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Beyond masses and blooms: the indicative value of oligochaetes

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Abstract

The European Water Framework Directive (WFD) defines a framework for assessing water bodies in Europe in the future. The conditions in the Directive impose a strong demand for "new" assessment systems. The AQEM project developed an assessment system for European streams using macroinvertebrates. Almost 900 samples were taken in about 400 streams covering 29 stream types distributed over eight countries. The role of the Oligochaeta within this European database was analysed. Almost half a million specimens of oligochaetes were collected in 772 samples. Eight families, 41 genera and 69 species were recorded, although identification emphasised the families Tubificidae and Naididae. Three countries identified oligochaetes to species level, most others restricted their identifications to easy identifiable taxa. Numbers of specimens, species, genera and families differed strongly between the countries due to method, although standardised, and taxonomic knowledge. About 50% of all collected oligochaete taxa had assigned biological and ecological indicator values for metric calculation in the AQEM assessment system. A further refinement of this indication list as well as increased coverage of oligochaete taxa was advised. Weighted averaging was used to evaluate the relation between oligochaete distribution and ecological quality class. It was concluded that when higher taxonomic levels are used in assessment, the quality evaluation results become biased. Furthermore, oligochaetes can tell us much more about the ecological status of streams than is commonly assumed. Differences in ecological optima among *Limnodrilus udekemianus*, *Ilyodrilus templetoni*, *Aulodrilus pluriseta*, *Nais communis*, and *Spirosperma ferox* are shown.

Introduction

Masses of tubifids cover mud bottoms, explosions of naidids hover in algal blooms; no wonder many people think of oligochaetes as indicators of pollution. But are those ambassadors representative of the whole Class Oligochaeta? In the European Water Framework Directive (WFD: European Commission, 2000), a European need and approach for surface water assessment is outlined. A main starting point in the assessment is the reference condition of a water type, which is a concept new to many European countries. The reference condition is proposed as the anchor point in assessment (European Commission, 2000). The difference between a current state of a test site and its reference is scaled in five classes and taken as quality measure. The WFD generated a strong demand for either "new" assessment systems fulfilling the WFD criteria or adaptation of existing systems to meet these criteria.

The project "The development and testing of an integrated assessment system for the ecological quality of streams and rivers throughout Europe using benthic macroinvertebrates (AQEM)" (AQEM consortium, 2002; Hering et al., 2004) developed a European stream assessment system, using macroinvertebrates and environmental variables. Macroinvertebrates were used because many well described and easily identifiable species are useful for detecting changes in the environment on the regional scale desired (Resh & Unzicker, 1975; Persoone, 1979). This is a consequence of their diverse systematic origins, the duration of their life cycles (ranging from a few weeks to a few years) and the diversity of habitats they occupy (Rosenberg & Resh, 1984).

Assessing the ecological quality of European streams requires a sound and well-established methodology. In the AQEM project a large number of biological measures or metrics were tested independently for 28 of the 29 sampled European stream types. This process resulted in up to 18 core metrics, which were combined into a different multimetric index in each country.

A metric approach is most often based on a list of taxonomic entities and their biological and ecological characteristics. Typically, a list includes attributes such as functional feeding groups or habitat indications for each species. Relationships between species and their biological and environmental requirements or interactions are commonly used in applied ecology but are generally not quantified. Furthermore, the relationship between a species and an environmental condition is often unimodal (Shelford, 1913; Thienemann, 1955), i.e. a species performs best at a particular value (optimum) and performs sub-optimally or cannot survive if the value becomes either too low or too high (Odum, 1971). Assessment metrics use this knowledge to assign an indicator value, in most cases the optimum for each species, and calculate a final score for a whole species list.

Several techniques have been developed to quantify the species optimum curve, like non-least-squares regression (Gauch et al., 1974), generalised linear models (McCullagh & Nelder, 1989), or weighted averaging (Gauch, 1982). Ter Braak & Looman (1986) demonstrated the advantages of using weighted averaging despite the fact that the absence of species is disregarded.

One can question whether these techniques are useful for the application of oligochaetes in assessment. Oligochaetes have played an important role in assessment, particularly in their mass occurrences under disturbed conditions (Kolkwitz & Marsson, 1909; Hamm, 1969; Aston, 1973; Verdonschot, 1989). Mass occurrences are not only restricted to sites with severe organic pollution, but are also reported under conditions of eutrophication (e.g. Milbrink, 1973; Verdonschot, 1996) and drought episodes (Verdonschot, 1995). Also it has been argued that relationships with other environmental factors should not be neglected, such as substrate (Wachs, 1967), depth (Newrkla & Wijegoonawardana, 1987), chloride (Verdonschot, 1984), acidity (Healey & Bolger, 1984) and heavy metals (Chapman et al., 1982). These kinds of environmental relationships are often not accounted for by the current metrics. Metrics very often are restricted to higher taxonomic units like Oligochaeta or Tubificidae. Two problems occur when using the current metrics:

Higher taxonomic levels neglect differences between species.

Metrics more often do not include indicator values of oligochaetes.

To test whether these two assumptions are true the following questions were addressed:

1. What ecological indicator values did oligochaetes have at the outset in the metrics used in the project AQEM?
2. How are oligochaete taxa distributed over ecological quality classes and, more specifically, major environmental variables?
3. How should water quality assessment use oligochaetes in the future and at which taxonomic levels?

Material and methods

Data collection

The AQEM assessment system was based on a stream typology using the criteria defined by the EU Water Framework Directive under "System A". "System A" descriptors are defined by ecoregions (according to Illies, 1978), the catchment area (small 10–100, medium 100–1000, large 1000–10,000, very large > 10,000 km^2), geology of the catchment (siliceous, calcareous, organic), and altitude (high > 800, mid-altitude 200–800, lowland < 200 m). Using these WFD descriptors in the eight participating countries (Germany, Austria, Czech Republic, Greece, Italy, Portugal, Sweden and the Netherlands) resulted in the selection of 28 stream types.

