Palaeoecological research in the Lower Rhine

Alexander Klink

Contents

Figures

Tables

Summary

This is an account of the first few years of palaeoecological river research by means of insect remains in the Netherlands. In 1983 the first floodplain samples from the river Rhine were analysed and since then, step by step, we have been building up biological evidence concerning the Rhine in former days. This chapter should be considered as a report on the initial phase of this line of research in the Netherlands. As is symptomatic of ana new application in sience, numerous questions arise from the analysed material and very few answers that can be given. Nor do we fully comprehend the scope of palaeoecological river research. It is therefor that we decided to present the findings in a way that reflects the present state Dutch research.

The topics discussed here include the historical facts on the insect fauna of the Rhine and its chemical changes insofar they can be derived from direct or circumstantial evidence. The methods of collecting, identifying, dating and dataprocessing are described. The main focus of this chapter ,however, is on some interesting changes in the insect fauna which have been revealed by the sediment analyses and the problems that arise in tracing the factors responsible for these changes. Furthermore two cores with different insect communities are discussed, as examples of stratigraphy in the lower part of the Netherlands. The conclusive remarks look at the potentials of palaeoecological river research in respect to river restoration.

1. Historical data on the insect fauna and chemistry of the river Rhine in the Netherlands

1.1. Historical data on the insect fauna of the Rhine

Data on the insects inhabiting the Rhine in the past are very scarce. From the most comprehensive record of riverine insects (Albarda, 1889) we learn that the characteristic riverine Ephemeroptera, Plecoptera, Odonata and Trichoptera were still present in the 19th century. The best exponent of the Ephemeroptera is Palingenia longicauda. It burrowed in the claybanks in vast quantities (last recorded in 1907, Mol; 1985). The Plecoptera in the Rhine included the genera Oemopteryx, Isoperla and Chloroperla. These stoneflies became extinct in the early decades of this century (Geyskes,1940). Gomphus flavipes, a muddwelling dragonfly, was last collected in 1902 (Geyskes and Van Tol, 1983). The Trichoptera included , among others, Cheumatopsyche lepida, Lepidostoma hirtum, Psychomyia pusilla and many Hydropsyche species. The first two species have not been collected in the 20th century. The last record of Psychomyia pusilla dates back to 1933 (Fischer, 1934).

Very little is known about the Diptera. Van Der Wulp (1877) notes that adult Simuliidae (only 4 species described) are very common on places near the rivers Rhine and Meuse. The chironomids mentioned in his work cannot be assigned to the typical river fauna.

From the early records we can conclude that in the second half of the 19th and the first few decades of the 20th century a decline was observed in the larger insects. The present Rhine is deprived of Ephemeroptera (except Caenis species), Plecoptera, Anisoptera and Simuliidae. Apperently Trichoptera were absent from the Rhine for a long period of time, too. From 1978 on, however, a remarkable return of Hydropsyche contubernalis and some other caddis flies has been observed (Van Urk, 1984)

1.2. Chemical changes in the Rhine

Evidence that early pollution of the Dutch rivers did not go unnoticed can be found in the following quotation from Velsen (1768):

'Our people have always been utterly indifferent to a vital part of this country, the rivers. We used them and abused them as we please, without any supervision whatsoever. If the rivers were to die tomorrow not a soul would care or be grieved. Instead of worshipping her as gods or saints, we treat them as sewers, in which anyone may freely dispose of his wastes. This is what has caused their abominable state'

We may conclude that the pollution referred to above was predominantly organic, since large-scale mining activities did not start until the middle of the 19th century. And it was not until the 20th century that steelproduction became a major industry and pesticides based on Hg and As were commonly used.

In figure 1 the history of heavy metal pollution is inferred from analyses of old river sediments and stored soil samples from a lower branch of the Rhine. Organic pollution in former days has been deduced from the population statistics of the Netherlands.

The first decades of the 20th century may be characterized as the onset of a steep rise in organic and heavy metal pollution in the Rhine.

Since the Second World War an entirely new branch of industry has added its own characteristic compounds to the environment. With the development of the petrochemical industry the family of chlorinated hydrocarbons (DDT, PCBs, drins and dioxins) were released. In the 1960s and 1970s acetylcholinesterase inhibitors became in use as insecticides, resulting in concentrations in the Rhine of up to 50 µg/l (Greve, 1980). The initial rise in chlorinated hydrocarbons (as EOCl) is not known as no analyses were made until 1973. In the mid seventies, however, concentrations as high as 30 µg/l EOCl were measured (Greve, 1980). Concurrently, the pollution of the Rhine reached its maximum. Ever since improvements in oxygen content and a decline in micropollutants have been observed. The return of caddisflies in the Rhine, notably H. contubernalis could be the result of this improvement (Becker, 1987) (see section 1.1. and figure 1).

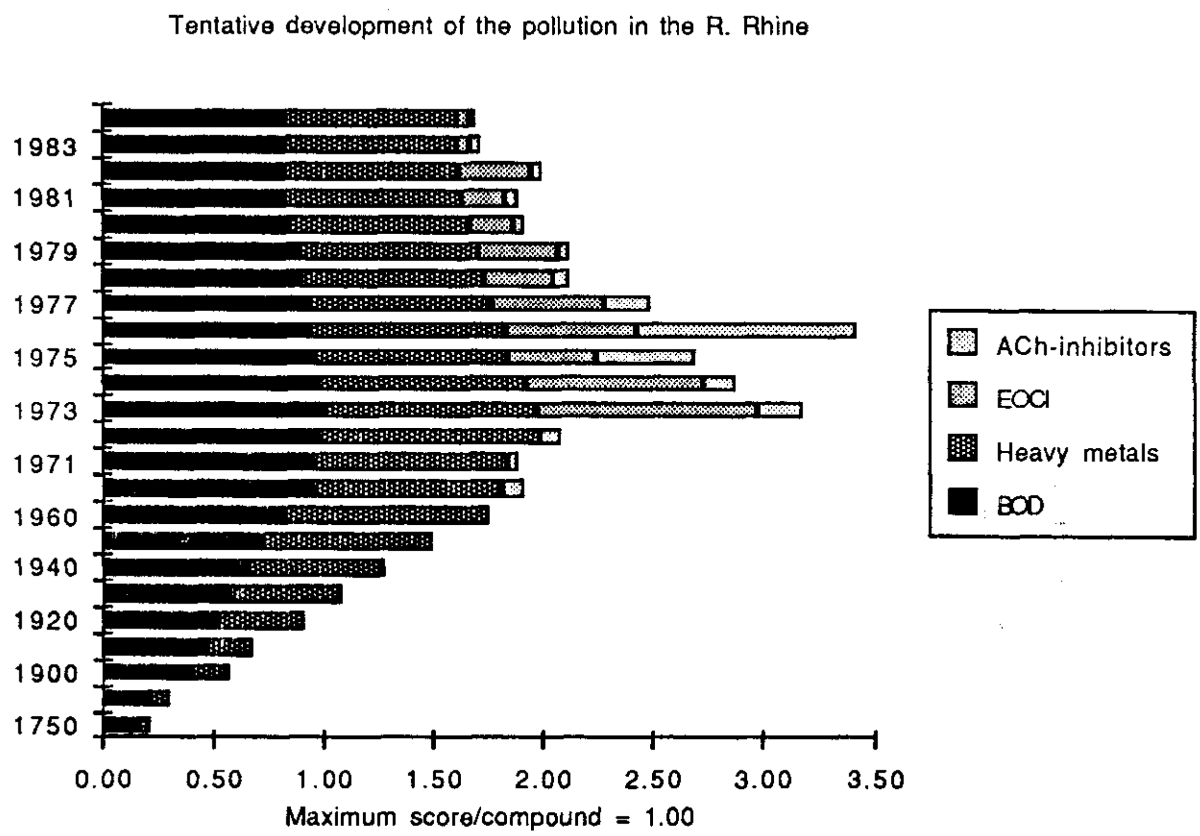

Fig. 1. Tentative compilation of the pollution history of the Rhine derived from direct and indirect evidence (sources CBS, 1983; Heuck-Van Der Plas (ed.), 1983; Greve, 1980; Government Institute for Sewage and Waste Water Treatment (RIZA), 1983; Dijkzeul, 1982; RIWA (Cooperating Rhine and Meuse Water Supply Companies), 1983 and 1984; Salomons and De Groot, 1978).

2. Localities and methods

2.1. Localities

The sampling sites in the Rhine are listed in figure 2.

(Figure 2 to be inserted here)

Figure 2. The Rhine-Meuse riversystem in the Netherlands. The sampling sites are numbered according to table 1.

