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The faunistic composition of the freshwater section of the river Rhine in The Netherlands: present state and changes since 1900

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Keywords

Rhine, The Netherlands, macroinvertebrates, fish, faunistic changes, species-diversity.

Abstract

A review is presented of the literature concerning changes in the fauna of the freshwater section of the Dutch branches of the river Rhine as a basis for more detailed studies on the subject. In addition, the present macroinvertebrate and fish fauna of the river Waal, the main branch of the Rhine in The Netherlands, was investigated by regularly sampling the filtering screens of the cooling-water intakes of the Gelderland power station, Nijmegen. Moreover the list of fish species was supplemented by those species recently caught by a number of professional fishermen and during own surveys on the rivers Waal, Lek and IJssel.

It is shown that the number of rheophilous invertebrate species has declined, while the number of euryoecious immigrant species has increased over the years. A number of brackish water crustaceans from the estuarine area was found to occur more than 100 km upstream of their original limits of distribution, because of the increased chlorinity of the river water.

After a sharp decline of the number of indigenous fish species during the nineteen-fourties to the early seventies, this number has increased since about 1975. Compared to about a hundred years ago a number of at least 6 fish species is still missing.

Kurzfassung

Eine Literaturübersicht über die Veränderungen der Fauna im Süßwasser-Abschnitt der niederländischen Teile des Rheins wird vorgelegt als Basis für künftige eingehendere Untersuchungen. Sie wird ergänzt durch die Ergebnisse regelmäßiger Besammlungen von Fischen und Wirbellosen der Waal, besonders am Rechen des Kühlwassereinlaufs des Gelderland-Kraftwerks, Nijmegen. Die Fischliste wird ergänzt durch Arten die von Berufsfischern und durch Fänge an Waal, Lek und IJssel nachgewiesen wurden.

Es wird eine Abnahme der rheophilen Invertebraten-Arten aufgezeigt, während die Zahl der euryöken eingewanderten Arten zugenommen hat. Crustacea des Brackwassers aus dem Mündungsbereich wurden über

100 km stromaufwärts ihrer ursprünglichen Verbreitungsgrenzen gefunden, in Folge des erhöhten Chloridgehalts des Flußwassers.

Nach einem plötzlichen Rückgang der Zahl einheimischer Fisch-Arten zwischen etwa 1945 und 1972 ist seit 1975 wieder eine Zunahme zu verzeichnen. Im Vergleich mit dem Zustand vor etwa 100 Jahren fehlen jedoch noch immer sechs Arten.

1 Introduction

As one of the largest European rivers, the river Rhine is of great economic importance to the countries through which it flows. The river has its origin in the Swiss Alps and subsequently passes through Switzerland, France, Federal Republic of Germany (F. R. G.) and The Netherlands. In The Netherlands the Rhine has the characteristics of a lowland river and divides into three major branches, Waal, Lek and IJssel, before it discharges into the North Sea.

Due to the increasing industrialization over the past century, the importance of the river Rhine as a shipping route has greatly increased. For this reason, the river bed was fixed by dikes, breakwaters and weirs. Besides these morphological changes, the water quality changed as a result of increasing amounts of sewage and industrial waste, while the water temperature rose due to the discharge of industrial cooling-water. It is now generally accepted that these changes in river morphology, hydrology and water quality were detrimental to the quality of the ecosystem of the river Rhine, especially in its lower reaches (e. g. WOLFF 1978, VAN URK 1984). A number of studies on faunistic diversity have recently been performed in German parts of the river (e. g. LELEK 1976, CONRATH et al. 1977, KINZELBACH 1978, CASPERS 1980a, 1980b, BLESS 1981, BÖVING 1981, WILSON & WILSON 1983, 1985, SCHMITZ 1986). However, knowledge of the present invertebrate fauna of the river Rhine and its branches in The Netherlands is relatively scanty. Most of the attention has been directed at the IJssel branch (VAN URK 1978, 1981, 1984), while only a very few studies have been published on the largest Rhine branch, the river Waal (KLINK & MOLLER-PILLOT 1982, WILSON & WILSON 1983).

In recent studies of the macrocrustaceans in the river Waal (VAN DEN BRINK & VAN DER VELDE 1986a, 1986b, VAN DEN BRINK et al. 1988) a number of species were encountered which had been absent from this river for a long period. In these studies the cooling-water filtering screens of the Gelderland power station, Nijmegen, were used as a sampling site. The intake of river water for use as cooling-water provides a good opportunity for long-term observations on the fauna of the river Waal (VAN DER VELDE et al. 1989). Such data have an increasing relevance today because of recent initiatives by the Dutch government with the aim of restoring the Rhine ecosystem (the so-called Rijnaktieplan), implying among others a rehabilitation of the habitats of rare and extinct (anadromous) riverine fish species.

In this paper the results of these faunistic observations are presented in addition to a review of the Dutch literature concerning changes in the faunistic composition of the freshwater area of the river Rhine in The Netherlands.

2 Sites and methods

A map of the Dutch Rhine stretches under study is presented in fig. 1. Aquatic macroinvertebrates and fish were sampled at the cooling-water intakes of the Gelderland power station, situated on the river Waal near Nijmegen, The Netherlands (Fig. 1). Details of the cooling-water intakes are given by VAN DEN BRINK & VAN DER VELDE (1986b). The cooling-water is withdrawn over the entire water column through pipes with a diameter of 4.5 m. The average velocity of the water just before the intake openings was $0.52\ m \cdot s^{-1}$ during the sampling periods. Cooling-water enters the intakes through a trash rack and is sieved by rotating drum screens or vertically travelling screens with about 2 x 2 mm mesh openings. Trapped macroinvertebrates, fish and other materials are washed from the screens and then sluiced onto a tray.

Sampling was carried out by collecting from the trays all faunistic material trapped in the course of 24 h, at least once a month during 1986 and weekly during 1987 (see also VAN DER VELDE et al. 1989).

In addition to the analysis of our own observations a survey was made of the literature concerning the occurrence of macroinvertebrates and fish in the area under consideration (Fig. 1). Sources with respect to the occurrence of macroinvertebrates were: ALBARD 1889, LE ROI 1912, 1913, 1915, LAUTERBORN 1918, REDEKE 1948, HOLTHUIS 1950, DEN HARTOG 1963, 1964, VAN URK 1978, 1984, CLAESSENS 1981, MOL 1981, 1984, 1985, VAN TOL & GEIJSKES 1981, KLINK & MOLLER-PILLOT 1982, VAN DEN BRINK & VAN DER VELDE 1986a, 1986b, VAN DEN BRINK et al. 1988.

