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Evaluation of the use of Water Framework Directive typology descriptors, reference sites and spatial scale in macroinvertebrate stream typology

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Abstract

The aim of this study was to test the effect of the Water Framework Directive typology descriptors on a macroinvertebrate-based stream typology, the use of reference sites in comparison to the use of degraded sites, and both degraded and reference sites. The EU research projects AQEM and STAR provided 1660 samples of 48 stream types sampled all over the major geographical gradients in Europe. The samples included gradients from reference conditions to samples with bad ecological quality. These stream types fit the WFD typological demands. The macroinvertebrate data were analysed by using Detrended Correspondence Analysis (DCA). The observed macroinvertebrate distribution was tested against the WFD river typology by a graphical interpretation of the ordination diagrams. The major macroinvertebrate distribution patterns in European streams were based on climate (temperature), slope (current velocity), and stream size. The WFD descriptors 'System A' for stream types are too rigid and should be replaced by temperature, current, and size. The differences in average numbers of taxa between the 1660 sites distributed over Europe were either caused by differences between local environmental factors or by sampling effort, not by temperature, elevation, stream order or latitudinal position. The distribution patterns using all samples, only reference samples, and only degraded samples showed that human stress diminished the natural differences between stream communities and typologies should therefore be based on reference conditions.

Introduction

It is of practical value to use stream types because numbers of comparable streams can be treated with the same method. But the finer the spatial scale the less clear type boundaries become and the more the applicability of a typology decreases. An ideal typology fulfils requirements of different objectives, is robust and easy to understand by non-specialists. Such an ideal typology remains a utopy. A typology will always be subjective and based on the objectives it is designed for (Verdonschot, 1990; Nijboer, in prep.).

Differences between climate, hydrology, geomorphology, geology, soil composition, land-use, vegetation and ecology make comparison of communities in running waters difficult or even impossible (Macan, 1961; Maitland, 1966). On the other hand, a typology generalises knowledge that can be applied on a wider scale (Pennak, 1971), and improves the comparability of running waters in management, assessment, and prediction (Hawkes, 1975). A typology thus adds to the intercalibration of the 10.

The use of a typology to classify streams has become an accepted part of ecological assessment (Wright et al., 1999; Hering et al., 2004). Stream types serve as 'classes' for which assessment systems can be developed and applied (Verdonschot, 1990). The comparison of conditions at a current site with those of a reference site belonging to the same stream type allows a type-specific evaluation (Hering et al., 2004). Reference conditions are best described at the scale of a type (Nijboer et al., 2004).

The underlying descriptors of typologies differ strongly. Three major approaches can be distinguished:

1. Biotic descriptors (such as the WFD predescribes; European Commission, 2000)
2. Biotic descriptors (e.g., Wright et al., 1984)
3. A combination of abiotic and biotic descriptors (e.g., Reynoldson et al., 1997).

The EU Water Framework Directive defined abiotic descriptors to classify stream types. This typology is an essential building block of the implementation of the WFD and offers a framework for assessment. For rivers, the Directive defined abiotic descriptors to establish the 'System A' typology. 'System A' descriptors are defined by ecoregions (according to Illies, 1978), size based on the catchment area classes (small 10–100, medium 100–1000, large 1000–10 000, very large >10 000 km^2), catchment geology (siliceous, calcareous, organic), and altitude (lowland < 200, medium-altitude 200–800, high >800 m). Using these abiotic descriptors, the participating countries in the EU research projects AQEM and STAR (Austria, Czech Republic, Germany, Greece, Italy, Latvia, Netherlands, Portugal, Sweden and United Kingdom) selected sites in 48 stream types to construct a standardised European stream classification. But do the abiotic descriptors based on the 'System A' of the WFD fit the distribution patterns of the organisms or communities present in the European streams?

The European Commission further recognised that the ecological status of water bodies should be determined by comparing these to near-natural or reference conditions. The WFD approach of using reference conditions in assessment is in agreement with the assessment approaches adopted in the USA (e.g., USEPA, 1996) and Australia (Davies, 2000). Communities are optimally developed under reference conditions (e.g., Karr & Chu, 1999). It is commonly accepted that human disturbance affects a stream ecosystem in such a way that communities become poor and look more alike (e.g., Wright et al., 1984; Verdonschot, 1990). Yet, would a stream typology become most explicit using only reference sites?

Verdonschot & Nijboer (2004) tested if the typology suggested in the WFD was useful for developing an assessment system for macroinvertebrates in streams. They concluded that the major macroinvertebrate distribution patterns in European streams follow climatological and geomorphological conditions and are well distinguished in terms of stream types. Thus, the WFD typology was useful for the development of type-specific assessment systems for streams using macroinvertebrates. Furthermore, it was shown that large-scale factors affected the macroinvertebrate distribution even on a very fine scale. The large-scale factors were indeed the variables that explained most of the variation in species composition. But as these factors even strongly act at the scale of stream types, a further refinement is most probably necessary to disentangle typological actors from water quality ones.

In this follow up study, additional data became available, which implied that enough data of reference sites provided the opportunity to do analyses with such sites solely, and the question of scale could be tackled. The objectives of this study were:

- To test whether the WFD abiotic descriptors for rivers are valid and fit the biotic ones when using a larger data set.
- To explore whether the stream typology should be based on reference sites only or also can include or solely use degraded sites.
- To explore the effect of scale in typology.

Methods

Data collection

In the EU research project AQEM, in total 889 macroinvertebrate samples representing 29 stream types were taken in 8 countries in 2000 and 2001. In the EU research project STAR, an additional 771 samples were taken in 13 countries in 2002 and 2003. The combined AQEM–STAR database composed 1660 samples representing 48 stream types (see Verdonschot, 2006). All samples together cover the major geographical gradients in

Europe. The AQEM site selection, sampling, sorting, and identification procedure was explained by Hering et al. (2004). The STAR samples were either processed according to a slightly adapted AQEM protocol (Furse et al., 2004) or according to several national sampling protocols: RIVPACS (Germany, Austria, Greece and United Kingdom), IBE (Italy), IBGN (France), DSFI (Denmark), LVS 240 (Latvia), PERLA (Czech Republic) and the national protocols of Poland, Sweden, and Portugal.

Handnets were used in all methods. All samples were taken within a stream stretch of <500 m of the respective stream. All samples were collected in at least two seasons, of which one was spring. The second sample was collected in summer or autumn, depending on the regional, geographical and climatological conditions. At the STAR-related sites replicate samples were taken. All samples were further processed in the same standardised way. Finally, different samples from the same site, either being replicates or taken using a different method, and samples taken in different seasons from the same site were kept in the analyses and treated as separate samples. Hereby, the variation caused by the different methods is accepted.

Identification took place to species-level when possible. In some areas, identification was limited to higher taxonomic levels due to a lack of taxonomic knowledge. Finally, all samples were combined into one European database.

Data analyses

For several reasons taxonomic levels within and between samples differed. This can be because of damaged specimens, lack of taxonomic knowledge in certain areas of Europe, lack of certain life stages, or lack of certain taxonomic groups in general. Therefore, taxonomic adjustment was needed to assure unambiguous data processing. Differences in taxonomic level could otherwise later prove to be the cause of differences between sample groupings. In this study a weighed taxonomic adjustment was applied according to the criteria described by Vlek et al. (2004). These criteria were applied to the total database. After taxonomic adjustment the macroinvertebrate abundances of each sample were transformed (${}^{2}\log(x+1)$) (Preston, 1962; Verdonschot, 1990).

The multimetric AQEM assessment system (Hering et al., 2004) was used to classify all AQEM samples into an Ecological Quality Class ranging from 5 (high quality) to 1 (bad quality). For all STAR samples only a pre-classification was available assigning the samples to the same quality classes based on the expert knowledge and abiotic field measurements. For data analysis three datasets were compiled: (i) ‘all samples’; 1660 samples, (ii) ‘reference samples’; 876 samples including only samples with an ecological quality classification good (class 4) and high (class 5), and (iii) ‘degraded samples’; 784 samples including only samples with an ecological quality classification moderate (class 3), poor (class 2), and bad (class 1). The inclusion of class 4 (good) in the group of reference samples was done because (i) the quality deviation from the reference is only slight and (ii) to obtain enough samples for reliable analyses.

Ordination was designed for data analysis in community ecology. Used in an explorative way it shows an ordination diagram that optimally displays how community composition varies (ter Braak & Šmilauer, 2002). In order to analyse the macroinvertebrate species composition in relation to stream type, detrended correspondence analysis (DCA) was used. DCA is an indirect ordination technique and part of the program CANOCO for Windows, version 4.2 (ter Braak & Šmilauer, 2002). In DCA, the samples are patterned in a multidimensional space based on their taxonomic composition.