According to the guidelines on site selection, sampling strategy and processing as described in the AQEM manual (AQEM consortium, 2002; Hering et al., 2004), macroinvertebrate samples were taken during 2000 and 2001 in approximately 400 streams in eight countries (Fig. 1). Twenty-nine stream types of different quality classes were represented. Identification was made to species level when and where possible (AQEM consortium, 2002). Due to lack on taxonomic knowledge in certain areas or for certain groups, identification was sometimes limited to higher taxonomic levels.

All 889 macroinvertebrate and environmental samples were combined into one European database, from which the oligochaetes were extracted (Table 1). Oligochaete taxa lists were adjusted to minimise differences in taxonomic resolution between countries, following the ideas for taxonomic adjustment given in Nijboer & Verdonschot

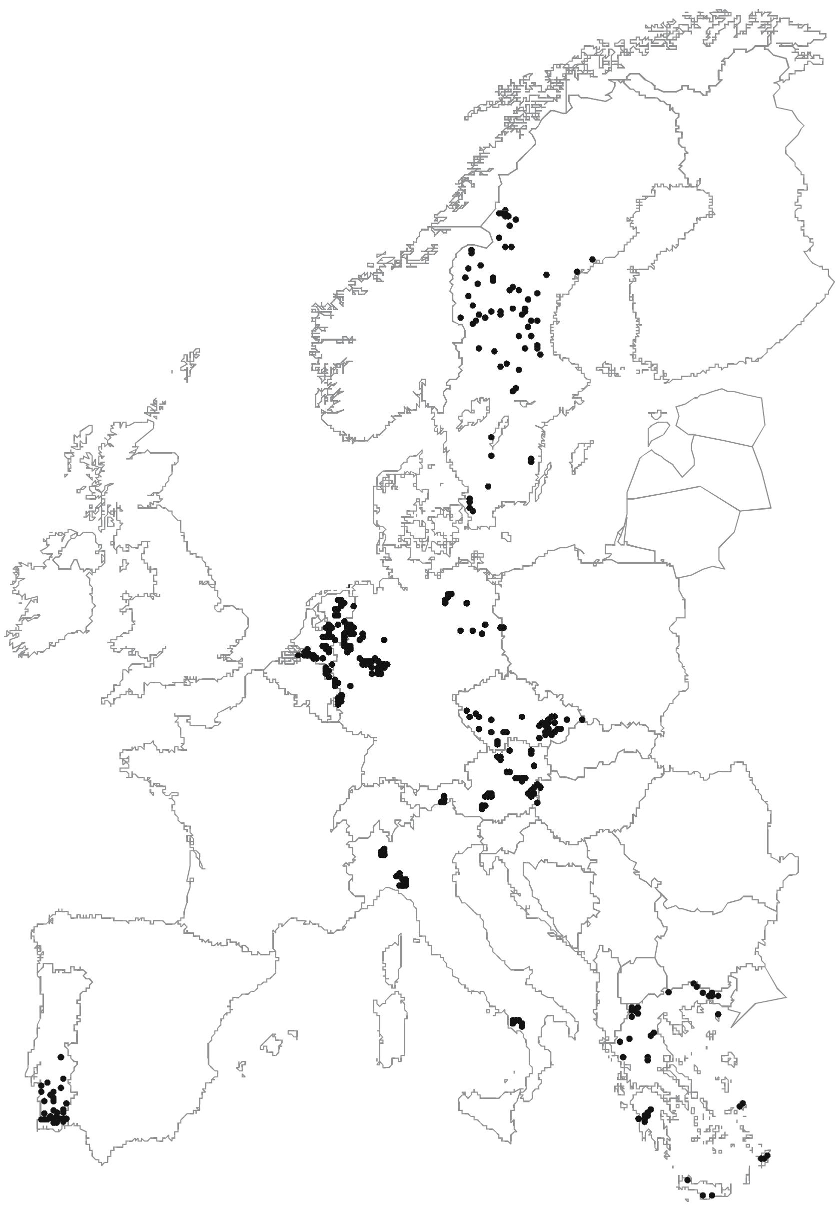

Figure 1. Distribution of the sampling sites over Europe.

Table 1. The composition of the oligochaetes present in the European AQEM database

	Samples	Oligochaete taxa	Specimens	Families	Genera	Species
Number	772	101	438,832	8	41	69

(2000), Schmidt-Kloiber & Nijboer (2004) and Vlek et al. (2004).

At each sampling site a large number of environmental parameters were recorded using a standardised "site protocol". The site protocol included 222 parameters (AQEM consortium, 2002). Environmental parameters were standardised and those variables that were measured at less than 2.5% of the sites were removed. Finally, 189 variables were included in the analysis. Two sites had too few variables measured to be included. The stream types were defined according to the WFD "System A" descriptors. The multimetric AQEM assessment system (Hering et al., 2004) was used to classify each site into an ecological quality class (EQC) ranging from 5 (high quality) to 1 (bad quality). Ultimately, the stream types and ecological quality classification were used to test the oligochaete distributions.

Autecological information

A large number of metrics (Table 2) were studied in the AQEM project. A number of these metrics, such as feeding types and microhabitat or current velocity preferences, require scores for the taxa. Therefore, an autecological database was generated to include this information. In order of priority, the autecological information was taken from Moog (1995), Schmedtje & Colling (1996), Verdonschot (1990), Van der Hoek & Verdonschot (1994), and additional information collected by the AQEM consortium. A distinction is made between those metrics based on taxonomic information only and those using autecological information for the individual taxa. The current indicator values of these individual taxa of oligochaetes of metrics were analysed.

