EPHEMEROPTERA AND PLECOPTERA OF THE RIVER DANUBE IN BADEN-WÜRTTEMBERG (GERMANY)

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A survey of mayflies and stoneflies was done within the scope of a pilot-project on trendbiomonitoring of macrozoobenthos in the Danube river system in Baden-Württemberg. 46 mayfly species and 19 stonefly species were recorded. In comparison to former studies, there are some which obviously are extinct now, predominantly stonefly species. Longitudinal distribution of both groups along the river gradient will not allow separation of biocoenotic zones. Faunistic elevation of mayflies and stoneflies of the Danube appears to be complete after three years of sampling (4 times per year), but not necessarily if single sampling sites are considered. There is a specific need for faunistic baseline data to enable description of faunistic shifts in consequence of diverse human activities influencing river ecology.

INTRODUCTION

Results presented here are part of the results of a pilot-project on trendbiomonitoring of macrozoobenthos in the Danube river system. The object of this project is to collect representative and comparable data on the occurrence of macrozoobenthos (Tricladida, Hirudinea, Mollusca, Crustacea, Ephemeroptera, Plecoptera, Odonata, Coleoptera, Heteroptera, Neuroptera, Trichoptera) for further comparisons and evaluations of trends in species richness and change in species composition in the future. Further descriptions of the project and preliminary results are given in MARTEN (1994 a, b). Trichoptera data are reported in detail in MARTEN *et al.* (1995).

Faunistic information on Ephemeroptera and Plecoptera of the upper Danube is rare: The first comprehensive list of mayflies and stoneflies is given in Liepolt's monograph on the River Danube (LIEPOLT, 1967). There records from diverse literature are reviewed. SANDER (1981) presents data on mayfly distribution in the Rivers Breg, Brigach and Danube. MALZACHER (1981 a) reported faunistics of Ephemeroptera in the southwest of Germany and gave an assessment of the status of endangerment for the red data book (MALZACHER, 1981 b). These findings were completed by further studies especially in the River Danube and its headstreams in the 80's (MALZACHER, 1987). Details on mayfly faunistics predominantly in the southern tributaries of the upper Danube are described by GRIMM (1980, 1986, 1987, 1988).

METHODS AND STUDY AREA

Regarding the diverse problems in managing quantitative surveys to obtain reliable data on population size of species, and in respect to the wide area, which has to be considered, when a project like this has to be established and accepted by money-giving politicians, we decided to apply qualitative methods with special regard to recording the species composition. Therefore methods used, were the classic ones, like kicksampling, collecting by hand in the water, and also collecting adults on the banks with the help of sweepnets, aspirators and tweezers. Collecting time was at least one hour at every sampling site. Density of animals was estimated by abundancy classes in the range from 1 to 7, as generally used in water quality investigation standards (LFU, 1992).

The project started in 1992 and samples were taken every two months between April and October; this means 4 times a year, at about 53 sites in the Danube catchment. Results presented here concern the years 1992 to 1994 and only the 14 sites at the River Danube, from which samples have been analysed completely now.

The upper Danube catchment area is in Baden-Württemberg, the south-eastern part of Germany (Fig. 1). The Danube is one of the three largest rivers in Baden-Württemberg. The two headstreams of the Danube, the Breg and the Brigach, rise at about 1000 m above sea level in the Black Forest and form together the Danube in Donaueschingen at 680 m (a.s. l.). The Danube then flows through the Jura mountains of the Swabian Alp and reaches after 270 km the town Ulm (480 m a.s. l.), where it leaves Baden-Württemberg towards Bavaria. From Ulm the Danube will need another 2500 km to reach the Black Sea. The mean discharge of the Danube at Ulm is about 119 m^3/s. One major tributary joining the Danube at Ulm is the River Iller, having an alpine character and a slightly higher discharge than the Danube itself. A special feature of the Danube is the stretch between the small towns Immendingen and Fridingen, where in the mean of the year about 50% of the water oozes away and rises 80 km southward in the source of the River Aach, which drains to the River Rhine system. In summer, this zone of the Danube is dry for about 150 days.

