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Evaluation of macro-invertebrate communities in side channels in the Dutch Rhine.

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Contents

1. Historical changes of the Dutch Rhine

1.1. Physical and chemical changes

The Rhine must have been considered a natural river until the 11th century. From than on the embankment of the river was given shape, resulting in a totally embanked river since the 14th century. This meant that the river was confined to a floodplain of only 1 – 2 km wide. The river was allowed to change its course between these banks. From the 16th century on groins of braided willow twines were placed at banks threatened by the river. Behind these groins rapid sedimentation took place and new land was reclaimed. From the middle of the 19th century to the twenties of the last century a second embankment took place and the river was confined to a narrow main channel. The islands were connected to the shores and every 150 - 200 m groins, constructed from rocks, were placed in the main channel to avoid the river to change its course and to keep the bottom on a navigable depth. As a result the main channel was narrowed from 700 to 300 m. Due to the increased current velocity, sail vessels in the early 20th century were hardly capable to sail upstream any more. At high discharge the water was allowed to inundate the floodplain and since the secondary embankment, a thick layer of clay has been deposited in the floodplains, covering the former variation of soil types. From the end of the 19th century the water quality decreased dramatically. In the early 20th century consumers complained about the “carbolic” taste of the salmon, which became extinct only a few decades later (van Drimmelen, 1987). Since the 1970’s, when the pollution was at its worst, the joint efforts of the Rhine countries resulted in a rapid increase in water quality. Nowadays the oxygen content of the Rhine is near saturation and the micro-pollutant concentrations have been successfully reduced below thresholds for drink water intake. Only for phosphate, nitrate and, incidentally, herbicides the levels are not satisfactory yet. The water quality is expected not to hamper the development of a, once again, very divers aquatic ecosystem. The navigation on the Rhine however is the most intensive in Europe with a total of 150 million tons/y of cargo (CBS, 2001) and even small scale nature development in the main channel is not tolerated.

In 1993 the World Wildlife Fund published Living Rivers (WWF, 1993). A report that advocated the following operations:

- Removal of the secondary embankment
- Digging out a large number of existing former channels in the floodplain, by peeling off the clay that has been deposited since the secondary embankment in the 19th century.

These aspects serve various purposes. In the first place they guarantee better protection against high discharges. Pastureland changes in river bound nature and the clay can be used to build houses and reinforce the primary embankment that showed many weak stretches.

At Christmas 1992 and February 1995 the Rhine reached record levels and in 1995 approximately 300.000 people were evacuated.

These near calamities have accelerated the protection measurements against floods. An emergency law has been installed and the dikes were strengthened with clay from the newly-dug side channels.

Since 1989 a number of side channels have been dug and more will follow. In Table 1 the side channels are noted in which aquatic macro-invertebrates have been monitored.

Table 1. Investigated side channels

year	name	connected to	connection	summer discharge m3/s
1989	Duursche Waarden	IJssel	downstream	0
1991	Blauwe Kamer	Nederrijn	downstream	0
1994 - 1997	Beneden Leeuwen	Waal	both	5?
1994	Opijnen	Waal	both	0,5?
1998 - 1999	Gameren	Waal	both	35

1.2. Changes in the invertebrate community

The reference situation has been established by means of literature study and paleoecological research in abandoned channels. Deposits in abandoned channels contain a rich sub fossil record of remains of insect larvae. Most important groups involved are mayflies (Ephemeroptera), caddis flies (Trichoptera), midges (Chironomidae) and black flies (Simuliidae) remains. Incidentally also stonefly (Plecoptera) and remnants of water bugs (Heteroptera) were identified. A total of 15000 insect remains, covering 167 taxa were encountered in 52 samples from floodplain deposits, dating from 5140 BP to 1914 AD (Klink, 1989). The species diversity in the oldest deposit (5140 BP) does not differ significantly from the situation in a very rich deposit from 1745. In later deposits many characteristic river bound species have disappeared. We can conclude that the invertebrate community of the Rhine in 1745 was still near natural. Although the river bound forests were cut, a lot of snag must still have been present in the river. In Table 2 the distribution of the macro invertebrates (insects) in the different habitats is shown (Klink, 1991).

