Monitoring macroinvertebrates in the River Rhine.

Results of a study executed in the Dutch part in 1988.

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CONTENT.

SUMMARY.

On the initiative of the International Commission for protecting the River Rhine against pollution (I.R.C.) the macroinvertebrates in the main stream of the River Rhine will be monitored with an interval of five years, starting in 1990.
The six sampling locations in the different branches of the River Rhine in The Netherlands were sampled for the first time in 1988. Three habitats were sampled: stones in the littoral zone of the the groynes or river banks, the deepest part of the river canal, and the river bottom between the deepest part of the river canal and the river bank.
On the stones 47 aquatic taxa of macroinvertebrates were found. The most important taxa were: *Gammarus tigrinus*, *Dreissena polymorpha*, *Dicrotendipes* gr. *nervosus*, *Bithynia tentaculata*, *Lymnaea peregra* f. *ovata*, *Ecnomus tenellus*, *Hydropsyche contubernalis*, *Cricotopus bicinctus*, and *C. intersectus*.
In both river bottom habitats 47 aquatic taxa of macroinvertebrates were found as well. *Gammarus tigrinus*, *Dreissena polymorpha*, *Ancylus fluviatilus*, *Bithynia tentaculata*, *Potamopyrgus antipodarum*, *Pisidium supinum*, *Hydropsyche contubernalis*, and *Chironomus* gr. *reductus* were the most important taxa. The total number of taxa found during this study was 69.
Water quality of the River Rhine, based on macroinvertebrates, was assessed to be moderately to slightly polluted, based on the Belgian Biotic Index.

INTRODUCTION.

After the severe pollution of the River Rhine in November 1986, caused by a fire in one of the factories of the chemical concern Sandoz near Basel, the different countries associated in the International Commission for protecting the River Rhine against pollution (I.R.C.), took the initiative to pay more attention to biological monitoring. Before that time, the control of chemical compounds in the river water had been emphasized.
One of the results of the initiative was an international measuring programme for monitoring the macroinvertebrates in the main stream with an interval of five years, starting in 1990 (Anon., 1989). The intention of this measuring programme was to assess the development of fish species, macroinvertebrates, plankton and water plants by means of quantitative studies on fixed sampling sites. With the results of these studies, it will be possible to visualize the results of efforts at the ecological rehabilitation of the River Rhine.

Preceding the start of the monitoring programme, the locations proposed in The Netherlands for the sampling of macroinvertebrates were sampled for the first time in 1988. The aim of that study was to obtain a set of data which could serve as a reference for the results of the investigations in 1990.
Data from previous years about the occurrence of macroinvertebrates in the different River Rhine branches in The Netherlands are very scarce. Klink & Moller-Pillot (1982) published a list of species found the River Waal, others (Van den Brink & Van der Velde, 1986a, 1986b; Van den Brink e.a., 1988, 1989; Bij de Vaate & Greijdanus-Klaas, 1990) reported about the occurence of single species.
Only in the River IJssel (figure 1.) relatively more attention has been given to some groups of macroinvertebrates during the last years (Van Urk, 1978, 1981, 1984; Van Urk & Bij de Vaate, 1990).
A recent summary of changes in the macroinvertebrate communities in the Dutch part of the River Rhine during this centuary has been given by Van den Brink e.a. (1990).

The results of the 1988 River Rhine macroinvertebrate monitoring are summarized in this report.

STUDY AREA.

Figure 1 shows the Dutch part of the River Rhine. Soon after passing the German-Dutch border near Lobith, the river splits up into two branches: the River Waal and the River Pannerdens Kanaal, going into western and northern direction respectively. East of Dordrecht, the River Waal splits up into the Rivers Beneden Merwede and Nieuwe Merwede. The rivers Nieuwe Merwede and Meuse flow together into the Hollandsch Diep, and after that in Lake Haringvliet. In this former estuary, formed by the Hollands Diep and Lake Haringvliet, water quality is mainly determined by the River Rhine accounting for 75 % of the discharge under average conditions. Current velocities in the area strongly depend on the River Rhine discharge: at high level of discharges (>3000 $m^3.s^{-1}$) the river character dominates while during periods of low flow (< 1700 $m^3.s^{-1}$) current velocities drop to a few $cm.s^{-1}$. Discharge of the rivers Nieuwe Merwede and Meuse into the North Sea goes via the Haringvliet sluices in the barrier dam forming the west bank of Lake Haringvliet. The River Beneden Merwede is connected up to the man-made canal Nieuwe Waterweg. This canal forms the connection between the harbors of Rotterdam and the North Sea. To prevent the extension of the area with brackish ground water around the Nieuwe Waterweg canal, discharge of the Rivers Rhine and Meuse is regulated by the Haringvliet sluices. This means the maintenance of a discharge of at least 1500 $m^3.s^{-1}$ via the Nieuwe Waterweg canal at sufficient discharge of both rivers. The Haringvliet sluices are closed when the combined discharge of the River Meuse and the River Rhine branches Nederrijn/Lek and Waal is below 1500 $m^3.s^{-1}$.

Near Arnhem, the River Pannerdens Kanaal splits up into the River Nederrijn and the River IJssel, going into western and northern direction respectively (Fig. 1). Downstream of the town of Wijk bij Duurstede the name of the River Nederrijn changes into the River Lek.
In the River Nederrijn three weirs have been constructed for the regulation of the water level and for the distribution of the River Rhine discharge to the river branches.

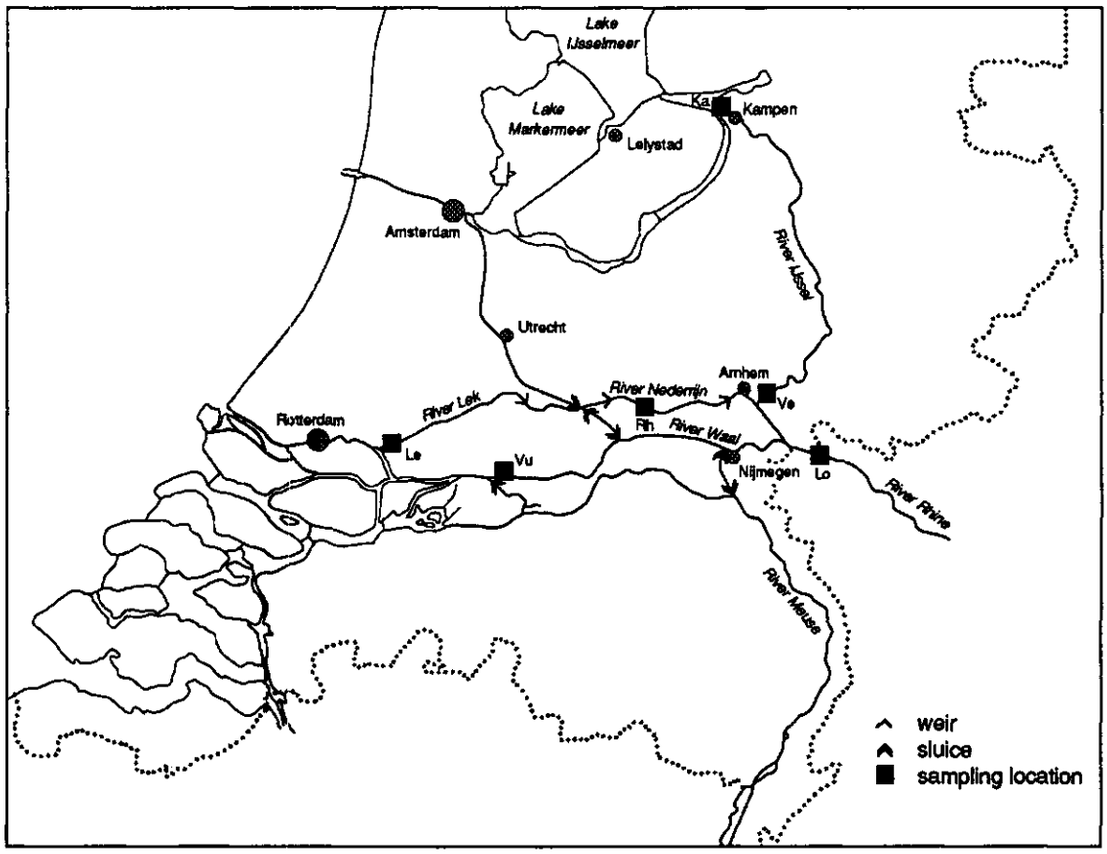
In the River Lek and in the downstream part of the River Waal the water level is influenced by tidal movements in the North Sea.