The options chosen in CANOCO will influence the result of the DCA ordination. In this study the following options were selected (ter Braak & Šmilauer, 2002):

- Detrending by 2nd order polynomials to reduce the ‘arch’ effect;
- Downweighting of rare species which reduces the influence of rare species and stresses the importance of more common ones in the analysis;
- Inter-sample distance that optimises the position of the samples in the ordination diagram;
- Hill’s scaling to allow for long gradients the sample distances to represent turn over distances.

To establish the percentage of overlap between groups of samples a graphical approach was used. Using more 'classical' clustering techniques, such as hierarchical agglomerative clustering, a number of reproducible but more or less subjective choices within the program must be made by the user and decide the results of the classification. The technique chosen in this study is based on the interpretation of the DCA ordination diagram by counting the number of samples present in adjacent groups. Therefore, within the resulting ordination diagram, which included the first and second ordination axes, the samples were labelled *a priori* according to stream type as defined in 'System A' of the WFD. The overlap between stream types was established by drawing contour lines, straight lines between adjacent sites of the same type, around each of the types and summing up all of the overlapping samples. The position of the contour line was the result of an iterative process of repositioning the contour line and re-counting the overlap until a minimum overlap was reached. Overlapping stream types were grouped into larger groups if more than 25% of the samples were positioned within the other type or group, and next the overlap between these new established groups was calculated again by summing up all the remaining overlapping samples. The groups with an overlap <25% of the samples were identified as an identifiable group. Each group was considered to represent a recognisable typological unit, and a next DCA run was performed for this respective group to identify groups within. This process was repeated until no groups could further be disentangled or the level of stream type as recognisable group was reached. Starting with the whole database, the groups recognised in the first ordination were considered to represent the highest hierarchical units and are considered the major groups in Europe, the further the 'pealing off' was done the lower hierarchical position a group represented: groups, sub-groups, and stream types, respectively.

The calculation of the overlap was restricted to axes one and two, as in each run only two to three major groups were separated. DCA plots the major grouping of samples along the first and the second major grouping along the second axis (ter Braak & Šmilauer, 2002). The DCA analyses were repeated for all six datasets; 'all samples', 'reference samples' and 'degraded samples'.

Based on the results a schematic overview was made including the hierarchy and clustering of the European stream types.

For a selected number of environmental variables the average value per stream type was calculated to support the interpretation of the group identification.

Results

Hierarchical grouping of stream types

In general, the loss of species due to taxonomic adjustment was very high (Verdonschot, 2006). Many species and combinations of species were assigned to genus-level and family-level. All major taxonomic groups were strongly reduced in number of taxa after adjustment. Major losses occurred in the Chironomidae, but also the numbers of Hydrachnidia, Megaloptera, Plecoptera, and Coleoptera taxa were strongly reduced. Gastropoda seemed to be best known throughout Europe and the decrease of the number of taxa was restricted to 61%.

The hierarchical position and number of samples per major group as well as all other groupings discussed further on and resulting from the DCA analyses are listed in Table 1. The most important environmental variables were averaged per stream type (Table 2).

The first DCA analysis of the 876 reference samples using species data, and stream types as labels, resulted in three major groups of stream types that correspond to three major landscape types in Europe (Fig. 1): Mountains, Lowlands and Mediterranean. These major groups have an average altitude of 481, 130, and 313 m, respectively. The ordination diagram (Fig. 1) shows that the widest spread of data points occurred within the samples of the Lowlands, samples belonging to the Mountains are more similar and, thus, less widely spread over the diagram, and finally, samples of the Mediterranean were projected along both Mountains and Lowlands groups. The Mediterranean dataset had a lower number of samples, while these samples originated

Table 1. Hierarchical grouping of European (groups of) stream types for Europe. Number of samples per group/type indicated for all samples, reference samples and degraded samples, respectively

	major group	group	sub-group	stream type	all samples	reference samples	degraded samples
Europe: all samples					1660	876	784
Mountains	x				645	339	306
Northern European Mountains		x			120	68	52
Northern Sweden			x	S01, S02	60	40	20
Boreal Highlands			x		60	28	32
				S03	30	22	8
				S04	30	6	24
Central European Mountains		x			441	224	217
Central European Mountains (medium-sized)			x		64	29	35
				C14	24	14	10
				D05	40	15	25
Central European Mountains (small)			x	A04, A05, A06, C04, C05, C15, C16, D04, D06, V01	377	195	182
Central Alps		x			84	47	37
				A02	26	14	12
				A03	26	13	13
				I05	32	20	12
Mediterranean	x				217	128	89
Central and Eastern Mediterranean		x			159	92	67
Greece (Medit.)			x	H01, H02, H03	80	53	27
Central Apennines			x	I06	34	18	16
Northern Apennines			x		45	21	24
				I23	23	11	12
				I24	22	10	12
Western Mediterranean		x			58	36	22
S-Portugal (medium-sized)			x	P04	32	20	12
S-Portugal (small)			x	P01, P02	26	16	10
Lowlands	x				798	409	389
Central and Southern Lowlands		x			572	257	315
Hungarian Plain			x	A01	24	11	13
Hellenic Balkans			x	H04, H05, H06, H07	72	43	29
Central European Lowlands			x	D01, D02, D03, I22, K02, N13, N14, O02, P03, U15, U23	476	203	273
Northern Lowlands		x			226	152	74
Southern Sweden			x	S05, S06	97	61	36
Baltic Province			x	L02	93	71	22
Western sub-alpine Mountains			x	F08	36	20	16

Table 2. Average values of selected major environmental variables per stream type for 48 stream types sampled in the AQEM and STAR research projects

Stream type	A01	A02	A03	A04	A05	A06	C04	C05	C14	C15	C16	D01	D02	D03	D04	D05
Altitude (m)	249	617	1060	433	478	458	348	367	419	303	322	56	41	41	363	287
S.D.	56	144	166	114	27	72	54	65	51	75	135	29	6	13	79	52
Catchment area (km^2)	199	255	32	262	45	32	28	32	587	29	261	55	3	538	18	382
S.D.	101	122	14	3	8	17	7	10	306	18	128	36	3	1139	10	244
Distance to source (km)	38.5	29.6	9.5	38.0	14.8	11.8	9.9	10.9	50.4	9.4	29.0	11.4	1.9	47.9	7.2	44.4
S.D.	10.7	8.9	3.1	3.9	2.4	4.0	2.1	2.8	20.2	2.7	7.6	7.3	1.6	60.0	2.5	18.3
Slope (%)	0.42	0.51	5.74	0.68	2.53	4.05	0.99	1.02	0.34	1.30	21.66	0.00	0.01	0.10	1.74	0.42
S.D.	0.30	0.24	5.14	0.17	1.68	3.88	0.41	0.58	0.14	0.75	89.75	0.00	0.01	0.06	0.67	0.24
Stream order	4.3	4.7	3.6	4.6	3.8	3.4	3.3	3.0	5.8	3.9	5.2	2.7	1.2	3.4	2.3	3.1
S.D.	0.9	0.5	0.6	0.5	0.4	0.8	0.5	0.4	0.6	0.7	0.7	0.6	0.4	0.7	0.7	0.3
Intermittent % sites	0	0	0	0	0	0	5	0	0	7	0	0	47	0	0	0
S.D.	0	0	0	0	0	0	22	0	0	26	0	0	52	0	0	0
Current velocity (m/s)	0.49	0.59	0.71	0.37	0.48	0.45	0.24	0.30	0.40	0.31	0.45	0.14	0.11	0.23	0.42	0.61
S.D.	0.18	0.25	0.26	0.18	0.40	0.26	0.13	0.13	0.25	0.21	0.23	0.16	0.20	0.12	0.30	0.25
Width (m)	5.9	22.7	6.7	11.4	4.0	5.1	2.8	3.2	17.3	4.0	12.4	6.5	3.6	10.2	3.6	17.6
S.D.	2.9	7.2	3.4	2.5	1.2	2.0	0.5	1.5	7.8	1.3	5.7	2.5	3.8	4.5	1.3	8.8
Depth (cm)	25	29	17	38	27	25	24	16	44	19	29	26	7	63	21	39
S.D.	6	11	6	13	10	19	13	4	11	9	8	16	5	35	13	13
EC (μS/cm)	415	331	113	112	100	90	454	289	235	608	480	695	340	553	192	240
S.D.	191	37	54	10	19	54	191	171	101	196	212	341	123	131	109	93
Cl (mg/l)	22.4	2.8	2.2	6.3	3.2	2.8	18.9	10.6	19.7	17.0	22.1	55.9	37.9	37.9	20.7	25.3
S.D.	12.3	0.3	0.3	1.7	1.8	1.1	17.8	6.1	13.5	14.5	20.5	29.3	10.0	13.7	19.1	6.2
pH	7.9	8.3	7.9	7.6	7.5	7.5	8.4	7.8	7.7	8.1	8.3	7.7	6.1	7.8	7.6	7.7
S.D.	0.2	0.3	0.2	0.3	0.2	0.3	0.4	0.4	0.7	0.5	0.6	0.4	0.9	0.3	0.5	0.7
Total hardness (mmol/l)	1.89	1.73	0.53	0.36	0.59	0.67	1.86	1.19	0.88	3.10	2.27	2.73	1.31	2.98	0.75	0.98
S.D.	1.24	0.19	0.24	0.04	0.13	0.51	0.78	0.86	0.39	1.09	1.02	0.88	0.46	2.10	0.25	0.39
O_2 (mg/l)	9.9	12.0	10.5	10.4	9.6	9.8	10.8	10.9	9.5	10.1	9.7	10.2	10.2	10.8	11.6	11.5
S.D.	2.6	1.3	0.9	1.4	0.4	0.4	3.2	2.0	2.5	2.7	3.1	2.8	0.8	1.6	1.9	1.3
Ammonium (mg/l)	0.35	0.01	0.01	0.01	0.01	0.03	0.34	0.11	0.09	0.21	0.41	0.41	0.14	0.19	0.13	0.20
S.D.	0.63	0.01	0.00	0.00	0.00	0.03	0.70	0.23	0.07	0.33	0.61	0.88	0.25	0.31	0.37	0.38
Ortho-phosphate (μg/l)	116	2	2	19	22	6	227	128	439	440	716	222	44	168	166	174
S.D.	161	1	2	5	15	4	195	116	260	418	732	210	44	185	330	188
Total phosphate (μg/l)	219	7	46	35	38	22	595	215	961	653	1211	413	91	390	340	244
S.D.	195	2	112	3	20	12	564	235	498	554	1171	351	76	209	698	193
Alkalinity (mmol/l)	1.62	1.61	0.54	0.29	0.47	0.62	2.84	1.53	1.14	4.86	3.63	2.42	0.40	3.41	1.02	0.56
S.D.	0.91	0.15	0.24	0.03	0.09	0.43	1.60	1.21	0.50	1.31	1.37	1.35	0.39	1.42	0.61	0.57

