	0		0		1	1	3	4	10	18	3	7	8	9	12
Baetis scambus	69.7	0.0057	0	0	0	0	0	0		0		0	0	0	0	0	1	0	1	3	9	16
Tvetenia calvescens	62.5	0.0064	0	0	0	0	0	0		0		0	0	0	0	0	0	0	0	2	4	4
Simulium ornatum	62.5	0.0067	0	0	0	0	0	0		0		0	0	0	0	0	0	0	0	1	1	4
Synorthocladius semivirens	43.4	0.0072	0	0	0	2	2	0		0		20	1	2	10	22	32	8	10	18	25	26
Rheocricotopus chalybeatus	50.3	0.0163	0	0	0	0	0	0		0		0	0	0	0	0	2	0	0	1	2	4
Nais behningi	48.9	0.0317	0	0	0	0	2	0		0		0	0	0	0	1	2	0	0	4	15	34
Eukiefferiella lobifera	50.0	0.0388	0	0	0	0	0	0		0		0	0	0	0	0	0	0	0	1	3	3
Nais alpina	48.0	0.0393	0	0	0	4	6	0		0		1	0	0	1	3	5	0	2	4	9	52
Baetis lutheri	49.7	0.0397	0	0	0	0	8	0		0		0	0	0	0	2	4	0	1	3	19	28

Glyptotendipes sp. seemed to prefer organically rich habitats with standing or slowly flowing water. Although this taxon was relatively common at Osek, at Cernotin it was not recorded. Similarly, also the mayfly *Cloeon dipterum* was not recorded at Cernotin, although it was a good indicator of org habitats at Osek and in further studies it could be regarded as possible indicative for habitats that are at least partly separated from the main channel.

On the other hand, the Crustacean *Gammarus roeselii* indicated different habitat types at these sites: at Osek it indicated org habitats, whereas at Cernotin it indicated pools. At Both sites, this species occured mainly at marginal habitats with standing or slowly flowing water and in some pools. In fact, the group for which this species was indicative depended only on which habitat type these marginal habitats were classified to.

The best indicator of **glide** habitats at Cernotin, *Nais bretscheri* (Oligochaeta), occured very scarcely in glides of Osek, even it reached the highest abundances in pools.
Hydrachnidia, the second-best indicator of glide habitats at Cernotin, were equally distributed in all habitat types at Osek. The indicational potential of this taxonomic group is strongly reduced, when not determined to species level, because of high interspecific variability of habitat preferences. Therefore this taxonomic group does not serve as a good indicator.
Cryptochironomus sp. was identified as an indicator of glide habitats at Cernotin, and also was most abundant in glides at Osek, though wasn't identified as statistically significant indicator there. Further studies are needed to evaluate its indicational potential.
Other chironomids like *Microtendipes* gr. *pedellus* and *Tanytarsus brundini/curticornis* as well as the Oligochaet *Pristina rosea*, that were identified as good indicators of glides at Cernotin were commonly (or mostly) recorded in riffles at Osek, that is probably why they were not identified as indicators at Osek. Actually some other indicators of glides at Cernotin (chironomids from *Thienemannimyia* group and unidentified species of subfamily Tanypodinae) were identified as indicators of riffles at Osek.

Generaly, the statistically significant indicators of **riffle** habitats at Cernotin were often rare at Osek and therefore low indicator values (eventually high p values) were assigned to them when considering them as indicators of riffles at Osek. This is the case of the best indicators of riffles at Cernotin (for example the chironomid *Tvetenia calvescens*, caddisflies *Hydropsyche incognita*, *Hydropsyche contubernalis* or the mayfly *Baetis lutheri*). On the other hand, many of the indicators of riffles at Osek were commonly found in glides of Cernotin (for example the mayfly *Baetis fuscatus*, the caddisfly *Psychomyia pusilla* or the chironomid *Orthocladius obumbratus*).

THE IMPORTANCE OF RARE HABITATS

Methods

In this study, rare habitats are defined as habitats that are represented by less than 5% of the area covered by the river reach and that are vulnerable to the hydromorphological degradation of the river channel. These habitats include marginal pools with organic substrata, sometimes with submerged parts of terrestrial plants (grass leaves, willow branches, stems and roots) as well as temporarily disconnected pools with different length of periods of communication with the main channel, with different substratum and temperature regime, and also mid-channel habitats composed of some rare substratum – e.g. tree trunks, branches and roots.

Lateral habitats may contribute more than 50% to the total corridor species richness (Karaus *et al.*, 2004) and rare habitats at our study sites are composed mainly of these lateral habitats.
Here we focus on the contribution of rare habitats to the river reach diversity.