Discharge of the River IJssel is strongly regulated by the weirs in the River Nederrijn and is maintained at a minimum of 285 $m^3.sec^{-1}$ as long as possible at low discharge of the River Rhine.
More information about the River Rhine branches is given by Van Urk (1984), Van Urk & Smit (1989) and Anon. (undated).

In general the flow canal in the lower River Rhine and its branches is fixed by groynes. Where groynes are absent, the river bank is mostly protected against erosion by the use of stones.

Average yearly discharge of the River Rhine near Lobith is about 2,200 $m^3.sec^{-1}$. Observed minimum and maximum discharge 780 and 10,300 $m^3.sec^{-1}$. on July 11, 1976 and March 30, 1988 respectively. Current velocity in the River Rhine near Lobith at minumum and maximum discharge is 0.7 and 2.0 $m.sec^{-1}$ respectively. Average current velocities in the River Rhine branches at both discharges are 0.7 and 2.0 $m.sec^{-1}$ in the River Waal, <0.1 and 1.1 $m.sec^{-1}$ in the River Nederrijn/Lek, and 0.3 and 1.1 $m.sec^{-1}$ in the River IJssel.

Figure 1.: The Dutch part of the River Rhine including the sampling locations.



STUDY LOCATIONS.

Study locations (Fig. 1) have been chosen near the permanent field stations (Lobith, Kampen and Vuren) along the river, or on the basis of prevailing hydrological conditions (upstream/downstream, influence of weirs, tidal movements, a.o.). An important criterium for the choice was the imperative absence of a direct influence of waste water discharges upstream of the locations.

On every study location different sites (habitats) have been sampled:

* stones in the littoral zone of the groynes on the right and left bank (when groynes were absent, stones in the littoral zone of both river banks);
* one site at the deepest part of the river canal;
* one site at half the longest distance between the deepest part of the river canal and the river bank.

In table 1, a survey of the study locations in the River Rhine and its branches is given.

Table 1.: A survey of the study locations (kmr: the international accepted indication of river distance, in km).

River	Location	kmr
Rhine	Lobith	860
Waal	Vuren	951
Nederrijn	Rhenen	912
Lek	Lekkerkerk	982
IJssel	Velp	885
IJssel	Kampen	1002

On the right bank of the location Lekkerkerk and on the left bank of the location Kampen, groynes are absent. In stead, stones in the littoral zone of the river bank have been sampled.

METHODS.

Samples have been taken in the littoral zone of the groynes (around the head) on the right and left river bank, in the deepest part of the flow canal and on a site in the river located at half the maximum distance between the deepest part of the flow canal and the river bank. When groynes were absent (Lekkerkerk, Kampen), samples were taken in the littoral zone of the river bank.
To make sure that well colonized stones would be sampled, the sampling period chosen was in autumn, the period with the yearly minimum waterlevel in the river. At the location influenced by the tide (Lekkerkerk) sampling took place during low tide for the same reason. The sampling programme was executed between September 28 and October 19, 1988.

In the littoral zone of the river bank or the groynes only the macroinvertebrates on stones have been sampled. On both sampling sites of every location (right and left bank), five well overgrown stones were brushed in a plastic tray to remove the macroinvertebrates. Zebra mussels were cut from the stones. The macroinvertebrates were cleaned then by washing them on a 0.5 mm mesh width sieve before conservation in ethanol 96%. After cleaning the surface area of the stones was measured.

The river bottom was sampled with a grab designed by Bovens (1984). A drawing of this grab is given in figure 2. At the river bottom sampling sites of each location (at the deepest part of the river canal and at the "half distance") five bottom samples were taken. The samples were washed on a 0.5 mm mesh width sieve and the residue conserved in ethanol 96%. When bottom samples consisted of coarsly sand, or coarsly sand mixed with gravel, the macroinvertebrates were washed out by repeatedly mixing small parts of the sample thoroughly with water and decanting the supernatant over the sieve, until the animals had been collected from the whole sample. Bigger particles (pebbles and cobbles) were brushed and the materials brushed were handled as described above for the sampling of stones.

To convert the numbers of animals observed on the stones to densities per m^2 river bank surface, the following conversion factor was used: $N = \Sigma d * (10{,}000 / \Sigma a)$.
In this factor is: N = number of animals m^2,
Σd = sum of animals on n stones,
Σa = sum of the mean surfaces (cm^2) of the two largest sides of n stones.

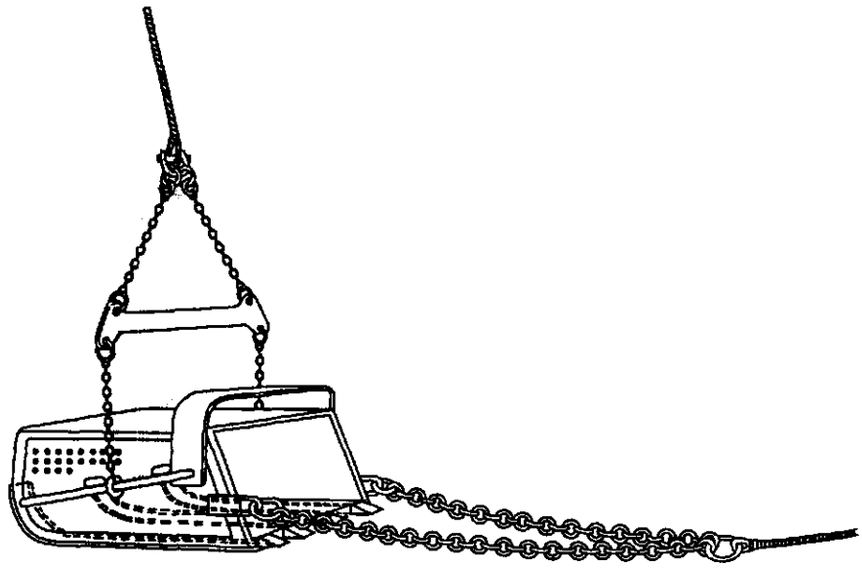
The presence of taxa in the habitats sampled is expressed in a value that indicates the chance of being found (abbreviated as c.f.-value).
When an organism occured in 1-20% of the samples this value is 1. At 21-40%, 41-60%, 61-80% and 81-100%, the c.f.-value is 2, 3, 4 and 5 respectively.

For the assessement of water quality based on the presence of macro-invertebrates the Belgian Biotic Index (BBI) was used (De Pauw & Vanhooren, 1983). Values can vary between 0 (very heavily polluted) and 10 (unpolluted or lightly polluted).

A cluster analysis has been executed by calculating euclidean distances of the data and using the complete linkage method (Van Tongeren, 1987). For this purpose densities of taxa have been tranformed into abundancy classes:

numbers	class
0	0
1	1
2 - 3	2
4 - 8	3
9 - 17	4
18 - 34	5
35 - 67	6
68 - 132	7
133 - 261	8
>261	9

Figure 2.: The grab designed by Bovens (1984).



RESULTS.