Stream type	D06	F08	H01	H02	H03	H04	H05	H06	H07	I05	I06	I22	I23	I24	K02	L02
Altitude (m)	205	326	243	678	365	310	626	166	75	1395	381	133	374	478	22	64
S.D.	49	41	269	343	395	274	247	69	57	215	116	14	96	111	19	50
Catchment area (km^2)	42	189	103	167	156	48	114	17	296	28	47	6	355	60	106	159
S.D.	16	111	155	181	228	56	137	11	319	35	0	5	214	75	48	110
Distance to source (km)	9.3	25.9	19.0	16.9	20.6	10.6	17.0	5.8	23.0	5.9	9.0	1.7	42.7	13.1	18.8	31.0
S.D.	2.4	10.5	18.3	12.0	16.5	5.6	9.6	2.9	19.2	4.1	0.0	1.1	18.0	9.1	5.4	18.8
Slope (%)	0.91	1.98	0.92	1.83	1.18	1.19	1.23	1.41	0.58	9.62	1.53	0.23	0.79	2.13	1.38	0.35
S.D.	0.30	0.95	1.38	2.24	1.81	1.23	1.50	1.65	0.71	4.32	0.85	0.08	0.33	1.24	0.93	0.23
Stream order	2.3	2.8	4.6	5.1	5.0	3.2	4.8	2.6	1.0	2.7		1.0	5.7	4.3	3.3	2.0
S.D.	0.4	0.5	1.8	1.2	1.1	1.5	1.2	0.5	0.0	0.9		0.0	0.5	0.6	0.5	0.5
Intermittent % sites	0	0	8	4	20	0	0	0	0	0	0	0	0	18	0	1
S.D.	0	0	28	20	41	0	0	0	0	0	0	0	0	39	0	10
Current velocity (m/s)			0.46	0.45	0.51				0.24	0.54		0.15	0.28	0.24		0.48
S.D.			0.33	0.36	0.36				0.21	0.18		0.22	0.10	0.16		0.24
Width (m)	4.4	8.4	6.2	5.0	7.0	9.3	5.3	2.4	5.6	5.1		2.9	14.4	3.1	5.8	6.8
S.D.	1.6	2.5	11.0	8.9	5.0	4.9	4.4	1.4	2.8	5.5		0.9	9.5	2.3	1.4	2.8
Depth (cm)	24	28	18	15	19	24	19	18	79	24	53	26	22	15	72	35
S.D.	6	11	8	7	7	18	10	11	62	10	14	9	5	4	23	13
EC (μS/cm)	128	660	400	303	488	432	191	466	584	327	782	247	298	469	401	419
S.D.	58	322	577	202	239	151	113	258	236	57	443	99	56	137	167	99
Cl (mg/l)	14.1		11.1	7.3	15.9	13.3	6.4	39.5	50.8	1.3	19.1	11.3	8.6	20.0	32.5	7.0
S.D.	14.1		13.6	7.4	14.8	11.8	5.6	33.0	46.4	1.4	5.6	6.6	7.4	12.8	7.6	2.7
pH	7.5	8.2	8.2	8.1	8.1	8.5	8.6	8.3	8.0	8.3	7.8	7.7	8.4	7.8	7.5	8.0
S.D.	0.6	0.1	0.5	0.7	0.4	0.4	0.5	0.6	0.4	0.2	0.2	0.2	0.2	0.3	0.3	0.2
Total hardness (mmol/l)	0.73		0.04	0.21	0.14	1.97	0.73	1.83	3.21	1.76	3.46	1.15	1.64	2.46		9.08
S.D.	0.78		0.08	0.41	0.19	0.83	0.47	1.20	1.02	0.29	2.50	0.18	0.29	0.78		2.16
O_2 (mg/l)	11.0	9.4	9.4	9.9	9.7	10.3	9.1	9.5	8.1	11.0	7.7	6.6	9.4	8.2		9.5
S.D.	1.3	0.2	2.1	2.0	2.0	2.1	1.4	1.6	2.8	2.3	0.9	1.4	1.0	3.0		2.2
Ammonium (mg/l)	0.22		0.09	0.34	0.14	0.02	0.23	0.01	0.03	0.00	0.08	0.16	0.40	0.62	0.10	0.27
S.D.	0.37		0.16	0.91	0.37	0.06	0.60	0.01	0.03	0.00	0.14	0.34	1.70	1.71	0.08	0.08
Ortho-phosphate (μg/l)	112		371	675	236	32	272	31	39	698	157	95	3	313	17	34
S.D.	172		623	674	371	14	525	3	19	835	218	174	9	466	11	17
Total phosphate (μg/l)			158	256	91	71	411	59	45	7	133	155	8	381	46	200
S.D.			232	227	134	96	619	33	24	4	213	237	17	589	31	49
Alkalinity (mmol/l)	0.45		2.33	2.57	3.52	3.59	1.53	3.43	4.37	2.90	3.61	0.79	2.93	2.33	1.99	4.07
S.D.	0.31		1.35	1.90	1.08	1.36	1.03	2.40	0.50	0.44	0.75	0.16	0.63	0.55	1.22	0.91

Continued on p. 46

Table 2. (Continued)