Table 2: Distribution of the aquatic insects in the different habitats in 1745 (paleoecological research) and 1985 (collection of exuviae).

Habitat	**1745**	**1985**
snags	67	0
vegetation	9	1
sandy bottom	11	6
silty bottom	14	4
rocks	0	77
eurytopic	0	12
total	**100**	**100**

The most striking difference between 1745 and 1985 is the disappearance of snag as most important solid substrate and the introduction of rocks, which are at present the most important habitat of the insect fauna. Also the importance of vegetation for the insect fauna is sharply declined and the bottom as a habitat has lost in importance. At present 12% of the insect fauna can be found in a variety of habitats and can be called eurytopic. The Rhine in 1745 was restricted only by the primary embankment. In the floodplain of 1 – 2 km wide the river was fairly free to change its course. The riverine woods were cut, but the river still contained large quantities of woody debris (snags). Not much later, large scale removal of snags must have taken place during the first channel training works in the 19th century. The bed of the river was more than twice as wide as in the present situation and as a consequence less deep. The erosion and sedimentation must have been in balance, because the river could loose its energy by eroding the banks and moving the sandbars. In the present situation the stream power is absorbed by erosion of the bottom at a rate of about 1 cm/year. In the reference, large sandy and muddy flats were present and they could fall dry and supported higher plants or characea. The sediment composition was finer and more heterogeneous than in the present state. Many species were confined to snags like filter feeders (Simuliidae, Hydropsychidae, Brachycentridae) and miners (Potamophilus acuminatus and other Elmidae, Symposiocladius lignicola and Stenochironomus). Vegetation, probably only abundant in the western part of the Netherlands, played a modest role in the 1745 deposit from the more dynamic Rhine in the eastern part of the Netherlands. The bottom inhabited 25% of the invertebrates. The relative importance of the bottom as a habitat has declined from 25% to 10%. At least in part this is due to the scouring of shores and bottom by the navigation

(Klink, 2002). What all these changes have done to the biodiversity in the river and floodplain is showed in Table 3.

Table 3: Decline in biodiversity in the Rhine from 1745.

Group	**total**	**1745**	**2000**	**lost**	**new**	**lost%**	**new%**
Tricladida	6	5	6	-	1	-	17%
Olychochaeta	44	44	44	-	-	-	-
Polychaeta	1	0	1	-	1	-	100%
Hirudinea	17	16	17	-	1	-	6%
Mollusca	76	73	75	1	4	1%	5%
Arachnida	78	77	78	-	1	-	1%
Crustacea	23	8	23	-	15	-	65%
Ephemeroptera	35	35	8	27	-	77%	-
Plecoptera	18	18	0	18	-	100%	-
Odonata	24	24	23	1	-	4%	-
Heteroptera	38	38	37	1	-	3%	-
Coleoptera	115	115	102	13	-	11%	-
Neuroptera	2	2	2	-	-	-	-
Lepidoptera	4	4	4	-	-	-	-
Trichoptera	79	79	50	29	-	37%	-
Chironomidae	225	225	205	20	-	9%	-
Simuliidae	6	6	5	1	-	17%	-
Total	**791**	**769**	**680**	**111**	**22**	**14%**	**3%**

Explanation of Table 3: The present situation is derived from monitoring of the main channel and the nature development projects stated in Table 1. Present-day species that were not encountered in historic literature or in the old river deposits are considered to have inhabited the former Rhine or its floodplain unless they are known as recent invaders (Bij de Vaate, 2003).

The data are derived from the following literature and unpublished data:

Albarda (1889); AquaSense (1998); Bij de Vaate & Klink (1995); Boesveld & van der Neut (2001); Den Besten (1994); Den Besten (1997); Drost et al. (1992); Fischer (1934); Geijskes (1948); Gittenberger et al. (1998); Higler (1995);Klink (1989); Klink (1994); Klink, (1995a); Klink (1997); Klink (1999a); Klink (1999b); Klink (2000a); Klink 2001); Klink & Moller Pillot (1982); Klink et al. (1995); Klink et al. (1996); Mol (1985a and 1995b); Pinkster & Platvoet (1986); Tittizer & Krebs (1996); Van den Brink (1990).