Diversity measures

Two components of diversity, taxa richness and dominance, were calculated separately. Both measures were calculated for data sets where samples of rare habitats a) were and b) were not included. As the taxa richness, the total number of taxa, and as the dominance the Simpson's index expressed as -ln(D) were used. Additionally K-dominance plots, showing pecentage cumulative abundance in relation to log species rank, were created for visual comparison of the diversity.

The individuality of rare habitats

The heterogeneity of species composition within glide, riffle and rare habitats was expressed as the Bray-Curtis dissimilarity indices. The sets of indices obtained for each group of habitats were compared to each other using Mann-Whitney U test.
The relationship between the increasing number of samples and taxa richness was compared between rare and glide or riffle habitats. For each type of habitat (glide, riffle and rare), following procedure was performed: the raw data matrix (samples as collumns) was duplicated and put next to the original one. Then the species richness was calculated for 1,2,.. (n-1) samples n-times (n = the number of samples), missing out each sample in turn. Thus, n values of species richness were obtained for 1 sample, for 2 samples, ... and for n-1 samples. The mean value of taxa richness for each number of samples was used to analyse the increase of taxa richness with the increasing number of samples. The differences in taxa richness between each two adjacent levels of quantity of samples (between 1 and 2 samples, between 2 and 3 samples,...n-1 and n samples) were calculated for that three types of habitats (rare, glides, riffles) and expressed as the proportion of the maximum difference obtained between each two levels. These values were compared between rare, glide and riffle habitats using Wilcoxon matched pairs test.

The contribution of rare habitats to the overall taxa richness was calculated as the proportion of the species (taxa) unique for rare habitats to the total number of taxa.

Results

Diversity measures

In total, 148 and 151 taxa were recorded at Cernotin and Osek, respectively. More than 50% of the total number of taxa occurred in both the rare and the common main channel habitats (58% and 54.6% at Cernotin and Osek, respectively). The taxa restricted in their occurence to rare habitats accounted for 14% and 8%, and to main channel habitats for 28% and 38%, at Cernotin and Osek, respectively (Figure 8).

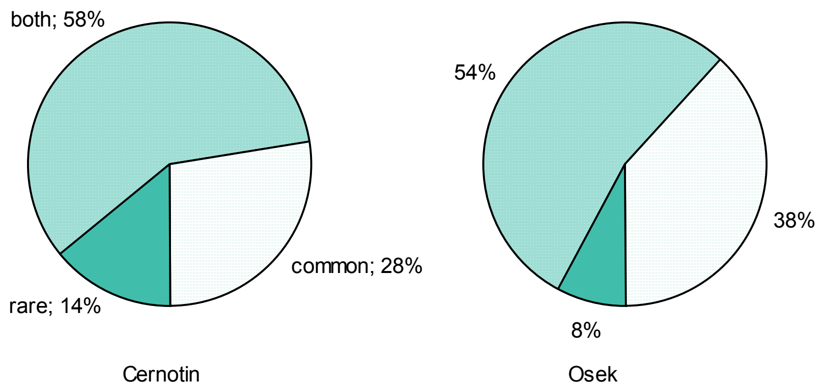

Fig. 8. Relative number of taxa restricted to rare habitats (rare), common mid-channel habitats (common) and occuring at both these types of habitats (both)

Both taxa richness and Simpson's index calculated for data sets including the rare habitats were higher than those calculated from data sets without rare habitats (Table 7, Figure 9.). The contribution of rare habitats to the diversity can be visually estimated using the K-dominance plot (Figure 10). At both sites we can identify high dominance (in both cases caused by early instars of mayfly *Caenis* sp.) of the communities inhabiting common habitats which decreased when rare habitats were added. It is obvious, that new habitats will produce new species. Similarly, heterogenous communities inhabiting rare habitats (see further) cause the decrease of dominance, because different species dominate at different habitats.

Table 7. Simpon's indices and number of taxa calculated from data sets where rare habitats were (all habitats) and were not (common) habitats

	Cernotin		**Osek**	
	common habitats	all habitats	Common habitats	all habitats
Simpson' index	2.077	1.940	2.259	2.006
Number of taxa	127	148	139	151