Stream type	N13	N14	O02	P01	P02	P03	P04	S01	S02	S03	S04	S05	S06	U15	U23	V01
Altitude (m)	47	19	128	294	87	94	263	134	315	501	790	107	10	27	66	351
S.D.	50	14	37	91	35	47	43	53	74	76	70	81	8	22	45	88
Catchment area (km^2)	26	33	321	31	44	249	190	121	63	72	37	193	234	49	168	32
S.D.	26	49	196	18	32	96	127	151	55	76	34	213	275	96	111	24
Distance to source (km)	8.6	6.6	29.8	14.3	15.3	46.4	32.9	20.7	13.9	15.8	9.7	28.5	30.7	7.3	27.5	9.2
S.D.	11.1	7.0	13.6	5.7	5.5	20.2	9.7	13.4	5.8	8.8	4.9	15.4	20.2	2.2	7.3	4.1
Slope (%)	2.85	1.02	0.11	1.13	0.70	0.39	1.14					1.50	0.21	3.60	3.75	5.45
S.D.	4.98	1.96	0.10	0.97	0.61	0.35	0.50					3.94	0.22	6.63	4.49	2.60
Stream order	2.0	1.9	3.1	1.7	1.6	2.9	2.8	3.2	3.0	3.5	3.3	4.1	4.6	2.8	4.3	3.5
S.D.	0.9	0.8	0.7	0.6	0.7	0.6	0.4	1.1	0.5	0.7	0.6	0.9	0.7	1.0	0.8	0.7
Intermittent % sites	6	16	0	93	55	62	100	0	0	0	0	6	27	0	0	0
S.D.	25	37	0	26	52	51	0	0	0	0	0	24	45	0	0	0
Current velocity (m/s)	0.27	0.24	0.09	0.31	0.22	0.33	0.25	0.00	0.00	0.00	0.00	0.00		0.44		0.41
S.D.	0.23	0.22	0.07	0.16	0.11	0.21	0.12	0.00	0.00	0.00	0.00	0.00		0.23		0.14
Width (m)	2.5	3.7	7.6	4.1	5.7	6.3	14.1	6.4	7.3	9.5	19.8	9.0	6.3	2.3	9.6	4.6
S.D.	1.8	3.2	3.2	2.1	3.2	4.0	5.5	2.1	5.7	3.5	9.7	6.0	3.8	0.8	4.6	2.1
Depth (cm)	20	26	44	20	31	26	68	42	35	37	37	38	31	43	41	16
S.D.	16	27	14	8	18	10	19	21	14	18	11	18	14	17	19	3
EC (μS/cm)	486	402	458	228	436	671		39	25	26	21	177	251	592	466	260
S.D.	169	174	233	223	210	585		22	4	21	16	249	99	110	97	132
Cl (mg/l)	27.7	31.5	21.9	25.8	56.1	166.3	10.8	1.7	0.8	0.8	0.7	15.7	11.6			3.2
S.D.	15.4	11.7	25.3	20.5	29.4	180.8	14.7	1.7	0.3	0.4	0.2	37.6	6.6			2.1
pH	7.0	7.2	7.5	7.5	7.7	7.8		6.7	6.8	7.0	6.8	7.0	7.5			7.8
S.D.	0.9	0.4	0.5	0.4	0.3	0.5		0.3	0.3	0.4	0.5	0.4	0.3			0.4
Total hardness (mmol/l)	1.83	1.54	2.22	0.74	1.06	1.89	2.42	0.14	0.09	0.11	0.08	0.51	1.16			2.29
S.D.	1.01	0.84	0.60	0.74	0.53	1.68	2.83	0.08	0.02	0.11	0.08	0.63	0.47			2.18
O2 (mg/l)	8.7	9.3	8.6	7.7	8.4	7.6	9.1	10.3	10.6	11.2	11.6	10.5	10.2			12.0
S.D.	1.7	2.2	2.8	2.3	0.6	1.5	1.2	1.1	1.1	1.2	0.9	1.8	1.8			1.0
Ammonium (mg/l)	0.29	0.21	1.06	0.20	0.03	0.09	0.04	0.01	0.01	0.00	0.00	0.28	0.07			0.12
S.D.	0.36	0.19	2.77	0.39	0.05	0.07	0.05	0.01	0.01	0.00	0.00	0.84	0.15			0.14
Ortho-phosphate (μg/l)	86	45	615	25				8	5	4	4	31	16			97
S.D.	187	39	1743					6	4	2	2	77	21			284
Total phosphate (μg/l)	177	124	1051	314	225	377	0	43	22	14	10	196	40			73
S.D.	240	90	2588	684	433	1089	0	29	12	11	12	825	31			131
Alkalinity (mmol/l)	2.06	1.74		1.00	0.97	2.04	1.71	0.08	0.06	0.08	0.06	1.95	1.74			2.20
S.D.	1.60	1.23		1.19	0.47	1.67	1.16	0.06	0.02	0.10	0.08	12.30	0.78			1.17

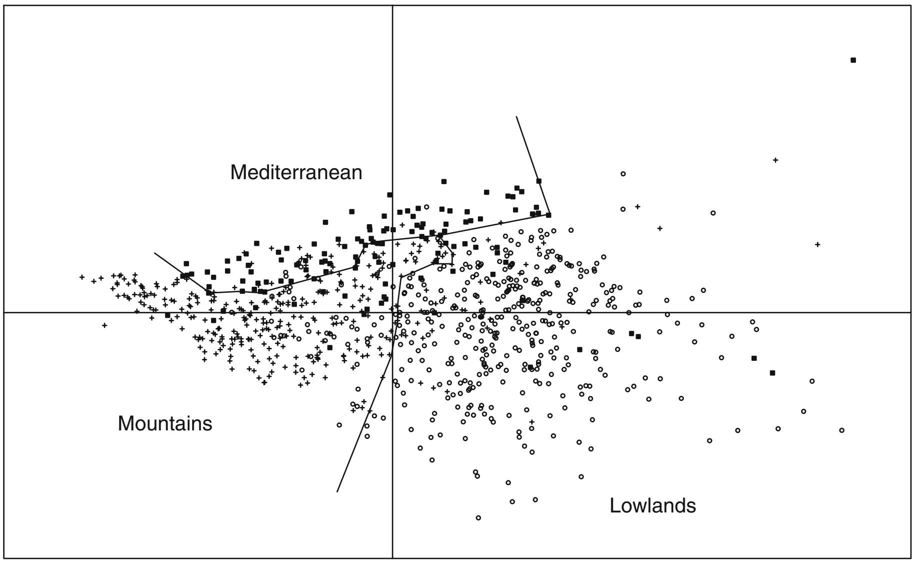

Figure 1. DCA ordination diagram of the axis 1 (horizontal; eigenvalues: 0.23) and 2 (vertical: eigenvalues: 0.13) of the (groups of) stream types within Europe based on species data of reference samples.

from a wider variety of landscapes of both high and low altitude. The dissimilarity of samples within Mountains and Lowlands suggests a wider variety of species combinations in the Lowlands.

The major group Mountains was divided into three groups (Fig. 2a; Table 1): Central Alps, Northern European Mountains and Central European Mountains.

In the diagram, the Central Alps are positioned more or less as an extension of the Central European Mountains (Fig. 2a). The Central Alps were further divided into stream: A02 and I05 types (Fig. 4c), both of which are calcareous streams (see Verdonschot, 2006), the former being medium-sized and the latter small, and stream type A03, small siliceous streams. The samples of the three stream types within the group Central Alps (average altitude 1024 m) were situated along a strong altitudinal gradient: two stream types were situated at altitudes higher than 800 m (stream type I05; average altitude 1395 m; stream type A03; average altitude 1060 m) and one just below the 800 m (stream type A02; average altitude 617 m). The catchment size of the latter is also much larger in comparison to the first two stream types.

The groups Northern vs. the Central European Mountains do not differ in average altitude; 435 m vs. 370 m. The difference in conductivity, alkalinity, and total hardness is evident (Table 2). These differences in ionic composition are most probably caused the very different geology of both groups.

Within the group Central European Mountains two sub-groups were identified (Fig. 3b, Table 1): the medium-sized stream types (with also a larger catchment) of the Central European Mountains (in the right upper corner of the diagram) and the small streams (with a smaller catchment) of the Central European Mountains (composed of 10 stream types). The samples show a gradual transition between both groups of stream types, whereby the samples of the medium-sized stream types of the Central European Mountains constituted one end of the gradient (right upper corner in the diagram: Fig. 3b) and overlap with the small stream types of the Central European Mountains which as a group could not be disentangled further. The medium-sized streams in the Central European Mountains were further divided into two stream types (Fig. 4b): C14 and D05, situated in the Czech Republic and Germany, respectively. The stream type C14 refers to acid-silicate geology (see Verdonschot, 2006), while the stream type D05 refers to a calcareous one.

The group Northern European Mountains was divided into two sub-groups (Fig. 3a) again caused by altitudinal differences: Northern Sweden with an average altitude of 224 m vs. the Boreal Highlands with an average altitude of 645 m. In