Stones in the littoral zone of the groynes and river banks.

Numbers of animals found on the stones in the littoral zones of the groynes and the river banks (Lekkerkerk and Kampen) are summarized in appendix 1. From the point of view of richness of species, the density in which the single species occur is not important. Only the presence of species is the determining factor.
Presence of taxa at the different locations, expressed in c.f.-values (see Methods), has been calculated for the stones of both river banks together. The results are given in table 2.

Table 2.: The presence of taxa on the the stones in the littoral zone of the groynes or river banks, expressed in c.f.-values.
Lob. = Lobith, Vur. = Vuren, Rhe. = Rhenen, Lek. = Lekkerkerk and Kam. = Kampen.

Taxon	Location						
	Lob.	Vur.	Rhe.	Lek.	Velp	Kam.	
Amphipoda							
Corophium curvispinum		1				1	
Gammarus pulex						3	
G. tigrinus	5	5	5	5	3	5	
G. sp.	1	3	2	4		1	
Tricladida							
Dugesia tigrina	2	2					
D. polychroa		1		1			
Oligochaeta							
Limnodrilus claparedeianus		1					
Oligochaeta sp.		1	1				
Psammoryctides barbatus		1					
Hirudinea							
Cystobranchus respirans	1						
Erpobdella octoculata		1		1	1	1	
E. testacea				1			
Glossiphonia complanata	1	1		2	1		
Helobdella stagnalis			1				
Gastropoda							
Ancylus fluviatilis	4		1	1	2		
Acroloxus lacustris				1			
Bithynia leachi							1
B. tentaculata	3	4	1	4	1	4	

Table 2, continuation.

Taxon	Location					
	Lob.	Vur.	Rhe.	Lek.	Velp	Kam.
Lymnaea peregra f. ovata	3	3	2	3	1	2
Physa acuta		3				
P. fontinalis				1		
Potamopyrgus antipodarum	1	2		1		
Lamellibranchia						
Dreissena polymorpha	5	5	5	5	4	5
Pisidium moitessierianum						1
Sphaerium corneum	1	1				2
Isopoda						
Asellus aquaticus			1		1	1
Trichoptera						
Ecnomus tenellus	1	1	2	1	1	4
Hydropsyche contubernalis	5	4	2		1	1
Tanypodinae						
Rheopelopia ornata			1			
R. sp.		1				
Chironomini						
Cryptochironomus sp.						1
Dicrotendipes gr. nervosus	5	4	5	3	1	3
Endochironomus albipennis					1	
Glyptotendipes sp.		1	5			3
Parachironomus gr. longiforceps	1	1				
Xenochironomus xenolabis					1	
Tanytarsini						
Micropsectra atrofasciata	1					
Rheotanytarsus rhenanus	2					
R. sp.	1	1				
Orthocladiinae						
Cardiocladius sp.			1			
Cricotopus bicinctus	5	3	5	2	2	2
C. intersectus		2	5	2	2	1
C. sylvestris			1		1	
C. triannulatus		4	1	1		
C. sp.	1					
Eukiefferiella discoloripes	1	1				
Limnophyes sp.				1		
Nanocladius bicolor	1					
Orthocladius sp.		1		1		
Paratrichocladius rufiventris	1	1	2		1	
Rheocricotopus chalybeatus		1	1	1		
Terrestrical organisms						
Diptera sp.					1	
Limnophius riparia		1				
Pleolophus brachypterus			1			
Tipulidae sp.						1

The species *Gammarus tigrinus*, *Dreissena polymorpha* and *Dicrotendipes* gr. *nervosus* have not only been found at every location, but on nearly all the stones as well.
At at least five of the six locations examined, the species *Bithynia tentaculata*, *Lymnaea peregra* f. *ovata*, *Ecnomus tenellus*, *Hydropsyche contubernalis*, *Cricotopus bicinctus* and *C. intersectus* were presented, mostly with a lower cf.-value than the group first mentioned.
More than 85% of the the animals found on the stones belonged to these nine species (Table 3.).

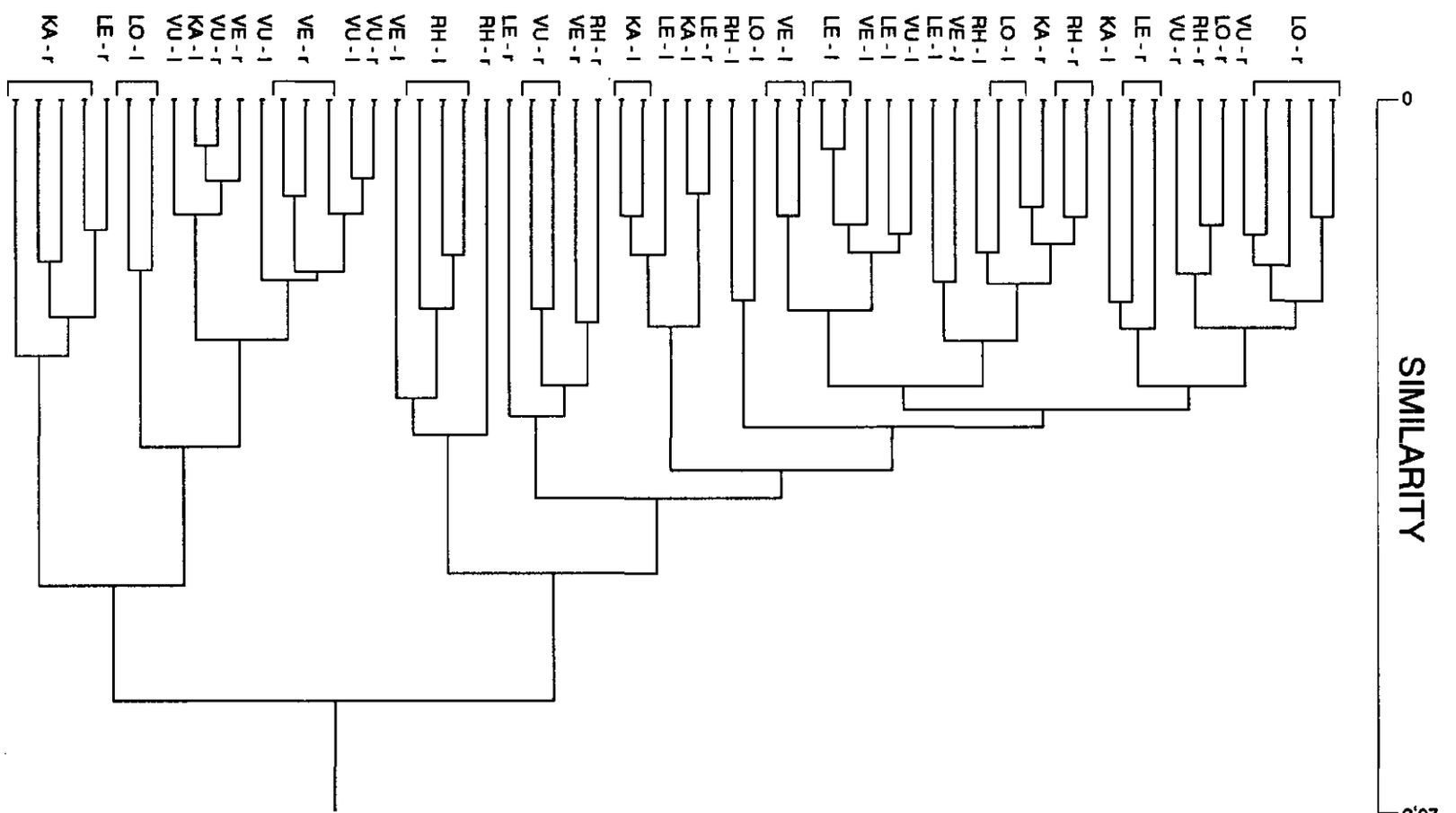
Table 3.: Average density (number per m^2) of the important macroinvertebrates on the stones in the littoral zone of the groynes or river banks on the different locations and the contribution of this group of species to the biocoenosis (expressed in percentages).
Lob. = Lobith, Vur. = Vuren, Rhe. = Rhenen, Lek. = Lekkerkerk and Kam. = Kampen.