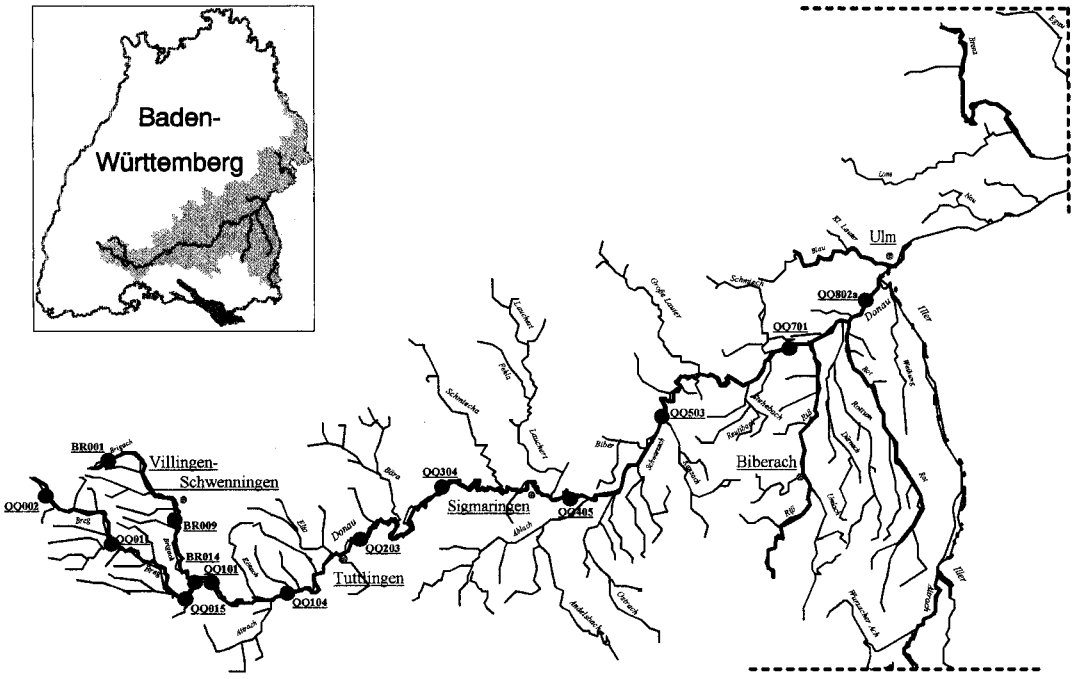

Fig. 1. The Danube catchment area in Baden-Württemberg and sampling sites indicated by the site-number.

The Danube catchment area is inhabited by 1.1 million people. The waste waters are purified by 236 sewage plants. Therefore the water quality in general is b-mesosaprob, but downstream of larger towns like Villingen-Schwenningen, Tuttlingen and Sigmaringen a-mesosaprobic aspects are still dominant. Further details concerning water quality and hydrochemistry are given in MARTEN (1994 c), details of climate, hydrology and geology in LIEPOLT (1967).

The sampling sites at the River Danube are indicated by the site-number in Fig. 1. The sampling locations at the Danube and its headstreams are the following (river/nearest town/site-no.): Breg/Katzensteig/QQ002; Breg/Hammereisenbach/QQ011; Breg/Hüfingen/QQ015; Brigach/St. Georgen/BR001; Brigach/Marbach/BR009; Brigach/Donaueschingen/BR014; Danube/Pfohren/QQ101; Danube/Zimmern/QQ104; Danube/Tuttlingen/QQ203; Danube/Hausen im Tal/QQ304; Danube/Scheer/QQ405; Danube/Daugendorf/QQ503; Danube/Nasgenstadt/QQ701; Danube/Donaustetten/QQ802a.

RESULTS AND DISCUSSION

Species composition

In 1992-1994, 46 mayfly species and 19 stonefly species were collected from the 14 sampling sites at the River Danube and its headstreams Breg and Brigach. In contrast to these data, the species numbers recorded with comparable sampling effort in the morphological similar River Fulda are 36 mayflies and 39 stoneflies (MARTEN, 1983). Especially in the case of stoneflies the River Fulda appears to be more diverse.

