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Directorate-General for Public Works and Water Management

Institute for Inland Water Managemant and Waste Water Treatment, RIZA

Biological monitoring of national fresh waters

River Rhine 1995

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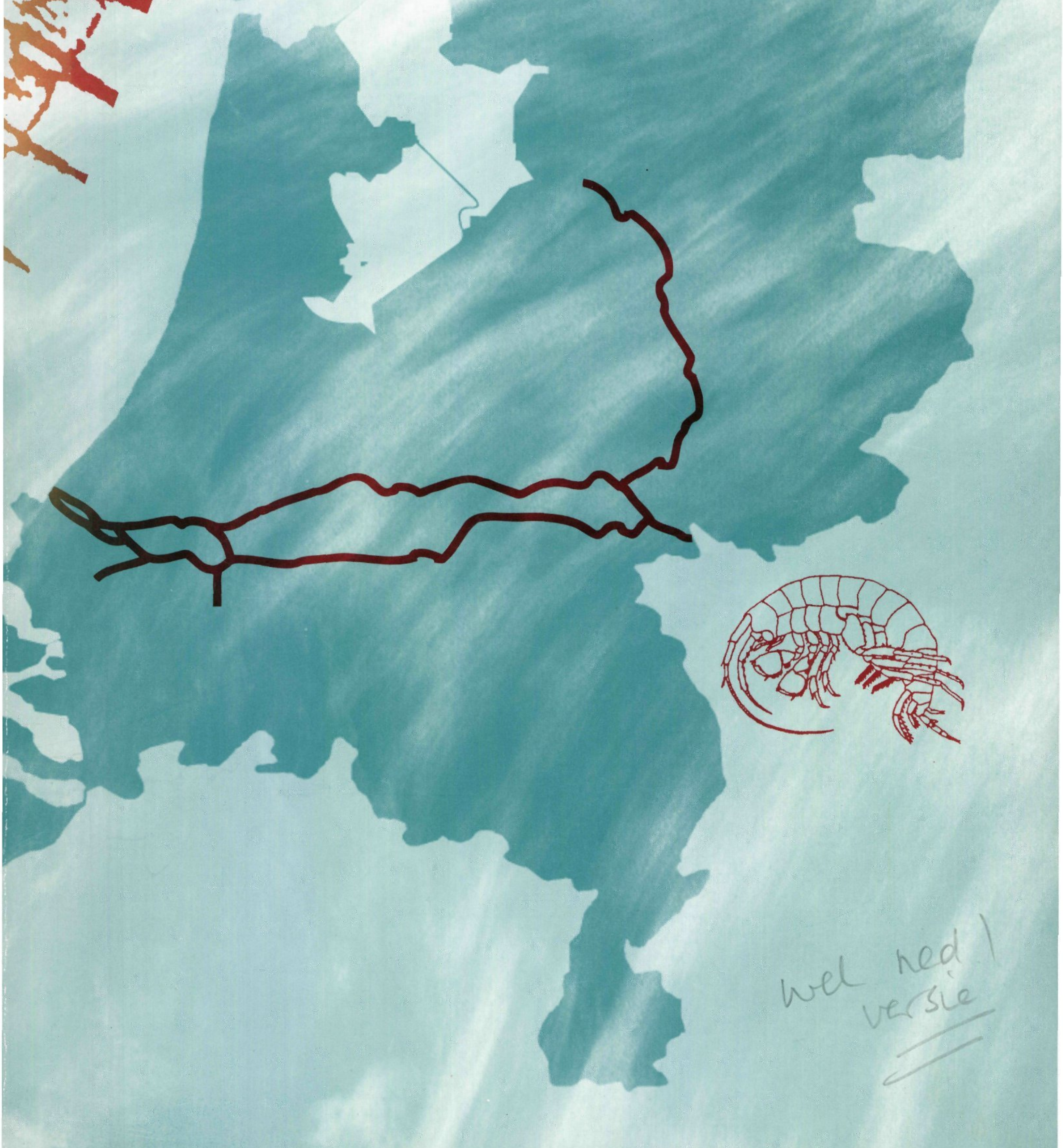

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Ministry of Transport, Public Works and Water Management

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RIZA Institute for Inland Water Management and Waste Water Treatment

P. Verdonschot

Biological monitoring of national fresh waters

Rhine 1995

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C. Bakker
R. Noordhuis
K.H. Prins

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Contents

[1] RIZA = Institute for Inland Water Management and Waste Water Treatment
[2] RIVM = National Institute of Public Health and Environmental Protection
[3] RIVO-DLO = National Fisheries Research Institute

Summary

The Rhine is the most important water system and the largest river in the Netherlands. The supply of water and sludge affects a major part (65 %) of the surface water in the Netherlands. The river Waal fulfils an important economic function as a shipping route between Rotterdam and Germany. Ecologically, the river is an important station and habitat for numerous species of plants and animals and provides an essential link in the distribution of organisms.

Ecological developments are followed by the Directorate-General for Public Works and Water Management in its annual monitoring programmes. A more extensive monitoring programme is carried out every four years. This report discusses the results of the first year of intensive monitoring, in 1995.

At the Dutch/German border, the Rhine has an even, average discharge of 2200 m^3 / sec. The river branches into the IJssel ,which flows into lake IJsselmeer, and the Lower Rhine and the river Waal, which eventually flow into the North Sea via the "lower rivers". When discharges are below 2320 m^3 / sec, the Lower Rhine/Lek river section is weired to guarantee sufficient water for the free-flowing Waal.

Water quality has improved markedly since the nineteen seventies. The establishment of many organisms is no longer impeded by the water's chemical quality. However, the contamination of surface water and the bed still has a toxic impact on aquatic organisms. Cadmium and some PCBs in particular present a serious risk to higher organisms.
Although water quality is improving, the availability of sufficient, suitable habitats still leaves a lot to be desired. The river is relatively uniform and the original dynamics of the river system are limited. There is limited variation in the areas that are affected by the river water to greater or lesser degrees and ecotopes such as shallow flowing water, floodplain forests and marshland are scarce. Work on restoring the ecotope diversity is underway in nature conservation development projects.

Ecological situation

Macrophytes

The structure and composition of macrophyte vegetation is highly dependent on the river's hydrodynamics and morphodynamics.
The main channel's high dynamics (such as high flow rates and large level fluctuations, but also the effect of the waves created by shipping traffic) result in there being hardly any vegetation there at all. Depending on the adopted management practices (grazing), there is a greater range of water and marshland vegetation in the more isolated waters. The riverbank overgrowth often has a vertical zoning pattern, from annual pioneer species on the bare river beaches, through Reed canary grass *Phalaris arundinacea* and willows *Salix* spp., to the species on the higher sections, which are more susceptible to the effects of flooding. Common reed *Phragmites australis* and rushes *Scirpus* spp. are the dominant species in the downstream and weired river sections, where water level fluctuations are lower.
To enable rich macrophyte vegetation to develop, besides expanding grazing, it will be necessary to maintain the river's limited effect in the waters of the floodplains.

Plankton

The plankton population density is positively correlated with the residence time.
The dynamic conditions in the main channel give rise to limited phytoplankton growth and a zooplankton community that mainly consists of small, fast-growing organisms (rotifers). These species are not capable of utilizing the large volume of nutrients in the river. In the waters of the winter bed, the nutrient supply in the form of phytoplankton can be better utilized by zooplankton and macrozoobenthos, and the population densities are significantly higher.
A characteristic of the Rhine is the high percentage of the diatom *Skeletonema*, possibly caused by this alga's high tolerance to salinity.

Macrozoobenthos

Improvements in water quality over recent years have led to an increase in the number of macrozoobenthos species and their population densities. However, the summer bed still has a relatively low number of species, owing to a lack of suitable habitats. The extremely high discharge rates in 1993 and 1995 showed that new and susceptible species can reach waters in the floodplains. Originally non-indigenous macrozoobenthos play a major role in the Rhine; 92 % of the total number of organisms come from other parts of the world. For example, the Caspian Sea shrimp *Corophium curvispinum* has a dominant presence in every branch of the Rhine. However, contrary to expectations, this species has not had an impact on the presence of other species.

Fish

There are also various non-indigenous species in the fish community. However, the largest percentage in numbers and in species is determined by indigenous, indifferent species, animals without a preference for a particular type of water. Of the number caught with hoop-nets, only 9 % were typical river species. For fish too, it is assumed that a lack of suitable habitats impedes the development of these species. Two requirements are the restoration of shallow, flowing water and stretches of water with macrophyte vegetation that are accessible to fish.

Amphibians

For amphibians, the river is primarily an important distribution area. The present situation does not provide the best living conditions. A low inundation frequency is important in the spawning grounds and the quality of the land biotopes is poor. For nature conservation development, it is necessary to pay attention to river dunes and hardwood floodplain forest as land biotopes, and the development of waters with low dynamics, in areas within the dykes, for example.

Birds

The Rhine's catchment area is of major importance for birds. In the winter in particular, the floodplains are visited by large groups of herbivores and, during freezing periods, the river is a

refuge for fish- and macrozoobenthos-eating waterbirds from other waters. The intensification of agriculture (improved drainage and more manure toxins) has led to an increase in the number of graminivorous birds. However, summer birds from damp and marshy biotopes have declined dramatically. The development of river ecotopes such as floodplain forests and marshland bring about new possibilities for these species.

Mammals

For mammals, the Rhine fulfils a function as a migration and dispersion route (Beaver and bats) and as a habitat for smaller species. Larger mammals and bats use the floodplains as a temporary stopping place and foraging area. It is important to ensure that there is a clear connection to the area within the dykes for these species when developing natural habitats in nature conservation development projects.

River restoration

The environmental requirements of the various species are sometimes in conflict with each other. Spatial separation offers a solution to the problem of giving all the river-bound species a chance. The scale on which the variation is put into effect in the process of organizing the river area can be in line with, for example, the natural variation in morphodynamics and hydrodynamics. The height of locations and the dynamics can be used as a basis for determining which type of nature conservation is most likely to succeed and where. For example, the prospects for aquatic plants, amphibians, limnic fish, macrozoobenthos in vegetation-rich water, and mammals are greater in river sections with low dynamics, such as the Lower Rhine/Lek and the downstream sections. Species from more dynamic conditions, such as pioneer vegetation and the inhabitants of river dunes and secondary channels are more likely to succeed along the dynamic sections of the Waal and IJssel rivers. It is also important to strengthen the relationship with the area within the dykes.

Photograph 0.1
The River Rhine (here the Waal at Ewijk) is an important shipping route. Nevertheless there are good opportunities for nature restoration, as in the case of this sandflat, which is already colonized by willows and poplars.

Zusammenfassung

Der Rhein ist die wichtigste Binnenwasserstrabe und der gröbte Strom der Niederlande. Die Zufuhr von Wasser und Schlamm ist für einen Grobteil (65 %) des niederländischen Oberflächenwassers von Bedeutung. Einer der Arme des Rheins, der Waal, spielt als Schiffahrtsverbindung zwischen Rotterdam und Deutschland eine wichtige wirtschaftliche Rolle. Ökologisch ist der Rhein ein wichtiger Lebensraum und Habitat für zahlreiche Pflanzen- und Tierarten und bildet er ein unentbehrliches Glied in der Verbreitung von Organismen.

Der Verwalter Rijkswaterstraat, das niederländische Generaldirektorat Wasserwirtschaft, beobachtet die ökologische Entwicklung durch alljährliche Messungen. Zusätzlich wird alle vier Jahre ein noch umfangreicheres Messungsprogramm durchgeführt. Die Ergebnisse der ersten intensiven Messung im Jahre 1995 werden in dem vorliegenden Bericht behandelt.

An der niederländisch-deutschen Grenze hat der Rhein einen gleichmäbigen Abflub von durchschnittlich 2200 m^3 / sec. Er entsendet einen Arm, die IJssel, zum IJsselmeer und mündet mit 2 weiteren Armen, dem Niederrhein-Lek und dem Waal, über die Unterläufe in die Nordsee. Bei Abflüssen unter 2320 m^3 / sec. wird der Niederrhein-Lek ganz oder teilweise gestaut, so dab der frei abfliebende Waal genügend Wasser behält.

Seit den siebziger Jahren ist die Wassergüte stark verbessert; für viele Organismen ist die chemische Zusammensetzung kein Hemmnis zur Ansiedelung mehr. Die Verunreinigung des Oberflächenwassers und des Bodens wirkt sich jedoch auf aquatische Organismen immer noch toxisch aus. Besonders Cadmium und einige PCBs sind für höhere Organismen gefährlich.
Trotz der besseren Wassergüte sind noch nicht genügend geeignete Habitate vorhanden. Der Flub ist verhältnismäbig einförmig und die ursprüngliche Dynamik des Flubsystems begrenzt. Die Vielfalt der mehr oder weniger vom Flubwasser beeinflubten Gebiete ist gering und Ökotope wie seichte Fliebgewässer, Auwald und Sumpf sind kaum vorhanden. Derzeit wird versucht, die Verschiedenheit der Ökotope durch Naturentwicklungsprojekte wiederherzustellen.

Die ökologische Lage

Wasser- und Uferpflanzen

Die Struktur und Zusammensetzung der Wasser- und Ufervegetation hängt in hohem Mabe von der Hydro- und der Morphodynamik des Flusses ab.
Durch die hohe Dynamik im Hauptbett (z.B. hohe Strömungsgeschwindigkeiten und starke Pegelschwankungen sowie von Schiffen verursachter Wellenschlag) gibt es dort kaum Vegetation. In den mehr abgelegenen Gewässern gibt es je nach Landschaftspflege (Beweiden) mehr oder weniger verschiedenartige Wasser- und Sumpfpflanzen. Die Uferbegrünung besteht oft aus vertikalen Zonen, von einjährigen Pionierpflanzen an den kahlen Stränden über Rohr-Glanzgras *Phalaris arundinacea* und Weiden *Salix* spp. bis zu den überschwemmungsempfindlicheren Arten auf den höher gelegenen Böden. Stromabwärts und in den gestauten Gebieten, wo die Pegelschwankungen geringer sind, sind Schilfrohr *Phragmites australis* und Teichsimsen *Scirpus* spp. dominant.
Für die Schaffung einer üppigen Wasser- und Ufervegetation mübte neben der Extensivierung des Beweidens der begrenzte Einflub des Stroms auf Gewässer in den Überschwemmungsräumen gewahrt werden.

Plankton

Die Planktondichte korreliert positiv zur Verweilzeit.
Die dynamischen Verhältnisse im Hauptbett sorgen für begrenztes Wachstum von Phytoplankton und einer Zooplanktongemeinschaft, die hauptsächlich aus kleinen, schnell wachsenden Organismen (Rädertierchen) besteht. Diese Arten sind nicht imstande, die grobe Menge Nahrungsstoffe im Flub voll zu nutzen. Im Hochwasserbett können Zooplankton und Makrofauna die Nahrung in der Form von Phytoplankton besser nutzen und liegt die Dichte bedeutend höher.
Typisch für den Rhein ist der hohe Anteil der Kieselalge Skeletonema, möglicherweise weil diese eine hohe Salztoleranz hat.

Makrofauna

Durch die bessere Wassergüte hat sowohl die Zahl der Makrofaunaarten als auch deren Dichte in den vergangenen Jahren zugenommen. Aus Mangel an geeigneten Ansiedlungsplätzen leben im Niedrigwasserbett jedoch immer noch verhältnismäbig wenig Arten. Bei den extrem hohen Abflüssen in den Jahren 1993 und 1995 hat sich wohl gezeigt, dab neue und empfindliche Arten die Gewässer in den Überschwemmungsräumen erreichen können. Ein bedeutender Anteil der Makrofauna im Rhein ist nicht einheimisch; 92 % aller Organismen stammt aus anderen Teilen der Welt. So ist zum Beispiel Kaspische Schlammgarnele *Corophium curvispinum* in allen Rheinarmen in grober Anzahl vertreten. Entgegen den Erwartungen hat dies jedoch keinen Einflub auf das Vorkommen anderer Arten.

Fische

Auch bei den Fischen kommen verschiedene nicht einheimische Arten vor. Den gröbten Anteil (zahlen- und artenmäbig) bilden jedoch einheimische indifferente Arten, die keine bestimmte Wasserart bevorzugen. Nur 9 % der in Reusen gefangenen Fische sind typische Flubfische. Auch bei den Fischen ist anzunehmen, dab der Mangel an geeigneten Habitaten die Entwicklung hemmt. Die Schaffung von seichten Fliebgewässern und für Fisch erreichbaren Gewässern mit Ufer- und Wasservegetation ist wünschenswert.

Amphibien

Zu Anfang war der Flub ein wichtiges Verbreitungsgebiet für Amphibien. Derzeit sind die Lebensbedingungen für diese Tiere nicht optimal. Für die Fortpflanzung ist eine geringe Überschwemmungsfrequenz erforderlich und die Landbiotope sind qualitativ schlecht. Binnendünen und Hartholz-Auwald als Landbiotop sowie Gewässer mit geringer Dynamik, zum Beispiel in angrenzenden landseitigen Gebieten, sind für die Naturentwicklung wichtig.

Vögel

Das Einzugsgebiet des Rheins bietet einen wichtigen Lebensraum für Vögel. Besonders im Winter halten sich grobe Gruppen Herbivoren in den Überschwemmungsräumen auf und bei Frost ist der Flub ein Zufluchtsort für Wasservögel aus anderen Gewässern, die sich von Fisch und Makrofauna ernähren. Die Intensivierung der Landwirtschaft (verbesserte Entwässerung und bessere Düngung) hat zu einer Zunahme der Zahl der Herbivoren geführt. Die Zahl der Brüter in feuchten, sumpfigen Biotopen hat jedoch stark abgenommen. Durch die Entwicklung von Flubökotopen wie Auwald und Sumpf werden jedoch neue Möglichkeiten für diese Arten geschaffen.

Säugetiere

Für Säugetiere ist der Rhein eine Migrations- und Dispersionsstrecke (Biber und Fledermäuse) und Wohngebiet (für kleinere Arten). Gröbere Säugetiere und Fledermäuse nutzen die Überschwemmungsräume als temporären Aufenthaltsort und Ernährungsgebiet. Für diese Arten ist es wichtig, dab bei der Entwicklung von Lebensräumen im Rahmen von Naturentwicklungsprojekten eine einwandfreie Verbindung zum landseitigen Gebiet geschaffen wird.

Wiederherstellung

Die Anforderungen, die die verschiedenen Arten an ihre Umwelt stellen, konfligieren in einigen Fällen. Um allen flubabhängigen Arten eine Chance zu geben, könnte man räumliche Trennung anwenden. Die Art und Weise, in der man in diesem Sinne bei der Einrichtung des Flubgebiets vorgeht, könnte zum Beispiel an die natürliche Variation der Morpho- und Hydrodynamik anschlieben. Anhand der Höhenlage und der Dynamik kann bestimmt werden, wo welche Natur die besten Chancen hat. Wasserpflanzen, Amphibien, Sübwasserfische, Makrofauna vegetationsreicher Gewässer und Säugetiere zum Beispiel haben in Flubgebieten mit geringer Dynamik, wie der Niederrhein-Lek und flubabwärts die besseren Chancen. Für Arten, die dynamische Verhältnisse bevorzugen, wie Pionierpflanzen und Tiere, die sich gern in Binnendünen und Nebenbetten aufhalten, sind die dynamischen Gebiete des Waals und der IJssel besser geeignet. Daneben ist es wichtig, das Verhältnis zum landseitigen Gebiet zu verstärken.

Résumé

Le Rhin est l'écosystème aquatique clé et le plus grand fleuve des Pays-Bas. L'arrivée des eaux et des boues influence une grande partie (65 %) des eaux de surface des Pays-Bas. Comme ligne de navigation maritime entre Rotterdam et l'Allemagne, le Waal joue un rôle économique important. Au niveau écologique, le fleuve représente l'hébergement et l'habitat importants de nombreuses espèces végétales et animales et constitue un maillon indispensable dans la répartition des organismes.

L'Administration nationale des Travaux publics et de la Gestion des Eaux surveille tous les ans l'évolution écologique. Un programme de surveillance plus étendu est appliqué une fois tous les quatre ans. Ce rapport traite des résultats de la première année de surveillance intensive, à savoir 1995.

Quand le Rhin traverse la frontière germano-néerlandaise, il a un régime régulier de 2200 m^3/sec. Aux Pays-Bas, il se subdivise en plusieurs bras, l'IJssel, qui alimente l'IJsselmeer, la section Rhin inférieur/Lek et le Waal qui finit par se jeter dans la mer du Nord en passant par les rivières inférieures. Quand le régime n'atteint pas 2320 m^3/sec, les barrages de la section Rhin inférieur/Lek entrent en action, partielle ou totale, pour garantir suffisamment d'eau au libre écoulement aval du Waal.

La qualité de l'eau s'est remarquablement améliorée depuis les années soixante-dix, la qualité chimique ne faisant plus obstacle à l'établissement de nombreux organismes. Toutefois, la pollution des eaux de surface et des fonds a toujours des effets toxiques sur les organismes aquatiques. Le cadmium et les polychlorobiphényles (PCB) présentent un sérieux risque pour les organismes supérieurs. Bien que la qualité de l'eau s'améliore, la disponibilité d'habitats adéquats, en nombre suffisant, laisse à désirer. Le fleuve est relativement uniforme et la dynamique initiale du système fluvial est limitée. L'effet qu'exercent les eaux fluviales sur les régions qu'elles traversent présente une faible variation, et les écotopes tels que les cours d'eau peu profonds, les forêts alluviales et les marécages sont rares. Des projets pour le développement de la conservation de la nature sont actuellement en cours et visent la restauration de la diversité des écotopes.

Situation écologique

Plantes aquatiques et végétation riveraine

La structure et la composition des plantes aquatiques et de la végétation riveraine dépend énormément de l'hydrodynamique et de la morphodynamique du cours d'eau.

La grande dynamique du chenal principal (ex. vitesse de courant élevée et grandes fluctuations du niveau de l'eau, mais aussi effets de vagues et remous créés par la navigation intérieure) est à l'origine de l'absence de toute végétation. Dans les eaux plus isolées, la diversité des plantes aquatiques et de la végétation riveraine présentes dépend de la gestion (des pâturages) appliquée. La végétation riveraine présente souvent un zonage vertical, des espèces pionnières annuelles sur les plages fluviales arides, à le Baldingere *Phalaris arundinacea* et au saule *Salix* spp., pour atteindre les espèces des aires plus élevées qui sont plus sensibles aux effets de crues. Dans les sections et retenues aval, à moindres fluctuations du niveau des eaux, le Roseau *Phragmites australis* et le scirpe *Scirpus* spp. dominent.

Pour assurer le développement de multiples plantes aquatiques et d'une riche végétation riveraine, il faudrait, outre l'augmentation des pâturages, maintenir l'effet limité des fleuves et rivières sur les eaux des lais.

Plancton

La densité de la population du plancton est positivement corrélée au temps de séjour.

Les conditions dynamiques du chenal principal sont à l'origine de la croissance limitée du phytoplancton et de la communauté du zooplancton, constituée notamment de petits organismes à croissance rapide (rotifères). Ces espèces sont incapables d'utiliser entièrement la grande quantité de nutriments présents dans le fleuve ou rivière. Dans les eaux du lit de basses eaux, le zooplancton et la macrofaune peuvent mieux utiliser la réserve de nutriments qui se présente sous forme de phytoplancton, et les densités de population sont beaucoup plus élevées.

Une des caractéristiques du Rhin est le taux élevé des diatomées *Skeletonema*, dû probablement à la haute tolérance à la salinité de ces algues.

Macrofaune

L'amélioration de la qualité des eaux de ces dernières années a entraîné l'augmentation du nombre d'espèces constituant la macrofaune et la densité de leur population. Cependant, le lit de basses-eaux qui ne dispose presque pas d'habitats adéquats ne compte qu'un faible taux de ces espèces. Les débits d'eau extrêmement élevés des années 1993 et 1995 ont montré que de nouvelles espèces sensibles peuvent atteindre les eaux des lais. Le rôle de la macrofaune du Rhin, d'origine non indigène, est grand, 92 % de l'ensemble des organismes proviennent d'autres parties du monde. La Crevette caspienne *Corophium curvispinum*, par exemple, est surreprésentée dans tous les bras du Rhin. Contrairement aux prévisions, cette espèce n'a toutefois eu aucun effet sur les autres espèces.

Poissons

La communauté des poissons comprend également diverses espèces non indigènes. Le taux le plus élevé des nombres et espèces est cependant déterminé par les espèces indigènes indifférentes, animaux sans préférence pour un type distinct d'eau. Du nombre pêché à la nasse, seuls 9 % étaient constitués d'espèces typiquement fluviales. Pour le poisson aussi, on suppose que le manque d'habitats adéquats fait obstacle au développement de ces espèces. Il est conseillé de restaurer les cours d'eau peu profonds et ceux à plantes aquatiques et végétation riveraine, accessibles aux poissons.

Amphibiens

Pour les amphibiens, le cours d'eau constitue à l'origine une importante aire de répartition. A l'heure actuelle, les conditions de vie n'y sont pas optimales. Une faible fréquence d'inondation est nécessaire pour les aires de reproduction, et la qualité des biotopes terrestres est médiocre.

Pour le développement de la conservation de la nature, il est important de fixer l'attention sur les dunes riveraines et les forêts alluviales à bois dur comme biotopes terrestres, et sur le développement des eaux à faible dynamique, par exemple dans les lais limitrophes.

Oiseaux

Le bassin hydrographique du Rhin est d'une importance majeure pour les oiseaux. L'hiver surtout, de grands groupes d'oiseaux herbivores se rendent sur les lais et, quand le gel sévit, le cours d'eau est un véritable refuge pour les oiseaux piscivores et mangeurs de la macrofaune, venus d'ailleurs. L'intensification de l'agriculture (drainage amélioré et une plus grande quantité de toxines d'engrais) a entraîné la croissance de la population d'oiseaux herbivores. Par contre, la population des oiseaux nicheurs des biotopes humides et marécageux a fortement régressé. Le développement des écotopes fluviaux, tels que les forêts alluviales et les marécages, offrira de nouvelles possibilités d'habitats à ces espèces.

Mammifères

Pour les mammifères, le Rhin sert de route de migration et de répartition (ex. Castors et chauves-souris), et d'habitat aux petits espèces. Les grands mammifères et les grandes chauves-souris résident temporairement sur les lais, où ils y trouvent leur nourriture. Il est important de réaliser une liaison évidente avec les sols à l'intérieur des digues pour ces espèces, lors du développement des habitats naturels visés par le projet de développement de la conservation de la nature.

Restauration des fleuves et rivières

Les exigences que posent les divers groupes d'espèces à leur environnement de vie s'opposent parfois les unes aux autres. La séparation spatiale répond à la question de savoir comment procéder afin de donner une chance à chaque espèce fluviale. L'échelle à laquelle l'aménagement de cette région fluviale devra répondre à cette variation peut correspondre, par exemple, à la variation naturelle de la morphodynamique et de l'hydrodynamique. Il est possible de déterminer le type de conservation de la nature qui a le plus de chance de réussir, et l'endroit concerné en se basant sur l'élévation et la dynamique du sol. Ainsi, les possibilités concernant les plantes aquatiques, les amphibiens, les poissons des eaux liminiques, la macrofaune des eaux riches en végétation et les mammifères sont plus grandes dans les sections à faible dynamique, comme celle du Rhin inférieur/Lek et les sections d'aval. Les possibilités des espèces que l'on retrouve dans les conditions plus dynamiques, comme les végétations pionnières et les habitants des dunes riveraines et chenaux secondaires, sont bien plus grandes le long des sections dynamiques du Waal et de l'IJssel. Il est en outre important de renforcer la relation avec les sols à l'intérieur des digues.

1. Introduction

Hero Prins (RIZA)

MWTL

This water system report is a knowledge report on the ecology of the branches of the river Rhine in the Netherlands. It describes recent ecological developments in the branches of the Rhine in relation to the policy on the ecological recovery of the Rhine. The ecological data has been collected by RIZA, within the scope of the MWTL monitoring programme, which is concerned with monitoring the water drainage situation in the Netherlands. The MWTL monitoring programme is described in (Weijden *et al.* 1995). The chapter entitled 'Rationale' provides more details on how the data was collected.

Monitoring

The monitoring programme is intended to indicate trends in the physical, chemical and ecological state of national waters, acting as a finger on the pulse. The programme also serves as a source of information for defining and evaluating the total water management policy, as in the fourth policy document on water management (Ministry of Transport, Public Works and Water Management, 1997) and the Water System Surveys (Ministry of Transport, Public Works and Water Management, 1996).

Most of the Rhine's catchment area is outside the Netherlands. Agreements are reached about water quality, water quantity and shipping on the basis of consultations between various international consultative bodies, such as the IRC (International Committee for the protection of the Rhine against Contamination), the IAWR (Internationale Arbeitsgemeinschaft der Wasserwerke im Rheineinzugsgebiet), the CHR (International Committee for Hydrology in the Rhine area) and the CCR (Central Committee for Rhine Shipping). A proper insight into the present situation in the Rhine is also important for these consultations.

This report is one of a series of reports containing both national summaries and water system reports. A national report on the latest developments has been published annually since 1992. A water system report on each water system is also published every four years, in which a more scientific analysis of ecological developments is provided.
Water system reports are published following a survey year, a year of intensive measurements. The survey year for the branches of the Rhine was 1995.

Structure of this report

This water system report is intended for various target groups. Besides being useful to water managers, it may be used as an up-to-date ecological reference work by policy workers in various ministries, provinces and local government bodies, as well as people working in research institutes.

The report begins with a general physico-chemical description of the various branches of the Rhine. Chapters 3 to 10 deal with developments in vegetation, plankton, macrozoobenthos, fish, amphibians, birds and mammals. Chapter 11 examines the ecotoxicological situation in the Rhine. Where possible, ecological developments are linked to physical and chemical developments in the Rhine. The way in which the data has been collected is discussed as briefly as possible, as it is described in detail in the working documents.

The final chapter integrates ecological developments. Where possible, conclusions are elucidated using recent ecological studies carried out in branches of the Rhine. Some recommendations are then made about the Rhine's future management.

Photograph 1.1
Sunset over the reedbeds of the "Ooijpolder" near the city of Nijmegen.

Photograph 1.2
Exceptionally high water in the floodplains of the River Rhine at Schenkenschanz, just over the German border.

2. The Rhine water system

Corian Bakker (RIZA)

Introduction

The river Rhine fulfils many functions. This report examines the Rhine's ecological function in detail. The Rhine provides an important natural habitat for plants and animals. The river is a migration route for organisms and carries food and sediment.

The Directorate-General for Public Works and Water Management has long considered the discharge of water, ice and sediment to be the most important of the river's functions. This function proved to be of the utmost importance during the high discharges of 1993 and 1995.

The Rhine also fulfils various economic functions. Shipping is the most important of these, particularly for the Waal, which links Rotterdam to Germany. A ship crosses the German/Dutch border at Spijk every three minutes.

Besides being the regional water supplier, the river is also a source of minerals (sand and clay), cooling water, for example for power stations, raw water for drinking water production, agricultural land, and fish. Finally, large sections of the branches of the Rhine have a function in water and riverbank recreation.

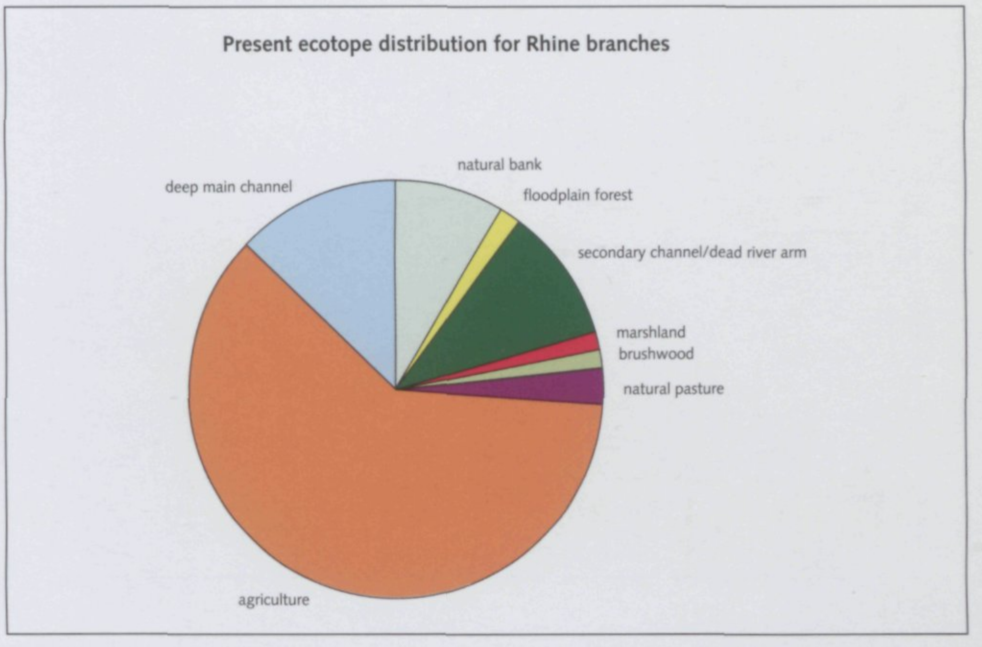


Figure 2.1
Distribution of ecotopes along the Rhine (excluding the sections of the river downstream from Gorkum). In the present situation, the greater part of the river consists of (cultivated) pastures and deep summer bed. Woods, marshland and shallow flowing water are scarce.

Photograph 2.1
The shipping function is very important for the Rhine. The river Waal is the transport route between Rotterdam and Germany. Besides the need to guarantee protection against flooding, the shipping traffic is also a limiting condition for the implementation of nature restoration projects.

Dynamics

Rivers distinguish themselves from other water systems by their dynamics. They move from upstream to downstream, from the main channel to the floodplain, and that movement is slightly different each day. In a natural river system the river's appearance is determined by its dynamics.

Even in the Rhine system, which has been influenced considerably by human intervention, hydrodynamics and morphodynamics still partially determine the formation of the landscape (Rademakers and Wolfert 1994). However, the scale on which these processes operate is smaller now, because the river is wedged between dykes and is streamlined by embankments, groynes and weirs.

The discharge fluctuations in the river give rise to its hydrodynamics. Differences in the duration, time and water depth of inundation give rise to a large variety of natural habitats for plants and animals, from the dry pastures, which are hardly ever flooded, to the ponds and channels that are permanently connected to the river.

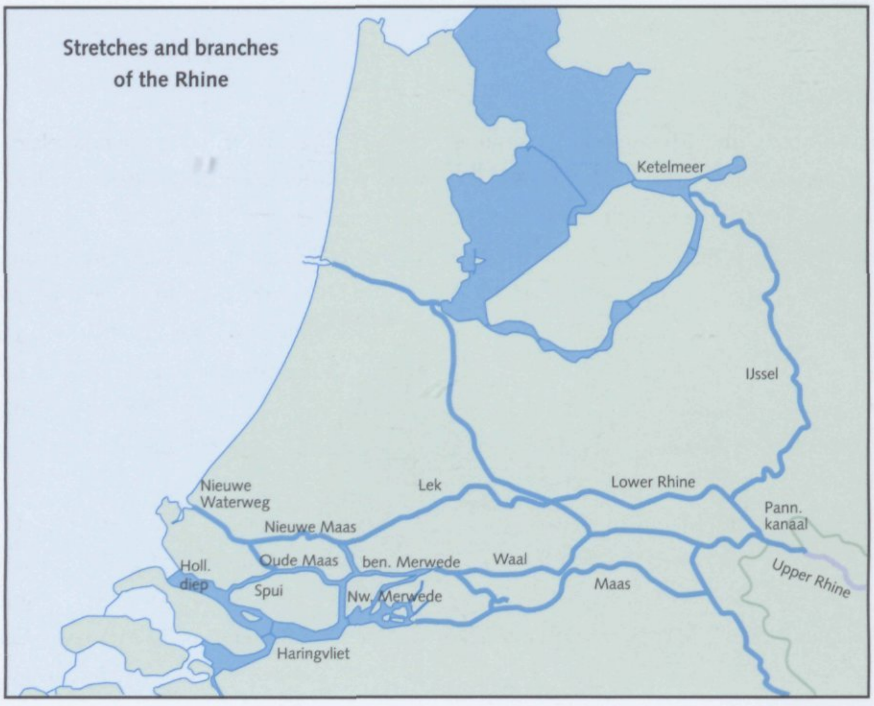


Figure 2.2
Overview of the Rhine with the names of the various sections of the river.

The discharge regime also influences groundwater levels and the aeration of the soil, factors which are co-determinants for the type of vegetation that develops.

Morphodynamics is a generic name for the mutability of the river bed produced by sedimentation and erosion. Banks and channels erode. Sand sedimentation on the banks can produce river dunes, silt up floodplains and close off old arms of the river.

The type of vegetation that can arise is the result of the interplay between the water levels and the supply and removal of sediment. In turn, these processes are also affected by the vegetation, which traps water-borne sediment, for example, or anchors the soil with its roots.

In a natural river system, various types of landscapes or ecotopes are produced by these dynamics. In the present-day Rhine, the river landscape is mainly determined by human intervention in the form of agricultural and nautical management.

Depending on the management and the space left by dykes, embankments and busy shipping traffic, the Rhine landscape consists of a more or less changing mosaic of ecotopes. Figure 1 shows the present distribution of ecotopes (Postma *et. al* 1996). This is examined in more detail in the description of the various sections of the river.

Regulation and the construction of embankments has created a uniform channel. The river has cut deep down into the bed and the floodplains

Table 2.1
Division into stretches and the characteristics (according to Postma *et al*. 1996).

		Length (km)	surface area (ha)	Morphological characteristic (1)	flow rate (cm/s) (2)	leveldynamics (m) (3)	tidaldynamics (cm)
Upper Rhine and Waal		**154**	**14590**				
Upper Rhine	Spijk-Pannerdensche Kop	11	2240	free flowing, highly meandering	> 100	>5	<30
Boven-Waal	Pann. Kop-Nijmegen	16	2500	free flowing, highly meandering	> 100	>5	<30
Midden-Waal	Nijmegen-St. Andries	44	5865	free flowing, slightly meandering	> 100	>5	<30
St. Andries-Waal	St. Andries-Zuilichem	17	2445	free flowing, slightly meandering	> 100	>5	<30
Beneden-Waal	Zuilichem-Gorinchem	12	1540	widened straight, no tide	70-100	<5	<30
Boven-Merwede/ Beneden-Merwede	Gorinchem-Dordrecht	24	3650	widened straight, no tide	30-50	<5	30-70
Oude Maas/Spui/Noord	Dordrecht-Haringvliet	30	4160	widened straight, with tide	50-70	<5	30-70
Lower Rhine-Lek		**165**	**10120**				
Pannerdensch Kanaal	Pann. Kop-IJsselkop	11	1520	free flowing, slightly meandering	> 1	<5	<30
Doorwerthse Rijn	IJsselkop-Wageningen	25	2215	weired, slightly meandering	50-70	<5	<30
Gestuwde Nederrijn & Lek	Wageningen-Hagestein	45	4550	weired, slightly meandering	30-50	<5	<30
Boven-Lek	Hagestein-Schoonhoven	24	1835	slightly meandering, with tide	70-100	<5	70-150
Lek-Nieuwe Maas	Schoonhoven-Maassluis	46	2690(4)	widened straight, witho tide	50-70	<5	70-150
Nieuwe Waterweg	Maassluis-Noordzee	14	2214(5)	straight with tide	70-100	<5	>150
IJssel		**116**	**11945**				
Boven-IJssel	IJsselkop-Dieren	26	3175	winding, free flowing	70-100	>5	<30
Midden-IJssel	Dieren-Deventer	33	3990	winding, free flowing	70-100	<5	<30
Sallandse IJssel	Deventer-Zwolle	34	3280	slightly meandering, free flowing	50-70	<5	<30
Beneden-IJssel	Zwolle-IJsselmeer	23	1500	widened straight, no tide	30-50	<5	<30

(1) Rademakers 1993
(2) average flow rate in the main channel, for average discharge
(3) level difference between average high water and agreed low discharge
(4) excluding port of Rotterdam
(5) including Caland Canal and Hartel Canal

have become increasingly higher and dryer owing to the accretion of silt.

A number of ecotopes that originally played an important part in the river area are highly under-represented nowadays. In particular, floodplain forest, marshland and shallow flowing water are scarce. It is not possible for sustainable populations of characteristic river organisms to develop in the remnants of these ecotopes, which are small and scattered.

Because summer embankments form a solid division between the main channel and floodplain area, an exchange of waterborne organisms is only possible at high water. The fertile floodplain area could, for example, fulfil an important function as a spawning and maturing ground for many fish species in the spring and early summer.

Ecological profiles

The dynamics in the various river branches form the basis for dividing the Rhine into three subsections (Upper Rhine-Waal, IJssel, and Lower Rhine-Lek), which are briefly described below (Rademakers *et al* 1995). These subsections are then further divided into stretches on the basis of geomorphological characteristics and in accordance with the categories used for drawing up targets (Postma *et al.* 1996). Table 1 shows several characteristics of the stretches of each subsection. See figure 2 for the location of the sections of the river.

Upper Rhine and Waal

The Rhine enters the Netherlands at Spijk as the Upper Rhine. The Upper Rhine is a wide, meandering river, which forms coarse sandy/fine gravely shallows along the banks. After 11 km, it divides into the Waal and the Pannerdensch Canal. From the point where it divides (the 'Pannerdensche Kop'), the Waal has large meandering bends until it cuts into the linear moraine at Nijmegen. There is seepage from the linear moraine and this has a major effect on the marshland and water vegetation in the isolated waters of the floodplains.

After Nijmegen, the *Midden-Waal* meanders slightly between the large basin areas of the *Betuwe* and the *Land van Maas en Waal*. The floodplains have largely been dug away owing to clay and sand excavation, which has given rise to many low pastures, complexes of clay pits and deep sand excavation pits.

Between Sint Andries and Zuilichem, the amplitude of the meanders increases, probably because of the former link to the Maas and the transection of the former natural levees.

After Zuilichem, the effect of high river discharges decreases steadily and tidal current and wind dynamics become more important. The river Waal then becomes the Boven-Merwede and soon divides into the *Beneden-Merwede* and the *Nieuwe Merwede*. In this section, the floodplains are flat and very narrow in some places. The main channel is wide, and stable islands are able to form along the banks.

Owing to its large discharge and "free" flow, the river Waal has relatively large morphodynamics and hydrodynamics. The busy shipping traffic also increases the dynamics. River dunes and young natural levees arise at various places (see intermezzo). Former sandbanks and islands in the Waal are now linked to the floodplains and form extensive sandy banks. Stream valley vegetation and natural levee woods occur here and there on the higher parts of the floodplains. On the lower parts there are willow woods, marshlands, and, important for grassland birds, pastures. Along the *Beneden-Merwede* and the *Oude Maas*, the land outside the dykes consists mainly of grass mud flats and osier beds.

At a number of places there are links to the river Maas (Maas-Waal Canal, St. Andries Canal, Andelse Maas) and the Lower Rhine-Lek (Amsterdam-Rhine Canal, Merwede Canal), however, they are all controlled by sluices. The only open link with the river Lek is at the *Nieuwe Merwede* river via "de Noord".

IJssel

After branching off from the Lower Rhine at the "IJsselkop", the IJssel is a highly meandering river that has broad, elevated floodplains and a low flooding frequency (the *Boven-IJssel*). These floodplains contain a lot of hawthorn thickets and hedgerows.

From Dieren, the river has the character of a sand river, but the floodplains are smaller and

Figure 2.3
A large number of plans are scheduled for various sections of the river, including plans for nature restoration, possibly combined with excavations and a number of recreational plans. A list has been compiled of plans which are scheduled for completion, by the bodies taking these initiatives, in around 2010. (according to Silva & Kok 1996).

less elevated (*Midden-IJssel*), until, at Deventer, the river continues as the *Sallandse IJssel* and only meanders slightly between the regularly inundated floodplains in a fairly straight bed. Along these stretches of the river, there are still many unexcavated floodplains which contain parts of the old river courses. The seepage from the Veluwe and Achterhoek areas means these waters provide a habitat for valuable marshland and water vegetation. Stream valley vegetation grows in the higher parts.

After the city of Zwolle, the river IJssel enters its lower reaches. It becomes wider. The floodplains are flatter and lower and the river eventually flows into lake Ketelmeer.

Unlike the banks of the Lower Rhine-Lek and the Waal rivers, the banks of the river IJssel are largely fixed with basalt and rip-rap.

Lower Rhine-Lek

The stretch from Pannerdensche Kop to the point where the river IJssel branches off from the Lower Rhine largely consists of a canal excavated in the 17th century (Pannerdens Canal), with relicts of the Old Rhine. Large sections of the Lower Rhine and the Lek are weired to guarantee sufficient discharge and thereby water depth for shipping traffic in the Waal and IJssel rivers, and to safeguard agriculture and drinking water supplies from lake IJsselmeer. Up to Wageningen, the river can be considered as free flowing in the morphological sense.

The weir at Driel is closed for an average of 130 days a year. The flow rate is exceptionally low during that period. From Wageningen, the weiring is almost permanently visible and there is a sharp decrease in the morphological dynamics. After the weir at Hagestein, the river is unweired again (*Boven-Lek*) and tidal dynamics predominate.

The waters and marshlands in the floodplains are less likely to dry out than in the other branches of the Rhine. The floodplains along the Lower Rhine are heavily excavated. The floodplains along the Lek are still largely unexcavated. Where seepage from the Veluwe region and the range of hills known as the *Utrechtse Heuvelrug* reaches the surface, there are areas of water and marshland vegetation characterized by great species diversity. Important pastures for grassland birds and geese are situated along the Lower Rhine. There are also similar pastures along the river Lek, especially inside the dykes.

Until Schoonhoven the Lek still has the character of a sand river. After this point (*Nieuwe Maas/ Nieuwe Waterweg*), river discharge has hardly any influence on water levels. The river flows through a highly urbanized district and the floodplain area is very small.

The sluices and weirs in this branch of the Rhine present a barrier to waterborne organisms. Migratory fish in particular are impeded in their migration to and from their spawning grounds.

Nature restoration

The Rhine largely consists of a deep uniform waterway with relatively elevated floodplains in which agricultural pastures predominate. The ecological value of the floodplains therefore largely consists of grassland birds on the agricultural pastures.

Little remains of the characteristic dynamics of a river system in this part of the river. This therefore restricts the large natural variation in habitats, which range from being highly influenced by the river water to hardly being influenced at all. This natural diversity of ecotopes cannot simply be restored. The limited space for the river within the main dykes and the construction of a safe and permanently navigable shipping route sets stringent conditions for the design. Nevertheless, a large number of initiatives have been worked out to restore the original character of the river (see figure 3). Different sections of the river have different potentials in this regard, and it is necessary to select the types of ecotopes that will be allowed to develop.

The nature-conservation target for the Rhine (Postma *et. al* 1996) identifies the type of ecotope that has the greatest chance of succeeding in a given location. Dynamic ecotopes would be particularly likely to succeed in the river Waal; it would be possible to create marshland along the weired river stretches and in the downstream stretches. A hardwood flood-plain forest is especially likely to succeed in the elevated floodplains of the river IJssel.

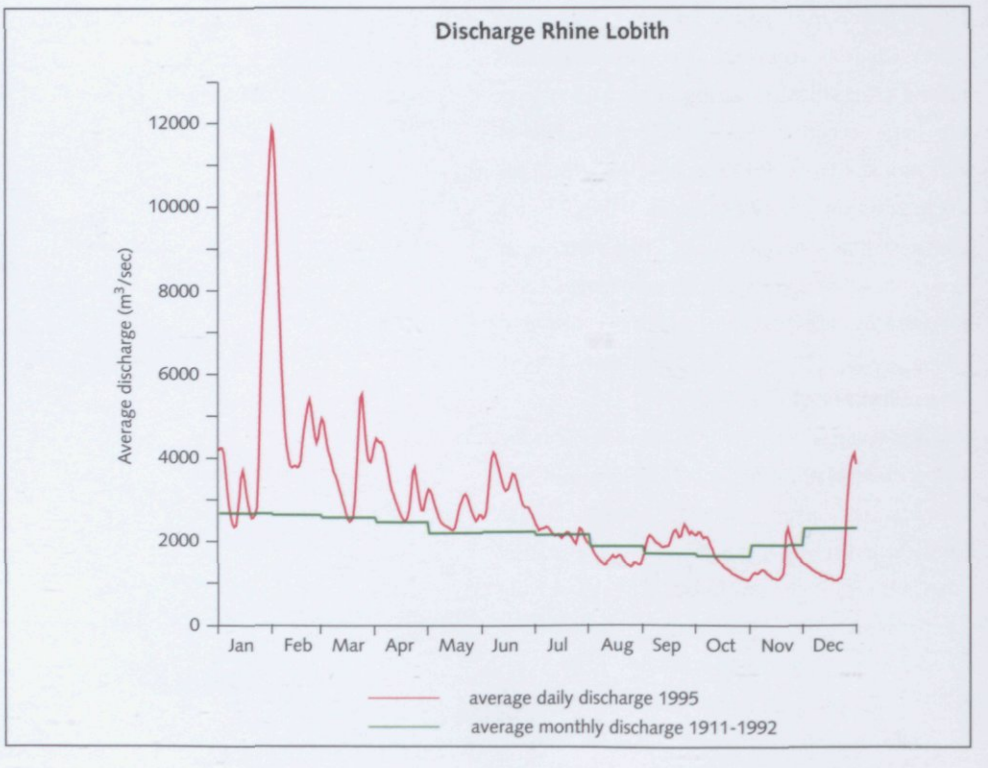


Figure 2.4
The average daily discharge in 1995 and monthly average discharge from 1911 to 1992 in the Upper Rhine at Lobith in m^3/sec. In 1995, the period from January to the end of June was especially wet, with an unusually high peak at the end of January.

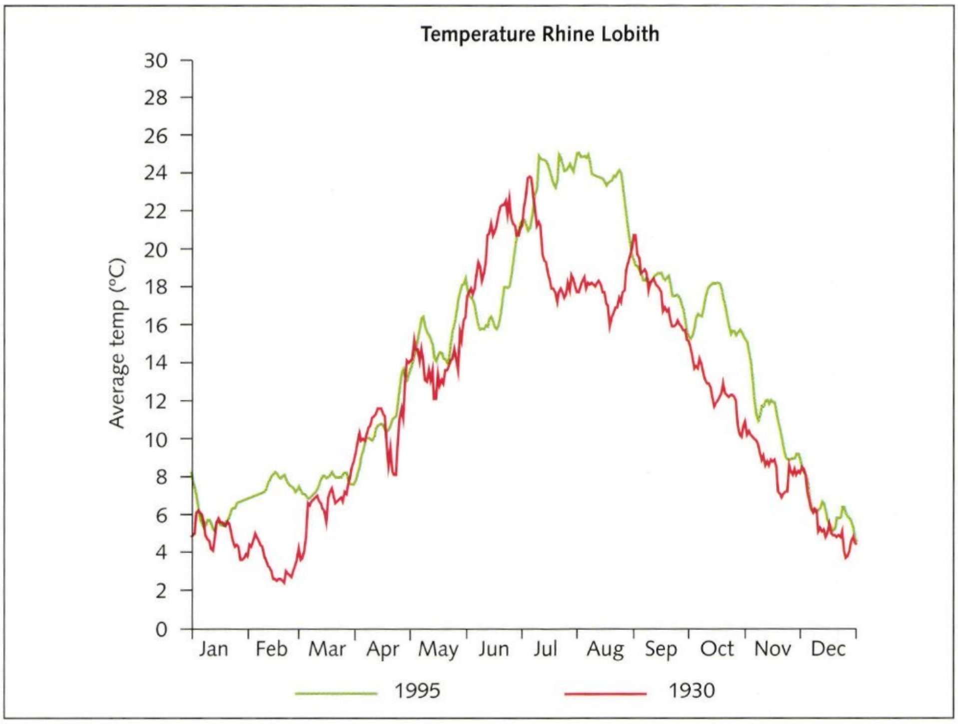


Figure 2.5
The temperature in the Rhine at Lobith in 1995. The temperature in 1930 is shown, besides the average daily temperature in 1995. The average water temperature increased by rather more than 3°C in the period between 1930 and 1995, as a result of the cooling water discharged by power stations and industry.

The existing plans for nature restoration are generally concerned with the partial restoration of processes such as current, tide, water level fluctuation, erosion, sedimentation and land accretion. The measures used to achieve this include management measures, such as natural grazing or spontaneous succession, and design measures. Design measures often include interventions that can be combined with measures for other functions. This could include, for example, lowering the floodplain by excavating the clay layer. This would provide space for marshland or wet-pasture ecotopes and also better runoff at high water. The excavated clay is used for brick making or dyke improvement. The recovery of the ecotopes of shallow, flowing water is achieved by excavating secondary channels. Constructing secondary channels increases the river's flow-through profile. They therefore help increase safety thanks to the lower water level at higher discharge rates (Silva and Kok 1996).

Physico-chemical characteristics

Discharge

The Rhine's discharge rate is relatively uniform, as indicated by figures for the average monthly discharge from 1911 to 1992 (figure 4). This is the result of the mixed discharge of rainwater and meltwater. Upstream from Basle, Switzerland the supply of meltwater peaks in the summer, whereas the discharge peak for rainwater is in the winter, downstream from Basle. The Waal and IJssel rivers are free flowing. The Lower Rhine is weired when discharge is low, and the minimum target for discharge into the IJssel river is 285 m^3/s. If discharge is lower than 1300 m^3/s (at Lobith), a volume of only 25 m^3/s flows through the Lower Rhine and the weirs at Driel, Amerongen and Hagestein are completely closed. If discharge is higher than 2320 m^3/s (at Lobith), the weirs are completely opened and the Lower Rhine flows freely. This occurs on average for 35 % of the time. However, in 1995 this situation applied for 194 days (53 %). Discharges were above average from December 1994 to July 1995. The extremely high discharge at the end of January was most striking in this period. A discharge peak of 11885 m^3/s only occurs once in 80 years, according to our current understanding. The period in which high water occurred at the end of the winter was normal, as was the occurrence of low water levels in October - November.