Table 1. Sampling sites by type and date of sedimentation/sampling

Number	River	Type	Date
1	Rhine	floodplain deposit	- 1745
2	Nederrijn	floodplain deposit	- 1880
3	Nederrijn	exuviae sampling	1981
4	IJssel	sediment core	?
5	IJssel	exuviae sampling	1986
6	IJssel	sediment core	?
7	Waal	exuviae sampling	1985
8	Waal	suspended solids (≥ 100μm)	- 1984
9	Boven Merwede	floodplain deposit	- 1914

10	Nieuwe Merwede 9	sediment core	?
11	Nieuwe Merwede12	sediment core	?
12	Schoonrewoerdse Wiel	sediment core	1750-1984

2.2. Methods

2.2.1. Collecting of the samples

The sediment samples were collected in three different ways.

- Sediment cores from the riverbed were taken by means of a mudcorer installed on a research vessel. The core from Schoonrewoerdse Wiel (nr. 12) was taken by means of scuba gear.

- Floodplain deposits were collected with hand auger equipment for soil research. The augers were drilled into the soil until a layer of coarse sand was met, indicating the former riverbed. Since these layers contain hardly any remains of invertebrates, the samples were taken from the silt layer directly on top of the sand was taken for analyses.

- Suspended solids were collected from the river itself by means of a driftnet (mesh 100 µm).

To compare these data with the present situation, monthly exuviae collections were carried out at three sampling stations from May to October by means of a driftnet (mesh 500 µm).

2.2.2. Processing of the sediment

The deposits were sieved over a mesh of 100 µm and the macro-invertebrate remains were handpicked under a magnification of 40-80 and preserved in ethanol 70%.

Only 5 insect orders were found in sufficient numbers for sample comparison. Distribution of aquatic Coleoptera remains was too local to take them in consideration, while no Odonata remains were found.

Of the non-insect groups, mollusc shells appeared to be absent in all but a few samples, while Tricladida, Oligochaeta and Hirudinea remains were not found at all. The Tricladida and Hirudinea contain no chitinous parts that stay intact in the sediment. The chitinous parts of the Oligochaeta (chaetae and cuticular penis sheaths in some Tubificidae) must have been lost in sieving or overlooked during sorting with this magnification. curiously no remains of Isopoda or Amphipoda were recognized.

The following groups are considered and identified according to the selected parts.

Groups	parts analysed
Ephemeroptera	mandibles
Plecoptera	maxilla
Heteroptera	tergites
Trichoptera	frontoclypeus
Diptera	headcapsule

2.2.3. Analyses of the remains

The remains of the insects were identified by means of the available literature on the various groups. As single references rarely provided complete identification by means of the selected parts a wide variety of special articles was consulted. The remains that could not be identified in this way were compared to the material in reference collections. If this was not successful either the taxa were drawn and given a tentative name (for example Chironomini gen. no. 1).

2.2.4. Dating of the samples

Abandoned main gullies were selected for the dating of the floodplain deposits. As old river maps show, the filling of these gullies is a proces that may take no more than a few decades. The layer directly on the coarse sand was taken for analyses of the remains as described and dated according to the period that the river abandoned that particular course. The estimated age of the sediment remains is the youngest possible age for the sediment contains an unknown fraction of older resuspended deposits. The inferred age of the sediment, therefore, is an underestimation of the average age of the sediment. The sediment cores from the present river bed have not been dated, because no old river maps could be applied to the coring sites, and no sequential isotope decay series have been found or are expected to be found in the fluctuating sedimentation and resuspension processes that take place in rivers (see also chapter 7 of this book: palaeolimnological methods).

2.2.5. Processing of the data

The identified remains were treated as units. This means that a mandible of a mayfly was counted as one mayfly. Mathematically this is not correct, since one mandible stands for only one half of one of the 25 instars that mayflies usually have.

The one part = one specimen approach was choosen instead of the mathematically correct alternative because; if not the numbers of hemimetobolic insects would have been too low to differentiate in statistical analyses.

The holometabolic insect remains were treated similarly except the Chironomidae in which especially half headcapsules of the Orthocladiinae were found, which were counted as half specimens.

The exuviae collections were summarized over the period of sampling (May-October).

Finally, the counts in the sediment samples and the exuviae collections were recalculated to a total of 500 specimens and ln(x+1) transformed for factor and cluster analyses. These analyses were done by the statistical package SYSTAT (Wilkinson, 1986).

3. Results

3.1. Outline of the changes in the macro invertebrates of the river deposits

A total of appr. 15,000 insect remains covering 167 taxa were found in 52 samples from sediment cores, floodplain deposits and coarse suspended solids, while exuviae collections contained a little over 13,000 specimens comprising 66 taxa.

From the statistical analyses it appears that subsamples from the same sediment core are always more closely related to each other than to samples from other cores or floodplain deposits, even in cores of 3 m long. In addition to the sedimentation process in the abandoned gullies referred to earlier, the analyses of the insect remains also show that sediment cores from the riverbed may represent only very brief periods.

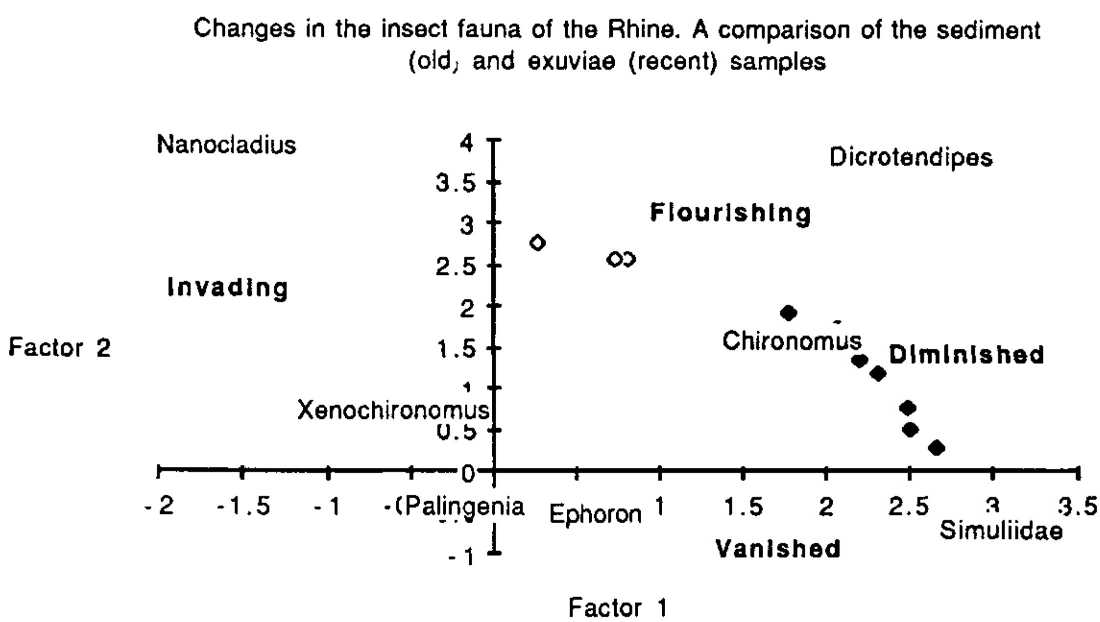

Fig. 3. Outline of changes in the insect fauna of the Rhine. The open diamonds stand for the exuviae collections, the closed diamonds for the summarized data from the different cores, floodplain deposits and the sample of the suspended solids.

The names of the taxa in figure 3 represent separate clusters by their most differentiating taxon. The bold-faced characterizations indicate the status of the clusters according to historical and recent documentation (e.g. the Nanocladius cluster includes species that have invaded the rivers). The distance from the clusters to the origin is a relative scale of abundance.

- The first quadrant of figure 3 contains taxa that are abundant in both sediment and exuviae samples. The Dicrotendipes cluster stands for Dicrotendipes nervosus and the Cricotopus/Orthocladius aggregate (not subdivided in the remains). They are underrepresented in the sediment samples but are "flourishing" so to speak in the present Rhine. In the exuviae collections Cricotopus bicinctus is by far the most abundant representative of the Cricotopus/Orthocladius aggregate.

The Chironomus cluster includes Chironomus spp., Cricotopus sg. Isocladius, Cryptochironomus spp., Glyptotendipes gr. pallens, Hydropsyche contubernalis, Parachironomus arcuatus, Pentaneurini (not identifiable to a generic level) and Polypedilum scalaenum. This cluster stands for species that are still plentiful in the Rhine but not as abundantly as in the sediment samples. Despite the spectacular return of Hydropsyche contubernalis in the Rhine since 1978/1979 (Van Urk, 1984), their relative abundance in the sediments has not been equalled (yet).