	Location					
Taxon	Lob.	Vur.	Rhe.	Lek.	Velp	Kam.
Gammarus tigrinus	980	2300	850	2100	25	3300
Dreissena polymorpha	300	3800	460	890	310	1100
Dicrotendipes gr. nervosus	120	130	450	610	6	190
Bithynia tentaculata	460	590	15	50	3	180
Lymnaea peregra f. ovata	80	200	10	20	15	30
Ecnomus tenellus	3	3	15	10	9	190
Hydropsyche contubernalis	1600	140	120	0	3	150
Cricotopus bicinctus	240	60	150	60	55	30
C. intersectus	0	12	440	20	20	8
Contribution (%) in biocoenosis	86	97	90	97	85	91

At some locations four of these dominant taxa have been collected on at least four stones at one side of the river and not at the other side. It concerned *B. tentaculata* at Lobith, *L. peregra* f. *ovata* at Vuren, *D.* gr. *nervosus* at Lekkerkerk and Kampen, and *C. bicinctus* at Kampen.

In the clustering analysis no distinct sampling locations with a clearly different biocoenosis could be distinguished. Figure 3 shows a dendrogram being the result of the clustering analysis.

Figure 3.: Dendrogram of the samples from the stones in the littoral zone of the groynes or river banks, based on the presence of macroinvertebrates.
LO = Lobith, VU = Vuren, RH = Rhenen, LE = Lekkerkerk, VE = Velp, KA = Kampen, r = right bank and l = left bank.



The river bottom.

General.

The toplayer of the river bottom was examined by eye. The composition varied from a mixture of gravel and coarse sand at Lobith to a mixture of sand and silt at the locations situated downstream in the different River Rhine branches. In the deepest part of the river canal, silt content in the toplayer was lower than at half the longest distance between this part of the river canal and the river bank.

The deepest part of the river canal.

Number of animals found in the bottom samples from the deepest part of the river canal are summarized in appendix 2. Samples has been taken at five locations: Lobith, Vuren, Rhenen, Lekkerkerk and Velp.
Presence of taxa in the samples is given in c.f.-values (see Methods) which are summarized in table 4.

Table 4.: Presence of taxa in the deepest part of the river canal at the different locations, expressed in c.f.-values.
Lob. = Lobith, Vur. = Vuren, Rhe. = Rhenen and Lek. = Lekkerkerk.

Taxon	Location				
	Lob.	Vur.	Rhe.	Lek.	Velp
Amphipoda					
Gammarus tigrinus	4	3	4	5	5
G. sp.	2		3	2	5
Tricladida	4		1		3
Oligochaeta					
Limnodrilus claparedeianus			3		
L. hoffmeisteri			4		
Oligochaeta sp.		1	4	4	4
Nais sp.	1	2			
Psammoryctides barbatus		1			3
Hirudinea					
Erpobdella octoculata			1		5
E. testacea	2				3
Glossiphonia complanata					5
G. heteroclita					2
Piscicola geometra			3		

Table 4, continuation.

Taxon	Location				
	Lob.	Vur.	Rhe.	Lek.	Velp
Gastropoda					
Ancylus fluviatilis	4				1
Acroloxus lacustris					1
Bythinia tentaculata	5	2	1		5
Gyraulus albus					1
Lymnaea peregra f. ovata	3	1	2		2
Potamopyrgus antipodarum	5		5	1	
Valvata piscinalis					1
Lamellibranchia					
Corbicula fluminea				5	
Dreissena polymorpha	5	2	5	1	5
Pisidium moitessierianum			1		
P. nitidum					3
P. subtruncatum			1		
P. supinum	3	1	5		1
P. sp.					1
Sphaerium corneum	3	3	2		4
Isopoda					
Proasellus meridianus	2				2
Trichoptera					
Ecnomus tenellus			1		
Hydropsyche contubernalis	5		2		3
Tanypodinae					
cf. Conchapelopia sp.					2
Rheopelopia ornata	1				
Procladius sp.			1		
Chironomini					
Chironomus gr. fluviatilis			2		
C. gr. reductus	1		5		
C. gr. thummi	1				
Cryptochironomus sp.			5	3	
Dicrotendipes gr. nervosus	3		4		4
Glyptotendipes sp.	2		3		
Paratendipes intermedius			1	1	
Polypedilum gr. breviantennatum			2		
Tanytarsini					
Rheotanytarsus sp.	3				
Orthocladiinae					
Cricotopus bicinctus	2				
C. sp.	3				
Eukiefferiella discoloripes	2				
Rheocricotopus chalybeatus			1		

Important species in this habitat of the River Rhine are the amphipod *G. tigrinus* and the bivalve *D. polymorpha*; they have been found at all locations. At Lobith the caddis fly larva *H. contubernalis*, the gastropods *A. fluviatilus* and *B. tentaculata* were the dominant species. Dominant taxa at Rhenen: the chironomid taxon *C.* gr. *reductus*, the bivalve *P. supinum*, the gastropod *P. antipodarum* and *G. tigrinus*.
At Velp, *D. polymorpha* and *G. tigrinus* were the dominant species. At the locations of Vuren and Lekkerkerk density of the macroinvertebrates was relatively low.
Average densities of the important taxa are given in table 5. In comparison with Lobith and Rhenen contribution of the above mentioned taxa to the biocoenosis was low at the locations with relatively low densities of these dominant taxa (locations at Vuren and Lekkerkerk).
The bivalve *C. fluminea* (Asiatic clam) in the samples at Lekkerkerk meant that a new species hab been found in the aquatic fauna of The Netherlands.

Table 5.: Average densities (number per m^2) of the important taxa occurring in the deepest part of the river canal and the contribution of this group to the biocoenosis (expressed in percentages).
Lob. = Lobith, Vur. = Vuren, Rhe. = Rhenen, Lek. = Lekkerkerk and Kam. = Kampen.

	Location				
Taxon	Lob.	Vur.	Rhe.	Lek.	Velp
Gammarus tigrinus	240	40	1300	600	3100
Dreissena polymorpha	150	15	160	7	2100
Ancylus fluviatilis	590	0	0	0	7
Bithynia tentaculata	370	50	40	0	510
Potamopyrgus antipodarum	100	0	1200	7	0
Pisidium supinum	60	5	700	0	14
Hydropsyche contubernalis	8500	0	50	0	160
Chironomus gr. reductus	7	0	26000	0	0
Contribution (%) in biocoenosis	90	48	96	47	70

The river bottom between the deepest part of the river canal and the river bank.

In contrast with the deepest part of the river canal, species richness and density of the macroinvertebrates collected from the bottom samples, taken at half the longest distance between that site and the river bank, were much lower. Numbers of animals found in these samples are summarized in appendix 2. Species richness can be derived from table 6 in which the presence of taxa is given, expressed in c.f.-values.

Table 6.: The presence of taxa in bottom samples taken at half the longest distance between deepest part and the river bank, expressed in c.f.-values.
Lob. = Lobith, Vur. = Vuren, Rhe. = Rhenen and Lek. = Lekkerkerk.