Temperature

The temperature of the river water is affected by the cooling water discharged by power stations and industry. Over the past 45 years, the

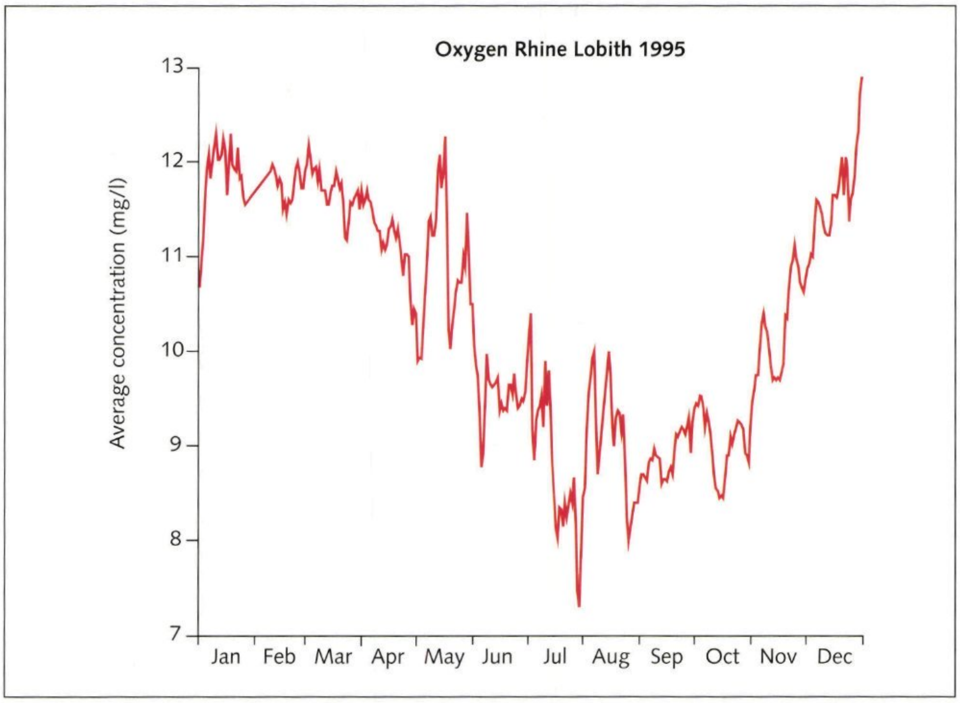


Figure 2.6
The oxygen concentration (6-hour averages) in the Rhine at Lobith. Oxygen concentrations in the Rhine have improved markedly since the nineteen seventies to the present levels, which are approaching the natural oxygen concentrations for the Rhine.

average temperature of the Rhine water has increased by almost 0.5 °C per decade. This increase is the same in the summer and winter. However, the temperature increase in the winter period is crucial to the survival of species that thrive in warm conditions (Breukel&Bij de Vaate 1996). At low water levels, the temperature can increase in the Lower Rhine, owing to the restricted flow rate. Even the insulated waters in the winter bed can warm up considerably, if the air temperature is high. However, no data is available on this.

The temperature of the Rhine water at Lobith is shown in figure 5.

Oxygen

Oxygen concentrations in the Rhine have improved markedly since the nineteen seventies and the annual average concentrations are approaching the saturation concentration for oxygen. It is assumed that oxygen distribution is no longer an impediment to the ecological

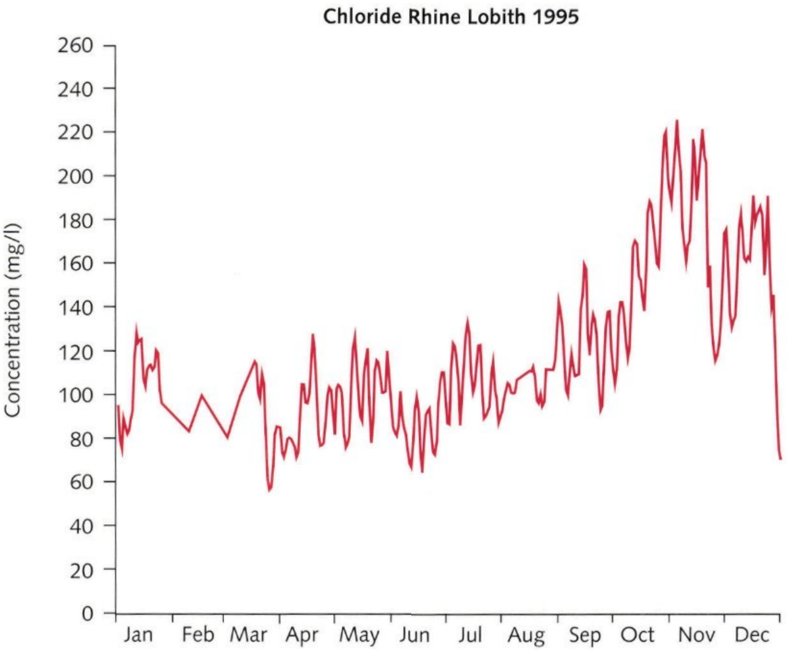


Figure 2.7
The chloride concentration in the Rhine at Lobith, in 1995. The chloride concentration only exceeds the level set by the water quality standard (200 mg/l) during the low-water period from October to November. The salt concentrations in the Rhine are more than 10 times the river's natural background concentrations. The French potassium mines form the largest source of salt.

Natural levees and river dunes

(Anne Sorber)

Sandy natural levees and active river dunes are important evidence of the river's morphodynamics. Because the branches of the Rhine are maintained by groynes, the morphodynamics are lower than in the natural situation.
However, during high discharges the river still deposits sand on the floodplains. When the water level has fallen, natural levees without any vegetation may erode in the wind, giving rise to dunes. During low water, the wind can also whip up sand in the groyne fields. Examples of river dunes are *Millingerduin* along the river Waal and *De Bol* along the river Lek.

The sand deposits along the major rivers were mapped out after the high waters of 1994 and 1995 (Sorber 1997). The sand deposits lay more or less at the same locations after both periods of high water. The greatest sedimentation had occurred on the inside of the meanders of the rivers, as a result of the strong flow close to the channel bed (helicoidal flow) moving towards the inside of the meander. The flow from the main channel onto the floodplain is also very important for the sedimentation of sand. This flow occurs where a floodplain becomes wider or when it is low, and also where there is no summer embankment. The flow rate reduces rapidly in the winter bed, so transported sand is deposited.

For river dunes to form, the wind has to have a large striking distance before reaching the sand supply, so that the force of the wind is sufficient to transport the sand (Isarin *et al.* 1995). In the case of a predominantly southwesterly wind, this means that there has to be a large flat area of land or a large expanse of water to the south-west of the sand supply. Moreover, the higher the location, the less likely the dunes are to disappear during a high discharge.

Sandy natural levees and river dunes are unique ecotopes in the area around a river. The dry sand is first colonized by the pioneer vegetation, which can then be followed by the stream valley plants. The high location, the sandy soil and the special vegetation attract insects, birds and amphibians. Extensive grazing in the area can help prevent the natural levees and river dunes from becoming overgrown. A regular supply of sand is also needed: at low water by the wind and at high water by the river.

Photograph 2.2
A sandy levee along the River Waal (Hurwenense Waard), left behind after the flood of 1995.

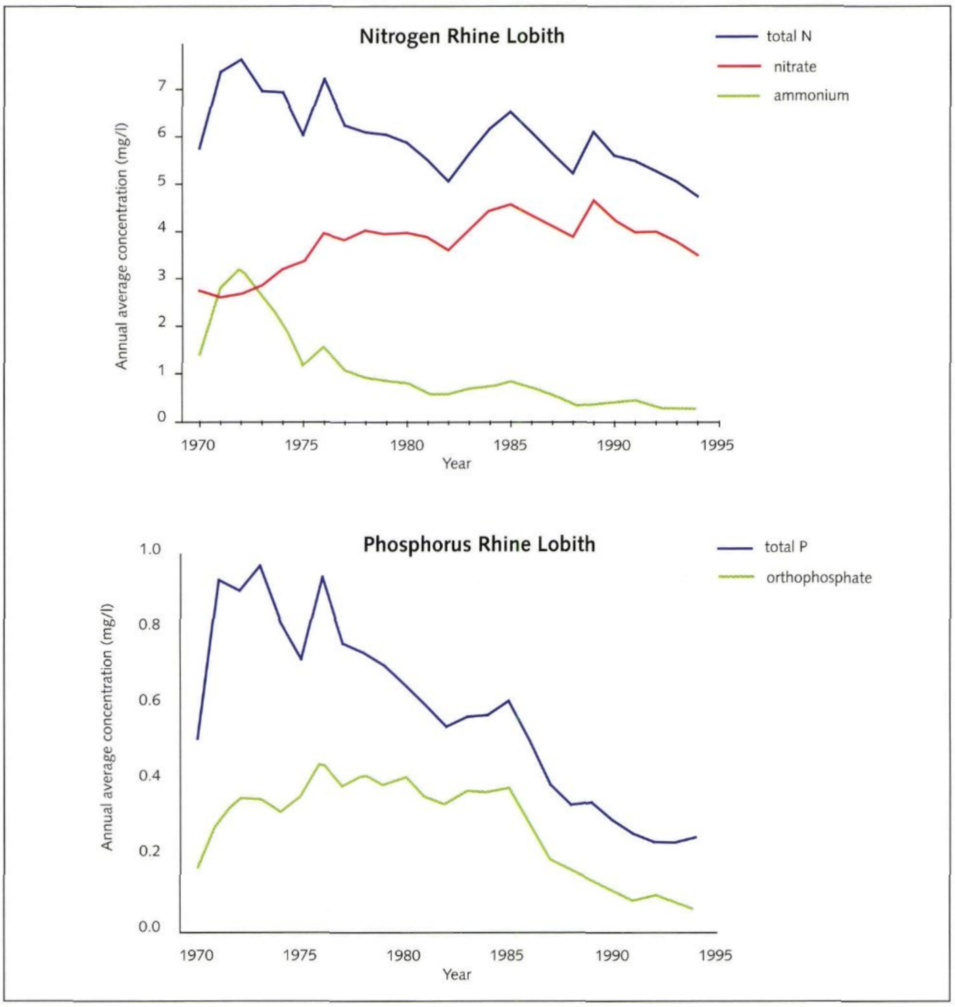


Figure 2.8
Annual average concentrations of nitrogen and phosphorous in the Rhine at Lobith. The introduction of phosphate-free washing powders has caused phosphate levels to fall considerably since 1985. Large-scale treatment of waste water has reduced the concentration of ammonium. However, the total nitrogen concentration has only dropped slightly.

recovery of the aquatic biocoenosis (Breukel 1993). In 1995, average concentrations remained above 7 mg/l (figure 6). Natural minimum oxygen concentrations for the Rhine are around 6-9 mg/l (CUWVO 1988).

Chloride

The concentration of salts, and particularly chloride, is very high in the Rhine. The salt load, which is mainly caused by discharges from French potassium mines, has dropped from an annual average of around 200 mg/l to around 150 mg/l, thanks to international agreements. The volumes released are linked to a maximum concentration, so extremely high salt concentrations are avoided if river discharges are low. However, the natural levels for the Rhine are 10-40 mg/l (CUWVO 1988). Dilution resulting from the Rhine's high discharge up to the end of June kept the chloride level relatively low in 1995 (figure 7). The levels shown in the figure occurred at Lobith. There is a fresh water to salt water gradient from the river Waal and the river Lek to the mouth of the estuary at the North Sea. The progression of the salinity gradient depends on the ratio of river discharge to tidal volume. When a high tide coincides with low river discharges, salt penetration from the sea can create brackish water as far upriver as the eastern part of the *Oude Maas* river and the mouth of the river Lek.

Nutrients

Figure 8 shows the annual average nutrient concentrations in the Rhine at Lobith. Following a considerable rise at the beginning of the nineteen seventies, the levels of total phosphorus and orthophosphate have steadily declined. The more rapid drop in the levels of these substances after 1985 was the result of the introduction of phosphate-free washing powders. On the other hand, nitrogen levels have only dropped slightly. There has been a shift in nitrogen compounds from ammonium to nitrate. This is probably accounted for by the large-scale treatment of waste water.

Micro-contaminants

Thanks to national and international environmental policies, such as the Rhine Action Plan, the levels of many heavy metals and organic micro-contaminants have declined considerably since the nineteen seventies. Nevertheless, these substances are still presenting problems, not so much in the aqueous phase but in the sediment, since they bind (strongly to extremely strongly) to suspended matter (the future bed of the watercourse).

Moreover, new substances are continually being manufactured that require attention and necessitate modification of the measuring work and analysis techniques (Breukel 1993).

Chapter 11 presents a detailed examination of the quality of Rhine water and the consequences for organisms.

Photograph 2.3
High water in the flood plain of the River IJssel at Kampen.

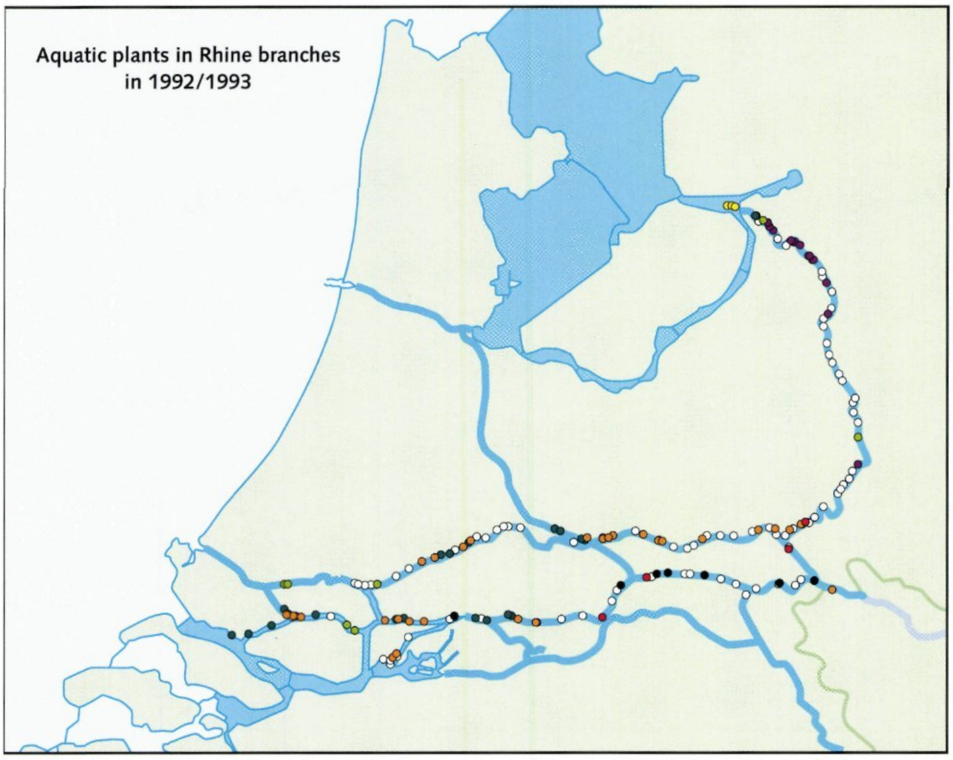
3. Macrophytes

Noël Geilen (Koeman en Bijkerk bv)

Introduction

The vegetation in the river area is greatly influenced by abiotic factors such as water level fluctuations and flow rate. Large fluctuations in water levels and high water in the summer reduce the survival likelihood of many species of macrophytes. Consequently, more species of aquatic plants are found in the flood plains than in the main channel, and bank vegetation is much more developed. In the summer bed, there are especially few macrophytes in the upstream sections of the unweired branches of the Rhine, the Waal and the IJssel rivers.

This chapter describes the situation in and along the Rhine on the basis of surveys conducted in 1992 and 1993. Trends and developments are described by examining the development of the vegetation in a number of nature restoration projects in the Rhine system.



○ no aquatic vegetation present
● Yellow water-lily *Nuphar lutea* occurs with various degrees of coverage, sometimes together with Fringed water-lily *Nymphoides peltata* and White water-lily *Nymphaea alba*
● Loddon pondweed *Potamogeton nodosus* is frequent to dominant, sometimes together with Yellow water-lily
● Fennel pondweed *P. pectinatus* occurs with a dense coverage
● Fennel pondweed occurs with a sparse coverage
● Fennel pondweed and Rigid hornwort *Ceratophyllum submersum* occur with a sparse coverage
● Rigid hornwort occurs with a sparse coverage
● Starwort *Callitriche* spp. occurs with a sparse coverage

Figure 3.1
Characterization of the survey points in the summer bed of the Rhine system on the basis of the abundance and distribution of aquatic plants in 1992/1993.

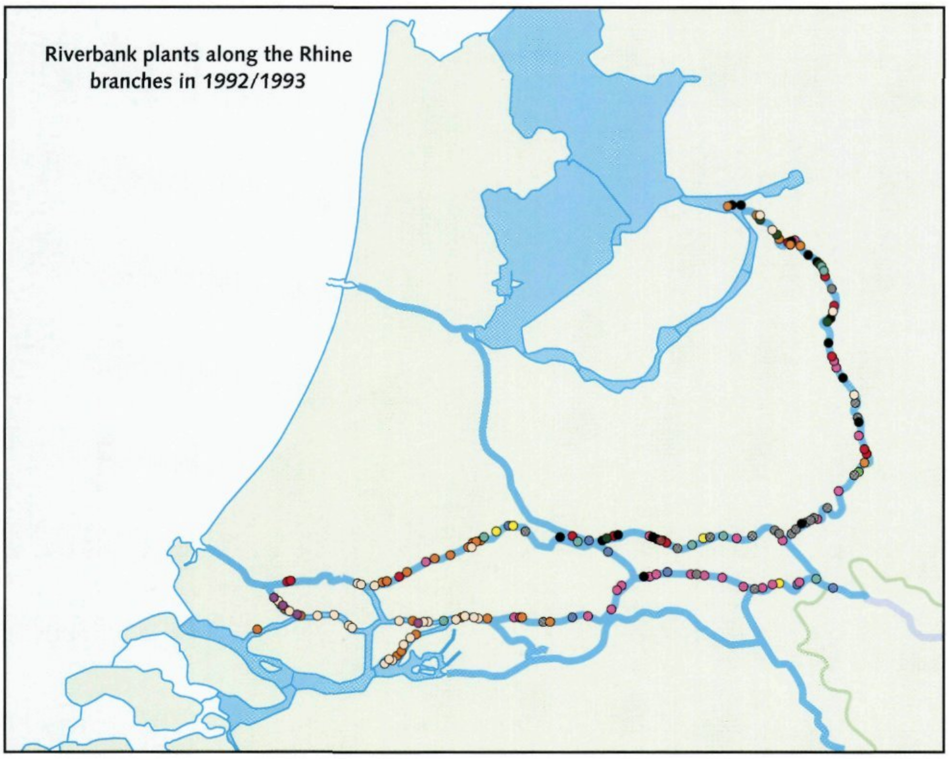
Results

Present situation

Aquatic plants are almost invariably only ever found in the Rhine summer bed in the weired parts and in the downstream section of the free-flowing branches of the river (figure 1). In all, 13 species of aquatic plants were found in the summer bed in 1992/1993. A thin covering of Fennel pondweed *Potamogeton pectinatus* and Rigid hornwort *Ceratophyllum demersum* is occasionally found in the unweired branches of the river. The water level fluctuations and flow rates are too excessive here for rich, extensive aquatic vegetation. Even Loddon pondweed *Potamogeton nodosus*, which is characteristic of flowing waters, is not capable of survival in the upstream section of the Waal or the IJssel rivers, the unweired branches of the Rhine.

The waters in the winter bed with no open link to the river generally have reasonably well-developed aquatic vegetation. In total, 19 species of aquatic plants were found. Comparing the old arms of the river with each other clearly reveals the effect of the hydrodynamics. Ponds that are less regularly connected to the river have more extensive and varied aquatic vegetation than ponds that are regularly or permanently under the influence of the river. Besides the fact that the current and the beating of the waves can affect aquatic-plant growth, the clarity of the water is also reduced by sludge swirling up from the bed. This severely impedes germination in the spring and the further development of submerged aquatic plants. Species that are highly dependent on the sheltered conditions of the isolated waters in the winter bed include Yellow water lily *Nuphar lutea*, Fringed water lily *Nymphoides peltata*, Shining pondweed *Potamogeton lucens* and Water soldier *Stratiotes aloides*. Previously, the latter species was regularly found in the river area, but has literally been flushed out of the area by increasingly more frequent high summer water levels.

The riverbank overgrowth in the floodplains of the branches of the Rhine often displays a vertical zoning pattern, which is greatly affected by the hydrology (De Graaf *et al.* 1990). On the lowest parts of the bank there are species that are least susceptible to inundation. The bare riverbanks become dry at low water levels, thus enabling germination of the seeds of all kinds of annual pioneer species that are in the bed, such as goosefoots *Chenopodium* and Pale persicaria *Polygonum lapathifolium*. These plants have to complete their life cycle during periods of low water levels, after which the seeds lie dormant in the bed again until conditions are once more favourable for germination. Higher up the bank, the duration and frequency of inundation are lower, and species are found with lower or no resistance to inundation. The helophytes are



- Reed canary grass *Phalaris arundinacea* with Branched bur-reed *Sparganium erectum*
- Reed canary grass with sparse coverage together with Amphibious persicaria *Polygonum amphibium*
- Reed canary grass with Amphibious persicaria, Gypsywort *Lycopus europaeus* and Common spike rush *Eleocharis palustris*
- Reed canary grass species-poor, possibly subtype with Garden angelica *Angelica archangelica*
- Reed canary grass with Slender tufted sedge *Carex acuta* and Purple-loosestrife *Lythrum salicaria*
- Reed canary grass species-rich with Water chickweed *Stellaria aquatica*, Great yellow-cress *Rorippa amphibia*, Marsh woundwort *Stachys palustris* and Yellow iris *Iris pseudacorus*. Slender tufted sedge is absent
- As above, but without Yellow iris
- Dominance of Common reed *Phragmites australis* and possibly Reed canary grass, with Reed sweetgrass *Glyceria maxima*, Sea club-rush *Scirpus maritimus*, Sweet flag *Acorus calamus*, Slender tufted sedge and occasionally dominance of Lesserbulrush *Typha angustifolia*, Grey club rush *Schoenoplectus tabernaemontanis* or Common spike rush
- Reed canary grass, Slender tufted sedge, Reed sweetgrass, Gypsywort, Sweet flag and Water mint *Mentha aquatica*
- Reed canary grass with Common spike rush
- Species-poor overgrowth in which Common reed is dominant
- Common club rush *Schoenoplectus lacustris* is extremely species-poor with sparse coverage
- Sea club rush

Figure 3.2
Characterization of the survey points in the summer bed of the Rhine system on the basis of the abundance and distribution of riverbank plants in 1992/1993.

among the species that occur in the regularly inundated zone, the zone that does not dry out during low discharges.

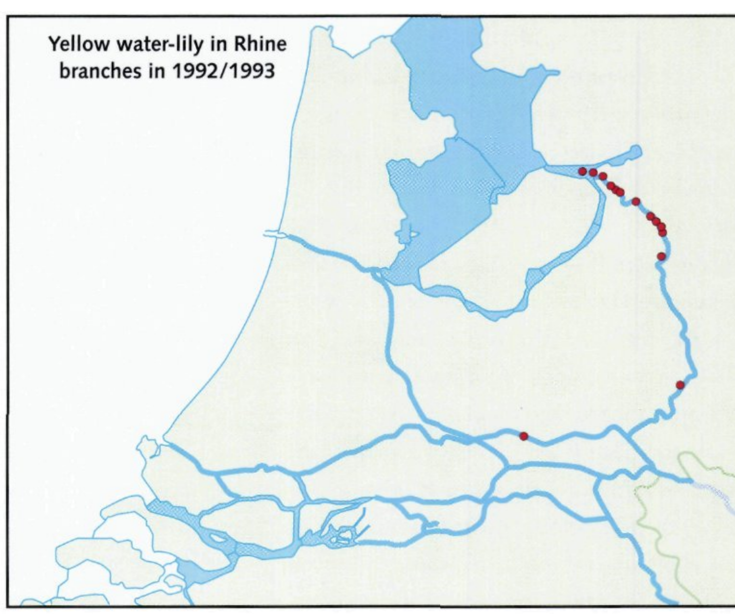
The dynamics in the water level fluctuations in the summer bed of the upstream sections of the unweired branches of the Rhine are too high for most species of helophytes. Helophytes may become totally submerged at high water levels, and may dry out completely during periods of low discharge. Neither situation is desirable. The only species of helophyte frequently found on the banks of the upstream section of the rivers is Reed canary grass *Phalaris arundinacea* (figure 2). Thanks to its growth strategy, this species is well adapted to the dynamic conditions of riverbanks. The "riverbank species" form a special group of plants that are found growing under these conditions, which include Samphire *Inula britannica*, Common fleabane *Pulicaria vulgaris* and the common cocklebur *Xanthium orientale*.

In the weired branches of the river and the downstream sections of the free-flowing Waal and IJssel rivers, the amplitude in the water level fluctuations is lower; the Reed *Phragmites australis* dominates riverbank overgrowth (figure 2), and Reed mace, rushes, and Reed sweetgrass *Glyceria maxima* appear. The banks of the waters in the floodplain also provide more opportunity for helophytes to develop, as they provide relatively more sheltered conditions. The occurrence of extensive helophyte overgrowth and the species composition are often determined by factors other than river dynamics, such as management practices. These factors are examined later.

Comparison of branches of the Rhine

The description of the present situation reveals a few distinct differences between the branches of the Rhine. The differences can be traced to differences in water level fluctuations and the duration of inundation. There are large water level fluctuations throughout the year in the free-flowing Waal and IJssel rivers, whereas the weired Lower Rhine and Lek rivers have much more constant water levels during the growing season. The water level fluctuations and flow

Figuur 3.3
Distribution of Yellow water lily *Nuphar lutea* in the summer bed of the branches of the Rhine, based on the monitoring data of 1992/1993.



rates decrease in the downstream section of the Rhine (from Gorinchem) and the effects of the tide begin to play a role. The differences in river dynamics in the river system lead to differences in sediment types. There is erosion at exposed locations and the sediment mainly consists of coarse sand fractions. There is sludge sedimentation in sheltered locations and organic matter may accumulate. All these differences show in the vegetation. This is demonstrated on the basis of the distribution of three plant species:

Yellow water lily displays a specific distribution pattern (figure 3) in the Rhine system. At high water levels, like those that occur in the river Waal and in the upstream section of the IJssel, the plants have difficulty forming leaves that reach the water's surface. At low water levels they break off again. The weired branches of the river and the downstream sections of the Waal and IJssel rivers are less dynamic and Yellow water lily may grow profusely in the summer bed at these locations. Yellow water lily is a "nymphoid" aquatic plant, which sets down roots in the soil of the water course and develops floating leaves. Nymphoid aquatic plants grow best in silty beds with a high concentration of organic matter. Beds of this type mainly occur in the downstream and weired section of the rivers and in the isolated waters of the floodplain.

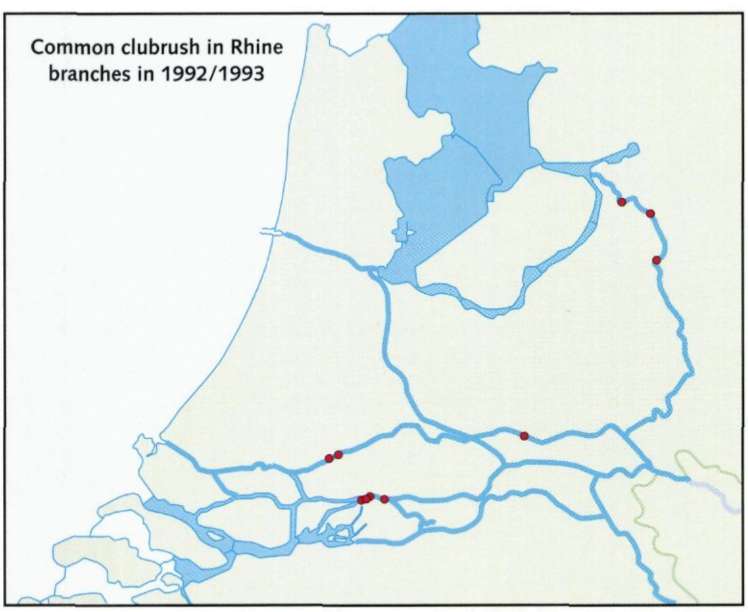


Figure 3.4
Distribution of Common club rush *Scirpus lacustris* in the summer bed of the branches of the Rhine, based on the monitoring data of 1992/1993.

A similar situation applies to **Common club rush** *Scirpus lacustris* ssp. *lacustris*, a helophyte that grows on the deepest side of the riverbank vegetation zoning. The species is susceptible to strong waves: stems can break off and plants can be washed away (Coops 1996). During periods when water levels are high, stems stretch, so the contact with the air and the oxygen supply are maintained. The long stems are vulnerable to waves at low water levels and easily break off. They may also dry out during sustained periods of low water levels. The distribution pattern of these species clearly shows that they only occur in the summer bed in sections of the Rhine system in which water level fluctuations are not excessive: the weired branches of the river and the downstream section of free-flowing branches, the Waal and IJssel rivers (figure 4).

Photograph 3.1
The Samphire is a typical riverbank species in the Rhine system.

One of the typical riverbank species common along the branches of the Rhine is the **Samphire**. Figure 5 shows the distribution of the species in the Netherlands (data from FLORBASE). This clearly shows where the name riverbank species comes from. Samphire is an uncompetitive (pioneer) species which grows in sandy locations in the floodplains. The species favours open locations in the overgrowth. Locations of this type are continually being recreated in the dynamic riverbank environment. The species also occurs regularly on groynes and hard bank revetments. The low number of occurrences

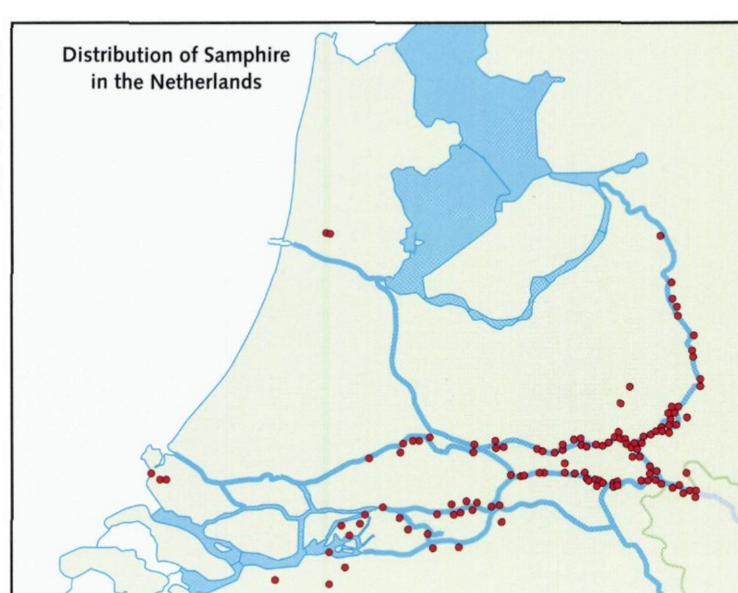


Figure 3.5
Distribution pattern of the Samphire *Inula britannica* in the Netherlands (data from FLORBASE). The occurrence of this species is closely linked to the river area.

along the downstream section of the IJssel river is striking. The dynamics are probably only high enough to enable the species to get established in the upstream section of this branch of the Rhine.

Developments and trends

Measures have been taken within the scope of nature restoration projects in recent years that have given the Rhine system more space (such as at *De Duursche Waarden* along the river IJssel, *Blauwe Kamer* along the Lower Rhine, and Leeuwense Waard and *Opijnen* along the river Waal). Existing waters in the winter bed were brought into direct contact with the river again and/or old river arms were re-excavated. These projects are intended to create the right preconditions for the development of characteristic river ecotopes. This will mainly create the dynamic ecotopes that have a major effect on the river. A monitoring programme has been set up to chart the developments in these areas.

In terms of the previous situation, increasing the effect of the river dynamics made conditions worse for the water vegetation that already existed before intervention. Van den Brink (1990) says that the occurrence of aquatic plants, for example, is largely influenced by hydrology. Figure 6 shows the cover provided by nymphoid aquatic plants, the dominant group of aquatic plants in the nature restoration area *De Duursche Waarden* (river IJssel). Part of this area was brought into direct contact with the river again in 1989. There has clearly been a marked reduction in the number of nymphoids on the surface since then. However, the number of species has increased, but these are species that provide very thin cover, and pioneer species growing in isolated waters only recently created (Doef 1995). Similar changes were also observed in other nature restoration areas in the Rhine system, after the river dynamics in a former isolated stretch of water had been reduced. The changes were most

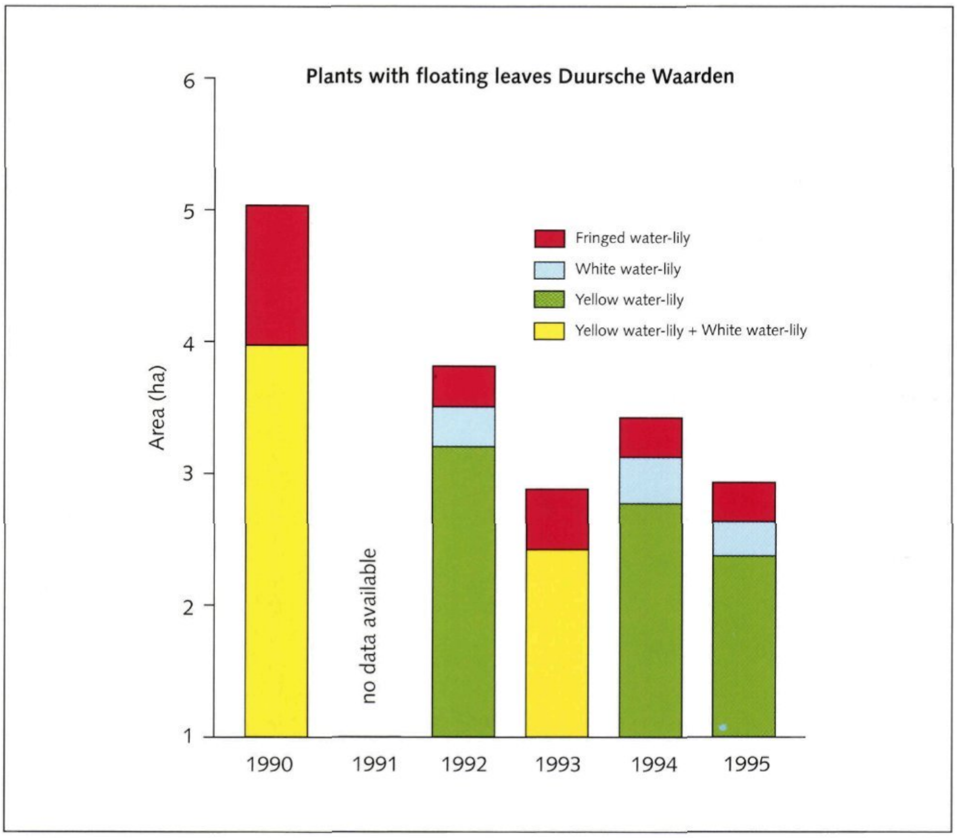


Figure 3.6
Some of the isolated waters in the winter bed in the nature restoration area *De Duursche Waarden* were brought into direct contact with the river in 1989, with a view to restoring a more natural river landscape. This had far-reaching consequences for the existing aquatic plant overgrowth consisting of Yellow water lily, White water lily and Fringed water lily, species that rely on conditions with low dynamics. Since the intervention, the total area covered by these nymphoids has diminished, owing to a deterioration in growth conditions because of the current, the beating of the waves and greater fluctuations in water levels. The nymphoids have only survived in the more isolated parts of the area.

Photograph 3.2
Aerial photograph of *De Duursche Waarden*, a nature restoration area along the river IJssel.

probably caused by an increase in the fluctuation of the water level, an increased flow rate and reduced clarity.

The riverbank overgrowth in these areas appears to change less dramatically. The new, bare riverbank zones seem to be beneficial to many species, such as Mudwort *Limosella aquatica* and Needle spike rush *Eleocharis acicularis*. The management practices adopted in areas of this kind seem to be more important for the development of riverbank vegetation than for the development of aquatic plants.

There is also grazing management in most areas. Although cattle densities are lower than in the intensively grazed floodplains, riverbank overgrowth often suffers severe damage. Grazing damage and trampling can delay or even completely interfere with the development of a helophyte belt and willow shoots. Grazing and trampling damage can be considerable, even with comprehensive grazing management, because pools of water in the winter bed are often used as watering holes.

Conclusions

Various surveys conducted along the branches of the Rhine (e.g. De Graaf *et al.* 1990, Knaapen & Rademakers 1990, Van den Brink 1990) show that the vegetation composition and structure are greatly affected by the hydrodynamics (the duration and frequency of inundation, the current and the beating of the waves) and morphodynamics (erosion and sedimentation processes). Especially since 1970, high waters during the summer, i.e., during the growing season of the plants, have had a considerable effect on the survival likelihood of macrophytes (De Graaf *et al.* 1990).

Surveys showed that, in spite of the reasonable numbers of plant species that were found, there had been a dramatic deterioration in aquatic and marshland vegetation in many waters of the floodplains, vis-à-vis the situation that existed in the nineteen fifties. The development of rich and varied aquatic and marshland vegetation therefore appears to be largely determined by the degree of isolation from the river. This is, therefore, an argument for excluding the river's influence from a section of the floodplains, by maintaining the existing summer embankments (De Graaf *et al.* 1990). This is backed up by descriptions of the developments in aquatic vegetation in a number of nature restoration areas.

Another major determining factor in the development of riverbank overgrowth is management, particularly grazing management. Floodplain forests would eventually appear in an ungrazed floodplain. Grazing makes the vegetative structure more and more open. Depending on the grazing intensity, this results in brushwood or pasture vegetation. When waters in the winter bed are severely damaged because they are used as cattle watering holes, the partial exclosure of the riverbank zone can still lead to the development of marshland vegetation.

In the summer bed, sections of the riverbank are unsuitable for the establishment of extensive riverbank vegetation. At places with high dynamics, such as along large sections of the river Waal, only a few pioneer species are capable of becoming established. In the weired and downstream sections of the Rhine system, waves from shipping and the resultant bank erosion are the limiting factors for the development of riverbank overgrowth. To prevent further bank erosion, many of these locations were provided with hard bank revetments made of materials such as rip-rap. In situations like these, it is possible to opt for nature-friendly river banks by constructing a dam or rows of piles to dampen the waves from shipping traffic. This results in a good combination of riverbank protection and riverbank layout, and a greater variation in riverbank overgrowth in the existing, narrow summer bed.

Method

A survey of summer bed vegetation in the branches of the Rhine was made within the scope of the biological monitoring programme in 1992 (river Waal) and 1993 (Lower Rhine, Lek and IJssel rivers). A survey was also made in 1992 of a selection of old arms of the river, spread across the winter bed of the Rhine system. Because this was done relatively late in the year, details of the vegetation in these arms of the river were again included for 1993. The surveys were made by the Dutch Institute for Ecological Research (NIOO/CTO), in Heteren (Lemaire 1994; Lemaire & van der Kooi 1994).
A total of 137 summer bed surveys were conducted. Along the banks, a 100 metre stretch was surveyed every three kilometres. A total of 203 winter bed surveys were conducted in the 26 selected old arms of the river. The species composition was described for each survey and an estimate was made of the coverage per species.
The description of the present situation is based on the 1992/1993 data, plus data on some other rivers: the *Nieuwe Merwede*, *Beneden Merwede*, *Oude Maas*, *Afgedamde Maas* (Coops 1996) and *Spui* (Smit *et al*. 1993). No surveys were made in 1994 and 1995 within the scope of the monitoring programme. As of 1996, riverbank plant surveys will be conducted by FLORON, for which the starting point will be a Dutch method based on the 5 x 5 km grid squares used to estimate the rarity of plant species (de la Haye 1995). Riverbank surveys in the summer bed will be based on a modified version of the method already used (lines of direction) (de la Haye 1996).

Does the Black poplar have a good basis?

River technology intervention and the intensive agricultural use of floodplains have resulted in a river landscape that now bears hardly any trace of typical river ecotopes. Many nature restoration projects attempt to restore the natural situation to some degree. Restoration of softwood floodplain forests, one of the typical river ecotopes, is often one of the goals of such projects. In the Netherlands, the tree cover in softwood floodplain forests consists of White willow *Salix alba* and Black poplar *Populus nigra*. Willows are still common in the present situation inside and outside the river area, so the seed supply need not be a problem. However, what is the situation with the Black poplar?

In the initial survey carried out in 1995, RIZA commissioned the ecological consultancy STL to chart the distribution of the Black poplar along a section of the Rhine system (Upper Rhine, Waal and Boven-Merwede rivers; Willink 1995). This will be followed in 1996 by a survey of the genetic variability of the populations that were found. The survey will be conducted by the Institute for Forestry and Nature Conservation Research (CPRO-DLO).

Black poplars, like the other willow-like trees, are dioecious, i.e., both male and female plants are necessary for seed formation. It is important that the distance between the two sexes is not too great, in order to prevent hybrids of different species of poplars occurring. Surveys have shown that the most important Black poplar source populations are upstream from Nijmegen. Large numbers of young specimens are mainly found upstream from the bridge at Ewijk. Distribution density and population size decrease steadily further downriver. Only a few specimens are found after Zaltbommel (Willink 1995).

The survey also covered Black poplar plantations. These have been planted by the Dutch Forestry Commission within the scope of a repopulation project. The young, naturally established populations and the planted populations are expected to produce sufficient seeds to colonize large sections of the Rhine system from early in the next millennium. The genetic survey should show whether the basis that appears to exist is also wide enough in this respect.

Photograph 3.3
Black poplar.

4. Phytoplankton

Loes Breebaart (RIVM), Ton Joosten (Koeman en Bijkerk bv) & Thomas Ietswaart (RIVM)

Introduction

The conditions for phytoplankton in rivers are not very favourable. The time available for algae to grow is limited to the water's residence time in the river. The flowing water creates a lot of turbulence and thereby causes high silt concentrations and less clarity. Such conditions result in only a small number of species thriving in the rivers. These are mainly diatoms, which are capable of efficient growth in low light intensities and are also resistant to the water's strong current. Consequently, all the major European rivers contain diatom genera such as *Stephanodiscus, Skeletonema* and *Aulacoseira*, the most important components of the phytoplankton. Other algae increase in numbers in the summer, particularly Chlorophyta genera such as *Scenedesmus* and *Chlamydomonas*, but these algae only become dominant at places where the water's residence time increases, such as in headwater reaches.
The unfavourable growth conditions in rivers result in the algae not being nutrient-limited quickly, especially in eutrophic rivers such as the Rhine (see chapter 2). This also means that Rhine water allowed into a stagnant reservoir can produce much higher algal biomasses than those ever found in rivers.

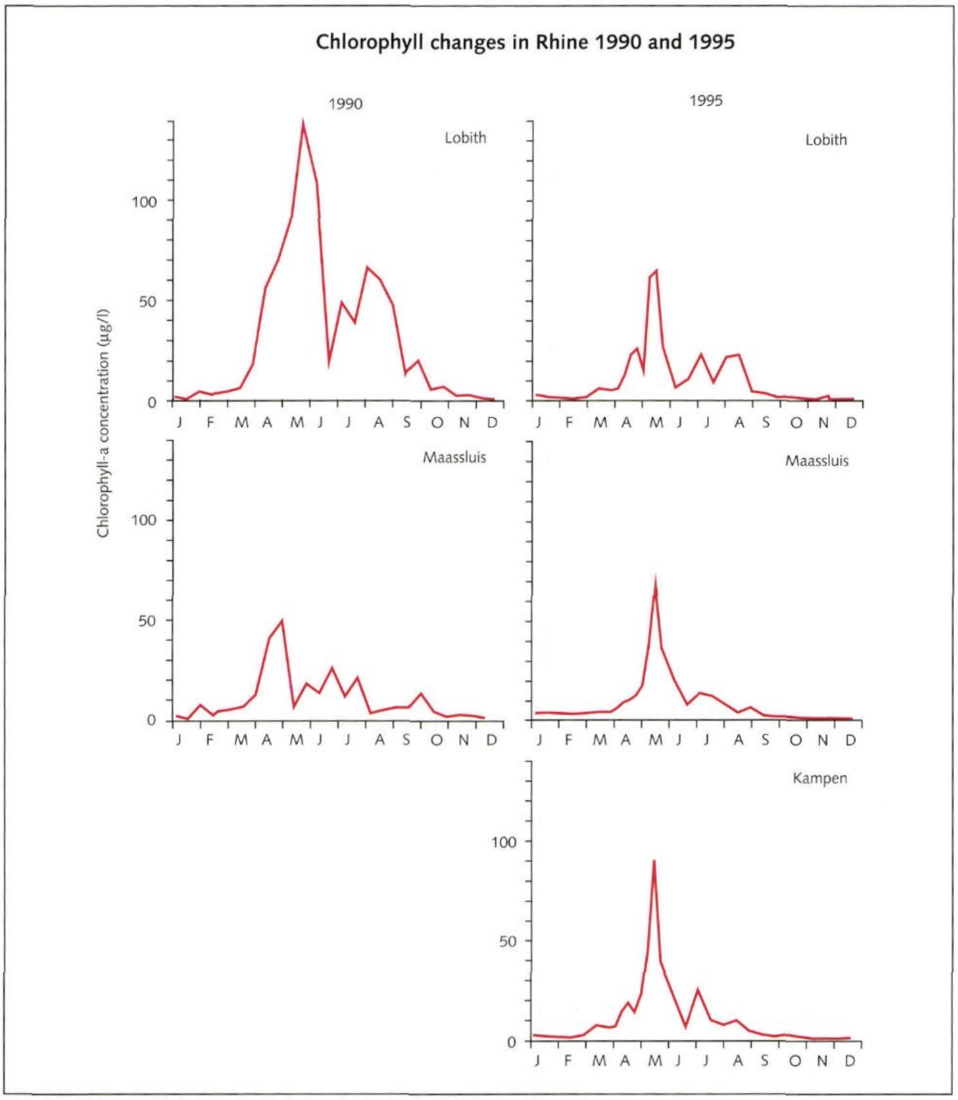


Figure 4.1
Chlorophyll-a concentration as a measure of phytoplankton biomass.

Results

Chlorophyll-a in 1990 and 1995

Chlorophyll-a, a measure of total algal biomass, reached maximum concentrations at Lobith, Maassluis and Kampen of 65, 68 and 91 mg/l respectively on 16 May 1995, (figure 1). In 1990, the chlorophyll-a maxima at Lobith and Maassluis were 138 and 50 µg/l respectively, on 23 and 1 May. The relatively low figure at Lobith in 1995 was probably caused by the Rhine's high discharge in that year; the higher the discharge, the lower the algal density (Admiraal *et al.* 1994). Similarly at Maassluis, with the exception of the spring peak, the chlorophyll-a concentration was higher in 1990 than in 1995.
The differences in chlorophyll-a concentrations between the 3 sampling points may be explained by the time required by the water mass to cover the distance between Lobith and Maassluis or Kampen. This could mean, for example, that the chlorophyll-a maximum measured at Maassluis had not yet been reached Lobith. This would also explain the relatively high concentration of chlorophyll-a measured at Kampen.

Total phytoplankton density in 1990 and 1995

In 1990 and 1995, the maximum phytoplankton densities (figure 2) at Lobith were 57033 and 68736 cells/ml respectively, and the figures for Maassluis were 25192 and 98743 cells/ml respectively. The maximum density measured at Kampen in 1995 was 87893 cells/ml.
The spring peak in 1995 mainly consisted of *Skeletonema subsalsum* at all the stations; at Lobith, Maassluis and Kampen the figures were 69 %, 64 % and 81 % cells/ml respectively. The profuse *Skeletonema* bloom at Lobith in 1990 did not occur at Maassluis, most probably because of a lack of silicate (Admiraal *et al.* 1994). In 1995, the peak at Lobith appeared to extend to Maassluis and Kampen, thereby excluding the possibility of low silicate levels.
The seasonal progression of maxima and minima in cell density in 1995 is comparable with that of chlorophyll-a. Differences may have arisen through differences in the species composition and/or the vitality of the cells.

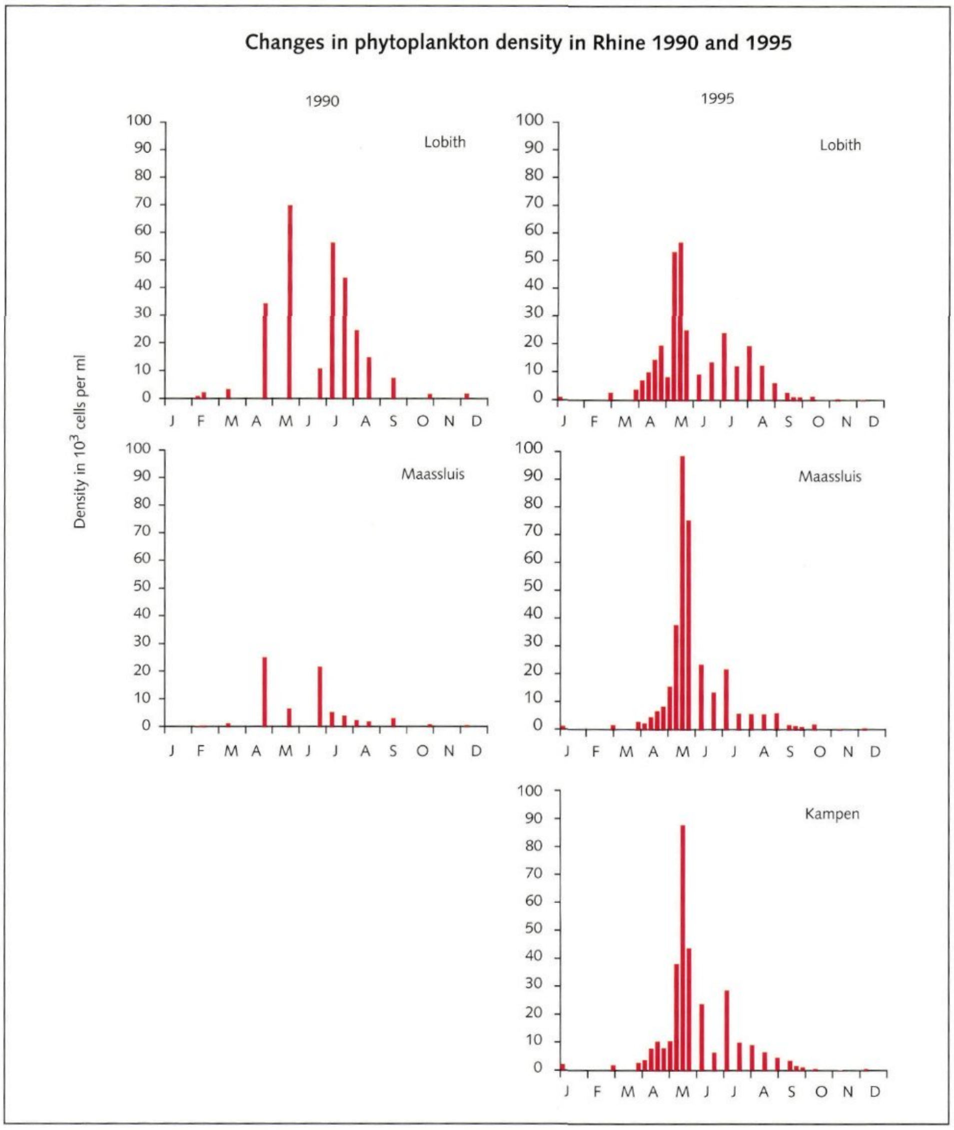


Figure 4.2
Comparison of the phytoplankton counts at Lobith and Maassluis in 1990 and 1995 and at Kampen in 1995.

The changes in phytoplankton concentration at Kampen were very similar to those at Maassluis. The *Skeletonema* peak was higher at both of these stations than at Lobith. See also 'species composition'.

Species composition 1995

In accordance with the characteristic river pattern, diatoms predominated at Lobith, Maassluis and Kampen; the months January and December formed the only exception to this, at Kampen. Cyanobacteria accounted for more of the biovolume than chlorophyta at Lobith and Kampen in the winter period. However, the absolute cell counts for these groups in the winter months were very low (figure 3).

Diatoms

At the Lobith and Kampen monitoring points, the *Stephanodiscus* group *hantzschii* (including *Cyclostephanos invisitatus*) was responsible for the first regeneration of phytoplankton, in the month of April (figure 4). The maximum counts of this group of species were considerably higher at Lobith than Kampen. The increase in phytoplankton at Maassluis was more gradual, without any pronounced *Stephanodiscus* maximum.

From mid April the *Skeletonema* species increased in number dramatically. In mid May the spring maximum for *Skeletonema subsalsum* and, to a lesser extent, *Skeletonema potamos*, was measured at all the monitoring points. The highest numbers were found in Maassluis, followed by Kampen. After a drop in cell counts in June, there was a second, smaller *Skeletonema* bloom in June, in combination with *Cyclotella meneghiniana*. *Skeletonema potamos* was more common than Skeletonema subsalsum in this period. The highest counts of the *Skeletonema* species were found in July at Kampen, followed by Maassluis. On the other hand, *Cyclotella meneghiniana* was more common at Lobith.