Saprobity was classified using three different metrics: the old German saprobic index, the new German saprobic index and the saprobic index according to Zelinka & Marvan (1961). These three metrics represent the development of saprobic metrics over time.

Concerning the feeding type, the majority of oligochaetes were classified as gatherer-collecters; this included most tubificids. Smaller groups included grazer-scrapers (most naidids), and one predator (*Chaetogaster*).

Indicative value of oligochaetes

The AQEM assessment system (Hering et al., 2004) results, after a country specific multimetric calculation, in a final EQC score. This score runs from 1, low quality, up to 5, high quality. Gaussian response curves were estimated using weighted averaging (program C2 (Juggins, 2003)) and N_2 weighted standard deviations (Ter Braak & van Dam, 1989) to establish the distribution range of oligochaetes over ecological quality classes. Weighted averaging summarises a unimodal response curve for each species. Two parameters are of interest: u = the optimum or mode for each species along the environmental gradient under study, and t = the tolerance of the species to the environmental variable. The calculations were done at family, genus and species level.

Optima and tolerances were also calculated for selected environmental variables. Therefore, first a Detrended Canonical Correspondence Analysis (DCCA) (Ter Braak, 1987), as part of the program CANOCO for Windows version 4.0 (Ter Braak & Šmilauer, 1998), was executed. DCCA is a direct ordination technique, which means that the environmental variables are directly related to the species composition at the sites. The ordination axes in DCCA were calculated as linear combinations of the environmental variables. The option down-weighting of rare species was used to emphasise more commonly distributed species.

DCCA was performed for two different data matrices: one with eight families (including both the total Oligochaeta as well as total Tubificidae and Tubificidae with and without hair setae) and one with only species included. As the program calculates optima and tolerances independently for each taxon, this overlap in input did not affect the results.

Table 2. AQEM metrics including oligochaetes

Ecological preference type	Metric	Taxonomic level
Ecological preference based metrics		
Saprobity	Saprobic index (Zelinka & Marvan in five classes)	Species
	German saprobic index (old version in four classes)	Species
	German saprobic index (new version in four classes)	Species
	Dutch saprobic index	Species
	Czech saprobic index	Species
	Biological monitoring working party (BMWP)	Class
Acidity	Acid class (according to Braukmann in four classes)	Species
	Acid index (Hendrikson & Medin)	Species
Zonation	Zonation (percentage of community preferring a certain zone in 10 classes with an additional index)	Species
Current	Current preference (percentage of community preferring a certain current velocity in seven classes)	Species
Microhabitat	Microhabitat preference (percentage of community preferring a certain microhabitat in eight classes)	Species
Feeding	Feeding types (percentage of community in nine classes)	Species
	RETI (Rhithron feeding type index)	Species
Locomotion	Locomotion type (percentage of community in six classes)	Species
Taxonomy based metrics		
	Abundance [ind m^{-2}]	Species
	Number of taxa	Species
	Average score per taxon (ASPT)	Class
	BMWP (Spanish version)	Class
	Danish strema fauna index (DSFI in two classes)	Family
	Belgian biotic index (BBI)	Family
	Indice biotico esteso (IBE in two classes)	Family
	Altered indice biotico esteso (IBE AQEM)	Family
	Diversity (Simpson index)	Species
	Diversity (Shannon–Wiener index)	Species
	Diversity (Margalef index)	Species
	Evenness	Species
	German fauna index (in five classes)	Species
	Portuguese index	Class
	Taxonomic group [%] (calculated for 30 groups)	Class
	Taxonomic group (number of taxa) (calculated for 32 groups)	Class
	Taxonomic group (abundance) (calculated for 32 groups)	Class
	Number of families	Family
	Number of genera	Genus

The taxonomic level in the respective measures is indicated (for reference see Hering et al., 2004).

Results

Data composition

Number of samples, number of oligochaete taxa, and number of individuals differed strongly between countries (Table 3). Germany sampled the most sites and Greece the least. The highest average number of oligochaete taxa was found in Austria, the lowest average number in Sweden. The highest average number of oligochaete specimens was collected in Austria, and the lowest number in Greece.

Table 3. Numbers of samples, average number of oligochaetes as well as of individuals per country per sample

Country	Number of samples	Average number of taxa	Average number of individuals
Austria	94	6.1	2394
Czech Rep.	70	5.6	591
Germany	144	3.0	27
Greece	30	1.6	3
Italy	130	2.8	316
Netherlands	149	5.7	426
Portugal	38	3.9	1590
Sweden	117	1.0	30
Total/average	772	3.7	672

Table 4. The identification level of the Oligochaeta in each country

Country	Number of oligochaetes			
	Oligochaete taxa	Families	Genera	Species
Austria	56	8	26	43
Czech Repub.	43	7	24	32
Germany	12	7	5	3
Greece	12	5	10	0
Italy	29	7	15	14
Netherlands	52	6	21	39
Portugal	13	5	8	6
Sweden	1	1	0	0

From looking at the identification level of the Oligochaeta in each country, it becomes clear that differences are large (Table 4). Austria, the Czech Republic and the Netherlands identified a high number of taxa, in contrast to Sweden, which only identified to the Class Oligochaeta. Germany, Greece and Portugal mainly restricted themselves to family and genus level.

The total number of individuals for the Oligochaeta, as well as for each of the oligochaete families, was extremely low in Greece, and relatively low numbers were collected in Sweden and Germany (Table 5). The numbers in Austria were extremely high.

Species level identification was done only in the Czech Republic, Austria and the Netherlands (Table 6). This concerned mainly species belonging to the families Lumbiculidae, Naididae and Tubificidae. These different features of oligochaete taxa and numbers in the European AQEM database surely affected the analysis results.