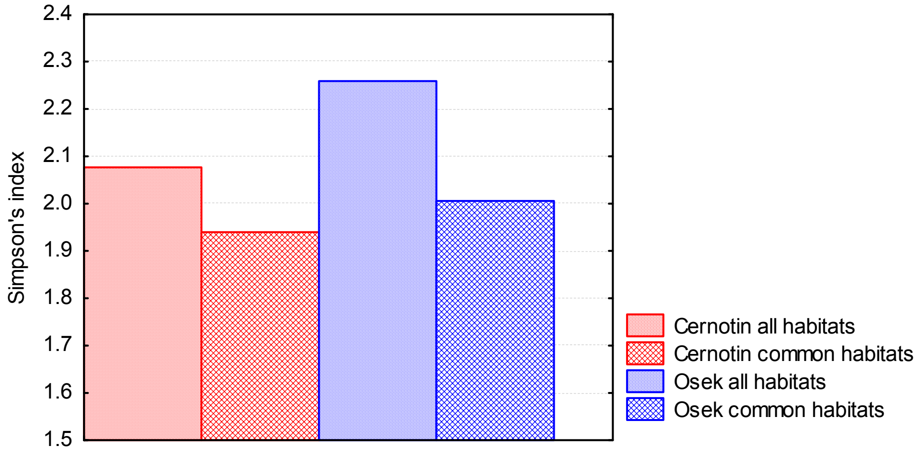

Fig. 9. Simpson's indices calculated for both sites from data sets including rare habitats and without them.

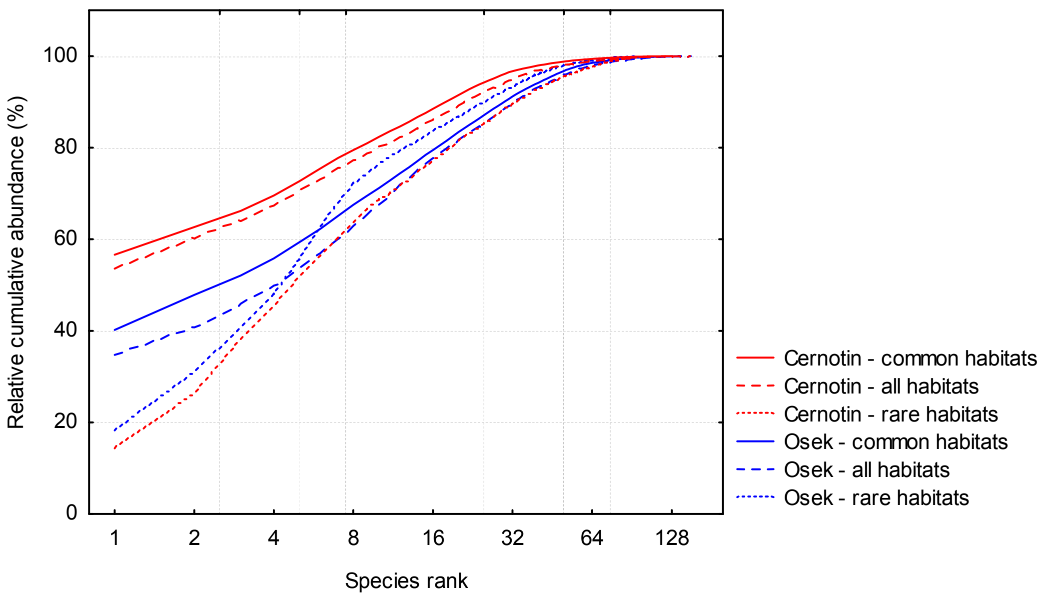

Fig. 10. K-dominance plot.

The individuality of rare habitats

Rare habitats exhibited significantly steeper increase of taxa richness in relation to the increasing number of samples, than glide or riffle habitats (Figure 11, Table 8).

Table 8. The p values of Wilcoxon matched pairs test used to compare the increase of taxa richness in relation to the number of samples.