More than twenty species of diatoms were found in the samples taken in 1995. Of these, *Thalassiosira incerta* and *T. australiensis* were previously unreported in the Rhine catchment area, but turned out to occur regularly, particularly in the summer and autumn, in combination with a third *Thalassiosira species*, *T. lacustris* (= *T. bramaputrae* sensu auct., non Ehrenberg). *Thalassiosira incerta* was even more abundant in 1995 than the species *Actinocyclus normanii*, which is superficially similar. The maximum count of *Thalassiosira incerta* was 261 cells/ml (19 July, Maassluis), and nowhere did Actinocyclus counts exceed 25 cells/ml.

Only limited numbers of pennate (two-sided symmetrical) diatoms were found. These were mainly species of the genera *Navicula*, *Nitzschia*, *Diatoma*, *Asterionella* and *Fragilaria*. The most abundant was *Asterionella formosa*.

Chlorophyta and Cyanophyta

The two most important Chlorophyta genera in the spring peak were *Chlamydomonas* and *Monoraphidium* (figure 5). *Monoraphidium* displayed a second peak in the summer, which was considerably higher at Lobith than at Kampen. *Scenedesmus* was the most abundant Chlorophyta genus in the summer. This maximum was higher than the summer peak at Kampen, which had been preceded by a clear drop in numbers. Low counts were found in the summer months at Maassluis vis-à-vis other locations.

Coelastrum astroideum had the highest count at Kampen, where, following a gradual increase, the species displayed two peaks in the period from the end of the June to the beginning of August. An identical pattern was observed at Lobith and Maassluis, however with much lower maxima.

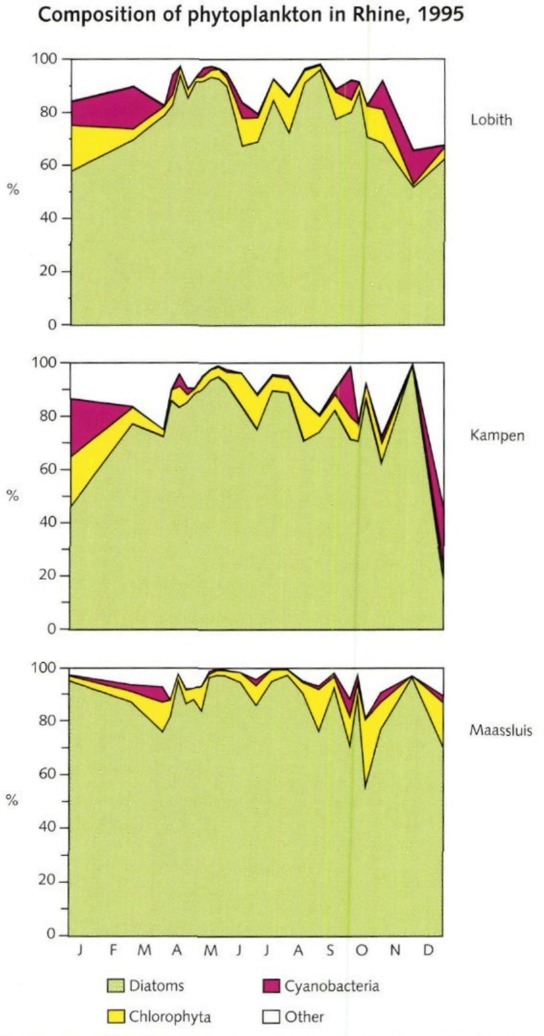


Figure 4.3
The seasonal change in phytoplankton composition in 1995; the bio-volume percentage of diatoms, Chlorophyta, Cyanobacteria and a remaining group are shown over time.

Planktothrix spp. made the greatest contribution to the cell counts of Cyanobacteria. The numbers of filaments were generally in the order of magnitude of the detection limit of the counting method used, which means the cell numbers counted displayed an irregular progression. The highest numbers were observed in April and May.

The remaining group (figure 3) mainly consisted of cryptophytes (*Cryptomonas* spp., *Rhodomonas* spp.), with the exception of the sampling data of 19 April at Lobith, 5 April at Maassluis and 19 August at Kampen, where bio-volumes were determined particularly by Mallomonas sp., the *Chrysococcus rufescens* group and *Mallomonas* sp. respectively.

Discussion

Basically speaking, the species composition of phytoplankton in the branches of the Rhine is comparable with that of other major eutrophic rivers. Mainly diatoms predominate, particularly the *Stephanodiscus* group *hantzschii*, *Aulacoseira* spp. and *Cyclotella* spp. However, there are some differences between the Rhine and, for example, the Maas. These are determined by factors such as hydrological influences (e.g. residence time), the nutrient composition and load, and salinity. *Skeletonema*, a species that can tolerate high salinity levels, is a more important species in the Rhine than in the Maas. Owing to the lower flow rate in the weired Maas vis-à-vis the Rhine, there was a higher percentage of green algae (Admiraal *et al.* 1993).

Developments

The composition of Rhine water has changed considerably in recent decades. The phosphate level and the concentrations of a number of toxins have dropped sharply. The total nitrogen concentration has remained more or less constant, but, owing to the effects of an increasing number of sewage treatment plants, there has been a shift towards nitrate. The species composition of phytoplankton also appears to have changed. For example, *Skeletonema subsalsum*, an important species in Rhine phytoplankton, has only been found in the Rhine since 1988, and the percentage of *Stephanodiscus hantzschii* has diminished in importance in the spring bloom. These shifts may have been caused by changes in the water quality. *Skeletonema potamos* and *S. subsalsum* are species with a relatively high tolerance to salinity, which may explain their presence in the saliferous Rhine water. On the other hand, they only recently became dominant, whereas the Rhine has been saliferous for much longer. The succession between species of algae may also be explained by other water quality parameters, such as toxins (Tubbing *et al.* 1993), and N:P ratios (Turpin 1994). However, the knowledge available at present precludes the possibility of establishing causal links or making predictions about species developments in the Rhine. No shifts have been detected in recent years at the group level.

The effect of, for example, weir management on algal composition is clear. If the water has a longer residence time, particularly in the summer, the number of Chlorophyta in the algal population will increase. There may even be sporadic increases in Cyanophyta concentrations. This phenomenon is most likely to occur in the Lower Rhine. High concentrations of Chlorophyta are least likely to occur in the free-flowing Waal and IJssel rivers. Newly developed stagnant waters in floodplains may well have a different species composition from that of the Rhine.

A higher rate of flow and the resultant shorter residence time cause a lower river phytoplankton biomass. However, a lower rate of flow causes the river's maximum chlorophyll concentration to be earlier along the longitudinal axis, and this is followed by a reduction. In 1990, the maximum in the Rhine was around the Dutch/German border. In the Maas, which sometimes has extremely low rates of flow, the

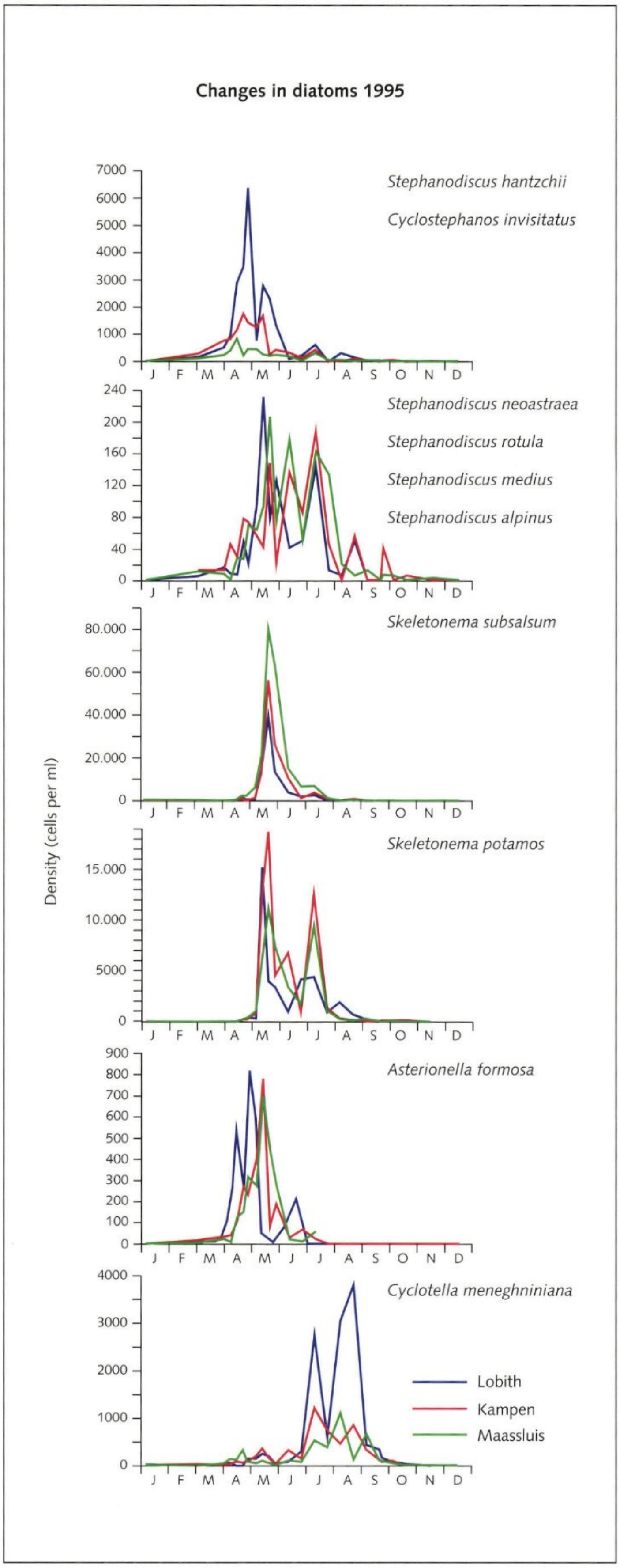


Figure 4.4
Seasonal change in the density (cells/litre) of some dominant diatoms, in 1995.

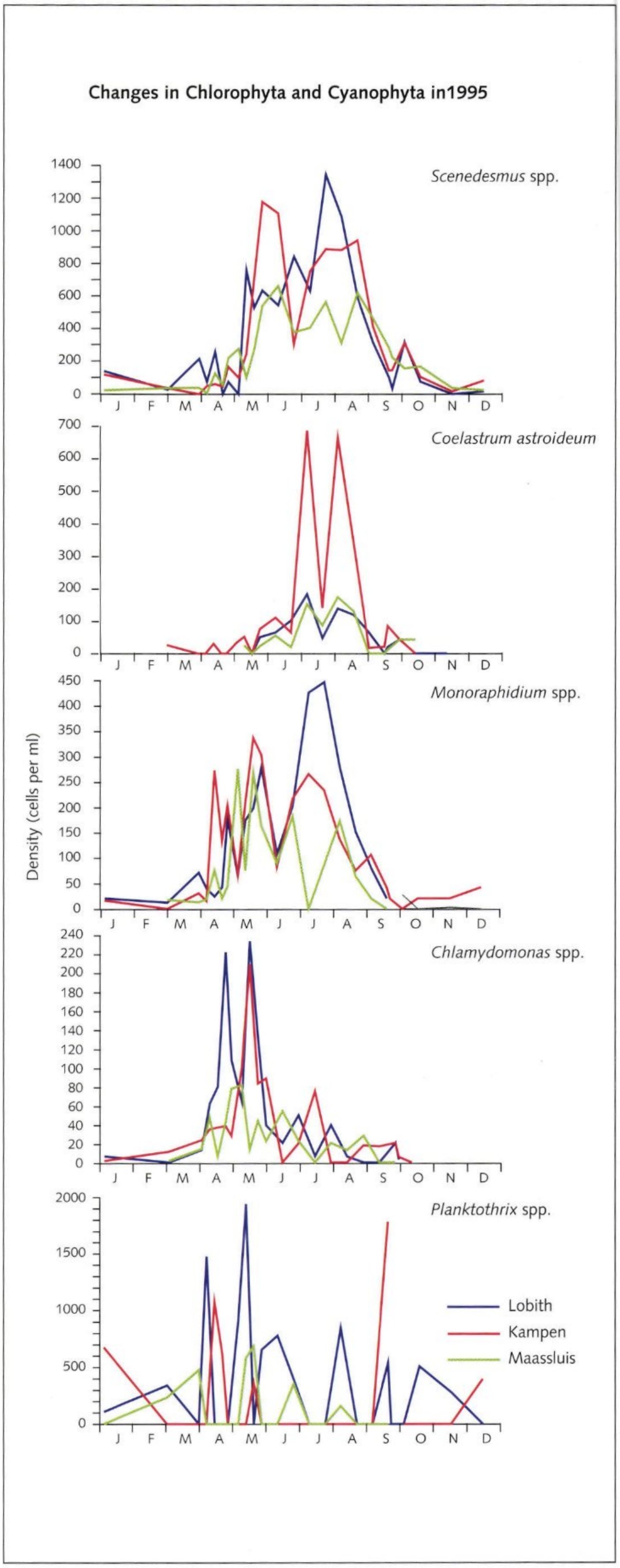
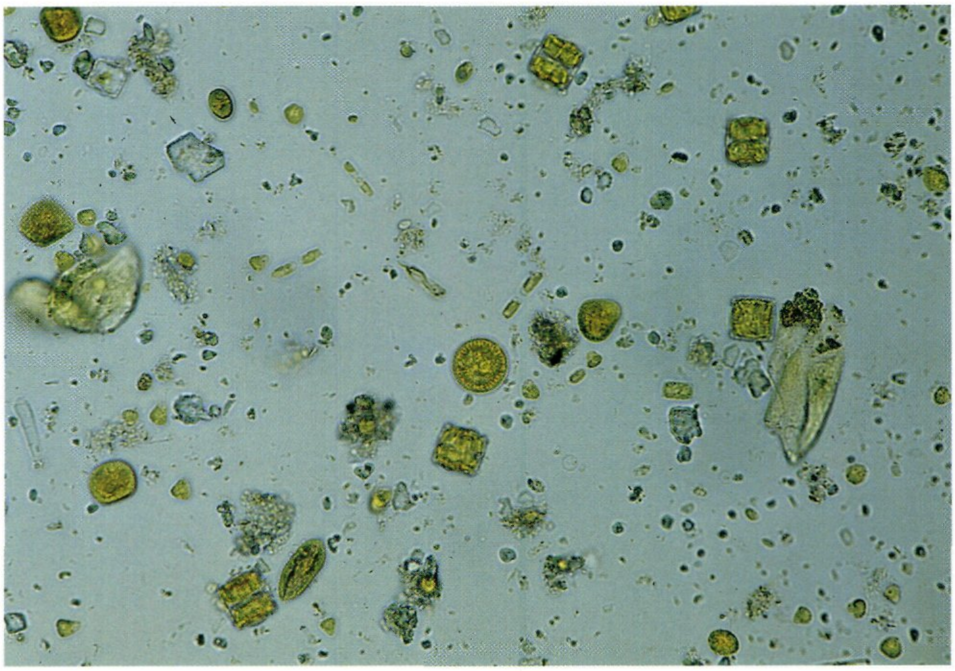


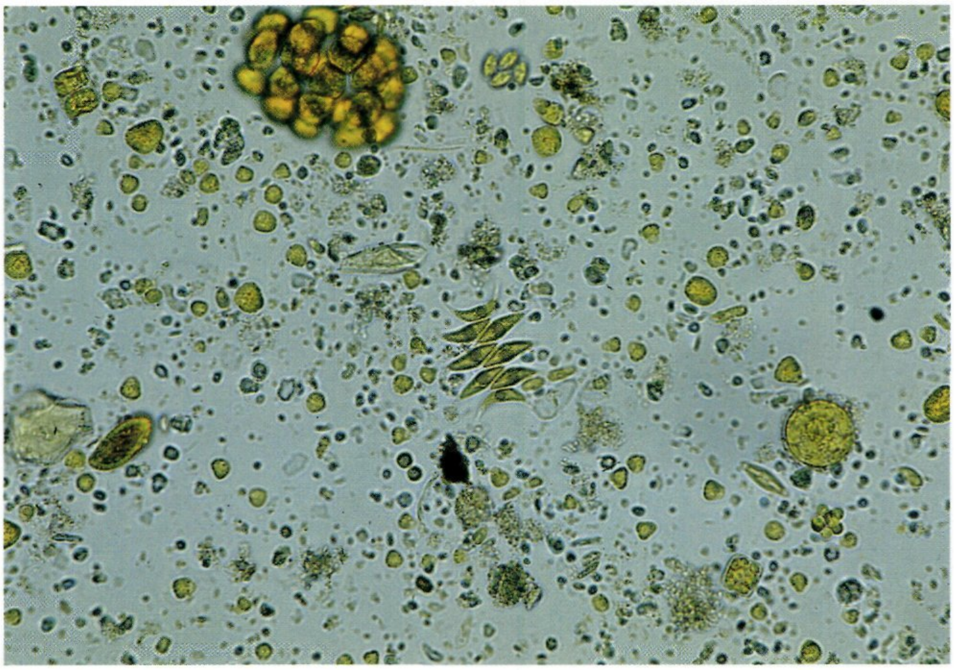
Figure 4.5
Development of the density (cells/ml) of some dominant Chlorophyta and Cyanophyta in 1995.

maxima for both phytoplankton and zooplankton are reached at an earlier stage in the river's course (Buijs 1992). The reduction that takes place downstream is probably caused by loss factors becoming relatively more important. The mortality rate of algae accounted for by lysis of the cells will increase as the algae age. There will also be a relative increase in the grazing pressure of zooplankton and benthic filter feeders.

As mentioned in the introduction, the flowing character of the river results in the algal growth in the Rhine being subject to limited light intensities for the greater part of the year. Consequently, the chlorophyll-a concentrations in the river only reach around 100 µg/l. However, the nutrient concentrations in the river water permit much greater algal densities. This is well-illustrated by the concentrations in stagnant waters fed by river water. Here, chlorophyll-a concentrations in excess of 200 µg/l are measured. The fact that algal growth in the Rhine is nutrient saturated also means that a further reduction in phosphorous and nitrogen concentrations in the Rhine water will not result in a proportional fall in chlorophyll concentrations. These will only start to fall when the phytoplankton in the branches of the Rhine are once more (also) controlled by the volume of available nutrients.



Photograph 4.1
River phytoplankton in the summer; the diatoms *Cyclotella menighiniana* and *Sceletonema potamos* can be seen.



Photograph 4.2
Phytoplankton from a dead river arm along the river Waal. The percentage of Chlorophyta (*Pandorina morum*, *Scenedesmus* spp.) is much higher than in the river's main channel, whereas the percentage of diatoms is much lower.

Conclusions

As in other rivers, phytoplankton in the Rhine is dominated by diatoms.

The total population densities are positively correlated with the water's residence time, and are therefore significantly lower than those in (semi) stagnant waters. Nutrients are not a limiting factor for the growth of algae in the river.

Characteristics such as the relative abundance of the saline-tolerant diatom *Skeletonema* and the low number of green algae in the Rhine vis-à-vis the Maas, for example, are related to the physico-chemical properties of the water, and the free-flowing character of the Rhine, as against the weired Maas.

Method

The phytoplankton species composition and the chlorophyll-a concentration in the Rhine were determined in the survey years 1990 and 1995 at Lobith and Maassluis. The town of Kampen was added in 1995. The species composition was determined monthly from the second half of October to the first half of March, every two weeks in the summer and weekly in the spring. The chlorophyll-a concentration was determined weekly in the spring and every two weeks in the remaining period.
A bucket was used to collect a 60 litre mixed sample at three locations. In Maassluis and Kampen the samples were taken across the entire width of the river, from either the ferry or the bridge and, at Lobith, from the pontoon of the Directorate-General for Public Works and Water Management. A one litre part sample was fixed using lugol for the phytoplankton counts. The phytoplankton counts were made using an inverted microscope with a magnification factor of 200-630x. Very small and extremely common species were counted in a smaller sub-volume than the larger and less common species. The chlorophyll-a concentration was determined for each location using the method stated in Dutch standard NEN 6520. The volume of the part samples required for this varied from 0.25 to 1 litre.

Photograph 4.3
Sampling from a bridge.

Secondary channels and channel bed algae
(Corian Bakker)

Diatoms dominate the phytoplankton composition of the Rhine. In the present situation, the largest percentage of these algae are found free-floating in the water column. There are clear indications that algae that lived on the plants and on the bed predominated in the past (Klink 1992). These benthic algae can achieve high production rates on shallow sand and sludge shallows. They are therefore an important source of food for grazing and scraping invertebrates, which in their turn are the prey of birds and fish.
Research carried out on a Rhine sedimentary deposit from 1745 shows that 70 % of the insects that live on diatoms had to rely on benthic algae in that period. In the present situation, the percentage living on this source of food has dropped to 55 % (Klink 1991). One of the objectives of nature restoration projects is to restore this source of food as an important link in the food chain (Worldwide Fund for Nature 1993). Suitable growth conditions for these algae are shallow water in which light can penetrate to the sandy bed. This habitat can be achieved by constructing secondary channels and dead river arms.

5. Zooplankton

Bob van Zanten & Thomas Ietswaart (RIVM)

Introduction

Zooplankton is the generic name for the fresh-water fleas, rotifers, and single-cell animals that live in the water column. The zooplankton vary in size from *Daphnia* (ca 3-4 mm), which is visible to the naked eye, to the smallest species (ca. 50 micro m), which can only be seen with a microscope. The food of zooplankton consists of organisms that float in the water, such as algae, bacteria and dead organic matter. In turn, zooplankton are eaten by planktivorous fish. The development of zooplankton is closely linked to that of the most important source of food, the algae. The spring blooms of zooplankton and phytoplankton in rivers therefore more or less coincide. The factors that determine which species can be eaten by zooplankton are mainly the size of the algal cells and the types of colonies they form. Small, free-swimming cells are the most suitable food.

As with phytoplankton, zooplankton in rivers is greatly affected by the hydrological conditions. The duration of growth is limited by the water's residence time in the river. The strong turbulence also prevents organisms staying in one place in the water column. The summer bed of rivers therefore mainly contains rapidly-growing, small species, particularly Rotifera (rotifers). Places where the water flows more slowly may provide a habitat for other groups, such as Crustacea (here consisting of freshwater fleas and copepods). A separate group is formed by the larvae of larger organisms, such as the Zebra mussel *Dreissena polymorpha*, which only remain free in the water for a short time.

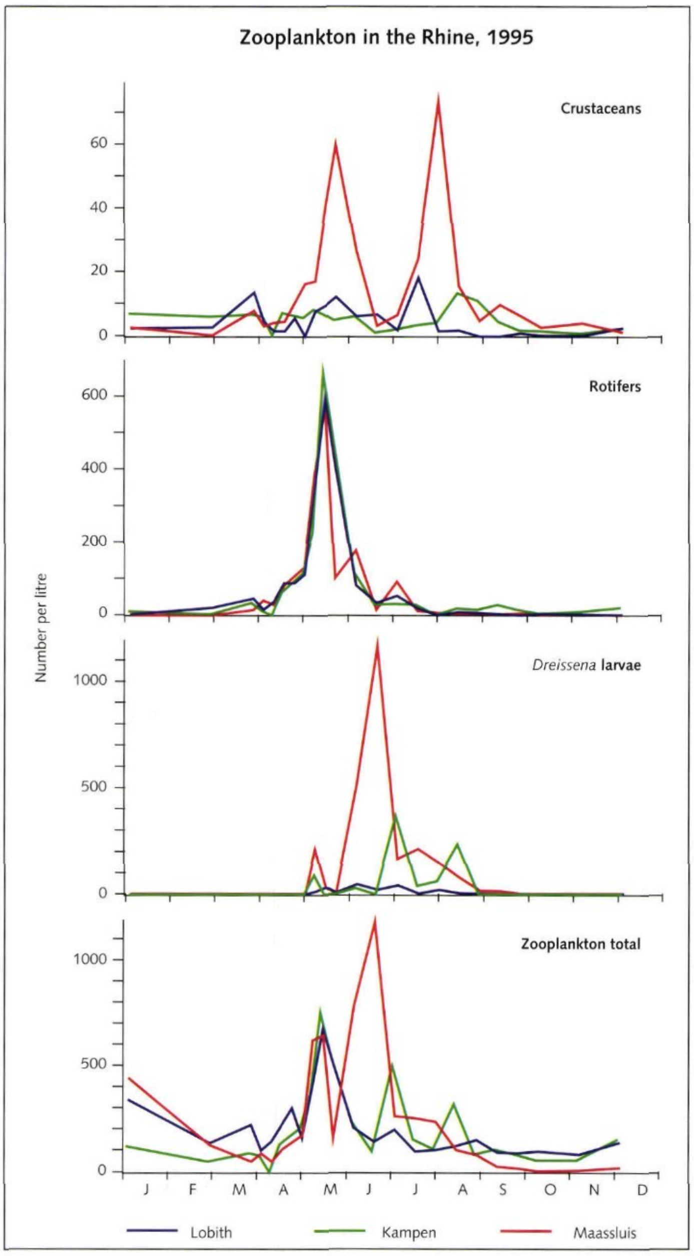


Figure 5.1
Population density of zooplankton as a function of time in 1995. The spring bloom of Crustacea and Rotifera in May is clearly visible. At Maassluis there was also a summer peak of the larvae of the Zebra mussel *Dreissena polymorpha*. The high total zooplankton density in January was caused by a relatively large percentage of single-cell organisms (protozoa) in the samples.

Results

As in the years 1987-1991 (figure 2), there was a spring bloom of zooplankton in 1995, which was closely linked to the spring bloom of phytoplankton (figure 1). The zooplankton bloom consisted of Rotifera and Crustacea. Total numbers at Lobith were low in comparison with other years. Besides the spring bloom at Maassluis, there was also a summer peak caused by planktonic larvae of the Zebra mussel *Dreissena polymorpha*.

The Rhine's discharges were extremely high in 1995, particularly in January and February (maximum of 11885 m^3/second at Lobith on 31 January). The high discharges had no effect on the seasonal progression of zooplankton. However, the high discharge may explain the low total density.

Species composition

Rotifera

Zooplankton in rivers is dominated by small grazers, the rotifers, more than is the case in stagnant, eutrophic surface water, in which the Crustacea are more numerous. This is also the case in Lobith and at Kampen (figure 3A and 3B). The domination of Rotifera in the summer at all the stations is possibly explained by their short generation time, approximately one day.

All three stations had maximum Rotifera counts of around 550 individuals per litre in de spring peak (figure 1B). These densities are comparable with those in the period 1987-1991 (figure 2B). The highest densities were clearly concentrated in the spring bloom and the densities in the rest of the year were lower by a factor of 10 or more.

The development of the dominant species of Rotifera is shown in figures 4 and 5. *Brachionus calyciflorus* is a relatively large rotifer (250-400 µm), which occurs in the river plankton in the spring bloom. The numbers vary from around 34 individuals per litre at Kampen to

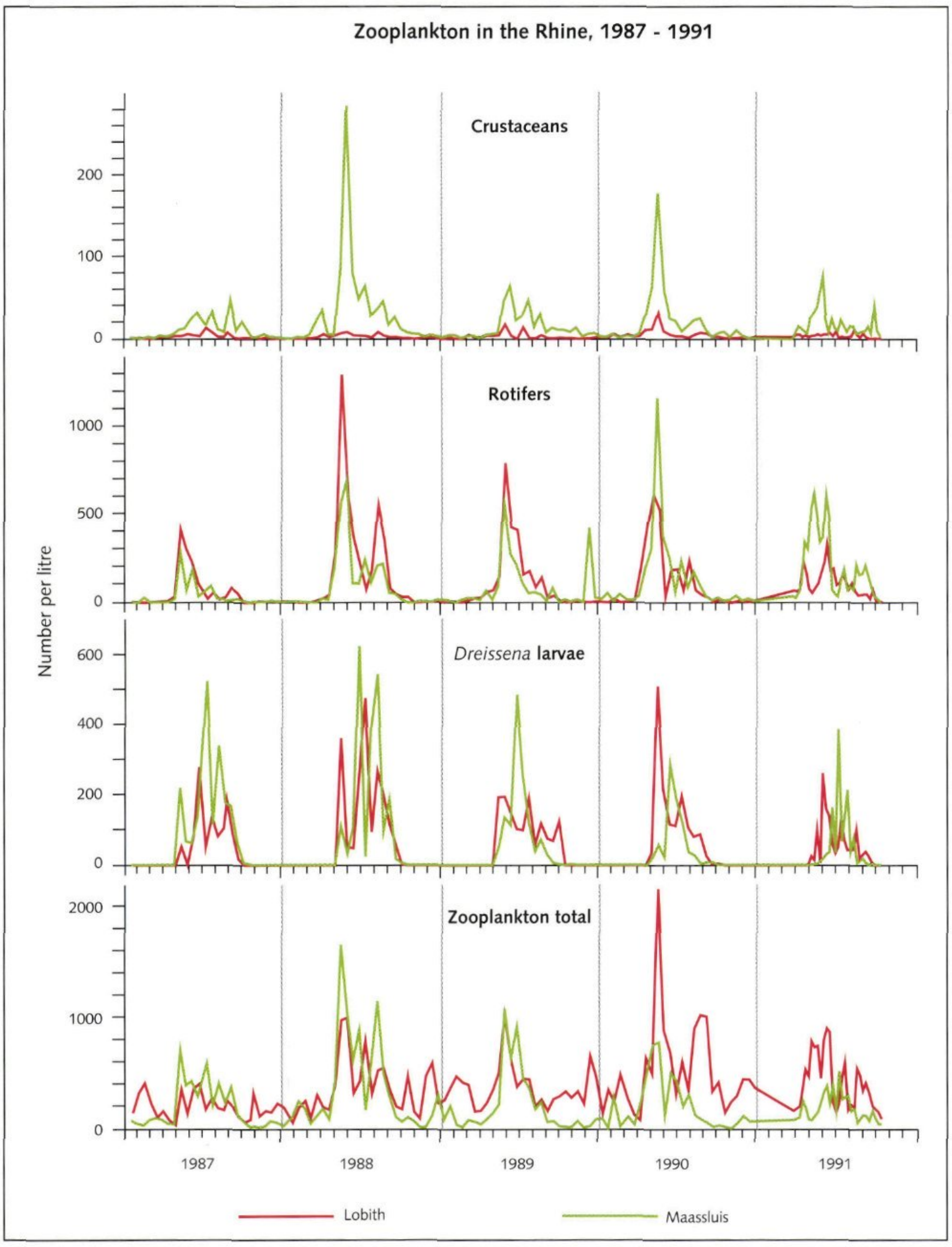


Figure 5.2
The density of all zooplankton and of the various species groups in the period 1987-1991.

65 individuals per litre at Maassluis. These numbers can vary greatly from year to year (see figure 5C). *Brachionus angularis* generally has a more homogeneous distribution throughout the year (figure 5A). In 1995 (figure 4A), the species was also mainly present in the spring bloom in densities comparable with those of *B. calyciflorus*. *Keratella cochlearis* and *Keratella quadrata* (figure 4) are smaller species. They occurred in densities of up to around 200 individuals per litre. Especially the smallest (80-320 μm) dominant rotifer, *K. cochlearis*, can achieve high densities. All four species occur in enormous numbers in the period from May to June. This tendency was also visible in the period from 1987-1991 (figure 5).

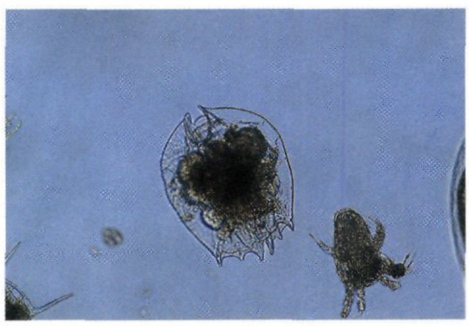
Crustacea (Cladocera, Copepoda)

If the water slows down or comes under marine influence, there is an increase in the percentage of copepods and branchiopods (freshwater fleas). This is expressed in the relatively high percentage of crustaceans at Maassluis (figure 3C, 2A). The maximum density here in 1995 was approximately 67 individuals per litre, whereas the maxima at Kampen and Lobith were around 10 individuals per litre (figure 1A). Most of the crustaceans consisted of the nauplii of copepods (particularly Cyclops); the dominant branchiopod was *Bosmina*.

Besides a possible different size composition of the phytoplankton, the unsuitability of the biotope probably explains the small number of crustaceans at Lobith and Kampen. At high flow rates species such as *Daphnia* cannot swim upright. On the other hand, large populations of branchiopods and copepods can occur in stagnant pools, dead river arms, gravel pits along the major rivers, and at the ends of rivers in tidal areas. These factors appear to be more important than the quality or composition of the water. The water quality is therefore not an obstacle to the occurrence of various groups of zooplankton.

Dreissena larvae

In the summer period there are often large numbers of larvae of the Zebra mussel *Dreissena polymorpha* in the Rhine zooplankton. This species is one of the few freshwater Bivalvia with a planktonic larval stage ("veligers"). It is striking that there were more *Dreissena* larvae in the Waal/Lek rivers than in the IJssel river. It is not clear whether this was caused by differences in population densities of Zebra mussels at the locations or by differences in the supply of larvae, which come from upstream populations (the larvae are planktonic for approximately three weeks and are therefore able to cover large distances). The highest counts in 1995 were at Maassluis (1165 individuals per litre). This is the highest recorded count thus far in the Dutch section of the Rhine (figure 1C). The fall in the *Dreissena* population in the Dutch section of the Rhine as a result of over-proliferation of the shrimp that originally came from the Caspian Sea *Corophium curvispinum* (Van den Brink *et al.* 1993), therefore appears to have had no effect on the concentration of larvae.



Photograph 5.1
River zooplankton are dominated by rotifers. The photograph shows a specimen of the species *Branchionus arceolaris*, together with a nauplius (young stage of a copepod).

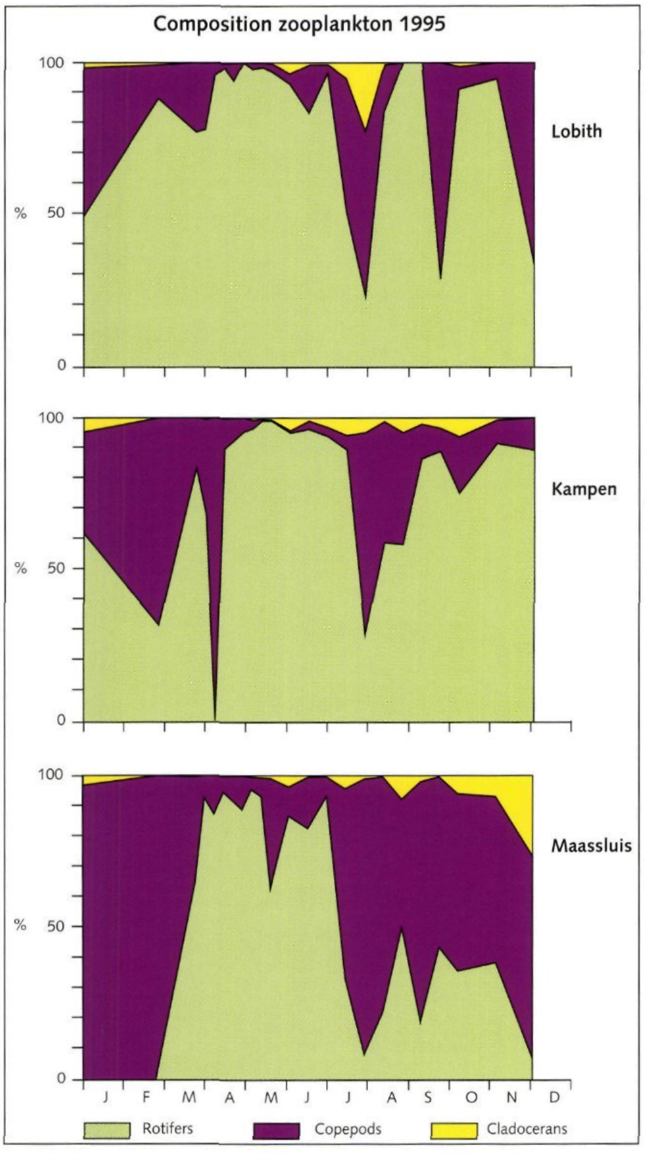


Figure 5.3
Species composition of zooplankton at the different sample locations. As in other rivers, zooplankton in the Rhine are dominated by rotifers (Rotifera).

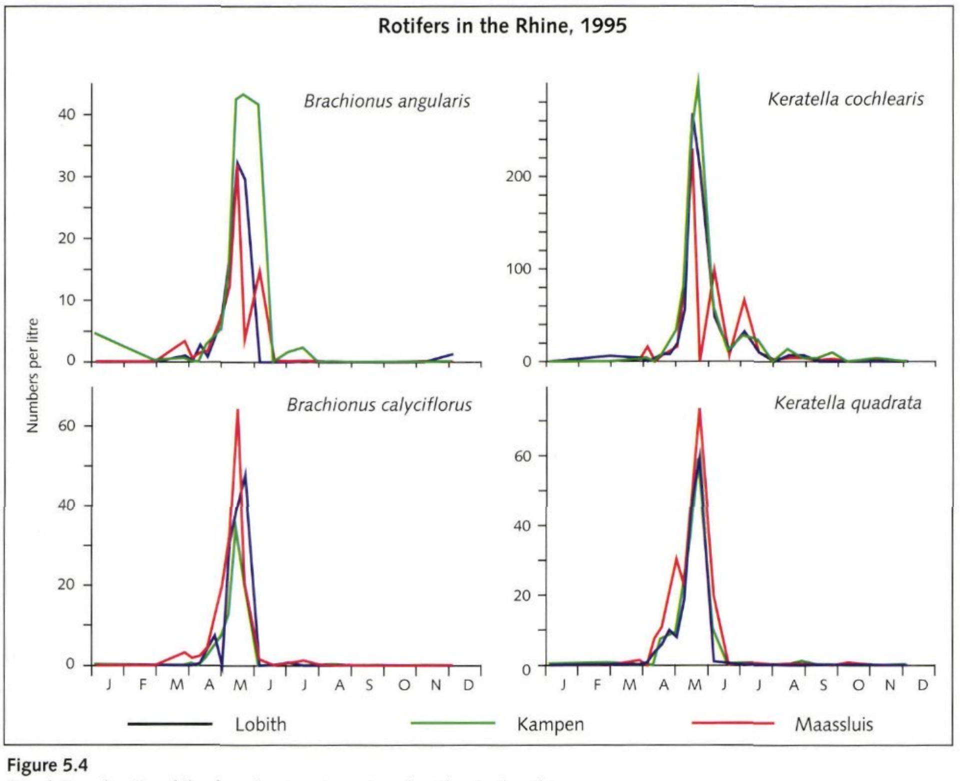


Figure 5.4
Population density of the four dominant species of rotifers in the Rhine.

Discussion

Besides food availability, the discharge of the branches of the river (i.e. the residence time) is largely determining for the population density of zooplankton (Winner 1975). The high discharges in 1995 clearly resulted in low chlorophyll-a concentrations and low rotifer population densities (figure 6).

This dependence mainly occurs in the spring (figure 6). The connection becomes less clear later in the year, possibly as a result of ecological interactions. Comparison with historical data (Peelen 1975) shows that the composition of Rhine zooplankton has not changed dramatically in recent decades.
As a result of the combination of high discharges and low food availability, zooplankton population densities are also much lower than in stagnant waters. For example, in spite of there being a higher percentage, the maximum rotifer population densities in the branches of the Rhine are a factor of four lower than those in lake IJsselmeer (Dekker 1995). Likewise in gravel pits along the Rhine, zooplankton population densities are found that are a factor of 100 higher than in the river (Neumann *et al.* 1994). This results in the ecological role of zooplankton in rivers being much smaller than in stagnant waters. The grazing pressure on phytoplankton in the branches of the Rhine and in the river Maas is in the order of only a few percent of the algal biomass per day (Gosselain *et al.*, to be published soon). A reduction in the flow rate by the construction of secondary channels will probably result in a higher grazing pressure, particularly in the channels, and possibly also in the main stream. The degree of influence this will have on the volume of algae in the Rhine depends on the ratio of grazing rate to algal production.

On the basis of the available data, it is impossible to confirm or deny whether the development of zooplankton is affected by toxic substances in the Rhine. It is known that removing toxic substances using XAD increases the relative growth rate of phytoplankton in the Rhine (Van Dijk *et al.* 1995). It is also known that the

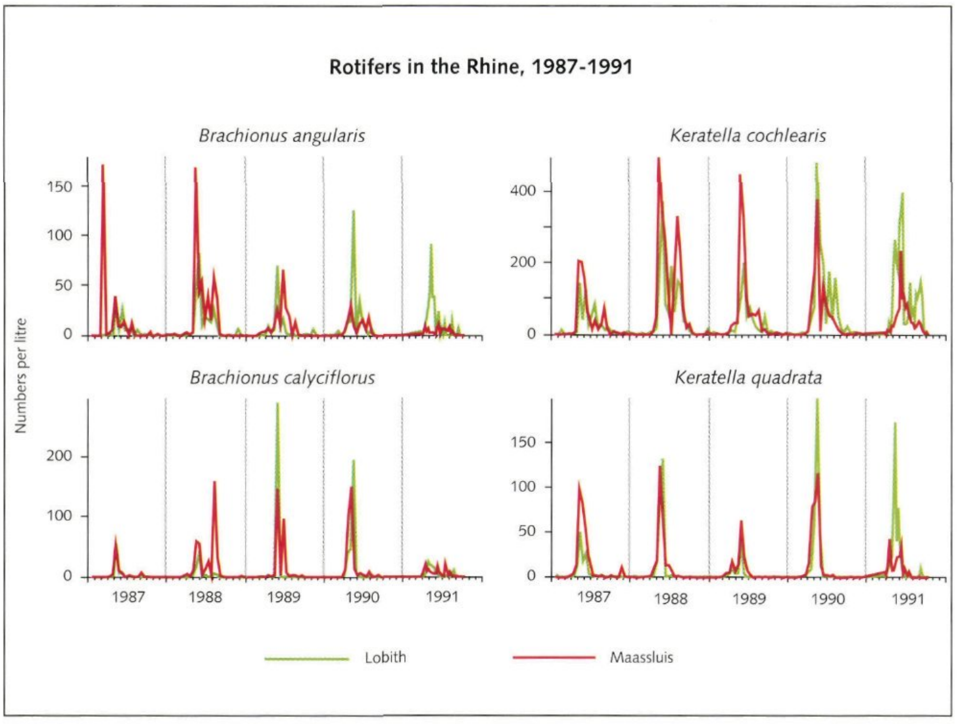
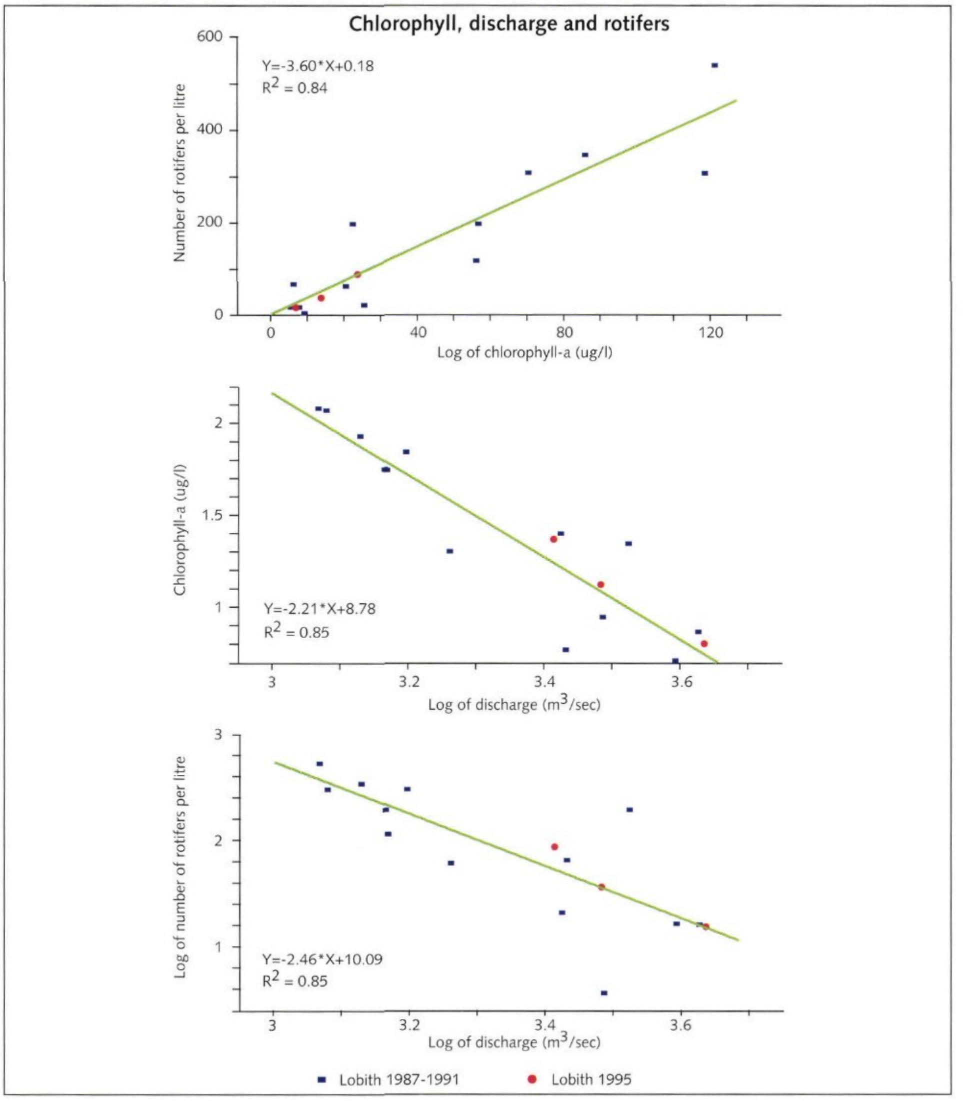


Figure 5.5
Developments in the population density of the dominant species of rotifers in the period 1987-1991.



species composition of the phytoplankton can change under the effect of toxins (Tubbing *et al.* 1993). These factors could affect the development of zooplankton. Besides these indirect effects, the zooplankton may also be directly affected by toxic substances in the Rhine. However, on the basis of a comparison with the toxicity data for phytoplankton and zooplankton, there is no reason to expect the concentrations in the Rhine water to lead to chronic effects on these organisms (see chapter 11).

Conclusions

As in other rivers, zooplankton in the Rhine are dominated by rotifers.

The total population densities are positively correlated with the water's residence time, and are therefore significantly lower than those in (semi) stagnant waters.

Method

From 1987 until 1991, inclusive, the National Institute of Public Health and the Environment (RIVM) studied the seasonal progression of zooplankton and phytoplankton in the Rhine, within the scope of the Ecological River Restoration project. In 1995, RIVM determined the species composition and population densities of zooplankton and phytoplankton at Lobith, Kampen and Maassluis, in connection with the Biological Monitoring of National Fresh Waters carried out by the Institute for Inland Water Management and Waste Water Treatment (RIZA). A one litre sample was used for phytoplankton, and a 20 litre sample was used for zooplankton, both of which were taken from a mixed sample of around 60 litres. A bucket was used to take the samples from the pontoon at Lobith, from the ferry at Maassluis and from the bridge at Kampen.

Figure 5.6
A: Population density of Rotifera at Lobith against the chlorophyll-a concentration. Figures 6B and 6C clearly show that the high discharges in 1995 resulted in low chlorophyll-a concentrations and low rotifer population densities. This data is from the beginning of the spring regeneration (April-May) in the years 1987-1991 and 1995. The monitoring points in 1995 are indicated by •.

6. Macrozoobenthos

Bram bij de Vaate, Marianne Greijdanus & John van Schie (RIZA)

Introduction

Invertebrates (macro-evertebrates or macrozoobenthos) are generally considered to be good indicators of the quality of river water (Hellawell 1986, Rosenberg & Resh 1993). They have already been the subject of studies in the Rhine for around 20 years (Van Urk & Bij de Vaate 1990, Bij de Vaate 1994). In recent decades, improvements in water quality resulted in a considerable increase in the number of species observed annually. Population densities have also undergone a major increase. However, that increase mainly occurred in species that did not originate in the Rhine, the so-called non-indigenous species, or immigrant species (Breukel & Bij de Vaate, 1996).

Most of the (sub)dominant species that were found in the various biotopes in the 1995 monitoring programme belong to this group of non-indigenous species.

Table 6.1
Summary of taxa that were only observed in the spring of 1995 at the IRC locations (see figure 1).

Oligochaete worms:	**Mayflies:**
Aulodrilus pigueti	*Heptagenia sulphurea*
Aulodrilus pluriseta	**Black flies:**
Dero digitata	*Simulium galeratum*
Potamothrix vejdovskyi	**Chironomidae:**
Specaria josinae	*Synorthocladius semivirens*
Vejdovskyella intermedia	**Molluscs:**
Crustaceans:	*Valvata cristata*
Dikerogammarus haemobaphes	
Caddis-worms:	
Psychomia pusilla	
Tinodes waeneri	

Results

Spring sampling

In the spring of 1995, it emerged that the stones in the riverbank zone of the river Waal and the Lower Rhine had been colonized by, amongst other species, the may fly *Heptagenia sulphurea* and the caddis-worm *Hydroptila* spec, which are two species that set relatively high requirements for water quality and are almost exclusively present in readily observable numbers in the spring.

Table 1 shows the taxa that are only observed in the spring, and, therefore, not during the August/September monitoring period. A new species to the fauna of the Netherlands is *Dikerogammarus haemobaphes*, which, like the species *Dikerogammarus villosus*, originally came from the Danube. *D. haemobaphes* was first found in 1994, in the catchment area of the Rhine, in the river Main (Schleuter *et al.* 1994).

Biotope sampling

Deep gravel bed

Only four samples were taken in this biotope; two in the Rhine, one in the river IJssel and one in the river Waal. The Enchytraeidae group (oligochaete worms) is dominant in this biotope (for a description of (sub)dominance, see Frantzen 1991 or Bij de Vaate & Greijdanus-Klaas 1995). This group consisted mainly of individuals that were difficult to identify but which were probably *Propappus volcki*, the only species of this family it was possible to name. The midge larva *Cladotanytarsus* spec. was the only subdominant species. This detritivorous species is intolerant of organic contamination (Wilson 1996).

Deep sand bed

The biocoenosis in and on the deep sand bed is characterized by the dominance of the Asian clam *Corbicula fluminea*, Caspian Sea shrimp *Corophium curvispinum*, a shrimp originally from the Caspian Sea and amphipods (Gammaridae) (table 2). The amphipods found in the samples were mainly juvenile specimens and could not, therefore, be further identified. In previous years, usually only one species was found, the amphipod *Gammarus tigrinus*. At the time, the juvenile specimens were also assumed to be of this species. There are now five species of amphipods in the branches of the Rhine. Besides the indigenous species *G. pulex* the non-indigenous species *G. tigrinus*, *Echinogammarus ischnus*, *Dikerogammarus haemobaphes* and *D. villosus* were also found. This time, the indigenous species were not found in this biotope. It is not only the amphipods that are dominated by immigrant species (see also table 4). Of the (sub)dominant taxa in table 2, only four of the 12 taxa (*Enchytraeidae* indet., *Propappus volcki*, *Chironomus* spec. and *Kloosia pusilla*) belong to the indigenous fauna.

There is an enormous variation in the number of taxa found in the deep sand bed. In the Waal river, for example, only 9 taxa are found, whereas up to 44 taxa are found in the Lower Rhine. In general, only a few macrozoobenthos species are capable of successfully colonizing the moving sand riffles in the river's alluvial catchment area (Morris *et al.* 1968). These

Photograph 6.1
Amphipod *Gammarus tigrinus*.

Photograph 6.2
Shrimp originally from the Caspian Sea (*Corophium curvispinum*).

Table 6.2
Dominant (**) ang subdominant (*) taxa per type of biotope in several branches and stretches of the Rhine system (- = not sampled).

	Taxon	Rhine	IJssel	Waal	Nieuwe Merwede	Oude Maas	Lower Rhine	Lek	Nieuwe Waterweg
Deep sand bed									
Oligochaet worms	Enchytraeidae indet.	-		**					-
	Propappus volcki	-						**	-
Crustaceans	*Corophium curvispinum*	-	**	*		**	*		-
	Gammaridae indet.	-	**		*				-
	Gammarus tigrinus	-				**	*		-
Chironomids	*Chironomus* spec.	-					*		-
	Kloosia pusilla	-		*					-
	Paratendipes intermedius	-						**	-
Molluscs	*Potamopyrgus antipodarum*	-	**						-
	Dreissena polymorpha	-	*			**	*		-
	Corbicula fluminalis	-			*		*		-
	Corbicula fluminea	-		**	**	*	**	**	-
Sandy riverbank zone									
Oligochaet worms	*Propappus volcki*	-		**					-
Crustaceans	*Corophium curvispinum*	-	*						-
	Gammaridae indet.	-		*	**	*	*	**	-
	Gammarus tigrinus	-	**						-
Molluscs	*Valvata piscinalis*	-			*				-
	Corbicula fluminalis	-			**		*		-
	Corbicula fluminea	-		**	*	**	**	**	-
Clayey riverbank zone									
Oligochaet worms	Enchytraeidae indet.	-	-	-			-	-	*
Crustaceans	*Neomysis integer*	-	-	-			-	-	*
	Corophium multisetosum	-	-	-			-	-	**
	Corophium curvispinum	-	-	-			-	-	*
	Gammaridae indet.	-	-	-	*		-	-	
Chironomids	*Cladotanytarsus mancus*	-	-	-	**		-	-	
Weekdieren	*Valvata piscinalis*	-	-	-		*	-	-	
	Pisidium spec.	-	-	-		*	-	-	
Stone riverbank zone									
Crustaceans	*Balanus improvisus*								**
	Corophium curvispinum	**	**	**	**	**	**	**	
	Corophium lacustre								*
	Corophium multisetosum								**
	Gammaridae	*		*	*	**		*	
	Gammarus spec.		*						
	Dikerogammarus spec.				*				
Chironomids	*Dicrotendipes nervosus*					*			
	Cricotopus intersectus		*						
Molluscs	*Bithynia tentaculata*				*	*			
	Dreissena polymorpha	*		*		*	*	**	
Macrophytes									
Oligochaet worms	Tubificidae zonder chaetae	-	*	-		*		-	
	Enchytraeidae	-		-				-	**
Crustaceans	*Sphaeroma hookeri*	-		-				-	*
	Corophium spec.	-		-		*		-	
	Corophium curvispinum	-	**	-	*			-	*
	Corophium multisetosum	-		-				-	**
	Gammaridae indet.	-		-	*		**	-	
	Gammarus tigrinus	-	**	-		*		-	
Ceratopoqonids	Ceratopogonidae	-		-		*		-	
Chironomids	*Cricotopus* spec.	-	*	-				-	
	Cladotanytarsus mancus	-		-			*	-	
Molluscs	*Potamopyrgus antipodarum*	-		-	**			-	
	Valvata piscinalis	-		-		*		-	
	Dreissena polymorpha	-		-		*		-	
	Corbicula fluminalis	-		-			*	-	
	Corbicula fluminea	-		-		*	**	-	

channel bed movements are clearly present in the river Waal, in contrast with the weired Lower Rhine, where there is minimum discharge in the summer months.