Autecological information

The AQEM autecological database contained 103 oligochaete taxa (Table 7). The available biological and ecological information was analysed for each metric. Metric values were available for about 50% of the taxa, except in the case of acidity with only 2% available, and feeding type with 90% available. The feeding type showed a very restricted distribution (Fig. 2). Though 90% of the oligochaete taxa are classified by feeding type, most appear to belong to the functional feeding

Table 5. Number of specimens per class and family of Oligochaeta in each country

Class/family	Austria	Czech Republic	Germany	Greece	Italy	Netherlands	Portugal	Sweden	Total number
Oligochaeta total	969		607		6	845		3529	5956
Enchytraeidae	4533	137	110		371	617			5768
Glossoscolecidae							53		53
Haplotaxidae	39	100	31	20	27				217
Lumbricidae	164	179	251	2	1122	278	474		2470
Lumbriculidae	9751	5131	1671	33	2052	7745	29		26,412
Naididae	70,102	4275	431	23	1297	2890	51,645		130,663
Propappidae	17,466	191							17,657
Tubificidae	121,968	31,382	748	5	36,243	51,073	8217		249,636
Total number	224,992	41,395	3849	83	41,118	63,448	60,418	3529	438,832

Table 6. Number of genera and species per oligochaete family in each country

Country	Number of	Haplotaxidae	Enchytraeidae	Propappidae	Naididae	Tubificidae	Lumbriculidae	Lumbricidae
Austria	Genera	1	5	1	7	7	4	1
	Species	1	3	1	19	14	4	1
Czech Republic	Genera	1	5	1	5	8	3	1
	Species	1	3	1	10	12	4	1
Germany	Genera					1	3	1
	Species						2	1
Greece	Genera	1			3	1	5	
	Species							
Italy	Genera	1	7		2	3	1	1
	Species	1	4		5	2	1	1
Netherlands	Genera		2		7	8	3	1
	Species		1		17	17	3	1
Portugal	Genera				5	1	1	1
	Species				3	1	1	1
Sweden	Genera							
	Species							

Table 7. Information content for 103 oligochaete taxa present in the AQEM autecological database

Ecological preference type	Number of classes	Number of indicators	% of oligochaetes with scores	Average score	Standard deviation
Zonation class	10	50	49		
Microhabitat type	8	65	63		
Saprobic index					
Old German index	1	4	4	3.28	0.21
New German index	1	18	17	3.04	0.62
Zelinka & Marvan	7	58	56	2.25	0.59
Current velocity class	7	53	51		
Acidity class	1	2	2	3.5	0.71
Functional feeding group	10	90	87		
Locomotion type	6	57	55		

category "gatherer–collector". This may be true for a number of tubificids, but it is doubtful for a number of naidids. Furthermore, most oligochaetes according to this approach belong to the locomotion categories burrower or sprawler (Table 8).

The oligochaetes in general showed a saprobic improvement when comparing the average score for taxa present using the old German saprobic index with that in the new one. This is because the old German saprobic index included mainly a few polysaprobic taxa, while the new one included a much higher number of taxa, including some with a meso- to oligosaprobic indication. Looking at the Zeklinka & Marvan scores, the number of taxa with saprobic valence scores in the oligo-saprobic plus beta-mesosaprobic classes appeared to be higher than the sum of those in the alpha-mesosaprobic and polysaprobic classes (Fig. 3). The average score shows that some taxa had a much lower saprobic valence in the old indices.

The number of oligochaete taxa preferring stagnant or slow flowing waters is much higher then those restricted to fast flowing ones (Fig. 4). The taxa were more evenly distributed over the microhabitat types (Table 8) as well as over the different river zones (Table 8).

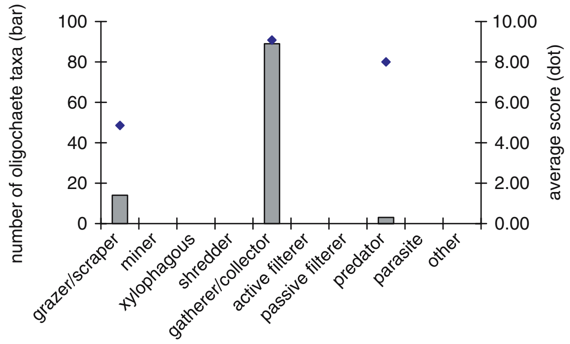

Figure 2. The number of oligochaete taxa in each functional feeding group and the average functional feeding score as present in the AQEM database.

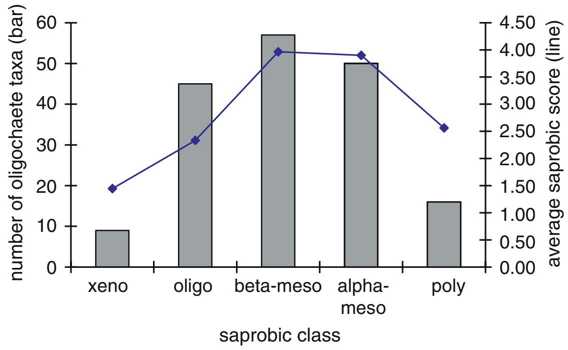

Figure 3. The number of oligochaete taxa in each saprobic class and the average saprobic index score per saprobic class, both according to Zelinka & Marvan (1961) as present in the AQEM database.