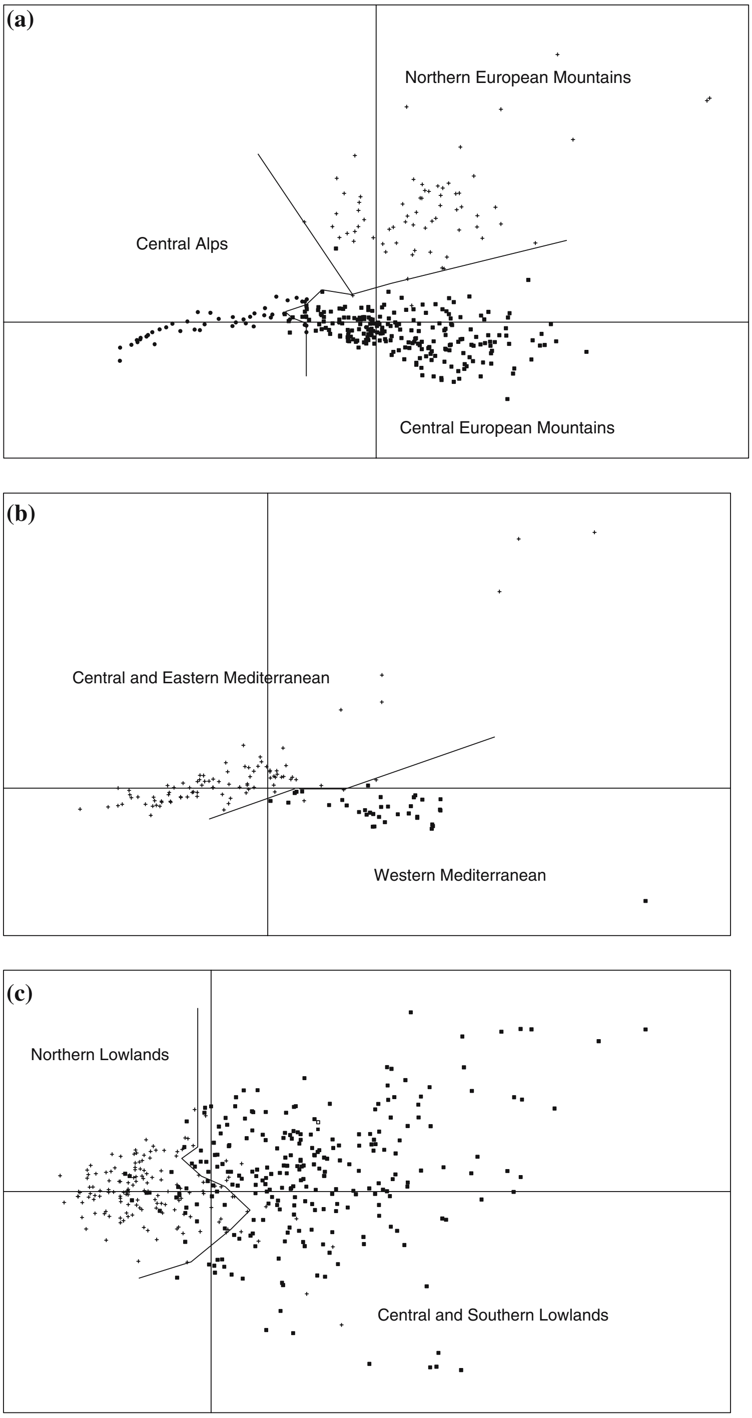

Figure 2. DCA ordination diagrams of the axis 1 (horizontal) and 2 (vertical) of the groups of stream types within the major regions in Europe based on species data of reference samples. (a) Mountains (eigenvalues axis 1: 0.17, axis 2: 0.14), (b) Mediterranean (eigenvalues axis 1: 0.31, axis 2: 0.23), (c) Lowlands (eigenvalues axis 1: 0.16, axis 2: 0.13).

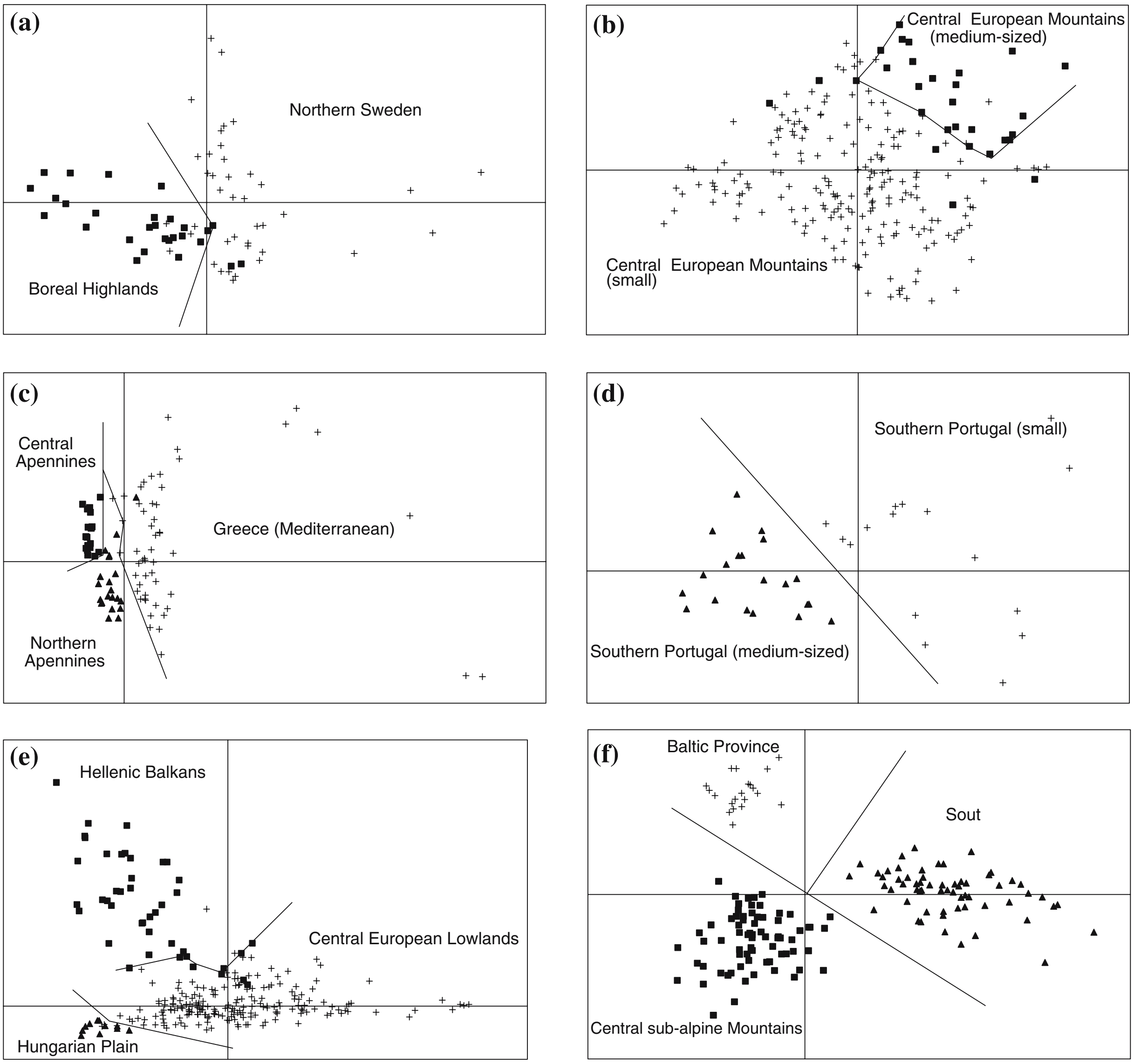

Figure 3. DCA ordination diagrams of the axis 1 (horizontal) and 2 (vertical) of the groups of stream types within the regions in Europe based on species data of reference samples. (a) Northern European Mountains (eigenvalues axis 1: 0.24, axis 2: 0.14), (b) Central European Mountains (eigenvalues axis 1: 0.15, axis 2: 0.11), (c) Central and Eastern Mediterranean (eigenvalues axis 1: 0.36, axis 2: 0.19), (d) Western Mediterranean (eigenvalues axis 1: 0.28, axis 2: 0.16), (e) Central and Southern Lowlands (eigenvalues axis 1: 0.19, axis 2: 0.16), (f) Northern Lowlands (eigenvalues axis 1: 0.16, axis 2: 0.12).

the diagram the samples of sub-group Northern Sweden (two stream types) were much more diverse in comparison to the samples of the sub-group Boreal Highlands. The sub-group Boreal Highlands contained two stream types (Fig. 4a): S03 and S04, with a medium-altitude (average altitude 501 m) vs. the high-altitude (average altitude 790 m) samples (see Verdonschot, 2006). The two stream types in Northern Sweden could not be disentangled further.

The major group Mediterranean divided into two groups (Fig. 2b; Table 1): the group Western Mediterranean refers to the Portuguese samples at an average altitude of 215 m, mostly intermittent streams, and the group Central and Eastern Mediterranean, that refers to the Italian and Greek samples situated at an average altitude of 362 m, mostly permanent streams. The Italian streams showed higher hardness and phosphate concentrations in comparison to the Greek ones (Table 2). The group Central and Eastern Mediterranean clearly included some outliers in the right upper corner of the diagram (Fig. 2c), while the group Western Mediterranean had one outlier in the lower right corner. The group Central and Eastern Mediterranean was divided further, especially along the first axis, into the three local regions (Fig. 3c): both Italian sub-groups of the Northern and Central Apennines (one stream type), respectively, on the left of the diagram and the Greek (three stream types) samples on the right. All three groups of samples were situated along a vertical gradient parallel to the vertical axis in the diagram (Fig. 3c). The sub-group Northern Apennines was further divided into two stream types (Fig. 4d): I23 and I24. The group Western Mediterranean was divided into the sub-groups of the Southern Portugese medium-sized (one stream type) and small streams (two stream types) (Fig. 3d).