Sandy riverbank zone

As with the deep sand bed, the biocoenosis of the sandy riverbank zone is dominated by the Asian clam and amphipods (table 2). It is assumed that the unidentifiable amphipods are mainly juvenile specimens of the amphipod *G. tigrinus*. Small numbers of other specimens of the species *Dikerogammarus villosus* were also found in some places.

In the river Waal, as in the "deep gravel bed" biotope, the oligochaete worm *Propappus volcki* was dominant in the sandy riverbank zone. It is a species that has an obvious preference for the somewhat coarser channel bed substrates (Reinhold-Dudok van Heel & Den Besten, in preparation).

In the *Nieuwe Merwede* river, both Asian and Asiatic clam Corbicula fluminalis are relatively important. The Asiatic clam seems to prefer coarser sand beds, whereas the Asian clam has a density optimum in sludge-rich sand beds (Reinhold-Dudok van Heel & Den Besten, in preparation). Both types of channel beds are found in the *Nieuwe Merwede* river. The group of (sub)dominant species in the sandy riverbank zone also mainly consists of species that did not originate in the Rhine. Only the oligochaete worm *P. volcki* is indigenous.

An average of 34 taxa were found per section. The figure varied from up to 53 in the *Nieuwe Merwede* river to a minimum of 21 in the Waal river.

Clayey riverbank zone

The clayey riverbank zone was sampled in three river sections, (see box: method). It is mainly saline-tolerant species that are dominant in the *Nieuwe Waterweg*, which indicates that the sampled locations are influenced by seawater. The other species that were found can also be characterized as saline-tolerant. An inherent feature of the brackish water is the relatively small number of taxa found (only six). The *Nieuwe Merwede* and the *Oude Maas* can be termed species-rich, in view of the number of taxa found, 50 and 48 respectively. The chironomid *Cladotanytarsus mancus*, which is dominant in the *Nieuwe Merwede* river, also achieves considerable population densities in the *Oude Maas* river, although not high enough to be counted among the group of (sub)dominants. The river snail *Valvata piscinalis* is numerous in the *Oude Maas* as well as the *Nieuwe Merwede* but is only dominant in the *Oude Maas*. This freshwater snail extends to the more sludge-rich channel beds. In the *Oude Maas*, *Pisidium* spec. was identified as a subdominant taxon. Because Pisididae are particularly difficult to identify as young organisms, they were not previously identified. The samples for this survey year have been further identified as the species *Pisidium nitidum*, *P. moitessierianum*, *P. henslowanum* and *P. casertanum*. These are all common species in the Netherlands. The species occurred in high numbers (850-1400) but not high enough to be designated as subdominant. Besides these four general and numerous species, *P. amnicum*, which is extremely susceptible to contamination, also occurs in low population densities. The more susceptible the *Pisidium* species is to contamination, the lower the population densities in which it is found.

Stone riverbank zone

Mud shrimps *Corophium* spp., amphipods *Gammarus* spp. and Zebra mussels *Dreissena polymorpha* are the most important taxa in the biocoenosis on stones in the riverbank zone (table 2). There are observable differences per section. For example, the brackish character of the *Nieuwe Waterweg* is also reflected in the biocoenosis found on stones there. The Brackish-water barnacle *Balanus improvisus* and the mud shrimps *Corophium lacustre* and *C. multisetosum* are clearly representatives of a brackish biocoenosis. Practically all the other species found are also saline-tolerant.

Mud shrimps have the highest population densities in the biocoenosis of every section. In the Rhine they account for more than 99 % of the biocoenosis; in the rivers the Waal, *Nieuwe Merwede*, Lower Rhine and the Lek, the figure is 80-95 %; in the river IJssel it is 73 % and in the *Oude Maas* and the *Nieuwe Waterweg* it is 50 %. The presence of the Caspian Sea shrimp means that relatively high amounts of sludge are deposited on the stones, which can form a barrier for the lithophile species (species that prefer to stay on stones or hard objects). Nevertheless, there was no demonstrable connection between the number of taxa found and the population density of *C. curvispinum*. The average number of taxa was 38 (if the Nieuwe Waterweg is excluded, where only an average of 8 taxa were found). The minimum number found was 26 (*Nieuwe Merwede*) and the maximum number was 55 (IJssel).

Macrophytes

With one exception, only riverbank vegetation was sampled. The only location sampled with submerged aquatic plants (pondweeds) was in the IJssel river. The samples were taken in a way that enabled the channel bed to be sampled as well as the vegetation. This is why practically all the (sub)dominant species (table 2) also have the same status in the other biotopes sampled in the riverbank zone. The species that only occur (sub)dominantly in this biotope are the waterlouse *Sphaeroma hookeri*, found in the *Nieuwe Waterweg*, and the Ceratopogonidae (biting midges), in the *Oude Maas*. *S. hookeri* is a brackish water species (Gledhill *et al.* 1993) that has thus far only occurred in this section. Ceratopogonidae are usually only found in low population densities. According to Mol (1984), the environmental preference is not known for any of the Dutch species in this family, there is also no mention of the family in the BMWP/ASPT index.

Developments

Macrozoobenthos samples have been taken in the branches of the Rhine within the scope of various projects in recent years. The results are often difficult to compare because of differences in the sampling strategy. However, converting them to an index value makes it possible to,

Photograph 6.3
The freshwater gastropod *Theodoxus fluviatilis* (Freshwater nerite).

nevertheless, indicate the developments that are taking place. The BMWP index (Biological Monitoring Working Party index) was calculated, and the ASPT value (Average Score Per Taxon value) was derived from it (Armitage *et al.* 1983). This biotic index was developed to provide an indication of the biological condition of rivers in England and Wales. The level of both values is mainly determined by the number of families found and their susceptibility to organic contamination (saprobe). The range for the BMWP index is generally 0 to around 500, but in practice will only exceed an upper limit of 300 if the observation results of several biotopes are combined. The index works as follows: in a list, a score is given from 1 (low susceptibility) to 10 (very susceptible) per taxon (often at the family level). The BMWP is a total count of the scores of all the taxa found. This means that a large number of species with low susceptibility can produce the same BMWP value as a low number of very susceptible species. The ASPT value, which is used to calculate the average score per taxon found, says more about the susceptibility of the individual species. This is between 0 and 10. The maximum achievable BMWP and ASPT values for the various biotopes in the Rhine have been calculated using historical data, and used as a reference value for comparing current values (Greijdanus-Klaas in preparation).

Table 6.3
The maximum attainable values for BMWP and ASPT indexes used as reference values for various biotopes.

	$BMWP_{ref}$	$ASPT_{ref}$
stenen oeverzone	282	6,1
zandbodem	155	5,5
slibbodem	64	4,3
vegetatie	110	4,8
biotopen totaal	365	6,5

Stones from banks of River IJssel

The oldest macrozoobenthos observation series in the major rivers in the Netherlands is that of the biotope "stones in the riverbank zone". This biotope has been sampled practically every year since 1975, in the period September/October, at four locations in the IJssel river. Up until 1981, the BMWP figure was clearly increasing (figure 1), after which it continued to fluctuate between 58 and 82 (average: 66; reference: 282). This fluctuation was mainly caused by taxa that only occur in low population densities. In one year they are found in the samples and in another they are not. On the other hand, the ASTP figure indicates an increase throughout the observation period, which indicates that the impact of organic substances has decreased. This latter indication also emerges from the river water's oxygen saturation percentage (Breukel & Bij de Vaate 1996). This reduction in contamination is also observable in a species such as the water-louse *Asellus aquaticus*, which is positively affected by impacts of this kind. This species was (sub)dominant in the period 1975-1981, after which populations densities declined dramatically.

In 1995, the Caspian Sea shrimp had a dominant presence in every branch of the Rhine. Fairly soon after the first few specimens had been observed in November 1987, at Lobith (Van den Brink *et al.* 1989), all the branches of the Rhine had been colonized. They were first observed in the IJssel river in 1989, when annual samples were being taken from the stones in the riverbank zone. Table 4 shows the population density changes on this substrate, in this branch of the Rhine. The figures are based on a single observation each year in the month of September or October. Five stones are sampled per location. Table 4 shows that, following the colonization phase of at least four years, a certain density stabilization occurred at a level that is approximately a factor of 20 lower than the maximum of 1992.

The biotopes "deep river bed" and "stone riverbank zone" were sampled in 1988 and 1990, within the scope of international monitoring organized by the International Rhine Commission. If the figures from these years are compared

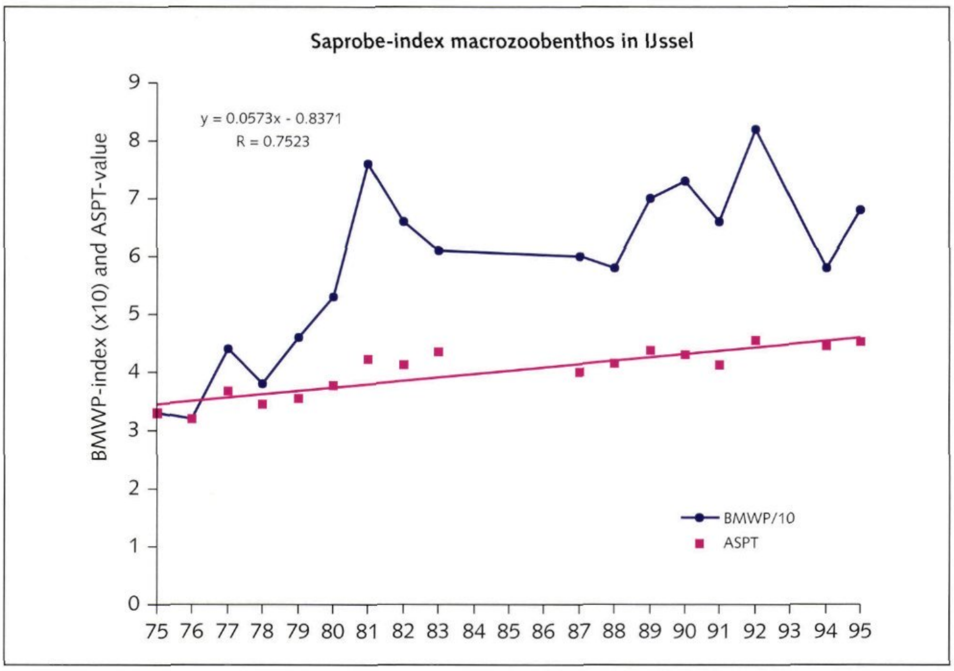


Figure 6.1
The increase in the BMWP index and the ASPT value derived from it, for the "stone riverbank zone" biotope, in the IJssel river.

Table 6.4.
Changes in the population density of the Caspian Sea shrimp (*Corophium curvispinum*) on the "stones in the riverbank zone" of the IJssel river, in the period 1989-1995 (-: not found; n.s.: not sampled).

Location	^{10}log number per m^2 (riverbank area)						
	1989	1990	1991	1992	1993	1994	1995
Velp	2,7	4,5	5,0	5,9	n.s.	4,6	4,5
De Steeg	<1,3	3,7	5,3	6,1	n.s.	4,4	4,1
Olst	-	<1,3	3,8	5,1	n.s.	4,2	4,2
Wijhe	-	1,5	2,4	5,6	n.s.	4,1	4,3

with those of 1995 (figure 2), it emerges that both the BMWP index and the ASPT value for both biotopes were higher at most locations in 1990 than in the other two years (1988 and 1995). An important component of the differences between the three years and between the biotopes themselves can be explained by the distribution in the observation results. On the basis of all the samples, in 1995 the BMWP index for the Rhine had a value of 91 (reference: 365) and an ASPT of 4.3 (reference: 6.5). Calculated for the individual biotopes in the different sections, the BMWP index varied from 12 to 65 and the ASPT value varied from 3.0 to 4.7.

Artificial substrate

The BMWP index and the ASPT value derived from it were calculated (figure 3) from the sum of all the annual observations of species on artificial substrate (see method).
Up to and including 1990, there was a clear increase in both indices, whereas a stabilization was noted in the period from 1993 to 1995. The Caspian Sea shrimp has had a dominant presence on the artificial substrate since 1990 (figure 4). The dominance is only broken by other species in the spring (Bij de Vaate *et al.* in press). Because they are present in large numbers and because they build silt-dwellings, they were expected to oust other species (Van den Brink *et al.* 1993). However, figure 4 shows that the total counts of organisms on the artificial substrate have increased since the arrival of the Caspian Sea shrimp. The counts without mud shrimps are in the same order of magnitude as the counts from before 1990. In 1991 and 1992, the counts throughout the season were also still comparable with those of previous years. In 1993 and 1994, there was no seasonal progression to speak of. The influence of the weather may have played a role in this. The arrival of the

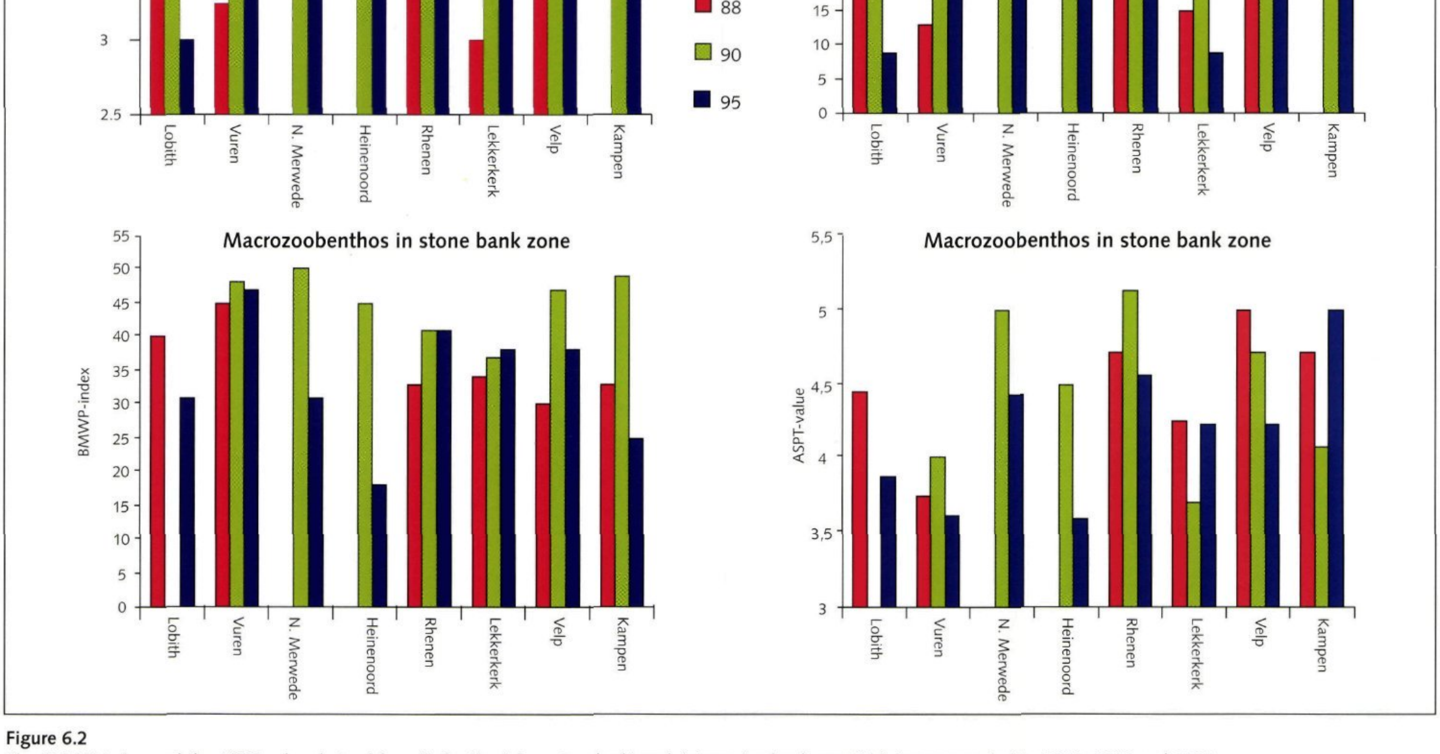


Figure 6.2
The BMWP index and the ASPT value derived from it, for the "deep river bed" and "stone riverbank zone" biotopes, sampled in 1988, 1990 and 1995.

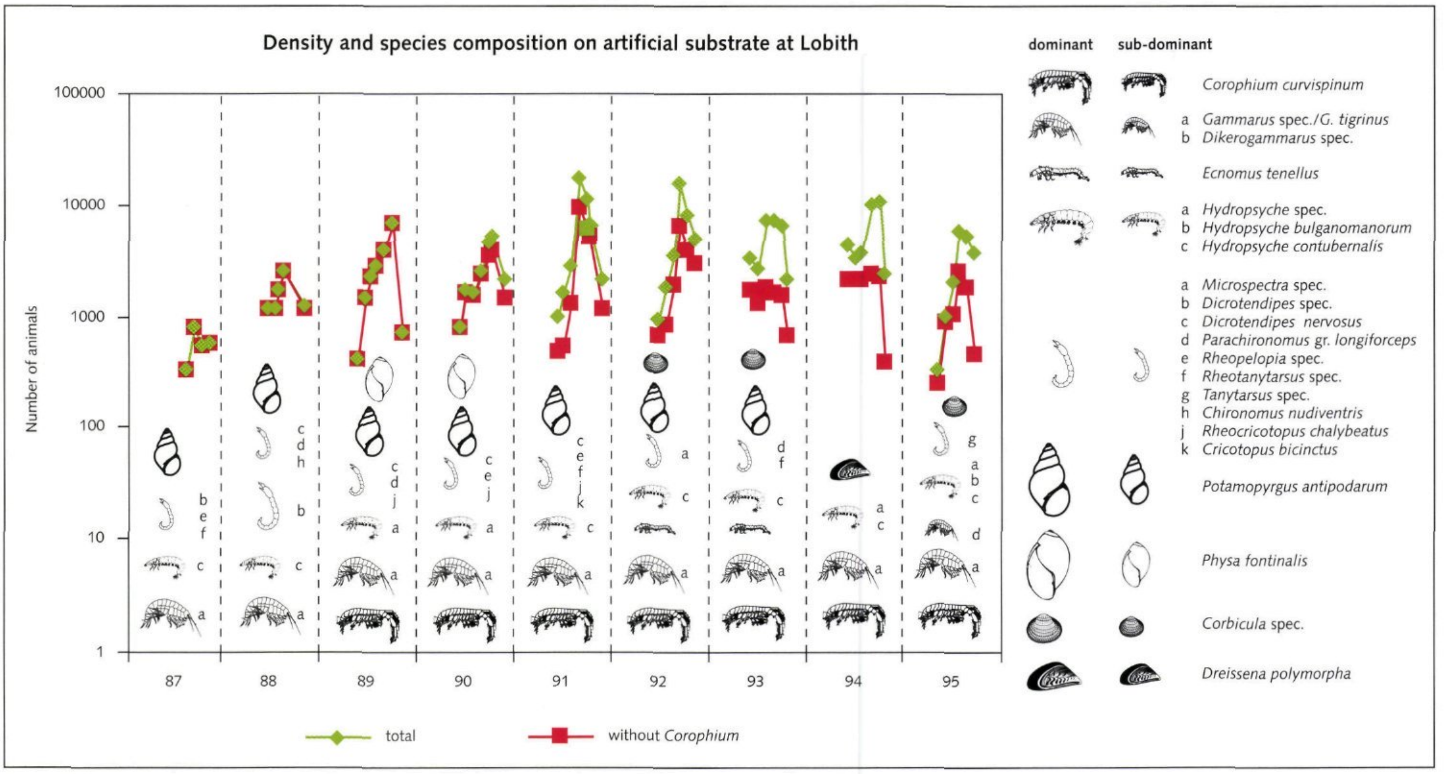


Figure 6.4
Dominant and subdominant taxa and the relative share of the Caspian Sea shrimp *Corophium curvispinum* on the artificial substrate in the Rhine, at Lobith. The figures show all the species that were dominant or subdominant for one or more sampling periods.

mud shrimp does not seem to have affected the dominance of species either. All the organisms are shown that were (sub)dominant on one or more occasions in the different months. The (sub)dominant species are all from the groups crustaceans, caddis-worms, chironomids and molluscs. In interpreting these figures, it must be remembered that the artificial substrate is only in the river for 4 weeks, which means the organisms do not have much time to oust each other. Clean substrate is placed in the water every month, so all the organisms are able to colonize the substrate.

Non-indigenous species

The number of species has clearly increased over the past 25 years, as a result of improved water quality (Van Urk & Bij de Vaate 1990, Van Urk *et al.* 1992, Bij de Vaate *et al.* 1992, Bij de Vaate 1994). The same is true of population densities. However, not all the species that were part of the original Rhine fauna have returned. Various non-indigenous species have established themselves in the Rhine over the years. A total of 32 such species have been found thus far (table 6). This represents more than 15 percent of the number of taxa. The opening of the Main-Danube Canal in September 1992 is the reason for the recent immigrants, which were mainly "Danube species" (Schleuter *et al.* 1994, Bij de Vaate & Klink 1995, Klink & Bij de Vaate 1996). The number of immigrants from the Danube over the next few years is expected to increase further. For instance, a water-louse (*Jaera istri*) from the Danube was also recently spotted in the Main (Schleuter & Schleuter 1995). Colonization of the Rhine by these species can be expected within the foreseeable future.

Target species

The three species selected as targets for the Rhine (Duel *et al.* 1996) were not detected in the Rhine section samples of 1995. However, a specimen of the dragonfly species *Gomphus flavipes* was found along the river Waal at Nijmegen (Habraken & Crombaghs 1997). This dragonfly had not been found in the Dutch section of the Rhine since 1902. The

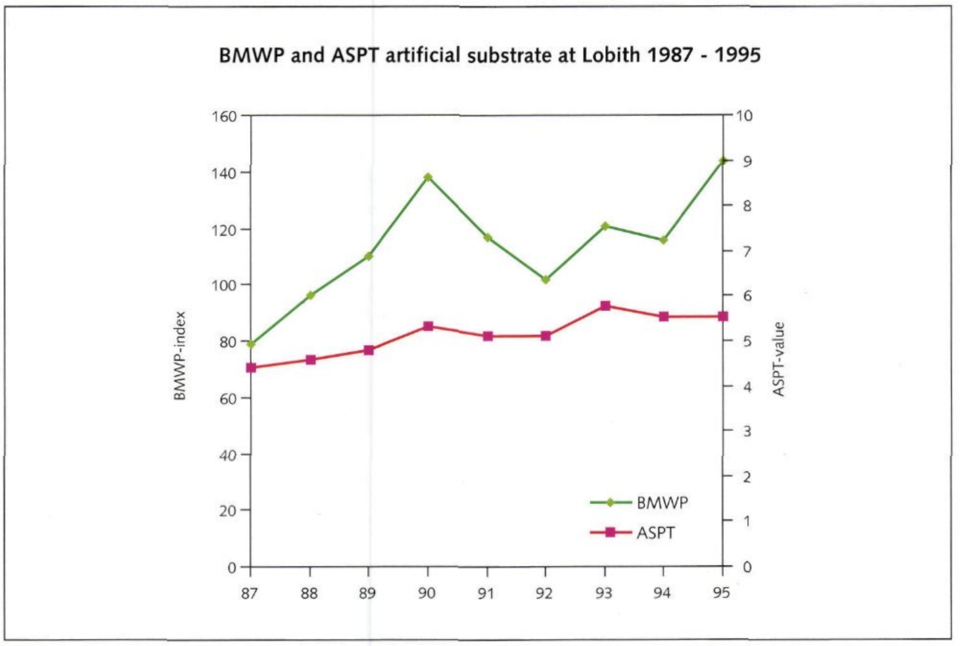


Figure 6.3
The BMWP index and the ASPT value derived from it, for the macrozoobenthos on the artificial substrate in the Rhine, at Lobith, calculated for the years 1987-1995.

Recolonization

An important condition for the river's recolonization with invertebrates is their presence upstream of the Netherlands. Being swept along by the current (known as organism drift), enables them to colonize new areas downstream relatively quickly. Periods with high discharge rates are especially suitable for this, not only because a high discharge in itself is a signal for various species to start to drift, but also because migration under such conditions is not only limited to animals that live in the main channel. The animals that live in the various isolated waters of the floodplains are also then able to populate new habitats. Following the extremely high discharge in the winter of 1994-95, a survey of the recolonization potential was carried out in February/March. This was done by taking samples in thirteen small stretches of water in the floodplains, such as erosion channels, which were created during the extremely high discharge. Studying precisely these stretches of water made it possible to be certain that no existing biocoenosis was being sampled. Around 20 % of the taxa found belonged to the group of species that were scarce or had disappeared from the Dutch section of the Rhine; these included various species of black flies (Simulidae) and may flies (Ephemeroptera). The table shows the list of species. It also shows whether the species was found in paleo-ecological studies and, therefore, whether it was originally found in the Rhine. A large number of these animals are rheophiles (i.e. they thrive in flowing water). The fact that they were not found in the samples taken within the scope of biological monitoring may indicate the absence of suitable habitats in the river's main channel.

Taxon	Habitat[1]	Palaeo[2]	Comments
Crustacea			
Crangonyx pseudogracilis	E		non-indigenous
Dikerogammarus villosus	E		non-indigenous
Gammarus roeseli	E		non-indigenous
Niphargus aquilex	HR		groundwater species
Rhithropanopeus harrisii	E		non-indigenous/brackish species
Ephemeroptera			
Baetis rhodani	LR	+	
Caenis horaria	L	+	
Caenis macrura	L	+	
Caenis robusta	L	+	
Heptagenia sulphurea	LR	+	
Potamanthus luteus	LR	+	
Plecoptera			
Nemoura spec.	LR	+	
Odonata			
Calopteryx splendens	V		
Gomphus vulgatissimus	PS		
Heteroptera			
Aphelocheirus aestivalis	LR	+	
Callicorixa praeusta	V		
Coleoptera			
Agabus nebulosus	V		
Esolus spec.	PS		
Graptodytes pictus	V		
Haliplus flavicollis	V		
Platambus maculatus	V		
Potamonectes canaliculatus	V		
Trichoptera			
Anabolia nervosa	V		
Halesus radiatus	V		
Hydropsyche bulgaromanorum	LR		non-indigenous
Mystacides azurea	PS		
Neureclipsis bimaculata	L	+	
Oecetis notata	LR	+	
Plectrocnemia cf. *geniculata*	LR?		
Polycentropus flavomaculatus	LR	+	
Psychomyia pusilla	LR	+	
Triaenodes bicolor	V		
Chironomidae			
Apsectrotanypus trifascipennis	PS		
Diplocladius cultriger	V		
Parametriocnemus stylatus	PS	+	
Polypedilum convictum	P		
Thienemanniella clavicornis agg.	V		
Thienemannimyia/Meropelopia spec.	PS		
Simuliidae			
Boophthora erythrocephala	R		
Odagmia ornata	R		
Wilhelmia spec.	R		

Photograph 6.4
The dragon-fly *Calopteryx splendens*.

[1] E = Eurytope (indifferent), L = Lithon (stones), LR = Lithorheon (stones in current),
P = Pelon (silty bottoms), PS = Psammon (sandy bottoms), R = Rheon (flowing parts of rivers), V = Vegetation
[2] Found in palaeo-ecological studies (Klink 1989).

Table 6.5
Species of scarce or vanished macro-evertebrates found in new stretches of water in the floodplains of the Rhine and Waal rivers in February/March 1995.

species has also not been observed upstream from the Netherlands, in the main channel (Anon. 1996). *Gomphus flavipes* has a strong preference for sludge-rich sand beds in the riverbank zone. The discovery of this specimen is ascribed to larval drift during a high-water period (see intermezzo).

The freshwater, lithophile gastropod *Theodoxus fluviatilis* (Freshwater nerite) has been absent from the branches of the Rhine for decades. Upstream, the species can be found up to around Cologne (Tittizer *et al.* 1990). In 1995, it was only found in the *Hochrein* and the *Oberrhein* (Anon. 1996). Research in a flume setup along the river IJssel (at Kampen) showed that the Rhine water quality is not the direct limiting factor for the occurrence of *Theodoxus fluviatilis* in the Dutch section of the Rhine (Van Schie 1996). A further study will be necessary to determine whether the species is also capable of breeding.

Finally, the Sand riverbank midge *Lipiniella arenicola* is a species found in eutrophic and hypertrophic, slow-flowing water with a fine, sandy bed and low silt levels (Smit *et al.* 1992, Reinhold-Dudok van Heel en Den Besten, in preparation). They can reach high local counts in the delta area, around Haringvliet, for example (Smit *et al.* 1991, Smit *et al.* 1992). They are not known in the major Dutch rivers (Moller Pillot & Buskens 1990). It is unclear whether they can actually occur in the branches of the Rhine. The fact that *L. arenicola* was not observed in the sections studied is also because their specific habitat was not sampled. The sampled sand beds were either too course or contained too much silt.

Table 6.6
Summary of immigrants currently present in the branches of the Rhine (excluding the brackish zones); °C = thermophile, Cl^- = euryhalien.

	Species	°C	Cl^-	Native of
Hydrozoa:	*Craspedacusta sowerbyi*	+		Eastern Asia
	Cordylophora caspia		+	Ponto-Caspian region
Oligochaeta:	*Branchyura sowerbyi*	+		Cosmopolite
Polychaeta:	*Hypania invalida*	+		Ponto-Caspian region
Tricladida:	*Dugesia tigrina*	+		North-America
Isopoda:	*Proasellus meridianus*			Mediterranean region
	Proasellus coxalis			Mediterranean region
Amphipoda:	*Gammarus tigrinus*	+	+	North-America
	Gammarus zaddachi		+	North Atlantic region
	Dikerogammarus haemobaphes			Ponto-Caspian region
	Dikerogammarus villosus			Ponto-Caspian region
	Echinogammarus ischnus	+	+	Ponto-Caspian region
	Orchestia cavimana		+	Ponto-Caspian region
	Corophium curvispinum	+	+	Eastern Europe
	Crangonyx pseudogracilis			North-America
Decapoda:	*Atyaephyra desmaresti*	+		Mediterranean region
	Palaemon longirostris	+	+	Area around the Atlantic Ocean and the Mediterranean
	Orconectes limosus			North-America
	Astacus leptodactylus			Eastern Europe
	Rhithropanopeus harrisii		+	North-America
	Eriocheir sinensis		+	Eastern Asia
Gastropoda:	*Potamopyrgus antipodarum*		+	New Zealand
	Lithoglyphus naticoides			Ponto-Caspian region
	Physella acuta	+		Mediterranean region
Bivalvia:	*Dreissena polymorpha*			Ponto-Caspian region
	Corbicula fluminea	+	+	Eastern Asia
	Corbicula fluminalis	+		Eastern Asia
Insecta:	*Hydropsyche bulgaromanorum*			Central Europe
	Rheocricotopus chalybeatus	+		Southern Europe
	Nanocladius spec.	+		Southern Europe
	Rheotanytarsus spec.	+		Europe except Northern Europe
	Rheotanytarsus rhenanus	+		Southwest Europe

Conclusions

Various observations lead to the conclusion that there was a definite increase in the BMWP/ASPT index up to 1991. This is an indication of an improvement in water quality. The relatively low BMWP/ASPT figures vis-à-vis the reference suggest low diversity in the sampled biocoenoses. This is an indication of a lack of biotopes in the river's main channel.

Nature restoration projects are underway in which secondary channels are constructed with the aim of restoring the biotopes that originally occurred in the main channel, such as shallow, slow-flowing water. Time will tell over the next few years whether these projects have been successful. Research in the floodplains already shows a lot of promise for the colonization of these biotopes (see box).

Once-only sampling will not be sufficient as more susceptible species of macrozoobenthos become established in the lower reaches of the Rhine. Any relevant changes in biocoenosis composition can also be expected to become visible in the spring. In future, a better picture could be obtained of the differences between individual years from the results of additional sampling in the spring and at the end of the summer.

Macrozoobenthos that were originally non-indigenous play a major role in the Rhine. Currently more than fifteen percent of the total number of species are non-indigenous. Expressing this in terms of percentages of the number of organisms makes the role of non-indigenous species even clearer: non-indigenous species account for 92 % of the total number of organisms. Since 1992, the Main-Danube Canal has provided a new influx of non-indigenous species. However, the introduction of species from elsewhere in the world is also possible, for example, from the ballast water of ships.

Methods

Biotope samples
The major biotopes were sampled in eight different river sections (table 7). The once-only samples were taken in August in accordance with the standard requirements for the MWTL monitoring programme (concerned with monitoring the water drainage situation in the Netherlands). The only biotope that could be sampled in every section was "stones in the riverbank zone". The other biotopes were not of the same importance in each section or were even absent in some cases. For example the "deep gravel bed" biotope is only found upstream. Macrophytes are also not present in sufficient numbers in every section.

Spring samples
Various species of may flies and caddis-worms are almost only ever observed in the spring (Greijdanus-Klaas, in prep.). The monitoring programme was therefore expanded with a survey in the spring, which focused on the occurrence of susceptible species such as black flies, caddis-worms and may flies. The research was conducted in April/June of 1995, at the IRC locations (figure 5). These are locations from which analysis results are also used by the International Rhine Commission (Anon. 1996).

Artificial substrate
Since July 1987, Rhine macrozoobenthos samples have been taken using a standardized artificial substrate consisting of glass marbles (Bij de Vaate & Greijdanus-Klaas 1989). Between April and October each year, samples are taken at four-week intervals. Only four samples were taken in 1987, because sampling only began in July of that year.

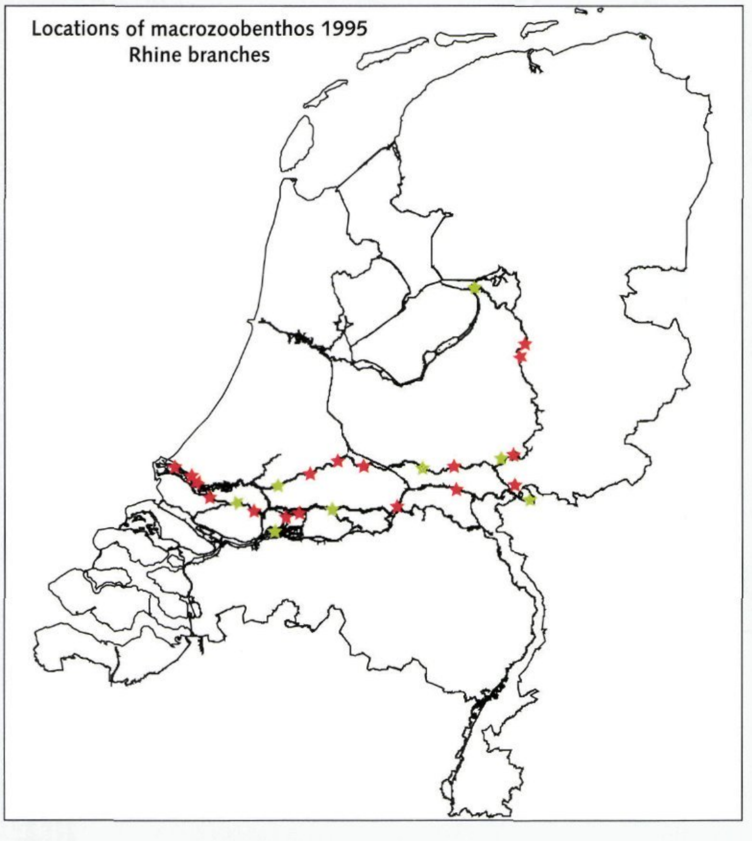


Figure 6.5
Sampling locations, the locations that are also sampled for the International Rhine Commission (IRC locations), are coloured green.

River section	Biotopes					
	deep gravel bed	diepe sand bed	sandy riverbank zone	clayey riverbank zone	stone riverbank zone	macrophytes
Rhine (km 858-868)	+				+	
Waal (km 868-961)	+	+	+		+	
Nieuwe Merwede (km 961-980)		+	+	+	+	+
Oude Maas (km 981-1003)		+	+	+	+	+
Nieuwe Waterweg (km 1011-1028)				+	+	+
Lower Rhine (km 879-947)[1]		+	+		+	+
Lek (km 947-989)		+	+		+	
IJssel (km 879-1005)	+	+	+		+	+

[1] From the geographical point of view, the Lower Rhine becomes the river Lek 929 kilometres downstream, at the intersection of the Amsterdam Rhine Canal). However, for data-processing purposes, the Lower Rhine/Lek has been divided into a weired section, known as the Lower Rhine, and an unweired section, the river Lek. The transition in this case is just below the weir at Hagestein, 947 kilometres downstream.

Table 6.7. Summary of biotopes sampled in the various sections.

Photgraph 6.5
Washed up shells can give a good impression of the mollusc fauna in the river. On this photograph of a short stretch of the high water mark along the Waal at Bemmel shells of *Bithynia tentaculata*, *Dreissena polymorpha*, *Corbicula fluminea* and *C. fluminalis* can be recognized.

7. Fish

Tom Buijse (RIZA) & Wobbe Cazemier (RIVO-DLO)

Introduction

The composition of the fish community and the differences in it that are found in the various branches of the Rhine are described below. In addition to the data from sampling carried out within the scope of the MWTL monitoring programme (concerned with monitoring the water drainage situation in the Netherlands) (see method box)), recently gathered information from nature restoration projects has also been added. This sampling information is additional because it also particularly focuses on the fish community in the floodplain.

The development of the fish community is discussed on the basis of guilds. The division into guilds is based on a preference for spawning substrate, flow, and migration behaviour (Quak 1994). The relationship between the guilds characterizes the water system. Major rivers are generally species-rich systems thanks to the broad diversity of the habitat. On the one hand, there are species that require flowing water for their entire lives, whereas other species are dependent on the times when the river breaches its banks. This enables them to populate isolated waters for the rest of the time, where they breed among the aquatic plants, or alternatively, it enables them to leave the isolated waters for a while and to use the main channel as a means of distributing themselves. A distinction is made between eurytope species (indifferent), limnic species (that thrive on aquatic plants) and rheophilic species (riverine). Eurytope species have no particular preference for flowing or stagnant water; limnic species mainly prefer stagnant water with aquatic plants. The rheophilic species form a larger group and can be further divided into three subguilds ('obligate', 'partial' and 'estuarine'). The obligate rheophilic species depend on the main channel and the riverbank zone of flowing water throughout every stage of their lives; partial rheophilic species are dependent throughout each stage of life on adjacent waters that are permanently connected to flowing waters; estuarine rheophilic species are dependent throughout each stage of life on slow-flowing, brackish

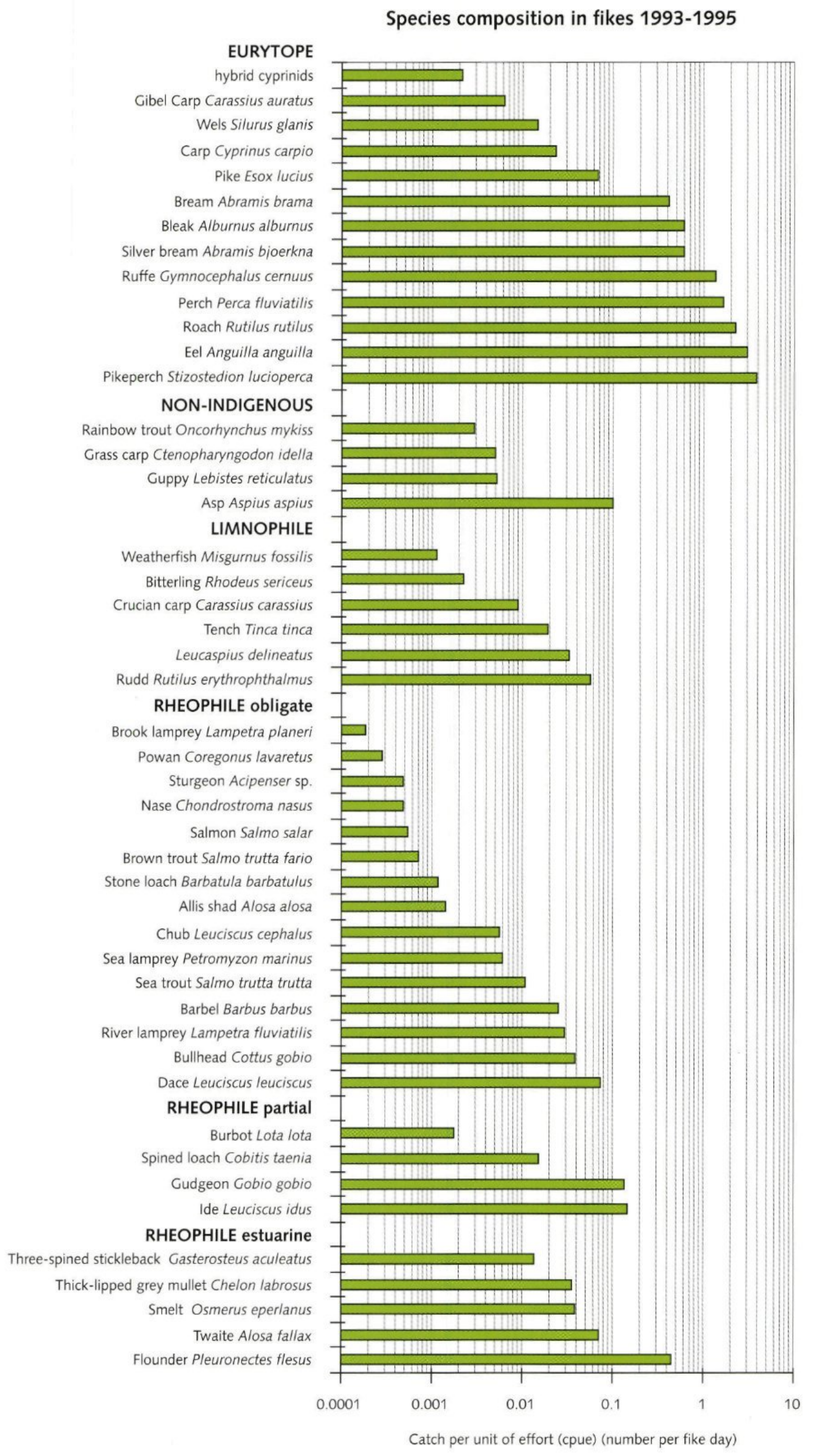


Figure 7.1
The average catch per 24-hour period in the fikes of professional fishermen (cpue, catch per unit of effort) over the period 1993-1995. Forty-two original fish species and four non-indigenous species were found in the branches of the Rhine. Many endangered fish species are found in very small numbers.

water in a permanent open connection between the estuary and the sea. These guilds all have various representatives in major river systems. There are also non-indigenous species, which are discussed separately, because, although they could be classified in these guilds, they are not part of the original indigenous fish community.

Results and discussion

Species composition

The Dutch freshwater fish community includes 46 species (De Nie 1996), plus nine non-indigenous species. Forty-two indigenous as well as four non-indigenous species are found in the branches of the Rhine (figure 1). Of the original 46 indigenous fish species, eight have all but disappeared, 21 are endangered and 17 are not endangered (Dutch Nature Conservancy Council 1994). Of the species found in the branches of the Rhine, among the eurytope species, only the Bleak *Cyprinus alburnus* and Wels *Silurus glanis* are endangered, and of the limnic species, only the *Leucaspius delineatus*, the Bitterling *Rhodeus sericeus* and the Weather loach (*Misgurnus fossilis*). Of the rheophilic species, only the Ide *Leuciscus idus*, Three-spined stickleback *Gasterosteus aculeatus* and the Flounder *Platichthys flesus* are seen as not being endangered. All the other species are endangered or the original populations have become extinct in the Netherlands. However, fish are caught in the Netherlands that are considered as extinct species. These are escapes or originate from release programmes or populations from other rivers. The latter we could see as vagrants or pioneers.

The catches in the fikes show that a large number of species considered to be endangered in the Netherlands are caught in the branches of the Rhine, all be it in small numbers. Of these species Bleak, Gudgeon *Gobio gobio*, Dace *Leuciscus leuciscus*, Twaite shad *Alosa fallax*, Smelt *Osmerus eperlanus*, Bullhead *Cottus gobio*, River lamprey *Petromyzon fluviatilis*, Barbel *Barbus barbus* and *Leucaspius delineatus* are caught in reasonable quantities.

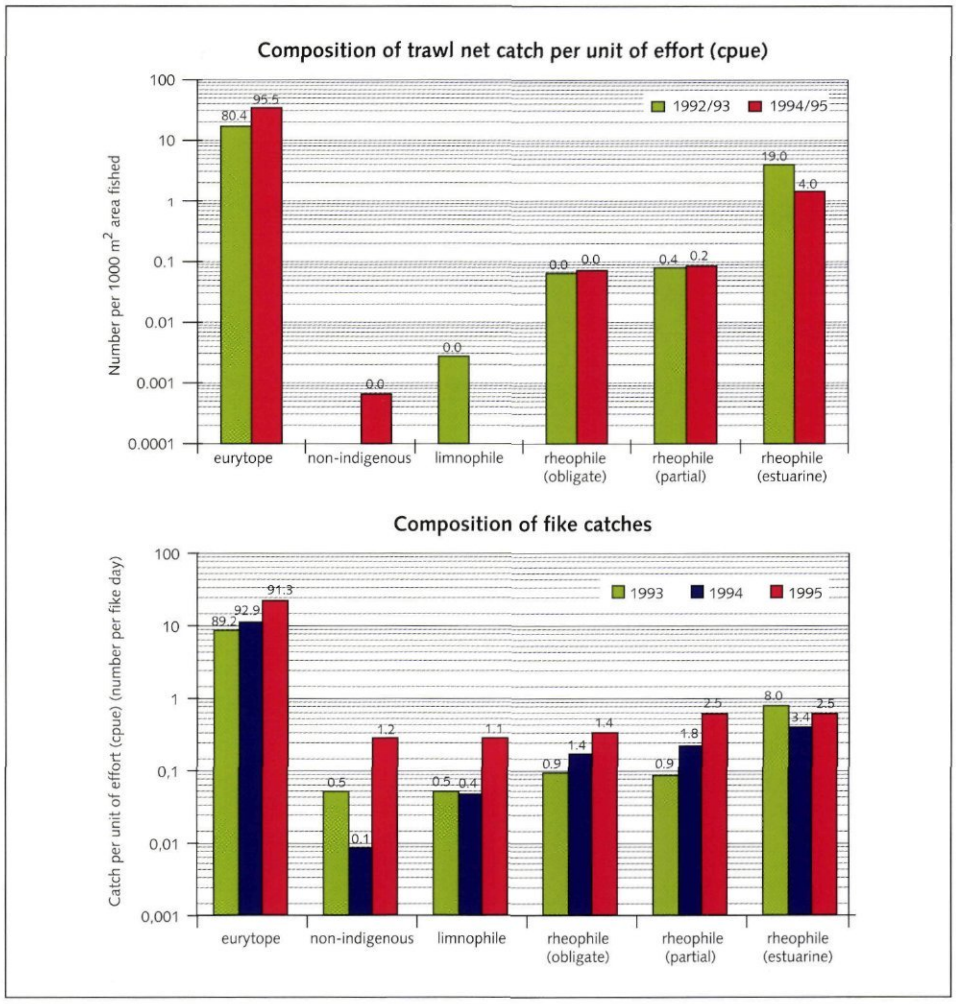


Figure 7.2
The composition of the catch in (a) fikes and (b) the trawl net, divided according to years and guilds. The counts above the bars are the percentages of the total catch. The fish community of the Rhine's branches consists practically entirely of eurytope species, which together account for around 90 % of the catches.

From 1993 to 1995, fike catches increased by a factor 3. The fish community in the branches of the Rhine consists almost entirely of eurytope species, which together account for around 90 % of the catches (figure 2a). Although they dominate the fish community, the interrelationships are not discussed here because they are not typical of the rivers. Limnic species account for less than 1 % of the catches, but are probably underestimated, as the sampling focuses on the main channel and the adjoining waters, whereas these species belong in isolated waters with aquatic plants. Sampling in 14 waters in the floodplain showed greater numbers of limnic fish species were found in this type of water (de Laak *et al.* 1994). In the case of the obligate and partial rheophilic species, there was an increase between 1993 and 1995 in both the numbers and the percentage represented in the catch. Although no far-reaching conclusions can be drawn from this, it is certainly a welcome development. The percentage of estuarine rheophilic species has dropped, but the catches have remained the same. In the case of non-indigenous species, the changes are the result of the rise of the Asp *Aspius aspius* (see intermezzo).

From 1993 to 1995, fike catches of Roach *Rutilus rutilus*, Bullhead, Dace, Chub *Leuciscus cephalus*, Ide and Gudgeon, increased by more than a factor 5, whereas Twaite shad numbers decreased. The changes may have been caused by coincidences or by annual differences in discharge and temperature (hot and cold summers), for example, and may, therefore, not point to a development. Nevertheless, it is advisable to report these findings, although, in view of the short period, it is too early to speak of a trend.

The branches of the Rhine have only been sampled twice thus far with a trawl net (drag-net). This means it is impossible to say anything about trend developments as yet (figure 3). The results paint a hopeful picture that trends

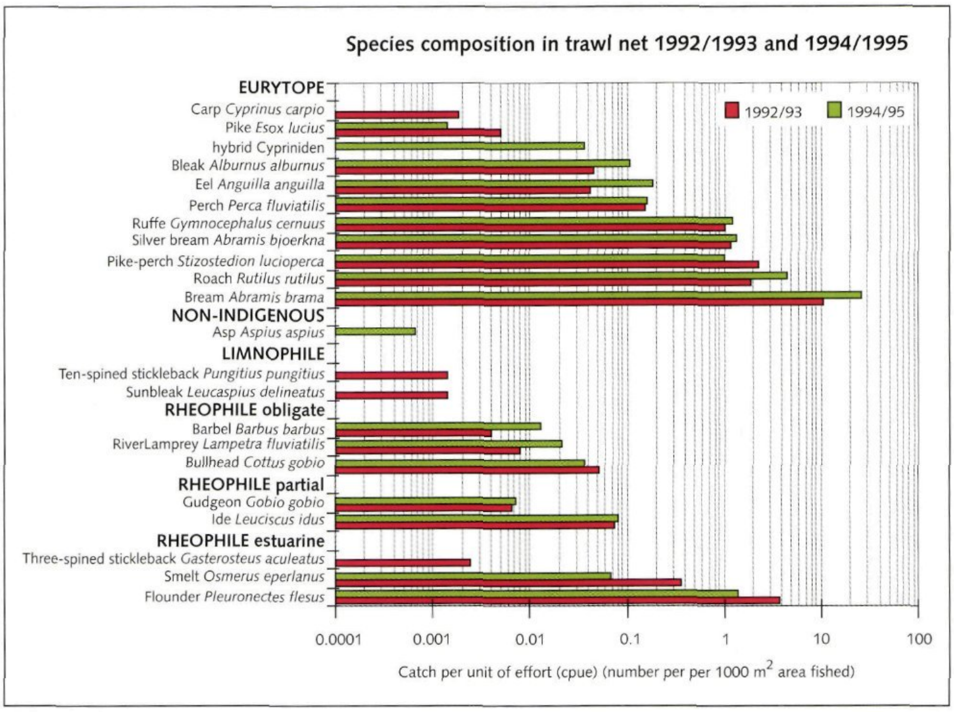


Figure 7.3
Average trawl net catches per 1000 m^2 area fished in the six winter months of 1992/1993 and 1994/1995.

will become visible in due course. The samples taken in the winters of 1992/1993 and 1994/1995 correspond largely with the population densities of very common eurytope species. This suggests that sampling provides a useful reflection of fish levels. Any increase in the numbers of less common rheophilic species should be visible in the catch nets.

However, fewer species were caught using the trawl net than the fikes. At present sampling levels, trawl nets appear to be suitable for catching common species, but not for catching the scarcer ones; all the species with a population density of less than 1 specimen per 50 fike days (figure 1) that were caught were missing in the trawl net catches, with the exception of the two members of the Three- and Ten-spined stickleback *Pungitius pungitius* (figure 3).

Spatial distribution

The Nieuwe Merwede river, which has varied riverbanks, especially in the lower reaches and close to the Biesbosch district, has the greatest richness of species in freshwater fish (figure 4a). The greatest diversity of habitats is found here, together with the Biesbosch district. Although there are only a few open connections between the two areas, exchanges are nevertheless possible. This supports the assumption that increasing habitat diversity would lead to a greater diversity of species. Limnic species and partial rheophilic species are found less often in the Oude Maas and Nieuwe Waterweg than elsewhere; obligate rheophilic species are found less often in the Oude Maas than elsewhere. Estuarine rheophilic species are found more often in downstream than upstream stretches. This is not surprising, because the species found are, on the one hand, Flounder and Thick-lipped grey mullet *Chelon labrosus*, species that spawn in the marine environment and can mature in the brackish tidal area, and, on the other hand, Twaite shad, which, although they spawn in freshwater, are believed not to stray far up the rivers (Taverny 1991, de Groot 1992). It is unlikely that Twaite shad successfully breed in the Netherlands at present.