Recent studies on the fish populations in the river branches have also been carried out by the Netherlands Institute for Fishery Investigations (e. g. CAZEMIER 1988). Sources with respect to the occurrence of fish in the past were: HOEK 1893, 1916, LAUTERBORN 1918, REDEKE 1941, 1948, VAN DRIMMELEN 1957, VERHEY 1961, VAN DE KANT 1963, REUTER 1966, VAAS 1968, VAN WIJCK 1971, PEETERS & WOLFF 1973, OSKAM 1973, LOBREGT & VAN OS 1977, OOMEN & VAN WIJCK 1978, HADDERINGH et al. 1983, DE BOER & TE BRINKE 1984, CAZEMIER 1984, 1988, VAN DRIMMELEN 1987. In addition to literature data, some unpublished observations of the authors and of colleagues have been included in this review. Only catches of intact animals from the summer-bed of the river have been recorded in the tables presented in this paper. Records of exuviae and catches of imagines of insects have been omitted because of their uncertain origin (KLINK & MOLLER-PILLOT 1982). This was done in order to get a clear picture of possible changes in the composition of fish and macrofauna communities in the freshwater part of the river Rhine and its branches Waal, Lek and IJssel in The Netherlands since 1900. The nomenclature of the macroinver-

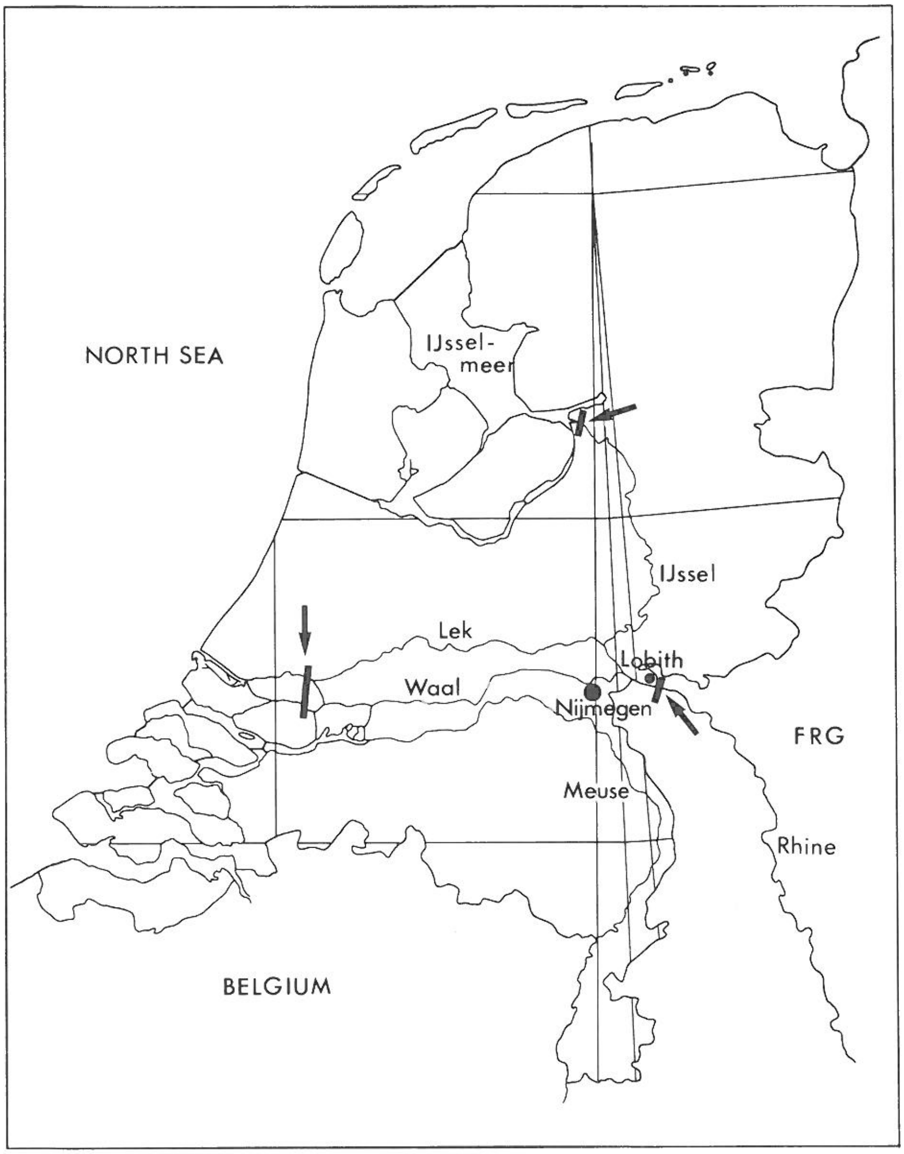

Fig. 1: Map of The Netherlands with the main rivers. Arrows indicate the borders of the area under consideration.

tebrates and of the fish was according to MOL (1984) and NIJSSEN & DE GROOT (1987) respectively.

Physico-chemical parameters of the river Rhine over several years (Fig. 2) were obtained from Rijkswaterstaat (DBW/RIZA, Lelystad) (RIZA 1970, DBW/RIZA 1985) and from the literature (REDEKE 1948, ZIJLSTRA 1980, DIJKZEUL 1982).

3 Results and discussion

3.1 Physico-chemical parameters

Fig. 2 shows some major changes in physico-chemical parameters of the river Rhine in The Netherlands as measured at Lobith near the Dutch-German border (Fig.1). Conspicious changes in water quality include an increase in chlorinity and eutrophication over the years, and a decrease in oxygen content until 1970. During the last decades the average water temperature increased significantly, by about two degrees Celsius, from 10.9 °C to 12.8 °C in 1985 (REDEKE 1948, DBW/RIZA 1985). Thanks to the purification of sewage and industrial organic waste in the seventies, the oxygen and ammonium contents in particular have been restored to normal levels (ZIJLSTRA 1980, DIJKZEUL 1982). Despite these improvements in water quality there are at present a number of parameters that still persist in unnaturally high concentrations. Some of these parameters, such as phosphate, nitrate and chlorinity, are even increasing in quantity (Fig. 2). Apart from the parameters presented in fig. 2 there is a still growing list of compounds (micropollutants) present in the river water which are alien to the ecosystem and toxic to macroinvertebrates and fish, such as heavy metals, PCBs and other hydrocarbons (DIJKZEUL 1982, DBW/RIZA 1985). Especially in the lower Rhine sediment, concentrations of various heavy metals are now two till tenfold the concentrations at the beginning of the century (SLOOFF 1983, Rijkswaterstaat 1987).

3.2 Biological parameters

3.2.1 Macroinvertebrate communities

Table 1 presents a list of the macroinvertebrate species trapped on the screens of the Gelderland power station during 1986–1987, together with species collected by handnet catches, as well as by sampling stones and artificial substrates in the littoral border of the rivers Waal and Lek during 1981–1982 (KLINK & MOLLER-PILLOT 1982), and by sampling stones and sediment in the littoral border of the river IJssel during 1981 (VAN URK 1984).