Groups like mayflies (Ephemeroptera), stoneflies (Plecoptera) and caddis flies (Trichoptera) are very sensitive to pollution and habitat deterioration (Tittizer and Krebs, 1996). Of the 35 species of mayflies once living in the Dutch Rhine only 8 have survived. It was not until 1991 that the burrowing mayfly Ephoron virgo recolonized the Dutch Rhine after an absence of 6 decades (Bij de Vaate, Klink & Oosterbroek, 1992). All 18 species of stoneflies have disappeared from the Dutch Rhine. Of the 79 species of caddis flies, 29 species are lost. Less than a decade ago Psychomyia pusilla was found once again in the Dutch Rhine. The Simuliidae have almost vanished. The other groups managed quite well. Of the Coleoptera the once abundant family of Elmidae has become very rare and 20 species of Chironomidae are still missing. In total, at least 111 (14%) species have become extinct in the Dutch Rhine from 1745 onwards.

Striking is the fact that of the non-flying invertebrates a lot of pontocaspian species have recently managed to colonize the Rhine through the Rhine-Main-Donau Canal (open since 1992). For a review on this subject see Bij de Vaate (2003). Recent research (Klink, 2002) revealed the recent colonizers already make up 50% of the total invertebrate fauna in the Rhine. It is very likely that some of these species (Dikerogammarus villosus as predator and Corophium curvispinum as space competitor) hamper the ecological rehabilitation of the indigenous species.

2. Macro invertebrate development in the side channels of the Gamerensche Waard

2.1. Cluster analyses

A total of 139 samples of macro invertebrates has been identified. In total 322 taxa were recognized. A first glance at the data is performed with the cluster program TWINSPAN (Hill, 1979). In Table 4 the results are displayed for the most abundant taxa. Typical of the fauna in the Rhine are the dominance of Oligochaeta, Mollusca, Crustacea and Chironomidae. Members of other groups are rare or absent. The first cluster is mainly characterized by Limnodrilus claparedeianus, Pisidium species and Chironomidae. All these taxa inhabit sedimentation areas in which fine particles are settling. By far the most samples of the large channel belong to this cluster (except G 33, the inlet). Also all the samples of O5Z belong to this cluster. The second cluster contains species characteristic for more harsh conditions. Especially the Chironomidae Kloosia pusilla, Paratendipes nubilus and Robackia demeijerei are, with their slender shape, adapted to the shifting river sand. Of the Mollusca , the recent invader Corbicula fluminea, reaches its highest densities in these dynamic sand bottoms. Remarkable is the absence of Pisidium species in this cluster. The success of Corbicula in the Dutch Rhine may well be caused by the lack of competition in the shifting sand, which in fact is the dominant habitat in the main channel. The sampling stations belonging tot this cluster are the inlet of the large channel station O32 in the east channel and the sediments in the west channel. Also the sand bottoms between the groins are inhabited by the members of this cluster. The third cluster is characterized by inhabitants of solid substrates in the current. The rocks on the groins in the main channel and the stones in the inlet of the west channel belong to cluster 3.

Table 4: Cluster analysis of the whole dataset.

Taxa	Cluster 1	Cluster 2	Cluster 3
Limnodrilus claparedeianus	++		
Procladius	++		
Pisidium casertanum	++		
Pisidium henslowanum	+		
Pisidium subtruncatum	+		
Pisidium nitidum	+		
Polypedilum bicrenatum	+		
Microchironomus tener	+		
Valvata piscinalis	+		
Chironomus plumosus agg	+		
Polypedilum nubeculosum	+		
Limnodrilus hoffmeisteri	++	+	
Chironomus	++	++	
Cryptochironomus	+	+	
Chironomus nudiventris	+	+	
Cladotanytarsus mancus gr	+	+	
Pisidium moitessierianum	+	+	
Corbicula fluminalis	+	+	
Chironomus acutiventris	+	++	
Potamopyrgus antipodarum	++	+	+
Hypania invalida	++	++	+
Corbicula fluminea	++	+++	+
Ceratopogonidae	+	++	++
Dikerogammarus villosus	+	+	++
Corophium curvispinum	+	+	+++
Kloosia pusilla		+	
Paratendipes nubilus		+	
Polypedilum scalaenum		+	
Robackia demeyerei		+	
Enchytraeidae		+	+
Cricotopus triannulatus		+	++
Paratrichocladius rufiventris			+
Neozavrelia fuldensis			+
Orthocladius			++