- The second quadrant consists of two discrete clusters of species which have largely vanished from the Rhine. The Simuliidae cluster includes (besides Simuliidae) Microtendipes gr. chloris and Procladius spp.. No Simuliidae and Microtendipes gr. chloris were found in exuviae samples at all, while Procladius appeared to be extremely rare in the exuviae collections, in contrast to the sediment samples.

The Ephoron virgo cluster differs from the Simuliidae cluster only in that the 30 taxa involved are less abundant. These taxa are frequently found in the sediment samples but are absent or extremely rare in the exuviae collections. The taxa concerned are mainly riverine Ephemeroptera and Trichoptera (e.g. Ephemera, Ephemerella, Baetis spp. Heptageniidae, Leptophlebiidae and Brachycentrus subnubilus, Cheumatopsyche lepida, Hydropsyche pellucidula, Lepidostoma hirtum, Psychomyia pusilla), the adults of which were all collected on the river banks in the last century (Albarda, 1889). Noteworthy is the occurrence of Byssodon maculatum (Simuliidae). It is uncertain if the species was ever caught alive in the Netherlands since the only encountered record may well refer to Byssodon maculatum and Wilhelmia equina (Van Der Wulp 1877). According to Rubsow (1964), Byssodon maculatum inhabits large lowland rivers, from Western France (river Seine) to the ultimate eastern part of the USSR (river Kolima). Even in the Mississippi this malicious biting blackfly has been collected.

- In the third quadrant we only find the Palingenia cluster. It contains 98 of the total of 167 taxa. The cluster lies close to the origin, which means that the species involved are not abundant and infrequently met in the dataset. Most of its species are extinct in the Rhine, including Palingenia longicauda itself, Aphelocheirus aestivalis and Potamanthus luteus. Species characteristic for large rivers are some sanddwelling chironomid taxa (Beckidia zabolotzkyi, Chernovskiia "macrocera", Paratendipes connectens 3 Lipina, Paratendipes intermedius, Robackia demeijerei and Potthastia gaedii). They have not been collected alive in the Dutch rivers. An other chironomid (Symposiocladius lignicola) has recently been described (Cranston, 1982). The larvae mine in submerged wood and are thus confined to snaghabitats. The Trichoptera in this cluster are Chimarra marginata, Goeridae, Hydroptilidae, Micrasema spp., Odontocerum albicorne, Oligoplectrum maculatum and Rhyacophila spec. These taxa are not characteristic of lowland rivers and predominantly live upstream. We do not know if these species have actually ever inhabited the Lower Rhine.

- The clusters in the fourth quadrant contain species that hardly occur in the sediment samples and can therefor be characterized as invaders.They all belong to the Chironomidae. The Nanocladius cluster includes Nanocladius spp., Rheocricotopus chalybeatus, Rheotanytarsus spp. and Parachironomus longiforceps. The Xenochironomus cluster includes the less abundant midges Synorthocladius semivirens and Xenochironomus xenolabis. Their absence in all but a few (recent?) sediment samples may be due to the physical changes taking place in the Rhine. Two of the most conspicuous changes are the rising of the water temperature and the changing habitats. These topics will be discussed below.

3.2. Possible effects of long-term changes in the temperature of the Rhine

Climatic conditions have changed and thermal pollution has increased. This combination has so far caused a rise of 2.5°C in the average Rhine temperature since 1908 (Department of Public Works, 1851-....; RIWA(Cooperating Rhine and Meuse Water Supply Companies), 1983). Also, ice observations in the Rhine over the last two centuries (fig. 4) show that there has been a steady increase in the temperature of the river since the middle of the last century. The documented invasion of the freshwater shrimp (Atyaephyra desmaresti: Decapoda) in the Rhine can be considered as biological evidence for rising winter temperatures (Van Den Brink and Van Der Velde, 1986). The species has a southern European distribution and was first collected in the Netherlands in 1915 (Redeke, 1936).

Number of days/decade when ice occurred in the Rhine
(after Jansen, 1983)

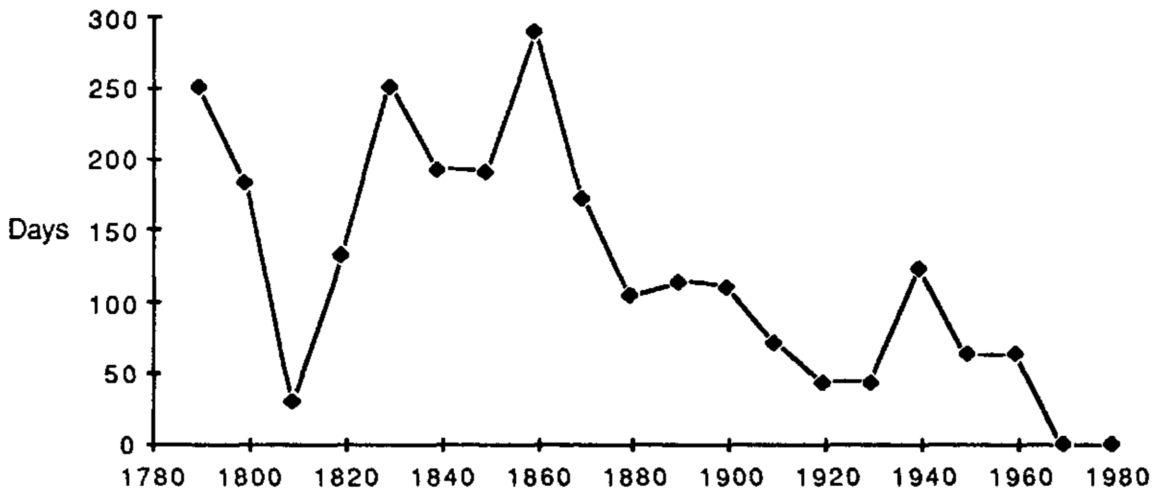

Figure 4. Number of days with ice in the Rhine at the German-Dutch border since 1780

Other species for which the rise in temperature may have been beneficial are the "invaders" Nanocladius, Rheocricotopus chalybeatus, Nanocladius rectinervis and the Rheotanytarsus species. They are very abundant in the Rhine today, and can well add up to 60% of the total insects in the exuviae collections. Rheocricotopus chalybeatus has a southern distribution. In Europe, the species does not occur in Scandinavia (Fittkau and Reiss, 1978), but is very common in the river Po in Italy (Rossaro, 1984) and the Llobregat in Spain (Prat e.a., 1984). The species has also been collected in Lebanon (Moubayed and Laville, 1983) and Syria (Reiss, 1986). Nanocladius rectinervis roughly follows the same distribution pattern as Rheocricotopus chalybeatus. In Europe, the genus Rheotanytarsus is restricted to the area south of Scandinavia (Fittkau and Reiss, 1978). The distribution area of R. photophilus is not clear. An other species (R. rhenanus) has recently been described by Klink (1983), who collected the species not only in Dutch rivers but also in the rivers Meuse in S. Belgium, Lahn (W. Germany), Loire (France) and Tisza (Hungary). Saxl (pers. comm.) collected material from the river Krems (Austria), and Moubayed (pers. comm.) caught the species in Lebanese rivers. No collection sites north of the Netherlands are known at the moment.

Future research may produce evidence that the expansion of these species to the north is due to the rise in river temperatures. It should be more interesting, though, to trace species showing a reverse trend, which would allow us to monitor the negative effects of thermal pollution. The Rhine is unsuitable for such research, however, because of the other profound changes that have taken place.

3.3. Changing habitats in the Rhine and their effect on the insect fauna

The original habitats in the Rhine can to some extent be deduced from the insect remains and historical research. The riverbed must have been a gradient passing from coarse sands in the erosive zones to silt in the deposited areas. Stones did not occur in the natural riverbed. Part of the banks may have been covered with vegetation with dead trees providing snag-habitats. The biological importance of the snaghabitat has been pointed out by Bencke e.a. (1984). The historical struggle of man against wood debris in rivers has been described in a case study by Triska (1984).

