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Environmental monitoring in Baden-Württemberg with special reference to biocoenotic trend-monitoring of macrozoobenthos in rivers and methodical requirements for evaluation of long-term biocoenotic changes

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Abstract

Biomonitoring methods from a comprehensive study of man-made impacts on urban and on the near-natural environment are presented. Part of the environmental monitoring in Baden-Württemberg is a biocoenotic trend-monitoring project on macrozoobenthos in running waters which has resulted in a database enabling long-term trend assessment of biocoenosis in diverse rivers and streams in the future. About 561 species of macrozoobenthos have been recorded (21 species for the first time in Baden-Württemberg). Data are analysed for different purposes: methodological requirements for aquatic trendbiomonitoring, status of endangerment according to the Red Data Book, and first assessment of faunistic long-term changes in the River Rhine.

Calculation of cumulative species numbers over number of samples offers sampling success and therefore represents a good way to show how sure or complete results of a given faunistic approach are at a given time. One sample provides less than 25% of the fauna recorded within a three years period of quarterly inspections. To collect the main fraction (90%) of species, it takes 3 years of quarterly collections if all species recorded only once during the whole period are neglected. Several rare species were recorded within the project. 34% of mayflies, stoneflies and caddisflies are endangered.

The River Rhine and its changes in faunal composition within the last century is the example to illustrate the principle of biocoenotic trend-monitoring. The more recent samples of the macrobenthic fauna of the River Rhine indicate an improved quality and diversity because of improved water quality. Several species, indicative of good water quality have returned, and invasion of neozoans is still high, too. However, with respect to extinct species of macrozoobenthos, especially stoneflies, mayflies and caddisflies, mentioned by former authors, there is still a marked absence of indigenous species in the River Rhine.

Introduction

A comprehensive study of man-made impacts on urban and on the near-natural ecological environment is performed in Baden-Württemberg, one by the federal states of Germany since 1983. Different strata and ecological units like forests, grasslands, soils and running waters are investigated and assessed with the help of different bioindicators (Erhardt et al., 1992). Regular intensive biocoenotic monitoring in running waters started within a pilot project on the upper River Danube in 1992 and was extended to the catchments of River Neckar and River Rhine in the area of Baden-Württemberg in 1995 (Marten, 1994a, 1996a, 1997a). Extensive data sets provide the base for indication of long-term changes. Data collected so far are still in the process of evaluation and assessment. To present elaborated biocoenotic trends for all our monitoring sites, longer time series are necessary. The paper presented here will focus on objectives, on project design, methodical requirements for assessment, and will give the most famous example of long-term biocoenotic monitoring in running waters, the River Rhine.

The concept of environmental monitoring

In 1983 the State Government of Baden-Württemberg established a working group called 'Immissionsökologisches Wirkungskataster' at the State Agency for Environmental Protection of Baden-Württemberg in Karlsruhe. Its objective was to assess and document air pollution effects on urban as well as on near natural ecosystems with the help of different bioindicators. In 1998 the group was reorganized and is called now 'Biologische Umweltbeobachtung' with the aim to combine additionally data from air, soil and water, given by measuring activities of various governmental institutions, to an integrative environmental monitoring system. The specific objectives of the environmental monitoring programme are:

– Documentation, analysis and evaluation of the actual status and future changes of natural and man-influenced ecosystems.

– Definition of the present state, calculation of natural fluctuation levels, and determination of background loads.

– Documentation and evaluation of the development of ecosystems in the light of nutrient enrichment and climate change.

– Diagnosis of critical short time loads with the help of biological early warning systems (monitoring pollution caused by industrial accidents).

– Collecting background information on selected representative ecological units of the environment, giving the reference data for evidence of environmental change for reasons one cannot imagine now.

– Advice and recommendation to the government referring to the gathered information on the condition of the environment.

To achieve these objectives, already during the initial phase about 200 sampling and measuring stations have been established in representative ecosystem units of Baden-Württemberg, as there are regional types of forests, meadows and running waters. At some of these sites (10) active bioindicators have been exposed. Table 1 gives an overview of objects, methods, parameters and sampling frequency with respect to each ecosystem unit and to the applied active bioindicator. At nearly all sites important physical and chemical parameters in the air, the soil and the water were measured, to describe the microclimatic and general abiotic situation. Additionally, morphological features and soil type were classified in order to complete the ecological description and to document changes in land structure. Having this abiotic basic information, sites were monitored using different biological effect monitoring standards. In forests, mosses, lichens and herbaceous plants are investigated in the frame of vegetation analysis to get an idea of the species inventory, the long-term vitality and the nutrient supply of the plants. Additional laboratory analyses were carried out, to monitor the loads with heavy metals, dioxin, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons. This was done every 4 to 5 years. With the same frequency in the liver of mice and deer heavy metals are analysed as a kind of accumulation monitoring. To complete the ecological approach, some zoological components, especially characteristic detritivorous groups are surveyed and analysed concerning chemical loads. A similar programme is given for meadows, but the subjects partly changed according to the natural occurrence of the biota (LfU, 1994).

In running waters acidification is monitored, watching biometrics of brown trout and measuring their loads with heavy metals and aluminium. Additionally biocoenotic monitoring of macrozoobenthos is done to analyse trends in community structure with the help of biological and diversity indices, and to offer reliable data for faunistic and long-term water quality assessment. The species of the macrozoobenthos community are of all bioindicators in the aquatic environment the most well known. These various groups like mayflies, stoneflies, caddisflies, water beetles, snails and crustaceans already have been used since several decades as water quality indicators for the enrichment of organic material in the context of water quality mapping of local impacts of urban runoff (Alf et al., 1992).