The sampling using the trawl net does not confirm the picture of species diversity based on the fike catches. In all the branches of the river, the trawl net consistently catches fewer species than the fike, which makes trawl net catches less suitable for providing an overall view of the diversity in the fish community (figure 4b).

Fikes and trawl nets correspond reasonably well in terms of the composition of the fish community in all the river branches (table 1). The eurytope species dominate each branch. Relatively more specimens of non-indigenous species and limnic fish are caught in the fikes, whereas relatively more specimens of estuarine rheophilic species are caught in the trawl net. In the lower river area, from approximately the Boven Merwede and the Lek rivers, the percentage of estuarine rheophilic species increases dramatically. Limnic species were found most often in the IJssel, Lek and Nieuwe Merwede rivers, non-indigenous species mainly in the Nieuwe Merwede. This mainly concerned a large number of Asps (intermezzo). A relatively large number of rheophilic specimens were found in the river IJssel, whereas there appeared to be little

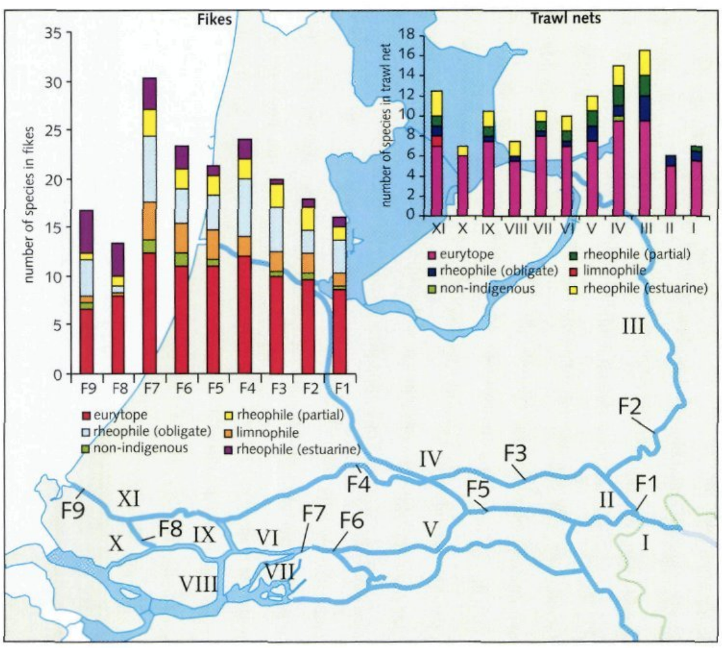


Figure 7.4
The spatial distribution of the number of species over the years, grouped for guilds based on (a) fike and (b) trawl net catches. The differences between the areas can be explained in particular by the diversity of habitats, the presence of barriers and penetration by saline water.

River branch	Eurytope		non-indigenous		Limnophile		Obligate rheophilic		Partial rheophilic		Estuarine rheophilic	
	fike	trawl net	fike	trawl net	fike	trawl net	fike	trawl net	fike	trawl net	fike	trawl net
Upper Rhine	****	*****	*	0	**	0	**	***	**	**	**	0
Pannerdens Canal	-	***	-	0	-	0	-	**	-	0	-	0
IJssel	*****	*****	**	0	***	0	***	***	***	***	***	****
Lower Rhine	****	*****	*	*	**	0	**	**	**	***	*	***
Lek	*****		0		***		**		***		***	
Waal	****	****	*	0	**	0	**	**	**	**	**	**
Boven & Beneden Merwede	-	*****	-	0	-	0	-	**	-	**	-	****
Nieuwe Merwede	*****	*****	***	0	***	0	**	**	***	**	***	****
Dordtse Kil	-	****	-	0	-	0	-	**	-	0	-	****
Oude Maas	*****	*****	0	0	**	0	**	**	**	**	***	****
Spui	-	****	-	0	-	0	-	0	-	0	-	***
Nieuwe Maas & Nieuwe Waterweg	****	*****	*	0	*	**	***	**	**	**	****	*****

Table 7.1
The numerical abundance of guilds of fish species in the river branches on the basis of fike catches per 24-hour period from 1993 to 1995 and trawl net catches per 1000 m^2 area fished in the six winter months of 1992/1993 and 1994/1995.
'0' < 0.001 < * < 0.01 < ** < 0.1 < *** < 1 < **** < 10 < *****, - = not sampled

difference between the weired Lower Rhine/Lek and Waal rivers. The major difference between the Lower Rhine and the Lek in the numbers of estuarine rheophilic fish species suggests the weirs act as a barrier to migration upstream.

Nature restoration projects in the floodplains

The greater part of the present river area is characterized by solid transitions from land to water. The winter dykes protect the land behind them against inundation and the summer dykes ensure the main channel has sufficient depth for shipping. At the same time, the summer dykes separate the main channel and the floodplains, which means there is no dynamic transitional zone between the land and water. This results in a uniform main channel with little variation in habitats and flow rates. The floodplain is characterized by a large number of isolated stretches of water, which flood more abruptly and less often than they would in a natural situation; adjoining waters are scarce and there were no secondary channels until recently. The nature restoration projects that are underway along the major rivers involve, amongst other things, lowering or cutting through summer dykes, to link stretches of water to the rivers, or the construction of secondary channels. The assumption is that the fish community will benefit from this (Schouten & Quak 1994). The initial results are promising (Krekels & Verbeek 1994, Verbeek *et al.* 1995). At two locations along the river Waal, where admittedly small, but what is important, flowing secondary channels have been constructed, the result has been a major increase in the percentage of obligate and partial rheophilic fish species (figure 5). Samples from waters in the floodplain, which differ in depth, inundation frequency and vegetation, have shown that limnic fish species are mainly found in floodplain waters with vegetation and a low inundation frequency (de Laak *et al.* 1994). Only low population densities of limnic species occur in the main channel (figure 1). This means that vegetation-rich waters in the floodplain play an important role. It would be advisable for nature restoration projects to focus on floodplains with a high inundation frequency. The present frequencies are relatively low. Cutting through the summer dykes to create flowing secondary channels seems to offer realistic possibilities for growth in the populations of rheophilic fish species.

Salmonids and other anadromous migratory fish

Since 1994, the migration of salmonids and other anadromous migratory fish has been monitored in the spring and autumn at three locations, in the rivers Lek (weir at Hagestein), Waal (Woudrichem) and the Maas (weir at Lith) (Cazemier 1995). These are species that hatch in fresh water and then migrate to the sea to mature, after which they make the return journey as adults. Examples include Salmon *Salmo salar*, Sturgeon *Acipenser sturio*, Twaite shad and River lamprey. Samples are taken using salmon nets, course mesh nets that are placed across the river's current. As of 1997, this sampling procedure will be a fixed part of the MWTL monitoring programme. In 1994 and 1995, a few dozen salmon and hundreds of sea trout were caught (table 2). They are put

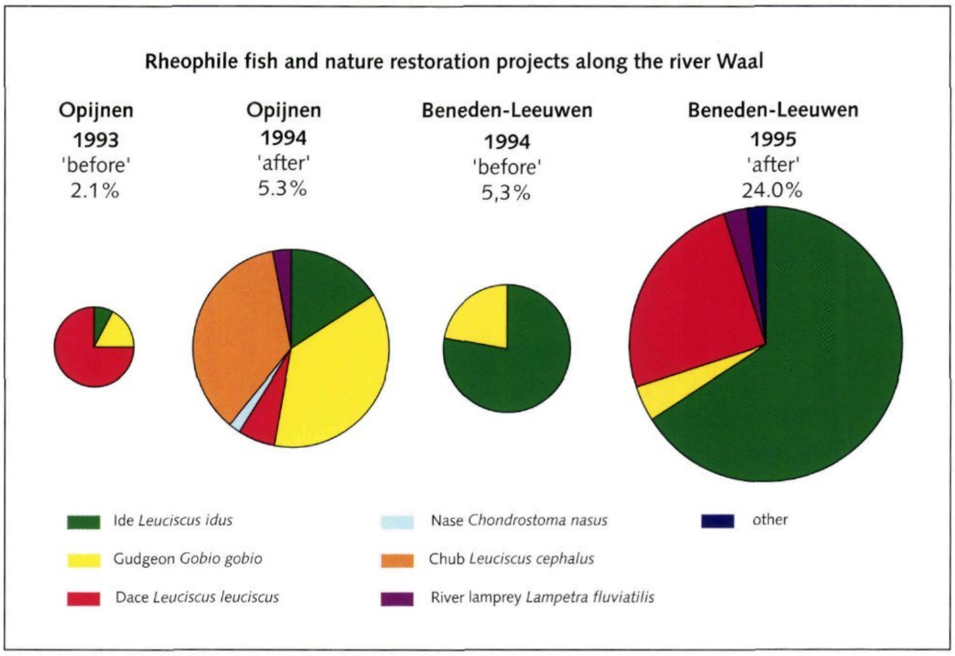


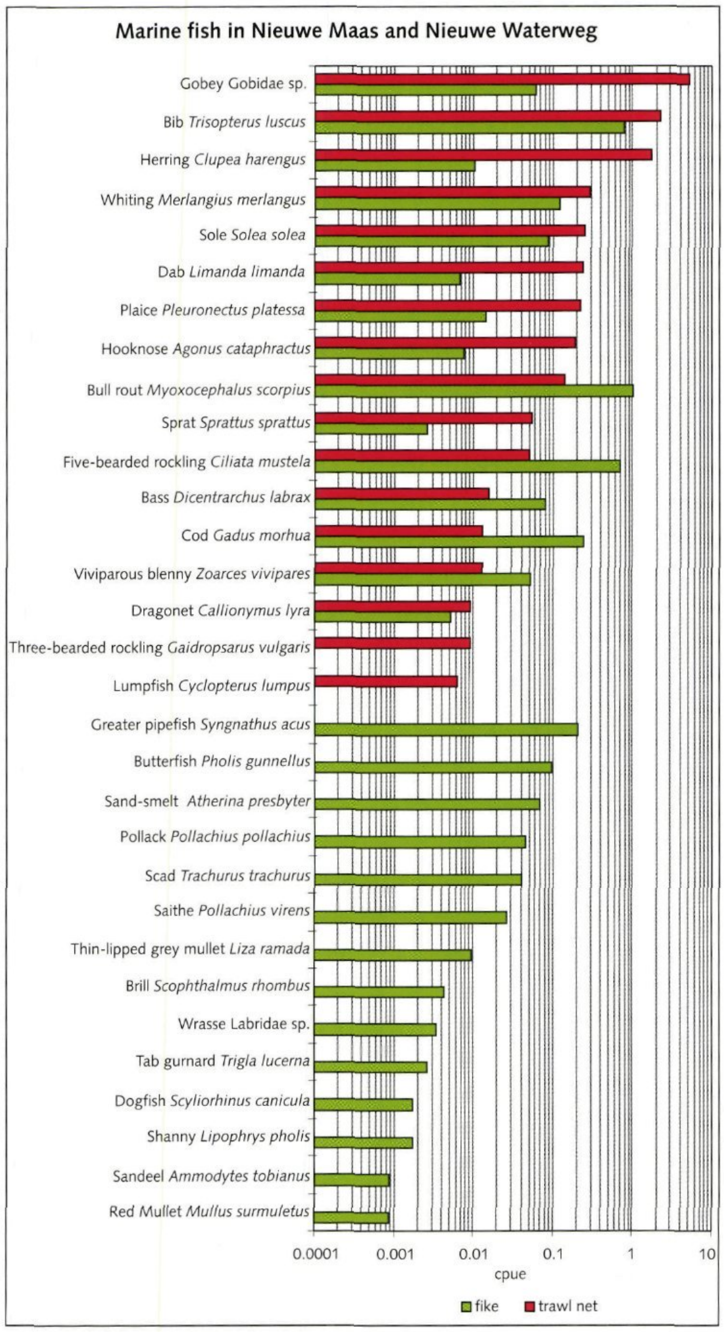
Figure 7.5
The increase in the percentage of obligate and partial rheophilic fish species shortly after the construction of the flowing secondary channels in the nature restoration projects along the Waal river at Opijnen and Beneden-Leeuwen.

back after being measured and also often marked. The marking programme is intended to provide information about migration routes. There have already been a few reports.

Marine species in the Nieuwe Waterweg

Besides the freshwater fish species, a large number of marine species are also found in the Nieuwe Waterweg (figure 6), 31 species in total. This makes it the most species-rich water of the branches of the Rhine. Marine species accounted for around 30 % of the trawl net catch, including Goby Gobiidoe, Bib *Trisopterus luscus* and Herring *Clupea harengus*; the figure for the fike was around 50 %, with mainly Bull rout *Myoxocephalus scorpius*, Five-bearded rockling *Ciliata mustela* and, again, Bib. We ought not to attach too much significance to this large number of species. The Nieuwe Waterweg is an uninteresting canal with very little variation in habitat. However, it is extremely important that it currently provides the only permanently open link between the North Sea and the Rhine and Maas rivers. This means it fulfils a role in the migration of fish between freshwater and saline water, which has been lost in other places.

Figure 7.6
The average catch of marine fish species in the Nieuwe Waterweg and Nieuwe Maas in the fikes of professional fishermen (per 24-hours in 1995) and the trawl net (per 1000 m^2 area fished in the six winter months of 1992/1993 and 1994/1995) (cpue, catch per unit of effort). The Nieuwe Waterweg is important because it currently provides the only permanently open link between the North Sea and the Rhine and Maas rivers. This means it fulfils a role in the migration of fish between freshwater and saline water, which has been lost in other places.



Conclusions

Almost the entire range of freshwater fish fauna is found in the branches of the Rhine. Indifferent species dominate the fish community. The most endangered species are only found in low population densities.

It is assumed that the limited habitat diversity and, to a lesser degree, the quality of the water, are the most important problems impeding the development of a fish community with the closest possible resemblance to the one that originally existed. Nature restoration projects in which the dynamic transition zone between land and water is restored can make an important contribution to this.

Table 7.2
The catches of salmonids and other anadromous fish species in salmon nets at three locations in the Rhine and the Maas rivers, in the spring and autumn of 1994 and the spring of 1995.

Location	Period	Species				
		Salmon *Salmo salar*	Sea trout *Salmo trutta*	Rainbow trout *Oncorhynchus mykiss*	Twaite shad *Alosa fallax*	"Sturgeon"
Lek						
(weir at Hagestein)	spring 1994	1	29	1	1	
	autumn 1994	10	24	3		1
	spring 1995	11	78	1	4	
Waal						
(at Woudrichem)	spring 1994	14	71	6	2	
	autumn 1994	1	11	4	2	
	spring 1995		20	2		
Maas						
(weir at Lith)	spring 1994		7	1		
	autumn 1994	6	59	2		
	spring 1995	1	53			

Method

The fish community is routinely sampled by the National Fisheries Research Institute (RIVO-DLO) using a trawl net and with the cooperation of professional fishermen with fikes. Fish levels are sampled at eight locations along the branches of the Rhine using fikes. These waters have also all been sampled using trawl nets. Another four river branches are likewise sampled using trawl nets. The fikes are at fixed locations; trawl nets are used to take samples at many places (Wiegerinck *et al*. 1995, 1996) (see table).

When the trawl net is used to take samples, a distinction is made between three habitats. In the main channel, samples are taken in the central section and along the riverbank, however, always where the water is at least 1 metre deep. Samples are also taken in adjacent waters where there are open links to the river and where the research ship can navigate. Shallow adjoining waters and isolated waters in the floodplain are not sampled in this way within the scope of the MWTL monitoring programme. This has consequences for the given species composition, because these types of waters contain habitats for limnic species. The waters and the associated fish community are characteristic of a river's inundation area (Schiemer & Waidbacher 1992).
The method employed indicates how the results can be used. Catches from fishing tackle do not provide an overall view of the total extent of the fish community. The picture is made more complete using various methods. As with any fishing tackle, fikes and trawl nets catch fish selectively according to species and size. The species and size composition of the catches therefore currently provide the best possible but also a distorted picture of the fish community (Daan 1996). Using the same fishing tackle in different waters makes it reasonably possible to compare the differences between the waters. In addition, when a time range has been built up, changes in the numbers of a fish species or guild of fish species can be described. The time range is still short at the moment. Fike sampling was set up in 1987 and the present setup went into use in 1993. Trawl net sampling was carried out in 1992.

Table 7.3
Overview of river-section sampling using the fikes of professional fishermen and the trawl net.
s = side; m = middle; a = adjoining adjacent water; - = not sampled

	Fike			Trawl net	
River branch	**1993**	**1994**	**1995**	**1992/93**	**1994/95**
Upper Rhine	1	1	1	s-a	sma
Pannerdens kanaal	-	-	-	---	sm-
IJssel	1	1	1	sma	sma
Lower Rhine	1	-	-	sma	sma
Lek	1	1	-		
Waal	2	2	2	sma	sma
Boven & Beneden Merwede	-	-	1	sma	sma
Nieuwe Merwede	1	1	1	sm-	sm-
Dordtse Kil	-	-	-	-ma	-ms
Oude Maas	1	1	1	-ma	sma
Spui	-	-	-	---	sm-
Nieuwe Maas & Nieuwe Waterweg	1	1	1	-ma	sma

Photograph 7.1
In addition to the MWTL biological monitoring programme data on fish is sometimes gathered within separate or related projects, like in this case in an oxbow lake along the river Waal.

The Asp *Aspius aspius*: a new piscivor in the inland waters of the Netherlands
(Tom Buijse)

The Asp did not originally occur in the Rhine's catchment area. Although the first report in the Netherlands came from the river Roer, in Limburg, in 1984, there have been few reports of the Asp in the river Maas since then. Until recently, the Asp only occurred in Europe east of the Elbe, in rivers that discharge into the Baltic Sea, the Black Sea and the Caspian Sea. There are various non-exclusive explanations for its occurrence in the Rhine's catchment area. Releases in Germany and the construction of the Rhine-Main-Danube canal play a role (De Nie 1996). The spectacular increase in the Netherlands is now occurring via the Rhine's catchment area. From 1993 to 1995, the numbers grew by a factor 10 on average. In 1995, the professional fisherman cooperating in the MWTL monitoring programme caught 474 specimens in the Nieuwe Merwede river, which it is true, is only a tiny number in comparison with the other 60,000 fish he caught and registered. The Asp has also reached lake IJsselmeer via the IJssel river.

From April to June, the Asp spawns on the stony bed which is swept by the current. Unlike other cyprinids, after feeding as a juvenile on zooplankton and invertebrates, the Asp develops into a true piscivor. Mature Asps are solitary, dwell near the surface and live on small fish. They can grow up to a metre long. The species lives in the lower reaches of rivers and sometimes also in dead branches.

In the Danube, the Asp lives alongside Pike *Esox lucius*, Pike-perch *Stizostedion lucioperca* and Wels. The Asp is therefore not expected to oust these species from Dutch rivers; a new piscivor has joined the fish community. If the Asp continues its spectacular expansion, anglers will soon be able to look forward to catching a fantastic species.

Photograph 7.2
The Asp, which was not part of the Dutch ichtyofauna until very recently, now appears to be able to reproduce in the river Rhine.

8. Amphibians

Raymond Creemers[1], Ben Crombaghs[2] & René Krekels[3]

[1]Stichting RAVON (Research into Reptiles, Amphibians and Fish in the Netherlands), [2]Limes divergens (Consultancy for Nature Conservation and Landscape), [3]Bureau Natuurbalans (Consultancy for Ecology and Education)

Introduction

The life cycle of amphibians is played out in the water as well as on the land. The floodplains of the branches of the Rhine are rich in potential breeding waters for amphibians. The degree to which these waters can be used by the various species for successful breeding depends on the quality of both the aquatic biotope and the terrestrial biotope. In river ecosystems, the aquatic biotope's suitability for breeding is largely determined by the inundation frequency of the waters (Creemers, 1994a). Suitable terrestrial biotopes for amphibians are characterized by well-developed structural variations. Places out of reach of high water are also essential for some species to enable successful hibernation.

Nature restoration in floodplains is combined with interventions in the aquatic and terrestrial biotopes. The consequences of nature restoration projects will therefore be seen in a changing spectrum of species and the population densities in which they occur. This chapter examines the distribution of the species in floodplains of the branches of the Rhine, the ecological requirements of the species, and the current value of some nature restoration project areas and nature conservation areas along the branches of the Rhine.

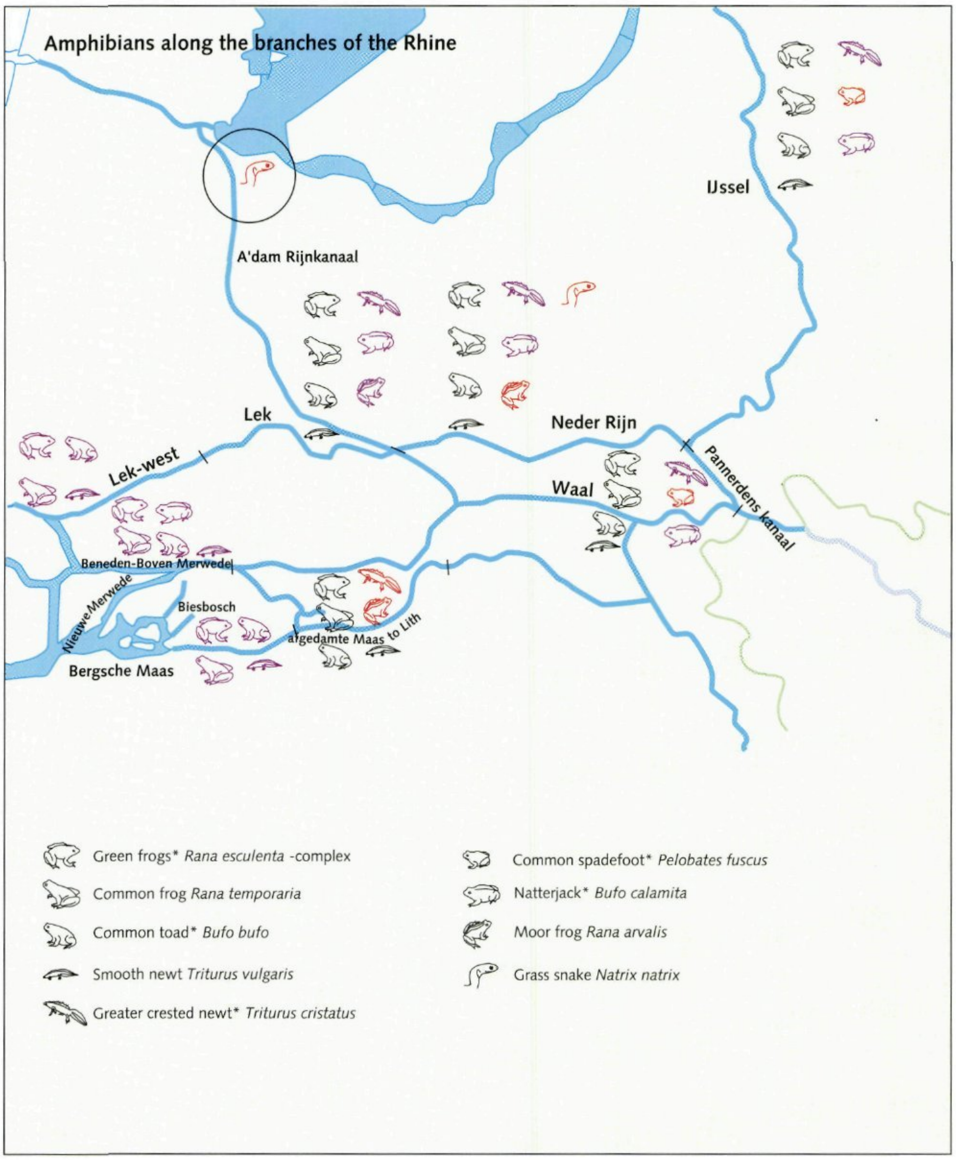


Figure 8.1
Overview of the occurrence of amphibians along the branches of the Rhine in the Netherlands. Of the 16 species that occur in the Netherlands, a total of 10 occur here. Of these, five species are classified as riparian species.(*)
black = common, purple = uncommon, red = rare

Results

Sixteen species of amphibians occur in the Netherlands, 10 of which occur in the floodplains of the branches of the Rhine (Creemers *et al.* 1996). The distribution of these species is shown in figure 1. On the basis of their presence in the floodplains of the branches of the Rhine, the species can be divided into five common species (Edible frog *Rana esculenta*, Lake frog *Rana ridibunda*, Common frog *Rana temporaria*, Common toad *Bufo bufo*, Smooth newt *Triturus vulgaris*), one less, common species (Natterjack toad *Bufo calamita*) and four rare species (Pool frog *Rana lessonae*, Greater crested newt *Triturus cristatus*, Common spadefoot *Pelobates fuscus* and Moor frog *Rana arvalis*).

Common species

Of the five common species, four occur in equal numbers along all the branches of the Rhine. One species is more prevalent in a particular region. The Edible frog, Common frog, Common toad and Smooth newt are common species in the floodplains of all the branches of the Rhine. These four species are also common throughout the country. They are known to occur in more than half of all the five x five kilometre grid squares used in the Netherlands to estimate the rarity of species. They occupy 30 to 60 % of all the waters studied in the floodplains. They actually breed in 25 to 35 % of these waters (Creemers 1994a). The floodplains and the area around the rivers form an important centre of prevalence for the Common toad and the green frogs (Edible, Lake and Pool frog) in their distribution throughout the country.

The Lake frog mainly occurs in floodplains in the western Netherlands. This species clearly thrives best in the watery part of the Netherlands, which is below sea level. In the floodplains of the Waal and Lek rivers, in the western Netherlands, the Lake frog often replaces the Edible frog. On the basis of the criteria adopted

Species	Distribution			Centre of prevalence	Red List status	Occurrence	Decline	Importance of floodplains
	Waal	IJssel	Rhine					
Riparian species								
Common toad *Bufo bufo*	***	***	***	1	not currently endangered	65 %	14 %	+
Natterjack toad *Bufo calamita*	***	***	***	1	not currently endangered	64 %	15 %	+
Edible frog[a] *Rana esculenta*	**	**	**	1	not currently endangered	26 %	40 %	+
Greater crested newt *Triturus cristatus*	**	**	**	2	vulnerable	17 %	35 %	(+)
Common spadefoot *Pelobates fuscus*	*	*		2	endangered	2 %	62 %	(+)
Neutral species								
Common frog *Rana temporaria*	***	***	***	1	not currently endangered	74 %	10 %	0
Smooth newt *Triturus vulgaris*	***	***	***	1	not currently endangered	57 %	18 %	0
Lake frog[b] *Rana ridibunda*	***	*	***	3	not currently endangered	>9 %	<25 %	?
Pool frog[c] *Rana lessonae*	**	**	**	2	vulnerable	>11 %	>25 %	0
Moor frog *Rana arvalis*			**	1	vulnerable	21 %	32 %	0

Distribution in and around the floodplains of the various branches of the Rhine:

*** common, occurs especially in the western part of the branch of the Rhine concerned
** uncommon, occurs especially in the western part of the branch of the Rhine concerned
* rare

Centres of prevalence : 1= throughout the Netherlands; 2=Pleistocene grounds, 3=Holocene grounds
Occurrence : percentage of occupied five x five kilometre grid squares used to estimate the rarity of species (total of 1677 five x five kilometre grid squares) in the years 1985-1994
Decline : reduction in number of occupied five x five kilometre grid squares used to estimate the rarity of species vis-à-vis the reference period before 1950.

Importance of floodplains for the species:

+ : floodplains fulfil an obvious current function as a key area;
(+) : seldom if ever overflowing waters in floodplains and in the immediate vicinity are of major importance as a current or as a potential key area
? : unknown
0 : floodplains not of specific importance; the species has no specific preference for areas inside or outside dykes

a,b,c : one hybrid and two species jointly form the green frog complex

Table 8.1
Overview of the occurrence of amphibians in and around the floodplains of the branches of the Rhine, the status of the species and the situation in the country as a whole. The table shows the distribution in and around the floodplains in the three branches of the Rhine, the centre of prevalence in terms of national distribution, the Red List status, the occurrence in the five x five kilometre grid squares, the decline (present period 1985-1994 vis-à-vis the reference period before 1950) and the importance of floodplains for the species. Floodplains are mainly of specific current or potential importance for the first five of the species mentioned.

in the Red List (Creemers 1996), all the aforementioned species are currently classified as non-endangered amphibians in the Netherlands (see table 1).

Less common and rare species

The less common and rare species that occur in the floodplains of all the branches of the Rhine are the Natterjack toad (less common), and the Greater crested newt and Pool frog (both rare). The Moor frog and the Common spadefoot are both rare species with a distribution limited to the floodplains of one or two branches of the Rhine (table 1). The Moor frog is only found along the Lower Rhine/Lek (Creemers 1991), whereas the Common spadefoot is mainly limited to the floodplains and adjoining areas along the IJssel river. The species is only known to occur at one location along the river Waal (figures 1 and 2). The occurrence in floodplains of the Moor frog and the Common spadefoot is largely determined by the radiating effect of major centres of prevalence in their national distribution (see Bergmans & Zuiderwijk 1986). The type of landscape behind the dykes and the presence and robustness of populations in the adjacent area within the dykes is a greater factor in the occurrence of these species than the differences between the floodplains of the branches of the Rhine.

The Natterjack toad currently occurs in 26 % of the five x five kilometre grid squares used in the Netherlands to estimate the rarity of species, which means it is not classified as an endangered species (Creemers 1996). However, since 1950, the species has disappeared from 40 % of its original distribution area and is therefore declining rapidly. If the species continues to decline at the same rate, it will be classified as a vulnerable species within a few years. The Greater crested newt, Pool frog and Moor frog are classified as vulnerable species (rate of decline 25-50 %; current occurrence 5-25 %), whereas the Common spadefoot is considered as an endangered species (rate of decline 50-75 %; current occurrence 1-5%).

Discussion

The importance of floodplains

Owing to the large populations that occur, the river area and the floodplains provide an important centre of prevalence in the national

Photograph 8.1
The Common spadefoot predominantly occurs on the floodplains of the river IJssel.

Utrecht 1986). Most of the data is more recent (Willink & Cuppen 1993, Creemers 1994a and 1994b, Smit 1994).

Historical data on the occurrence in floodplains of the Greater crested newt, Smooth newt, Moor frog, Common frog, Lake frog and Pool frog is so incomplete that no conclusions can be drawn about any decline that may be occurring in these species in the floodplains of the branches of the Rhine.

A number of distribution summaries appeared in the nineteen seventies for the Common toad (Van den Bergh & Stumpel 1978), Natterjack toad (Van den Bergh & Stumpel 1975) and for Edible frogs (Van den Bergh & Stumpel 1977). A striking fact is that, in the past, the Natterjack toad was very common in the floodplains of the branches of the Rhine. The species is currently only common on a local basis and appears not distribution of the Common toad and Edible frog. The species are therefore classified as riparian (see table 1).

The national distribution pattern for the Natterjack toad, Greater crested newt and Common spadefoot shows that they are found relatively often in river and stream valleys (Lenders 1989, Creemers *et al.* 1996). These species are therefore also classified as riparian.

The Natterjack toad also clearly thrives best in the floodplains themselves. The Greater crested newt and Common spadefoot prefer waters that flood very infrequently, if at all. Waters in sections of floodplains with no embankments meet the minimum requirements of these critical species rarely (Lower Rhine/Lek), if ever (Waal and IJssel). It is therefore not surprising that, along the more dynamic branches of the Rhine (Waal and IJssel), the most robust populations of these species have largely been driven back to waters in sections of the floodplains with embankments and, within the dykes, to the waters at the base of the dyke.

Historical data on amphibians in floodplains

Distribution research on amphibians in floodplains only got properly underway in the early eighties (Frigge 1981, Provincial Department of Public Works and Water Management (PWS)

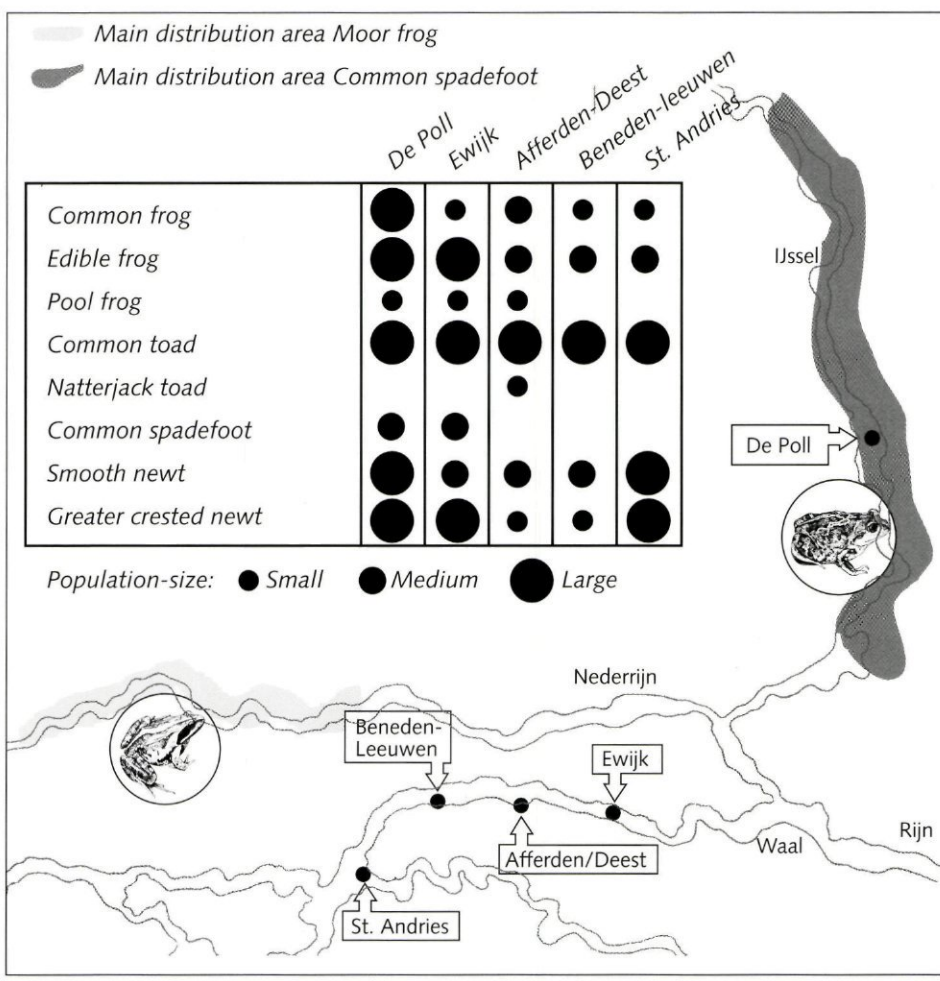


Figure 8.2
Amphibian population sizes in five model areas. The regional centres of prevalence are also shown for the Common spadefoot and the Moor frog. These locations largely determine the occurrence of the Common spadefoot and/or Moor frog in and around floodplains.

The effect of small-scale nature restoration projects

Compensatory measures for amphibians at Ewijk

During the Weurt-Deest dyke improvements in 1993, the breeding water of the Greater crested newt and Common spadefoot inside the dykes was banked up and two new pools were constructed in the vicinity.
Six species of amphibians occurred in the original breeding water, but increasing drying out of the ground and a falling water table meant that breeding was not always successful. The restoration work focused on maintaining and restoring the amphibian populations and concentrated in particular on rare species.
Even shortly after the work's completion it became clear that the Greater crested newt and Common spadefoot were reproducing more successfully. The number of larvae caught of both species and the species diversity in general showed a definite positive response from 1993 onwards (graphs below). The population of the Common spadefoot, which had a very high average age, now has a more healthy composition thanks to successful breeding in 1993, 1994 and 1995 (graphs on right).
Pool frogs were also observed for the first time in 1995, which increased the species diversity to 7 species.
Within the first year of the construction of the new pools (1992), four species of amphibians were observed, including the Greater crested newt.
The success at Ewijk is one of the many examples of how relatively limited intervention in the river landscape can bring about significant results in the battle to maintain endangered species of amphibians in the river landscape. However, it is necessary to establish the right initial conditions to ensure the successful (re)colonization of endangered species. These species are classified as endangered with good reason: their aquatic and land biotope requirements are high. If the requirements are not satisfied, colonization cannot take place. This means that major nature restoration projects should pay individual attention to the possibilities for establishing amphibian populations.

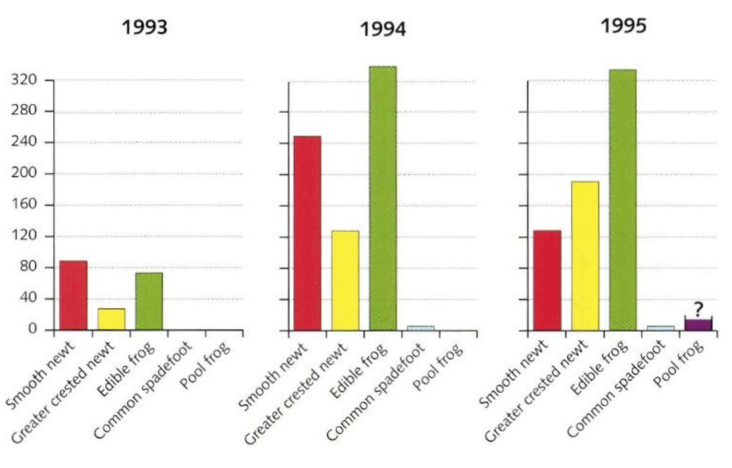


Figure 8.3
In the period from 1993 to 1995, standardized research was conducted into the reproduction success of 5 of the 7 species of amphibians that occur in Ewijk.
It emerged that restoration work resulted in a sharp increase in the successful reproduction of endangered species such as the Greater crested newt and the Common spadefoot.

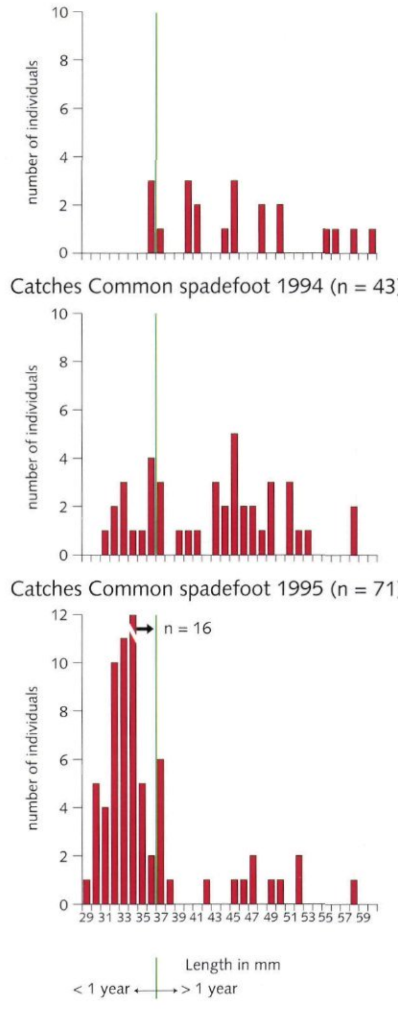


Figure 8.4
After the restoration work on the breeding water, there was an obvious increase in the number of juvenile Common spadefoot frogs (< 37 mm) caught.

to achieve the population densities it is known to have achieved in the nineteen seventies. It is unclear whether this is connected with a lack of specific counts of this species or with natural number fluctuations within populations. However, in view of the pioneer character of this species, an obvious contributory factor is the decline in the number of suitable breeding sites since that time, owing to a reduction in the number of clay excavation operations in floodplains, which has led to a structural decline. Nature restoration projects in the areas around the rivers can be expected to provide the species with new opportunities. Here too, the highest population densities will mainly be reached shortly after the execution of the projects. With the decline in the dynamics and pioneer situations, populations will again decline in numbers or even disappear completely.

Extensive research was conducted in 1995 into the occurrence of the Common spadefoot in the valley of the IJssel river (Creemers & Crombaghs 1995). This area has long been recognized as one of the key areas for this species in the Netherlands. The Common spadefoot is mainly found around the transition from floodplain to higher sandy ground, where ponds, canals, ditches and pools are used for breeding. There were three known sites where the species occurred in the floodplains of the IJssel river. However, after 1992, there was no longer any evidence that the species was actually breeding in the floodplains. The species has probably disappeared as a result of the extremely high waters in 1993 and 1995. On the basis of a count using one x one kilometre grid squares, the Common spadefoot is estimated to have declined between 57 and 82 % in the IJssel valley (inside and outside the dykes). This trend is of the same order of magnitude as the national trend based on a count employing the five x five kilometre grid squares used to estimate the rarity of species in the Netherlands.

Ecological requirements for habitats

A serious problem faced by all amphibians in terms of population densities is the absence of a suitable land biotope. Where there is a lack of brushwood, thickets, wooded banks and floodplain forests, most species only occur in low population densities. In agricultural floodplains, there is often such a lack of terrestrial biotope that amphibians move to the dyke or the area inside the dyke, where they spend the summer, autumn and winter. This leads to considerable spring migration across the dykes. Because of the large numbers involved, the annual amphibian migration is most noticeable in the spring. However, they also migrate in the summer and autumn, although spread over a longer period and in lower numbers. At places with stretches of water on the inside of the dyke, the spring migration often takes place from the floodplain dyke or, sometimes, from the area outside the dyke.

Requirements for the terrestrial biotope

Because it needs to be close to water throughout all the seasons, the Edible frog is the species that is least dependent on the terrestrial biotope. The robustness of populations of this species is therefore largely determined by the area of suitable aquatic biotope. The Common spadefoot requires open sand in the land biotope. The species inhabits river dunes and open areas in hardwood floodplain forests. Both biotope types are currently rare in the floodplains of the Netherlands. The Natterjack toad prefers to spend most of the year in sandy areas not reached by high water. These may be transshipment sites inside the dykes but also brick factory sites in the floodplain.

Requirements for the aquatic biotope

The Greater crested newt and the Common spadefoot are critical in the aquatic biotope. Although they are essentially riparian species, if they occur at all nowadays, it is only in small population densities, in the floodplain, which often overflow. These species obviously thrive best in clear waters with well-developed vegetation and no fish. Waters of this type are found relatively more often on the inside of the base of the dyke.

Edible frogs and Smooth newts are common, but the larger populations of these species are frequently found in waters that are not often in contact with the river. The population densities of Pool frogs are also higher in waters with low dynamics. The Pool frog is considered to be the most critical species among the green frogs. Although the Pool frog's distribution pattern is incomplete, the available data indicates that the species is mainly found in waters in which Greater crested newts also occur (Creemers 1994b).

The Natterjack toad's pioneering character in the aquatic biotope is shown by its preference for shallow waters, often with no vegetation. Recently excavated claypits, pools temporarily filled by precipitation and inundated pasture land are the most suitable breeding sites for this species (Creemers 1994a, Willink & Cuppen 1993). In the area around the river, the species occurs more often outside than inside the dyke. The requirements in terms of water quality and inundation frequency are subordinate to the specific preference the species has with regard to the aquatic and terrestrial biotope.

The Common toad and the Common frog have far lower requirements in terms of the richness of the structure of vegetation and the quality of the breeding waters. The occurrence of these species and the population sizes mainly depend on the quality of the land biotope, the terrestrial habitat where the juvenile and mature amphibians search for food and/or hibernate. The Common toad's larvae are not eaten by fish, which enables the Common toad to breed in large numbers in fish-rich waters, such as in large pools and dead river arms.

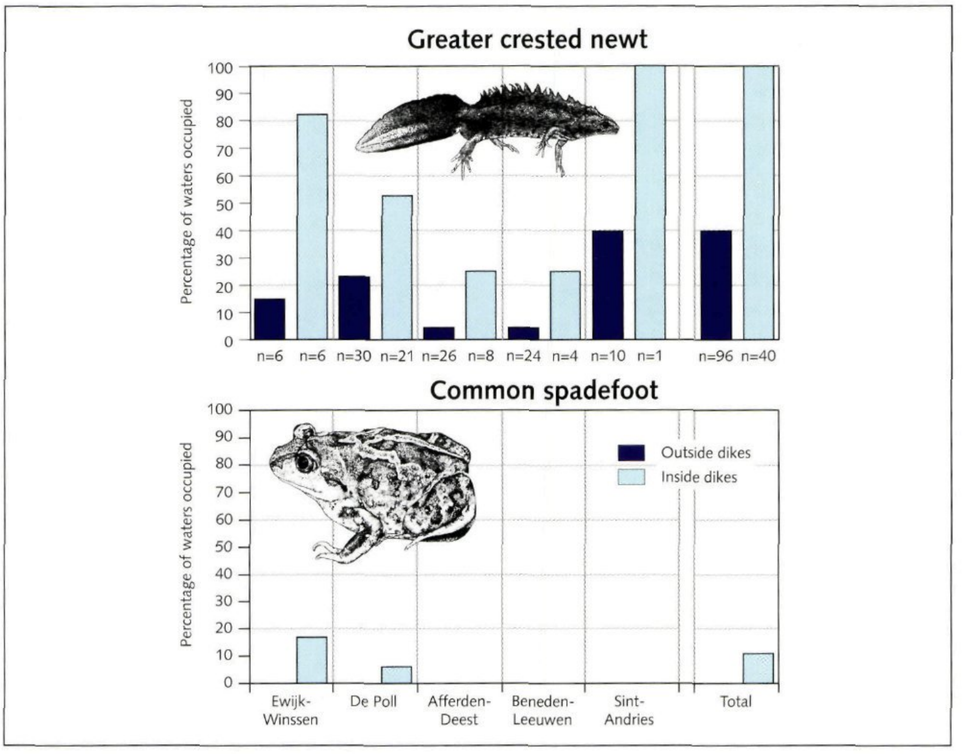


Figure 8.5
The percentage occupation of the Greater crested newt and the Common spadefoot in waters inside and outside the dykes in five model areas. Waters inside the dykes are used relatively more often as breeding places.

Present nature restoration projects and amphibians

Floodplains along the branches of the Rhine where nature restoration projects are either underway or scheduled include those at Millingerwaard, Sint-Andries, Ewijk, Afferden-Deest, Beneden-Leeuwen, De Rijswaard, Opijnen, De Wageningse Bovenpolder and De Duurse Waarden. The amphibians that occurred during or before the start of the nature restoration projects are well-known for all of these floodplains.

However, thus far there has been no monitoring of the effects on amphibian numbers of nature restoration projects, such as the construction of secondary channels. This does not mean it is impossible to estimate the present and future value of these areas as a habitat for amphibians on the basis of what is already known or on the basis of single studies. Present concepts about nature restoration projects in floodplains are based on three starting points:

1. The management and development of terrestrial biotopes such as floodplain forests and river dunes

Methods

In the early spring (February/March), regular visits are made to dykes and roads to count migrating amphibians. The counts are mainly based on observations made during field trips to the breeding waters and migration routes during the day and at night. The various floodplain waters are also searched for eggs and larvae in May/June.

Photograph 8.2

2. Increasing river dynamics by levelling main channel embankments and constructing secondary channels
3. Nature restoration projects along the length of the river

The anticipated consequences of the above for amphibians are discussed briefly below.

Development of terrestrial ecotopes.

Of the three starting points, nature restoration projects that concentrate on terrestrial biotopes for amphibians are the most promising. Converting intensively used pastures and agricultural land into brushwood, river dunes and/or floodplain forests creates important and varied land biotopes for amphibians. Extensive grazing also leads to more varied land biotopes. Areas not reached by high water are important for the hibernation of toads (Bosman 1993 and 1995).

Consequently, extreme floods in the winter detrimentally affect the survival chances of species such as the Common toad and, especially the Natterjack toad. During hibernation, the latter species cannot switch to cutaneous respiration, when the hibernation site is inundated for a long period (Bosman 1995). The Common toad responds to inundation by leaving the hibernation site. However, there is little likelihood of survival aboveground in the winter.

Increasing the river dynamics.

Cutting through the main channel embankments and constructing flowing secondary channels increases floodplain river dynamics. In confined areas, this is more likely to reduce the quality of breeding waters than to increase it. The waters with low dynamics, which are also necessary, can only continue to exist or be developed in sufficiently large floodplains with ample relief (see intermezzo).

However, many floodplains in the Netherlands offer little room for improving the survival chances of amphibians by constructing channels. In many parts of the country, the floodplains are too narrow and have little relief, which means secondary channels cannot help produce the positive effects possible in reference areas abroad. It should also be pointed out that in floodplains that currently have a low herpetological value, locally increasing the dynamics will have little effect on the already marginal population levels of common species (Creemers 1994a and 1994b).

Nature restoration projects along the length of the river.

These projects usually ignore existing cross-relationships between areas inside and outside the dyke. Nature restoration projects for amphibians cannot be seen as separate from these connections. These cross-relationships are practically never considered in current nature restoration projects. The only exception is the "Noordoever Nederrijn" project.

A few model areas

A number of areas in the Dutch river landscape that are important for amphibians are discussed below, along with some nature restoration projects in which those responsible believe important new habitats for amphibians will also be created:

* A small-scale nature restoration project inside the dyke, at Ewijk,
* A few nature restoration projects outside the dykes, to wit Afferden-Deest, Beneden-Leeuwen and St. Andries
* An existing area of high value for amphibians, the De Poll Country Estate (figure 2).

Eight species of amphibians occur. The highest number in any one area is seven (figure 2). The population sizes of the species differ in each area. With the exception of the Natterjack toad, the population levels of the riparian species (table 1) are reasonable to good. The areas therefore provide a good representation of amphibian populations in the floodplains of the Netherlands.

If the breeding waters of the Greater crested newt and the Common spadefoot in the aforementioned areas are subdivided into the waters inside and outside the dykes, it emerges that both species breed relatively more often in the waters inside the dykes (figure 3). In fact, the Common spadefoot only occurs inside the dykes. This development is a result of the dramatic changes that have occurred in many places in the Dutch river landscape.

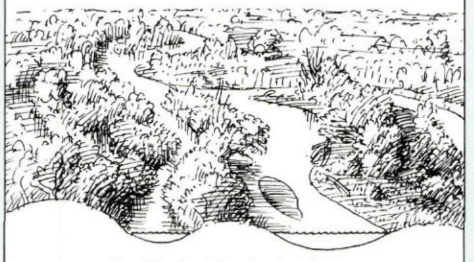
Figure 3 shows that the limit of the habitat of amphibians is not the floodplain dyke. However, nature restoration projects are often limited to the floodplains, which, in the case of critical species, means that no provisions are made for the restoration of important sub-habitats for amphibians.

Nature restoration projects for amphibians should therefore pay more attention to the existence of cross-relationships between areas inside and outside the dykes. This applies to relationships between sub-habitats as well as the function of the waters inside the dykes as a source (of juveniles) for adjoining habitats outside the dyke.

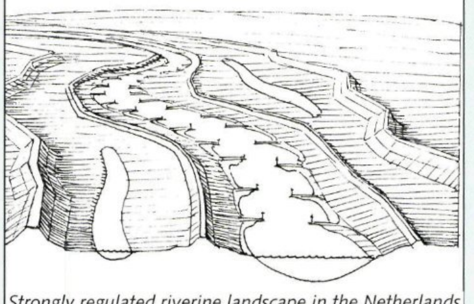
The Szigetköz, a reference area

The Szigetköz, in North-West Hungary, is an example of a floodplain forest complex along the Danube. As with other floodplain forests along the Danube, the area is home to large populations of amphibians. The floodplains without embankments are wide, have lots of relief and contain floodplain forests. The area has dozens of secondary channels, varying from flowing secondary channels to very dried out remains of channels. Besides winter flooding, the Danube also has what are known as the "Green floods", which occur in the spring or early summer, during the amphibian breeding season.

As in the Dutch floodplains, the best and most species-rich breeding waters are found in the parts that are least affected by the river dynamics. Consequently, it is only in the final stage of drying out that secondary channels have a function for amphibians, when the remaining pools and dead river arms become overgrown with macrophytes. The available claypits, pools and flood areas are also important for breeding amphibians. Owing to the unpredictable conditions in terms of water levels, the amphibians with a long and extended breeding season are better equipped to respond to the continuously changing water levels.



Undisturbed riverine landscape



Strongly regulated riverine landscape in the Netherlands

Giving shape to this need not involve plans for large-scale projects in the areas inside the dykes. Excellent results can be achieved, if nature restoration projects in the floodplains also provide for the creation of small stretches of surface water in adjoining parts of the area inside the dykes. Small-scale nature restoration projects of this kind need not take up more than a few hundred square metres. Positive experience has already been gained from this in various locations in the Netherlands. By way of illustration, a brief description is provided below of a small-scale nature restoration project in the Weurt/Deest dyke section, which was carried out by the Groot Maas & Waal Polder District (see intermezzo).

Before dyke improvements were made, a study was carried out to determine which sites in the area would be suitable for the construction of ponds. The reaction of the populations of endangered species to the restoration of their breeding waters was monitored for several years. This made it possible to take prompt action when the endangered species still faced the threat of extinction owing to unexpected developments.

There are now large, robust populations of both the Greater crested newt and the Common spadefoot. Conducting a proper preliminary study and, certainly in the case of low populations of endangered species, monitoring population developments during the first few years after nature restoration projects, considerably increases the likelihood of the projects succeeding.

Conclusions

There is a lack of reference material on the former occupation of floodplains by amphibians (before 1980), which makes it impossible to make any definitive statements about their progress or decline. However, there are no reasons for assuming that their decline in floodplains differs significantly from their decline nationally.

The decline of the Natterjack toad in the floodplains of the branches of the Rhine is probably a result of a decrease in the number of clay excavation operations, whereas the Common spadefoot has probably disappeared from areas outside the dykes because of high winter waters.