+ = 1 – 10 specimens; ++ = 11 – 100 specimens; +++ = >100 specimens

In Tabel 5 the average values of the current velocity and grain size distribution are displayed.

Table 5. Abiotic characteristics (± standard deviation) of the sites with the different clusters.

Taxa	Cluster 1	Cluster 2	Cluster 3
Substrate	soft	soft	solid
Average streamvelocity	6 ± 10	34 ± 19	56 ± 12
	Grainsize distribution		
? 2 µm	10 ± 9	4 ± 7	
? 16 µm	17 ± 15	7 ± 12	
? 63 µm	37 ± 19	16 ± 19	
? 210 µm	63 ± 24	31 ± 22	
> 210 µm	36 ± 31	69 ± 26	

In Table 5 becomes clear that the average stream velocity has a strong impact on the grain size distribution of the sediment and thus on the community of the macro invertebrates. The transition between cluster 1 and 2 seems to take place somewhere between 6 and 34 cm/s. The silt content diminishes from 37% to 16% and fraction > 210 µm rises from 36 to 69%.

Table 6. Distribution of the samples par site in the different clusters.

Sampling sites	Cluster 1	Cluster 2	Cluster 3
G15	8		
G19	7		
G25	5	2	
G33	1	6	
G55	4	2	
G6	5	1	
O32Z	1	3	
O5Z	14		
W25K	1	4	1
W2N	2	4	
K1B		6	
K2B		6	
W4N		6	
G55H			2
K1S			5
K2S			5
S6H			6
W1S			8

In Table 6 the most samples of the large channel belong to cluster 1. Only the inlet, G33 belongs to cluster 2. The cause for the exceptional samples has not been cleared jet. The lowermost site in the east channel collects the silt at low flow and all the samples score in cluster 1. In the west channel cluster 2 is predominant. The exceptional samples on W25 are taken at very low flow (cluster 1) and very high flow (cluster 3). The exceptional samples on W2N were both taken at low flow. Site W4N is influenced by the wave action of the river traffic. The bottom between the groins is inhabited by cluster 2 species and all solid substrates belong to cluster 3.

2.2. CANOCO analysis

In order to find more relevant relations between the macro-invertebrates and the abiotic factors, Several runs have been performed with CANOCO (version 4 by Ter Braak and Smilauer, 1998). In Figure 1 the outcome is given of a DCCA with 2nd order polynomials.