Taxon	Location				
	Lob.	Vur.	Rhe.	Lek.	Velp
Amphipoda					
Gammarus tigrinus	3	3	5	5	3
G. sp.	2	2	3	1	
Oligochaeta					
Limnodrilus claparedeianus			4		
L. hoffmeisteri			3		
Oligochaeta spp.	2	1	4	2	
Nais sp.		1			
Gastropoda					
Acroloxus lacustris				1	
Potamopyrgus antipodarum			1		
Valvata piscinalis	1				
Lamellibranchia					
Corbicula fluminea				5	
Dreissena polymorpha	5		2		1
Pisidium nitidum	1				
P. supinum	1		2		
Sphaerium corneum	1		1		2
Unio pictorum			1		
Tanypodinae					
Rheopelopia ornata			1		
Procladius sp.	1				
Chironomini					
Chironomus gr. fluviatilis			5		
C. gr. reductus	1		5		1
C. gr. thummi	1				
Cryptochironomus sp.			1	2	
Dicrotendipes gr. nervosus	2		1		
Endochironomus albipennis	1				
Glyptotendipes sp.	1		1		
Polypedilum gr. nubeculosum			1		
Terrestrical organisms					
Hemiptera sp.		1			

Only the amphipod *G. tigrinus* has been found in relatively low densities at all locations. At Rhenen the highest species richness including the maximum number of animals was found.

Clustering analysis of the data from this habitat (C) and the habitat 'deepest part of the river canal (Cd)' resulted (figure 4) in distinct clusters for Lobith-Cd (all five samples), Velp-Cd (all five samples), and Rhenen-Cd (four samples). Higher densities

of the next invertebrates led to this distinction:
a. the amphipod *G. tigrinus* (Velp-Cd);
b. the bivalves *D. polymorpha* (Lobith-Cd , Velp-Cd and Rhenen-Cd) and *S. corneum* (Velp-Cd);
c. the gastropods *B. tentaculata* (Lobith-Cd and Velp-Cd), *P. antipodarium* (Lobith-Cd and Rhenen-Cd) and *A. fluviatilis* (Lobith-Cd);
d. the chironomid *C.* gr. *reductus* (Rhenen-Cd);
e. the leeches *E. octoculata* and *G. complanata* (Velp-Cd).

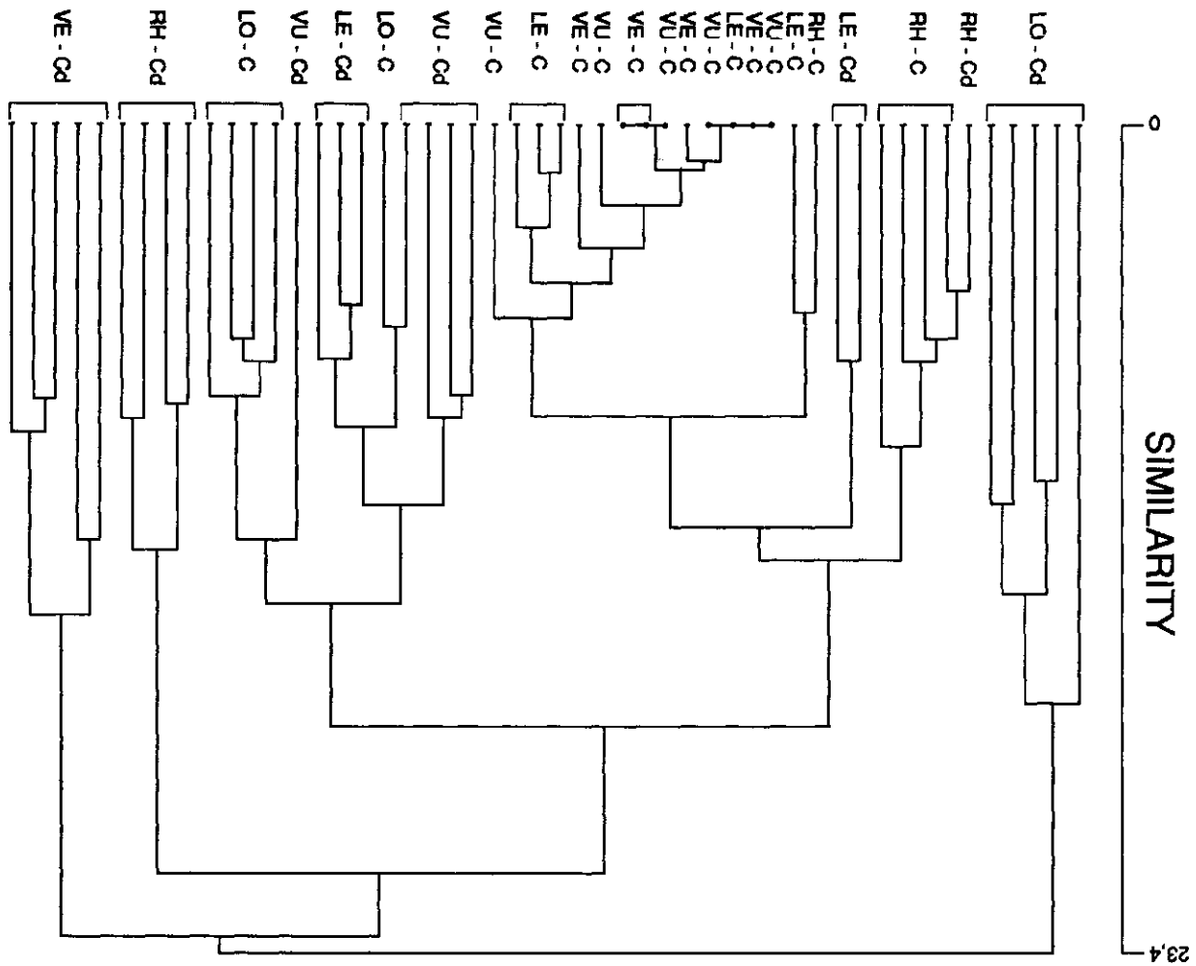
Assessment of water quality.

Values for water quality at the different sampling locations in the River Rhine branches, based on the presence of macro-invertebrates, and assessed with the Belgian Biotic Index (BBI) are given in table 7.
The values, based on species composition in all sampled habitats, indicate a moderately (value 6) or slightly (value 7) polluted situation.

Table 7.: Water quality in the River Rhine in BBI-values calculated from the species composition in the sampled habitats.

river	location	BBI
Rhine	Lobith	6
Waal	Vuren	6
Nederrijn	Rhenen	6
Lek	Lekkerkerk	6
IJssel	Velp	7

Figure 4.: Dendrogram of the samples from the deepest part of the river (C) and from the part at half the longest distance between the deepest part and the river bank (Cd), based on the presence of macroinvertebrates.
LO = Lobith, VU = Vuren, RH = Rhenen, LE = Lekkerkerk, VE = Velp and KA = Kampen,



DISCUSSION.

General.

A complete list of macroinvertebrates found in the three different habitats sampled at five (river bottom habitats) or six (solid substrate habitat) locations is given in appendix 3. This list includes about 60% of the number of aquatic taxa found in the Lower River Rhine in the period 1970 - 1988 as given by Van den Brink, e.a. (1990). The information given by these authors is based on results of different studies executed in that period. A large number of collecting and sampling methods have been used. In table 8 the number of taxa collected, belonging to different groups of macroinvertebrates, is given.

Table 8.: Number of taxa collected in the Dutch part of the River Rhine:
A = period 1970 - 1988 (Van den Brink, e.a., 1990);
B = this study.

	Number of taxa	
Group	A	B
Amphipoda	5	3
Isopoda	3	2
Tricladida	3	2
Oligochaeta	15	6
Hirudinea	10	7
Gastropoda	10	10
Lamellibranchia	7	9
Decapoda	5	0
Odonata	2	0
Heteroptera	2	0
Ephemeroptera	2	0
Trichoptera	5	2
Chironomidae	51	28
Total	120	69

When the results of this study are compared (Table 8.) with this survey it can be concluded that some groups of organisms have clearly been underrepresented in the samples, specially:

a. the Oligochaeta:
   This can be a sampling artefact. These fragile invertebrates need special attention during the washing procedure of the samples and a sieve with finer meshes is

necessary.

b. the Decapoda:
   The sampling procedures were not suitable for collecting these animals.
c. the Chironomidae:
   A lot of species only live in special habitats. The relatively low number of taxa found in this study can mainly be attributed to the low number of habitats investigated.