Table 8. Number of oligochaete taxa present in the AQEM autecological database with indications for locomotion type, zonation class and microhabitat type

	Number of taxa	Average score	Standard deviation
Locomotion type			
Swimming/diving	17	–	–
Burrowing/boring	31	–	–
Sprawling/walking	37	–	–
(Semi)sessil	8	–	–
Other	2	–	–
Zonation class			
Eukrenal	7	1.29	0.76
Hypocrenal	10	1.40	0.84
Epirhithral	23	1.22	0.52
Metarhithral	31	1.32	0.48
Hyporhithral	40	1.48	0.55
Epipotamal	47	1.87	0.71
Metapotamal	45	1.69	0.67
Hypopotamal	29	1.21	0.49
Litoral	45	2.00	0.85
Profundal	31	1.94	0.89
Microhabitat type			
Pelal	47	3.09	1.56
Argyllal	9	2.56	0.53
Psammal	43	3.19	1.40
Akal	21	2.19	1.03
Lithal	27	2.04	1.51
Phytal	35	3.71	2.58
POM	25	2.04	2.95
Other	5	1.80	1.10

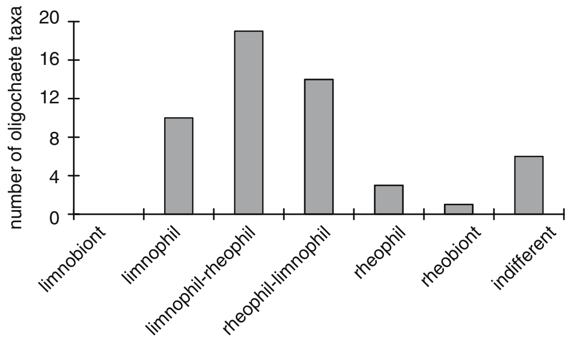

Figure 4. The number of oligochaete taxa in each current velocity class as present in the AQEM database.

All metrics based on ecological preferences included information on oligochaetes. The taxonomy based metrics mostly included oligochaetes, either as class or as family, except for one that included genus and one that included species level.

Indicative value of oligochaetes

In total 772 samples from the AQEM database were used, to establish the relation between oligochaetes and the EQC according to the AQEM assessment system. Plotting the number of oligochaete taxa found at each site against its final EQC, there appeared to be no relationship at all (Fig. 5). Up to 12 oligochaete taxa per sample can be found in each EQC.

However, by taking the abundances into account a clear trend becomes visible (Fig. 6). The better the ecological quality becomes, the less abundant the oligochaetes get.

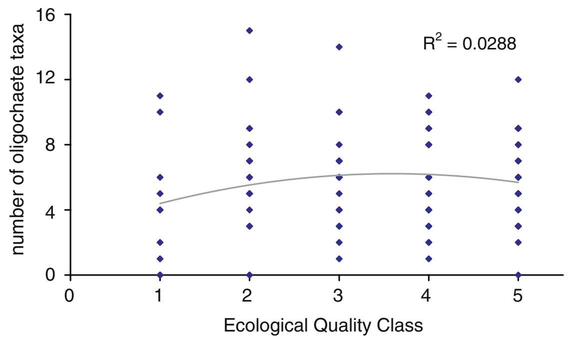

Figure 5. The number of oligochaete taxa per sample plotted against the ecological quality class (ranging from 1 = bad to 5 = high) according to the AQEM assessment system.

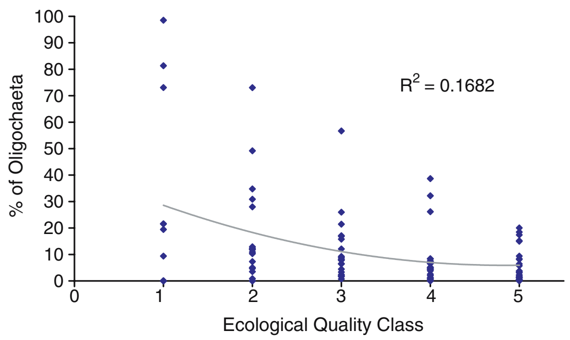

Figure 6. The percentages of oligochaete specimens per sample plotted against the ecological quality class (ranging from 1 = bad to 5 = high) according to the AQEM assessment system.

The average number of individuals of five selected oligochaete species (namely, *Limnodrilus udekemianus*, *Ilyodrilus templetoni*, *Aulodrilus pluriseta*, *Nais communis*, and *Spirosperma ferox*) each representing one EQC, plotted against the EQC, illustrates a clear distribution pattern (Fig. 7). This gradient in distribution along EQC's is a good example of the wide distribution of oligochaetes over the ecological quality gradient.

Table 9 includes the optima and tolerances for family, genus and species level of all oligochaetes. The table shows the differences between oligochaete taxa with respect to ecological quality. In general, the Oligochaeta prefer EQC two, but at the family level there is a difference between the Tubificidae, preferring a quality lower than two, up to the Propappidae with a class four preference. The same tendency is true for the individual genera and species (Table 9). Thus, in general, identifying oligochaetes at a higher taxonomic level obscures

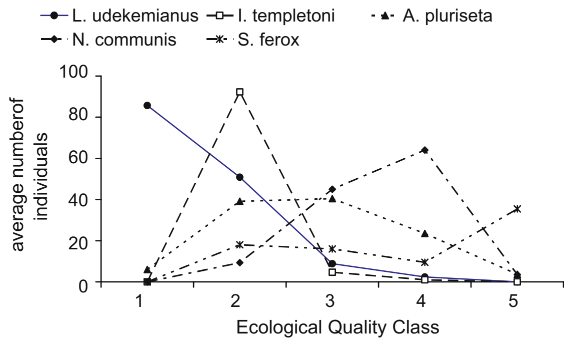

Figure 7. The average number of individuals of five selected oligochaete species, *Limnodrilus udekemianus* (20 samples), *Ilyodrilus templetoni* (11 samples), *Aulodrilus pluriseta* (43 samples), *Nais communis* (22 samples), and *Spirosperma ferox* (14 samples), plotted against the ecological quality class according to the AQEM assessment system.

real ecological differences at the species level. The distinction between Tubificidae with and without hair setae did not show a clear difference.