Cernotin	glide	riffle
rare	0.028	0.043
glide		0.225

Osek	glide	riffle
rare	0.046	0.018
glide		0.345

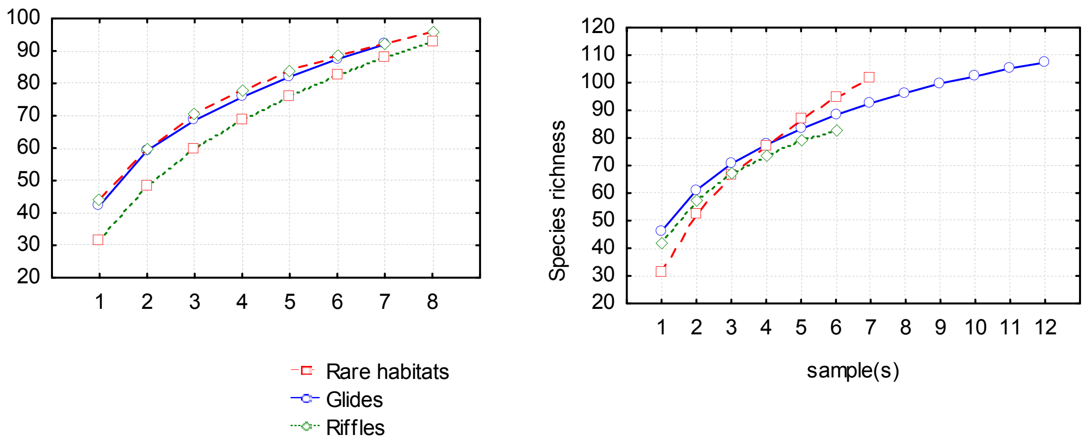

Figure 11. The increase of taxa richness in relation to the increasing number of samples

This pattern was more evident at Cernotin than at Osek. Also the dissimilarity of communities inhabiting rare habitats was significantly higher than that of riffle and pool habitats (Table 9). Additionally, no significant difference either in the Bray-Cutis dissimilarity indices or in the increase of taxa richness was found between glide and riffle habitats.

Table 9. The p values of Mann-Whitney U test used to compare the dissimilarity of communities of rare, glide and riffle habitats.

Cernotin	glide	riffle
rare	0.000	0.000
glide	-	0.830

Osek	glide	riffle
rare	0.000	0.000
glide	-	0.146

All these results confirm the importance of rare habitats as an element causing the increase of the biological diversity of the river reach, regardless of the potential importance of these habitats as the refugium for many invertebrates during extreme (low or high) discharges. Especially the high heterogeneity between rare habibats, which causes that every next rare habitat induce the growth of taxa richness, makes these habitats very valuable.

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14. Summary

Literature overview

Some contributions involved a more extensive literature overview. Alterra compiled an overview relating to indicators definition and selection criteria. BOKU described relationships between siltations and benthic invertebrates and also detailed elucidated methods for measuring of habitat characteristics. UDE described a selection and a development of metrics used for an evaluation of morphological degradation of streams in dependence on stream types. MasUniv provided a more general overview relating to a relationship between hydrology/hydromorphology and benthic macroinvertebrates. Some of the partners also provided End-note files with lists of references which are linked to their study catchments and study stressors (BOKU, CNRS-UPS, MasUniv). These files are also the part of the report.

Aims

Aims of the individual partners were slightly different. Alterra dealt detailed with a question which species (macroinvertebrates, macrophytes and fish) are good indicators for changes in hydrology and morphology. BOKU aimed at the finding macroinvertebrate indicators for siltation and a correlation between biological metrics and gradient of siltation. CEH studied the relationship between structure of macrophyte and macroinvertebrate communities and hydromorphological features at the reach scale and also a substrate heterogeneity at the mesohabitat scale. UDE showed a calculation of different indices using morphological and biological parameters and their use for the assessment of the hydromorphological degradation for different stream types. UNIBUC-ECO evaluated its sampling sites in term of abundance and densities of different macroinvertebrates groups on different substrates. CNR-IRSA plans to compare data on microhabitat characteristics and hydromorphological features recorded at different spatial scales and also data on microhabitat characteristics and hydromorphological features recorded in main and secondary channels. CNRS-UPS prepared data from 105 sites in the study catchment for further analyses. The aim of the SLU case study was to test how well the four organism groups could detect the pre-defined naturalness gradient and whether or not the organisms groups are correlated in their response to the stress gradient both in terms of diversity, community composition and index values. MasUniv focused on evaluating a relationship between hydromorphological and biological parameters at reach scale and habitat analyses at habitat scale.

Data analysis

The Indicator Species Analysis was the most used analysis to identifying benthic invertebrate that may serve as indicators for different habitat types (BOKU, UDE, MasUniv). Results from this analysis were mostly cross-checked by experts. From ordination methods was used non-metric

Multidimensional Scaling (BOKU, MasUniv), CEH and SLU used Principal Component Analysis and Detrended Correspondence Analysis.

Results

Alterra provided a list of macroinvertebrates, macrophytes and fish indicators for hydrological disturbance, morphological disturbance and drought with evaluating of their identifiability, reliability and rarity. The selection of indicators is based on a review of easily available literature and large datasets.

BOKU created a list of taxa known from the investigated catchment and their function as potential indicators for siltation and the list of biological metrics correlated with the proportion of fine sediments and the variance of substrates. Futhermore there are presented indicator values of macroinvertebrate species for the three groups of dominant substrates (akal/psammal, meso-/microlithal, mega-/macrolithal). This analysis was based on 24 samples from AQEM project and experts opinions.