The major group Lowlands was divided along the first axis into two groups (Fig. 2c; Table 1): the group Central and Southern Lowlands, a heterogenous group of samples that is quite widely scattered over the right side of the diagram (average altitude of 131 m) and the group Northern Lowlands that is positioned as a more homogeneous group of samples at the left of the diagram (average altitude of 127 m). Only differences in chloride and conductivity are clear (Table 2). The group Central and Southern Lowlands was further divided into three sub-groups (Fig. 3e): the sub-group Hellenic Balkans (four stream types), and the sub-group Hungarian Plains (one stream type), both situated at the left side of the diagram along the second axis, and the

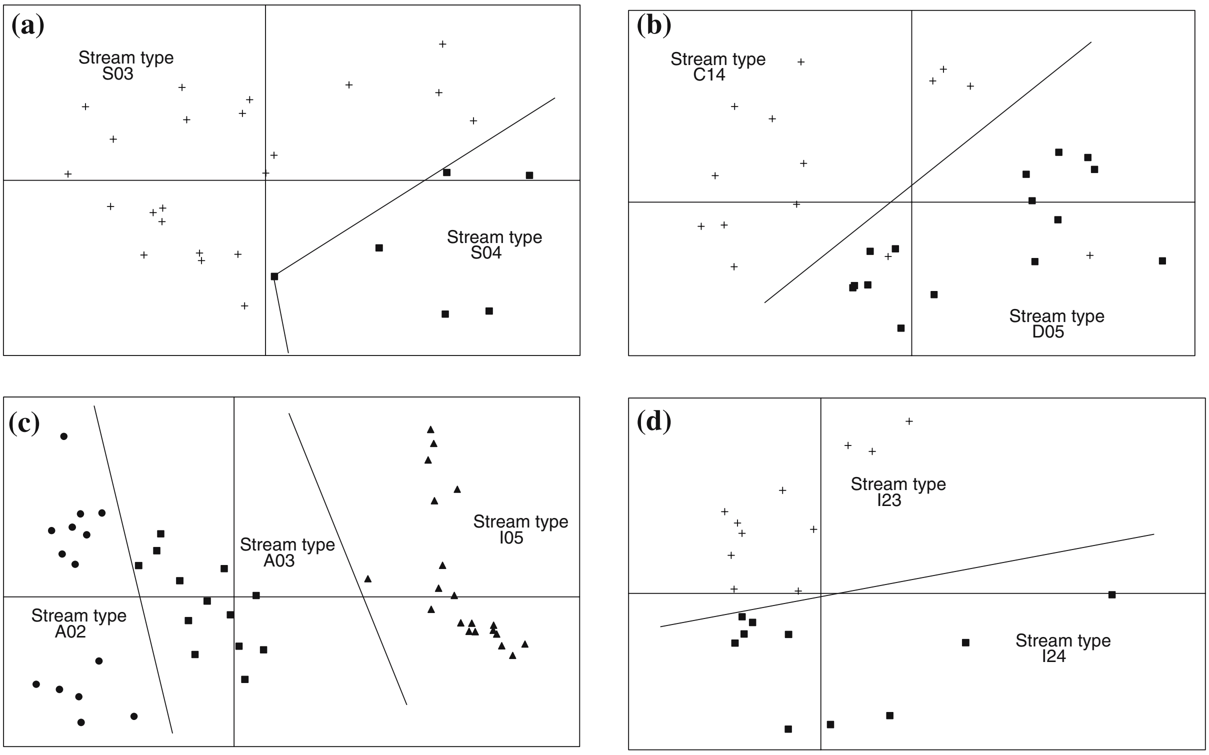

Figure 4. DCA ordination diagrams of the axis 1 (horizontal) and 2 (vertical) of the (groups of) stream types within the local regions in Europe based on species data of reference samples. (a) Boreal Highlands (eigenvalues axis 1: 0.20, axis 2: 0.11), (b) Central European Mountains (medium-sized; eigenvalues axis 1: 0.14, axis 2: 0.10), (c) Central Alps (eigenvalues axis 1: 0.17, axis 2: 0.13), (d) Northern Apennines (eigenvalues axis 1: 0.24, axis 2: 0.16). For explanation of stream type codes see Verdonschot (2006).

sub-group Central European Lowlands (11 stream types), a diverse and widely spread group of samples along the first axis. The sub-group Hellenic Balkans is situated at a higher altitude (average of 294 m) and had a steeper slope. The sub-group Central European Lowlands could not be disentangled further. The group Northern Lowlands was very clearly divided into three sub-groups (Fig. 3f): in the left upper corner the sub-group Baltic Province (one stream type), in the left lower corner the sub-group Western sub-alpine Mountains (one stream type), and to the right along the first axis the sub-group Southern Sweden (two stream types).

Diversity along European environmental gradients

To explore further the drivers of differences in data composition, changes of taxon diversity along major environmental gradients that can be linked to ecoregions were explored. Macroinvertebrates distribute along temperature gradients which are best expressed in either latitudinal, elevational and stream order gradients (Ward, 1985). By plotting the average number of taxa per sample along the latitudinal gradient from Sweden down to Portugal for the reference samples, no relation at all became evident (Fig. 5). There was even a decrease in the average number at the lower latitudes (more southern samples) indicated, which contradicts the findings of Vannote & Sweeney (1980) and Jacobsen et al. (1997). The R^2 value indicates that a correlation is completely absent. The results were similar for the altitudinal gradient. At higher altitude, temperature decreases and the numbers of taxa would be expected to decrease as well (Ward, 1982; Furse et al., 1984; Quinn & Hickey, 1990). The relation between the numbers of taxa and altitude in Europe is shown in Fig. 6. Although the regression line goes somewhat down, the R^2 value shows that there was no trend between altitude and number of taxa.

Going down from a first to a seventh order stream, along the river continuum, temperature again should rise (Hawkes, 1975; Vannote et al., 1980). The relation between the number of macro-invertebrate taxa and stream order in the studied European dataset showed no relationship (Fig. 7).

The average number of individuals per sample showed huge variation between countries. Densities of macroinvertebrates can differ due to the stream and the habitat. Fast and varying current velocities (e.g., Townsend et al., 1997) as well as presence/absence of shelter often relate to lower numbers of specimens (Hynes, 1970). Other authors indicated additional factors being responsible for density differences, such as substrate type (Gore & Judy, 1981), presence of (bank)vegetation, alkalinity (Armitage, 1958),

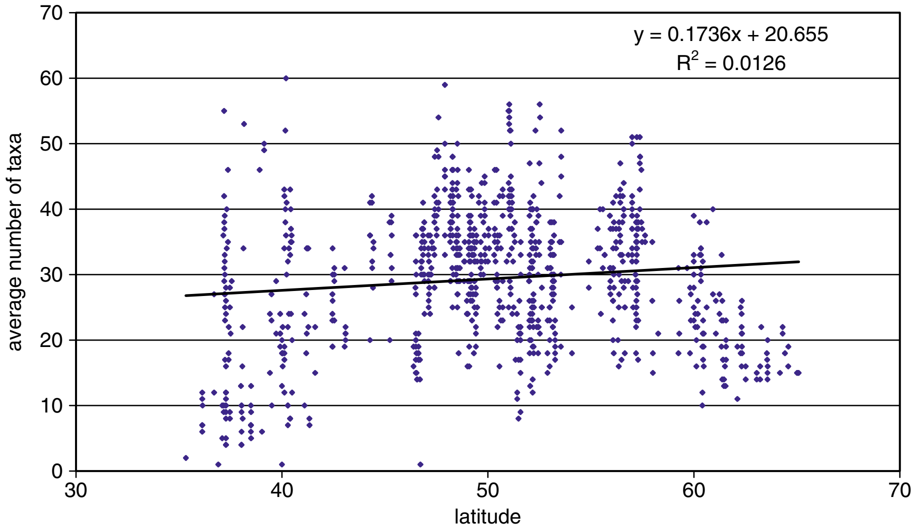

Figure 5. The average number of taxa per sample of the reference sites plotted against latitude.