The changes which have affected the Rhine habitats are discussed in this book (Van Urk) but in brief the following has happened. The natural forests along the Rhine must have been cleared long ago. The low-lying parts of the flood-plains, however, were partly covered by stands of willow until the late 19th/early 20th century the old river maps show. Jetties consisting of basalt were built from the second half of 19th century. Recently part of the banks are protected by grauwacke to prevent erosion from the increasingly powerfull cargo-vessels. In consequence the habitat distribution in the Rhine has changed completely. The vegetation and snag have been replaced by heavy boulders and the gradients in the composition of the riverbed have disappeared because of the jetties

Changes in the insect fauna in the Rhine in relation to their habitat

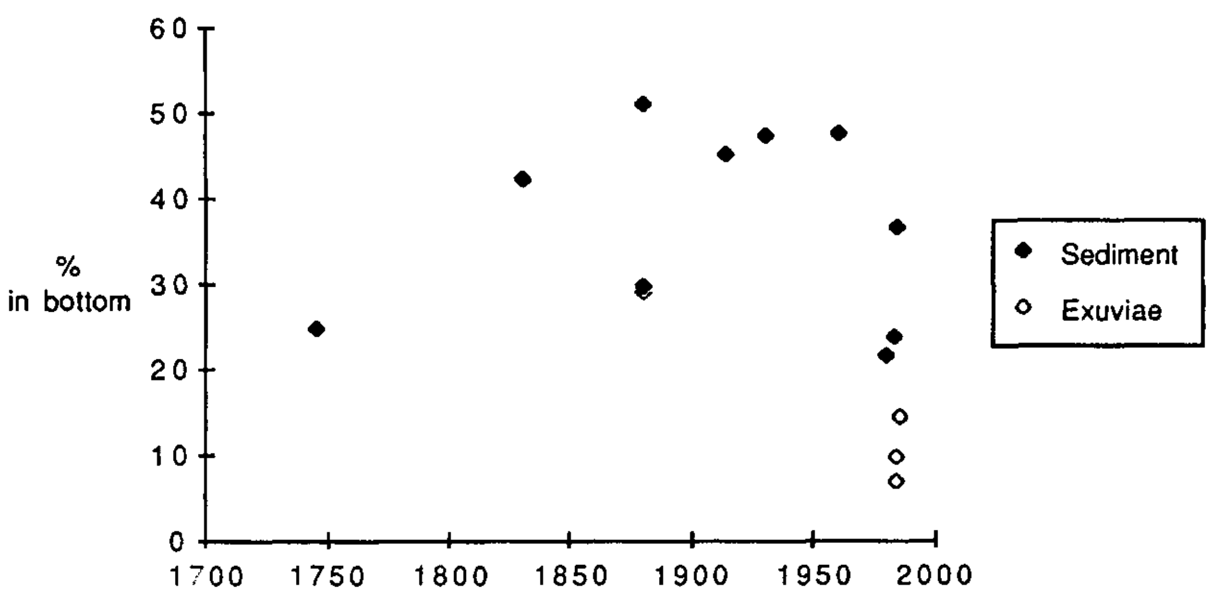

Figure 5. Relative abundance of insect fauna living in the bottom, related to the inferred age of the sediment (old) and exuviae (recent).

The overall impact of changed habitats on the insect fauna can be derived from figure 5.

The sediments contain 20-55% of bottom-dwelling insect remains, while in the recent situation not more than 15% of the insect fauna lives in the bottom.

The "invader" species Parachironomus longiforceps and Xenochironomus xenolabis (see 3.1) may have benefitted from these altered habitats. The former live in colonies of Bryozoa (Ertlova, 1974). The latter inhabit sponges (Pagast, 1934). In the present Rhine both Bryozoa and Porifera are confined to the stones on the banks and jetties. To what extent the natural snag provides a suitable habitat for these colonies is still uncertain. Unlike the supposed thermophilic invaders, the distribution area of these midges and their hosts extends into Scandinavia.

3.4. Incidence of deformities in headcapsules of muddwelling Chironomus larvae

As mentioned above a great deal of physical changes have taken place in the riverbed of the Rhine. Especially the bottom-dwelling fauna has suffered by them. However the mud habitat still exists in the Rhine. Chironomus larvae prefer it. Unfortunately heavy metals and other pollutants are accumulating in this sediment. According to Cushman (1984), Hamilton and Saether (1971), Warwick (1985) and Wiederholm (1984), the incidence of deformities in the headcapsules of Chironomus larvae is strongly propagated by xenobiotic pollutants. The most suspect compounds are heavy metals and chlorinated hydrocarbons. However,causal relationships however between particular pollutants and deformities are not yet known. In the Rhine deformities of up to 40%

are no exception (Van Urk and Kerkum, 1986).

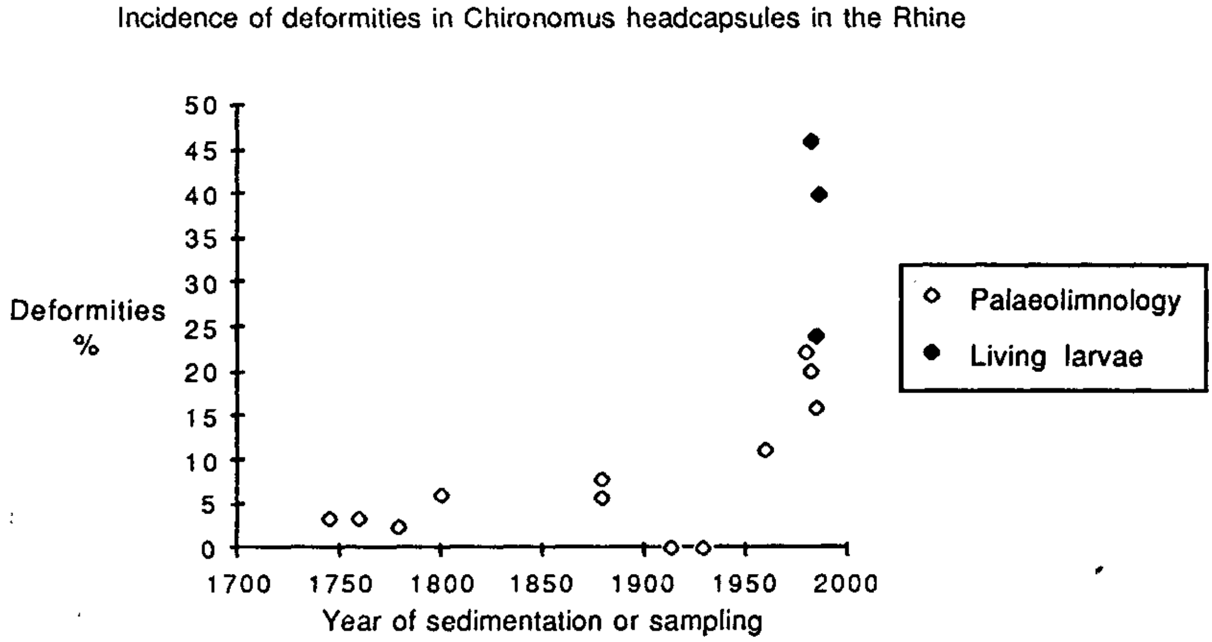

Figure 6. The incidence of deformities in the headcapsules of Chironomus larvae, related to the inferred (underestimated) sediment age.

Comparing the percentage of deformities in the sediment samples with recently collected living larvae, as done in figure 6, we can see a trend in the incidence of head deformities and the (underestimated) age of the sediment. Despite the lack of reliable sediment dating, it is obvious that deformities occured as early as the 18th century, but that the sharp incline was only generated in this century. The rise in heavy metal concentrations (fig. 1) is strikingly similar to this rise in deformity rates. The relationship has yet to be proven by laboratory research, as concurrently with the rise in heavy metals the levels of other pollutants have been increasing too. Phenol pollution in the early 1900s, vfor instance was traced because salmon meat tasted 'carbolic' (Van Drimmelen, 1982).

3.5. Changes in the Diptera fauna of the Rhine

One of the most striking discrepancies found between the sediment samples and exuviae collections is the absence of Simuliidae in the present Rhine. The habitat of Simuliidae is solid substrate in the current, a habitat which is heavily propagated by the presence of jetties. The cause of their extinction is unknown but it could be related to the quality of the suspended solids, their food resource. Another factor adversely affecting their existence is fluctuating current velocities. In the case of the Rhine instantaneous fluctuations are generated by the wave action from navigation, especially around the jetties.