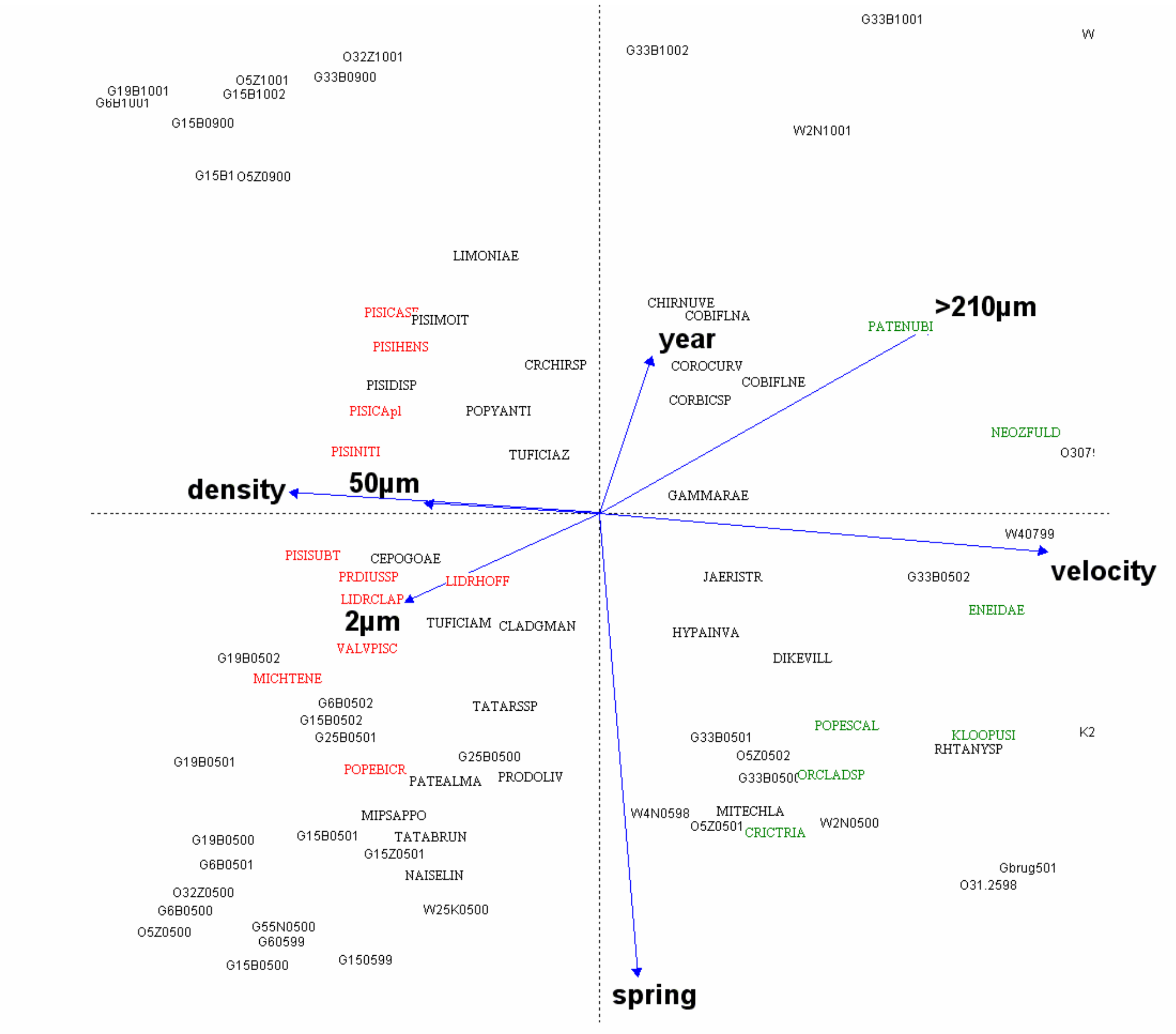

Figure 1. CANOCO ordination diagram of the soft sediments.

In Figure 1 the velocity and the grain size distribution play a most decisive rule in the distribution of the macro-invertebrates. The red species can be found in Table 4 in cluster 1 and the green species represent the cluster 2 and 3. The densities of the invertebrates decrease with the increase of the current velocity. Striking is the importance of the season in the ordination diagram. The samples were taken in May or October, with a few exceptions. In spring the macro invertebrate community has the largest diversity. Of a total number of 322 taxa, 284 were collected in spring and only 173 taxa from the autumn. A number of 149 taxa was collected in spring only, while only 38 taxa are exclusive for the autumn. In Table 7 the more abundant species are listed with a preference for spring or autumn.

Table 7. Number of samples in which the listed taxa occurred in spring and in autumn. Explanation of third column in text.