Comparing our own data with those of the other studies mentioned, it becomes clear that our sampling method is predominantly useful for collecting the more mobile and open water species, such as macrocrustacea (Table 1) and fish (Table 3), which either occur in low

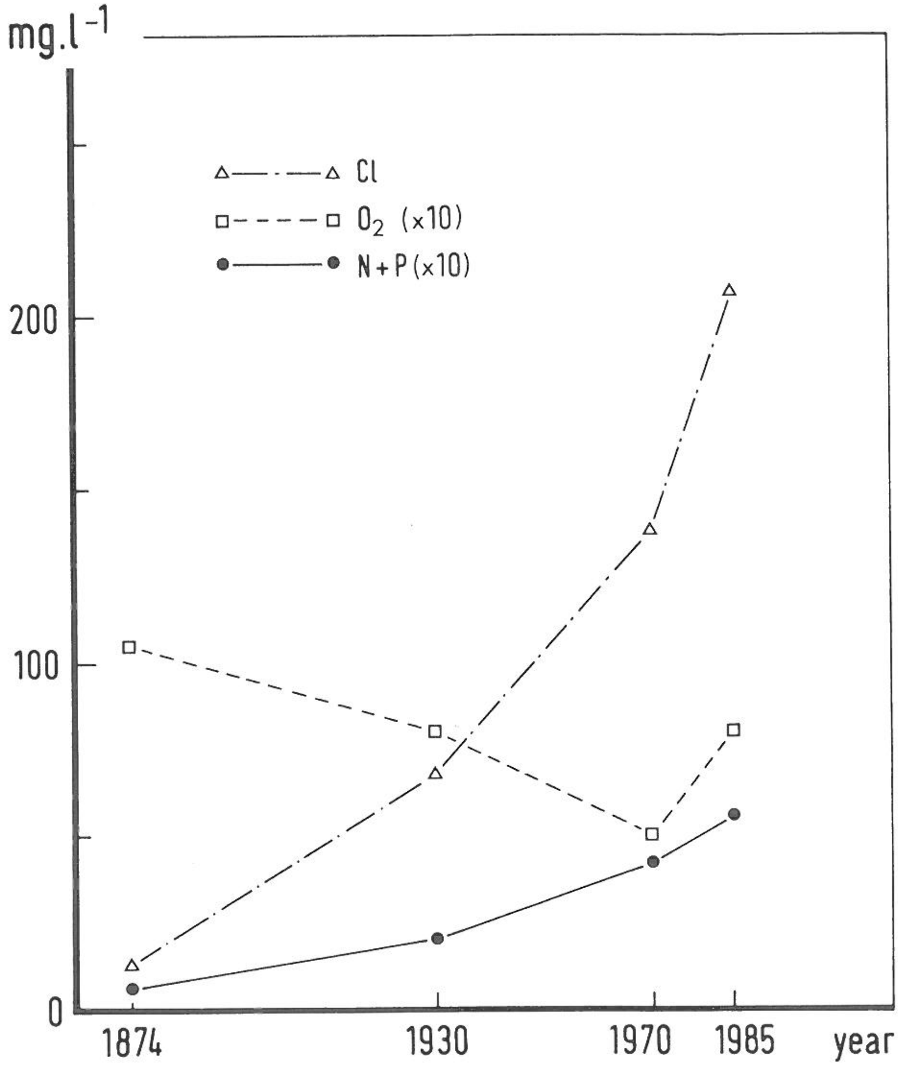

Fig. 2: Major changes in some abiotic parameters of the river Rhine in The Netherlands over the years. Yearly mean concentrations are presented. O_2 = the oxygen concentration; N + P = the sum of the nitrate, ammonium and ortho-phosphate concentrations; Cl = the chlorinity of the river water.

densities near the banks of the rivers or are too fast for handnet collecting. A disadvantage is that Oligochaetes and Chironomids are too small to be entrained in our samples (the mesh size of the filtering screens being about 4 mm^2). It is also possible that specimens of these taxa are not sucked in at all, because of their relatively sessile way of living near the banks of the river.

Because of the variety of sampling methods used, a combination of our data with those of the other studies mentioned is likely to yield a clear overall picture of the macroinvertebrates in the freshwater part of the river Rhine in The Netherlands (Table 1). Hence, the total number of at least 122 species which has been collected in the three separate investigations in the Dutch Rhine branches (Table 1) can be considered to represent the number of species potentially inhabiting this section of river. Excluding those species which have been collected only rarely and in very low numbers, the total number of macroinvertebrates occurring more or less commonly in the freshwater part of the Dutch Rhine branches is 65. Most of these species are chironomids (51 %), followed by worms (18 %), molluscs (14 %), macrocrustaceans (12 %) and non-chironomid insects (5 %). An interesting observation is the relatively high percentage of immigrants (85 %) among the macrocrustaceans (Table 1). This phenomenon will be discussed below.

The list of species presented in table 1 shows a great deal of resemblance to recent lists of macroinvertebrates collected by handnet catches and light traps (CASPERS 1980a), or by the use of a diving pit (SCHMITZ 1986) in the upper Niederrhein, which is the section of the Rhine just before it enters the German industrial area of the Ruhr-Gebiet. However, a clear difference with these lists is the absence in the German Rhine stretch of brackish-water species, such as the euryhaline crustaceans *Palaemon longirostris, Eriocheir sinensis, Rhithropanopeus harrisi* and *Gammarus zaddachi*. This difference may be explained by the fact that these crustaceans are dependent on estuarine conditions for their reproduction. As a result, the abundance of these species gradually decreases as one goes upstream, as was demonstrated for the prawn *Palaemon longirostris* (VAN DEN BRINK & VAN DER VELDE 1986b).

A literature survey on long-term changes in macrofauna communities in the river Rhine is handicapped by lack of information on the former occurrence of taxa such as Diptera, on which relatively few attention has been paid. However, palaeolimnological studies (KLINK, 1983, 1986) seem to fill into this knowledge gap. In Diptera communities of Dutch Rhine stretches a shift was observed in taxa composition: in the oldest Rhine sediments Simuliidae were most abundant, while in the youngest sediments Chironomidae dominated the dipteran fauna (KLINK 1986). For the macroinvertebrate groups which received most attention in former studies, a species list is presented in table 2. Since 1900 the total number of species for these groups declined sharply, from 83 to the present 40 species. This decline was due to the extinction of many strictly riverine species, among which stream dwelling aquatic insects were the largest group (Table 2). Most plecopteran species were last recorded in the Dutch part of the river Rhine before the start of this century (CLAESSENS 1981). Around 1940 the characteristic riverine ephemeropteran and trichopteran species disappeared from the large Dutch rivers (MOL 1984). Finally during the last fourty years the large stream mussels of the genus *Unio* also became extinct in the river Rhine (PEETERS & WOLFF 1973). Undoubtedly, the decrease in water quality, the deterioration of natural habitats (e. g. decline of aquatic macrophytes, loss of soft sandy river banks) and the increase in shipping traffic are major causes of the decline in macroinvertebrate species in the river Rhine (KLINK & MOLLER-PILLOT 1982, VAN URK 1984, VAN URK et al. 1985, KLINK 1986). A similar decrease in species-richness was noted for other parts of the river Rhine, such as the Hochrhein (CASPERS 1980b), the Oberrhein (KINZELBACH 1972, 1978), the Mittelrhein (KINZELBACH 1972) and the Niederrhein (CASPERS 1980a, BLESS 1981, SCHMITZ 1986).