At family level the DCCA ordination showed a gradient running from families occurring in fast running streams with steep slopes (Haplotaxidae, Enchytraeidae, Propappidae) down to slow flowing, eutrophic streams with low slopes (Tubificidae) (Fig. 8). The same gradient was seen for the ordination at genus level, and is therefore not shown. Also, the species level shows a comparable pattern (Fig. 9). From the DCCA ordination, analysis two major explanatory variables were selected: altitude, representing gradients in current, slope and temperature, and total phosphorus concentration, representing organic pollution and eutrophication gradients. The optima and tolerances for family, genus and species levels with respect to altitude and total phosphorus illustrate that oligochaetes vary individually along each gradient; thus each taxon shows its own characteristic response (Table 9).

Discussion

The AQEM project was based on a standard procedure of sampling, sorting and identification. Despite the use of these standardised field protocols and guidelines, the number of taxa, the number of specimens and the taxonomic resolution for the Class Oligochaeta differed among

Table 9. The optima and tolerances of the ecological quality class (EQC), altitude (m) and total phosphate [t-P μg/l] for families, genera and species

Taxonname	EQC		Altitude		t-P	
	Optimum	Tolerance	Optimum	Tolerance	Optimum	Tolerance
Class/family						
Oligochaeta	2.24	1.16	232	182	440	746
Tubificidae	1.79	0.97	175	104	505	583
Tubificidae with hair setae	1.94	1.00	152	117	425	641
Tubificidae without hair setae	1.78	0.94	166	108	604	736
Naididae	2.49	0.99	280	207	426	1093
Enchytraeidae	3.30	1.51	583	388	128	255
Lumbriculidae	3.38	1.07	306	231	247	418
Lumbricidae	3.56	1.20	249	221	268	570
Glossoscolecidae	3.62	1.12	149	86	229	570
Haplotaxidae	3.71	1.37	402	248	498	612
Propappidae	4.11	0.93	473	219	59	70
Genus						
Aulodrilus	2.62	0.69	158	213	183	503
Bothrioneurum	2.81	0.72	335	117	1353	130
Branchiura	3.00	0.94	88	25	25	347
Bythonomus	3.66	0.81	250	37	141	62
Cernosvitoviella	3.90	1.07	989	233	18	16
Chaetogaster	3.41	0.73	286	156	110	156
Cognettia	4.13	1.04	566	255	42	174
Dero	2.37	0.93	44	60	557	1252
Eiseniella	3.27	1.07	267	251	417	776
Enchytraeus	4.62	1.39	451	118	380	526
Fridericia	3.25	1.31	853	334	61	163
Haplotaxis	4.16	0.85	435	255	532	642
Henlea	3.01	1.08	901	180	22	24
Ilyodrilus	2.02	0.21	12	6	112	64
Lamprodrilus	5.00	0.94	1380	141	44	347
Limnodrilus	1.60	0.92	194	92	677	791
Lumbricillus	3.53	1.09	590	298	611	714
Lumbriculus	2.84	0.99	73	92	119	207
Marionina	2.88	1.31	865	163	24	20
Mesenchytraeus	3.90	1.47	1056	234	47	185
Nais	2.62	1.07	340	205	526	1178
Ophidonais	2.07	0.61	115	72	174	869
Pachydrilus	2.00	0.94	240	141	34	347
Piguetiella	4.00	0.94	420	141	1120	347
Potamothrix	1.32	0.80	201	70	583	661
Pristina	3.42	0.95	252	179	205	182
Pristinella	3.11	0.47	252	114	149	78
Propappus	4.11	0.93	473	219	59	70
Psammoryctides	2.19	1.12	202	121	792	997

Continued on p. 137

Table 9. (Continued)

Taxonname	EQC		Altitude		t-P	
	Optimum	Tolerance	Optimum	Tolerance	Optimum	Tolerance
Quistodrilus	1.83	0.71	3	2	170	82
Rhyacodrilus	2.70	1.09	203	235	803	656
Rhynchelmis	3.69	0.98	478	132	20	62
Slavina	3.27	0.84	128	134	142	70
Specaria	2.15	0.63	330	11	38	19
Spirosperma	4.47	1.11	376	70	485	824
Stylaria	1.94	0.94	26	50	142	433
Stylodrilus	3.58	1.07	370	222	270	452
Trichodrilus	3.22	1.36	290	273	467	439
Tubifex	1.42	1.00	172	89	421	455
Uncinais	2.00	0.94	19	141	260	347
Species						
Aulodrilus japonicus	2.63	0.68	162	223	103	64
Aulodrilus limnobius	3.00	0.94	30	141	160	347
Aulodrilus pluriseta	2.57	0.82	135	177	659	1175
Bothrioneurum vejdovskyanum	2.81	0.72	335	117	1353	130
Branchiura sowerbyi	3.00	0.94	88	25	25	347
Bythonomus lemani	3.66	0.81	250	37	141	62
Cernosvitoviella atrata	3.09	1.01	833	36	20	13
Chaetogaster cristallinus	3.00	0.94	215	141	165	347
Chaetogaster diaphanus	3.80	0.71	339	226	44	22
Chaetogaster diastrophus	1.67	1.41	410	445	719	604
Cognettia sphagnetorum	4.22	1.02	510	215	28	12
Dero digitata	2.67	0.92	17	14	166	72
Dero obtuse	1.71	0.89	24	14	133	66
Eiseniella tetraedra	3.27	1.07	267	251	417	776
Enchytraeus albidus	1.00	0.94	230	141	1560	347
Fridericia striata	4.00	0.94	225	141	330	347
Haplotaxis gordioides	4.29	0.75	455	253	559	674
Ilyodrilus templetoni	2.02	0.21	12	6	112	64
Limnodrilus claparedeanus	2.18	0.82	161	85	389	413
Limnodrilus hoffmeisteri	1.57	0.96	190	100	607	864
Limnodrilus profundicola	1.08	0.93	185	96	334	55
Limnodrilus udekemianus	1.71	0.81	183	71	386	230
Lumbricillus lineatus	2.00	0.94	8	141	70	347
Lumbricillus pagenstecheri	4.08	1.26	361	39	1184	358
Lumbriculus variegatus	2.83	0.98	71	84	119	208
Marionina argentea	3.00	0.94	835	7	43	30
Marionina riparia	3.27	1.10	885	271	17	5
Mesenchytraeus armatus	3.87	1.49	1076	198	19	21
Nais alpina	3.44	0.90	549	185	23	47
Nais barbata	1.12	0.75	234	37	642	141
Nais behningi	2.37	0.71	6	1	79	18
Nais bretscheri	2.70	1.31	278	197	221	248