Besides ecosystem monitoring at several sites there is use of active bioindicators in the way of exposures of standardized plant cultures like cloned spruce trees, grasses, borecole cultures and tobacco plants. These plants are used for accumulation monitoring of deposited toxicants like for instance heavy metals or for indication of inputs of photo-oxydants, for example ozone. These cultures are continuously exposed during their specific vegetation period, harvested and analysed one to eight times a year, depending on the species examined. Finally yet importantly there is one hot spot measuring station located along the River Rhine in Karlsruhe where continuous biotests

Table 1. Methods used for the biological effect monitoring in different ecosystem units in Baden-Württemberg

Biological Effect Monitoring (BEM)

Ecosystem Monitoring:	Object	Bioindication Method	Parameters	Sampling frequency
Forests	Mosses, lichens, herbaceous plants, trees	Vegetation analysis	Species inventory, vitality, nutrients, heavy metals, dioxine, PCB, PAH	every 4 to 5 years
	Liver of mice and deer	Accumulation monitoring	Heavy metals	every 4 to 5 years
	Earthworms, springtails, grasshoppers, beetles	Community analysis	Species inventory Biological indices	every 4 to 5 years
Meadows	Herbaceous plants	Vegetation analysis	Species inventory, vitality, nutrients, heavy metals, dioxine, PCB, PAH	every 4 to 5 years
	Earthworms, springtails, grasshoppers	Accumulation monitoring Community analysis	Heavy metals Species inventory, biological indices	every 4 to 5 years
Running waters	Brown Trout	Acidification monitoring	Biometrics, heavy metals, aluminium	every 5 years
	Macrozoobenthos	Biocoenotic monitoring, Trend analysis	Species diversity, biological indices Faunistic and water quality assessment	4 times a year
Active Bioindicators:	**Object**	**Bioindication Method**	**Parameters**	**Sampling frequency**
Exposure of plant cultures	Cloned spruce trees, grass, borecole cultures	Accumulation of deposited toxicants	Heavy metals PCB, PAH	continuously exposed, analysed 1-5 times a year
(terrestrial)	Tobacco plants	Indication of impacts of photooxidants (e. g. ozon)	Degree of discoloration and necrotic alteration	continuously exposed, analysed 8 times a year
Continuous biotests for running waters	Algae-Toximeter Daphnia-Toximeter	Monitoring acute effects of toxicants (e. g. pesticides)	Delayed fluorescence Swimming activity	continuous measurement

for monitoring acute toxicity are installed. Algae and *Daphnia* toximeters permit the detection of peaks of herbicides and insecticides with continuous measurements (Marten, 1996b).

Biocoenotic changes in the River Rhine – motor for the establishment of intensive biocoenotic trend-monitoring in Baden-Württemberg

The best example to show the principle of long-term biomonitoring is the changed faunal composition in the River Rhine during the last century. This was made possible because already at the beginning of the century biologist have been examining the macrozoobenthos of the river and described the faunal composition of different stretches of the Rhine (Neeracher, 1910; Lauterborn, 1917; Felber und Lininger (Felber, 1908 in Caspers, 1980). At the beginning of the century the number of species was quite large. Especially in the 1960s and the 1970s the diversity of autochthonous macroinvertebrates decreased severely (Marten, 1994b). Increase of species diversity in the following years was due to colonization with neozoens, especially molluscs and crustaceans, having low demands on ecological quality of water courses (Kinzelbach, 1972, 1977, 1978).

Recovery of the Rhine biocoenosis in the 80's was interrupted by the conflagration in a chemical depot of the Sandoz company in Schweizerhalle near Basel, in November 1986 (Braukmann et al., 1987). However, regarding only the absolute species numbers, a few years after the accident the fauna indicated that the Rhine had fully recovered. On the other hand, also at this time differentiated biocoenotic comparison revealed considerable changes in species composition: when comparing the two major surveys in 1903–1910 and 1987–1989, there only 26% of the species are recorded in both periods. 34% of the former inhabitants are now extinct, 40% of the inhabitants have been recorded for the first time. Among these are the well-known neozoans (Marten, 1994b). Comparing the results of the first and the last two major surveys of the River Rhine, in 1903–1910 and 1995–1998, the similarity between the faunal composition at the beginning and at the end of the century is low (24%,