The inundation frequency is the decisive limiting factor for the successful reproduction of many amphibians. Waters that overflow frequently are not very suitable for reproduction. Moreover, at present the quality of the land biotope is a limiting factor for many species. Proper habitats can be created through nature restoration projects and marginal populations can make a definite recovery within a few years and show signs of expansion. However, these nature restoration projects have to take into account the ecological requirements of the species concerned.

For amphibians, the present nature restoration projects in floodplains mainly lead to the development of suitable terrestrial biotopes outside the dykes. With regard to the breeding waters, it is by no means always the case that nature restoration projects in floodplains result in more breeding opportunities for amphibians. This requires the presence of small stretches of water at locations in the floodplain with a low inundation frequency, or the construction or existence of waters in adjoining parts of the area inside the dykes. This mainly applies to the maintenance and development of populations of originally indigenous riparian species that are endangered in the Netherlands.

Photograph 8.3
The Moor frog is within the Dutch Rhine system only found along the Lower Rhine - Lek. In several other European river deltas however, like here in the delta of the river Pechora in Russia, it is common.

9. Birds

Martin Poot[1] & Leo van den Bergh[2]

[1]SOVON (Collaborative Organizations for Bird Census Work in the Netherlands) [2]Bird Task Force for Major Rivers

Introduction

This chapter is concerned with the waterbirds and summer birds in the Rhine catchment area. In view of the area's major importance as a migration route and winter location for waterbirds, and the readily available monitoring data, the main focus will be on this group. With regard to summer birds, specific attention is paid to species that are characteristic of marshy woodland or floodplain pasture.

Waterbirds

Table 1 shows various waterbird species that are characteristic of the Rhine system. Various species reach internationally significant numbers here. The Rhine system is particularly important for herbivores (figure 1).

Although the numbers that occur in the lower river area are generally smaller, this area stands out because of the large number of benthivores (macrozoobenthos-eaters). The greatest numbers of herbivores are reached in the Waal and IJssel subsections of the river, probably in connection with the larger floodplain area.

Table 9.1
Season's maximum for each branch of the Rhine in the 1994/95 season and the season's maximum for the entire Rhine system in 1994/95 and in the 1989/94 period. Bold figures exceed the 1 % standard (Meininger *et al.* 1995).

Species	Waal	IJssel	Rhine/Lek	Lower branches	Rhine total	1989/94
Great crested grebe *Podiceps cristatus*	552	383	338	250	**1.339**	**1.467**
Cormorant *Phalacrocorax carbo*	1.131	816	924	469	**3.287**	**7.008**
Grey heron *Ardea cinerea*	161	204	182	80	593	684
Mute swan *Cygnus olor*	262	570	561	240	1.321	**1.891**
Bewick's swan *Cygnus columbianus*	**600**	**1.782**	**471**	3	**2.856**	**3.023**
Bean goose *Anser fabalis*	1.559	10	284	12	1.837	**4.520**
White-fronted goose *Anser albifrons*	**44.470**	**54.104**	**18.025**	1.559	**102.269**	**111.602**
Greylag goose *Anser anser*	**2.245**	954	616	599	**4.173**	**3.675**
Egyptian goose *Alopochen aegyptiacus*	301	440	374	65	1.002	605
Wigeon *Anas penelope*	**27.586**	**17.085**	**14.462**	3.365	**60.921**	**55.843**
Gadwall *Anas strepera*	139	76	**286**	**901**	**1.368**	**1.260**
Teal *Anas crecca*	907	670	841	798	2.908	3.612
Mallard *Anas platyrhynchos*	5.960	7.262	5.834	5.206	**24.262**	**30.110**
Pintail *Anas acuta*	163	283	263	2	**709**	**721**
Garganey *Anas querquedula*	38	28	23	2	89	108
Shoveler *Anas clypeata*	**522**	**564**	325	70	**1.308**	**1.967**
Pochard *Aythya ferina*	1.879	**7.002**	1.545	1.370	**10.918**	**16.806**
Tufted duck *Aythya fuligula*	3.284	4.102	1.904	7.286	**12.182**	**35.529**
Goldeneye *Bucephala clangula*	23	30	62	84	157	535
Smew *Mergus albellus*	124	85	61	62	**286**	**1.125**
Goosander *Mergus merganser*	78	158	144	39	400	**2.248**
Coot *Fulica atra*	9.394	**19.236**	**17.075**	3.732	**49.437**	**49.212**
Oystercatcher *Haematopus ostralegus*	476	1.336	1.367	941	4.103	4.573
Golden plover *Pluvialis apricaria*	69	201	227	27	440	1.705
Lapwing *Vanellus vanellus*	**21.796**	**30.053**	**36.819**	7.809	**85.381**	**192.745**
Black-tailed godwit *Limosa limosa*	1.719	**4.245**	**3.682**	513	**10.159**	**12.523**
Curlew *Numenius arcuata*	1.063	671	1.588	230	2.204	**4.214**
Black-headed gull *Larus ridibundus*	19.503	**40.450**	**38.830**	5.618	**100.423**	90.340
Common gull *Larus canus*	2.199	6.452	6.431	1.015	15.137	**18.049**
Herring gull *Larus argentatus*	185	269	300	7.634	7.910	3.871
Greater black-backed gull *Larus marinus*	53	49	28	600	657	236

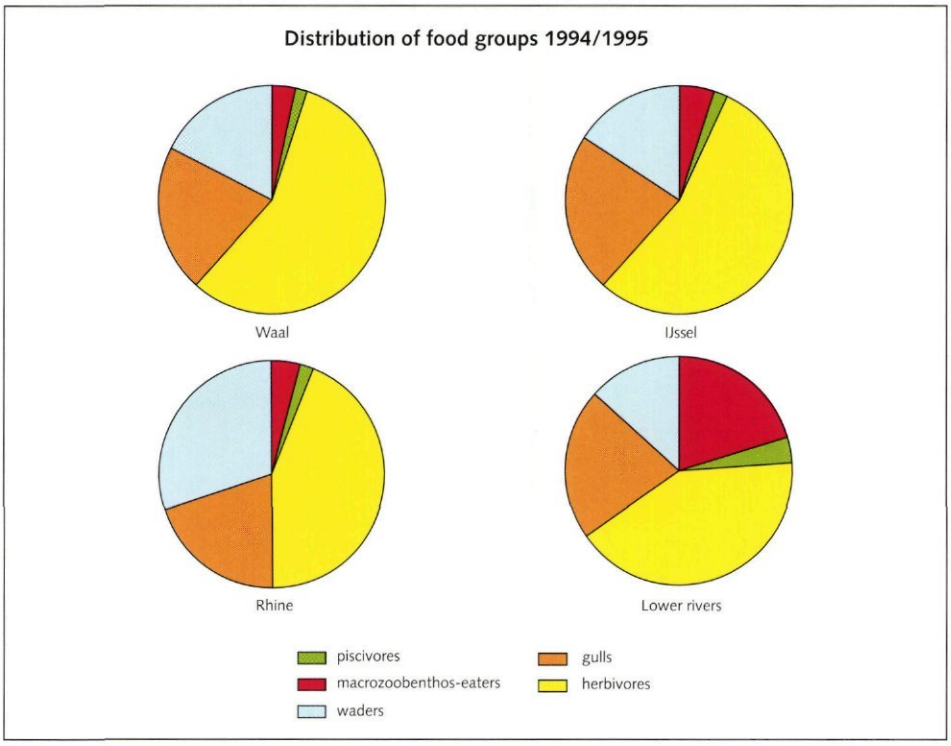


Figure 9.1
Distribution of the total number of bird days of all waterbird species in the 1994/95 season, per subsector, classified according to species groups.

Importance in different periods of the season

The Bewick's swan *Cygnus columbianus* is an example of a species that breeds in arctic Russia and only arrives in the river area in late autumn (figure 2). The Coot *Fulica atra* is a common breeding bird in the Netherlands, which increases in number from September. For both species, the Rhine area is especially important as a winter location, as it is for the Mute swan *Cygnus olor*, Mallard *Anas platyrhynchos*, Tufted duck *Aythya fuligula*, White-fronted goose *Anser albifrons*, Wigeon *Anas penelope*, Goosander *Mergus merganser* and Smew *Mergus albellus*.

A small number of waterbird species use the catchment area of the Rhine as a migration area. The numbers of Shoveler *Anas clypeata*, for example, display a clear autumn and spring peak. The Black-tailed godwit *Limosa limosa* is a species that mainly uses the Rhine catchment area in the early spring. In 1995, the total number present at any one time exceeded 10,000. The floodplains along the Rhine are an attractive area for recuperating after the long migratory flight from Africa. In the early spring, Black-tailed godwits prefer to stay on boggy land and in the vicinity of shallow water, conditions that are easily found in the floodplains of the branches of the Rhine. Later, they spread out across the interior to brood. The largest numbers of Black-tailed godwits stay in the Rhine/Lek area. This is probably connected with the favourable location relative to the breeding areas.

Although the summer months are missing from the analysis presented here, it is known that the floodplains are important for moulting Lapwings *Vanellus vanellus*. It is suspected that the numbers are at least of the order of magnitude of those in the autumn. The birds forage in the floodplains and usually rest on the beaches and longitudinal embankments directly alongside the river.

Effect of high water levels

A striking phenomenon in the 1994/95 season was the extremely high Rhine water discharge peak in the winter, in February 1995. The high water levels left the floodplains under water for a long time, and meant much less food was

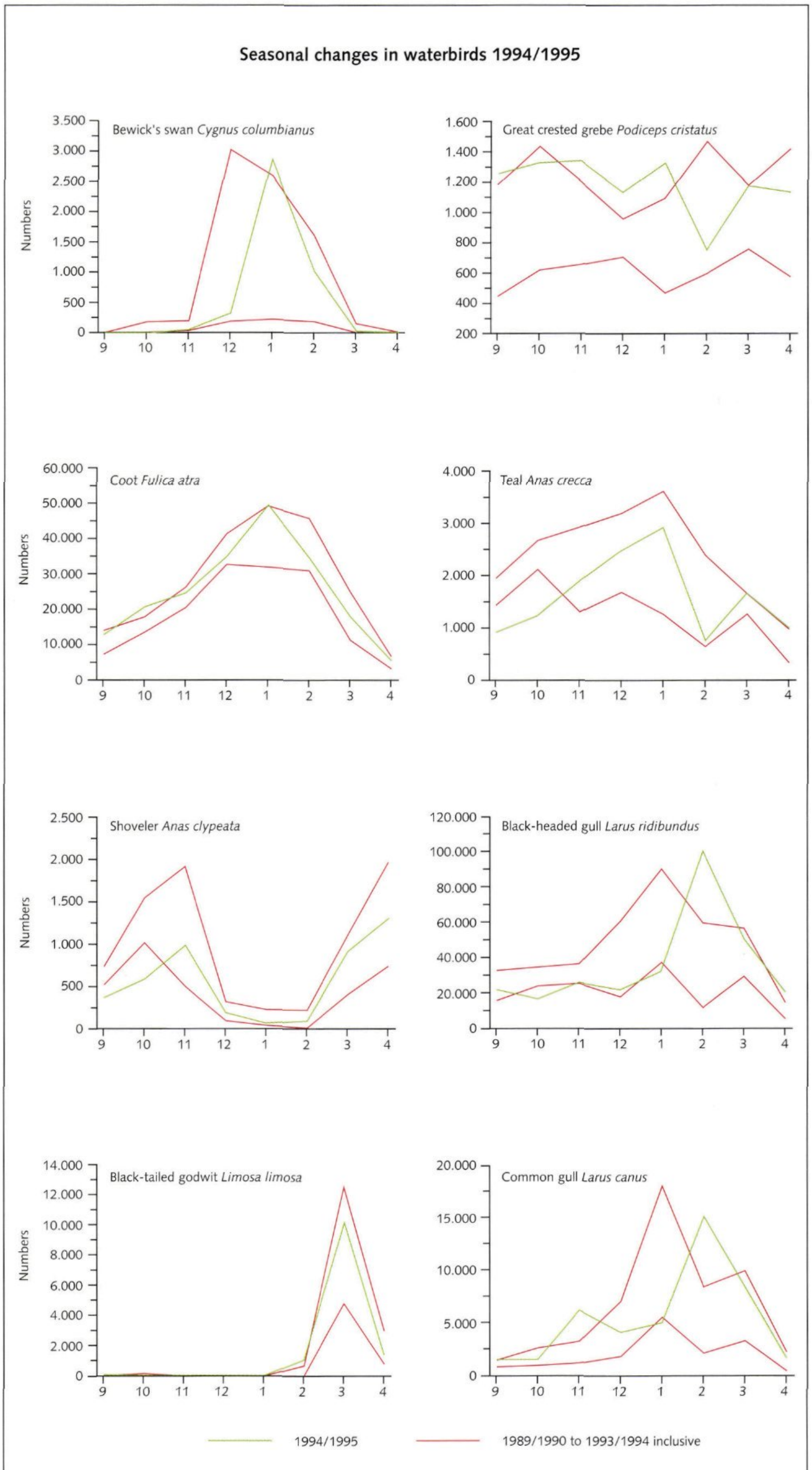


Figure 9.2
Seasonal changes for 8 waterbird species in the 1994/95 season (thick line) and, by way of comparison, the minimum and maximum numbers in the 5 preceding seasons (1989/90 to 1993/94) (dotted lines).

available for some species. The Teal *Anas crecca* is one example of a species that had to relocate to other areas (figure 2). Great crested grebes were present in noticeably lower numbers in February. The water's strong flow and increased turbidity must have been a disadvantage to the Great crested grebes, which rely on their eyesight for catching fish. Gulls directly benefited from the major inundations. Seepage in adjoining agricultural areas inside the dykes meant these birds had access to increased food supplies. Seepage increases the soil's moisture content, which makes all kinds of soil organisms, such as earthworms more accessible. Food supplies also increased because food particles broke loose and floated in the water, or were washed up along the dykes.

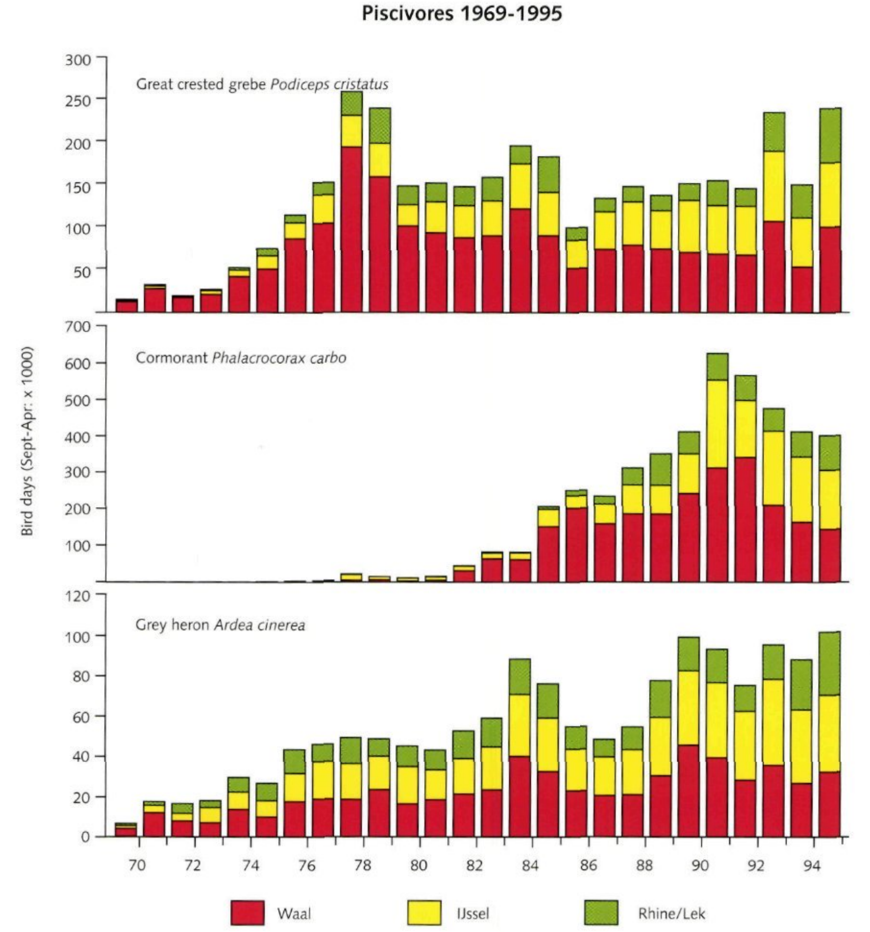


Figure 9.3
Number of bird days per season (September-April) for 3 different piscivorous bird species, Great crested grebe, Cormorant and Grey heron, during the 1969/70 to 1994/95 period in the various branches of the Rhine.

Developments affecting waterbirds

Piscivores

The Great crested grebe and the Cormorant *Phalacrocorax carbo* display a sharp increase in the number of bird days (for an explanation of the term "bird day", see the box "methods"). There was a particular increase in the number of bird days of the Great crested grebe in the nineteen seventies, after which it remained stable, whereas the figure for the Cormorant noticeably increased in the nineteen eighties and has remained stable in the nineteen nineties (figure 3). The Grey heron *Ardea cinerea* has been increasing throughout the entire period, in line with the growth in the numbers of breeding birds in the Netherlands. The years with relatively low numbers correlate with the occurrence of severe winters.

Great crested grebes and Cormorants mainly forage in claypits and sandpits, etc., in the Rhine catchment area. The river branches themselves are less suitable for piscivores. On the one hand, this is because there are fewer fish. On the other hand, because of poorer clarity, as a result of the flowing river water, which is a disadvantage to birds that rely on their eyesight for hunting. In the nineteen seventies the excavation of base materials created many clay-, sand- and gravel-pits. This increased the area of habitat suitable for the Great crested grebe. Important new freshwater winter locations were also created outside the river area, through projects such as the construction of the Haringvliet Dam. There are strong indications that this has led to a large-scale change in migration behaviour in the North-West European population of the Great crested grebe. Ringing data has shown that halfway through the nineteen seventies an increasingly larger percentage of Great crested grebes started to spend the winter in the Netherlands, rather than on the major lakes of Switzerland (Adriaensen *et al.* 1993). In the mid-seventies, the Cormorant had not yet recovered from the sharp decline brought about by poisoning and pursuit in the preceding decades. It was only in the nineteen eighties, when Cormorant populations increased again across Europe that the numbers also increased along the Rhine. It is plausible that the levelling off and decline in the number of bird days of the Cormorant in the early nineties was a result of the area's carrying capacity having been reached. The same may apply to the Great crested grebe at the end of the nineteen seventies, when, as with the Cormorant, the number of bird days fell sharply and stabilized, after a sharp peak.

There is no clear relationship between developments in numbers and changes in food availability. Changes in the stocks of fish species that are suitable as prey are important, but little is known about this. Chapter 7 reports, along with water quality improvements, recent increases in fike catches of various species of fish from 1993 to 1995, which would suggest a visible effect on the numbers of fish and thereby piscivorous birds. The greater number of bird days of the Great crested grebe in the 1992/93 and 1994/95 seasons may be connected with this.

The Goosander and the Smew are species that only appear in reasonable numbers in some years in the Rhine catchment area. Goosanders and Smews mainly appear in severe winters (figure 4). The Rhine's branches then serve as a temporary relocation place for these piscivores, which presumably originated from the lake IJsselmeer area or areas further north or east.

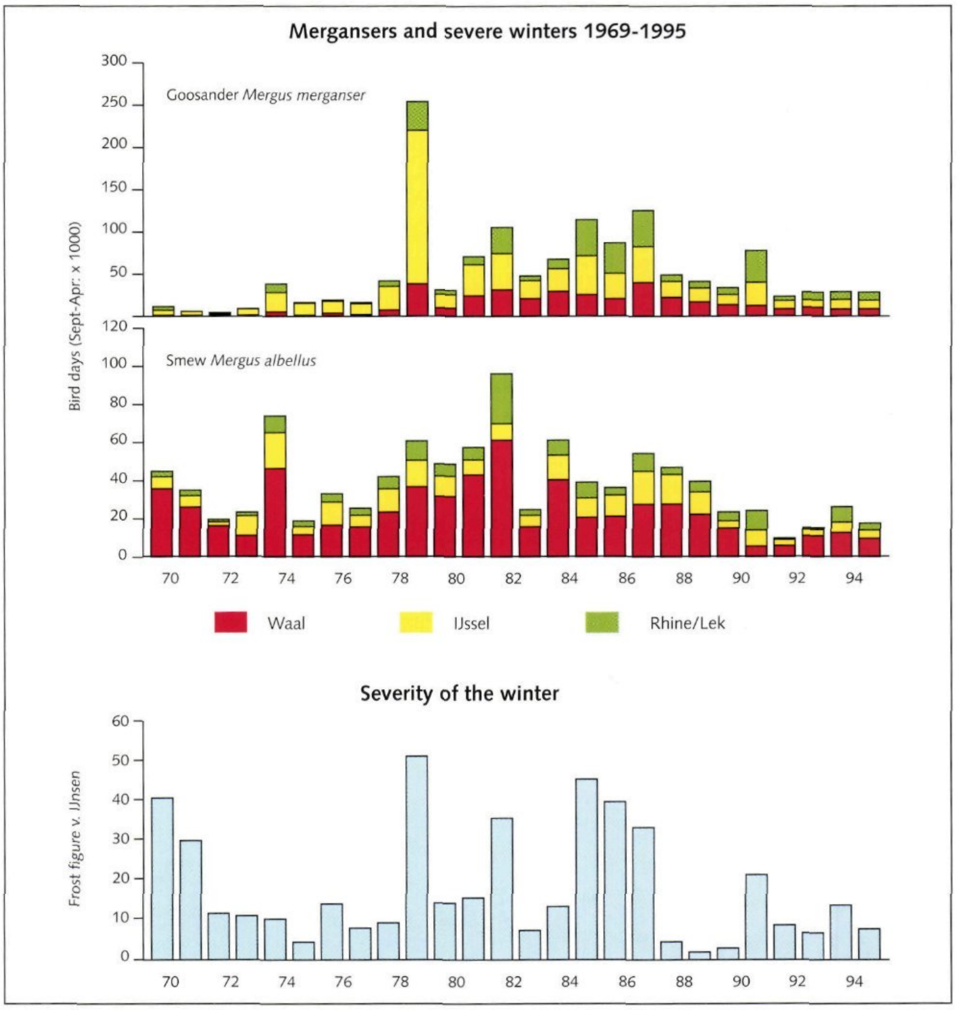


Figure 9.4
Number of bird days per season (September-April) of Goosander and Smew during the 1969/70 to 1994/95 period and the severity of the winter according to the IJnsen number (1988).

Benthivores

There are sharp fluctuations in the number of bird days of the Pochard *Aythya ferina* and Goldeneye *Bucephala clangula*. This is probably accounted for by the effects of winter and the availability of food. Pochards prefer soft prey such as Chironomidae, which can occur in sharply fluctuating numbers each year. Goldeneyes eat shellfish and forage for small specimens of Zebra mussels *Dreissena polymorpha*, amongst other things. The larger number of Goldeneye bird days in the mid-eighties corresponded with the change in the figure for Tufted duck (figure 5). In the winter period, Tufted duck is a Zebra mussel food specialist.

Photograph 9.1
During the cold January 1996 the Lower Rhine (which has weirs) got frozen for the first time in decades. Near the "Blauwe Kamer" geese and ducks kept a part open for roosting.

Water quality improvements in the early nineteen eighties, thanks to reduced concentrations of heavy metals such as cadmium, led to a large increase in the number of Zebra mussels in the major rivers. Quantitative figures on this which are available for the IJssel river show the changes in Zebra mussel stocks. It emerges that the higher number of Tufted duck bird days in the IJssel runs parallel with the increase in Zebra mussels in the river IJssel from the early nineteen eighties (see graminivores). The recent decline in Tufted ducks also appears to be connected with the recently diminishing numbers of Zebra mussels, which is possibly accounted for by competition with a newcomer among the macro-zoobenthos, the Caspian shrimp *Corophium curvispinum*. The highest numbers of Tufted duck bird days have been recorded in the Oude Maas river. This is probably because this stretch is the one with the most embankments in the

Rhine catchment area. The embankments provide Zebra mussels with a large area for attaching themselves. The species hardly occurs at all on the river bed of the branches of the Rhine. The flow causes high dynamics in the sediment on the bed, which impedes the establishment and maintenance of Zebra mussels populations. Tufted ducks can readily harvest Zebra mussels that are attached to hard substrate.

Although the Coot has a herbivorous diet in the Rhine catchment area in the winter and mainly eats grass, the species may adopt specialized foraging habits for Zebra mussels, depending on the local food situation. In the Oude Maas river, where there are hardly any floodplains, the Coots probably mainly forage on Zebra mussels. This assumption is confirmed by the fact that the number of Coot bird days spent on the Oude Maas stretch of the river after the early eighties remained relatively high, and corresponded with the development in the numbers of Tufted duck, whereas there was a decline along other stretches of the Rhine (see graminivores). Reports have recently been received of a decline in benthivorous waterbirds in the areas around the lower river branches. A deterioration in food conditions is suspected of being the cause of this (Van der Winden *et al.* 1996).

The colonization of a number of new invertebrates in the Rhine catchment area may be connected with this. For example, there has been an explosive growth in the number of Caspian shrimp and the gammarid *Gammarius tigrinus* (see chapter 6). Although information is not currently available on what the effect of this colonization is on changes in the numbers of diving ducks, competition is expected for habitats between Caspian shrimp and Zebra mussels (Van den Brink *et al.* 1993). This would result in less food being available, particularly for the Tufted duck. On the other hand, it will be necessary to investigate whether these crustaceans will serve as a food source for benthivorous waterbirds. There has also been an increase in the Asiatic clam in the Rhine system since 1989, which is likewise potential prey of diving ducks. However, in comparison with Zebra mussels, this bivalve has a stronger shell, which makes it more difficult to digest (diving ducks swallow

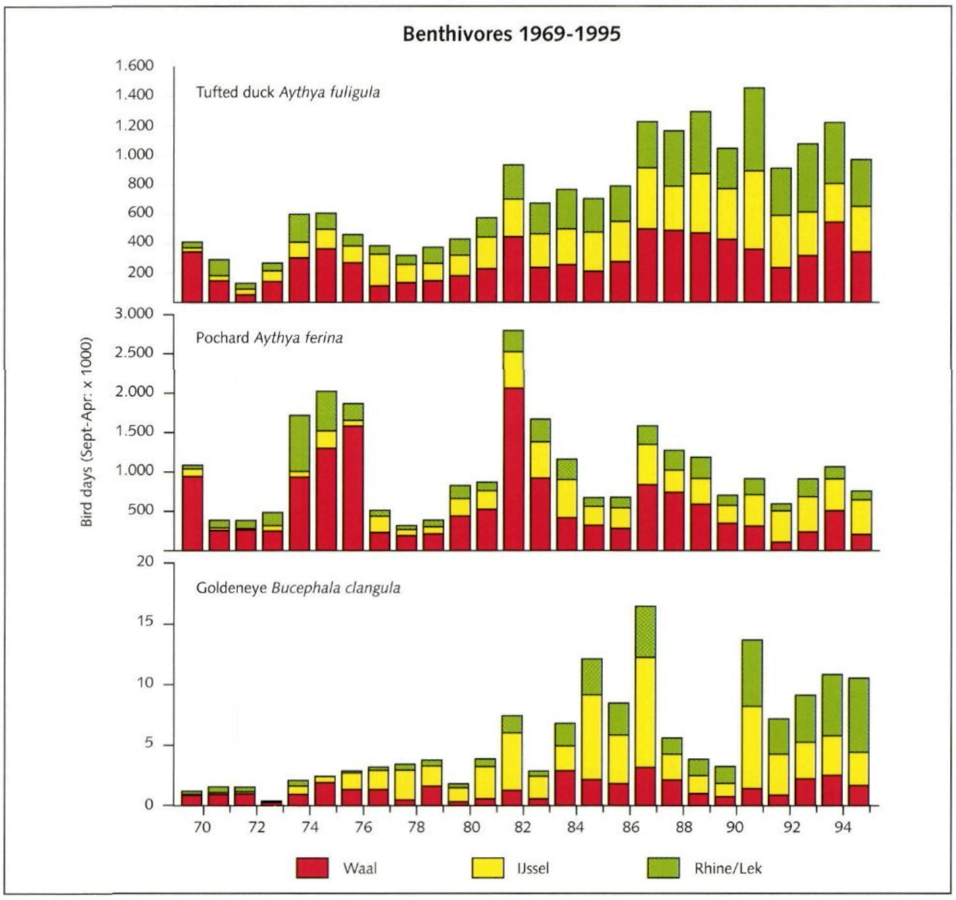


Figure 9.5
The number of bird days per season (September-April) of benthivorous waterbirds during the 1969/70 to 1994/95 period in the various branches of the Rhine.

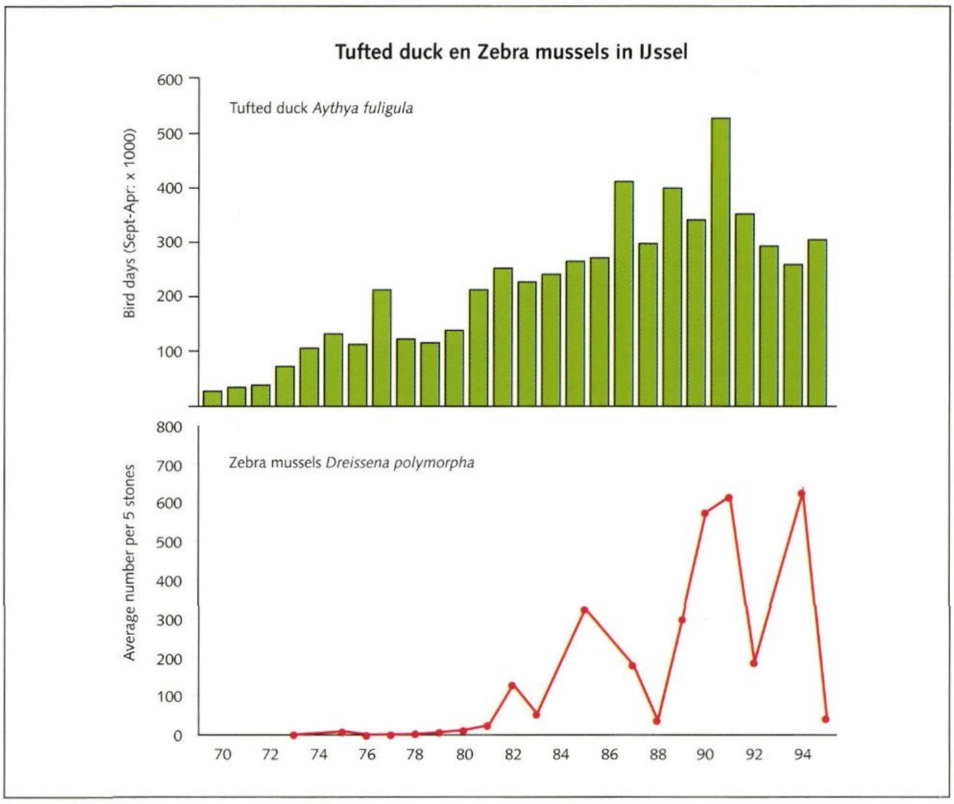


Figure 9.6
The number of bird days of the Tufted duck in de IJssel, the pre-eminent Zebra mussel specialist, during the 1969/70 to 1994/95 period (September-April) and the average number of Zebra mussels on 5 stones at 8 sampling locations along the embankment of the IJssel river (details RIZA, Noordhuis *et al.* 1997).

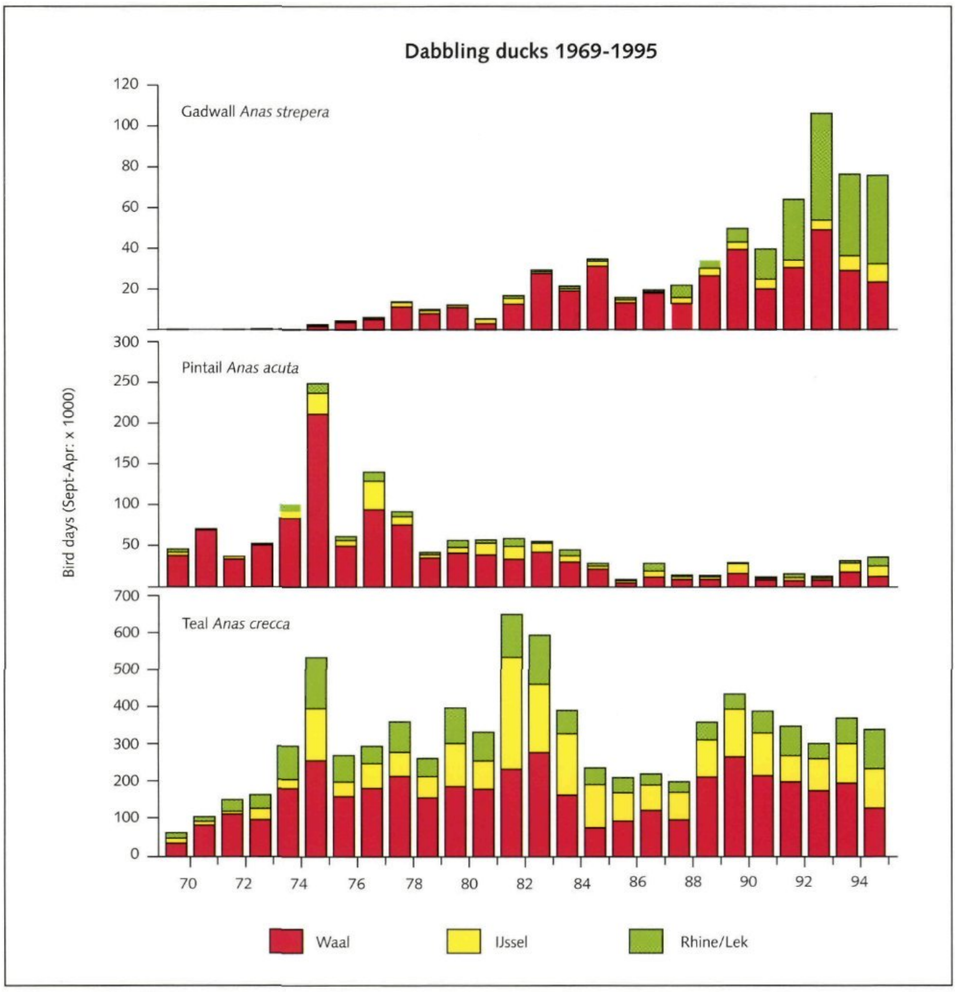


Figure 9.7
The number of bird days (September-April) of Gadwall (algae-eater) , Pintail and Teal (seed-eaters) during the 1969/70 to 1994/95 period in the various branches of the Rhine.

their prey whole and grind it in their strong gizzard). It is thus far not known whether diving ducks forage on the Asiatic clam (J. de Leeuw).

Herbivores

Herbivorous waterbirds can forage on various parts of plants; they may specialize in eating the green parts, the roots or the seeds. Although herbivorous waterbirds still make use of natural food sources, such as aquatic and marshland plants, they have increasingly become dependent on agricultural areas in Western Europe. There is a suspicion that recent population increases and/or changes in migration behaviour in a number of herbivorous waterbirds can be traced to the intensification of agriculture and the resultant greater availability of food in agricultural areas. This applies both quantitatively (owing to the longer growing season and more rapid growth) and qualitatively (higher nutritional value) (Van Eerden *et al.* in preparation).

Vegetative material is difficult to digest and, therefore, a relatively low-energy source of food. Whereas cows have a specialized stomach/intestinal tract and are therefore able to readily digest vegetative material, herbivorous waterbirds are only able to digest the plant's readily digestible substances. Generating a high food throughput in the stomach/intestinal tract (by, for example, drinking copiously) nevertheless enables waterbirds to forage on grass and other plants. This produces a balance in which the readily digestible substances are released in sufficient amounts and the indigestible parts are quickly removed. Although there are some species of herbivores in the Rhine system that mainly live on seeds (Pintail and Teal) or algae (Gadwall *Anas strepera*), most species are genuine floodplain grazers. After reaching a peak in numbers in the nineteen seventies, the Pintail has undergone a further decline, whereas Teal numbers originally increased in the nineteen seventies and then remained more or less stable. In the nineteen seventies, the Gadwall was a particularly scarce waterbird, but its numbers have increased considerably since the nineteen eighties (figure 7).

Graminivorous waterbirds

The various graminivorous waterbirds along the Rhine can roughly be divided into two groups. The species in the first group (Mute swan, Bewick's swan, Mallard and Coot, figure 8a) increased gradually from the nineteen seventies and reached a peak in the 1981/82 season. Numbers began to decline thereafter or remained more or less stable. Comparing the developments in the numbers of these species in the Rhine system with the numbers in other major water systems in the Netherlands (Haringvliet/Hollands Diep, the lakes between the former coast and empoldered land (Randmeren), and the Maas) reveals that this pattern is specific to the Rhine, and is not the result of changes in migration behaviour or rises and falls in population levels.

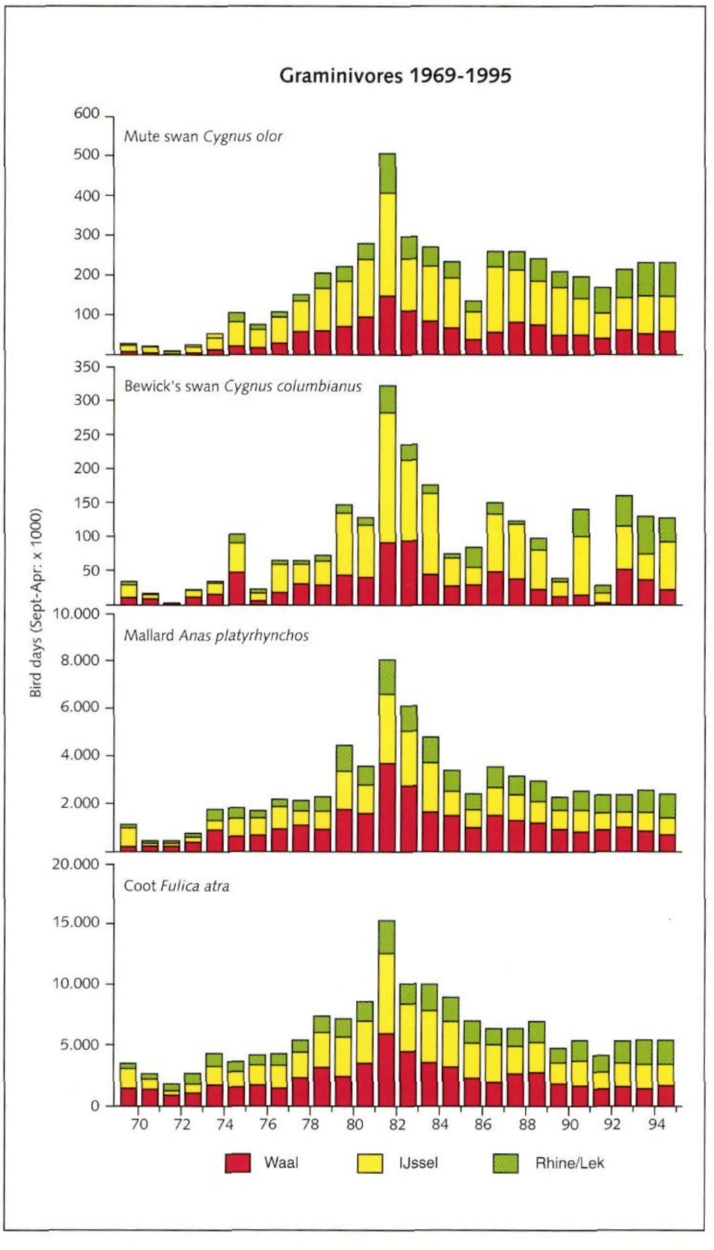
In the other group (White-fronted goose, Wigeon and Greylag goose *Anser anser*, figure 8b), there was no increase in numbers in the nineteen eighties but an increase in numbers started in the nineties and is continuing or recently appears to have stabilized. The same increase in numbers is apparent in other water systems in the Netherlands.

Therefore, the pattern for these species appears to be less specific to the Rhine, but more connected to developments at the level of the entire population.

The factors that led to the Rhine-specific developments in the numbers of Mallard, Coot, Mute swan and Bewick's swan in the Rhine system are unknown.

Effect of manuring and the agricultural use of land

In the period between 1970 and 1990, there



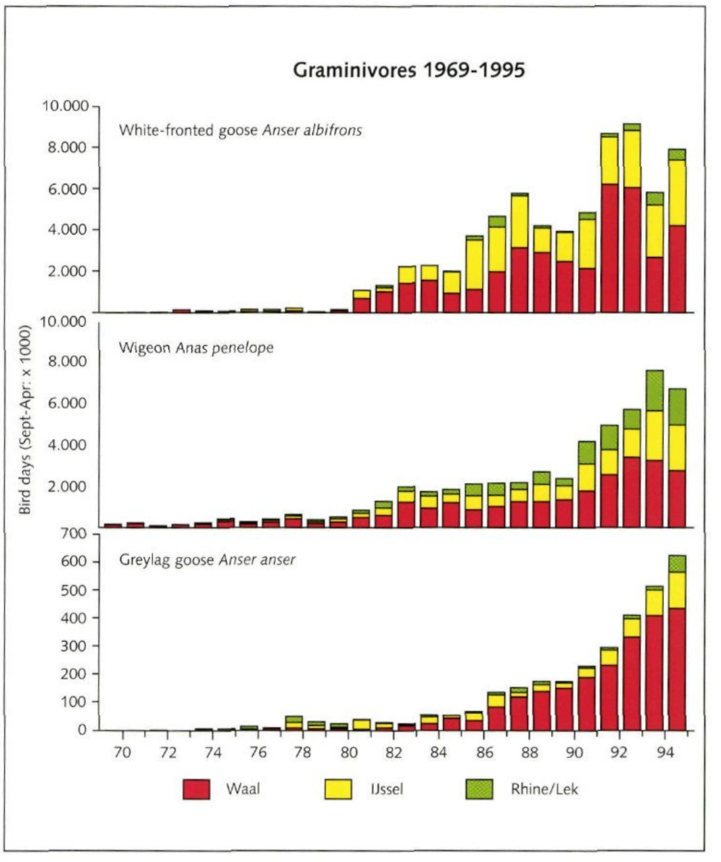


Figure 9.8b (above)
The number of bird days of 3 species of herbivorous waterbirds (White-fronted goose, Wigeon and Corn bunting) during the 1969/70 to 1994/95 period in the various branches of the Rhine. These species of birds also forage mainly on grass. The increase in the bird days of these species plays a role at the population level and follows developments in other water systems in the Netherlands.

Figure 9.8a (left)
The number of bird days (September-April) of 4 species of herbivorous waterbirds (Mute swan, Bewick's swan, Mallard en Coot) during the 1969/70 to 1994/95 period in the various branches of the Rhine. There is a striking correspondence in the development in the number of bird days of these birds, which mainly eat grass. This development is unique to the Rhine system in the Netherlands. See also figure 9 for possible causes of this development.

were major changes in the management of floodplain pastures and the agricultural use of the land concerned. Manure spreading on these pastures probably increased during the nineteen seventies, as it did in the areas inside the dykes, and reached a peak in the early nineteen eighties. After the peak, manure spreading decreased under the influence of new agricultural policies (figure 9). The trend in manure spreading displays a striking similarity to the developments in the numbers of the aforementioned species of waterbirds. It seems plausible that the increase and later reduction in manure spreading had an impact on the availability of food for graminivorous waterbirds. Increases in manure spreading lead to increases in grass production and the length of the growing season. Young shoots are particularly attractive to graminivorous waterbirds, as they are more readily digested (less fibre) and have a relatively higher concentration of nutrient-rich substances than older vegetation.

A secondary effect of increased manure spreading is a change in the composition of the plant communities in pastures. Species such as Crested dog's tail *Cynosurus cristatus* and Sweet vernal grass *Anthoxanthum odoratum* have become rare as a result of the sharp increase in competitive pressure from grass species that can grow rapidly. For example, Rough meadow grass *Poa trivialis* is a species that has increased sharply owing to extra nutrients being available (De Graaf *et al.* 1990). This species is an ideal food source for many graminivorous waterbirds. In general, the grass cover has become more uniform (less species-rich). It is not inconceivable that this type of grass cover could be well-utilized by herbivores that operate in large groups, such as the Wigeon and White-fronted goose.

The recent decline in herbivorous species may also be partly accounted for by the reduced area of floodplain pasture. The area used for green maize (fodder) in the floodplains (figure 9) increased considerably in the nineteen eighties and nineties. Although corncobs left in fields after harvesting are an attractive source of food, they are generally eaten by a group of waterbirds within a few days. The deterioration

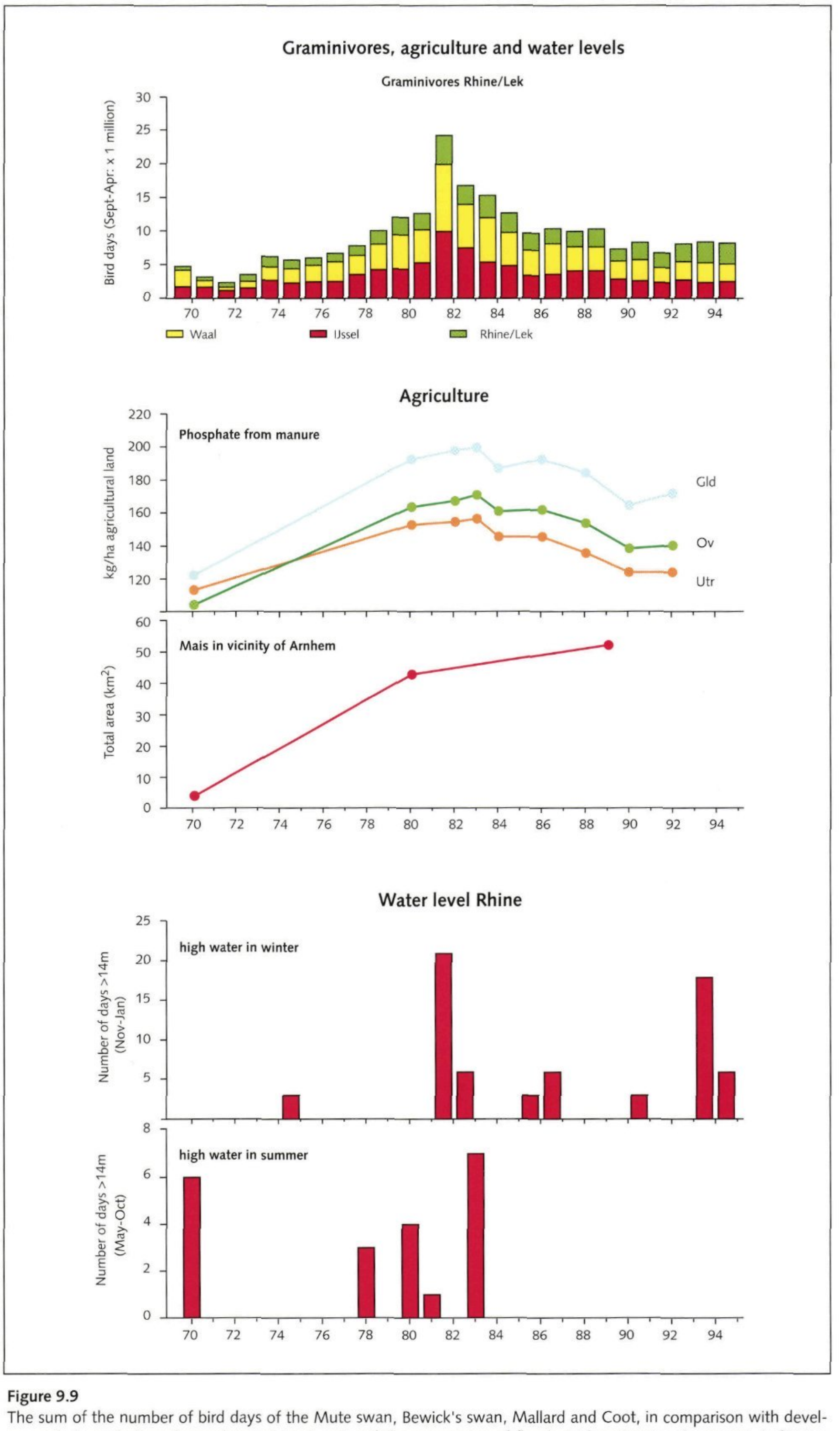


Figure 9.9
The sum of the number of bird days of the Mute swan, Bewick's swan, Mallard and Coot, in comparison with developments in agriculture (manuring and land use) and the occurrence of floods in the winter and summer. A division has been made according to the branch of the Rhine concerned (black: Waal, white: IJssel and striped: Rhine/Lek). Manuring is shown as the phosphate level from manure in Kg/hectare of agricultural land, in the provinces through which the Rhine flows. Manure is the most common fertilizer used in the floodplains. The increase in the acreage of maize in the vicinity of Arnhem is shown as a parameter for changes in land use (source CBS, soil statistics). Water levels above 14 metres at Lobith are shown as an indication of flooding. If this level is reached, main channel dykes in the area downstream overflow on a large scale (source RIZA). The winter period includes the months from November to January and the summer period includes the botanical growth period, the months from May to October.

in food conditions caused by reduced amounts of manure may also have contributed to the decline in herbivorous waterbirds.

Impact of inundation and improved drainage

Besides manuring levels and other changes in the agricultural use of land, other factors can also affect changes in the numbers of herbivores. The high peak of 1981/82 in the numbers of Mute swans, Bewick's swans, Mallards and Coots coincided with large-scale winter floods in that year. Winter floods generally have a positive impact on the occurrence of herbivores. The availability of large amounts of water can make pastures attractive to herbivorous species of waterbirds, because of the plentiful supply of drinking water (important for the process of digesting grass, see above). On the other hand, the nutrient-rich roots of plant species are easier to get at because the soil contains more moisture.

The protein-rich roots of clovers *Trifolium* spp., for example, are an important food source for many graminivorous species. The taproots of Dandelions *Taraxacum* spp. may form an important part of the diet of Bewick's swans in moist pastures. These swans are unable to pull them out of the ground if the soil is dry (Nienhuis & Epe 1995).

However, the relationship between large herbivore numbers and high water levels is far from clear (figure 9). There have been various high water levels since the winter of 1981/82 that have had no visible effect on graminivores. The peak of 1981/82 may have been more pronounced because it was a cold winter with a lot of snow (expressed in the IJnsen number, figure 4). Owing to the proximity of river water, floodplains are free of ice and snow sooner than the areas inside the dykes, for example.

Recent changes in land use may also have contributed to herbivore numbers being less high. Because floodplains can be better drained nowadays, it is likely that the effects of flooding have diminished. The surplus water is removed quicker, which means truly boggy conditions currently only exist for a relatively short period.

Like manure spreading, summer floods may have a major impact on the species composition of the grass cover. The summer floods at the end of the nineteen seventies and in the early eighties led to an increase in the area covered by plant communities such as the Crested dog's tail community (which also includes Rough meadow grass), species that are particularly suitable for herbivores; this was in contrast to the pastureland community with Tall oat grass *Arrhenatherum elatius*, which is less resistant to flooding in the growing season (De Graaf *et al.* 1990). Although this plant community is more rich in species, with high-growing herbs, the supply of plant species it provides that are attractive to herbivorous waterbirds is considerably lower (lower digestibility). The lack of summer floods since 1983 may possibly have resulted in shifts in plant communities. In comparison with the situation along the Rhine in the early eighties, there may have been a decline in the availability of food for herbivores, owing to the recolonization of the floodplains by flood-susceptible and also difficult-to-digest herbaceous plants.

It is clear that more attention will have to be paid in future to the relationship between the occurrence of herbivores and environmental factors. The competition between the various species of herbivores is also an important subject in this field.

Breeding birds

Of the 56 species of breeding birds on the Dutch Red List of endangered and vulnerable species (Osieck & Hustings 1994), in 1995 at least 28 bred in the catchment area of the Rhine in the Netherlands. Of 16 Red List species, at least 5 percent of the breeding population in the Netherlands are established along the Rhine and branches of the Rhine (table 2).

Major national significance can be attributed to the Rhine valley population of the Corn crake Crex crex in particular. The number of pairs has declined sharply since the nineteen seventies but, nevertheless, the catchment area of the Rhine is one of the last annually occupied breeding areas in the Netherlands. There was a small increase in 1995, especially along the Lower Rhine, where there were ten pairs in the floodplains near Wageningen. Sedimentation of river silt during the preceding winter floods resulted in periodic boggy and herb-rich floodplain pastures, the Corn crake's favourite breeding biotope in the area around the rivers.

The Rhine system plays a particularly important role for the characteristic species of breeding birds that inhabit marshy woodland or floodplain pastures. The species Little bittern *Ixobrychus minutus*, Spotted crake Porzana porzana, Black tern *Chlidonias niger* and Great reed-warbler *Acrocephalus arundinaceus*, which live in reed marshes have all declined along the branches of the Rhine. However, the decline in the Black tern and Great reed-warbler is less dramatic along the Rhine than it is nationally (Van Dijk *et al.* 1996). It is mainly falling water tables and the resultant increase in brushwood growth in marshlands that appear to play tricks on marshland birds in the Rhine catchment area (Erhart & Bekhuis 1996).

Even though the pastures in the Rhine valley floodplains represent only a very small part of the total area of pastureland in the Netherlands, a large percentage of the country's population of Garganey *Anas querquedula* and Corn bunting *Miliaria calandra* are established there. The White stork Ciconia cicionia can be included among these, even though human intervention plays a major role in this. The species had almost disappeared from the Netherlands but a reintroduction programme began to bear fruit in the nineteen eighties (van der Have & Jonkers 1996). In 1994, around forty free-flying pairs bred in the spacious surroundings of 'outdoor breeding stations' along the river IJssel (1 station) and the river Waal (3 stations), and largely foraged in the floodplains.