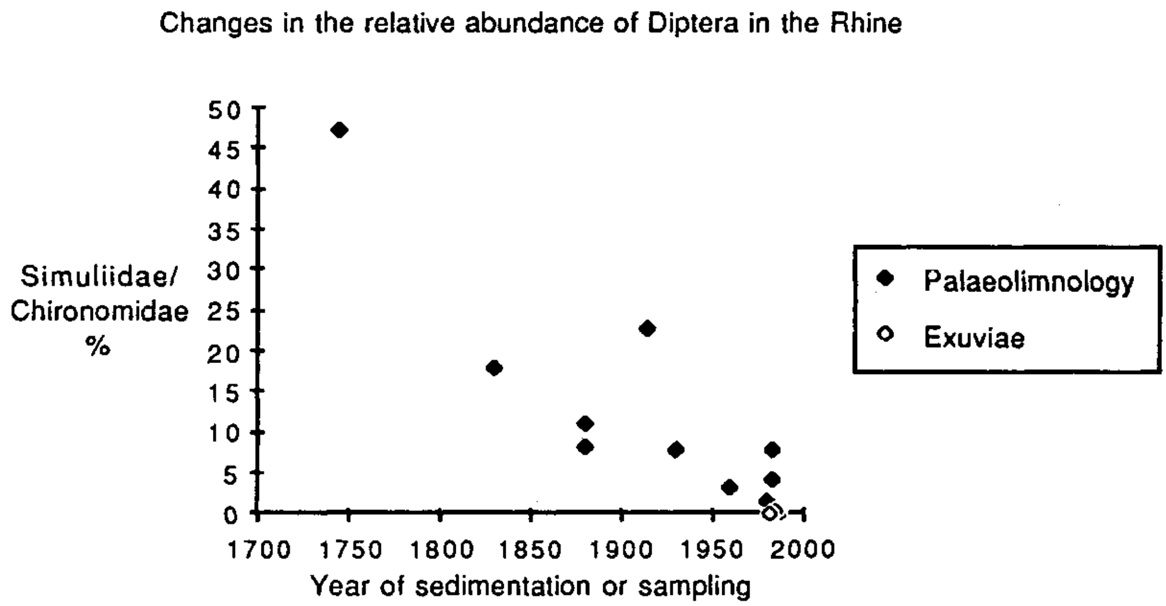

Figure 7. Changes in Diptera composition in the Rhine according to sediment samples and recent exuviae collections (Note the fact of age underestimation in the most recent sediments)

It goes without saying that research on the sensitivity of Simuliidae for chemical and physical factors can provide us with valuable information on the (no)effect levels of those factors. Such information is crucial if we want to attempt to restore the Rhine ecosystem.

4. Description of two cores of different origin: an example of floodplain stratigraphy

4.1. Description of a sediment core from a lake generated by a dikeburst

In the Netherlands most large rivers were embanked as early as the 13th century (Pons, 1957). When a river bursts through a short stretch of dike, the result is a large whirlpool which drills itself into the soil, leaving a small lake. In this way many dozens of lakes - called "Wielen" - were generated by the Rhine. The Schoonrewoerdse Wiel (1573) is one of the larger ones, with an area of approximately 0.25 km2 and a depth of 8 m. It was flooded several times in the past. It is not known how often this occurred, but in 1672 it was part of the Dutch 'waterlinie', a strip of land inundated as a defence against the army of Louis XIV of France. The Wiel has not flooded again since 1809, although it remained connected to a branch of the R. Rhine by means of a ditch. For the past 30 years it has been completely isolated.

In 1984 a sediment core (length 80 cm) was taken from the deepest part of the Wiel by means of scuba-gear. One half of the core was dated by means of 210Pb, and its phytoplankton analysed. The other half was processed for insect analyses. The core covers the period from appr. 1750 to 1984.

In figure 8 the percentage of typical river insects is shown against the depth of the sample (Depth 0-5 cm is the top. Despite a sharp decline in the riverine insects (Simuliidae, Heptageniidae and Hydropsychidae, as well as some rheophilic Chironomidae) the indirect influence of the river is still notable, even at a depth of 10 cm (1972).

This core tells us that large areas of the western part of the Netherlands are deposited by the Rhine and that even in stagnant water we have to be aware that older remains of river insects may interfere with the expected species composition.

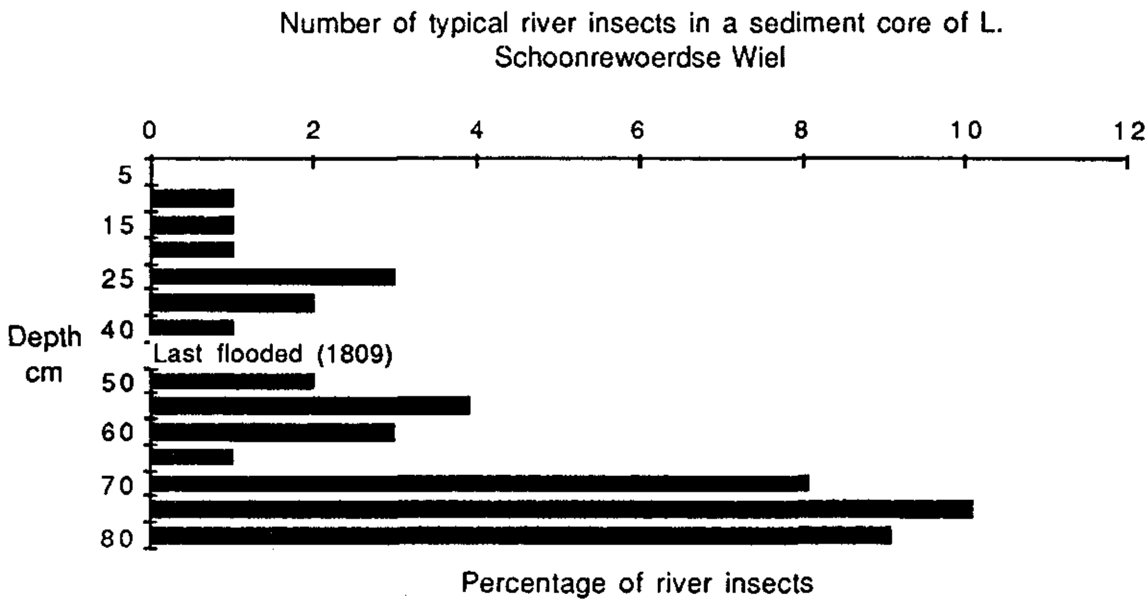

Figure 8. Percentage of typical river insects in the sediment core of L. Schoonrewoerdse Wiel

(Depth 35 cm was discarded since no subfossil insects were found. The reason is unknown)

4.2. Description of a river deposit in the freshwater tidal belt in the western part of the Netherlands

In 1986 two sediment cores were taken from the Nieuwe Merwede (fig. 2, table 1). The insect analyses of one of the cores will be discussed here in order to point at some typical aspects of interpretating riverdeposits. The genesis of this tidal area is discussed by Van Urk (1984) and will only be summerized here.

In 1421 there was a disastrous flood in the south-western part of the Netherlands (The Saint-Elizabeth flood). The river Merwede completely washed away a vast area of land. In the following centuries sedimentation progressed and resulted in the formation of a dense system of small and large creeks. A century ago this system was cut through by a newly dug river called the Nieuwe (New) Merwede.

The soil composition in the core is roughly as follows:

0-40 cm: predominantly coarse sand with pieces of wood

40-190 cm: peat and clay in varying quantities

190-240 cm: predominantly fine sand and clay

In figure 9 the insect analyses have been summarized by means of a factor analysis.

The most striking feature of the figure is the clear separation between the upper and lower part of the core. The peat in between hardly contain any insect remains. When we take a closer look at the clusters, the interpretation is as follows. The Simuliidae cluster stands for river inhabiting taxa. Apart from Simuliidae it includes Harnischia spec., Potthastia gaedii, Stenochironomus spec., Hydropsyche contubernalis, Polypedilum scalaenum and a score of less abundant river inhabiting taxa. TheLimnephilidae cluster includes Micropsectra spec., Zavrelia pentatoma, Glyptotendipes pallens, Chaetocladius spp., Metriocnemus with 3 species, Bryophaenocladius spec. and Limnophyes spec. Especially the first two representatives can reach high abundances in small slow-flowing streams in the eastern part of the Netherlands. The latter 4 genera (all Orthocladiinae) are (semi)terrestrial, which may be evidence that the creek was a very shallow one, with parts falling dry temporarily.

Factor analysis of a sediment core from the lower Rhine
(Nieuwe Merwede core 9)

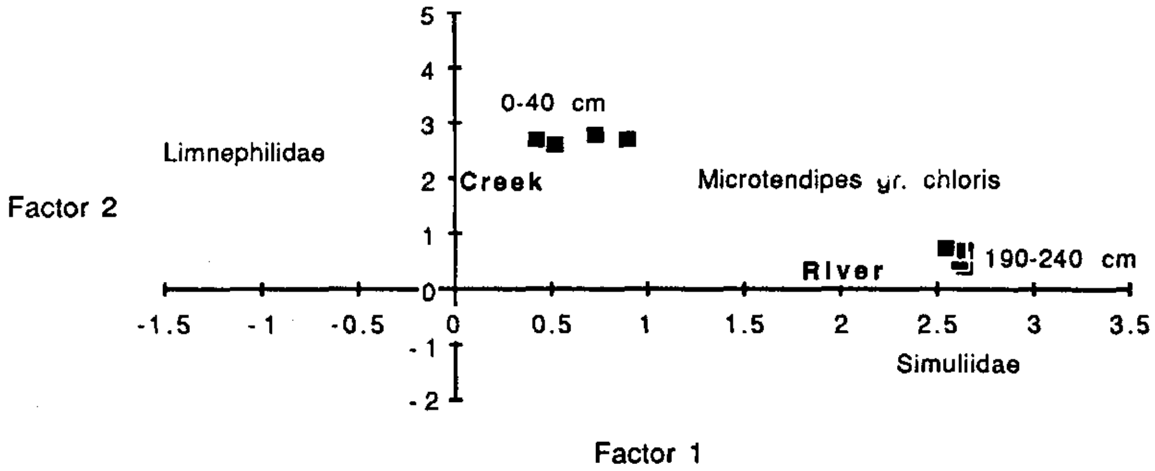

Figure 9. Factor analyses of the samples and insects in a sediment core in the Nieuwe Merwede.