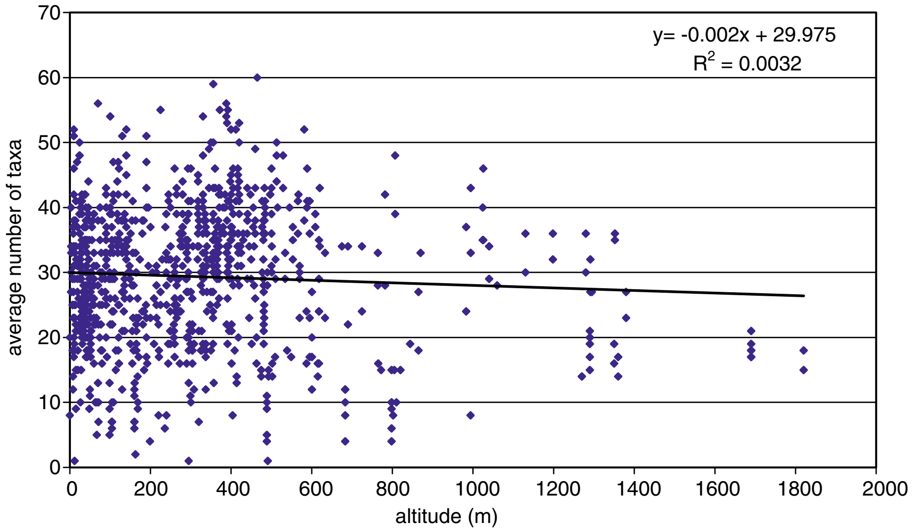

Figure 6. The average number of taxa per sample of the reference sites plotted against altitude.

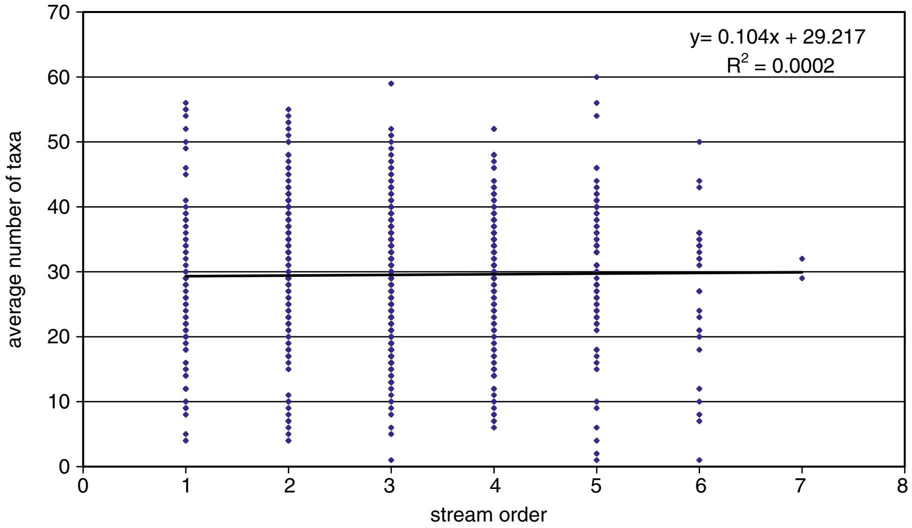

Figure 7. The average number of taxa per sample of the reference sites plotted against stream order.

pollution (Hynes, 1960), season, or biotic interactions (e.g., presence of fish). As only reference and good sites were included in this analysis, pollution can be excluded as a cause of variation. A high number of sites were sampled at least twice which excludes season. Plotting the average current velocity versus the average number of taxa (adjusted) no relation was shown ($R^2 = 0.05$) (Fig. 8). Similar results were observed for valley slope, a more general timeless parameter for potential current velocity ($R^2 = 0.01$; figure not shown). As all samples were taken by using a multihabitat sampling approach, all habitats present at a site were sampled. But the number of habitats present per stream can differ between types and as the specimens of most populations show irregular distributions, density estimates are always difficult (Statzner et al., 1998). As Hynes (1970) stated "by their very nature river beds are difficult to sample accurately", most probably this is also one of the major causes for the density differences found in this study.

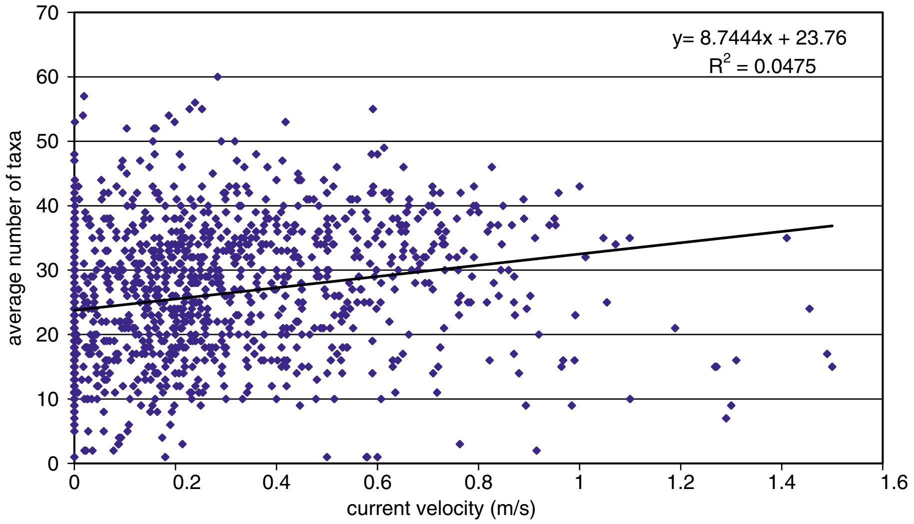

Figure 8. The average number of taxa per sample of the reference sites plotted against current velocity.

Reference or degraded samples in relation to taxonomical level

At the European level, the separation of the three major groups performed best for species-level data (±15%) (Table 3) in comparison with family-level data (±20%) (Table 3; see Verdonschot, this issue). Within the species data the datasets of reference samples and all samples scored even.

Within the major groups the overlap of species-level data was much smaller than that of family-level data: 2–4% vs. 7–9%, respectively. In both datasets the separation between groups of stream types was best using samples of reference sites:

Table 3. Percentage overlap of species-level (before /) and family-level data (after /) of samples from all sites, only reference sites, and only degraded sites for major groups, groups, sub-groups, and stream types (see Table 1)

Overlap for	Species data	All samples	Reference	Degraded
Major groups	Europe	15.1/20.2	15.1/20.1	15.6/17.0
Groups	Mountains	2.0/6.0	1.8/2.4	6.9/7.5
	Lowlands	8.0/12.3	3.8/11.7	4.6/12.6
	Mediterranean	0.5/8.3	0.1/7.8	0.2/5.6
	Average	3.5/8.9	1.9/7.3	3.9/8.6
Sub-groups	Northern European Mountains	6.7/7.5	8.8/7.4	13.5/13.5
	Central European Mountains	3.4/3.9	2.7/3.1	7.8/7.4
	Central and Eastern Mediterranean	5.0/20.8	1.1/10.9	4.5/16.4
	Western Mediterranean	0.0/0.0	0.0/2.8	0.0/4.5
	Northern Lowlands	3.1/8.8	0.0/2.0	0.0/4.1
	Central and Southern Lowlands	8.0/7.5	1.9/3.5	11.4/8.6
	Average	4.4/8.1	2.4/4.9	6.2/9.1
Stream types	Central Alps	1.2/2.4	0.0/2.1	5.4/2.7
	Boreal Highlands	5.0/3.3	0.0/3.6	0.0/3.1
	Central European Mountains (medium-sized)	9.4/3.1	6.9/0.0	5.7/0.0
	Northern Apennines	4.4/0.0	0.0/0.0	8.3/0.0
	Average	5.0/2.2	1.7/1.4	4.9/1.5
	Overall average	27.9/39.4	21.1/33.8	30.5/36.1

1.9% for species data vs. 7.3% for family data (Table 3). The separation between groups of samples was best in the major group Mediterranean based on species-level data but based on family-level data the major group Mountains showed the least overlap. In both species and family-level datasets, the major group Lowlands showed the greatest overlap. This is in concordance with the diverse distribution of samples in the ordination diagrams.

Within the groups the overlap of species-level data is much smaller than that of family-level data: 2–6% vs. 5–9%, respectively. Again, in both datasets the separation between groups of stream types was best in the reference samples: 2.4% for species-level data vs. 4.9% for family-level data (Table 3). For species-level data the group Northern Lowlands showed little overlap. The separation between groups of samples was best in the group Western Mediterranean, a group that even did not show any overlap in the species-level data. Most overlap was seen in the group Northern European Mountains for species-level data and in the group Central and Eastern Mediterranean for family-level data.

Within the sub-groups the overlap of family-level data was somewhat smaller than that of species-level data: 1–2% vs. 2–5%, respectively. Again, in both datasets the separation between groups of stream types was best in the reference sites: 1.7% for species-level data vs. 1.4% for family-level data (Table 3). The smallest overlap was shown in the sub-group Boreal Highlands for species-level data and in the sub-group Northern Apennines for family-level data.

In general, the degraded samples showed largest variation in overlap, whereby large overlap indicated a higher number of degraded samples.