CEH found out macrophyte indicator species for upstream and mid-catchment sites of the study catchment and for an increased tendency towards low-flows and reduced water surface area within the channel. They also found associations between the number of individuals of macroinvertebrates family and mesohabitats (gravel, margin, *Ranunculus*, sand and silt, *Berula*, *Callitriche*, *Schoenoplectus* and emergent vegetation). They analysed data from 8 sampling sites in the study catchment and also a more comprehensive quantitative dataset from the work of J. F. Wright.

UDE provided a list of scores of indicator taxa in four stream types with references, from which the index values were derived. They also described morphological parameters used to defining the Structure Index for hydromorphological classification of each site. In addition, a new group of metrics was developed („German Fauna Index“; one index for each stream type investigated), based on a stream type-specific list of indicator taxa. The scores of the individual metrics were summarised in a Multimetric Index, which ranges from 5 (high status) to 1 (bad status). The analyses were based on samples from AQEM project (12-38 sampling sites per stream type).

UNIBUC-ECO made a preliminary analysis of structure of benthic fauna in the study catchment. They have sampled two sites from October 2004, from May 2005 the sampling has been performed monthly.

SLU found out that the number of taxa of phytobenthos and bentic fauna are correlated well, i. e. if there are few taxa of phytobenthos there are also few taxa of macroinvertebrates. A similar pattern were found for fish and macrophytes, where a high macrophyte taxon richness correlated with a low fish diversity. Macrophytes were also found special since a site with a high macrophyte diversity generally contains few species of the other organism groups. Regarding environmental variables, the most important variables for macroinvertebrates was the amount of sand in the stream and the water temperature, for fish among others an amount of agricultural land in the catchment and for macrophytes an amount of suspended particles. The evaluated data originated from ten sampled streams in the study catchment.

MasUniv focused among others on hydromorphological features at reach scale as shading, coverage of bank line by tree vegetation and its width that were positively related to taxa richness of Coleoptera, Plecoptera, Oligochaeta, EPT taxa, abundance of shredders and many other metrics. Many biological characteristics correlated significantly also with both summary hydromorphological indices (HQA, HMS), score arising from substrate and band features. At habitat scale there were presented indicator species relating to the study catchment for different mesohabitats (pools, glides, riffles). The analysis at reach scale was based on data from 24 sampling sites from STAR project, the habitat analyses were done on data from two sampling sites (each involved 28 sampling points processed separately) in the study catchment.

15. Conclusion

Some partners focused in their analyses only on macroinvetebrate community (BOKU, UDE, MasUniv, UNIBUC-ECO). Alterra provided lists of indicator species also for macrophytes and fish. CEH included analyses of macrophyte community structure. SLU tested all four organism groups (fish, macrophytes, macroinvertebrates, phytobenthos) how well they detect the stress gradient.

It is obvious that the preliminary lists of **species indicators** have to be validated by detailed studies and cross-checked by experts. Alterra did a valuable overview what criteria we have to meet during an indicator selection. We have also to keep in our mind that the indicators are stream type specific and so we can not create an universal list of indicators applicable for all pilot catchments. We also know that the temporal and spatial distribution of freshwater organisms responses to various levels of environmental factors, mainly flow velocity, substrate compositions, water temperature, and food availability. Therefore we should refer individual indicators to specific stressors and also study distribution patterns of indicator taxa independent on degradation magnitude.

The analyses of relationships between **biological parameters** and hydromorphological gradient (at reach scale) showed some metrics to be quite good potential indicators for substrate variability and substrate composition. BOKU found out for example metrics „Number of EPT-taxa“, „Number of taxa“, „Diversity“, „% sensitive taxa“ to be important. UDE found for the stream type D05 „mid-sized streams in lower mountainous areas of Central Europe“ following four metrics correlated to the hydromorphological quality of the classes and supplemented „German Fauna Index D05“: „Shannon-Wiever-Diversity“, „Number of Ephemeroptera, Plecoptera, Trichoptera, Coleoptera, Odonata and Bivalvia“ (EPTCOB), „Percent xylophagous taxa, shredders, active filter feeders and passive filter feeders“ („Feeding Type Index“) and „Percent akal (grave), lithal (stone) and psammal (sand) habitat preferences“ („Habitat Index“). Masaryk University also mentioned these metrics as significant. CEH found a significant difference between seven mesohabitats in terms of taxon richness and the density of individuals for 33 most frequently occurring taxa at mesohabitat scale.