Despite the general decrease in species-richness over the years there are some observations which indicate a recent improvement in water quality. The trichopteran *Hydropsyche contubernalis* is a typically riverine species which occurs in large quantities in the river Rhine in The Netherlands nowadays. Although it had been absent from The Netherlands for several years, the species was found again in 1979 (VAN URK 1981). In the upper Niederrhein and Mittelrhein too, this species had not been found for several years, until in the late seventies a mass occurrence was observed (CASPERS 1980a, SCHMITZ 1986, BECKER 1987). Other riverine species which have recently been discovered in the river Waal near Nijmegen, after an absence of many years, are the waterbug *Aphelocheirus aestivalis* and the dragonfly *Calopteryx splendens* (Table 1). In the river IJssel VAN URK (1984) recently collected some specimens of *Anodonta anatina* and *Unio pictorum*. Despite fairly intensive investigations these mussels had not been found in the Rhine branches during the early 1970s (PEETERS & WOLFF 1973, VAN URK 1978). The recent improvement in oxygen content is considered a major factor in the return of these species to the Rhine ecosystem (BLESS 1981, VAN URK 1984, BECKER 1987).

In contrast to other taxa, the macrocrustaceans of the river Rhine in The Netherlands have shown a remarkable increase in species-richness since 1900 (Table 2). This increase was due to an introduction of exotic species from North America and Eastern Asia, an immigration of endogenous brackish water species from the estuarine area of the Rhine, together with an immigration of exotic species from the Mediterranean and the Ponto-Caspic areas (DEN HARTOG & VAN DER VELDE 1987). Among the latter group of immigrants the amphipod *Corophium curvispinum* is new for the Dutch fauna. The species was first collected in 1987 in the Dutch Rhine stretch at Lobith (Fig. 1). Other recent immigrants in the freshwater section of the river Rhine are some brackish water crustaceans. Before 1980 the prawn *Palaemon longirostris*, the crab *Rhithropanopeus harrisi* and the amphipod

Gammarus zaddachi were found exclusively in the tidal area of the rivers Rhine, Meuse and Scheldt and the adjacent surface waters in the western part of The Netherlands (HOLTHUIS 1950, DEN HARTOG 1964, ADEMA 1981, VAN DEN BRINK & VAN DER VELDE 1986b, PINKSTER & PLATVOET 1986). Due to increasing salt discharges and eutrophication of the Rhine water (Fig. 2) the distributional limits of these species have been extended upstream by a distance of more than 100 km (VAN DEN BRINK & VAN DER VELDE 1986b, VAN DER VELDE et al. 1989). The stony embankment of the rivers, the increased water temperature and the improved oxygen content of the river water also contribute to a suitable habitat for these crustaceans (VAN DEN BRINK & VAN DER VELDE 1986b, DEN HARTOG & VAN DER

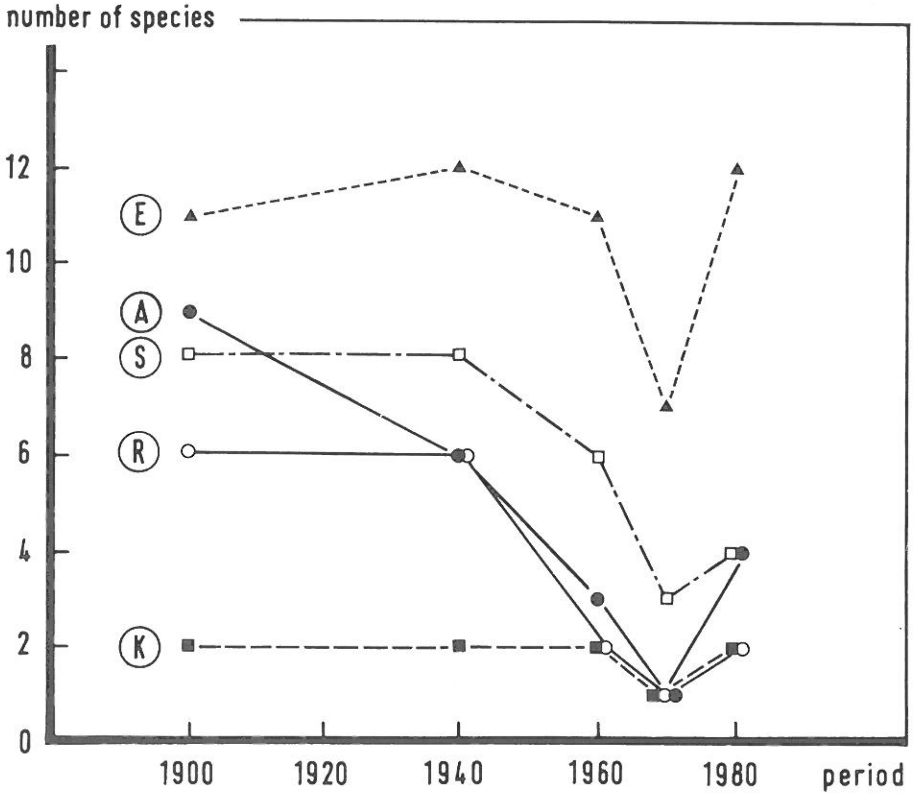

Fig. 3: Changes in species-richness for various fish groups of the river Rhine in The Netherlands. Rare species (indicated in table 3 by 1) are excluded. E = "euryoecious" species, A = anadromous species, S = stagnophilous species, R = rheophilous species and K = katadromous species. Period: 1900 = ± 1900; 1940 = ± 1940; 1960 = 1960–'69; 1970 = 1970–'79; 1980 = 1980–'87.

VELDE 1987). However, the brackish water immigrants still depend on estuarine conditions for their reproduction. As a consequence, the populations of these crustaceans in the river Waal at Nijmegen exhibit seasonal fluctuations in density and highly skewed sex ratios, due to migratory movements (VAN DEN BRINK & VAN DER VELDE 1986b, VAN DER VELDE et al. 1989).