The list of mayfly species recorded in the Danube river during the present study is compared to records given by earlier authors (Table 1), most of them obtained by SANDER (1981) and MALZACHER (1981 a, 1987). The number of mayfly species known from the Danube increased from 13 in 1967 (LIEPOLT, 1967), 38 in 1981 (Sander l. c.), 41 in 1987 (Malzacher l. c.), to 50 in the present study. Interesting records generated by the present study are *Baetis pentaphlebodes* (the only of 13 *Baetis* species!), *Rhithrogena beskidensis, Rh. degrangei, Ecdyonurus macani* and *Ephemerella notata.* Some of the earlier findings were not stated now. Most important of those species are *Heptagenia coerulans, Leptophlebia vespertina, L. marginata* and *Potamanthus luteus. Electrogena lateralis,*

Table 1. List of Ephemeroptera recorded in the upper River Danube and its two headstreams Breg and Brigach. Years in brackets are years of sampling. B.-W. = Baden-Württemberg, G. = Germany (here: Baden-Württemberg and Bavaria).

EPHEMEROPTERA	LIEPOLT 1967 (09-66) G	SANDER 1981(1960) B.-W.	MALZACHER 1981 (73-79) B.-W.	MALZACHER 1987(1986) B.-W.	MARTEN (1992-94) B.-W.
SIPHLONURIDAE					
Siphlonurus aestivalis EATON, 1903		X	X	X	X
Siphlonurus alternatus (SAY, 1824)		X		X	
Siphlonurus lacustris (EATON, 1870)		X		X	X
Ameletus inopinatus EATON, 1887	X	X		X	
BAETIDAE					
Baetis alpinus (PICTET, 1843)		X	X		X
Baetis buceratus EATON, 1870		X	X	X	X
Baetis digitatus BENGTSSON, 1912			X	X	X
Baetis fuscatus (LINNE, 1761)			X	X	X
Baetis lutheri MÜLLER-LIEBENAU, 1967		X	X		X
Baetis melanonyx (PICTET, 1843)					X
Baetis muticus (LINNE, 1758)		X	X	X	X
Baetis niger (LINNE, 1761)		X	X	X	X
Baetis pentaphlebodes UJHELYI, 1966					X
Baetis rhodani (PICTET, 1843)		X	X	X	X
Baetis scambus EATON, 1870		X	X	X	X
Baetis vardarensis IKONOMOV, 1962					X
Baetis vernus CURTIS, 1834		X	X	X	X
Centroptilum luteolum (MÜLLER, 1776)	X	X	X	X	X
Centroptilum pennulatum EATON, 1870		X		X	X
Cloeon dipterum (LINNE, 1761)	X	X	X	X	X
Cloeon simile EATON, 1870		X			
Procloeon bifidum (BENGTSSON, 1912)		X		X	X
HEPTAGENIIDAE					
Epeorus sylvicola (PICTET, 1865)		X	X		X
Rhithrogena beskidensis ALBA-TERC. & SOWA, 1987					X
Rhithrogena carpatoalpina KLONOWSKA et. al. 1987					X
Rhithrogena degrangei SOWA, 1969					X
Rhithrogena iridina (KOLENATI, 1839)			X	X	X
Rhithrogena semicolorata (CURTIS, 1834)	X	X		X	X
Ecdyonurus dispar (CURTIS, 1834)	X	X	X	X	X
Ecdyonurus insignis (EATON, 1870)	X				
Ecdyonurus macani THOMAS & SOWA, 1970					X
Ecdyonurus torrentis KIMMINS, 1942		X			X
Ecdyonurus venosus (FABRICIUS, 1775)		X		X	X
Electrogena lateralis (CURTIS, 1834)	X				
Electrogena cf rivuscellana SARTORI & LANDOLT, 1991					X
Heptagenia coerulans ROSTOCK, 1877	X				
Heptagenia fuscogrisea (RETZIUS, 1783)		X	X	X	X
Heptagenia sulphurea (MÜLLER, 1776)	X	X	X		X
EPHEMERELLIDAE					
Ephemerella mucronata (BENGTSSON, 1909)	X	X	X	X	X
Ephemerella notata EATON, 1887					X
Serratella ignita (PODA, 1761)		X	X	X	X
Torleya major (KLAPALEK, 1905)		X	X	X	X
CAENIDAE					
Caenis beskidensis SOWA, 1973			X	X	X
Caenis horaria (LINNE, 1758)		X		X	X
Caenis luctuosa (BURMEISTER, 1839)		X		X	X
Caenis macrura STEPHENS, 1835					X
Caenis rivulorum EATON, 1884			X	X	X
LEPTOPHLEBIIDAE					
Leptophlebia marginata (LINNE, 1767)		X			
Leptophlebia vespertina (LINNE, 1758)		X			
Paraleptophlebia submarginata (STEPHENS, 1835)		X	X	X	X
Habroleptoides confusa SARTORI & JACOB, 1986		X		X	X
Habrophlebia fusca (CURTIS, 1834)	X	X		X	X
Habrophlebia lauta EATON, 1884				X	X
EPHEMERIDAE					
Ephemera danica MÜLLER, 1764	X	X		X	X
POTAMANTHIDAE					
Potamanthus luteus (LINNE, 1767)	X				
NUMBER OF SPECIES:	13	35	24	33	46