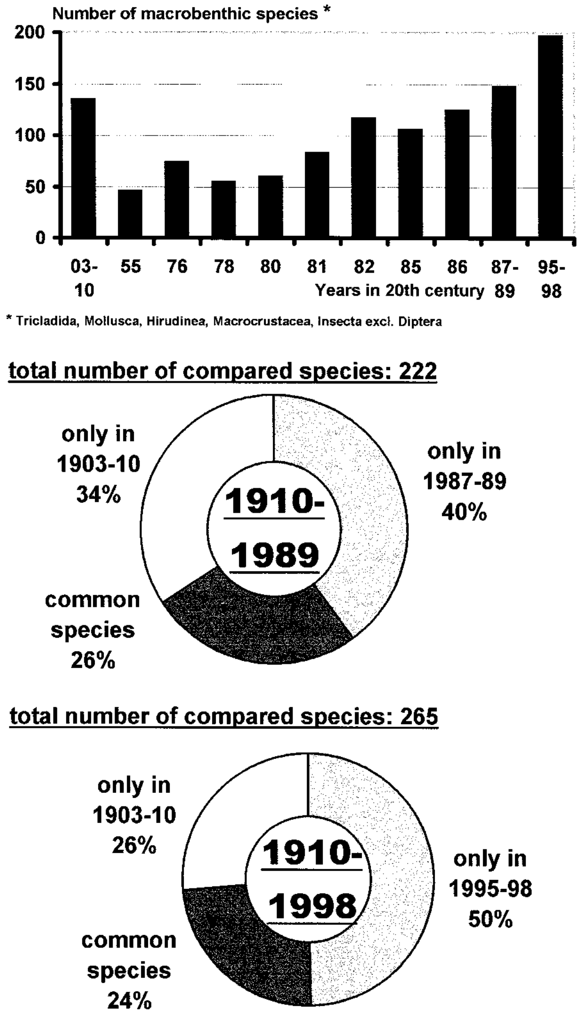

Figure 1. Number of species of selected groups of macrozoobenthos in the 20th century and biocoenotic comparison of macrozoobenthos in the river Rhine during three main sampling periods, 1903–1910, 1987–1989 and 1995–1998 (further explanations see text).

63 species). About 50% or 132 species recently inhabiting the Rhine have been recorded at the end of the century for the first time. Out of the 265 comparable species (taxonomical validation) 70 species are only known from the beginning of the century (Figure 1). Nowadays these formerly abundant species completely disappeared from the river.

Calculation of the saprobic index used for assessment of water quality, as shown in governmental water quality maps, reveals the same good, β-mesosaprobe situation for all three major sampling periods, despite immense changes in faunal composition in the Rhine since the beginning of the century. In the light of this contradiction – the saprobic and the faunistic point of view –, stressed already years ago (Marten, 1994b), the state agency of environmental protection of Baden-Württemberg decided to establish a regular monitoring programme on macrozoobenthos of rivers and streams ('trend-biomonitoring') to observe biocoenotic fluctuations as an indicator for long-term changes in various running waters.

Materials and methods

The project of biocoenotic monitoring in rivers of Baden-Württemberg started in 1995. 100 sampling sites have been selected and investigated to record the recent occurrence of macrozoobenthos species, to answer questions concerning sampling strategy and sampling frequency, and to have a base for selection of suitable permanent long-term monitoring sites. In Baden-Württemberg there are the main rivers Rhine, Neckar and Danube, where 20 of the 100 sites were placed. The others are located in the main tributaries, at sites near the headwaters and at their confluence (Figure 2).

Sampling of organisms was performed using the classic handnet kick-sampling method, collecting by hand in the water at different substrates (e.g. wood, stones), and collecting adults on the banks with the help of sweep nets, aspirators and tweezers. Collecting time was at least one hour at every sampling site. Density of animals was estimated using abundance classes in the range from 1 to 7 as generally used in middle European water quality investigation standards. Collections were carried out 4 times a year, between April and October.

Material of most taxonomic groups was identified up to species-level using recent taxonomic literature (reference list can be ordered from the author, 256 titles). With respect to the high identification effort due to the need of microscopic preparations and determination of species richness, Oligochaeta, Hydacarina and Diptera were identified only to the level necessary for the German standard of water quality assessment, which focuses on selected species. Species-identification of various insects was possible only, when the adults from the banks of the river were available. Existing keys for aquatic stages of different groups (e.g., Plecoptera, Trichoptera) do not enable identification to species-level, because nymphs of several species are unknown. First group specific faunistic results are given in detail in different papers (Marten