3.2.2 Fish communities

The changes in fish fauna of the freshwater section of the Dutch Rhine branches are presented in table 3 and fig. 3. With respect to migratory behaviour and preference or non-preference for running or stagnant waters the fish fauna can be divided into anadromous, katadromous, rheophilous, stagnophilous and more or less "euryoecious" species (REDEKE 1941). These different fish groups showed different reactions to the changed environment of the river Rhine (Fig. 3). The most dramatic change occurred among the characteristic riverine species, i. e. the anadromous and rheophilous species. The anadromous sturgeon *(Acipenser sturio)* had already become extinct in the large Dutch rivers at the beginning of this century (VERHEY 1961). Soon afterwards, the allis shad (*Alosa alosa*) and the houting *(Coregonus oxyrinchus)* started to decline sharply. Overfishing and river regulation are considered to be the main factors responsible here (VERHEY 1961). After 1940, salmon *(Salmo salar)* and allis shad *(Alosa alosa)* became rare species, although of course their decline had started earlier (Table 3). The construction of weirs in the upper courses of the river and other hydrotechnical works, such as the dam in the Haringvliet, caused a further decline (DEELDER & VAN DRIMMELEN 1959, LELEK 1976, WOLFF 1978, CAZEMIER 1988). Other river species such a barbel *(Barbus barbus)*, stippled bleak *(Alburnoides bipunctatus)*, chub *(Leuciscus cephalus)*, dace (*Leuciscus leuciscus*) and nase *(Chrondrostoma nasus)* decreased during the same period, probably as a result of increasing pollution together with a decline in oxygen content of the river water and a loss of suitable spawning-grounds. Besides the typical riverine species the stagnophilous species strongly declined in species-richness (Fig. 3). Probably the deterioration of habitats with aquatic vegetation is a major cause for this decline because most stagnophilus species prefer vegetated habitats (LAMMENS 1986). The decline of the stagnophilous bitterling *(Rhodeus sericeus)* can be attributed to the decline of unionids in the river Rhine (Table 2), because bitterlings need these mussels as a substrate for spawning.

Compared with the other species, the katadromous and "euryoecious" species showed more tolerance to the deterioration of their habitat (Fig. 3). For the katadromous eel (*Anguilla anguilla*) and flounder (*Platichthys flesus*) the main reason for their survival in the river Rhine probably lies in the fact that they are sea-spawners. As a consequence the most vulnerable egg and larval development takes place in a marine environment, which is more stable than the riverine environment. "Euryoecious" species such as bronze bream *(Abramis brama)*, silver bream *(Abramis bjoerkna)* and roach *(Rutilus rutilus)* showed the greatest tolerance to the changed environment. These organisms are the most abundant fish species in the Dutch Rhine branches nowadays.

In order to sustain the declining fish-stock of the river Rhine, several (non-)indigenous species have been introduced in the past (e. g. HOEK 1916, VOOREN 1972, DE GROOT 1985). However, these attemps have failed in most cases, certainly because the environmental conditions were not suitable at the time. The pikeperch *(Stizostedion lucioperca)* is the only fish species which has shown a major increase since its introduction in the river Rhine in 1883 (Table 3). This success has been attributed to the fact that only geographical barriers limited the natural distribution of this species (DE GROOT 1985). In addition, its great tolerance for eutrophication (LAMMENS et al. 1986) must be taken into account in order to explain its present successful occurrence in the river Rhine.

4 Concluding remarks

It can be concluded that the faunistic diversity has greatly declined since 1900, a decline which was most dramatic among the rheophilous species (Fig. 4). The decrease in water quality (chemical pollution, eutrophication, raised salinity, thermal pollution), together with a deterioration of natural habitats (decline of aquatic macrophytes, loss of suitable substrates for settlement and spawning) are considered major causes for this decline. As for anadromous fish species such as sturgeon, shads, houting and salmon, the construction of hydrotechnical works (e. g. weirs, dams) which act as physical barriers, together with overfishing, were the main causes of their becoming extinct.

The number of fish species in the river must have been as much as 40 about a century ago. Because of many detrimental influences the number of species decreased gradually to about 28 in the early seventies. Especially in the F. R. G. pollution with degradable organic matter was greatly reduced in the seventies. Water quality parameters (oxygen content, ammonium content) resumed recently more normal values. The number of fish species increased to about 36 species nowadays, of which 32 are indigenous. Riverine and anadromous species however are still rather scanty.

While the percentage of rheophilous macroinvertebrate species declined, that of immigrants increased over the years (Fig. 4). This increase reflected the immigration of several euryoecious species into the Rhine ecosystem. Among these immigrants a number of euryhaline crustaceans extended their distributional range upstream, due to the increased salinity of the river Rhine.

The recent reappearance of several rheophilous macroinvertebrates and fish species may be attributed to the improved oxygen content of the river water. Although these findings

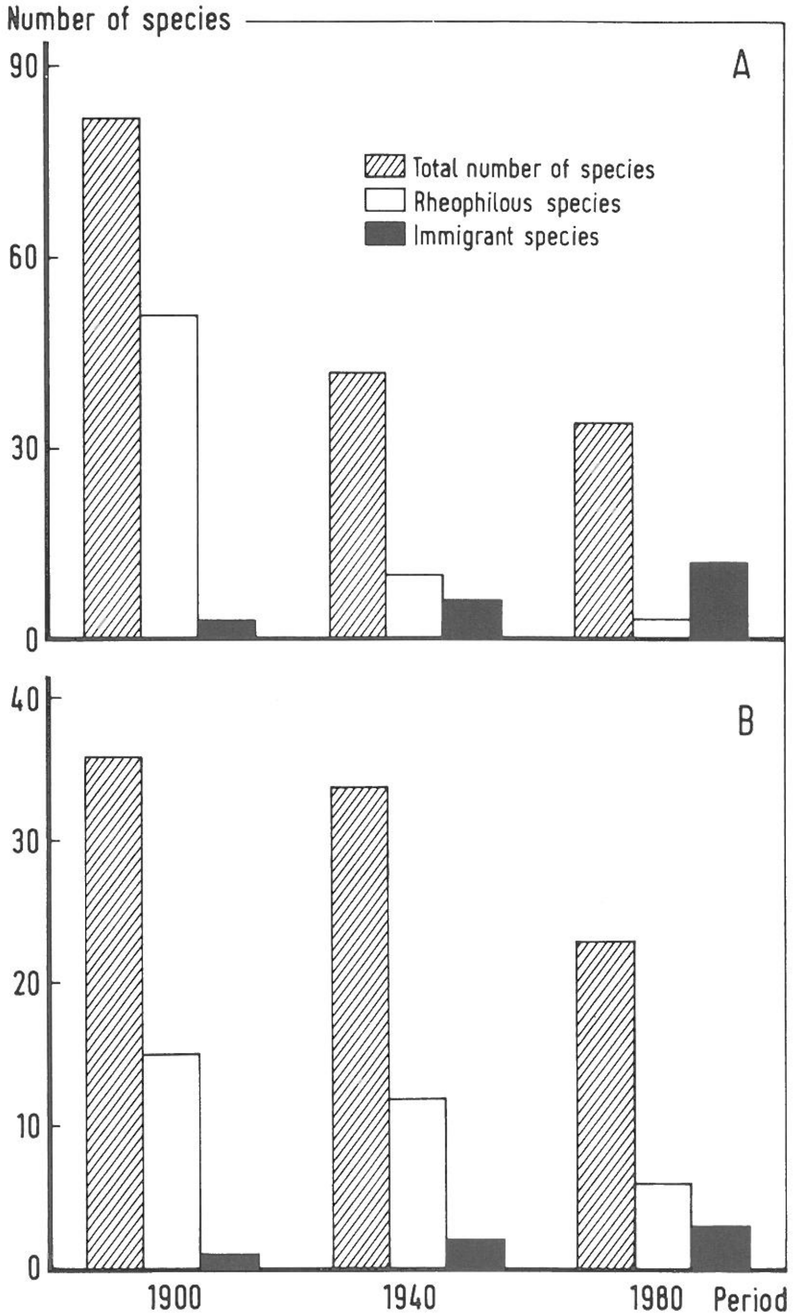

Fig. 4: Changes in the species-richness of the macrofauna (A) and the fish fauna (B) of the river Rhine and its branches in The Netherlands. For the changes in macrofauna community only the taxa presented in table 2 are used. For the changes in fish community the rare species are omitted.