Continued on p. 138

Table 9. (Continued)

Taxonname	EQC		Altitude		t-P	
	Optimum	Tolerance	Optimum	Tolerance	Optimum	Tolerance
Nais communis	2.90	0.77	301	352	75	100
Nais elinguis	1.85	0.99	209	61	433	493
Nais pardalis	2.32	0.78	21	8	250	120
Nais pseudobtusa	1.00	0.45	193	18	346	41
Nais simplex	2.05	0.85	167	105	1141	487
Nais stolci	2.82	1.08	487	162	13	12
Nais variabilis	2.10	0.99	242	219	42	46
Ophidonais serpentina	2.07	0.61	115	68	174	869
Pachydrilus subterranus	2.00	0.94	240	141	34	347
Piguetiella blanci	4.00	0.94	420	141	1120	347
Potamothrix bavaricus	1.00	0.05	192	1	614	228
Potamothrix hammoniensis	1.66	1.13	219	118	716	1119
Potamothrix moldaviensis	1.32	1.08	191	31	356	110
Pristina aequiseta	3.00	0.94	215	141	214	10
Pristina amphibiotica	2.38	0.65	67	74	96	74
Pristina bilobata	3.16	0.71	266	231	198	57
Pristina foreli	3.61	1.28	295	47	73	48
Pristina longiseta	3.94	1.41	334	84	119	188
Pristina menoni	4.00	0.94	260	141	129	347
Pristina rosea	4.00	0.94	215	141	108	347
Propappus volki	4.11	0.93	473	219	59	70
Psammoryctides barbatus	2.19	1.12	202	121	792	997
Quistodrilus multisetosus	1.83	0.71	3	2	170	82
Rhyacodrilus coccineus	3.30	1.00	153	145	297	343
Rhyacodrilus falciformis	2.16	1.22	248	515	1255	355
Rhyacodrilus subterraneus	2.00	0.94	31	141	189	347
Rhynchelmis limosella	4.25	0.71	138	304	315	559
Slavina appendiculata	3.27	0.84	128	134	142	70
Specaria josinae	2.15	0.63	330	11	38	19
Spirosperma ferox	4.47	1.11	376	70	485	824
Stylaria lacustris	1.94	0.94	26	50	142	433
Stylodrilus brachystylus	4.54	0.69	449	127	34	27
Stylodrilus heringianus	3.27	1.01	340	244	281	491
Stylodrilus parvus	4.43	0.86	338	100	695	315
Tubifex ignotus	2.01	0.32	194	88	176	124
Tubifex tubifex	1.42	1.00	172	89	423	456
Uncinais uncinata	2.00	0.94	19	141	260	347

countries. Knowledge of Oligochaeta appeared to be sparsely distributed and depended on the presence of specialists in the respective countries. Therefore, the results presented were biased by the samples from Austria, the Czech Republic and the Netherlands, in which oligochaetes were carefully processed and identified to the species level. This, for example, explains the importance of altitude and total phosphorus as explanatory variables.

That oligochaetes play an important role in the stream ecosystems becomes clear from the number of individuals of Oligochaeta collected throughout

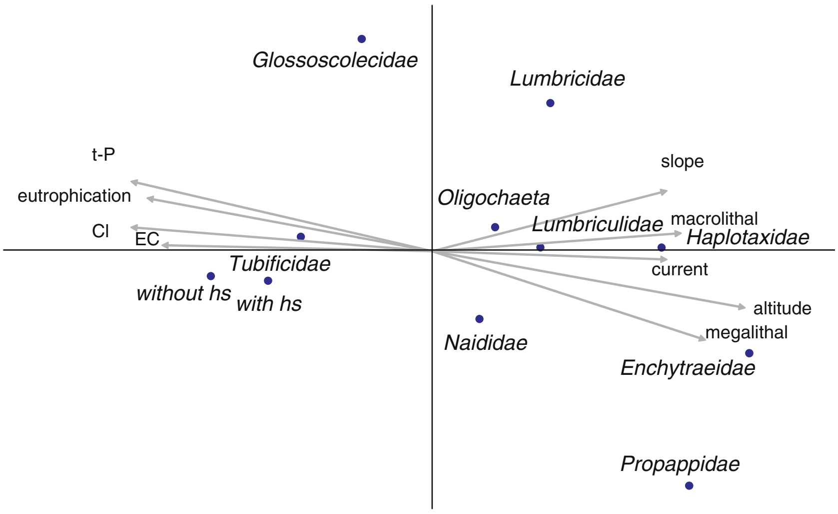

Figure 8. DCCA ordination diagram of the axis 1 and 2 of the families of oligochaetes (hs = hair setae).