given by LIEPOLDT (1967), may be confused with *E. rivuscellana*, which is not sure too, since we did not succeed in collecting adults.
The findings of Plecoptera in the upper Danube system are given in Table 2. Today there are no exciting stoneflies in the upper Danube and some of the earlier findings are still in the tributaries like *Nemoura cinerea* and *N. marginata*, or in my opinion are confused with other species (*N. mortoni, N. undulata, Protonemura risi, Perlodes jurassicus, Perla bipunctata*). Some of the species mentioned in Liepolts monograph on the Danube, species which are not easy to be confuse, have not been found during the present study. Most important of those are *Oemopteryx loewii, Taeniopteryx* spp., *Capnia* sp. *Isogenus nubecula* and *Perla burmeisteriana*, species, which generally are extinct or endangered in the middle of Europe (ZWICK, 1984; MARTEN 1994 d).
As far as can be seen from the material on the tributaries of the Danube, there are some more stonefly species in the tributaries today, which generally are not found everywhere in the middle of Europe, like *Nemoura sciurus* AUBERT, 1949 (Schmiecha at Albstadt-Onstetten), *N. avicularis* MORTON, 1894 (Lauter at Herrlingen), and *Leuctra moselyii* MORTON, 1929 (Iller at Ulm-Wiblingen). Most interesting stonefly in the tributaries is *Besdolus imhoffi* (PICTET, 1841) (Grosse Lauter at Lauterach, Rot at Rot), a perlodid stonefly known from the River Rhine from the beginning of the century (NEERACHER, 1910) and since that time is extinct from this stream. The only Central European stream where *B. imhoffi* is known to survive outside of Baden-Württemberg is the River Uffinger Ach in Bavaria (ZWICK & WEINZIERL, 1995).

Table 2. List of Plecoptera recorded in the upper River Danube and its two headstreams Breg and Brigach. Years in brackets are years of sampling. B.-W. = Baden-Württemberg, G. = Germany (here: Baden-Württemberg and Bavaria).