indicated possibilities for a further increase in faunal diversity, the ecosystem of the river Rhine still is far from a normal, undisturbed riverine system. Besides water quality parameters also attention should be paid to restoration of natural habitats for the return of more delicate riverine species.

Summary

A literature survey of the occurrence of aquatic macroinvertebrate and fish fauna in the freshwater part of the river Rhine and its major branches Waal, Lek and IJssel in the Netherlands (Fig. 1) is presented. These data, supplemented with the present macroinvertebrate and fish fauna, investigated by regular sampling of the cooling-water filtering screens of the Gelderland power station near Nijmegen, are shown in tables 1 and 3.

It can be concluded that faunistic diversity has seriously declined since the beginning of this century (Figs 3, 4). It are especially stream-dwelling aquatic insects such as mayflies, stoneflies and caddisflies which have become extinct, together with anadromous and strictly rheophilous fish species (Figs 3, 4; Tables 2, 3). The increase in shipping traffic, the construction of hydrotechnical works, overfishing, the deterioration of natural habitats for settlement and spawning, the decrease in water quality (Fig. 2) and the increase in toxic pollutants are considered to be at the root of this decline in diversity.

Recently a number of rheophilous macroinvertebrates and fish species has been collected which had been absent from the river Rhine in The Netherlands for several years (Tables 1–3). The reappearance of these species is considered to be caused by the improvement of the oxygen content of the river water since the 1970s (Fig. 2).

Among the macroinvertebrate immigrants recently collected at the Gelderland power station a large number of brackish water species was found (Tables 1, 2), reflecting the increased salinity of the river Rhine (Fig. 2).

Zusammenfassung

Die Literatur wurde durchgesehen auf das Vorkommen der wirbellosen Makrofauna und der Fischfauna, in der Süßwasserstrecke des Rheines in den Niederlanden d. h. seiner wichtigsten Arme, Waal, Lek und IJssel. Das heutige Vorkommen dieser Tiergruppen im Waal, dem Hauptarm des Rheins in den Niederlanden, wurde an der Gelderland-Elektrizitätswerke in Nimwegen untersucht. Das Material, das mit dem Kühlwasser der Gelderland-Elektrizitätswerke aufgepumpt wurde, wurde regelmäßig aufgesammelt und registriert (Tabelle 1).

Es stellte sich heraus, daß die Artenvielfalt seit Anfang des Jahrhunderts stark zurückgegangen ist (Abb. 4). Der Rückgang betraf besonders die strömungsliebenden Wasserin-

sekten wie Ephemeroptera, Plecoptera und Trichoptera, sowie die anadromen Wanderfische und typischen Flußfische (Abb. 3, 4; Tabellen 2, 3). Für den Rückgang der Artenvielfalt sind wahrscheinlich die Zunahme des Schiffsverkehrs, wassertechnische Maßnahmen, Überfischung, die Vernichtung natürlicher Habitate und Laichplätze und die Verschlechterung der Wasserqualität (Abb. 2) verantwortlich.

Vor kurzem wurden wieder einige strömungsliebende Makrofauna- und Fischarten gefunden, die schon seit Jahrzehnten nicht im holländischen Teil des Rheines angetroffen wurden (Tabellen 1–3). Die Wiederkehr dieser Arten ist vermutlich auf das verbesserte Sauerstoffangebot des Flußwassers seit den siebziger Jahren zurückzuführen (Abb. 2).

Das Neuauftreten verschiedener wirbelloser Brackwasserarten bei den Gelderland-Elektrizitätswerken (Tabellen 1, 2) kann als Folge der Zunahme des Salzgehaltes des Flusses (Abb. 2) angesehen werden.

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Table 1: A recent list of macroinvertebrates from freshwater stretches of Dutch Rhine branches.
* = immigrant species; 0 = rare; 1 = less common; 2 = common.; + = additional records (recent observations Institut for Inland Water Management and Waste Water Treatment [DBW/RIZA]).

Source:	Klink & Moller-Pillot (1982)	Van Urk (1984)	own data
Branch	Waal, Lek	IJssel	Waal
Tricladida:			
Dugesia polychroa (Schmidt)	2	2	0
* *Dugesia tigrina* (Girard)	1	2	0
Dendrocoelum lacteum (Müll.)	0		
Oligochaeta:			
Lumbriculus variegatus (Müll.)	1		
Limnodrilus claparedeianus Rat.		1	
Limnodrilus hoffmeisteri Clap.		1	
Limnodrilus uudekemianus Clap.		+	
Peloscolex cf. *moszynskii*		+	
Potamothrix hammoniensis (Mich.)		+	
Potamothrix moldaviensis Vejd. & Mraz.		+	
Psammoryctides albicola (Mich.)		+	
Psammoryctides barbatus (Grube)		+	
Tubifex tubifex (Müll.)		0	
Dero digitata (Müll.)		+	
Nais bretscheri Mich.		0	
Nais elinguis Müll.		1	
Nais simplex Piguet		0	
Stylaria lacustris L.	2	2	
Hirudinae:			
Glossiphonia complanata (L.)	1	1	
Glossiphonia heteroclita (L.)	1	1	
Helobdella stagnalis (L.)	1		
Hemiclepsis marginata (Müll.)	0	+	0
Theromyzon tessulatum (Müll.)		+	
Erpobdella octoculata (L.)	2	2	2
Erpobdella testacea Sav.			0
Erpobdella nigricollis Brandes			0
Piscicola geometra (L.)		+	2
Cystobranchus respirans (Tros.)			0
Gastropoda:			
Valvata piscinalis (Müll.)			+
* *Potamopyrgus jenkinsi* (Smith)	0		

Table 1: List of macroinvertebrates (cont.).