	spring	autumn	9-92/11-93
Elmis spec.	5		+/+
Psychomyia pusilla	4		+/+
Apsectrotanypus trifascipennis	4		absent
Brillia modesta	5		absent
Tvetenia spec. A.	3		absent
Tvetenia calvescens	9		+/-
Paralauterborniella nigrohalteralis	6		absent
Microtendipes chloris agg	18		+/+
Parachironomus arcuatus gr	9		+/-
Paratendipes albimanus	15		+/-
Micropsectra apposita	15		-/-
Micropsectra atrofasciata	13		-/-
Paratanytarsus dissimilis agg	7		+/-
Tanytarsus ejuncidus	13		+/-
Prodiamesa olivacea	27	1	
Orthocladius spec.	30	2	
Kloosia pusilla	30	2	
Robackia demeyerei	13	1	
Caenis macrura	10	1	
Tanytarsus brundini	20	2	
Potthastia gaedii	9	1	
Rheotanytarsus	18	2	
Polypedilum scalaenum	21	3	
Polypedilum bicrenatum	20	3	
Nais elinguis	12	2	
Vejdovskyella intermedia	6	1	
Oulimnius	6	1	
Tanytarsus	40	7	
Harnischia	11	2	
Potamothrix moldaviensis	17	4	
Limnomysis benedeni	8	2	
Cricotopus triannulatus	26	8	
Smittia spec.		10	
Dendrocoelum romanodanubiale	2	12	
Number of taxa	33	20	

Of a total of 139 samples, 86 were taken in spring and 53 in autumn. A ratio of 3:2 for spring:autumn would be expected if taxa showed no preference for either period. The taxa in Table 7 show a clear preference for spring or autumn. The taxa in red are rare in the Dutch Rhine and may be recovering from their absence in the past decennia. From all the other taxa only Smittia, a terrestrial Chironomidae and the Caspian triclad Dendrocoelum romanodanubiale seem to prefer autumn instead of spring.

Is the strong preference for spring due to the normal life cycle or not?

Partially the answer can be found in a comparable study in the French Meuse. From September 1992 until May 1994 all available habitats were examined for macro invertebrates (Klink and Bij de Vaate, 1994). Not only in September 1992, but also in November 1993 data were collected that can give a clue whether the spring taxa in the Rhine, occur elsewhere in autumn as well. In the third column of Table 7 we can see that only the two Micropsectra species have only been encountered in spring. The other species have not been collected at all, or occur in September 1992 and/or in November 1993. At least part of the preference for spring seems to be characteristic for the invertebrates in the (Dutch) Rhine. It seems interesting to investigate the levels of insecticides during the growing season, since it is common knowledge that the different trophic levels can be affected by the chemical composition of the Rhine (De Jong and De Wit, 1994).

2.3. The recolonization process

Since 1998 the Gamerensche Waard has been monitored for macro-invertebrates. The west and east channel were already connected to the river since 1996. In the spring of 2000 the large channel was also connected to the river. In Table 8 the number of species rises rapidly between 1999 and 2000. Probably due to the intensified sampling. After 2000, saturation seems to have taken place with a total of about 170 taxa.

Table 8. Development of the biodiversity in the Gamerensche Waard.

year	number of samples	number of taxa
1998	15	76
1999	13	98
2000	36	174
2001	41	165
2002	32	170

In Table 9 the development of mollusks is given for the soft substrate of the large channel. In 1998 only the east part of the large channel has been investigated. This part was isolated from the river and Bythinia tentaculata and Radix ovata were present. In 1999 less suitable habitats were sampled and these two snails have not been found. Also the western part of the large channel was sampled in 1999, resulting in a number of bivalves. After the upstream connection of the river even more Pisiidae colonized the large channel. In 2002 even small numbers of Ancylus fluviatilis and Pisidium amnicum were found. In the mean time the numbers of Valvata piscinalis are steadily declining and Gyraulus albus disappeared after the connection with the river.

Table 9. Development of mollusks in the soft sediments of the large channel.

year	1998	1999	2000	2001	2002
Bithynia tentaculata	+				
Radix ovata	+				
Gyraulus albus	+	+			
Musculium lacustre	++	++			+
Valvata piscinalis	+++	++	++	+	+
Unio pictorum		+	+		
Pisidium casertanum plicatum		++	++	++	++
Pisidium subtruncatum		+	++	++	++
Pisidium supinum		++			+++
Corbicula fluminalis		++	+++	+++	+++
Pisidium moitessierianum		+	++	++	++
Potamopyrgus antipodarum		+	+++	+++	++++
Corbicula fluminea		+	+++	+++	+++
Pisidium casertanum			++	++	++
Pisidium henslowanum			++	++	++
Pisidium nitidum			++	+	++
Sphaerium solidum			+	++	++
Dreissena polymorpha			++	++	+
Ancylus fluviatilis					+
Pisidium amnicum					+
number of samples	**2**	**4**	**13**	**13**	**9**
number of taxa	**5**	**11**	**13**	**12**	**16**

From other groups also species have disappeared, due to the connection with the river. Of the caddis flies Agraylea multipunctata, Mystacides longicornis and Oecetis lacustris have disappeared. The same is true for the mayflies Caenis horaria and C. robusta. In the whole project the river bound Caenis macrura has colonized and incidentally larvae of Ephemera lineata and Ephoron virgo are encountered.