Discussion

In this analysis taxonomic adjustment was done as well as downweighting of rare species. Both choices reduce the variation within the dataset. This was necessary to make all data mutual comparable but at the same time information got lost. One option would have been to redo the taxonomical adjustment after each DCA run per resulting group, e.g., after the first run the three major regions in Europe could be re-adjusted. The advantage is that each finer grouping would be based on more information. The disadvantage is that results would become uncomparable between different groupings within each major region as well as within all other groupings. The objective of this analysis was to compare groupings within Europe in a defined and comparable way. Therefore, all items discussed further on relate to the adjusted data and one should keep in mind that these were data were on the 'best achievable' overall European level, which is not always the species level.

Hierarchical grouping of stream types

Based on the AQEM data, Verdonschot & Nijboer (2004) concluded that the macroinvertebrate distribution over Europe appeared to be strongly related to geographical position. Stream types were hierarchically grouped over major regions, regions and local regions. The addition of the STAR research project data almost doubled the number of macroinvertebrate samples of European rivers. The analyses of this study showed that again three major groups were distinguished. This is in accordance with the AQEM results (Verdonschot & Nijboer, 2004), although each group was less restricted to specific geographical regions, for example the major group Lowlands which now included the Northern Lowlands, composed of the Scandinavian Lowlands and the more continental situated Baltic Province (Latvia), along with the sub-mountainous (atlantic) French area, the Po valley and the Hellenic Balkans. Thus, the term Lowlands with an average altitude of 130 m covered a wide and discontinuous area over Europe and can be better referred to as a low slope landscape, then as a geographical area of (North-Western) Europe. The Mountains, with an average altitude 481 m, included the sub-mountainous to alpine areas of Central and Northern Europe. This major group was less geographically restricted and more related to a steep slope landscape. The major group Mediterranean was solely restricted to the area with a Mediterranean sea climate and situated at lower altitudes with an average altitude of 313 m. The three major groups probably represent the major combination of geomorphological and/or climatological conditions of the sampled sites. The driving forces behind are most probably current (slope) and temperature.

Verdonschot & Nijboer (2004) divided the Mountains into Northern Scandinavia, and the high and low alpine regions. These three regions are much alike to the present groups of Northern European Mountains, Central Alps and Central European Mountains, respectively. These names better define the groups distinguished. The division between the Northern and both the Central European Mountains are most probably due to differences in climatological conditions. The Northern European Mountains and the Central Alps differ in altitude, which can be seen as differences in climatological and geomorphological or slope conditions. The Central European Mountains were separated into the small and the medium-sized streams; size or dimensions was probably the dividing factor.

The major group Mediterranean was divided according to the same scheme as presented by Verdonschot & Nijboer (2004). It could be taken into consideration to name the Western Mediterranean as the Mediterranean Lowlands or Atlantic Mediterranean due to the influence of the Atlantic climate and as it only refers to Portuguese sites not Spanish ones. The Central and Eastern Mediterranean could also be indicated as the Mediterranean Mountains, as the sites were all situated at higher altitudes. The differences with the Hellenic Balkans are the sub-continental climatological influences in the latter. The Western Mediterranean streams were divided in small- and medium-sized streams.

The major group Lowlands was separated into the Central and Southern Lowlands and the Northern Lowlands. This clearly deviates from the former Western and North-Eastern Lowlands (Verdonschot & Nijboer, 2004). This new grouping is probably due to differences in climatological conditions, caused by the inclusion of newly sampled lowland stream types all over Europe in the more flat or low slope areas in Europe. The stream type Western sub-alpine Mountains (F08) was classified among the Northern Lowlands, possibly due to the atlantic climatological conditions at somewhat higher altitude in this mountain area. The conditions are probably comparable to the climatological colder lowland areas of Southern Sweden and of the Baltic Province (Latvia), in combination with a lower slope that could cause comparable environmental circumstances. The latter two can be distinguished based on substrate composition. Another explanation could be a taxonomical composition or the identification level used of the Western sub-alpine Mountains sites that differ from the other Central European Mountains, as the French data did only lose 47% of their taxa due to species-level data adjustment. This means that these data more often were identified to higher taxonomical levels (genus or family).

The WFD stream typology descriptors were linked to ecoregion, catchment size class, geology of the catchment and altitude class. Ecoregion and altitude are both related to climate (temperature, precipitation) and geomorphology. Precipitation and geomorphology (especially slope) set the conditions for the streams current velocity and size. The latter is also directly linked to the catchment size. Finally, the geology is related to geomorphology, hydrology and chemistry of the stream. It is a question whether chemistry is of importance at the scales of this study with only using reference sites. But geology affects hydrology, e.g., calcareous mountains will be much drier then siliceous ones. This in its turn affects current velocity, permanency (not included in this study), and water temperature. All together the driving forces behind these descriptors are temperature, current velocity and stream size.

Several larger groups of stream types could not be further separated, e.g., the Central European Lowlands and the Central European Mountains with 11 and 10 types, respectively. This especially occurred in geographical areas where stream types that are situated close to each other were sampled. This is conform the River Continuum Concept (RCC) that states that stream communities can be viewed as continua consisting of mosaics of population aggregations responding to the gradient of physical factors formed by the drainage network (Vannote et al., 1980). The thought that communities gradually change along environmental gradients is not only true for gradients along one river, but this is also true along landscape gradients that run over different catchments. These gradients will not always change gradually and some gradients can be quite short and then even look abrupt. Where such changes occur communities will overlap and some species are found in neighbouring communities. In such situations these species produce transitional zones or ecotones (Sobolev & Utekhin, 1979; Park, 1948). Short gradients can also be found going uphill where the slope increases and climatological conditions become more and more extreme. Species turn-over along such a gradient will increase and transitions in species composition will occur.

The European landscape is a mixture of mountains and lowlands across two climatological gradients; one north–south from the tundra down to the Mediterranean climate, and one west–east gradient from the atlantic to the continental climate. Over this macro-mosaic the WFD stream type system is set as the basis for stream typology and the starting point for intercalibration. The study showed that the stream types using the WFD 'System A' descriptors are probably less useful at finer scales. Macroinvertebrates responded to the driving forces of the three major factors of temperature, slope and size. Thus, the stream typology should take these three parameters as a starting point. Next streams with comparable major environmental conditions can be mapped and reference conditions can be defined as such. These groups of streams will cross boundaries of stream types, as can be seen in Central European Mountains as well as in the Central European Lowlands, and will also cross boundaries of individual countries. For intercalibration refined analyses are needed, especially for large areas with comparable environmental conditions, to reach a more ecologically relevant typology. This will go beyond the current WFD descriptors of 'System A' for stream types.

Environmental variables and gradients

Despite a standardised protocol the environmental variables measured showed a scattered result. A number of variables was only measured in a restricted number of streams. This affected the interpretation of the data and made a direct gradient analysis approach less effective. Some stream types could clearly be distinguished and identified by their abiotic description while others were much harder to interpret. The results showed that more attention should be given to not only keep with the protocol but also include in a protocol only the relevant variables.

Going along some major European environmental gradients, i.e., latitude, elevation and stream order, each one of these did not cause large differences in taxon richness. This means that the problems of standardising the sampling protocol still can be a major cause of differences in data composition. On the other hand, such suggested gradients may not be existing?

Reference or degraded samples

One of the criticisms on the European stream typology of Verdonschot & Nijboer (2004) was the use of samples from reference as well as degraded sites to construct the typology. It is commonly accepted that stress will degrade a community and degraded communities of different stream types become more similar (e.g., Karr & Chu, 1999). Therefore, it was tested whether the use of reference sites would give better results. Indeed, the reference samples performed best which supports the hypothesis that human stress diminishes the natural differences between stream communities. The higher overlap in the degraded samples also indicates the higher number of degraded samples taken into account, e.g., Northern European Mountains, Central European Mountains and Central and Southern Lowlands (Table 3). This does not mean that all our samples consisted of completely undisturbed conditions (e.g., Nijboer et al., 2004). Human impact in Europe, especially in accessible areas such as the lowlands, goes back to far before medieval times. Still, samples of these recent reference conditions performed best and were most optimally separated. This underlines the basic principle of the WFD that European Member States are required to identify reference conditions for defining the reference community, setting the upper anchor for quality classification and expressing degradation as deviation from this upper anchor (Wallin et al., 2003).

Conclusions

The conclusion of this study were:

- Not all WFD abiotic descriptors for rivers appeared to be valid and fit biotic ones. Three

major parameters further divided the three major groups of stream types in Europe; climate (temperature), slope (current velocity) and stream size. Especially, the geographic descriptors (e.g., ecoregion) did not fit well. Thus, the WFD descriptors for stream types should be interpreted in such way that temperature, slope and stream size constitute the basic parameters to define stream types.
- Human stress diminishes the natural differences between stream communities and typologies should therefore be based on reference conditions.
- Neither temperature, nor elevation, stream order or latitudinal position is solely causes the differences in average numbers of taxa between the 1660 sites distributed over Europe.

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