PLECOPTERA	LIEPOLT 1967 (09-66) G	MARTEN (1992-94) B.-W.
TAENIOPTERYDIDAE		
Brachyptera seticornis (KLAPALEK, 1902)		X
Oemopteryx loewii ALBARDA, 1889	X	
Taeniopteryx spp.	X	
NEMOURIDAE		
Amphinemura sulcicollis (STEPHENS, 1835)	X	X
Nemoura cambrica STEPHENS, 1835		X
Nemoura cinerea (RETZIUS, 1783)	X	
Nemoura marginata PICTET, 1836	X	
Nemoura mortoni RIS, 1902	X	
Nemoura undulata RIS, 1902	X	
Nemurella picteti (KLAPALEK, 1900)	X	X
Protonemura intricata (RIS, 1902)		X
Protonemura meyeri (PICTET, 1841)		X
Protonemura nimborum (RIS, 1902)	X	
Protonemura nitida (STEPHENS, 1835)	X	X
Protonemura risi (JAC. & BIANCHI, 1905)	X	
LEUCTRIDAE		
Leuctra albida KEMPNY, 1899	X	X
Leuctra braueri KEMPNY, 1898	X	
Leuctra digitata KEMPNY, 1899	X	X
Leuctra fusca (LINNE, 1758)	X	X
Leuctra hippopus KEMPNY, 1899	X	X
Leuctra inermis KEMPNY, 1899	X	X
Leuctra nigra (OLIVIER, 1811)	X	
CAPNIIDAE		
Capnia spp.	X	
PERLODIDAE		
Diura bicaudata (LINNE, 1758)	X	X
Isogenus nubecula NEWMAN, 1833	X	
Isoperla oxylepis (DESPAX, 1936)		X
Perlodes jurassicus AUBERT, 1946	X	
Perlodes microcephalus (PICTET, 1833)	X	X
PERLIDAE		
Dinocras cephalotes (CURTIS, 1827)		X
Perla bipunctata PICTET, 1833	X	
Perla burmeisteriana CLAASEN, 1936	X	
Perla marginata (PANZER, 1799)		X
CHLOROPERLIDAE		
Chloroperla tripunctata (SCOPOLI, 1763)	X	X
Siphonoperla torrentium (PICTET, 1841)	X	X
NUMBER OF SPECIES:	27	19

Longitudinal zonation

Distribution of mayflies at 14 stations along the longitudinal profile of the Rivers Breg, Brigach and Danube is given in Table 3, that of stoneflies in Table 4. Species are arranged according to their focal point of distribution. The number of vertical lines is the number of records at each station (nymphs and/or adults); maximum is 12 vertical lines according to the 12 sampling periods.
Number of mayfly species is arround 20 (17 to 27) at each site, accept in the River Brigach, where a maximum of 16 species has been recorded. Most species start with their longitudinal distribution in the Breg and in the Brigach. There is no significant interruption in the distribution or change in species possibly caused by large tributaries or change of physiographic characters. Especially in the potamon the mayfly community is more or less homogenous. In the rhithron the number of sampling sites is surely too low to distinguish specific zones. But there are several species clearly restricted to the rhithron comunity like *Baetis alpinus, B. melanonyx, B. niger* and

Rhithrogena degrangei and some restricted to the potamon like *Baetis vardarensis* and *Ecdyonurus macani*.
In stoneflies the situation is different: Most species are dominant in the epirhithron, only *Perlodes microcephalus* and *Leuctra fusca* inhabit more or less the whole upper River Danube. The extinction of species in the middle stretch (QQ203, QQ304) is caused by severe pollution.

Table 3. Longitudinal zonation of Ephemeroptera in the Danube river system. Numbers in brackets (on top) are species numbers.