The cluster between these two extremes is either formed by taxa which occur in both large rivers and small streams (e.g. Microtendipes gr. chloris), or by taxa that can not properly be identified in the samples (e.g. Pentaneurini).

According to geological studies (Zonneveld, 1960; Verbraeck, 1970; Verbraeck and Bisschops, 1980; Berendsen, 1982) peat formation and river deposits alternate in holocene deposits in the western part of the Netherlands. The bulk of peat formation took place in the subboreal (2000-5000 BP) as part of the so-called Holland peat, which has a widespread lateral extension throughout the western part of the country. The most recent peat formation must date from (long) before 1421 flood, for no peat wasformed in this area since (Zonneveld, 1960). The age of the river deposit at the lower end of the core has not been established, but it must be considerably old, and probably several thousands of years. We may consider the insects in this deposit as the inhabitants of the natural Rhine or Meuse. As pointed out in 3.3. we believe that in the natural Rhine the number of insects that inhabited the bottom compares to those that inhabited the solid substrate, which also is the case in these deposits with an even distribution over both types of habitats (45% each). If its supposed age is correct the natural swamp forests near the river must have consisted mainly of Alnus. On the lower parts willow coppice must have grown. The higher parts were covered with Quercus, Ulmus, Fraxinus and Corylus (Zonneveld, 1960; Van Der Woude, 1981).

The tidal creek deposit in the top of the core is of unknown age but could date from after the Saint-Elisabeth flood (1421) when the numerous smaller and larger tidal creeks had been formed. This deposit reveals that these creeks used to be inhabited by caddisflies (Limnephilidae). This is an important fact, as Van Urk (1984) found a distinct absence of Trichoptera in these tidal creeks, on behalf of recent research. From this evidence we can only conclude that the absence of Trichoptera must be entirely due to river pollution, as the morphology of the creeks is still quite natural.

The relatively high estimated age of the entire core attributed to the facts that the Nieuwe Merwede is approximately 5 m deep at the drilling location and that the pleistocene deposits lie another 5 m deeper. Furthermore the location is erosive, for no recent river deposit was found in the top of the core.

5. Concluding remarks

In this palaeoecological study it was felt as a serious drawback that no reliable dating method exists for river sediment cores. For the time being this problem can be partly overcome by collecting floodplain deposits, with restriction of unsystemetic underestimated ages of the deposits.

Palaeoecology in large rivers appears to be a powerful instrument, however, in generating the species composition of former insect faunas and in revealing the differences between a former and the present situation.

As a consequence of large scale chemical and fysical changes which have taken place in the Rhine, the insect fauna of the river has changed completely. An 80-100 insect taxa have disappeared from the river over the last few centuries (see appendix). The changes in habitats documented in literature are reflectedby the changes in the insect fauna. Also without historical evidence, we observed important changes in the individual taxa. To mention three:

- The propagation of species with a southern distribution as a supposed effect of long term rize in temperature of the Rhine.

- A positive relationship between the deformities of headcapsules and the heavy metal content of the riversediment

- The decline and extinction of Simuliidae over the last few centuries against their past abundance.

This study can be considered as the initial phase of palaeolimnological river research in the Netherlands. The changes observed in the Rhine by means of sediment analyses still stand fairly isolated, since no direct links can be made with responsable factors. Therefore the second phase of palaeoecological research in the Dutch Rhine should focus on establishing these links. A possible approach is relating the biological characteristics in the sediment to the levels of persistent pollutants. An other line of approach would be to determine the sensitivity spectra of the extinct indicator species still living in other rivers. These spectra would help a lot if we try to make the Rhine suitable for these species again.

Acknowledgements

The research was financed by the Institute for Inland Water Management and Waste Water Treatment and National Institute for Water Supply ~~voor Drinkwatervoorziening~~. The author is greatly indebted to Drs. G. van Urk for the fruitful discussions and critical comments on the manuscript.

6. References

Albarda, H., 1889

Cataloque raisonné et synonymique des Neuroptères observés dans les Pays-Bas et dans les Pays limitrophes

Tijdschrift voor Entomologie 32: 211-375

Becker, G., 1987

Lebenszyklus, Reproduktion und ökophysiologische Anpassungen von Hydropsyche contubernalis, einer Köcherfliege mit massenvorkommen im Rhein

Inaugural-Dissertation Köln 108 pp.

Bencke, A.C., Van Arsdall Jr. T.C., Gillespie, D.M., 1984

Invertebrate productivity in a subtropical blackwater river: the importance of habitat and life history

Ecological Monographs 54(1): 23-63

Berendsen, H.J.A., 1982

De genese van het landschap in het zuiden van de provincie Utrecht

Utrechtse geografische Studies 25: 259 pp.

CBS (Centraal Bureau voor de Statistiek) 1983

Statistisch zakboek 1983

Staatsuitgeverij: 's-Gravenhage 385 pp.

Cranston, P.S., 1982

The metamorphosis of Symposiocladius lignicola (Kieffer) n.gen., n.comb., a wood-mining Chironomidae (Diptera)

Entomologica scandinavica 13: 419-429

Cushman, R.M., 1984

Chironomid deformities as indicators of pollution from synthetic, coal derived oil

Freshwater Biology 14: 179-182

Dijkzeul, A., 1982

De waterkwaliteit van de Rijn in Nederland in de periode 1970-1981

Report Government Institute for Sewage and Waste Water Treatment (RIZA) 82.061: 112 pp.

Ertlova, E., 1974

Einige Erkenntnisse über Chironomiden (Diptera, Chironomidae) aus Bryozoen

Biologia Bratislava 29: 869-876

Fischer, F.C.J., 1934

Verzeichnis der in den Niederlanden und dem Nachbargebiete vorkommenden Trichoptera

Tijdschrift voor Entomologie 77: 177-201

Fittkau, E.J., Reiss, F., 1978

Chironomidae. In: J. Illies (ed.) Limnofauna Europaea

Fischer Verlag Stuttgart p. 404-440

Geijskes, D.C., 1940

Verzeichnis der in den Niederlanden vorkommenden Plecoptera, mit einigen geschichtlichen, ökologischen und systematischen Bemerkungen

Tijdschrift voor Entomologie 83: 3-16

Geijskes, D.C., Van Tol, J., 1983

De libellen van Nederland (Odonata)

Koninklijke Nederlandse Natuurhistorische Vereniging, Hoogwoud 368 pp.

Greve, P.A., 1980

Toxische microverontreinigingen in de Rijn

H_2O 13: 360-364

Hamilton, A.L., Saether, O.A., 1971

The occurrence of characteristic deformities in the chironomid larvae of several Canadian Lakes

Canadian Entomologist 103: 363-368

Hueck Van Der Plas, E.H. (ed.), 1983

Zware metalen in aquatische systemen. Geochemische inventarisatie biologisch onderzoek in Rijn en Maas en de daardoor gevoede bekkens 1. Geochemische inventarisatie

Rapport Organisatie voor toegepast natuurwetenschappelijk Onderzoek TNO 127 pp.

Klink, A.G., 1983

Rheotanytarsus rhenanus n.sp. A common midge of the lithorheophilic fauna in large lowland rivers (Diptera: Chironomidae)

Entomologische Berichten 43: 136-138

Mol, A.W.M., 1985

Een overzicht van de Nederlandse haften (Ephemeroptera) 2. Overige families

Entomologische Berichten 45: 128-135

Molt, E.L., 1961

Verontreiniging van het Rijnwater. In: Drinkwatervoorziening 13e vakantiecursus

Moormans periodieke pers Den Haag p: 46-71

Moubayed, Z., Laville, H., 1983

Les chironomides (Diptera) du Liban 1. Premier inventaire faunistique

Annales Limnologica 19(3): 219-228

Pagast, F., 1934

Uber die Metamorphose von Chironomus xenolabis Kieff. eines Schwammparasieten (Dipt.)

Zoologische Anzeiger 105: 155-158

Pons, L.J., 1957

De geologie, de bodemvorming en de waterstaatkundige van het Rijk van Nijmegen.