Stones in the littoral zone of the groynes and river banks.

The number of taxa found at each location is not only determined by regularly occurring taxa but by a single specimen of a taxon as well. The occurrence of these single specimens in the total sum of five samples from both river banks at each location can be interpreted as migratory organisms which have been caught coincidentally. In most cases (at Vuren, Rhenen, Lekkerkerk and Velp) these single specimens explain the difference in species richness at both river banks (Table 9.). The relatively big difference between both river banks at Lobith is inexplicable. One year later (on October 6, 1989) this location was resampled and at both river banks 22 taxa (without single specimens) were found. At Kampen, some hundred meters upstream of the location, there is some local industrial activity on the left bank. This may be an explanation for the difference in species richness between the right and left bank.

Table 9.: Number of taxa on the stones in the littoral zone of the groynes or the river banks. Between brackets the number of taxa without single specimens.

river	location	river bank(s)		
		right	left	both
Rhine	Lobith	15 (8)	20 (17)	24 (17)
Waal	Vuren	28 (15)	15 (12)	29 (18)
Nederrijn	Rhenen	16 (12)	13 (13)	18 (17)
Lek	Lekkerkerk	10 (8)	14 (9)	18 (12)
IJssel	Velp	12 (8)	11 (6)	17 (12)
IJssel	Kampen	14 (12)	9 (7)	16 (13)

The river bottom.

According to Tittizer & Schleuter (1986) and Schleuter & Tittizer (1988) species richness and population density of macro-invertebrates decreases with the increase of smaller particles in the toplayer of the river bottom. The results of this study led to the same conclusion. In the deepest part of the river canal the substrate consits of coarser-grained material than at half the longest distance between this part and the river bank. The same relation exists between the upstream locations (Lobith, Rhenen and Velp) and the downstream ones (Vuren and Lekkerkerk). In table 10 the number of taxa observed in both habitats is given. The relatively high number of taxa in the 'C'-habitat (for explanation see text table 10) at Rhenen is striking. This location is situated between two weirs in the River Nederrijn which were in operation during the sampling period. In that case discharge of the river is very low (about 40 m^3/sec. on average) and the differences between both distinct habitats will diminish as well.

When single specimens of taxa are left out of consideration, the contribution of taxa of the 'C'-habitat to the total number of taxa observed in the samples from the river bottom is neglectable (Table 10.).

Table 10.: Number of taxa in the deepest part of the river canal (Cd), at half the longest distance between this part and the river bank (C), and in both habitats (Cd+C). Between brackets the number of taxa without a single specimen of a taxon.

river	location	habitat		
		Cd	C	Cd+C
Rhine	Lobith	22 (19)	11 (3)	27 (20)
Waal	Vuren	9 (6)	2 (2)	9 (6)
Nederrijn	Rhenen	25 (20)	16 (11)	27 (20)
Lek	Lekkerkerk	7 (4)	6 (4)	9 (4)
IJssel	Velp	23 (20)	3 (3)	23 (20)

Assessment of water quality.

The biological assessment of water quality with the Belgian Biotic Index (BBI) is based on a sampling procedure with a hand net (De Pauw & Vanhooren, 1983). With this hand net all accessible aquatic habitats must be explored. Sampling effort should cover an effective river stretch of 10 to 20 m in a limited period of time.
The sampling methods used in this study differed from the recommended procedure. The most important difference is the bottom surface sampled which is larger when a

hand net is used. On the other hand, with this method it is impossible to sample stones effectively in the littoral zone of the groynes. Because indicator organisms of a good water quality used in the index are in general animals living on solid substrates, it is necessary to examine these stones carefully. Other solid substrates like water plants were absent at the study locations chosen.

Species richness in the habitat 'river bottom between the deepest part of the river canal and the river bank' was relatively low, and in general the species occurring were found in the habitat 'river bottom deepest part of the river canal' as well. Species composition in the first mentioned habitat did not contribute therefore to a higher BBI-value (Table 11.).

Table 11.: The Belgian Biotic Index based on the samples from the three habitats examined (A), the habitats 'stones in the littoral zone' and 'bottom deepest part river canal' (B), and only based on the habitat 'stones in the littoral zone'(C).

river	location	BBI		
		A	B	C
Rhine	Lobith	6	6	5
Waal	Vuren	6	6	6
Nederrijn	Rhenen	6	6	5
Lek	Lekkerkerk	6	6	5
IJssel	Velp	7	7	5

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Appendix 1.

Number of animals collected at the locations of Lobith, Vuren, Rhenen, Lekkerkerk, Velp and Kampen from the stones in the littoral zone of the groynes on the right (sample R1-R5) and left bank (sample L1-L5) or from the stones in the littoral zone of the river banks when groynes are absent (Lekkerkerk: right bank; Kampen: left bank). The surface given is the mean value (cm^2) of the two largest sides of each stone.

Lobith

	samples from the stones									
	R1	R2	R3	R4	R5	L1	L2	L3	L4	L5
Amphipoda										
Gammarus tigrinus	18	41	166	75	12	3	14	2	2	2
G. sp.			2				1			
Tricladidae										
Dugesia tigrinus	1					6		5		15
Oligochaeta										
Oligochaeta sp.			1							
Hirudinea										
Cystobranchius resprespirans					1					
Glossiphonia complanata								1		
Gastropoda										
Ancylus fluviatilis	27	7			2	5	4	17	19	9
Bithynia tentaculata						19	11	46	22	11
Lymnea peregra f. ovata	1					4	1	9	1	4
Potamopyrgus antipodarum							1			1
Lamellibranchia										
Dreissena polymorpha	5	13	25	18	16	2	3	5	4	5
Sphaerium corneum							1	1		
Trichoptera										
Ecnomus tenellus				1						
Hydropsyche contubernalis	29	2	1		5	136	47	43	50	83
Chironomini										
Dicrotendipes gr. nervosus	3	2	1	4	1	8	3		9	2
Parachironomus gr. longiforceps		1								
Tanytarsini										
Micropsectra atrofasciata						1				
Rheotanytarsus sp.	1									
Rheotanytarsus rheanus				1		1	1			
Orthocladiinae										
Cricotopus sp.										2
Cricotopus bicinctus	7	3	3	4	4	11	5		12	15
C. triannulatus	1	1	1			11	2		1	6
Eukiefferiella discoloripes						2				2
Nanocladius bicolor					1					
Orthocladius sp.						1				1
Paratrichocladius rufiventris	1			1					2	1
Rheocricotopus chalybeatus										1
surface (cm^2)	258	377	403	495	232	269	222	297	207	203