EPHEMEROPTERA (46)	BRIGACH (27)			BREG (36)			DANUBE (34)							
	BR001	BR009	BR014	QQ002	QQ011	QQ015	QQ101	QQ104	QQ203	QQ304	QQ405	QQ503	QQ701	QQ802
Baetis alpinus														
Baetis melanonyx														
Baetis niger														
Electrogena cf rivuscellana														
Rhithrogena degrangei														
Rhithrogena carpatoalpina														
Habroleptoides confusa														
Centroptilum pennulatum														
Rhithrogena iridina														
Ecdyonurus venosus														
Epeorus sylvicola														
Ephemerella mucronata														
Habrophlebia lauta														
Ecdyonurus torrentis														
Procloeon bifidum														
Baetis lutheri														
Habrophlebia fusca														
Siphlonurus lacustris														
Heptagenia fuscogrisea														
Baetis digitatus														
Paraleptophlebia submarginata														
Rhithrogena semicolorata														
Baetis rhodani														
Centroptilum luteolum														
Ecdyonurus dispar														
Ephemera danica														
Baetis fuscatus														
Baetis muticus														
Baetis scambus														
Ephemerella ignita														
Siphlonurus aestivalis														
Baetis vernus														
Caenis luctuosa														
Caenis horaria														
Caenis rivulorum														
Baetis buceratus														
Baetis vardarensis														
Caenis beskidensis														
Ephemerella major														
Heptagenia sulphurea														
Rhithrogena beskidensis														
Ecdyonurus macani														
Baetis pentaphlebodes														
Ephemerella notata														
Cloeon dipterum														
Caenis macrura														
NUMBER OF SPECIES:	15	16	16	19	20	27	20	24	17	18	22	19	19	21

Stonefly fauna in the headstream Breg is richer (19 spp.) than in the Brigach (10 spp.). The latter is strongly influenced by human activities (waste water, agriculture, river regulation, fish-ponds).

Database for faunistical comparisons in the future

The primary purpose of this study was to give some baseline data for further comparisons in the future. The most important question in this context is, how sure are our recent results on the faunistic composition in the Danube, or, how complete is our taxalist? To verify the results, species numbers obtained for each sampling period were cumulated over time for each group. Fig. 2 gives the cumulative numbers of species over the three years collecting period (columns; April, June, August, October each year), and the cumulative abundance (abundancy classes, not individuals squares) for two representative sampling sites. The cumulative abundance only shows that we collected busily all the time. The increasing height of the columns shows that every sample contributes some new species, but in the third year the increase in species richness in both groups, the Plecoptera and the Ephemeroptera is not as high as in the years before. Faunistic elevation of mayflies and stoneflies seems to be completed after three years at some sites like on the River Breg at Katzensteig (Fig. 2), the River Brigach at St. Georgen and Marbach, the River Danube at Pfohren, Hausen and Daugendorf. On the other hand there are some sites were the number of species also increases considerably in the third year of investigation like in the River Breg in Hüfingen (Fig. 2), in the River Danube in Tuttlingen, Scheer and Nasgenstadt. In Tuttlingen this may be caused by improvement of water quality: the town has built a new sewage plant. In these cases, results of the running year will show, when the list of species will be as complete as that of the other sites!

The results of the 14 different sites from each sampling period were summarized and the resulting number of species over the different sampling periods were cumulated (Fig. 3). Mayflies and stoneflies of the River Danube will be recorded by the given method with about 90% of the species after two years. Collections in the third year yielded only few additional species fo the Danube, and presumably in the following years there will be found only single new species, provided that there will be no drastic increase in species numbers

Table 4. Longitudinal zonation of Plecoptera in the Danube river system. Numbers in brackets (on top) are species numbers.

PLECOPTERA (19)	BRIGACH (10)			BREG (19)			DANUBE (5)							
	BR001	BR009	BR014	QQ002	QQ011	QQ015	QQ101	QQ104	QQ203	QQ304	QQ405	QQ503	QQ701	QQ802
Amphinemura sulcicollis	II			III										
Chloroperla tripunctata				III										
Isoperla oxylepis	II			III										
Leuctra hippopus	I			III										
Protonemura intricata				III										
Protonemura meyeri				III										
Protonemura nitida				I										
Leuctra inermis	III			IIII	III									
Siphonoperla torrentium	II			II	I									
Diura bicaudata				III		I								
Leuctra digitata		I		II		I								
Dinocras cephalotes				I	I									
Nemoura cambrica					I									
Perla marginata				II	I	I								
Nemurella picteti				III	I					I				
Leuctra albida	IIII			III	III						II			
Brachyptera seticornis	II			IIII	III	I	I					I		
Perlodes microcephalus	IIIIIII	I	III	IIIIIII	IIIIIII	IIIIIII	II	I				II	II	
Leuctra fusca		I			I	II	III	I			II	II	IIII	I
NUMBER OF SPECIES:	8	3	1	17	10	6	3	2	0	1	2	3	2	1