Along the river Waal there is a small population of Corn buntings, which is however, seldom located in the same floodplains during consecutive years. In 1994, more floodplain brushwood as a result of the winter floods helped increase the population, but not as much as in the Maas valley in the same year. The relatively minor importance of the small Rhine valley population is growing, as the species has practically disappeared from agricultural land (Hustings *et al.* 1995).

Although the Rhine valley is an important stronghold for the Garganey, with around 200 breeding pairs, their numbers are diminishing rapidly. There has also been a sharp drop across the country as a whole since the nineteen seventies (van Dijk *et al.* 1996). Following a decline during this period, the species has stabilized at a lower level in the floodplains of the Ooijpolder (Nijmegen). The numbers fluctuate as a result of the water level in the spring (figure 11). The species is still declining in the

Table 9.2
Summary of rare species and Red List species of which at least 5% breed along the branches of the Rhine, shown in declining order (decline: -- 25-50 %, - 10-25%. Increase: + 1-33 %, ++ 33-100 %. 0 <10 % increase/decline).

Species	Population in the Netherlands	%	Habitat	Rhine trend	Nl trend
Corn crake *Crex crex*	50-60	33	pasture	--	--
Penduline tit *Remiz pendulinus*	200-225	31	marshy woodland	++	+
White stork *Ciconia ciconia*	200	25	pasture	++	++
Little ringed plover *Charadrius dubius*	650-1000	21	riverbanks	0	-
Black tern *Chlidonias niger*	1100-1300	16	marshland	-	--
Kingfisher *Alcedo atthis*	170-200	15	marshy woodland	0	0
Garganey *Anas querquedula*	1000-1900	12	pasture	-	--
Spotted crake *Porzana porzana*	150-400	12	marshland	-	-
Sand martin *Riparia riparia*	10.500	11	riverbanks	0	-
Corn bunting *Miliaria calandra*	80-100	10	pasture	+	--
Little bittern *Ixobrychus minutus*	8-12	10	marshland	--	--
Great reed-warbler *Acrocephalus aruninaceus*	380-420	9	marshland	-	--
Little owl *Athene noctua*	9000-12.000	8	farmyards	0	-
Barn owl *Tyto alba*	1000-1100	8	farmyards	+	+
Little grebe *Tachybaptus ruficollis*	1000-1300	7	clay pits	-	-

The international importance of the Rhine system for waterbirds

(Martin Poot)

Table 3 compares the numbers of waterbirds in January 1995 in the Netherlands part of the Rhine area with the total North-West European population (Meininger et al. 1995) and the numbers present along the entire International Rhine in January 1995 (Koffijberg *et al.* 1996). Internationally important numbers of waterbirds spend the winter along the branches of the Rhine in the Netherlands. In the case of 12 species, more than 1 % of the total North-West European population was present; in the case of Bewick's swan, White-fronted goose, Wigeon and Gadwall, the figure was more than 5 percent.

Comparing the number of waterbirds along the Rhine branches in the Netherlands and the total number along the entire Rhine, from the river's source in the Alps to its mouth in the North Sea, shows that no fewer than 32 % of all waterbirds are found along the branches of the Rhine in the Netherlands. This is even though the area of the system is less than 13 percent of the total catchment area of the Rhine. Proportionally as well as in numbers, herbivorous species of waterbirds represent a large part of the total number of birds (figure 10). The extensive area of lush floodplains makes the Rhine system in the Netherlands an attractive winter location for these species. The favourable geographic location of the Netherlands, with its generally mild winters, vis-à-vis other important migration routes and winter locations in the low lands of North-West Europe, plays a role in this.

In Germany and France, the Rhine valley soon becomes narrow to the south and the river landscape is much less imposing. The floodplains are less wide and the surrounding countryside is formed by increasingly hilly terrain with a lot of forest. Herbivores still dominate the waterbird population, but in much smaller numbers than downstream in the Netherlands. There are particularly large numbers of piscivorous waterbirds, such as the Great crested grebe *Podiceps cristatus*, Cormorant and Goosander (see table 3). The German/French section is attractive to these species because there are large stretches of water in the form of reservoirs, gravelpits etc., which are rich in fish. These stretches of water do not freeze over quickly owing to their depth, and they also form a suitable winter location for fish. The greater clarity of these waters in comparison with the flowing and therefore relatively turbid river, are another advantage to piscivorous waterbirds that rely on their eyesight for hunting.

Still further south, along the Rhine in Southern Germany and Switzerland, the picture is mainly dominated by benthivorous waterbirds (figure 10).

The Bodensee in particular has become an important winter location for these species since the colonization of the Zebra mussel from the South-East in the nineteen sixties, owing to the construction of the Danube Canal. The percentage of benthivores in this section of the Rhine is actually higher than indicated in figure 10 (no less than 83 %), because the large numbers of Coots mainly eat Zebra mussels here, whereas they are classified in the figure as herbivores, which is what they in fact are in other areas. The many diving ducks and Coots benefit from the available biomass, thanks to the shallow water and low flow rate. Flowing water impedes birds in their diving, as they quickly float away from suitable foraging locations. Somewhat similar conditions exist in the Netherlands in the Hollands Diep and lake Ketelmeer, where, by Dutch standards, there are relatively large numbers of diving ducks. However, the best areas in the Netherlands for benthivores are lake IJsselmeer and lake Markermeer.

Species	Rhine system in the Netherlands	% of total population	International Rhine	% in Netherlands Rhine system
Little grebe *Tachybaptus ruficollis*	44	<1	1 706	3
Great crested grebe *Podiceps cristatus*	1 327	>1	12 584	11
Cormorant *Phalacrocorax carbo*	1 971	<1	12 377	16
Mute swan *Cygnus olor*	1 321	<1	4 648	28
Bewick's swan *Cygnus columbianus*	2 856	17	2 879	99
Whooper swan *Cygnus cygnus*	293	>1	600	49
Bean goose *Anser fabalis*	846	<1	9 986	8
White-fronted goose *Anser albifrons*	102 269	23	222 364	46
Greylag goose *Anser anser*	3 742	3	10 603	35
Barnacle goose *Branta leucopsis*	640	<1	21 773	3
Egyptian goose *Alopochen aegyptiacus*	648	-	702	92
Shelduck *Tadorna tadorna*	70	<1	191	37
Wigeon *Anas penelope*	60 921	8	95 594	64
Gadwall *Anas strepera*	1 368	5	9 814	14
Teal *Anas crecca*	2 908	<1	10 084	29
Mallard *Anas platyrhynchos*	24 262	>1	105 372	23
Pintail *Anas acuta*	76	<1	532	14
Shoveler *Anas clypeata*	63	<1	464	14
Pochard *Aythya ferina*	8 640	2	60 317	14
Tufted duck *Aythya fuligula*	12 182	2	132 688	9
Goldeneye *Bucephala clangula*	124	<1	8 267	1
Smew *Mergus albellus*	286	2	524	55
Red-breasted Merganser *Mergus serrator*	48	<1	140	34
Goosander *Mergus merganser*	400	<1	1 834	22
Coot *Fulica atra*	49 437	3	134 544	37

Table 9.3
Numbers of waterbirds in January 1995 in the Rhine system area of the Netherlands (with the percentage of the total population) and the total number of waterbirds along the entire international Rhine (with the percentage present in the Rhine system area of the Netherlands).

Photograph 9.2
Goosanders and Smews.

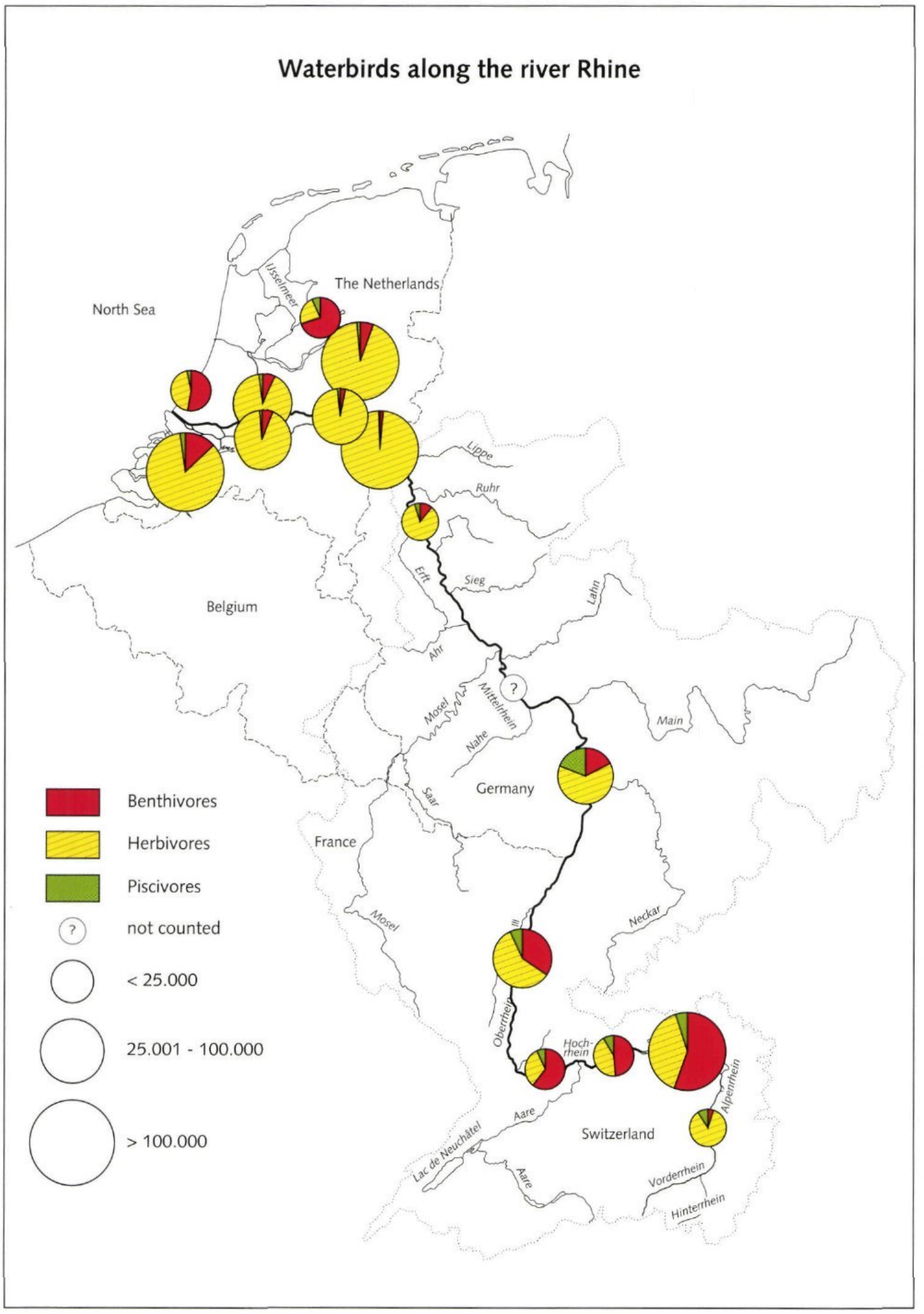


Figure 9.10
Distribution of waterbirds along the International Rhine in January 1995, divided according to preferred food. The size of the circles indicates the total number of birds (from Koffijberg *et al.* 1996).

Methods

Waterbirds: Many of the series of counts conducted along the IJssel, Waal, Rhine and Lek rivers since the 1969/70 season were carried out by volunteers under the co-ordination of the Bird Task Force for Major Rivers (Van den Bergh et al. 1979). For the downriver areas, figures were used from the Province of South Holland and from shipping counts carried out by the South Holland division of the General-Directorate of Public Works and Water Management. Since 1992/93, waterbird monitoring in the national freshwaters has been co-ordinated by SOVON (Collaborative Organizations for Bird Research in the Netherlands), on the instructions of RIZA and the Information Knowledge Centre for Nature Conservation Management of the Ministry of Agriculture, Nature Conservation and Fisheries. It was decided to discuss the waterbirds that occur in the winter half of the year because this fitted in better with the annual cycle of the species under discussion.
Counts are mainly available from the period from September to April, inclusive. For the purposes of discussion, the Rhine water system was divided into 4 subsections; Waal, IJssel, Rhine and the lower rivers (Beneden-Merwede and Oude Maas, the Lek from Schoonhoven, the Nieuwe Maas and the Nieuwe Waterweg).
The results for the 1994/95 season are compared with the average figure for the previous five seasons. The developments in the numbers over the longer term (going back to the 1969/70 season) are presented on the basis of the number of bird days per season (September-April). This number has been calculated for each species of bird by multiplying the seasonal sum of the monthly counts by the average number of days per month in the period from September to April, inclusive. The data on the counts for 1986 carried out in the subsection made up of the lower rivers is less complete. The figures were not used in presenting the developments in bird days. The counts were more or less complete for the other Rhine branches. To calculate the number of bird days, the figure entered for missing counts was the average of the previous and the following count. This was only necessary in a few instances.

Breeding birds: In the Rhine catchment area, most colonial birds and rare species are counted annually within the scope of the SOVON's National Species Study of Breeding birds. Annual counts are also made in random monitoring areas, within the scope of SOVON's Breeding Bird Monitoring Project (BMP), in collaboration with the Central Bureau for Statistics (CBS). The breeding bird monitoring network receives financial support from the IKC.

nearby dead river arms of the Rhine (reed marshes). These developments are not unique, as long-term censusing projects elsewhere in the Netherlands, in a large number of randomly selected breeding bird monitoring project sites (BMP plots), indicate the species is gradually declining in pastureland areas and rapidly declining in marshland areas. The reasons for the sharp decline in marshlands are not known but falling water tables (increased brushwood growth) will certainly play tricks on the species. The Garganey is therefore doing relatively well in the floodplains but in marshy areas it shares in the malaise many marshland birds are facing at present, both in the Rhine catchment area and elsewhere in the Netherlands.

Conclusions

The Rhine catchment area is important for many species of birds at various times throughout the year. The largest numbers of birds are present in the winter, when the Rhine system is extremely important to herbivores in particular. In severe winters, the Rhine branches also provide an important refuge for piscivorous and benthivorous waterbirds from other waters.

The water of the Rhine branches is generally still free of ice when other major waters in the Netherlands are frozen. In the summer half of the year, the rich diversity of biotopes provides breeding opportunities for a few waterbirds that are characteristic of watery and moist areas. In the early spring, the area is important for Black-tailed godwits, which recuperate after the long migratory flight from Africa, before dispersing over breeding areas inside the dykes. The area fulfils another important function in the late summer, when large numbers of Lapwings gather in the floodplains to moult.

By Dutch standards, natural processes still have a major impact in the Rhine catchment area. These natural dynamics, their extent and the presence of lush floodplains make the area attractive to birds. However, the Rhine system is also increasingly being affected by the actions of human beings. Major interventions involving far-reaching ecological changes include, on the one hand, increased water management of the river branches through the construction of weirs, more longitudinal embankments, and channelization. On the other hand, major changes have occurred in the floodplains in the use of the land and through the intensification of agriculture. There are indications that some species of herbivorous birds have temporarily benefited from increased manure spreading. Improved floodplain drainage, with the resultant very limited effect of inundations, the changing use of land and the lower levels of manure applied to the soil are probably the reason for, amongst other things, more uniform grass cover, which particularly enables grazers that operate in large groups to benefit.

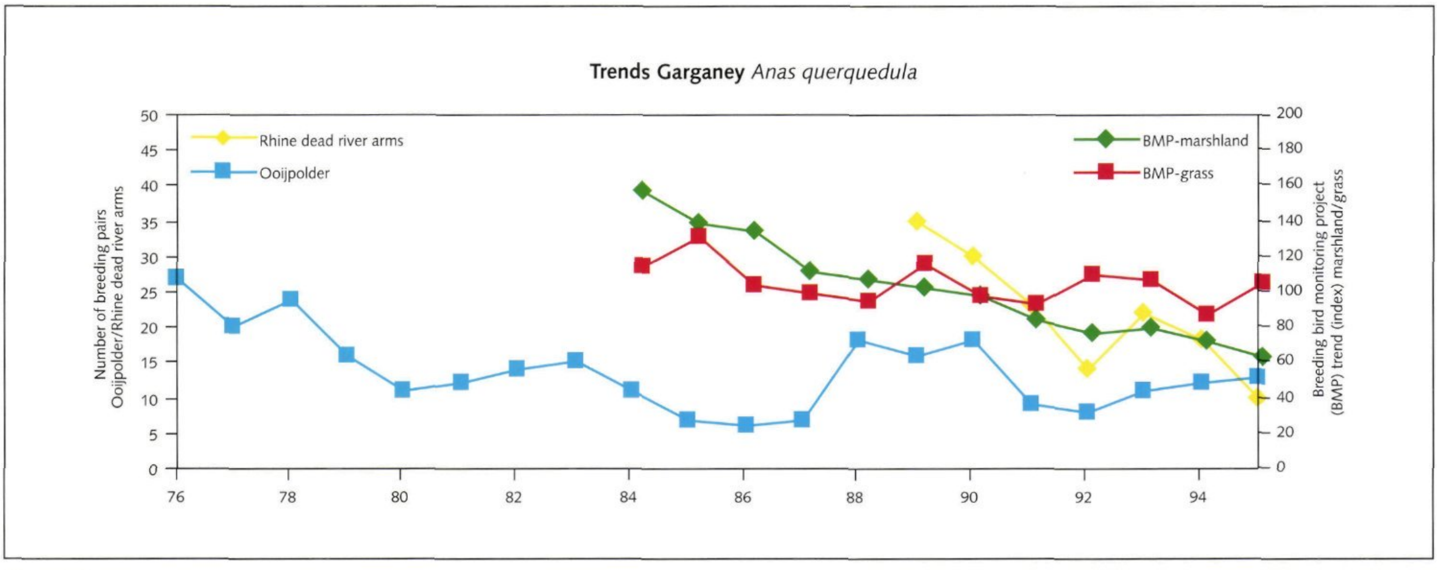


Figure 9.11
Changes in the number of Garganey in the Ooijpolder (floodplain pasture) and dead river arms of the Rhine (marshland inside the dyke), compared with the national trends in pasture and marshland. Indexes are shown that are calculated on the basis of breeding bird counts in trial areas, where counts are made from year to year within the scope of the SOVON's Breeding Bird Monitoring Project (BMP).

10. Mammals

Dennis Wansink[1] & Floor van der Vliet[2]
[1]Association for the study and protection of mammals, [2]Bat Foundation

Introduction

Relatively little is known about the distribution of mammals throughout the Netherlands. Nevertheless, the river area provides an important habitat for various groups of mammals. The river and its floodplains can fulfil various functions for mammals. Mammalian species may be temporarily or permanently resident, or they may use the river as a migration route. For some species, the river may present a barrier to any expansion of the area in which they are found. This chapter looks in detail at the importance of the river and the floodplains for a number of particular species.

Results

Of the 65 species of mammals that still occur in the Netherlands, 37 have been found in the Rhine's floodplains and tributaries since 1970 (table 1). A number of these species are specifically reliant on water (figure 1). When interpreting the table, it is important to realize that there are hardly any specific programmes for counting or monitoring mammals in the floodplains (with the exception of the annual count made by the ARK foundation, in Gelderse Poort, report of co-worker W. Bosman). Most of the data is concerned with coincidental sightings or mammals that are found dead. Species with a very noticeable presence, such as Moles *Talpa europaea*, Rabbits *Oryctolagus cuniculus*, Hares *Lepus europaeus* and Hedgehogs *Erinaceus europaeus*, are often reported, whereas other common species that are more hidden, such as the Common shrew *Sorex araneus*, Pipistrelle *Pipistrellus pipistrellus* or Polecat *Mustela putorius* are not.

The lack of a species along a particular river branch, according to the table, does not therefore indicate that the species does not occur there. The table mainly says something about the intensity of counting along the various river branches. For example, counts of mice and bats are mainly made along river stretches with old, dead river arms, claypits and enclosed landscapes, places where most species are expected.

On the other hand, two species are included in the table which are only known to have been observed once: Red squirrel *Sciurus vulgaris* and Pine marten *Martes martes*. Although this cannot be proven, the sightings probably concerned coincidental observations of wandering individuals.

Insectivores

With the exception of the Bicoloured white-toothed shrew *Crocidura leocodon*, all the insectivores that are indigenous to the Netherlands were observed in the floodplains. All the species use the floodplains as their permanent residence location.

Even species that prefer dry areas, such as the Greater white-toothed shrew *Crocidura russula* live here. The only places where the Greater white-toothed shrew is not found are the floodplains of the river Lek and along the Spui/Dordtse Kil/Merwede/Oude Maas, probably because few counts have been made in these areas. The absence of the Greater white-toothed shrew along the river Lek is probably accounted for by the fact that the species does not occur inside the dykes either - at Krimpenerwaard and Alblasserwaard - (Hoekstra 1992, Mostert 1995b).

The Water shrew *Neomys fodiens* appears to be absent along the IJssel and Waal rivers. However, the species was found during the period 1930-1970 (Van Laar 1992). According to Hollander & Van der Reest (1994), there has been a sharp decline in the number of Water shrews in the Netherlands since 1960, owing to both the poorer water quality and the disappearance of natural bank slopes as a result of canalization and bank protection measures. Things should improve for the Water shrew, now that the quality of the Rhine water is improving and natural banks are being created here and there. It is not easy to establish whether or not the Water shrew is present and

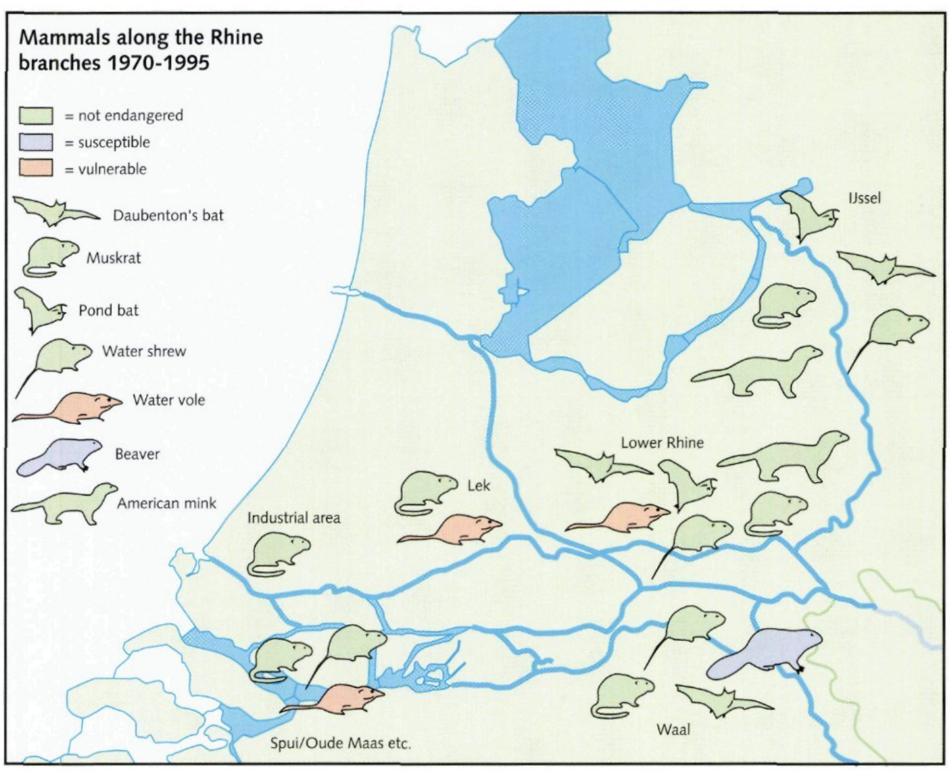


Figure 10.1
The water-reliant species of mammals that were observed along the Rhine and its branches in the period 1970-1995. The lack of observations is not evidence that the species does not occur here, but may be an indication that not many counts have been made in the area. Additional observations can be sent to the VZZ in Utrecht. The colour of the symbols indicates the status of the species according to the Red List of endangered and vulnerable mammals in the Netherlands (Lina & Van Ommering 1994). The Otter has not been observed with certainty along these rivers for the past 25 years.

Species	IJssel	Waal	Lower Rhine	Lek	Merw/OMaas D.Kil/Spui	Nrd/N.Maas Ind.Area
1. Hedgehog *Erinaceus europaeus*	x	x	x	x	x	x
2. Mole *Talpa europaea*	x	x	x	x	x	x
3. Common shrew spec. *Sorex araneus/coronatus*	x	x	x	x	x	x
4. Pygmy shrew *Sorex minutus*		x	x	x	x	x
5. Water shrew *Neomys fodiens*			x	x	x	
6. Greater white-toothed shrew *Crocidura russula*	x	x	x			x
7. Whiskered bat *Myotis mystacinus*			x	x		
8. Daubenton's bat *Myotis daubentonii*	x	x	x			
9. Pond bat *Myotis dasycneme*	x		x			
10. Pipistrelle *Pipistrellus pipistrellus*	x	x	x	x	x	x
11. Nathusius' pipistrelle *Pipistrellus nathusii*	x	x	x	x	x	x
12. Brown long-eared bat *Plecotus auritus*	x	x	x	x		
13. Serotine bat *Eptesicus serotinus*	x	x	x	x	x	
14. Noctule bat *Nyctalus noctula*	x	x	x	x		
15. Hare *Lepus europaeus*	x	x	x	x	x	
16. Rabbit *Oryctolagus cuniculus*	x	x	x	x	x	x
17. Squirrel *Sciurus vulgaris*	x					
18. Bank vole *Clethrionomys glareolus*	x	x	x	x	x	
19. Common vole *Microtus arvalis*	x	x	x	x	x	
20. Short-tailed field vole *Microtus agrestis*		x	x	x		
21. Water vole *Arvicola terrestris*	x	x	x		x	
22. Muskrat *Ondatra zibethicus*	x	x	x	x	x	x
23. Beaver *Castor fiber*		x				
24. Harvest mouse *Micromys minutus*	x	x	x	x	x	x
25. Wood mouse *Apodemus sylvaticus*	x	x	x	x	x	
26. House mouse *Mus domesticus*		x	x			x
27. Common rat *Rattus norvegicus*	x	x	x		x	x
28. Black rat *Rattus rattus*	x		x		x	
29. Weasel *Mustela nivalis*	x	x	x	x	x	x
30. Stoat *Mustela erminea*	x	x	x		x	x
31. Polecat *Mustela putorius*	x	x	x	x	x	x
32. American mink *Mustela vison*	x		x			
33. Pine marten *Martes martes*			x			
34. Beech marten *Martes foina*	x	x				
35. Badger *Meles meles*	x	x				
36. Fox *Vulpes vulpes*	x	x	x	x		x
37. Roe *Capreolus capreolus*	x	x	x			
Total number registered species	29	30	32	22	20	16

Table 10.1

Species observed in the floodplains of the branches of the Rhine from 1970 to 1995, inclusive. These are incidental observations. There is no mammal monitoring along the branches of the Rhine. **bold** = characteristic for freshwater environment. River sections: IJssel: Westervoort - Kampen; Waal: Tolkamer - Gorinchem; Lower Rhine: Pannerden - Rijswijk; Lek: Rijswijk - Krimpen aan de Lek; Merwede/Oude Maas/Dordtse Kil/Spui: Gorinchem - Hoogvliet/Hollands Diep/Goudswaard; Noord/Nieuwe Maas/Industrial area: Krimpen aan de Lek - Maasvlakte.

Species	Distribution	Tree/building inhabitant	Importance of water
Whiskered bat and Brandts bat *Myotis mystacinus/brandtii*	low number, distribution throughout the country	building & tree	-
Daubenton's bat *Myotis daubentoni*	in watery areas fairly common	tree	+
Natterer's bat *Myotis nattereri*	insufficient information	tree	?
Geoffroy's bat *Myotis emarginatus*	only in Limburg	building	?
Pond bat *Myotis dasycneme*	not very common in watery areas	building	+
Greater mouse-eared bat *Myotis myotis*	in South Netherlands, but very rare	building	"
Pipistrelle *Pipistrellus pipistrellus*	common	building	"
Nathusius' pipistrelle *Pipistrellus nathusii*	fairly common, especially in the late summer	building	"
Serotine bat *Eptesicus serotinus*	fairly common	building	"
Noctule bat *Nyctalus noctula*	locally in wooded areas	tree	"
Brown long-eared bat *Plecotus auritus*	especially in enclosed landscape, but not very common	building & tree	"
Leislers bat *Nyctalus leiseri*	very rare in woody areas	tree	?

Table 10.2

The above overview indicates the status (distribution) and the importance of water for the various species of bats found in the Netherlands (+ = very important, " = relatively important, - = of little importance, ? = unknown). It is not possible to be certain about this for all species. Bat surveys using bat detectors have only been carried out over the past fifteen years. The detectors convert the ultrasonic sounds bats use for their orientation into sounds that are audible to human beings. The overview also indicates whether the breeding colonies of the species are in buildings or in trees.

the best way is to lay traps that the animal can walk into, especially in boggy banks. Research of this kind, using traps, is time-consuming and is seldom carried out. This means that the distribution figures for this species are extremely fragmental.

Bats

The distribution picture of bats along the rivers is based on detector observations and counts at hibernation sites (table 2). Pipistrelle and Nathusius' pipistrelle *Pipistrellus nathusii* have been observed along practically every stretch of the Rhine and its branches. The only area in which they have not (yet) been observed is along the Caland canal. In the western part of the branches of the Rhine (Nieuwe Maas and Merwede up to the North Sea coast), the only other species known to have been observed, besides these two, is a Serotine bat *Eptesicus serotinus* along Dordtse Kil. This is in contrast to the river IJssel and the Lower Rhine, where seven and (possibly) eight species were found respectively.

As far as is known, the bats mainly use the floodplains as a foraging area; nothing is known about the presence of summer colonies. The likelihood of foraging bats is therefore largely determined by the presence of colonies inside the dykes. However, a number of brick factories in the floodplains are used for hibernation (see box).

Besides Otters *Lutra lutra* and Beavers *Castor fiber*, bats are probably the only mammals that use the river itself as a migration route, for migration between residence locations and hunting areas, and between hunting areas themselves, as well as between summer residence locations and hibernation sites. However, very little data is available on this. Ringing studies in the nineteen fifties established that the Pond bat *Myotis dasycneme* uses the river IJssel as a migration route between its summer residence locations in Friesland and Groningen, and marlpits in South Limburg, where the species hibernates. It is not known whether this is still the case (report of co-worker G. Glas).

Bats migrate along the coast in late summer and autumn. Nathusius' pipistrelle has been observed during migration at Maasvlakte in the late summer. Moreover, two unusual species have been observed at the same location in the lighthouse, namely the Bicoloured bat *Vespertiliu murinus* and Leislers bat *Nyctalus leisleri* (Mostert & Wondergem 1993). These observations are probably connected with the migration of bats along the coast.

Photograph 10.1
Water bats *Myotis daubentoni* (photograph) and Pond bats *M. dasycneme* are the only bats that are directly reliant on water. They 'rake' their prey from the water's surface. This works best if the surface of the water is undisturbed, such as when there is no wind or in a sheltered place. Overgrowth growing up the bank provides shelter. However, overgrowth in or on the water (e.g. Duckweed) is a disadvantage to these two species. The other bats are also indirectly reliant on water, owing to the many insects that generally live around water.

Lagomorphs

Rabbits and Hares have been observed almost everywhere. Rabbits have even been identified as permanent residents in the few green locations on industrial sites along the Caland canal and the Nieuwe Waterweg. The vegetation in this area is probably a little too sparse for the Hare.

Voles

The voles include a few species that are characteristic of the bank zone. These are the Muskrat *Ondatra zibethicus*, the Water vole *Arvicola terrestris* and the Root vole *Microtus oeconomus*. These are species that are also largely reliant of water for their migration and dispersion.

The Root vole was not observed anywhere until 1995. Nor are there any historical accounts of it being present in the Rhine's floodplains and tributaries. In 1995, pellet studies along the Oude Maas revealed skeletal remains of Root voles; however, there is no certainty as to whether the species also lives in the floodplains. The absence of this vole is possibly connected with the presence of the Short-tailed vole *Microtus agrestis* and the Common vole *Microtus arvalis* in the floodplains. In areas that are not excessively wet, the Root vole has probably been driven out by the Short-tailed vole and the Common vole (Van Apeldoorn *et al.* 1992). For example, the Root vole is found inside the dykes around the Nieuwe Waterweg, where Short-tailed voles are absent both inside and outside the dykes. However, Common voles are found there inside the dykes.

The Water vole is absent along the river Lek and in the Nieuwe Maas and Nieuwe Waterweg industrial and urban area. This is probably an artefact, because the species does occur inside the dykes in this environment. On the other hand, according to Niewold (1993), the Water vole is declining in number. The possible causes he cites are changes in the biotope, such as intensive bank management, the falling water table, ploughing pastures and intensive Muskrat hunting, which also results in the capture of Water voles. In spite of the intensive hunting, the Muskrat occupies the entire stream valley of the Rhine and its tributaries.

Of the other voles, the Common vole is particularly common in the floodplains. This is not so surprising, as it is one of the species that are characteristic for pioneer vegetation and which is frequently found in regularly inundated floodplains. Short-tailed voles and Bank voles *Clethronomys glareolus* are more likely to be found at later stages of vegetative growth, and they stay in the vicinity of boscages on the higher ground.

Beaver

In the autumn of 1994, 15 Beavers were released in the Ooijpolder, near Nijmegen, with the intention of creating a second population of Beavers in the Netherlands. The project got off to a bad start: six of the animals died within a few weeks of being released (Nolet 1995). Five others disappeared and possibly also died. In April 1995, one was sighted in the neighbourhood of Ewijk. The others were still in the Ooijpolder around this time. Not much information is available on why the animals died: are the reasons related to the Ooijpolder or the area from which the animals originally came (Germany)?

On the other hand, the population in the Biesbosch is doing well. The population is growing and the animals occasionally make excursions along the Merwede in the direction of the Afgedamde Maas (Dijkstra 1996).

True mice

The most frequently observed true mouse is the Wood mouse *Apodemus sylvaticus*. In the Netherlands, the Wood mouse achieves the highest population densities in dry, relatively disturbed environments, on nutrient rich soil (Wammes 1992). The floodplains are a good example of such environments. Field mice have a large radius of activity and are among the species that quickly colonize new areas. After a flood, the Wood mouse is the first species found in the floodplain (report of co-worker W. Bosman).

Other common true mice in the floodplains include the Harvest mouse *Micromys minutus* and the Common rat *Rattus norvegicus*. Although both of these species are often found in damp areas, they are not reliant on them. They generally migrate to dryer ground in the winter half of the year. Both require thick bank vegetation.

The House mouse *Mus musculus* and the Black rat *Rattus rattus* are only found in or near human habitats, such as around ports.

Predators

The small Mustelidae, the Weasel *Mustela nivalis*, Stoat *Mustela erminea* and Polecat are found everywhere. The floodplains probably provide a good habitat for these species because of the wide variety of prey and the absence of human interference. These species are truly in paradise during periods of high water, when the shrews and mice are driven from their shelters and forced to find scarce, higher ground.

American mink *Mustela vison* have been observed in a few places, particularly along the river IJssel. These are probably always specimens that have escaped from mink farms. No young minks actually born in the wild have been found along the Rhine and its branches thus far.

Of the larger Mustelidae, the Badger *Meles meles* and the Beech marten *Martes foina* are regularly seen in the floodplains. It is not clear whether they live here permanently. Both species occupy large territories. At Havikswaard, along the river IJssel, Badgers regularly occupy additional sets, but these are abandoned during periods of high water. A Badger also occupied a set at Millingerwaard for a time. A few Badgers are permanent residents of high ground along the floodplains of the Maas, where some of the sites have been specially created for Badgers.

Apart from the danger of flooding, Badgers also run the risk of being poisoned. Badgers that presumably foraged in the Maas floodplains were found to have higher levels of cadmium, mercury, copper and zinc than Badgers that did not forage in river floodplains (Ma & Broekhuizen 1989). In a third of the animals, the exposure limit for cadmium had been exceeded (200 microgram/g dry weight), leading to the likelihood of kidney damage. Ma & Broekhuizen attribute the high concentrations to the Badger's diet, which mainly consists of earthworms. Earthworms are able to digest relatively many heavy metals in the soil (Kerkhofs 1993). This means that other species with a diet comparable to that of the Badger (e.g. Moles and shrews) run the same risk. Practically all the Maas floodplain Badgers concerned in this study died as victims of traffic.

Badgers and Stone martens are therefore only found in the floodplains of the Rhine and its branches if there are populations inside the dykes. The same applies to the Pine marten that was observed in the floodplains of the Lower Rhine. It is not clear whether the floodplains formed part of the habitat for this Pine marten. The specimen was a victim of traffic and may therefore have been a dispersing individual.

Foxes *Vulpes vulpes* are observed everywhere, except along Merwede/Oude Maas/Dordtse Kil/Spui. The Fox does not occur in this area inside the dykes either. During the course of this century, the Fox has expanded its area from east to west. There has also been an expansion outwards from the dunes, which was probably originally accounted for by animals that escaped from captivity. The two expansions are approaching each other near Rotterdam. Foxes have also been observed at Dordtse Biesbosch, but not yet in the area in between.

The floodplains offer an opportunist like the Fox many possibilities but, in most places, the floodplains probably only form part of the habitat.

Artiodactyla

The same applies to Roes *Capreolus capreolus* as to Foxes. They have also expanded their area from east to west during the course of this century, but they have not yet succeeded in colonizing the Oude Maas area.

The Roe inhabits the land between deciduous forest and open ground and is only found in more open ground if the forests are overpopulated. Therefore, Roes do not readily choose to live in floodplains that offer little shelter.

On the other hand, the floodplains provide an ideal biotope for Red deer *Cervus elaphus*. They have not yet been observed here because Red deer are kept in enclosed reserves. In principle, around Rheden they could easily reach the floodplains of the IJssel river.

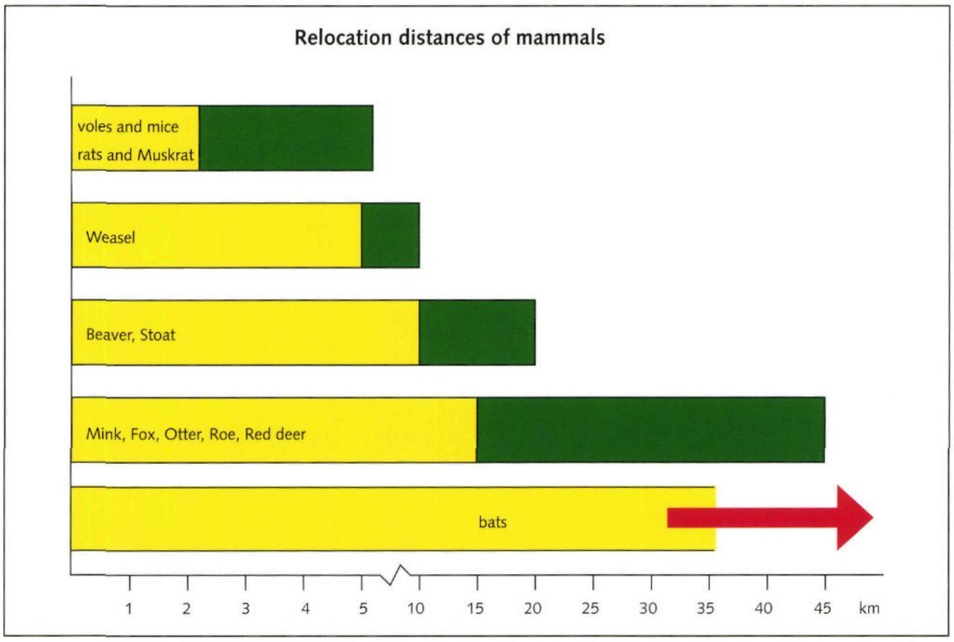


Figure 10.2
Distances that some species of mammals travel during daily (within their home range: white) and long-distance relocations (dispersion: shaded). Recolonization of an inundated floodplain is easier for a Weasel than a mouse. However, without the presence of mice, Weasels would not readily live in a floodplain. According to Apeldoorn (1994).

Discussion

All kinds of measures have been taken in and along the Rhine and its branches to give the river a natural appearance. The river is allowed to overflow its banks in a number of places; (floodplain) forest growth is encouraged and water pollution is restricted. This probably has a positive effect on some species of mammals. The Water shrew, for example, probably benefits from the cleaner water. As the (floodplain) forests grow older, more trees will probably provide a suitable habitat for bats to establish colonies. Modifying the abandoned brick factories and bunkers (compare the example of the Blauwe Kamer brick factory) creates suitable hibernation sites in the floodplains. More will have to be done to also make these buildings suitable for breeding colonies. At present, they are too cold and damp.
The increasing diversity in types of vegetation will probably increase the food supply for mammals, which means more floodplains will provide a suitable habitat for mammals.

However, the inundation of the floodplains also has detrimental consequences for the non-flying species of mammals. They have to be able to withdraw to higher parts quickly enough and to colonize the floodplains again from there. Therefore, special mounds have been constructed in the floodplains for Badges. It has also been suggested that the same should be done for Beavers. At present, Badges, Beavers and other species of mammals have to seek safety inside the dykes when the river flows well beyond its banks. This forces them into unknown areas where there is also more human activity, such as road traffic.
At locations where floodplains offer no high-water refuge sites, the floodplains can only be recolonized, if there are populations of the mammalian species inside the dykes. In that case, it is worth remembering that the speed at which populations expand is not the same for all species (see figure 2). The Wood mouse will re-establish itself quicker than the Bank vole.

Conclusions

The river itself probably fulfils a function for just a few species of bats, Beavers, Coypus Myocastor coypus and Otters, in that it serves as a migration and dispersion route, and, for bats, also as a hunting area. The river's current is too strong for smaller mammals.
The floodplains can provide an important habitat for smaller non-flying species of mammals, up to the size of a Hare, although some uncertainties are involved, the greatest of which is flooding.

Bats and the larger non-flying species of mammals probably only use the floodplains as a temporary residence location and as a foraging area. They are only found in the floodplains if there are populations inside the dykes, close to the river. Exceptions to this are the Beaver and, if they were to occur in this area, the Otter and the Coypu.

The major rivers form a barrier for the non-flying species of mammals. If (rare) species die out on one side of the river, it is probably difficult for them to recolonize the area on their own (e.g. the Stone marten).

Method

The most important source of the data used here was the database of the CZI contact group for mammal surveys (Contactgroep Zoogdier Inventarisatie (CZI)). The database was originally put together for the production of the guide to Dutch mammals entitled *Atlas van de Nederlandse zoogdieren* (Broekhuizen *et al.* 1992). The database contains observations of mammals up to and including 1988.
The observations recorded in the database are shown in atlas blocks (5 x 5 kilometres), sometimes in a kilometre block and occasionally in a hectometre block. To be certain that a species has been observed outside the dykes, only observations at the hectometre level can be used, and sometimes those at the level of the kilometre block, providing the kilometre block is situated entirely outside the dyke.
The CZI data for the period from 1970 up to and including 1988 was used for this report. For more recent observations, regional mammal and bat task forces were approached and survey reports were consulted of the Forestry Commission, SOVON (Collaborative Organizations for Bird Research in the Netherlands), the foundation Stichting ARK, the field task force of VZZ and the Mammals task forces of the youth groups (Jeugdbonden).
In the case of bats, particular use was made of the data collected between 1987 and 1993 for the bat atlas project conducted by the bat research foundation (Stichting Vleermuisonderzoek (SVO)) and the bat task force of the Netherlands (Vleermuiswerk-groep Nederland (VLEN)). Random bat surveys were carried out on each river section. This means the picture of the numerousness of the species is incomplete but the overview of the presence of species along the various river sections is reasonably complete.

Bat hibernation sites

(Floor van Vliet)

In the Netherlands, bats hibernate from October to April. The hibernation sites chosen are frost-free, dark, quiet and have a high humidity. Most species of bats use spaces underground, but some species also or almost exclusively use hollow trees. The marlpits in South Limburg are known hibernation sites for bats. Bats also hibernate in fortresses, bunkers and cellars (figure 3).

In the river area, bats hibernate in various bunkers that are situated here and there close to the river. Where found, the numbers are low. Large numbers of hibernating bats are accommodated in some of the fortresses close to the river along the Hollandse Waterlinie, a strip of land flooded as a defence in historical times.

The disused kilns of brick factories in the floodplains provide reasonable hibernation sites, with their thick, brick arched roofs, even if the majority are not frost-free, owing to all the openings (chimneys and entrances to the kilns). The bats usually crawl into gaps between the bricks. The species found hibernating in brick factories are Whiskered bat Myotis mystacinus, Daubenton's bat *Myotis daubentonii*, Natterer's bat *Myotis nattereri* and Brown long-eared bat *Plecotus auritus*.

Various brick kilns have been specially furnished for hibernating bats. The kiln of the former Blauwe Kamer brick factory, at Rhenen, which is in the care of the foundation *Stichting Het Utrechts Landschap*, was partly modified in 1991 for hibernating bats. All but one of the entrances were sealed and soil was placed on top. Hibernating bats were observed after the modifications. It is not known how quickly bats respond to improvements in a hibernation site. The next few years should show whether there has been a further increase in the number of bats at Blauwe Kamer. Only a few hibernating bats are found in most brick factories each year. Numbers in excess of ten are only found in the brick factories at Olst and Windesheim (report of co-worker G. Glas). However, it ought to be remembered here that bats in brick kilns may easily be missed, owing to the large number of cracks in which they can hide. The number of bats counted in these buildings should therefore be seen as the minimum.

Only a few places in the floodplains contain hollow trees that provide hibernation possibilities for bats. Houses and buildings also provide hibernation possibilities for bats. For example, bats were found hibernating in the cellar of a farm on a floodplain in Gelderland. Many farms have cellars but they are often used too intensively for bats to use them as hibernation sites. An increasing number of cellars are also heated, which makes the climate unsuitable for hibernating bats (report of co-worker G. Glas).

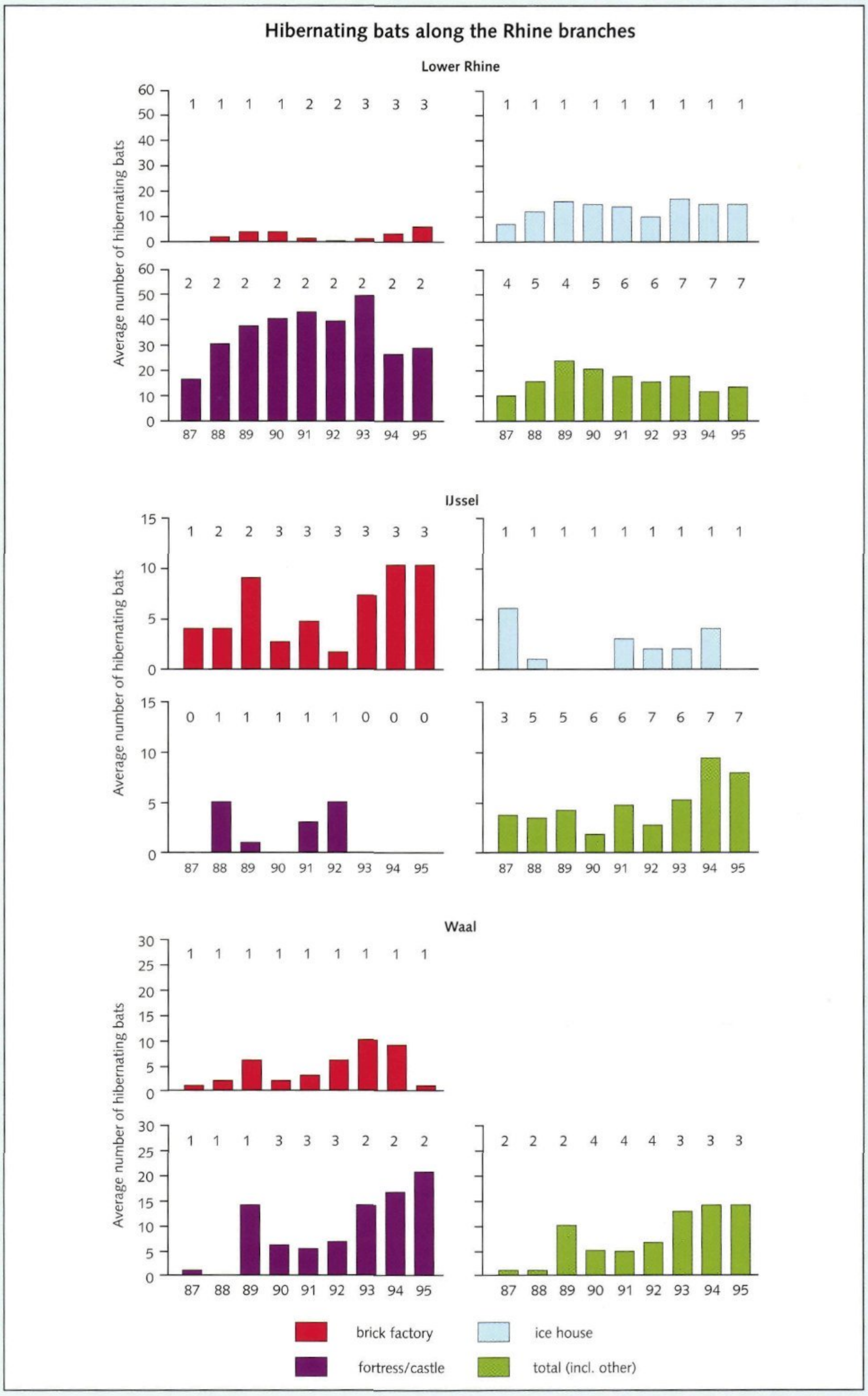


Figure 10.3
Average number of hibernating bats in buildings along the river Waal, the Lower Rhine and the river IJssel in the winters of 1986/87 up to and including 1994/95. The average numbers are indicated for brick factories, icehouses and fortresses. The category 'total' includes these three types of buildings, plus a few less common types, such as a bunker, a culvert and a railway bridge. The numbers above the columns refer to the number of buildings in which a count was made. Generally speaking, there appears to have been an increase in the number of hibernating bats along the IJssel and Waal rivers and a slight decrease along the Lower Rhine. The degree to which these winter counts provide an indication of changes in the bat numbers remains a point for discussion. In any case, it is clear that brick factories along the river IJssel have a more important function (vis-à-vis fortresses and icehouses) than along the other two river branches.

11. Ecotoxicology

Hannie Maas (RIZA), Dick de Zwart (RIVM) & Henk Pieters (RIVO-DLO)

Introduction

The Rhine and its branches are an important water supply source in the Netherlands. A great deal of the drinking water in the Netherlands is produced from Rhine surface water. The Rhine also serves as the main source of water for industry, agriculture, shipping, fishing, recreation and for combating falling water tables in nature conservation areas.

Thanks to international cooperation and legislation (including the International Rhine Committee and the North Sea Conference) and the national environmental policy (including the policy document on water management, the Rhine Action Plan, and the National Environmental Policy Plan), the quality of Rhine water improved considerably in the nineteen eighties. The toxicity of the surface water also decreased sharply. With the exception of places in the direct vicinity of discharge points, the concentrations of the hazardous compounds present in the Rhine are too low to detect acute effects. The more subtle effects of chronic exposure are also difficult to establish clearly.

However, a reduction of 50 % or more in emissions of priority microcontaminants (IRC 1987) is no guarantee for establishing a "healthy" ecosystem, to which indigenous species can return. Although the substances designated as priority substances will have a harmful effect on water quality, other substances may also contribute to the quality of the ecosystem. Hendriks *et al.* (1994) have demonstrated that just 11 % of the identified organic compounds in Rhine surface water account for the toxicity. A subsequent supply from the bed of the water course and the use of priority substance replacement compounds may also be the reason why water quality has not improved sufficiently for the return of indigenous species following the reduction.

The existing quality of the environment in various compartments of a water system is generally established on the basis of measuring the concentration of a relatively limited number of chemical compounds. However, in a water system like that of the Rhine and its branches, the enormous range of potential toxicants present makes it impossible to establish all the effects and relationships to plant and animal species. Ecotoxicology approaches this problem by monitoring a limited number of organisms and then extrapolating the consequences or risks for the entire aquatic ecosystem from the results.

Standardized tests (bioassays) are used to directly measure the biological availability and the combined effect of substances, in order to provide information on the effects of the known and unknown substances present in the compartments.

Many substances accumulate in organisms and may present a threat to higher species along the food chain. An insight into the biological availability and distribution of substances in the food chain is obtained by measuring the accumulation of the substances in a number of organisms. The results of the studies are related to the chemical quality of water and sediment and to the effects that occur in particular species in the field. In the biological monitoring programme, the current risks of contamination of the water system of the Rhine and its branches are determined at a single location in the system. A study of quality changes over time has been conducted on the basis of research data from previous years, measurement data from RIVO and RIVM (governmental research institutes) and research data from the Rhine Action Programme. The monitoring programme consists of three parts: bioaccumulation in Eel and Zebra mussels, toxicity measurements in surface water, and field and laboratory studies of the effects produced by the beds of water courses.

Results

Accumulation in Eel

With the exception of mercury, there are no differences in accumulation levels in Eel caught at Lobith or Culemborg (figure 1). The mercury concentration in Eel from the river Lek in Culemborg is a factor of 1.5 higher than the concentration found in the Rhine at Lobith.