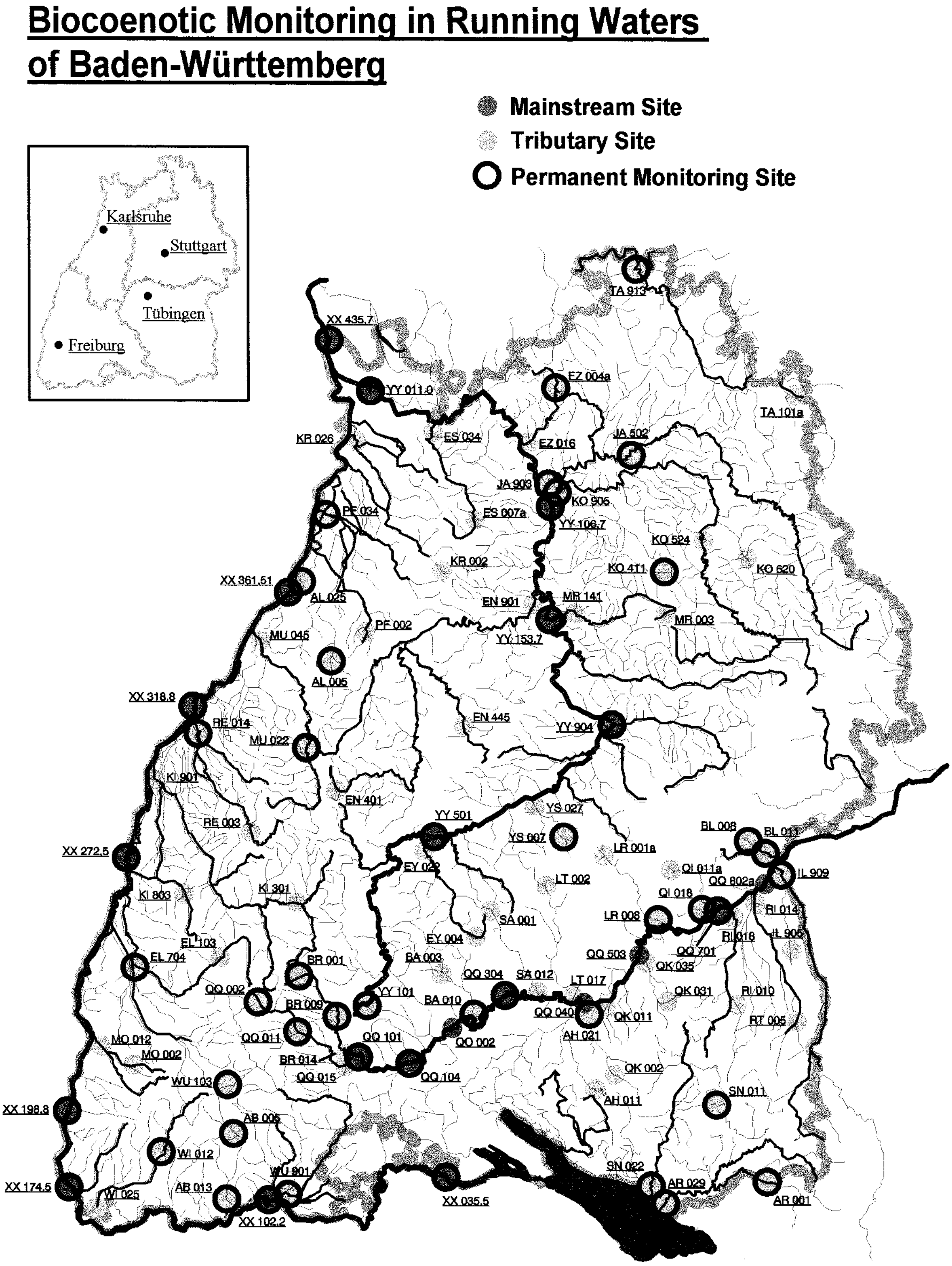

Figure 2. Map of Baden-Württemberg (Germany) with biocoenotic monitoring sampling stations.

1995, 1997a; Marten et al., 1996: Marten, 1997a; Marten & Fischer 1998; a, b, 1999; Gorka et al., 1998).

When comparing faunal data of different periods, changes in nomenclature and in taxonomic status or even the description of new species required adaptations of recent species lists to the taxonomic situation of lists of former times. Therefore different numbers of 'comparable species', exist depending on which data sets actually are compared (see example Rhine).

Results

Taxonomic groups dealt with in this study and the number of species already found (in brackets) are as follows: Porifera (5), Turbellaria (9), Mollusca (51), Oligochaeta (5), Hirudinea (19), Crustacea (19), Ephemeroptera (77), Plecoptera (48), Odonata (18), Coleoptera (77), Heteroptera (24), Neuroptera (7), Trichoptera (162), Bryozoa (6), Diptera (30). Four groups are represented by only one species: *Gordius aquaticus* (Gordiidae, Nematomorpha), *Hypania invalida* (Ampharetidae, Polychaeta), *Agriotypus armatus* (Ischneumonidae, Hymenoptera), *Nymphula nymphaeata* (Pyraustidae, Lepidoptera). In this way 561 species of macrozoobenthos have been recorded so far.

Notwithstanding that still there are taxonomic problems to be solved in several taxa, the results are adequate to answer the main question concerning the faunistic approaches: which sampling effort is necessary to collect baseline information on the species composition of a single site for future comparisons and evaluation of biocoenotic changes?

Basic results of faunistic investigations are species lists giving the number of specimens collected at one or more sampling sites or sampling dates. Comparison of results of eight samples over a period of two years at a single site is given in Table 2. These data from the River Breg, a headwater of the River Danube, show, that out of the 83 species, there are only four species regularly found at each date (heavy-faced type). On the other hand there are several species collected only once during the two years period (underlined ones). Between these extremes there are intermediate levels of occurrence.

Calculation of cumulative species numbers over a number of samples offers sampling success and therefore yields an impressive way to show how sure results of a given faunistic approach at a given time are. Regarding a three year period of quarterly collections of caddisflies, the main fraction of species collected after three years would have been collected after two years. It is evident that only 25% of the species list of a 3 years survey will be obtained from one inspection (Figure 3).

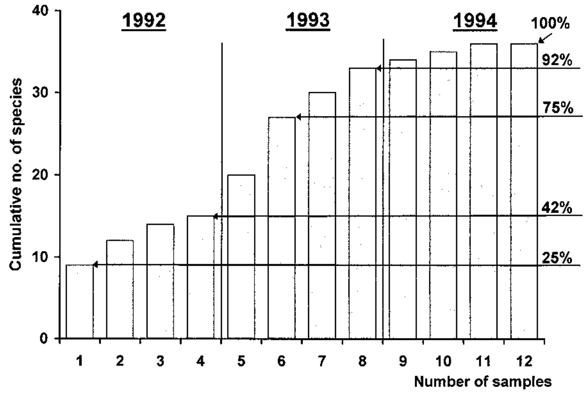

Figure 3. Sampling success of Trichoptera within a three year period, expressed as cumulative number of species (see text).