UDE means that multimetric systems seem to be well suited to detect the impact of hydromorphological degradation on the invertebrate fauna because the Multimetric Index integrates parameters potentially affected by different kinds of hydromorphological degradation. On the other hand a crucial point is a profound knowledge on reference conditions. Masaryk University will concentrate an study of main hydromorphological features as the lateral conectivity, floodplain characteristics, habitat patterns, bank fixation, meandering and braiding of channel. In this connection it seems to be highly appropriate “Floodplain Index” proposed by Waringer that was developed for large braided river systems. Some partners (BOKU, MasUniv) pointed out the importance of rare habitats (temporary pools, wettened areas created by spates) as an element causing the increase of the biological diversity of the river reach. These habitats may be classified as key habitats and their existence indicate an unimpacted functioning floodplain systems. Species occured at these habitats are potentional indicators and deserve our attention.

ANNEX 1. WP2, Subtask 2.1 overview

Progress of works on subtask 2.1 (04/05/2005)

Task 2: *Hydromorphological changes and aquatic and riparian biology*
Subtask 2.1 Review and data collation
Subtask leader: Masaryk University - MasUniv (Libuse Opatrilova)
Other Partners involved: *ALTERRA, BOKU, NERC-CEH, CNR, SLU, UDE, UNIBUC-ECO, CNRS-UPS*

Hypothesis

- *What are the relations between hydrology/hydromorphology and species composition?*
- *Which species or biological parameters are good indicators for changes in hydrology/hydromorphology?*

DETAILED WORKPLAN - ACTIVITIES

1. Review of existing literature and linkage to reviews of other project

We are collecting literature related to subtask hypothesis. Review carried out in REBECCA project is available for linking to existing reviews and literature databases (provided by Nikolai Friberg from NERI).

Project Rebecca – the main aim of this project is to establish links between ecological status of surface waters and physico-chemical quality elements and pressures from different sources (including hydromorphological alterations). A literature review in this project was carried out using the following procedure: ISI Web of Science and Aquatic Sciences and Fisheries Abstracts (ASFA) were used to search for all journal papers which included three words: river OR stream OR watercourse, a hydromorphological search word and a biological search word. A total of approximately 17,000 references were extracted. References from journals considered less likely to hold key publications (e.g. journals covering tropical rivers) were removed. This reduced the number of papers to 11,705. The titles, abstracts and journal details of these papers are kept in an Endnote file named 'Hydromorph_1946_2004.enl'.

2. Collection of historical and present day biological data (MasUniv)

Study design
Multi-scale approach: microhabitat, stretch and catchment scale

Microhabitat – microhabitat distribution of macroinvertebrates
Stretch – biological response to site characteristics
Catchment – climate, hydrological, land use and geomorphological characteristics of catchment and their effect on macroinvertebrate communities

Data

Microhabitat scale: 6 sites (Becva – Osek, Becva - Cernotin, Svratka – Uncin, Svratka – Zidlochovice, Jihlava – Ivancice, Dyje – Pohansko). Microhabitat-specific samples of macroinvertebrates, substrate characteristics, current velocity, depth.

Stretch scale: 24 STAR project sites (macroinvertebrates, phytobenthos, RHS survey, site characteristics), 5 AQEM project sites (macroinvertebrates, site characteristics), 18 sites from Water Research Institut (WRI) monitoring (macroinvertebrates) + hydromorphological parameters derived from maps, GIS and discharge records obtained from Czech Hydrometeorological Institute.

Comparison of paired stretches having different hydromorphological characteristics (Becva River - Cernotin, Osek; Trebuvka stream - Dlouha Loucka, Borsov).

River Habitat Survey and some additional measurements of channel morphology were done. The multihabitat samples of macroinvertebrates representing stream stretches are available for Trebuvka stream. In case of Becva River, microhabitat samples were kept separately. Phytobenthos were sampled in both rivers.