Vuren

	samples from the stones									
	R1	R2	R3	R4	R5	L1	L2	L3	L4	L5
Amphipoda										
Gammarus tigrinus	252	48	166	9	27	17	54	77	109	4
G. sp.	10	1		1				1	4	
Corophium curvispinum								1		
Tricladidae										
Dugesia tigrinus	1				6		1			
D. polychroa				2	2					
Oligochaeta										
Oligochaeta sp.	5									
Limnodrilus claparedeianus	1									
Psammoryctides barbatus	1									
Hirudinea										
Erpobdella octoculata	7									
Glossiphonia complanata					1					
Gastropoda										
Bithynia tentaculata	41	31	2		13	16	39	19	31	
Lymnea peregra f. ovata						4	21	6	25	3
Physa acuta	6	5	1		3		2		4	
Potamopyrgus antipodarum	4									
Lamellibranchia										
Dreissena polymorpha	304	40	10	2	192	114	170	137	226	27
Sphaerium corneum	6									
Isopoda										
Asellus aquaticus	1									
Trichoptera										
Ecnomus tenellus			1							
Hydropsyche contubernalis		28	6	3	7	1	1	1		
Tanypodinae										
Rheopelopia sp.		1								
Chironomini										
Dicrotendipes gr. nervosus		10	4	6	4			8	1	9
Glyptotendipes sp.								1		1
Parachironomus gr. longiforceps										1
Tanytarsini										
Rheotanytarsus sp.				1						
Orthocladiinae										
Cardiocladius sp.				1						
Cricotopus bicinctus		4	5	2	1			5		2
C. intersectus		1		2						1
C. triannulatus		1							1	
Eukiefferiella discoloripes		1								
Paratrichocladius rufiventris		3	1							
Rheocricotopus chalybeatus		1								
Terrestrical organisms										
Limnophyes riparia								1		1
surface (cm^2)	260	443	371	333	359	412	208	327	370	198

Rhenen

	samples from the stones									
	R1	R2	R3	R4	R5	L1	L2	L3	L4	L5
Amphipoda										
Gammarus tigrinus	31	20	49	32	30	17	9	16	10	
G. sp.		3		1		1	1			
Hirudinea										
Helobdella stagnalis				1						
Gastropoda										
Ancylus fluviatilis				2	1					
Bithynia tentaculata				2				2		
Lymnea peregra f. ovata				1			1		1	
Lamellibranchia										
Dreissena polymorpha	7	18	8	10	8	32	12	36	1	
Trichoptera										
Ecnomus tenellus		1				2		2		
Hydropsyche contubernalis	3		6	18						
Tanypodinae										
Rheopelopia ornata				2						
Chironomini										
Dicrotendipes gr. nervosus	18	15	25	25	9	2	8	7	1	
Glyptotendipes sp.	3	4	4	3	5	2	6	6	1	
Orthocladiinae										
Limnophyes sp.									1	3
Cricotopus bicinctus	2	4	5	4	6	3	3	3	5	6
C. intersectus	1	6		2	6	12	18	2	42	49
C. sylvestris									3	1
C. triannulatus	4	1								
Orthocladius sp.									1	5
Paratrichocladius rufiventris		1				1			1	
Rheocricotopus chalybeatus				2						
Terrestrical organisms										
Pleolophus brachypterus							1			
surface (cm^2)	182	255	272	255	213	202	462	314	384	280

Lekkerkerk

	samples from the stones									
	R1	R2	R3	R4	R5	L1	L2	L3	L4	L5
Amphipoda										
Gammarus tigrinus	200	83	83	150	145	26	50	40	57	14
G. sp.	6	1		5	1	3			2	4
Tricladidae										
Dugesia polychroa				1						
Hirudinea										
Erpobdella octoculata				1		8				
E. testacea										1
Glossiphonia complanata	1		1							1
Gastropoda										
Ancylus fluviatilis										1
Acroloxus lacustris										1
Bithynia tentaculata				9	1	1	1	1	1	5
Lymnea peregra f. ovata		3	1	1		1				1
Physa fontinalis			1							
Potamopyrgus antipodarum								1		
Lamellibranchia										
Dreissena polymorpha	23	12	13	146	91	23	22	18	11	6
Isopoda										
Asellus aquaticus				9						
Trichoptera										
Ecnomus tenellus				4						
Chironomini										
Dicrotendipes gr. nervosus						38	32	24	63	26
Endochironomus albipennis									2	
Orthocladiinae										
Cricotopus bicinctus						4		1	2	10
C. intersectus						1			1	4
surface (cm^2)	448	690	462	280	413	304	236	280	240	435

Velp

	samples from the stones									
	R1	R2	R3	R4	R5	L1	L2	L3	L4	L5
Amphipoda										
Gammarus tigrinus					1	5	1		1	1
Hirudinea										
Erpobdella octoculata			2							
Glossiphonia complanata	1									
Gastropoda										
Ancylus fluviatilis		1	1					4	1	
Bithynia tentaculata		1								
Lymnea peregra f. ovata						4		1		
Lamellibranchia										
Dreissena polymorpha	7	4		27	14	33			4	17
Isopoda										
Asellus aquaticus	1			1						
Trichoptera										
Ecnomus tenellus	2									1
Hydropsyche contubernalis						1				
Chironomini										
Cryptochironomus sp.								1		
Dicrotendipes gr. nervosus				1			1			
Xenochironomus xenolabis										1
Orthocladiinae										
Cricotopus bicinctus				4	7	5			3	
C. intersectus		3			1	3				
C. sylvestris									2	
Paratrichocladius rufiventris				2						
Terrestrical organisms										
Diptera sp.									1	
Tipulidae sp.		1							7	
surface (cm^2)	400	348	337	425	330	143	383	355	281	457

Kampen

	samples from the stones									
	R1	R2	R3	R4	R5	L1	L2	L3	L4	L5
Amphipoda										
Corophium curvispinum					1					
Gammarus tigrinus	87	88	27	70	58		190	148	29	150
G. pulex	2	5			1			5		30
G. sp.		1		5	4		10	4	3	6
Hirudinea										
Erpobdella octoculata									1	
Gastropoda										
Bithynia leachi									1	1
B. tentaculata	3	5	1	26				1	7	1
Lymnea peregra f. ovata				6	1			1		
Lamellibranchia										
Dreissena polymorpha	26	3	1	63	21	65	22	17	33	45
Pisidium moitessierianum				1						
Sphaerium corneum		2		13					2	1
Trichoptera										
Ecnomus tenellus	2	3	9	5		6		9	2	14
Hydropsyche contubernalis	10			28						
Tanypodinae										
Dicrotendipes gr. nervosus	9	9	2	20	6					
Glyptotendipes sp.	16	1	4	8	11					
Tanytarsini										
Cricotopus bicinctus	1	3	1		3					
C. intersectus		2								
surface (cm^2)	185	213	200	252	393	344	210	218	227	334

Appendix 2.

Number of animals collected in the bottom samples (A1-A5 and B1-B5) at the locations of Lobith, Vuren, Rhenen, Lekkerkerk and Velp. Series A: deepest part of the river canal; series B: half the longest distance between the deepest part of the river canal and the river bank.

Lobith

	bottom sample									
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5
Amphipoda										
Gammarus tigrinus	5		21	5	2		1	5	3	
G. sp.	9		4				1	1		
Tricladidae	2		3	1	1					
Oligochaeta										
Oligochaeta sp.							22	1		
Nais sp.				51						
Hirudinea										
Erpobdella testacea	1		1							
Gastropoda										
Ancylus fluviatilis	65	2	13	2						
Bithynia tentaculata	20	6	17	6	3					
Potamopyrgus antipodarum	2	1	7	3	1					
Lymnea peregra f. ovata	1		2		1					
Valvata piscinalis						1				
Lamellibranchia										
Dreissena polymorpha	8	2	7	2	2					
Pisidium nitidum									1	
P. supinum	2		4	2						1
Sphaerium corneum		2	2	1		1				
Isopoda										
Proasellus meridianus		42	2							
Trichoptera										
Hydropsyche contubernalis	800	12	228	76	72					
Tanypodinae										
Rheopelopia ornata			1							
Procladius sp.									1	
Chironomini										
Chironomus gr. reductus		1								
C. gr. thummi			1						1	
Dicrotendipes gr. nervosus	5		1		1	1	1			
Endochironomus albipennis							1			
Glyptotendipes sp.			1	1			1			
Parachironomus gr. arcuatis									1	
Tanytarsini										
Rheotanytarsus sp.	6		2		3					
Orthocladiinae										
Cricotopus sp.	1		2		1					
Cricotopus bicinctus	1		3							
Eukiefferiella discoloripes	2			1						