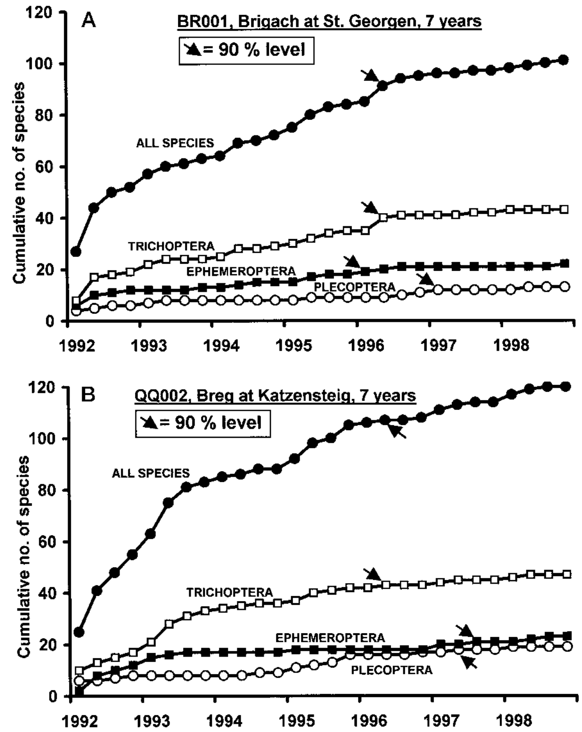

Figure 4. Cumulative species curves over a seven year sampling period concerning the species of all taxa of macrozoobenthos, and mayflies, stoneflies and caddisflies separately from two sites at the River Brigach (A) and the River Breg (B).

For some stations of the biomonitoring project already data for a seven year period have been collected.

Table 2. Results of eight macrozoobenthos samplings done within a period of two years at a single site of the River Breg. Species steadily found on each date are indicated in bold. Species collected only once during this period are underlined

	Breg 03.04.95	Breg 24.5.199	Breg 16.8.199	Breg 2.10.199	Breg 02.04.96	Breg 31.05.96	Breg 01.08.96	Breg 07.10.96
Polycelis felina		1	3	2		2	2	1
Ancylus fluviatilis	**3**	**3**	**4**	**4**	**4**	**3**	**5**	**5**
Radix peregra							1	
Gammarus fossarum	1	2		4		1	1	1
Baetis alpinus	12	7	2	2	6	17		9
Baetis melanonyx							1	
Baetis muticus						5		
Baetis niger			1			1		
Baetis rhodani	**5**	**28**	**28**	**30**	**45**	**49**	**12**	**57**
Baetis scambus			1				9	3
Baetis vernus				1			6	5
Ecdyonurus venosus		1	5		2			
Electrogena lateralis						1		
Epeorus sylvicola	14	1		11	7	10	5	6
Ephemerella mucronata	15	34			23	27		
Habroleptoides confusa	3			5	6			10
Habrophlebia lauta						1	2	
Paraleptophlebia submarginata					1			
Rhithrogena carpatoalpina		10			32	10	5	
Serratella ignita			48				38	5
Siphlonurus lacustris		1						
Amphinemura sulcicollis		1				2		
Brachyptera seticornis	17	8			29	5		
Chloroperla tripunctata							1	
Dinocras cephalotes				2				
Diura bicaudata			9	2				1
Leuctra albida			10				3	5
Leuctra hippopus						6		
Leuctra inermis						8	10	
Nemoura avicularis	1			1				
Nemurella pictetii		1						
Perlodes microcephalus		3						
Protonemura intricata		2						
Protonemura meyeri						1		
Siphonoperla torrentium		6				4		
Agabus guttatus			1					
Anacaena lutescens	1							
Cryptopleurum subtile				1				
Elmis aenea	2	5	8			3		
Elmis maugetii	**10**	**2**	**7**	**15**	**7**	**19**	**5**	**10**
Esolus angustatus	1	1				2	2	
Haliplus lineatocollis				1				2
Haliplus wehnckei		1						
Helophorus arvernicus				1				
Hydraena dentipes	1							2
Hydraena gracilis	2	1	2	4	1		1	
Hydraena lapidicola								1
Limnius perrisi		8	11	9	10	12	2	5
Limnius volckmari	8			4		1	2	
Oreodytes sanmarki	**6**	**5**	**4**	**4**	**5**	**6**	**1**	**5**
Platambus maculatus			3	2	1			2
Velia caprai		3	1	6				2
Adicella reducta								1
Allogamus auricollis				1	2			
Anabolia nervosa						1	2	
Anomalopterygella chauviniana		6				4		
Apatania fimbriata		2	2	2				4
Chaetopterygopsis maclachlani				2				
Chaetopteryx villosa				6				2
Drusus annulatus		1	1			1		
Ecclisopteryx dalecarlica	10		4		12	1	2	14
Glossosoma boltoni						10		
Glossosoma conformis					16		1	
Glossosoma intermedium	2							
Hydatophylax infumatus				4	2			1
Hydropsyche dinarica	7	7	19		10	12	2	21
Hydropsyche instabilis		1	1		1	4	1	
Hydropsyche siltalai							1	
Hydropsyche tenuis						1		
Limnephilus centralis			1					
Limnephilus rhombicus								1
Melampophylax mucoreus		2						1
Micrasema longulum	1	5		2	1	3	2	
Odontocerum albicorne	6	4	16		3	7	13	7
Parachiona picicornis		1						
Philopotamus ludificatus				1				
Philopotamus montanus		1	2					
Potamophylax cingulatus	2	1	1	1	3		2	
Potamophylax latipennis	1		4	2	14	5	7	1
Potamophylax luctuosus						3		
Rhyacophila dorsalis			6			2	3	
Rhyacophila tristis		2	2	5	5		1	2
Silo pallipes	5	1	1			3	1	3
NUMBER OF SPECIES:	25	37	31	31	26	38	34	32