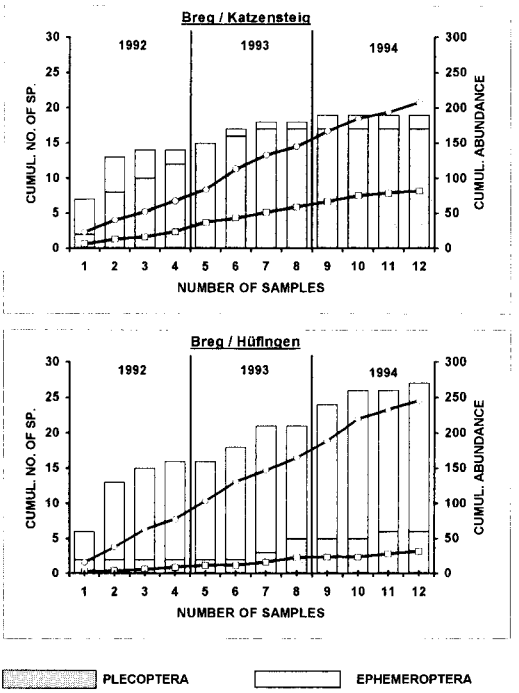

Fig. 2. Cumulative species numbers (columns) and cumulative abundance (squares) of Ephemeroptera and Plecoptera at two representativ sampling stations the River Breg at Katzensteig and the River Breg at Hüfingen.

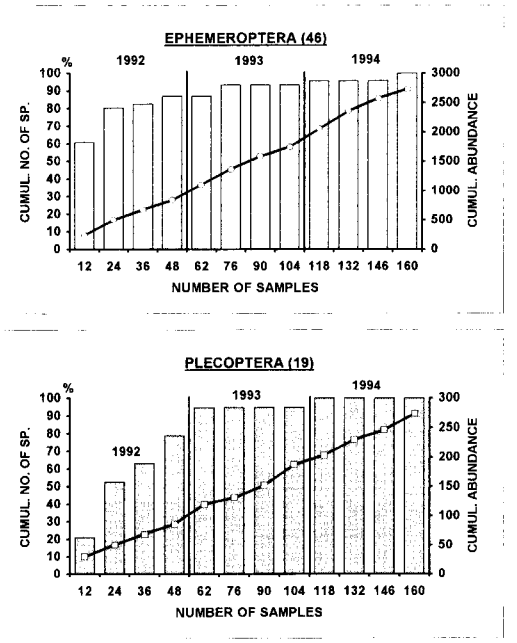

Fig. 3. Cumulative species numbers (columns) and cumulative abundance (squares) of Ephemeroptera and Plecoptera. Results of all sampling sites in each sampling period summarized.

as a consequence of improved water quality. The situation is similar in other species rich taxa groups like beetles and caddisflies (MARTEN, 1995 a, b). But considering groups, which are generally characterized by only few species and high abundance of the single species, for example the Gammaridae, the maximum of species number will be achieved much earlier.

CONCLUSIONS

There is a specific need for well founded baseline data on occurrence and abundance of macrozoobenthos to give reliable assessments of faunistic changes, and to draw conclusions in relation to water pollution, or also to give a basis for the assessment and protection of endangered species. Faunistic comparisons based on only one or two sampling periods, generally providing data on not more than 50% of the existing fauna, or even based on faunistic surveys of almost unknown extent, which concerns most historical surveys, are of doubtful value.

Faunistic shifts described on such a small data base are to some extent inevitable. Concerning the general need for biological monitoring I agree with HYNES (1994) who recently pointed out that «biological monitoring has at least for the foreseeable future a research element to it, and research scientists should not regard monitoring as not worthy of their time»! In Baden-Württemberg we expanded the programme on biological trendmonitoring to the whole country with about 100 sampling sites, considered to be representative for most important rivers and brooks in this area.

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