Ontwikkeling van het land van Maas en Waal en een gedeelte van het Rijk van Nijmegen

Verslagen Landbouwkundig Onderzoek (63.11) Bodemkundige Studies 3: 156 pp. + bijl.

Prat, N.F., Puig, M.A., Gonzalez, G., et al, 1984

Llobregat In: B.A. Whitton (ed.) Ecology of European Rivers

Blackwell, Oxford p. 527-552

RIWA (Cooperating Rhine and Meuse Water Supply Companies), 1983

Jaarverslag 1983. Deel A: de Rijn

RIWA (Cooperating Rhine and Meuse Water Supply Companies)

Report 76 pp.

RIWA(Cooperating Rhine and Meuse Water Supply Companies), 1984

Jaarverslag 1984. Deel A: de Rijn

RIWA(Cooperating Rhine and Meuse Water Supply Companies)

Report 96 pp.

Government Institute for Sewage and Waste Water Treatment (RIZA) 1983

De waterkwaliteit van de Rijn in 1982

Report Government Institute for Sewage and Waste Water Treatment (RIZA) 83-080: 1-39

Redeke, H.C., 1936

La crevette d'eau douce, Athyaephyra desmaresti (Mill.) dans les Pays-Bas

Mémoires Musée Histoire nationale Belgique 3(2): 227-231

Reiss, F., 1986

Ein Beitrag zur Chironomidenfauna Syriens (Diptera: Chironomidae)

Entomofauna 7(11): 153-168

Department of Public Works 1851-....

Tienjarige overzichten der waterhoogten en afvoeren

Staatsuitgeverij 's Gravenhage

Rossaro, B., 1984

The chironomids of the Po River (Italy) between Trino Vercellese and Cremona

Aquatic Insects 6(2): 123-135

Rubsow, I.A., 1964

14. Simuliidae (Melusinidae). In: E. Lindner (ed.) Die Fliegen der palaearktische

Region

Schweizerbart'sche Verlagsbuchhandlung Stuttgart Band III-4: 689 pp.

Salomons, W., De Groot, A.J., 1977

Pollution history of trace metals in sediments, as affected by the Rhine River

Publikaties Waterloopkundig Laboratorium Delft Hydraulica Laboratorium 184: 21 pp.

Triska, F.J., 1984

Role of wood debris in modifying channel geomorphology and riparian areas of a large lowland river under pristine conditions: A historical case study

Verhandlungen Internationale Vereinigung für theoretische und angewandte Limnologie 22: 1876-1892

Velsen, C., 1768

Rivierkundige verhandelingen. Afgeleid uit waterwigt- en waterbeweegkundige grondbeginselen. En toepasselijk gemaakt op den Rhyn, de Maas, de Waal, de Merwede en de Lek

Harlingen pp 3

Verbraeck, A., 1974

Toelichting bij de geologische kaart van Nederland 1:50000, blad Gorkum Oost (38 O)

Rijksgeologische Dienst Haarlem 140 pp.

Verbraeck, A., Bisschops, J.H., 1971

Toelichting bij de geologische kaart van Nederland 1:50000, blad Willemstad Oost (43 O)

Rijksgeologische Dienst Haarlem 112 pp.

Warwick, W.F., 1985

Morphological abnormalities in Chironomidae (Diptera) larvae as measures of toxic stress in freshwater ecosystems: indexing antennal deformities in Chironomus Meigen

Canadian Journal of Fisheries and aquatic Sciences 42: 1881-1914

Wiederholm, T., 1984

Incidence of deformed chironomid larvae (Diptera: Chironomidae) in Swedish lakes

Hydrobiologia 109: 243-249

Wilkinson, L., 1986

SYSTAT: The system for statistics

Evanston Illinois

Zonneveld, I.S., 1960

De Brabantse Biesbosch. Een studie van bodem en vegetatie van een zoetwatergetijdendelta

A. Summary with text figures and tables

Bodemkundige Studies 4: 210 pp

Van Drimmelen, D.E., 1982

De visserij in het stroomgebied van de Rijn Syllabus voor de cursus "De Rijn, waterbron van Nederland"

Stichting postakademiale Vorming Gezondheidstechniek

Cursus " de Rijn Waterbron van Nederland" 2.5: 16 pp.

Van Urk, G., 1984

Lower-Rhine-Meuse

In: B.A.Whitton (ed.) Ecology of European Rivers

Blackwell Oxford p. 437-468

Van Urk, G., Kerkum, F.C.M., 1986

Misvormingen bij muggelarven uit Nederlandse oppervlaktewateren

H_2O 26: 624-627

Van Den Brink, F.W.B., Van Der Velde, G., 1986

Observations on the seasonal and yearly occurrence and the distribution of Atyaephyra desmaresti (Millet, 1831) (Crustacea, Decapoda, Natantia) in The Netherlands

Hydrobiological Bulletin 19(2): 193-198

Van Der Woude, J.R., 1981

Holocene paleoenvironmental evolution of a perimarine fluviatile area

Dissertation Vrije Univ. Amsterdam 118 pp.

Van Der Wulp, F.M., 1877

Diptera Neerlandica. De tweevleugelige insecten van Nederland

Martinus Nijhoff, 's Gravenhage 497 pp. + bijl.

List of taxa in the sediment and exuviae collections

TAXON	HABITAT	PALAEO	RECENT
EPHEMEROPTERA			
Baetidae	LR	+	
Caenis spec.	L	+	+
Cloeon spec.	L	+	+
Ecdyonurus spec.	LR	+	
Ephemera spec.	PS	+	
Ephemerella spec.	LR	+	
Ephoron virgo	PS	+	
Heptagenia spec.	LR	+	
Leptophlebiidae	V	+	
Palingenia longicauda	P	+	
Potamanthus luteus	LR	+	
Raptobaetopus tenellus	PS	+	
Rhithrogena spec.	LR	+	
PLECOPTERA			
Nemouridae	LR	+	
Perlidae	LR	+	
HETEROPTERA			
Aphelocheirus aestivalis	LR	+	
TRICHOPTERA			
Athripsodes aterrimus	V	+	
Athripsodes spec.	V	+	
Brachycentrus subnubilus	LR	+	
Ceraclea spec.	LR	+	+
Cheumatopsyche lepida	LR	+	
Chimarra marginata	LR	+	
Cyrnus spec.	L	+	+
Ecnomus tenellus	L	+	+
Glossosomatidae	LR	+	
Goeridae	LR	+	
Hydropsyche angustipennis	LR	+	
Hydropsyche contubernalis	LR	+	+
Hydropsyche pellucidula	LR	+	
Hydropsyche saxonica	LR	+	
Hydropsyche spec.	LR	+	+
Hydroptilidae	V	+	
Lepidostoma hirtum	LR	+	
Leptoceridae	V	+	
Limnephilidae	PS	+	
Lype spec.	L	+	
Micrasema spec.	LR	+	
Molanna spec.	PS	+	
Mystacides longicornis	V	+	
Neureclipsis bimaculata	L	+	+
Notidobia ciliaris	PS	+	
Odontocerum albicorne	LR	+	
Oecetis spec.	V	+	
Oligoplectrum maculatum	LR	+	
Phryganea bipunctata	V	+	
Polycentropus flavomaculatus	LR	+	
Psychomyia pusilla	LR	+	
Rhyacophila spec.	LR	+	

List of taxa in the sediment and exuviae collections

TAXON	HABITAT	PALAEO	RECENT
Sericostoma spec.	PS	+	
SIMULIIDAE			
Byssodon maculatum	V	+	
Eusimulium spec.	LR	+	
Prosimulium spec.	LR	+	
Simuliidae gen. 1	LR	+	
CHIRONOMIDAE-TANYPODINAE			
Labrundinia spec.	?	+	
Pentaneurini	?	+	+
Procladius spec.	P	+	+
Tanypus spec.	P	+	+
DIAMESINAE			
Diamesa carpatica	LR	+	
Diamesa spec.	LR	+	
Monodiamesa bathyphila	PS	+	
Potthastia gaedii	P	+	
Potthastia longimana	P	+	
Prodiamesa olivacea	P	+	+
Syndiamesa spec.	LR	+	
ORTHOCLADIINAE			
Acricotopus lucens	V	+	
Brillia longifurca	LR	+	+
Brillia modesta	LR	+	+
Bryophaenocladius spec.	T	+	+
Cardiocladius fuscus	LR	+	+
Chaetocladius piger agg.	T	+	
Chaetocladius spec.	T	+	
Chaetocladius? spec.	T	+	
Corynoneurinae indet.	V	+	+
Cricotopus flavocinctus	LR	+	
Cricotopus sg. Isocladius	L	+	+
Cricotopus triannulatus	LR	+	+
Cricotopus trifasciatus	L	+	
Cricotopus/Orthocladius	LR	+	+
Diplocladius cultriger	V?	+	
Eukiefferiella claripennis agg.	LR	+	+
Eukiefferiella ilkleyensis	LR	+	
Eukiefferiella spec.	LR	+	+
Gymnometriocnemus spec.	T	+	+
Heterotrissocladius marcidus	PS	+	
Hydrobaenus lugubris	T	+	+
Limnophyes spec.	T	+	+
Metriocnemus fuscipes	T	+	+
Metriocnemus hirticollis agg.	T	+	+
Metriocnemus terrester	T	+	+
Metriocnemus? spec.	T	+	
Nanocladius spec.	E	+	+
Orthocladius (Euorthocladius) rivulorum	LR	+	
Orthocladius (Euorthocladius) spec.	LR	+	+
Paracladius conversus	PS	+	+
Parakiefferiella bathophila	L	+	
Parametriocnemus stylatus	PS	+	