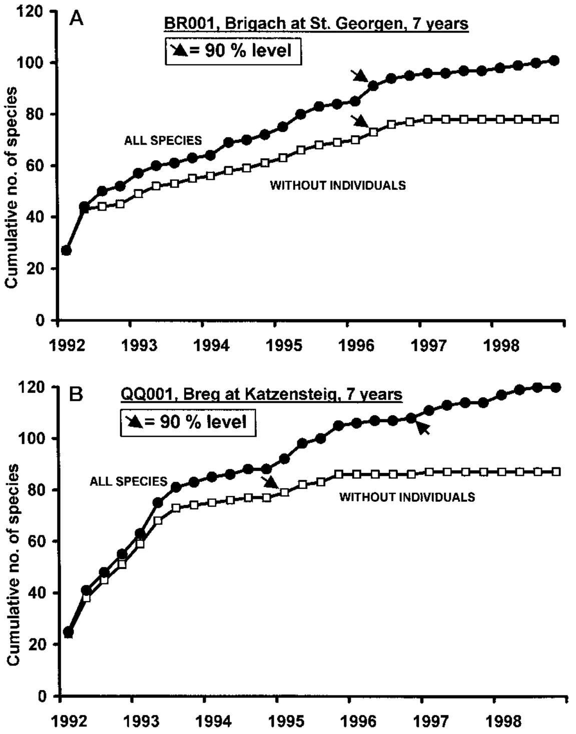

Figure 5. Cumulative species curves concerning the species of all taxa groups, and all species except those recorded only once during the seven year sampling period from the River Brigach (A) and the River Breg (B).

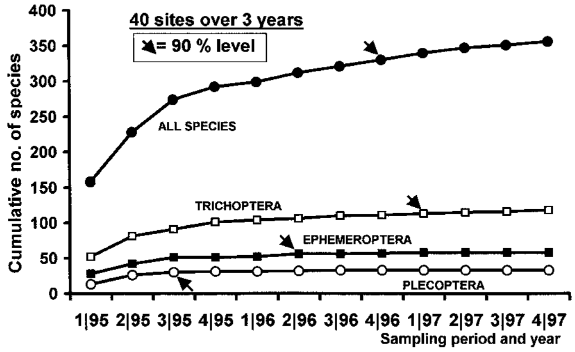

Figure 6. Cumulative species curves indicating sampling success of species of all taxa of macrozoobenthos, and of mayflies, stoneflies and caddisflies separately. Data are summarized from 40 different sampling sites.

In Figure 4 cumulative species curves are given for the species composition of all taxa and, separately, for the most important groups, mayflies, stoneflies and caddisflies. Results concern two sites, the River Brigach (Figure 4a) and the River Breg (Figure 4b), two slightly polluted headwaters of the River Danube. The arrows indicate the 90% level of occurrence with respect to the species number obtained after 7 years. In the Brigach site the 90% level was reached after 4 years, in the Breg site it took 5 years to obtain 90% of the species of the 7-year period. Nevertheless at both sites it took a number of years to reach the 90% level. Especially in the River Breg the number of taxa steadily increased during the whole period if considering all taxa. The process of surveying the species composition appears never to be finished.

For this reason solutions were selected to obtain a visibly and reliable faunistic result for our sites after a certain time. The first way is to neglect all species recorded only once. The consequence of this is that the 90% level will be reached recognizable earlier, after 3 (Breg) or 4 (Brigach) years. If data are presented in this way, there is no further increase of species in the following years (Figure 5).

Another way is to combine results from different sampling stations, for example for all the sites of the upper reaches of the tributaries of Rhine, Neckar and Danube (Figure 6). In this case the 90% level will be reached after 2 years, and this although the 40 sites, of which results were combined here, belong to different regional running water types. Combination of results of all 100 sites investigated, means that the 90% level will be reached again somewhat earlier, in the range of 3 to 8 samples, depending on the taxonomic group examined.

A large number of rare and endangered species has been recorded within this project. For example, out of 102 mayfly species known from Germany, there are 84 species recorded in the state of Baden-Württemberg, but 77 of them have been observed within the trend-biomonitoring project. Out of these, 37 species are listed in the Red Data Book in one of the 4 classes of endangerment. 9 species have been recorded for the first time in Baden-Württemberg. Among the 48 stonefly species in this project, 16 are endangered species and 4 recorded for the first time in Baden-Württemberg. The numbers for caddisflies are: 162 species, 55 species of those in the Red Data Book, and 8 species recorded for the first time in Baden-Württemberg (Table 3).

One more positive result of the trend-biomonitoring project is the increase of knowledge of the fauna of important rivers, for example the upper River Danube. There has been stated a considerable increase in numbers of mayflies and stoneflies known from the Danube, in comparison to results given by former authors (Figure 7, Marten, 1997a).

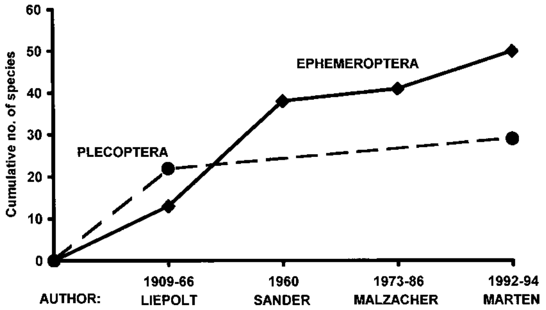

Figure 7. Increase of records of mayflies (Ephemeroptera, full line) and stoneflies (Plecoptera, interrupted line) from the upper river Danube given by different authors.