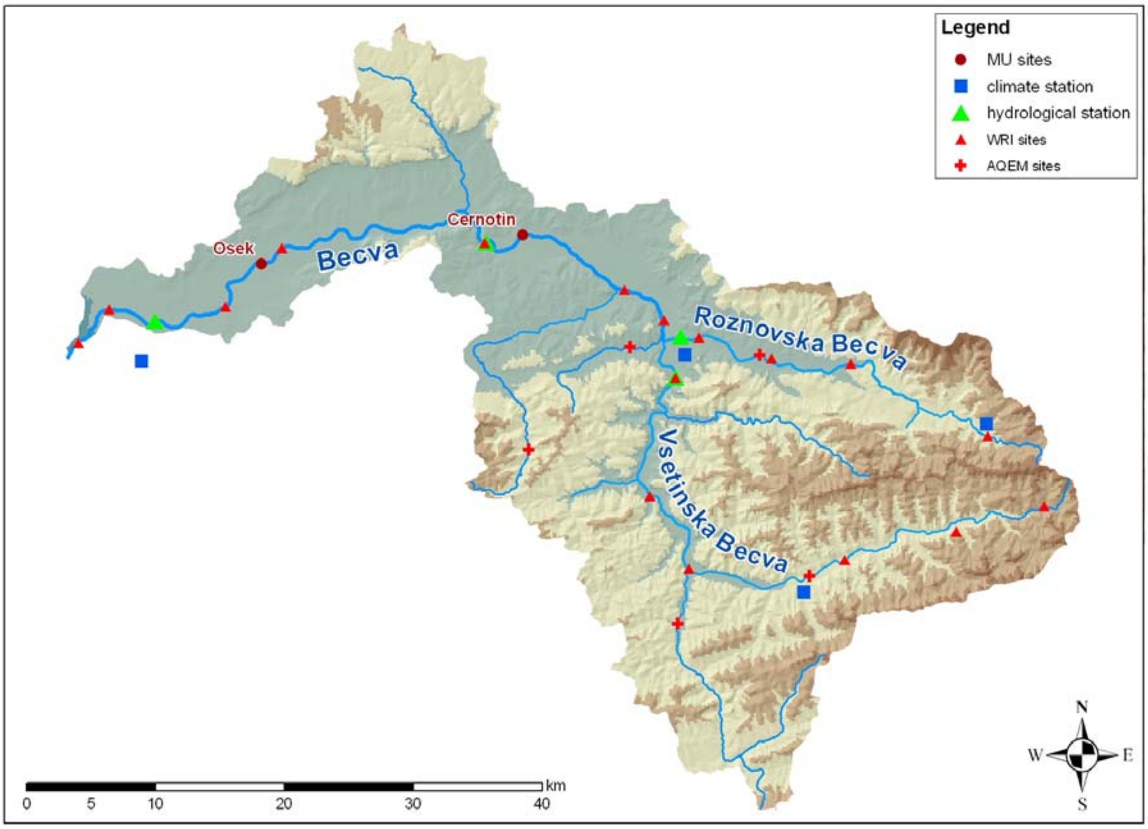

Figure 1. Location of sites and stations within Becva River catchment where biological and environmental data were collected.

3. Data analyses (MasUniv)

Stretch scale

a) Land use analysis 1: We will compare land-use in the whole catchment and in segments derived from dividing the main stream length into 2 km stretches (that means 2, 4, 6, etc. km from sampling site). The relationships between biota (macroinvertebrates and phytobenthos) and land-use at different spatial scales will be analysed.

b) Land use analysis 2: The land-use will be surveyed in buffer zones adjacent to the river in the width of 400 m and 1000 m – 200, resp. 500 m wide area along each river bank for 53 sampling sites. Length of this buffer is 1 km for small rivers and 5 km for middle and large rivers upstream from the sampling site. Taxonomic and functional composition of macroinvertebrate and phytobenthos communities will be used in analyses which will be done separately for small and large rivers. Additionally, width of riparian vegetation will be analysed: 100 m stream sections in total length of 1 km for small rivers and 5 km for middle and large rivers. We will study influence of this riparian vegetation width in different distances from the sampling site (Fig. 2).