List of taxa in the sediment and exuviae collections

TAXON	HABITAT	PALAEO	RECENT
Paratrichocladius rufiventris	LR	+	+
Psectrocladius gr. sordidellus	V	+	+
Psectrocladius platypus	V	+	
Psectrocladius psilopterus	V	+	
Pseudorthocladius spec.	T	+	+
Pseudosmittia spec.	T	+	+
Rheocricotopus spec.	LR	+	+
Smittia gr. aquatilis	T	+	+
Symposiocladius lignicola	V	+	
Synorthocladius semivirens	V	+	+
CHIRONOMINI			
Beckidia zabolotzkyi	PS	+	
Chernovskiia "macrocera"	PS	+	
Chironomini gen. 1	?	+	
Chironomus gr. plumosus	P	+	+
Chironomus gr. uliginosus	P	+	+
Cladopelma gr. laccophila	P	+	+
Cladopelma gr. lateralis	P	+	
Cryptochironomus spec.	PP	+	+
Cryptotendipes gr. holsatus	PS	+	
Demeijerea rufipes	L	+	
Demicryptochironomus vulneratus	PS	+	
Dicrotendipes gr. nervosus	L	+	+
Dicrotendipes notatus	L	+	
Einfeldia dissidens	P	+	
Endochironomus albipennis	P	+	+
Endochironomus gr. dispar	V	+	
Endochironomus tendens	P	+	
Glyptotendipes caulicola	V	+	+
Glyptotendipes gr. pallens	P	+	+
Glyptotendipes gr. signatus	V	+	
Glyptotendipes spec.	?	+	+
Harnischia spec.	P	+	+
Kiefferulus tendipediformis	P	+	
Kloosia pusilla	PS	+	+
Lipiniella arenicola	PS	+	+
Microchironomus tener	P	+	+
Microtendipes gr. chloris	PS	+	
Microtendipes rydalensis agg.	?	+	
Microtendipes tarsalis agg.	?	+	
Parachironomus arcuatus	L	+	+
Parachironomus longiforceps	L	+	+
Paracladopelma laminata agg.	PS	+	
Paracladopelma spec.	PS	+	
Paralauterborniella nigrohalteralis	?	+	
Paratendipes connectens 3 Lipina	PS	+	
Paratendipes gr. albimanus	PS	+	
Paratendipes intermedius	PS	+	
Phaenopsectra spec.	P	+	+
Polypedilum cf. uncinatum	?	+	
Polypedilum gr. bicrenatum	P	+	+
Polypedilum laetum agg.	L	+	+

List of taxa in the sediment and exuviae collections

TAXON	HABITAT	PALAEO	RECENT
Polypedilum nubeculosum	P	+	+
Polypedilum pedestre agg.	V	+	+
Polypedilum scalaenum	PS	+	+
Polypedilum sordens	V	+	+
Pseudochironomus prasinatus	PS	+	
Pseudochironomus spec.	PS	+	
Robackia demeijerei	P	+	
Stenochironomus spec.	V	+	
Stictochironomus spec.	PS	+	
Tribelos intextus	P	+	
Xenochironomus xenolabis	L	+	+
Zavreliella marmorata	V	+	
TANYTARSINI			
Cladotanytarsus gr. mancus	PS	+	+
Micropsectra spec.	LR	+	+
Paratanytarsus confusus	L	+	+
Paratanytarsus tenuis	L	+	+
Rheotanytarsus spec.	LR	+	+
Stempellina spec.	PS	+	
Tanytarsus gr. brundini	PS	+	
Zavrelia pentatoma	P	+	
TOTAL TAXA		167	66
E = EURYTOPE			
L = LITHON			
LR = LITHORHEON			
P = PELON			
PS = PSAMMON			
T = TERRESTRIAL			
V = VEGETATION			
?=UNKNOWN			

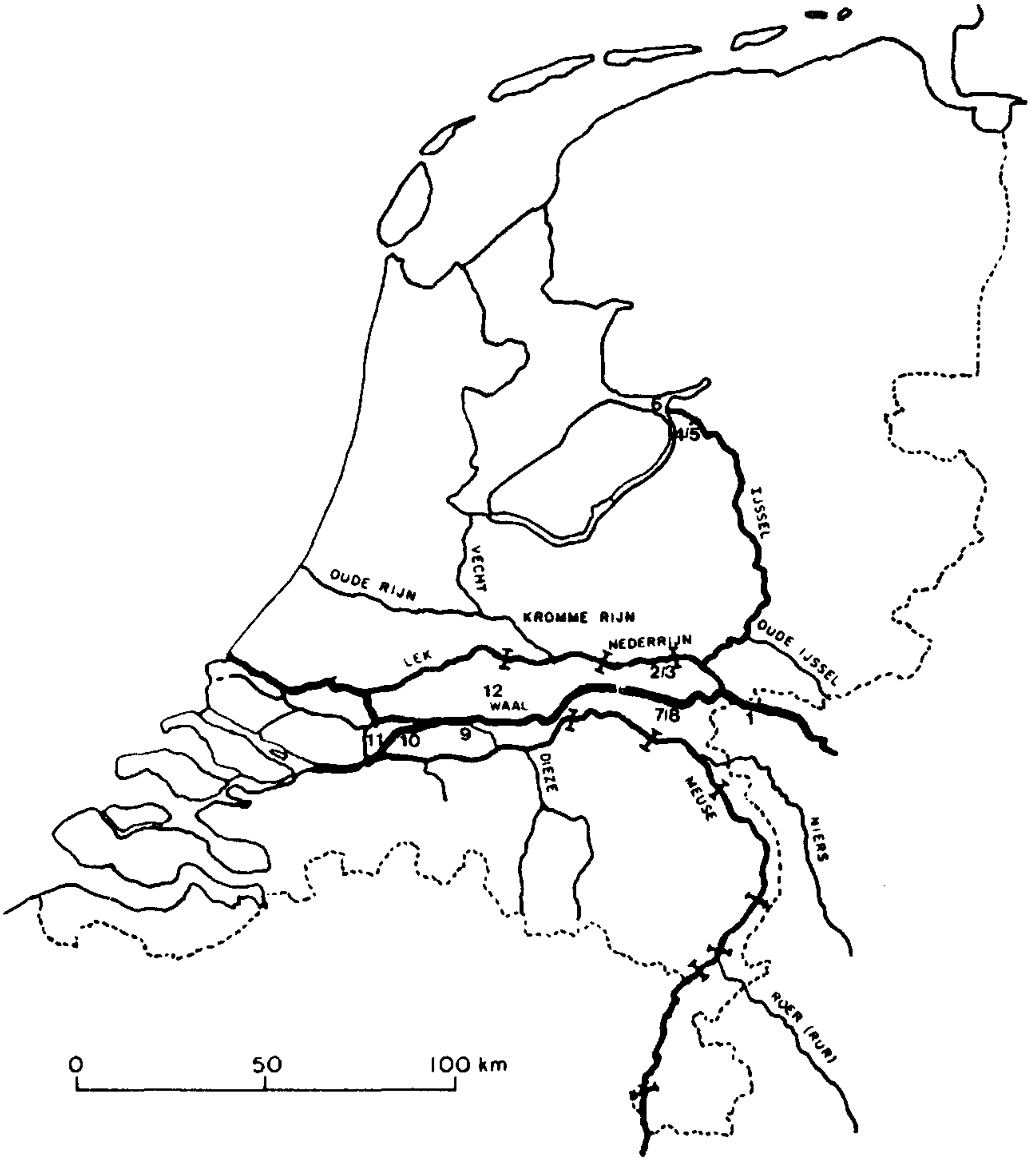

Fig. 16.1 The Rhine-Meuse system in the Netherlands. The Kromme Rijn, Oude Rijn and Vecht do not form a part of the main system nowadays. Canals are not shown. The figures indicate km signs.