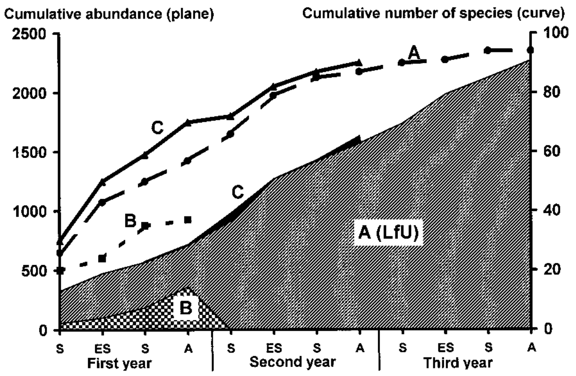

Figure 8. Efficiency of sampling activity of different collectors (A, B, C) for the river Breg at Katzensteig (Danube system) expressed by the cumulated species number (lines) and the cumulated abundance (planes) of successive samples. Samples were taken in spring (S), early summer (ES), summer (S) and autumn (A) over a three-year period.

The most important condition for establishing a successful monitoring programme is to produce correct results and this means to have at one's disporal qualified scientists, with the required knowledge in taxonomy of the regional fauna, and be sure, that they will use their knowledge. General practice in governmental water quality monitoring programmes is because of lack of own personal, to award contracts to free-lance biologists. Experience shows that there are huge differences between different collectors and scientists being commissioned with the investigation (Figure 8). Sampling activity and sampling success of different collectors is expressed by the cumulative number of individuals collected (planes, number of individuals here transformed to abundance classes!) and by the cumulative number of species (curves) of successive samples. Number of collected individuals is directly correlated to the diligence of the collector. The number of species also expresses the knowledge, experience and diligence of taxonomical work. The standard (A) was defined by the author. Results of the first contract worker (B) were too bad to continue the project. The second contract worker (C) yielded better results than the standard (A). This example shows that there is a special need for a kind of quality management and control to obtain good results also in the future.

Discussion and conclusions

Within the project on biocoenotic monitoring of macrozoobenthos in Baden-Württemberg valuable faunistic data have been collected, analysable for different purposes, and providing the base for long-time trend assessment of biocoenoses in diverse rivers and streams in future. There is no comparable monitoring project in other regions of Germany (LAWA, 2000). About 561 species of different macrobenthic taxonomical groups have been recorded. Data are important for example for the Red Data Book and for nature conservation programmes. Many rare and endangered species have been recorded within the whole biomonitoring project. Twenty-one species of mayflies, stoneflies and caddisflies have been observed for the first time in Baden-Württemberg. About 34% of the 287 species of mayflies, stoneflies and caddisflies recorded during the project are endangered according to the classification of the Red Data Book.

Calculation of cumulative species numbers over number of samples offers sampling success and therefore represents a good way to show how sure or complete results of a given faunistic approach are at a given time. If sampling success at a single sampling site is calculated this way, it is evident that one sampling provides less than 25% of the fauna, recorded within a three years period of quarterly inspections. Regarding this, there is no need thinking about changes in species composition or even in dominance of single species on the basis of data covering only short periods of monitoring. Results show, that to collect the main fraction (90%) of species, it takes about 4 to 5 years if regarding one single sampling site (quarterly collections). Neglecting all species recorded only one time during the whole period will shorten the sampling period down to 3 years to receive 90% of the species. Similar effects will be reached when combining results from different sampling sites. In this case two years of quarterly collections are sufficient to receive the main fraction of species.

Table 3. Species numbers of mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddisflies (Trichoptera), status of endangerment in Germany, and first records in Baden-Württemberg

Biocoenotic Monitoring in Running Waters:

- Contribution to the data base on aquatic insects in Baden-Württemberg -

Recent knowledge on species numbers:

	Ephemeroptera (MALZACHER et al. 1998; MARTEN et al. 1996, 1999)	Plecoptera (REUSCH & WEINZIERL 1998; MARTEN et al. 1996, 1999)	Trichoptera (KLIMA et al. 1994, 1998)
Germany:	102	120	311
Baden-Württemberg:	84	78	242

Data generated by the biocönotic trendmonitoring:

	Ephemeroptera	Plecoptera	Trichoptera
Total of recorded species:	77	48	162
Species listed in the Red Data Book of Germany:	32	16	55
First records of species in Baden-Württemberg:	*Baetis liebenauae* Keffermüller, 1974 *Baetis vardarensis* Ikonomov, 1962 *Ecdyonurus aurantiacus* (Burmeister, 1839) *Ecdyonurus picteti* (Meyer-Dür, 1864) *Ecdyonurus subalpinus* Klapalek, 1907 *Ecdyonurus submontanus* Landa, 1969 *Procloeon pulchrum* Eaton, 1885 *Rhithrogena hercynia* LANDA, 1969 *Rhithrogena savoiensis* Alba-Tercedor et Sowa, 1987	*Leuctra mortoni* Kempny, 1899 *Leuctra moselyi* Morton, 1929 *Nemoura sciurus* Aubert, 1949 *Nemoura uncinata* Despax, 1934	*Anabolia furcata* BRAUER, 1857 *Apatania muliebris* McLACHLAN, 1866 *Athripsodes commutatus* (ROSTOCK, 1874) *Glossosoma bifidum* McLACHLAN, 1879 *Hydropsyche bulbifera* McLACHLAN, 1878 *Hydroptila martini* MARSHALL, 1977 *Hydroptila simulans* MOSELY, 1920 *Tinodes pallidulus* McLACHLAN, 1878