Source: Branch	Klink & Moller- Pillot (1982) Waal, Lek	Van Urk (1984) IJssel	own data Waal
Bithynia tentaculata (L.)	2	2	2
Physa fontinalis (L.)	2	1	
* *Physa acuta* Drap.			0
Radix peregra (Müll.)	2	1	2
Stagnicola palustris (Müll.)	0	2	0
Ancylus fluviatilis (Müll.)	1	2	
Acroloxus lacustris (L.)	1	1	
Ferrissia wautieri (Mirolli)		+	
Lamellibranchia:			
Unio pictorum (L.)		0	
Anodonta anatina (L.)		0	
Sphaerium corneum (L.)		1	1
Sphaerium rivicola (Lamarck)		+	
Pisidium henslowanum (Shepp.)		1	
Pisidium casertanum (Poli)	0		
* *Dreissena polymorpha* (Pall.)	2	2	2
Decapoda:			
* *Atyaephyra desmaresti* (Mill.)	0		2
* *Palaemon longirostris* M.-Edw.			2
* *Orconectes limosus* (Raf.)			2
* *Eriocheir sinensis* M.-Edw.			2
* *Rhithropanopeus harrisi* (Gould)			0
Amphipoda:			
Gammarus pulex (L.)	2		1
* *Gammarus tigrinus* Sexton	0		2
* *Gammarus zaddachi* Sexton			2
* *Orchestia cavimana* Heller			0
* *Corophium curvispinum* Sars			+
Isopoda:			
Asellus aquaticus L.	2	2	1
* *Proasellus coxalis* (Dollfus)			0
* *Proasellus meridianus* (Rac.)	0		0
Odonata:			
Ischnura elegans (v. d. L.)		0	
Calopteryx splendens (Harris)			0

Table 1: List of macroinvertebrates (cont.).

Source: Branch	Klink & Moller-Pillot (1982) Waal, Lek	Van Urk (1984) IJssel	own data Waal
Heteroptera:			
Aphelocheirus aestivalis (Fab.)			0
Sigara falleni (Fieber)			0
Ephemeroptera:			
Caenis luctuosa Burm.	0		
Cloeon dipterum (L.)	0		
Trichoptera:			
Cyrnus trimaculatus (Curtis)	0	1	
Ecnomus tenellus (Rambur)	0	1	
Hydropsyche contubernalis McL.	2	2	2
Molanna angustata Curtis		+	
Ceraclea fulva (Rambur)	0	+	
Chironomidae:			
Conchapelopia melanops (Wied.)	0		
Procladius sp.	2	2	
Rheopelopia ornata (Mg.)	2	+	
Potthastia longimanaus K.	0		
Prodiamesa olivacea Mg.	0		
Brillia longifurca K.	0		
Brillia modesta (Mg.)	0		
Cardiocladius capuchinus (Zett.)	0		
Cricotopus bicinctus (Mg.)	2	+	
Cricotopus curtis/cylindraceus	0		
Cricotopus intersectus (Staeg.)	2	+	
Cricotopus sylvestris (Fab.)	2	+	
Cricotopus triannulatus (Macq.)	2	+	
Eukiefferiella calvescens Edw.	1		
Eukiefferiella claripennis Lundb.	0		
Eukiefferiella gr. *discoloripes*	0		
Limnophyes sp.	0	+	
Nanocladius bicolor (Zett.)	1		
Nanocladius rectinervis (K.)	0		
Nanocladius sp.		2	

Table 1: List of macroinvertebrates (cont.).

Source: Branch	Klink & Moller-Pillot (1982) Waal, Lek	Van Urk (1984) IJssel	own data Waal
Orthocladius sp.	1	+	
Paratrichocladius rufiventris (Mg.)	1		
Pseudosmittia gr. *virgo*	0		
Rheocricotopus gr. *chalybeatus*	0	+	
Rheocricotopus fuscipes (K.)	1		
Synorthocladius semivirens (K.)	1		
Chironomus f. l. *plumosus*	2	+	
Chironomus f. l. *reductus*	1	2	
Chironomus f. l. *fluviatilis*		2	
Cryptochironomus rostratus K.	2	+	
Cryptochironomus supplicans (Mg.)	1	+	
Cryptochironomus gr. *supplicans*	2		
Cryptochironomus gr. *defectus*		2	
Cryptocladopelma gr. *laccophilus*	1		
Dicrotendipes nervosus (Staeg.)	2	2	
Glyptotendipes sp.		2	
Endochironomus albipennis (Mg.)	0	2	
Harnishia sp.	2		
Microchironomus tener (K.)	2	2	
Parachironomus gr. *arcuatus* Goet.	1	2	
Parachironomus longiforceps K.	2	2	
Parachironomus sp. K	0		
Phaenopsectra sp.	0		
Polypedilum laetum agg.	0	+	
Polypedilum gr. *nubeculosum*	2	+	
Polypedilum breviantennatum Tshern.	2		
Polypedilum scalaenum Schrank	2		
Xenochironomus xenolabis K.	1	2	
Micropsectra atrofasciata K.	2	+	
Paratanytarsus sp.	1		
Rheotanytarsus sp.	2		
Muscidae:			
Limnophora riparia (Fallén)		+	

Table 2: Changes in species-richness of some macroinvertebrate taxa in freshwater stretches of Dutch Rhine branches.
* = immigrant; b = brackish-water species; t = thermophilous species; r = rheophilous species.

	1900	1940	1981–1987	status
Gastropoda:				
Theodoxus fluviatilis (L.)	+	+		r
Viviparus viviparus (L.)	+	+		
Valvata piscinalis (Müll.)	+	+	+	
* *Potamopyrgus jenkinsi* (Smith)			+	b
* *Lithoglyphus naticoides* (Pfeif.)	+	+		r
Bithynia tentaculata (L.)	+	+	+	
Physa fontinalis (L.)	+	+	+	
* *Physa acuta* Drap.	+	+	+	t
Stagnicola palustris (Müll.)	+	+	+	
Radix peregra (Müll.)	+	+	+	
Ancylus fluviatilis (Müll.)	+	+	+	
Acroloxus lacustris (L.)	+	+	+	
Ferrissia wautieri (Mirolli)			+	t
Lamellibranchia:				
Unio crassus batavus (Mat. & Rack.)	+	+		r
Unio pictorum (L.)	+	+	+	
Unio tumidus Phil.	+	+		
Anodonta cygnea (L.)	+	+		
Anodonta anatina (L.)	+	+	+	
Pseudanodonta complanata (Rossm.)	+	+		r
Sphaerium corneum (L.)	+	+	+	
Sphaerium rivicola (Lam.)	+	+	+	
Sphaerium solidum (Norm.)	+	+		
Pisidium amnicum (Müll.)	+	+		
Pisidium supinum Schm.	+	+		r
Pisidium henslowanum (Shepp.)	+	+	+	
Pisidium casertanum (Poli)	+	+	+	
* *Dreissena polymorpha* (Pall.)	+	+	+	
Decapoda:				
* *Atyaephyra desmaresti* (Mill.)		+	+	t
* *Palaemon longirostris* M.-Edw.			+	b
Astacus astacus (L.)	+	+		r
* *Orconectes limosus* (Raf.)			+	
* *Eriocheir sinensis* M.-Edw.		+	+	b
* *Rhithropanopeus harrisi* (Gould)			+	b

Table 2: Changes in species richness (cont.).