In Table 10 the development of the Chironomidae in the large channel is depicted. Species which are dependent of large organic material (Glyptotendipes pallens and Endochironomus albipennis) and decaying organic matter (Clinotanypus nervosus and Acricotopus lucens) have disappeared from the large channel. A large group of species has colonized the channel instead. Almost all species are bound to soft sediments. Orthocladius seems to be the only taxon also preferring solid substrates. Pseudosmittia is a terrestrial genus and due to the rapidly changing water levels it is likely to collect terrestrial species more often under water than in channels with a constant water level. The changes from 1998 to 1999 is due to the investigation in the open western part of the large channel in 1999 only. A number of species is adapted to hampered dynamic conditions typically in a situation where there is some wave action by wind and navigation. From 1999 to 2000 a number of species have appeared that are characteristic for stable sandy flats (Chironomus nudiventris, Lipiniella moderata, Stictochironomus and Stempellinella bausei) where, at least Lipiniella and Stictochironomus, live of the benthic diatoms (pers. obs. freshwater tidal flats). Species adapted to the most harsh conditions are Kloosia pusilla, Paratendipes nubilus and Robackia demeijerei. These very thin species are adapted to the shifting sand.

Table 10. Development of Chironomidae in the soft sediments of the large channel

year	1998	1999	2000	2001	2002
Clinotanypus nervosus	+				
Acricotopus lucens	+				
Glyptotendipes pallens	+				
Endochironomus albipennis		+			
Harnischia	++	++	+		+
Procladius	+++	+++	++	++	++
Psectrocladius sordidellus gr	+		+		+
Tanypus punctipennis	++		+	+	+
Chironomus	+	+	++	+++	+++
Chironomus plumosus agg	++	+		+	++
Cryptochironomus	++	++	++	++	++
Polypedilum bicrenatum	+	+++	++	+	+
Polypedilum nubeculosum	++	++	+	++	+
Cladotanytarsus mancus gr	++	+++	++	++	++
Cryptotendipes		++		+	+
Chironomus acutiventris		+	+++	+++	++
Microchironomus tener		++	++	++	+
Polypedilum scalaenum		+	+	+	+
Tanytarsus		+	++	++	+
Prodiamesa olivacea			+	+	+
Pseudosmittia			++	+	+
Chironomus nudiventris			++	+++	++
Cryptochironomus rostratus			+	+	+
Kloosia pusilla			+	+	+
Lipiniella moderata			+		+
Paratendipes albimanus			+	+	+
Paratendipes nubilus			+	++	++
Stictochironomus			+	+	+
Micropsectra apposita			+	+	+
Stempellina bausei			+	+	+
Orthocladius				+	+
Chironomus bernensis				+	+
Robackia demeyerei				+	+
Tanytarsus brundini				+	+
number of samples	**2**	**4**	**13**	**13**	**9**
number of taxa	**13**	**14**	**24**	**27**	**30**