From the example of the River Rhine it could be stated, that in case of monthly collections sufficient sampling success will be reached already after one year, but the sampling effort (12 times) will be considerably (50%) higher compared to quarterly collections over 2 years (8 times). High efficiency of quarterly collections may be due to the fact, that various macrobenthic species, especially the insects, have a clear seasonality, but on the other hand are not of high (traceable/collectable) abundance every year. Therefore, it may be of advantage to spread sampling activity over 2 years without neglecting the seasonality. This is fulfilled when following the regime of quarterly investigations. However, in both cases (River Rhine!) it is evident, that less than 40% of the species list of a 3 years survey at various sampling sites will be obtained with only one inspection. The assumption to have good baseline data after a three years collection period has been shown to be reliable for most taxa groups of macrozoobenthos (Marten, 1997a). In consequence, low frequency sampling (one or two times) cannot give reliable information to assess the actual ecological status, nor to describe faunal changes in time axis (Marten, 1997b).

Already years ago in chemical monitoring low frequency sampling was considered to give no reliable average values of the chemical situation in rivers and lakes, nor was it able to describe the worst possible situation (e.g., Forsberg, 1982). Biological sampling strategies have been discussed in depth by several authors (Resh, 1979; Raleigh & Short, 1981; Resh & Price, 1984; Statzner & Resh, 1993). It is well established, that biological sampling regimes should be based on at least three samples per year (spring, summer and autumn) to cover seasonality of species occurrence and may than be sufficient for a preliminary classification of benthic macroinvertebrate communities, but it also is clear, that three sampling occasions will not give a comprehensive species list (Furse et al., 1981; Otis et al., 1978). Gaufin et al. (1956) stated that the first three samples of successive sampling provide about 50% of species, but as many as 10 to 15% of species were not encountered until the eighth sample. Mauch (1963) found that, depending on circumstances (weather, seasonality), between 50 and 90% of species of a sampling site will be recorded by one inspection, on the assumption that at least four inspections will provide the complete set of species occurring at the given site. But in case of high habitat richness less than 50% of species will be recorded during one inspection. For ecological assessment, including details on functional feeding groups, Fink (1998) stated that investigations four times a year will provide an optimum of information. The optimal number of samples required for a species list depends on sampling method (sample size) and on the diversity and dispersion of the fauna; it also depends on the taxonomic level of identification (Needham & Usinger, 1956). High natural diversity and species-level of identification require a high number of samples to ensure a complete taxa list. This refers to the specific situation and cannot be generalized or applied elsewhere (Hellawell, 1978).

In contrast new governmental approaches on monitoring the ecological quality of running waters propose a general monitoring frequency at six-year intervals (Braukmann & Pinter, 1997). The draft of the EU Water Framework Directive recommends surveillance requirements of at least every three years for macrozoobenthos (chemical analysis every three months!) (Irmer, 2000). In respect of the given examples in the present study, this appears to be an insufficient sampling frequency for reliable and comprehensive information collection on the fauna, which is the indication of the ecological quality.

Drastic changes in faunal composition of the River Rhine within the last century provide the best example to illustrate the principle of biocoenotic trend-monitoring, enabled by intensive work of different biologists within the past century. The recent macrobenthic fauna of the River Rhine is of improving quality and diversity. Several species indicate good water quality, but invasion of neozoans is still high too, and sustainable consequences of high population densities of neozoans are not yet foreseeable. Nevertheless, there are many extinct species of macrozoobenthos, especially stoneflies, mayflies and caddisflies, mentioned by former authors as indigenous species in the River Rhine. Most of them are rare in general, and threatened from the nature conservation point of view. Changes in faunal composition especially in the last 10, 15 years confirm the improvement in water quality in the upper River Rhine, as shown by chemical parameters.

In other rivers, e.g., the Danube, intensity of former investigations was poor. The biocoenotic trend-monitoring project provided valuable data to improve basic knowledge on the fauna of the Danube and on the other hand stressed that, e.g., endangered mayflies like *Heptagenia coerulans*, *Leptophlebia marginata*, *L. vespertina* and *Potamanthus luteus* obviously disappeared from the river (Marten, 1997a). Other results of trend-biomonitoring activities are for example the recognition of longitudinal zonation patterns in rivers as already shown for the Danube (Marten, 1996a).

Presupposition for the realization of investigation activities, as shown by the example of the biocoenotic monitoring programme in rivers of Baden-Württemberg, is to have any official guideline or recommendation of such a programme. This will be given by the recent publication 'Länderarbeitsgemeinschaft Wasser' (LAWA, 2000) for monitoring long-term effects of background pollution in aquatic environments. In this government brochure intensive macrozoobenthos monitoring is recommended, based on the experiences in Baden-Württemberg, as the most practicable method for monitoring long-term effects of pollution in aquatic environments. The biocoenotic monitoring programme in rivers, initiated in Baden-Württemberg, should be extended to other regions of Germany, offering an efficient instrument for effect monitoring of long-term changes in our natural environment. Biological monitoring programmes however, need a kind of quality controlling, e.g., the use of cumulative species numbers of successive samples plotted against the number of samples necessary to show the desired degree of precision and to show the validity and the reliability of biological surveillance data. In Baden-Württemberg there is now a good data set available to enable description of future biocoenotic changes in the most important rivers of this area.

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