Vuren

	bottom sample								
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5
Amphipoda										
Gammarus tigrinus	3		2		1	1	1			1
G. sp.							2	1		
Oligochaeta										
Oligochaeta sp.			2							
Nais sp.	2		6					4		
Psammoryctides barbatus	1									
Gastropoda										
Bithynia tentaculata	5	2								
Lymnea peregra f. ovata	1									
Lamellibranchia										
Pisidium supinum	1									
Sphaerium corneum	3	1	1							
Dreissena polymorpha	1		1							
Terrestrical organisms										
Hemiptera sp.								1		

Rhenen

	bottom sample									
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5
Amphipoda										
Gammarus tigrinus	5	98	57	20		1	1	11	3	1
G. sp.		22	14	5			1	6		1
Tricladidae	1									
Oligochaeta										
Limnodrilus claparedeianus	4			9	6	1	5		5	13
L. hoffmeisteri	1		1	5	3	5	3		8	
Oligochaeta sp.	10		3	4	4		1	4	21	8
Hirudinea										
Erpobdella octoculata		1								
Piscicola geometra	1		4	1						
Gastropoda										
Bithynia tentaculata				6						
Potamopyrgus antipodarum	1	120	11	30	5				1	
Lamellibranchia										
Dreissena polymorpha	2	6	1	11	2		10	1		
Pisidium moitessierianum		2								
P. subtruncatum				1						
P. supinum		30	14	25	28			1	2	
Sphaerium corneum			5	6					1	
Unio pictorum							1			
Trichoptera										
Ecnomus tenellus		2								
Hydropsyche contubernalis		5		2						
Tanypodinae										
Rheopelopia ornata								1		
Procladius sp.		1								
Chironomini										
Cryptochironomus sp.	1	5	7	7	1	1				
Chironomus gr. fluviatilis			1	1		12	4	1	3	2
C. gr. reductus	23	1065	1110	840	550	38	19	9	25	22
Dicrotendipes gr. nervosus		3	2	4	1			2		
Glyptotendipes sp.		2	2	3						1
Paratendipes intermedius	1									
Polypedilum gr. breviantennatum		3		3						
P. gr. nubeculosum							1	1		
Orthocladiinae										
Rheocricotopus chalybeatus			1							

Lekkerkerk

	bottom sample									
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5
Amphipoda										
Gammarus tigrinus	16	36	5	12	14	1	24	3	9	5
G. sp.	1	8					8			
Oligochaeta										
Oligochaeta sp.	10		1	13	1		2	1		
Gastropoda										
Acroloxus lacustris										1
Potamopyrgus antipodarum					1					
Lamellibranchia										
Corbicula fluminea	4	8	6	16	13	2	12	6	1	1
Dreissena polymorpha	1									
Chironomini										
Chironomus gr. reductus								1		
Cryptochironomus sp.		1		11	1		1		2	
Paratendipes intermedius				1						

Velp

	bottom sample									
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5
Amphipoda										
Gammarus tigrinus	80	92	83	93	81	2	1			1
G. sp.	11	6	10	9	11					
Tricladidae	34		8	4						
Oligochaeta										
Oligochaeta sp.	10		13	12	1					
Psammoryctides barbatus	29		23	22						
Hirudinea										
Erpobdella octoculata	8	5	14	4	11					
E. testacea	2	3	2							
Glossiphonia complanata	8	4	4	3	2					
G. heteroclita	1		1							
Gastropoda										
Ancylus fluviatilis	1									
Acroloxus lacustris	1									
Bithynia tentaculata	20	11	35	4	2					
Gyraulus albus			1							
Lymnea peregra f. ovata			3	1						
Valvata piscinalis		2								
Lamellibranchia										
Dreissena polymorpha	15	4	262	6	5	2				
Pisidium nitidum	7		4	1						
P. supinum	2									
P. sp.	1									
Sphaerium corneum	16		5	2	3	2				1
Isopoda										
Proasellus meridianus	18	1								
Trichoptera										
Hydropsyche contubernalis	1		20	1						
Tanypodinae										
cf. Conchapelopia sp.				1	1					
Chironomini										
Dicrotendipes gr. nervosus	1		1	1	1					

Appendix 3.

The taxa observed in the three habitats examined in the River Rhine and its branches. S = stones in the littoral zone of the groynes or river bank, Cd = bottom in the deepest part of the river canal, C = bottom at half the longest distance between the deepest part of the river and the river bank.

Taxon	Habitat S	Cd	C
Amphipoda			
Corophium curvispinum	+		
Gammarus pulex	+		
G. tigrinus	+	+	+
G. sp.	+	+	+
Isopoda			
Asellus aquaticus	+		
Proasellus meridianus		+	
Tricladida		+	
Dugesia polychroa	+		
D. tigrina	+		
Oligochaeta			
Limnodrilus claparedeianus	+	+	+
L. hoffmeisteri		+	+
Oligochaeta sp.	+	+	+
Nais sp.	+	+	
Nematoda sp.		+	
Psammoryctides barbatus	+	+	
Hirudinea			
Cystobranchus respirans	+		
Erpobdella octoculata	+	+	
E. testacea	+	+	
Glossiphonia complanata	+	+	
G. heteroclita		+	
Helobdella stagnalis	+		
Piscicola geometra		+	
Gastropoda			
Ancylus fluviatilis	+	+	
Acroloxus lacustris	+	+	+
Bithynia leachi	+		
B. tentaculata	+	+	
Gyraulus albus		+	
Lymnaea peregra f. ovata	+	+	
Physa acuta	+		
P. fontinalis	+		
Potamopyrgus antipodarum	+	+	+
Valvata piscinalis		+	+

appendix 3, continuation.

Taxon	Habitat S	Cd	C
Lamellibranchia			
Corbicula fluminea		+	+
Dreissena polymorpha	+	+	+
Pisidium moitessierianum		+	+
P. nitidum		+	+
P. subtruncatum		+	
P. supinum		+	+
P. sp.		+	
Sphaerium corneum	+	+	+
Unio pictorum			+
Trichoptera			
Ecnomus tenellus	+	+	
Hydropsyche contubernalis	+	+	
Tanypodinae			
cf. Conchapelopia		+	
Procladius sp.		+	+
Rheopelopia ornata	+	+	+
R. sp.	+		
Chironomini			
Chironomus gr. fluviatilis		+	+
C. gr. reductus		+	+
C. gr. thummi		+	+
Cryptochironomus sp.	+	+	+
Dicrotendipes gr. nervosus	+	+	+
Endochironomus albipennis	+		+
Glyptotendipes sp.	+	+	+
Parachironomus gr. longiforceps	+		
Paratendipes sp.		+	
Polypedilum gr. breviantennatum		+	
Polypedilum gr. nubeculosum			+
Xenochironomus xenolabis	+		
Orthocladiinae			
Cardiocladius sp.	+		
Cricotopus bicinctus	+	+	
C. intersectus	+		
C. sylvestris	+		
C. triannulatus	+		
C. sp.	+	+	
Eukiefferiella discoloripes	+	+	
Limnophyes sp.	+		
Nanocladius bicolor	+		
Orthocladius sp.	+		
Paratrichocladius rufiventris	+		
Rheocricotopus chalybeatus	+	+	

appendix 3, continuation.

Taxon	Habitat S	Cd	C
Tanytarsini			
Micropsectra atrofasciata	+		
Rheotanytarsus rhenanus	+		
R. sp.	+	+	
Terrestrical organisms			
Diptera sp.	+		
Hemiptera sp.			+
Limnophyes riparia	+		
Tipulidae sp.	+		

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