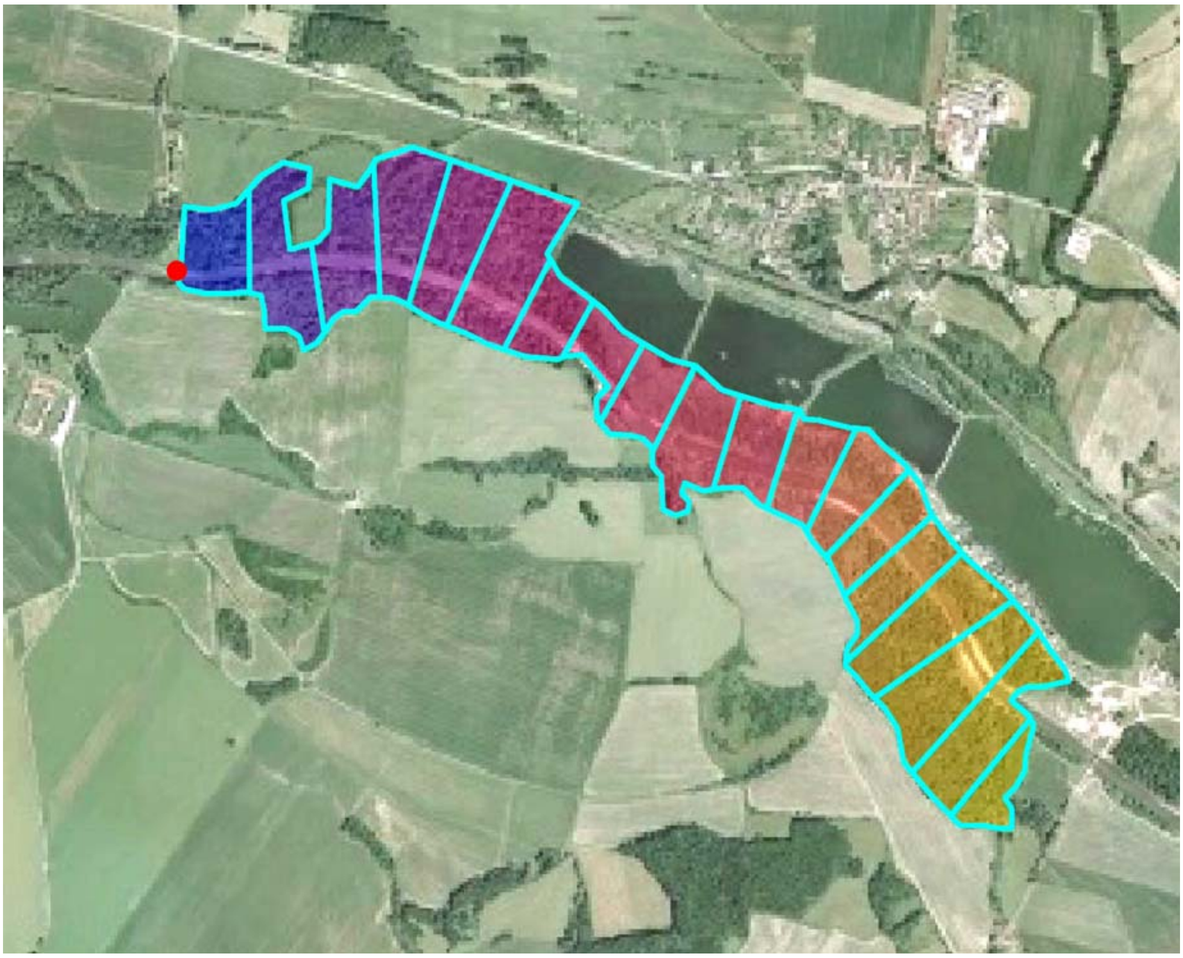

Figure 1. The extent of riparian vegetation in buffer zone of Becva River.

c) Hydromorphological comparison: we will compare recent channel sinuosity and width variation with the features derived from historical maps (1819-1858) of the Becva River.
d) Analyse RHS data for 24 STAR sampling sites and 2 sites on Becva River – hydromorphological conditions will be described by individual features, their variability within stream strech. Responses of macroinvertebrate and phytobenthos commuties to environmental characteristics are studied at stretch and larger spatial scales. Downscaling of ecological relationships to microhabitat level would be possible for macroinvertebrate samples from Becva River.

Microhabitat scale

a) identification of relations between biological characteristics and physical parameters of habitat. Diversity measures (indices and K-dominance plots), species traits characteristics, community structure and indices based on sensitive taxa will be analyzed together with hydraulic and substrate parameters (Becva, Svratka, Jihlava, Dyje).
b) relation between discharge regime and habitat inundation, durability and sedimentation regime will be studied. Habitat distribution and availability will be linked to ecological requirements of biota (life cycles, habitat preference, feeding strategies).
c) preference curves of selected taxa along environmental characteristics representing various spatial scale levels will be generated, regression analysis – relationship of abundances and environmental variables, cluster analysis, discriminant analysis, multidimensional scaling will be also used for data evaluation.
d) macroinvertebrate response to habitat heterogeneity and existence of rare habitats (e.g. K-dominance plots for macroinvertebrate community with and without rare habitats).

We would need from all partners in this subtask:

1. Collation of existing information on key taxa or functional groups identified in the study catchment. More regionally oriented overview.

2. Please check and update information in attached excel-file.

3. Please describe your analytical methods and approaches.

4. Preliminary results if there are some.

Time schedule of works

Overview received from partners: 18/5/2005
Draft review: 31/5/2005
Review contributions from partners: 15/6/2005
Data analyses: 30/6/2005
Deliverable 2.1 (No. 13): to be finished before 31/7/2005, parts from partners delivered to subtask leader before 10/7/2005; 25/7/2005 would be compiled text circulated to partners for comments.

Expected outputs for other tasks, workpackages

Links to subtask 2.2, 2.4, 2.5.
Links to WPs 6, 7 and 8