3. The added value of the channels in Gameren

The present added value for macro-invertebrates in the Rhine ecosystem can be seen by evaluating the community that is present in the side channels, compared to the community in the river itself. In Table 11 a comparison is made between the benthic chironomids in the main channel in 1745, 2002 and the species composition in the Gamerensche Waard. The data from 1745 are derived from paleoecological research on old river deposits (Klink, 1989). The "natural" number of benthic Chironomidae in the Dutch Rhine is not much more than the 41 species that were encountered in old river deposits. Some members of the shifting sand community in Russian rivers (Chernovskii, 1949) are still missing from the (fossil) record of the Rhine, though). The situation for benthic Chironomidae in the main channel is dramatically bad. The tow traffic scours the bottom and hardly any living creature can maintain itself, with the exception of Robackia demeijerei and an unknown Tanytarsus species. The density of all the macro invertebrates is as low as 300/m2 (Klink, 2001b). Since the traffic moves upstream along the left bank and downstream along the right bank also this effect can be noticed from the benthic chironomids. The left bank receives more wave action and only 9 species have been found up till now (density of all invertebrates 1200/m2). The right bank is the better place to be and 16 species have been collected here (total density 2700/m2). When we compare this with the 36 species present in Gameren (total density 3600 m2), we can speak of a near total recovery of the benthic chironomids. Only 5 species are missing from the "natural" community. This means that the hydrological conditions in the side channels are near natural and provide a sound starting point for further development of the natural river habitats.

Table 11. Chironomidae species composition in the Rhine in 1745, in 2002 and in the side channels of the Gamerensche Waard.

Taxa	Rhine 1745	Gameren 2000 - 2002	left bank 2000-2002	right bank 2000-2002	main channel 2000-2002
Beckidia zabolotzky	+				
Brillia flavifrons	+				
Demicryptochironomus vulneratus	+				
Paratendipes intermedius	+				
Chernovskyia macrocera	+				
Brillia modesta	+	+			
Chironomus balatonicus	(+)	+			
Chironomus muratensis	(+)	+			
Cladopelma gr. laccophila	+	+			
Cryptotendipes spec.	+	+			
Endochironomus albipennis	+	+			
Heterotrissocladius marcidus	+	+			
Micropsectra apposita	(+)	+			
Micropsectra atrofasciata	(+)	+			
Microtendipes chloris	+	+			
Paracladius conversus	+	+			
Paralauterborniella nigrohalteralis	+	+			
Polypedilum nubeculosum	+	+			
Tanypus punctipennis	(+)	+			
Tanytarsus pallidicornis	(+)	+			
Procladius spec.	+	+			
Lipiniella moderata	(+)	+			
Microchironomus tener	+	+			
Paracladopelma laminata agg.	+	+			
Tanytarsus brundini	+	+			
Stictochironomus spec.	+	+	+		
Stempellina spec.	+	+	+		
Polypedilum bicrenatum	+	+	+		
Tanytarsus ejuncidus	(+)	+	+		
Chironomus acutiventris	+	+	+		
Paratendipes nubilis	+	+	+		
Paratendipes gr. albimanus	+	+	+		
Harnischia spec.	+	+	+	+	
Prodiamesa olivacea	+	+	+	+	
Chironomus nudiventris	(+)	+	+	+	
Cryptochironomus spec.	+	+	+	+	
Kloosia pusilla	+	+	+	+	
Cladotanytarsus	+	+	+	+	
Polypedilum scalaenum	+	+	+	+	
Robackia demeijerei	+	+	+	+	+
Tanytarsus spec.	+	+	+	+	+
Aantal taxa	**41**	**36**	**16**	**9**	**2**

(+) can not be identified to species level in the old deposits, but is assumed to be present and is present on genus level.

In Table 1 we can see that in 1745 67% of the macro invertebrates lived on the snags in the river. The snags are gone and the rocks on groins and banks is an unsuitable habitat for many invertebrates if it was only for the wave action of the navigation, explaining the absence of

Simuliidae in the main channel (Klink, 1992). The WWF advocated in Living Rivers (1993) side channels as refugee for species which habitat have disappeared. The most important habitat in the side channels should be snags, like it was in the natural situation. These snags provide a home for species that filter the eutrophic water, shelter and food for small fish. With snag the side channels can become a three dimensional ecosystem for the macro invertebrates where it now only provides the bottom as a habitat. The natural provider of snags, the river bound forest, should be allowed to develop. With the forest also leaves could be fed upon by the invertebrates. Even if the habitat availability is near natural, immigrants like Dikerogammarus villosus and Corophium curvispinum can hamper the development of the natural community. The habitat diversity will however make the ecosystem much more complex and there is a fair chance that other species will deal with the dominance of these invaders.

4. Literature

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