	1900	1940	1981–1987	status
Amphipoda:				
Gammarus pulex (L.)	+	+	+	
* *Gammarus tigrinus* Sext.			+	b, t
* *Gammarus zaddachi* Sext.			+	b
* *Orchestia cavimana* Hell.			+	
* *Corophium curvispinum* Sars			+	
Isopoda:				
Asellus aquaticus L.	+	+	+	
* *Proasellus coxalis* (Dollfus)			+	
* *Proasellus meridianus* (Rac.)		+	+	
Heteroptera:				
Aphelocheirus aestivalis (Fab.)	+	+	+	r
Odonata:				
Gomphus flavipes (Charp.)	+			r
Calopteryx splendens (Harr.)	+	+	+	r
Ischnura elegans (v. d. L.)	+	+	+	
Ephemeroptera:				
Isonychia ignata (Walk.)	+			r
Baetis lutheri Müll.-Lieb.	+			r
Baetis rhodani (Pict.)	+	+		r
Cloeon dipterum (L.)	+	+	+	
Raptobaetopus tenellus (Alb.)	+			r
Ecdyonurus affinis (Eat.)	+			r
Ecdyonurus aurantiacus (Burm.)	+			r
Ecdyonurus dispar (Curt.)	+			r
Ecdyonurus insignis (Eat.)	+			r
Heptagenia coerulans Rost.	+			r
Heptagenia longicauda (Steph.)	+			r
Rhithrogena diaphana Nav.	+			r
Ametropus fragilis Alb.	+			r
Choroterpes picteti (Eat.)	+			r
Potamanthus luteus (L.)	+			r
Ephemera lineata Eat.	+			r
Ephemera vulgata L.	+			
Ephoron virgo (Ol.)	+			r
Palingenia longicauda (Ol.)	+			r
Brachycercus harrisella Curt.	+			r
Caenis luctuosa Burm.	+	+	+	

Table 2: Changes in species-richness (cont.).

	1900	1940	1981–1987	status
Plecoptera:				
Brachyptera risi (Mort.)	+			r
Brachyptera braueri (Klap.)	+			r
Oemopteryx loewii (Alb.)	+			r
Isogenus nubecula Newm.	+			r
Isoperla obscura (Zett.)	+			r
Dinocras cephalotes (Curt.)	+			r
Marthamea selysii (Pict.)	+			r
Perla burmeisteriana Cla.	+			r
Chloroperla tripunctata (Scop.)	+			r
Isoptena serricornis (Pict.)	+			r
Siphonoperla burmeisteri (Pict.)	+			r
Siphonoperla torrentium (Pict.)	+			r
Xanthoperla apicalis (Newm.)	+			r
Trichoptera:				
Cyrnus trimaculatus (Curt.)	+	+	+	
Ecnomus tenellus (Ramb.)	+	+	+	
Psychomyia pusilla (Fab.)	+			r
Cheumatopsyche lepida (Pict.)	+			r
Hydropsyche angustipennis Curt.	+	+		r
Hydropsyche contubernalis McL.	+	+	+	r
Hydropsyche exocellata Duf.	+			r
Hydropsyche ornatula McL.	+			r
Molanna angustata Curt.	+	+	+	
Athripsodes albifrons (L.)	+			r
Ceraclea alboguttata (Hag.)	+			r
Ceraclea fulva (Ramb.)	+	+	+	
Ceraclea riparia (Alb.)	+			r
Oecetis notata (Ramb.)	+			
Oecetis tripunctata (Fab.)	+			r
Setodes punctatus (Fab.)	+			r
Setodes viridis (Four.)	+			r

Table 3: Changes in the fish-fauna of freshwater stretches of Dutch Rhine branches.
* = introduced; 0 = not recorded; 1 = (very) rare; 2 = common; ? = doubtful record.

Period:	1900	1940	1960–1969	1970–1979	1980–1987
Anadromous species:					
Petromyzon marinus L.	2	2	2	1	2
Lampetra fluviatilis (L.)	2	2	2	1	2
Acipenser sturio L.	2	1	0	0	0
Alosa alosa (L.)	2	1	?	0	1
Alosa fallax (Lac.)	2	2	?	0	1
Salmo salar L.	2	2	0	?	?
Salmo trutta trutta L.	2	2	1	1	2
Coregonus oxyrinchus (L.)	2	1	0	0	0
Osmerus eperlanus (L.)	2	2	2	2	2
Katadromous species:					
Anguilla anguilla (L.)	2	2	2	2	2
Platichthys flesus (L.)	2	2	2	1	2
Rheophilous species:					
Barbus barbus (L.)	2	2	1	0	1
Alburnoides bipunctatus (Bl.)	1	0	0	0	0
Leuciscus idus (L.)	2	2	2	1	2
Leuciscus cephalus (L.)	2	2	1	0	1
Leuciscus leuciscus (L.)	2	2	2	2	2
Chondrostoma nasus (L.)	2	2	1	1	0
* *Ctenopharyngodon idella* (Val.)	0	0	0	0	1
* *Hypophthalmichthys molitrix* (Val.)	0	0	0	0	1
Noemacheilus barbatulus (L.)	2	2	1	1	0
Stagnophilous species:					
Esox lucius L.	2	2	2	2	2
* *Cyprinus carpio* (L.)	2	2	2	2	2
Carassius carassius (L.)	2	2	2	1	1
* *Carassius auratus* (L.)	0	?	0	0	2
Tinca tinca (L.)	2	2	2	2	1
Rhodeus sericeus (Pall.)	2	2	2	1	0
Cobitis taenia L.	2	2	1	0	1
Misgurnus fossilis (L.)	2	2	1	0	1
Silurus glanis L.	0	1	0	1	1
* *Ictalurus melas* (Raf.)	0	0	0	1	?
* *Ictalurus nebulosus* (Le S.)	0	0	1	0	?
Pungitius pungitius (L.)	2	2	2	0	2

Table 3: Changes in the fish-fauna (cont.).

Period:	1900	1940	1960–1969	1970–1979	1980–1987
"Euryoecious" species:					
Gobio gobio (L.)	2	2	2	2	2
Abramis brama (L.)	2	2	2	2	2
Abramis bjoerkna (L.)	2	2	2	2	2
Alburnus alburnus (L.)	2	2	2	2	2
Rutilus rutilus (L.)	2	2	2	2	2
Rutilus erythrophthalmus (L.)	2	2	2	2	2
Gasterosteus aculeatus L.	2	2	2	1	2
Gymnocephalus cernuus (L.)	2	2	2	1	2
Perca fluviatilis L.	2	2	2	2	2
* *Stizostedion lucioperca* (L.)	1	2	2	1	2
Lota lota (L.)	2	2	2	1	2
Cottus gobio L.	2	2	1	0	2
Coregonus lavaretus (L.)	0	1	?	0	1
Coregonus albula (L.)	0	1	0	0	0