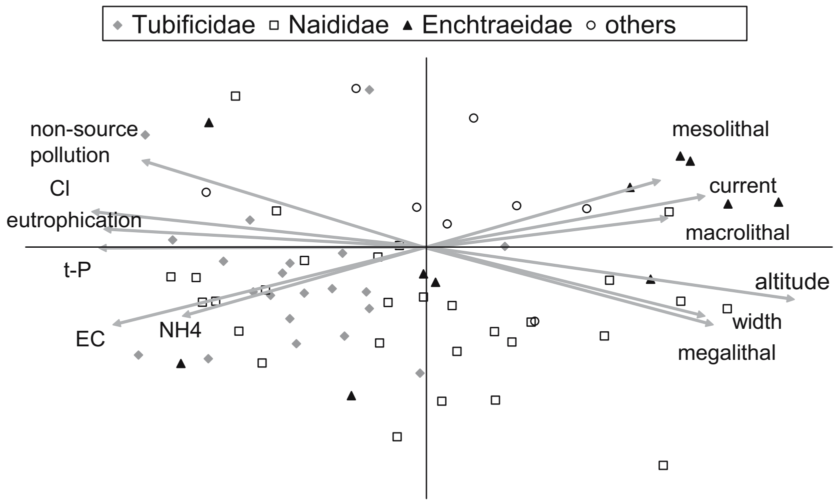

Figure 9. DCCA ordination diagram of the axis 1 and 2 of the species, grouped and indicated by family label, of oligochaetes.

the project, about half a million. Oligochaetes are known to occur in all kinds of aquatic habitats all over Europe (Brinkhurst & Jamieson, 1971; Timm, 1999), which argues for taking this organism group much more seriously in assessments.

The composition of a stream community is the result of the interaction of environmental and biological factors. The explanation of the distribution of oligochaetes is often based on environmental data, without regard to biological interactions. Nevertheless, the use of biological and ecological information from an autecological database would improve the usability of oligochaetes in assessment. The AQEM autecological database is an example of such. Two biological traits were explored: feeding type and locomotion type. The classification of functional feeding groups according to Merrit & Cummins (1984) was used in the AQEM autecology database. This is equivalent to the classifications by Juget & Lafont (1994) and Moog (1995). But, although most oligochaetes have comparable feeding mechanisms, their food and food preferences show subtle differences (Brinkhurst et al., 1972;

McMurtry et al., 1983; Rodriguez et al., 2001). The ecological meaning and applicability of such differences need further attention.

The locomotion type of oligochaetes appeared to be less distinctive, and values assigned to the species show little variation. Nevertheless, Sperber (1950) previously classified the naidids into 10 locomotion types based on tube and free living species that either do not swim or move, or swim with different movements. It is still a question what the ecological meaning of these categories is, but again more knowledge is needed and should be included in the autecological database. Laboratory observations and experiments could reveal the ecological significance of these groups.

The ecological information strongly focused on the indication of organic pollution. From a historical point of view this is not surprising. It is already long known that oligochaetes are primarily related to organic pollution because they use readily degradable organic matter as food (e.g. Uzunov, 1979; Milbrink, 1980). The differences between the old saprobic index, the new saprobic index and the saprobic valence reflect the development of knowledge in this field. Although Kolkwitz & Marsson (1909) indicated that different species not only preferred polysaprobic, but also β-, α-, and oligosaprobic conditions, it took almost a century for this information to be adopted in assessment. The assumption of Lafont (1985) that the water quality responses of Tubificidae with and without hair setae would differ is not supported by these findings, because optima of both groups were in the same EQC.

The ecological indications for current velocity are in line with the expectations. Most oligochaetes generally prefer standing or slow flowing conditions (Korn, 1963). The equal class distribution of oligochaetes across microhabitats and river zones is also confirmed by other authors. Lazim & Learner (1987) showed that the distribution of tubificids was determined by the physical nature of the substratum, and that species preferences differ. The phytal preferences of naidids were shown by Verdonschot (1987, 1989) and Kairesalo & Koskimies (1987). In general, the sampling techniques used in the foregoing studies are an important question. If mixtures of habitats were sampled, which is often the case, the results can be biased. It is therefore of great importance to study the microhabitat needs of oligochaetes.

The ecological indications included in the AQEM autecological database could be extended for most oligochaete taxa, and possibly in some cases a refinement of categories can be taken in consideration, e.g. locomotion types. Furthermore, attention is needed for the acidity preference of most oligochaetes, as such information is lacking.

The altitude – eutrophication gradient shown in the analysis is strongly influenced by the countries where the samples were taken. The Netherlands mainly consist of lowland streams that are more or less eutrophied (Verdonschot, 1999), in strong contrast to the Czech Republic and Austria, which are represented by mountain streams with much lower nutrient concentrations.

Outlook

Mass developments and blooms of oligochaetes have long been used as indicators either for organic pollution or eutrophication. That oligochaetes can tell us more about the condition of a stream is illustrated by the distribution of different taxa over the ecological quality classes. The European WFD has asked for a diagnostic tool to evaluate water quality. Diagnosis is necessary not only to assess quality, but also to indicate potential measures for recovery or restoration. Ecologists should therefore develop techniques that can tell a manager more than just a limited five class system of assessment valuation. Ecologists should extract detailed information from the species they collect in order to precisely determine the condition of a site. These results clearly show the need of using species rather than higher taxonomic levels in assessment. This information should be the basis for management advice. To be able to extract detailed information from a species list, knowledge on the niche requirements of each of the respective species is necessary. Oligochaetes are an important part of the aquatic community, they can be found everywhere, comprise a large part of the secondary productivity and play a vital role in the food chain. Thus, oligochaetes should become an important diagnostic tool for aquatic ecologists.

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