In 1995, the concentrations of mercury and DDT were still well above the Maximum Acceptable Risk level (MAR) (figure 1). The levels of mercury exceeded the MAR by a factor of around 3. Although the exceedences are not serious, the risks presented by these substances to the aquatic ecosystem are not entirely excluded. The concentrations of PCB153 and HCB are still relatively high. The concentration

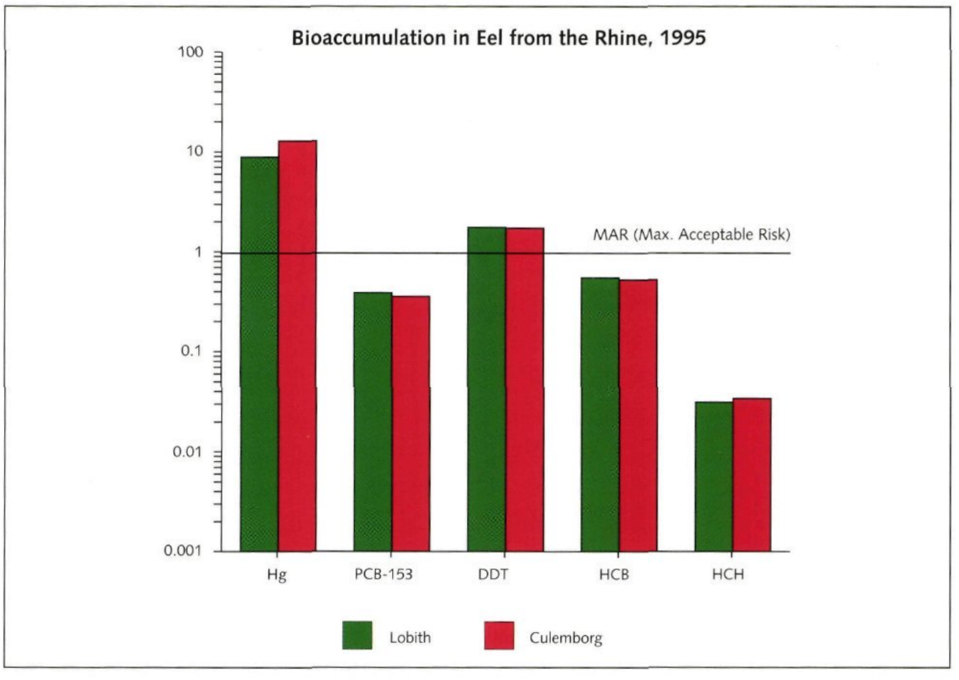


figure 11.1
The exceedence factor of the Maximum Acceptable Risk for substances measured in Eel from the Rhine, at Lobith and Culemborg. An exceedence of the MAR (> 1) signifies a threat to the aquatic ecosystem.

at Lindane is close to the Negligible Risk level (NR=MAR/100).

Accumulation levels in Eel at Lobith are comparable with those at Hollandsch Diep and Haringvliet. Hexachlorobenzene forms an exception to this. The levels of this compound in suspended matter are decreasing sharply as a result of evaporation or breakdown in the Rhine downstream, which is apparent from the level of accumulation in Eel.

In lake Ketelmeer, the concentrations of substances in Eel are generally a factor of 2-3 lower than the concentrations at Lobith. In clean areas, such as the Wolderwijd, concentrations of PCB153 and HCB in Eel have been measured that are a factor of 30 lower.

In 1995, higher concentrations were measured in Eel in the Rhine compared with those in the river Maas at Borgharen. In the Maas, just lindane was 3 times higher than the accumulation level measured in the Rhine.

Developments and trends

In 1988, RIVO conducted an extensive monitoring campaign within the scope of the Rhine Action Programme (Van der Valk *et al.* 1989a), in which concentrations in Eel were measured along various branches of the Rhine. It emerged that the concentrations in Eel measured at Lobith differed only slightly from the concentrations measured in the river Waal (at Tiel) and the river Lek (at Krimpen). In the river IJssel (at Deventer) the concentrations were generally at a slightly lower level.

RIVO has been taking measurements at various locations in the Rhine catchment area since the early nineteen eighties. Figure 2 shows the trend for the accumulation of a number of substances in Eel caught at Lobith and Culemborg from 1985.

At Lobith, there were large fluctuations in the levels of all substances. In spite of the decrease in the concentrations of substances in water and suspended matter (Hoogeveen 1994), no clear decrease in accumulation levels was observed. At Culemborg, the levels remained similar over the years. DDT levels decreased sharply after 1989 but increased again in 1995. However, a definite decrease can be seen in HCB levels. The level has been below the MAR since the early nineteen nineties.

The levels of mercury at Culemborg are striking in that they were higher than those at Lobith throughout the monitoring period. In the Rhine, at Lobith, the reduction in the total mercury

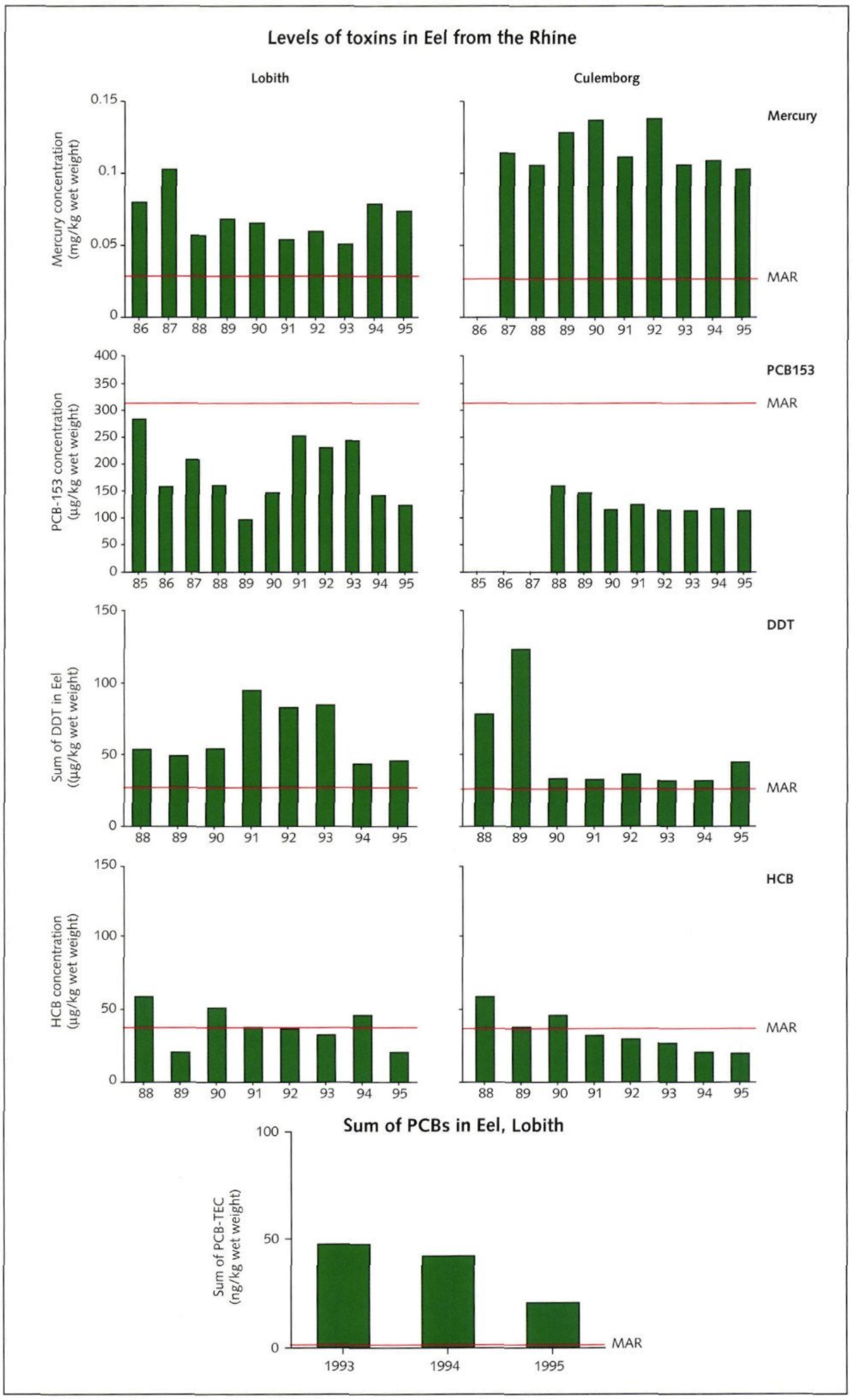


Figure 11.2

Concentrations of mercury, PCB 153, (GDDT, HCB and (GPCB-TEC (mg/kg$_{wet}$), measured in Eel from the Lek at Culemborg and Lobith (RIVO). The levels have been corrected for "standard" fish (5 % fat and 10 % dry weight).

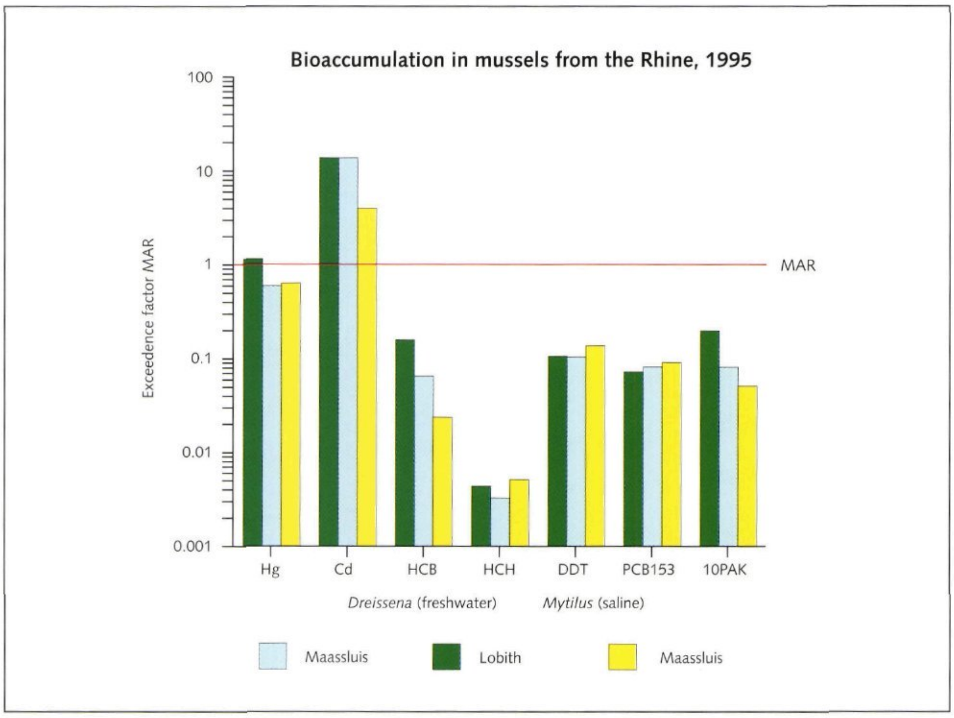


Figure 11.3
The exceedence factor of the Maximum Acceptable Risk for substances measured in Zebra mussel from the Rhine at Lobith and at Maassluis. Bioaccumulation in the saline section of the Nieuwe Waterweg at Maassluis was measured in the saltwater mussel Mytilus. An exceedence of the MAR (> 1) signifies a threat to the aquatic ecosystem.

concentration, by a factor of 4 since 1980 (Hoogeveen 1994), is not reflected in the accumulation levels of mercury in Eel. Pieters and Hagel (Pieters and Hagel 1992) attribute the hold-up in the reduction of accumulation levels in Eel to the continuing high level of methylmercury, through food organisms, from the river bed. The Eel, which was caught at Culemborg, possibly had more contact with the (older) sediment, than the Eel caught in the Rhine at Lobith, where there is greater erosion.

Non-ortho and mono-ortho PCBs, substances, which because of their physical properties are similar to extremely toxic chlorobenzodioxins, were only measured at the Lobith location. The concentrations in Eel, expressed as Toxicity Equivalent Concentrations (TEC) against the extremely toxic compound 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), fell sharply in 1995, but are still far above the indicative MAR (factor 33). Compared with Hollandsch Diep and Haringvliet, these concentrations are still a factor of 1.5 to 2 higher. This means that these compounds can be expected to present serious threats throughout the aquatic ecosystem, particularly to piscivorous higher organisms. In the case of the Otter, for example, a "no effect concentration" for PCB-TEC was derived of around 35 ng per kg food (Leonards *et al.* 1989a). Measurements made at Lobith in 1995 revealed a concentration in fish of 13 ng per kg fish. The greatest effects are expected from PCBs and dioxin compounds. The effect of other substances is less. However, if the combination of substances in water and sediment are taken into account, the concentrations found for PCB-TEC can certainly contribute to the toxicological impact on Otters.

The levels of the pesticides not shown in figure 2, lindane, dieldrin and octachlorostyrene (OCS), are gradually but significantly falling at Lobith and Culemborg. The level of hexachlorobutadiene (HCBd) continues to fluctuate considerably (Verboom *et al.* 1995).

Accumulation in Zebra mussels

Figure 3 shows the accumulation levels measured in Zebra mussels suspended in the water at Lobith and Maassluis vis-à-vis the MAR. The concentrations at Maassluis are generally slightly lower than those measured at Lobith, but the difference never exceeds a factor of 2.

Only the concentrations of heavy metals in Zebra mussels approach or exceed the MAR. The organic microcontaminants are a factor of 10 lower. The lindane concentration is negligible.

The Zebra mussels were suspended in the upper freshwater section of the Nieuwe Waterweg. The saltwater mussels were suspended at the deeper saline water level. The concentrations in both types of mussels were measured and

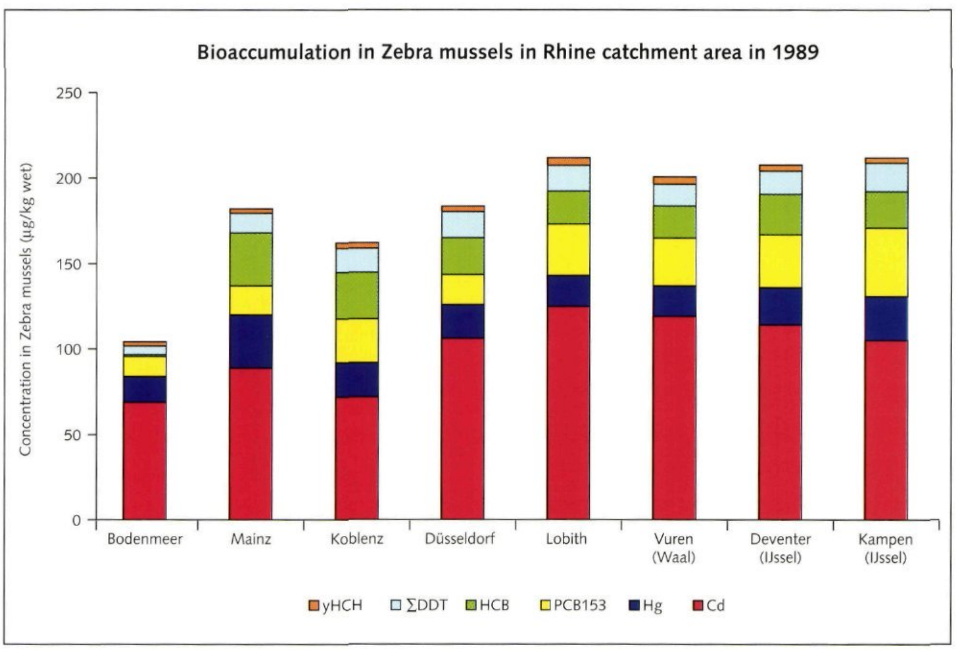


Figure 11.4
Concentrations of heavy metals and organic microcontaminants in Zebra mussels suspended in the Rhine catchment area, from lake Bodenmeer to lake IJsselmeer (van der Valk *et al.* 1989b). The values have been corrected for "standard" mussels (10 % dry weight and 1.3 % fat). The shaded values signify an exceedence of the MARmussel (see table in method box), and therefore a threat to the aquatic ecosystem.

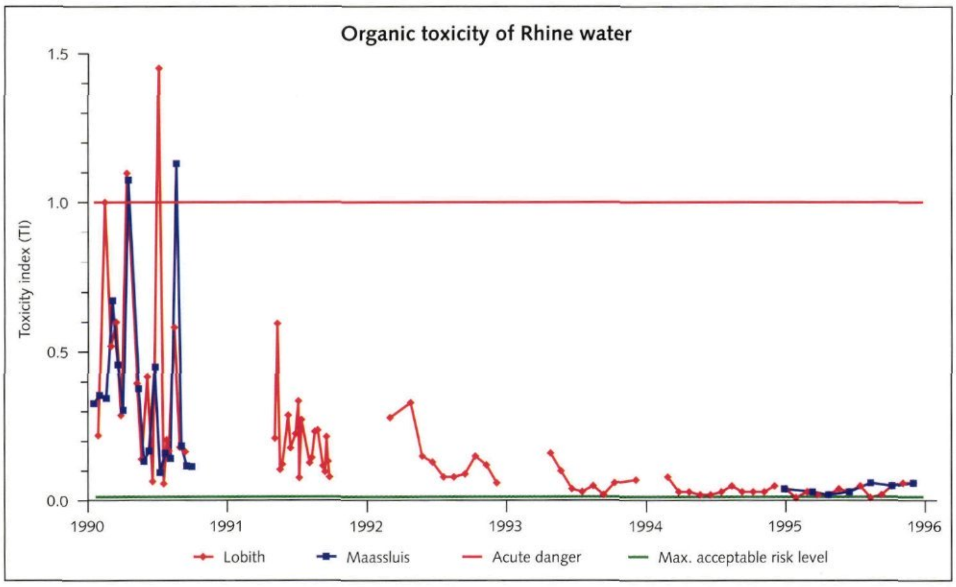


Figure 11.5
The toxicity has been determined regularly at the Lobith and Maassluis locations in recent years. Most organic micro-contaminants present in the water are concentrated using XAD resin. Metals and highly polar compounds do not occur in the concentrate. The toxicity was only determined in this period using the Microtox test, in which the luminosity of the bacterium *Photobacterium phosphoreum* is inhibited by the presence of toxicants. A toxicity index (TI) higher than or equal to 1 indicates an acute threat. The likelihood of environmental damage is considered acceptable for a TI of less than 0.01.

corresponded reasonably (figure 3). The differences that were found can be attributed to a difference in the availability of substances in a saline or freshwater environment. However, it is also possible that the freshwater section contains relatively more Rhine water than the saline section (Pieters *et al.* 1996).

When compared with the concentrations found in the sedimentation areas in the Rhine catchment area, the concentrations of heavy metals are in line with each other. The concentration of lead in mussels at Lobith was approximately a factor of 2 higher than in the sedimentation areas, but was a factor of 10 lower than the indicative MAR (1 mg/kg_{wet}). PCB levels were clearly higher in sedimentation areas, and levels of GPAHs at Lobith were again the highest.

The accumulation levels in Zebra mussels measured in the Maas at Eijsden were comparable with those measured in the Rhine at Lobith. Higher accumulation levels in the Maas were only found for cadmium and PAHs.

Developments and trends

Accumulation in suspended Zebra mussels was only measured on an incidental basis, so no long-term trends are available. However, in 1988, within the scope of the Rhine Action Programme, a comparable study was conducted in the entire Rhine catchment area, from lake Bodenmeer to lake IJsselmeer (Van der Valk *et al.* 1989b).

Figure 4 shows that mercury concentrations remain at the same level throughout the Rhine catchment area. The levels of cadmium in Zebra mussels are also fairly high in lake Bodenmeer. The levels in mussels generally increase after Koblenz and remain relatively constant in the Netherlands.

In comparison with 1988, the heavy metal concentrations measured in 1995 at Lobith (figure 3) showed little change. The accumulation levels of organic microcontaminants fell by at least a factor of 3 in comparison with the figures for 1988.

Rhine water toxicity

Figure 5 shows toxicity levels at the two Rhine locations for the period 1992-1995. From 1990, we see a continuing reduction in the organic toxicity of Rhine water, and the assumed acceptable risk level was approached in 1994 and 1995 (toxicity index <0.01). The number of short-term episodes involving high to extremely high toxicity also fell sharply during the same period. This picture is not confirmed by the available chemical analyses carried out in recent years. Chemical analyses from 1995 and before showed that concentrations of organic compounds at Maassluis were generally slightly lower than at Lobith (Hendriks 1993, Hoogeveen 1994). However, there is hardly any difference between the toxicity levels measured at Lobith and Maassluis.

The toxic response was compared with the organic contaminants that were chemically analysed in the period 1992-1995, at Lobith. This concerned an increasing number (around

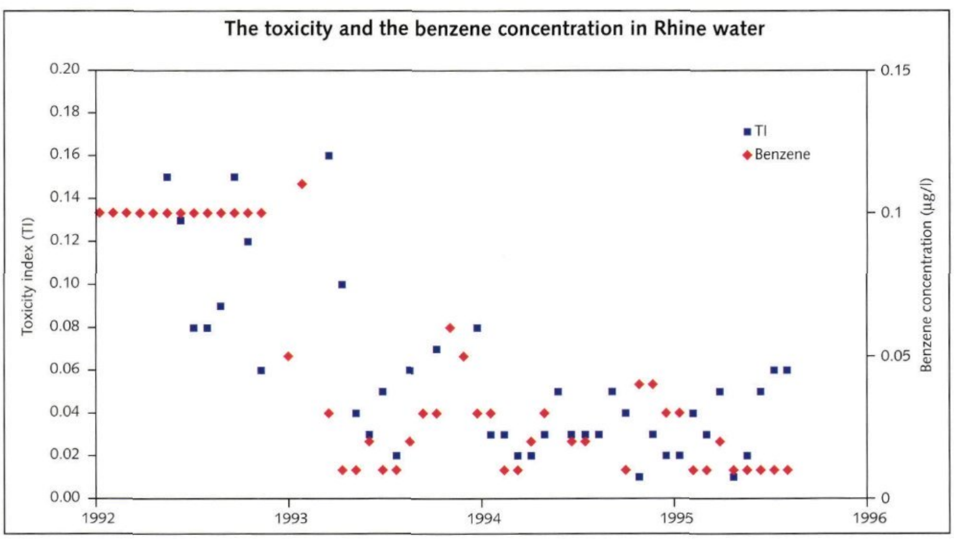


Figure 11.6
Of all the concentrations of organic contaminants in water measured at Lobith only the benzene concentration displayed a correlation with the toxicity detected.

20-70) of compounds in the OCBs (DDT, lindane and drins), plus a few organophosphorus pesticides (simazine and atrazine). Later in the monitoring period, additional measurement data became available on the concentrations of a wide range of pesticides (such as: triazines, phenylureum and phenol herbicides), PAHs, and aromatic and possibly chlorinated hydrocarbons. The time series of many compounds show no or hardly any dynamics. From a comparison of the observed toxicity, which also displayed very low dynamics in this period, and the measured concentrations of all these compounds, it emerged that, once a number of contradictory measurement values had been removed, only the benzene concentration displayed a correlation with toxicity (figure 6). However, the benzene concentration measured is far below the concentration at which a slight effect is still observable using luminescent bacteria (the EC20).

The Rhine water at Lobith had to be concentrated by a factor of 100 to cause acute effects on luminescent bacteria. In 1989, Hendriks (Hendriks 1994) had to concentrate the water 50 times to measure acute effects on water fleas. This method did not include heavy metals and extremely lipophilic compounds, such as PCBs. However, on the basis of toxicity data for phytoplankton and zooplankton for these substances, no chronic toxic effects are anticipated.

Developments and trends

In 1994, in a joint venture between a number of institutes (RIWA, RIVM, KIWA and PWN), three monitoring campaigns were carried out to measure the toxicity and genotoxicity of Rhine water, and to make an ecological survey of the macrozoobenthos species present at the locations (Noij *et al.* 1996). The toxicity of Rhine water concentrates was measured using five different toxicity tests, a practice which provides considerable added value in comparison with a single toxicity test using bacteria.

The toxicity measurements produced a value (similar to the MAR methodology) that indicates the fraction of potential species of organisms present that will suffer detrimental effects during long-term exposure (Fraction unprotected; Fu). Figure 7 shows the average and standard deviation of the calculated value for the entire Rhine catchment area, for the three monitoring campaigns.

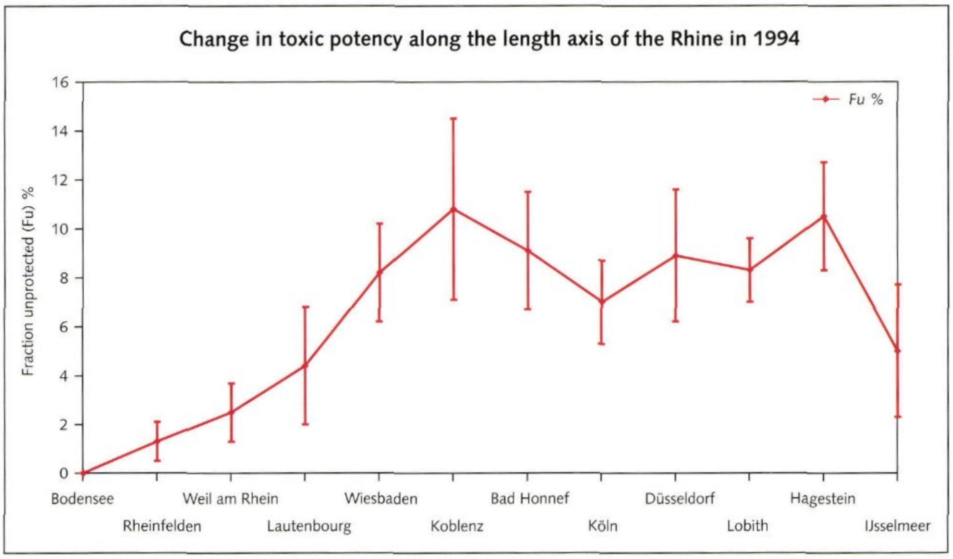


Figure 11.7
The change in the fraction of potentially unprotected species (%) along the longitudinal axis of the Rhine in 1994. The figure shows the average and the standard deviation of three measurements taken in February, June and October.

The toxicity level is considered acceptable in the downstream stretch of the Rhine. In the section after the entry of the Main and Moezel, toxicity increases and remains at a similar level in The Ruhr and the Dutch section. Toxicity levels are clearly lower at lake IJsselmeer (Andijk).

For 1994, the toxicity estimate at Lobith, which is based on only one bacteria measurement, as indicated in figure 5, shows a slight exceedence of the toxicity level that is still considered acceptable. This level can be considered as the level that theoretically protects 95 % of the potentially occurring species in an ecosystem (corresponds with the MAR approach), or fails to protect 5 % of the species. Similarly, the average Fu value observed in 1994 for the Rhine at Lobith, on the basis of measurement data using five different acute toxicity tests, indicates an estimated possibility of effects occurring in around 8 % of the species (figure 7). The results from both monitoring programmes therefore correspond with each other.

A comparison of the ecotoxicity and genotoxicity (Ames test) along the longitudinal axis of the Rhine indicated a large degree of correspondence (Noij *et al.* 1996). The richness of species of insect larvae was more difficult to interpret because the occurrence of certain species also depends very much on the river's changing character, in the sense of the river's current and drop. The report discusses the effect of the various natural biocoenoses. The declining richness of species at various locations in the Rhine can largely be attributed to the toxicity there. In the area from Wiesbaden to Lobith, species diversity was low and dominance was determined by the Orthocladinae group. At Lobith, there was a complete absence of taxa such as Ephemeroptera, Tanypodinae and Tanytarsini. However, the occurrence of *Hydropsyche* indicates a slight improvement in water quality as compared to previous years.

Toxicity of the bed of the water course

The levels of contaminants in suspended matter in the Rhine are fairly high and usually exceed the limiting value (Eys 1996). The contamination of the bed of the water course in the river Lek, at Hagestein, is mainly caused by HCB and PCB153, which slightly exceed the test value. Levels of the heavy metals cadmium, mercury and copper, PAHs, PCBs and other pesticides measured exceed the limiting value by a factor of from 1.5 to no more than 5. This means the sediment is classified as class 3 (Ministry of Transport, Public Works and Water Management, 1994b).

Biological monitoring of Rhine water in recent years, Developments and trends

(Hannie Maas and Jan Hendriks)

The 1986 disaster at the Swiss chemicals concern, Sandoz, provided an impetus for water management authorities in the Netherlands to carry out more intensive checks of the prevention and discharging of environmentally hazardous compounds. Checks of the surface water include continuous monitoring. Chemical analyses alone do not provide an insight into the effects of chemicals on aquatic organisms, so biological monitoring is also carried out in addition to chemical monitoring.

Biological monitors are systems that automatically measure physiological or behavioral parameters continuously or semi-continuously. Changes in the surface water are detected by a biological response, such as the swimming behaviour or activity of fish or water fleas, or the inhibition of algal photosynthesis.

There has been a biological fish monitoring system at the Lobith measurement point since 1988, where the quality of the Rhine water is continuously measured. The biological monitoring network of measurement points has been expanded over the years to include a system for water fleas (Daphnia). Both systems have also been installed on the monitoring pontoon at Eijsden. Various drinking water companies in the Netherlands also use a fish monitoring system at the point of entry of their drinking water. Systems of this type have also been set up in Germany at various places along the Rhine.

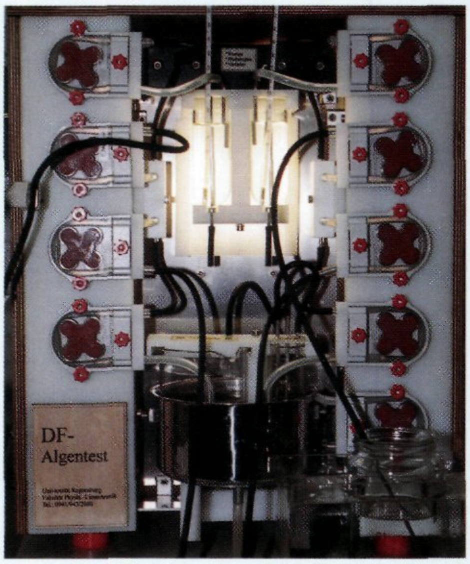
The systems operate well in practice. Following a trial period, the systems now register water quality continuously, without many interruptions or false alarms (Hendriks and Stouten 1993, Noppert and Hendriks 1995). However, not many responses occur in fish in the currently improved Rhine water quality. Behavioural changes are also only expected at concentrations that are a factor of 10 to 100 below the lethal concentration. Average and peak concentrations of compounds that are detected and for which toxicity data is available are often far below these concentrations.

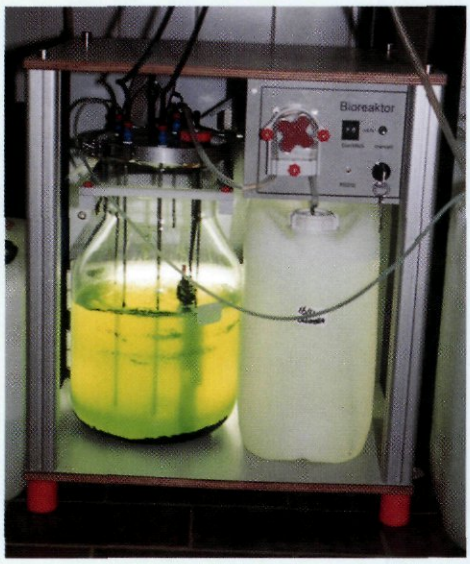
Attention is now focusing on more sensitive systems, at least for substances that are not detected by fish.

The daphnia system has provided a response in the field more often, in the form of effects that are also confirmed by random samples from the surface water and which are sometimes related to increased concentrations of identified compounds.

Many systems have been examined in Germany for their feasibility and reliability. This study resulted in at least three systems being recommended: the daphnia system, the algae monitor and the bacteria monitor. The set can also be expanded with a mussel monitor. Fish monitoring is considered too insensitive but will nevertheless continue at many places.

The RIZA laboratory has already acquired some experience with the algae monitor, which assesses the response of algal photosynthesis. This system is shortly due to be installed and tested at the monitoring station in Lobith.





Photograph 11.1 and 11.2
The quality of Rhine water will soon be monitored using (amongst other things) the algae monitor. This device measures the response to contaminants on the basis of algal photosynthesis. This system of biological monitoring is much more sensitive than the existing fish monitoring systems.

On the basis of a comparison of the chemical concentrations of heavy metals in the sediment and toxicity data on organisms, the possibility of a combined effect leading to this substance group contributing to the toxicity effect on water fleas cannot be excluded. No toxic effect is expected from the other substance groups, nor are any effects anticipated on midge larvae.

The average population density of chironomids (*Chironomus* sp.) was 262 specimens/m^2 (AquaSense, 1996), a value far below the normal value (1500) for the population density of midge larvae that occur in relatively clean Rhine sediments. On the basis of physico-chemical parameters, the sampled sediment was characterized as sand-containing sludge, for which a different normal value may apply. Den Besten (Den Besten 1996) employed a normal value of 500 specimens/m^2 for these types of sediments. In that case, the measured population densities of around 260 chironomids indicate a moderate effect. A population density of only 3 specimens/m^2 was counted for the Tanypodinae sp., a species mainly found in river beds containing organic material. This indicates that the substrate is probably less suitable for the occurrence of chironomids.

Nineteen percent of the larvae of *Chironomus* sp. were found to have jaw abnormalities, which represents a significant difference from the reference value.

The bioassays also showed increased effects on the survival of midge larvae, but this was not significantly different from the values in the reference sediment (Witteveen and Bos 1996).

Only a slight mortality rate was observed for water fleas in interstitial water. The reproduction of these organisms was not impeded.

In 1994, a study was also made of the sediment from the Nieuwe Maas (Brienenoordbrug) and the Oude Maas (Puttershoek) (AquaSense 1996, Witteveen and Bos 1995). Practically no midge larvae were found at either location, although the substrate was considered suitable. No chemical data is available on the location in the Nieuwe Maas. The sediment of the Oude Maas is classified as class 3, on the basis of the heavy metals mercury and copper, PCBs, PAHs and DDT.

The reproduction of water fleas was severely impeded in the Nieuwe Maas sediment. The interstitial water of the Oude Maas sediment led to severe effects on water flea reproduction and high a mortality rate. The mortality rate for midge larvae was also higher. The levels of heavy metals in this sediment explain the effects that were observed.

Developments and trends

Hardly any information is available on toxic effects in the river beds of the flowing sections of the river. At the end of the nineteen eighties, a few harbours in Arnhem, Wageningen, Rheden and the Port of Rotterdam area were studied. However, the results in the case of these highly contaminated beds cannot be related to the quality of the Rhine water system. A few locations in the Rhine, IJssel and Lek rivers were ecologically and toxicologically assessed in 1988 and 1990 (Mulder, 1993). The locations were Tolkamer (port of refuge), the weir complexes at Driel, Amerongen and Hagestein, and the Ganzediep at Kampen. The river beds were all highly contaminated (classes 4 and 3) with heavy metals, PAHs, PCBs and OCBs. At Driel and Hagestein, the population density of Chironomus larvae complied with the normal value. The population density was lower at Amerongen, Tolkamer and Kampen.

Water flea mortality occurred at all the locations and reproduction was impeded. At Tolkamer, Driel and Hagestein, the mortality rate of midge larvae was also higher. These effects were partly explained on the basis of chemical analyses.

Conclusions

With the exclusion of a few parameters, the ecotoxicological effects measured in various compartments of the water system were similar throughout the entire system.

Accumulation levels in organisms were found in the Rhine water system that could present a threat to the entire aquatic ecosystem. In the case of the heavy metal cadmium and the planar PCBs, the measured concentrations in organisms were so high that the threat to the ecosystem, particularly to the higher organisms, has to be considered as serious (50 % of the species are not protected). Mercury and DDT also exceed the MAR.

There has been a marked improvement in the quality of Rhine surface water in recent years but it does not yet entirely comply with the acceptable risk level derived for this measurement.

The quality of the suspended matter and the river bed still exceeds the limiting value. There are severe effects on river bed organisms at a few locations. Laboratory studies and field observations reveal effects that can partly be explained by the chemical concentrations in the river bed.

Developments and recommendations

The results from the biological monitoring network show that the contamination of the surface water and bed of the water system of the Rhine and its branches still produces toxic effects in aquatic organisms. However, the effects have diminished in recent years. Concentrations of a few priority substances in organisms have decreased in recent years but may still present a serious threat. The decrease in the accumulation levels of other substances appears to have come to a halt, however, some concentrations are far below the risk level.

Further reductions in the emission of the priority substances, mercury, cadmium and PCBs are required. However, it would be advisable to also pay attention to other, as yet unknown, substances, which account for some of the toxicity that cannot currently be explained.

The necessity of cleaning up the beds of contaminated water courses depends very much on

Cadmium, mercury and lead

Extremely hazardous effects can result from large concentrations of heavy metals getting into the food chain. Cadmium affects, amongst other things, the reproduction and population size of crustaceans (Van Leeuwen *et al.* 1985), which may lead to changes in an aquatic ecosystem's functional structure. Mercury is converted in the aquatic environment into methyl mercury, a form which is readily taken up by organisms. Increased mercury uptake can lead to severe damage to the nervous system. This phenomenon came to light in the nineteen fifties in a large group of people living in a bay in Japan, who, along with their household pets and birds, became sick through eating mercury-contaminated fish from the bay. Lead is known to severely harm the production of red blood cells, which can in turn lead to various secondary effects.

Polychlorinated biphenyls (PCBs)

PCBs are produced in large amounts for various industrial uses. Many congeners of PCBs are known, the most toxic of which are the coplanar (flat) structures. PCB hazards are mainly seen as a result of secondary poisoning in the food chain. The main environmental danger presented by these substances is their chronic toxicity (reproduction) and teratogenic effects (foetal malformation). The effects can be seen in the brooding success of piscivorous birds (Koeman *et al.* 1972, Van der Gaag *et al.* 1989, Den Besten 1996) and in the breeding of seals (Reijnders 1980). They have also been linked to the Otter's extinction in the Netherlands.

Organochlorine compounds (∑DDT, HCB, HBCd, drins, OCS and lindane)

This group of extremely lipophilic and, therefore, highly accumulating compounds, are released as a byproduct of the chemicals industry, but are also deliberately released into the environment to combat diseases and plagues in crops. The most well-known compound, DDT and its metabolites DDE and DDD, are extremely persistent. Owing to the high bioaccumulation properties and effects of DDE, which have been demonstrated in bird populations (Koeman *et al.* 1972), these compounds were banned in many western countries at the end of the nineteen seventies.

The effect of drins and endosulphane is comparable with that of DDT. One of the things known about HCB is that the compound affects the production of red bloodcells, which can result in weight loss and the death of organisms.

Polycyclic aromatic hydrocarbons (PAHs)

A principal source of PAH emissions into the environment is the atmospheric deposition of particles, which are released into the atmosphere through the incomplete combustion of fossil fuels. The compounds also enter the aquatic environment through discharges of oil compounds and the leaching of bank protection material. The main hazard PAHs present to humans and the ecosystems is caused by the mutagenic or carcinogenic properties of a large number of congeners.

Although PAHs are generally highly lipophilic, bioaccumulation hardly occurs. Most organisms, especially the higher species, are capable of breaking down PAHs. However, this does not reduce the hazards faced by organisms. Breaking down PAHs can lead to the formation of metabolites that produce mutagenic or carcinogenic effects.

the local situation. High discharge rates mean that the contaminants in the bed of the water course may be completely removed at some locations by erosion, and then deposited elsewhere by sedimentation. More detailed river bed studies in various harbours along the Rhine and its branches are underway or scheduled (Ministry of Transport, Public Works and Water Management, 1994a).

Methods

Contaminants in organisms:

Substance uptake is measured in two organisms from different trophic levels, the Zebra mussel (*Dreissena polymorpha*) and the Eel (*Anguilla anguilla*). The Zebra mussel is a primary consumer, which feeds by filtering suspended matter out of the water. The substances bound to the suspended matter accumulate in mussel tissue. In the 1995 survey year, Zebra mussels from the relatively unpolluted lake IJsselmeer were suspended for a few weeks in nets from the monitoring pontoon at Lobith and in the Nieuwe Waterweg, at Maassluis. Because the location at Maassluis was possibly too saline for the Zebra mussels, saltwater mussels (Mytilus edulis) from the Eastern Scheldt were also suspended at the same location.

The Eel is a secondary consumer and feeds on various types of food, including macrozoobenthos, Zebra mussels and fish. Eel has a high fat content, which results in a high accumulation of lipophilic compounds in particular. The Eel migrates very little in the spring, which makes the measurements representative for the location. RIVO makes annual catches of Eel at various locations in the Rhine catchment area, within the scope of the Rhine Action Programme and for the biological monitoring network. The water system of the Rhine and its branches includes the locations Lobith, in the Rhine, and Culemborg in the river Lek.

Eel and Zebra mussels are analysed for a large number of compounds, including heavy metals, Polychlorinated biphenyls (PCBs), Organochlorine compounds (OCBs); only mussels are examined for Polycyclic Aromatic Hydrocarbons (PAHs) (see box: substances). A selection of these substances will be discussed in this report.

Eel and Zebra mussel consumption leads to a risk of further accumulation in top predators, such as piscivorous and mussel-eating birds, and piscivorous mammals (including Otters), through secondary poisoning. The levels measured in the organisms are checked against the Maximum Acceptable Risk level (MAR), while taking into account secondary poisoning (Beek, 1995). The MAR is defined as the concentration at which 95 % of the potentially occurring species in the aquatic ecosystem are theoretically protected. The values used for checking are shown in table 1.

Contamination in Rhine water:

RIVM assessed the toxicological quality of the Rhine water in the years 1990-1995, as part of the water system surveys and the Rhine Action Programme. The toxicological assessment was based on the results of toxicity tests carried out in the laboratory using organic concentrates of sampled river water. Concentrating the toxicants present in the water appears to be a good method of enabling the detection of toxicity below the level of the acute effects that occur. The toxicity index (TI) is calculated as a measure of the local toxicity, which can then be related to an estimate of the environmental risk:

- A TI>1 means that the surface water has to be diluted to render it no longer acutely toxic, which indicates an acute hazard
- A TI<0.01 means the likelihood of environmental damage is considered acceptable, which means the toxicity concentration would have to be 100 times greater for acute effects to be produced.

A connection between these figures was sought in the biological monitoring programme of the Directorate-General for Public Works and Water Management. Monthly measurements were taken in the Rhine in the period from 1992 to 1995, at the Lobith monitoring station. Maassluis was also sampled in alternate months for just one year (1995) as part of a monitoring cycle lasting four years. The acute toxicity tests were carried out using luminescent bacteria, in accordance with the Microtox method (Maas, 1993).

Contamination in river beds:

The Rhine carries a large amount of suspended matter, which transports microcontaminants. There is little or no deposition of the suspended matter in the free flowing river area. The greatest sedimentation occurs close to weirs and sluices, in groyne fields and, finally, in the delta area of Haringvliet and lake Ketelmeer. Harbour areas may be highly contaminated locally (Ministry of Transport, Public Works and Water Management, 1994a).

Studies of sediments involve a complete assessment based on chemical, ecological and ecotoxicological parameters. In the field, the population density of midge larvae (Chironomidae sp.) and the percentage of malformations in *Chironomus* larvae are measured as the ecological effect parameters. The toxicological assessment is based on the toxicity tests carried out in the laboratory using midge larvae (*Chironomus riparius*) and water fleas (*Daphnia magna*), in sediment/water systems or a watery extract taken from the bed of the water course. The sediments are classified as low, moderate or highly toxic, on the basis of criteria determined for the effects on the survival, development or reproduction of the organisms.

In 1995, the effects of the bed of the river were only investigated in the biological monitoring network at a location in the Lek, at Hagestein, above the weir. This sediment was deposited recently and its analysis indicates the current risk of contamination from the suspended matter that is being transported by the Rhine at present.

Substance	MAR (mg/kg) fish	MAR (mg/kg) mussel
(methyl)-mercury	0,0226	0,0247
cadmium	0,0133	0,008*
PCB153	0,32*	0,084*
HCB	0,038	0,0147
SDDT	0,026	0,048
lindane	0,37	0,154
S10PAHs	--	0,94*
SPCB-TEC	64×10^{-9} **	--

* not determined in the integral standardization of substances (Integrale Normstelling Stoffen (INS)) (Beek, 1995).

** derived from Beurskens and Van de Guchte (1993).

Table 11.1:

Critical concentrations (MAR_{food}) for aquatic systems, based on levels in fish and mussels (in mg/kg_{wet}). The Maximum Acceptable Risk levels (MARs) are derived in accordance with the methodology established within the scope of the integral standardization of substances (Integrale Normstelling Stoffen (INS); Ministry of Housing, Spatial Planning and the Environment; Beek, 1995). Toxicity data ($NOEC_{chron}$) on lower and higher organisms is set out in a log-logistic distribution of probability (Aldenberg and Slob, 1991), from which an MAR based on direct effects (mg/l) and an MAR based on indirect effects (mg/kg_{food}) can be derived. The most critical value determines the MAR_{eco}, the value at which 95 % of the potentially occurring species in the aquatic ecosystem are theoretically protected, taking into account secondary poisoning. Using BCFs for "standard" fish and mussels, the MAR_{eco} was converted into critical concentrations for these organisms.

12. Synthesis

Corian Bakker (RIZA) & Annemiek Demon (RWS Eastern Netherlands Division)

Introduction

This is the first water system report for the Rhine. Trends can be indicated for a small number of organism groups on the basis of historical series. Where possible, additional data from local (nature restoration) projects has been used. Where no historical data was available, the report only provides a picture of the present situation.

This chapter examines the following questions:
1. How dynamic is the present Rhine (still)? Which species dominate and are they species that are characteristic of a dynamic river ecosystem? Can the differences in morphology and hydrology between the various river branches be seen in the flora and fauna?
2. Which (management) measures will turn the Rhine back into a dynamic, living river? Are specific measures necessary for each species group and will those measures result in characteristic river species? How do those different measures relate to one another?
3. Is the current approach (the present policy) the right one?
Do nature restoration projects help produce a living river? Which ecotopes are still missing?

Monitoring results

How dynamic is the Rhine?
The collected data does not produce a very heterogeneous picture, in spite of the major differences in morphodynamics and hydrodynamics between the various stretches of the Rhine, at least in terms of the potentials of those processes (Rademakers *et al.* 1996, Silva *et al.* 1996). In other words, the monitoring results indicate a relatively uniform Rhine system. The MWTL data that forms the basis of this report (see chapter 1) is principally concerned with the main channel (Fish, macrozoobenthos, plankton, vegetation). This means the differences in the different stretches of the river may not be clearly reflected in the results. Owing to the low level of exchanges between the main channel and the floodplains, variations in species composition in the floodplains are not seen in the main channel.

Vegetation is practically absent from the main channel, although the downstream stretches and the weired parts of the Lower Rhine have a sparse covering of aquatic plants. The riverbank vegetation in these stretches is dominated by Reed. In the upstream stretches, Reed canary grass is dominant. However, on the more dynamic stretches of the river, along the Waal, there are some typical riverbank plants, such as Common cocklebur and Common fleabane.

The plankton composition is practically the same in the various branches of the Rhine, and, as in other major rivers, phytoplankton is dominated by diatoms. The available nutrients are not used optimally by the phytoplankton, owing to the rapid currents. The zooplankton, which is dominated by rotifers, flows through before the phytoplankton can be grazed. The grazing pressure on phytoplankton is only a few percent of the algal biomass per day. In stretches with a longer residence time, such as waters in the floodplain, chlorophyll-a concentrations occur that are on average twice as high. Zooplankton concentrations are found in these waters up to one hundred times higher than the density in the river's main channel.

Thanks to the improved water quality, the number of species of invertebrates and the densities in which they occur are increasing. However, the total numbers remain relatively low in the main channel, probably as a result of a shortage of suitable habitats. Samples taken from newly formed waters in the floodplain, after the high water in the spring of 1995, showed that various true river species, such as black flies, had been able to reach these locations. This appears to demonstrate the possibility of ecotopes that are created by nature restoration projects being colonized. Many non-indigenous species also seem capable of reaching the Rhine; more than 15 % of the species found were non-indigenous.

All the fish species that occurred in the original Rhine system are still found, however not in their natural number ratios. There are only minor differences in the fish community in each stretch of the river and it is mainly made up of eurytope (indifferent) species. The rheophilous (riverine) species still only occur in small numbers but appear to be on the increase. The number of estuarine reophilic species increases in the downstream stretches, from the Boven-Merwede and the Lek. The barrier effect of the weirs means that this group is uncommon in the Lower Rhine. Relatively many rheophilic species were caught in the river IJssel (probably because of the favourable current conditions, see chapter 2, table 1).
A (much) greater variation in water depth, current speed and substrate is required for fish and macrozoobenthos than occurs in the present shipping channel. As mentioned above, the main channel is almost completely lacking in vegetation. Vegetation is necessary as a substrate, for food and as shelter. A rich variation in aquatic vegetation only occurs in isolated waters, which can only be reached by fish and macrozoobenthos at (extremely) high water levels. There are not many waters in open connection with the river that offer conditions such as gently sloping banks and low waves, which are beneficial for the development of vegetation.

Waters with low dynamics and a rich diversity of vegetation are also important for amphibians. There are no places in the main channel and the larger stretches of the floodplain for this group of animals. They are now dependent on the smaller isolated waters behind the main channel dykes. The river area once supplied a large amphibian biomass through a wide range of waters that were isolated to varying degrees along the nutrient-rich river. River systems in other countries have much higher population densities, which provide food for predators, such as the Grass snake, herons and storks and Water shrew (Creemers 1991).

The present Rhine system has become very important for herbivorous water birds in the winter half of the year. The trends in the composition and numbers of species of birds are a reflection of changing conditions in the floodplain, owing to the intensification of agriculture. This means herbivorous water birds can be designated as culture-adapted. It is mainly the breeding birds that have suffered from these developments in the river landscape; characteristic breeding birds of moist and marshy conditions have declined sharply.

In the downstream parts of the Waal and Lek rivers, the number of birds that forage on macrozoobenthos is increasing, owing to the large numbers of Zebra mussels, which are prolific on the dams and embankments in the area.

Finally, the limited data available on mammals indicates there is little differentiation in each stretch of the river. Greater habitat diversity is needed throughout the entire area. The river is a migration route for bats and could also provide one for Otter and Beaver.

The present Rhine system is ecologically impoverished. Exchanges of aquatic organisms between the main channel and the waters in the floodplain are often impossible or limited to periods of high water. Securing the main channel for shipping means that it becomes increasingly deeper. The floodplains silt up and become higher and dryer. The uniformity can be seen in the distribution of ecotopes in the branches of the Rhine; (agricultural) pastures and the deep main channel take up most of the area (Postma *et al.* 1996 see figure 1, the lower rivers are not shown).

On a smaller scale, it is possible to point to a few differences between the river branches.

Owing to the altitude of the floodplains, part of the floodplain of the IJssel river is suitable for agriculture. The Waal river includes a long section with shallow riverbanks between groins and ponds, and some dynamic dead river arms. Along the Lower Rhine, there is the occasional stream valley pasture. There are some valuable natural areas with low dynamics in the weired river branches and behind the main channel dykes. Some natural areas with high dynamics can still be found outside the main channel dyke, along the unweired sections. There are only limited sections that display the variation in dynamics that was present in the original river system.

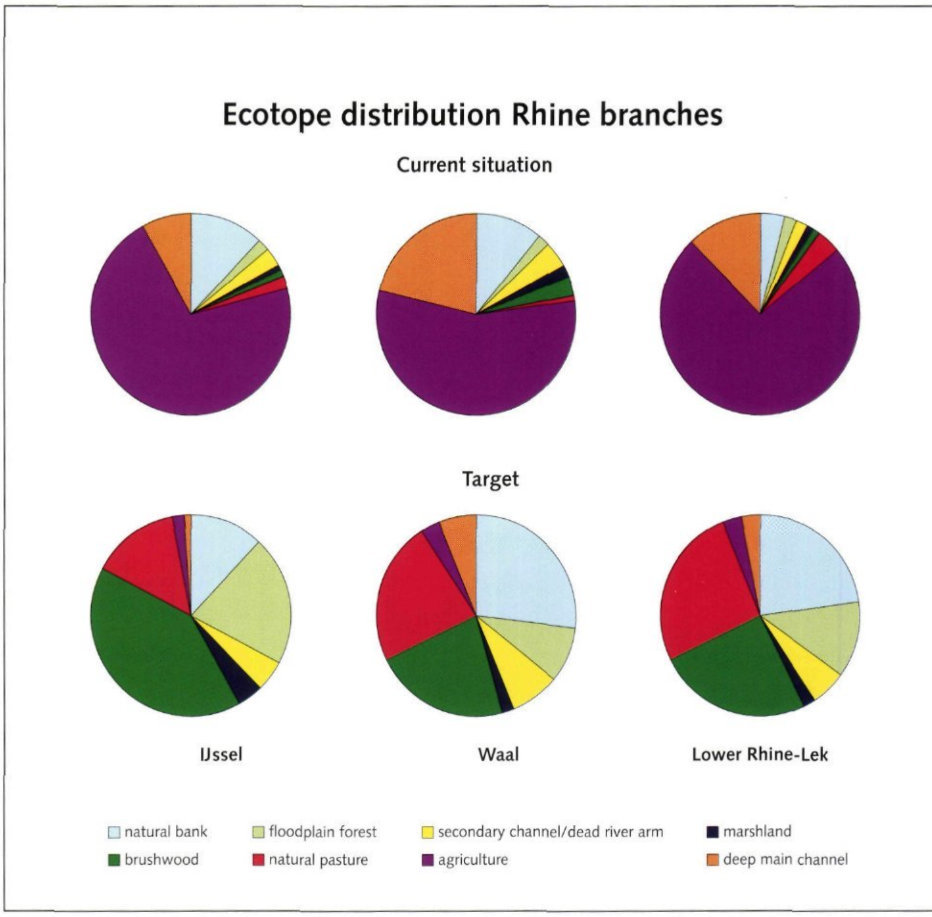


Figure 12.1
The distribution of ecotopes in the IJssel, Waal and Lower Rhine in the present situation and after achieving the target (Postma *et al*). In the present situation, there is little differentiation between the various river branches and agricultural (pasture) land dominates. In the target, there is a greater diversity of ecotopes and the difference between the river branches is clearer.

Measures are needed to turn the river into a more suitable habitat for the various groups of organisms.

Management measures

Table 1 shows which management measures have an effect on the groups of animal and plant species discussed here. The table shows that measures that have a positive effect on a particular group may well have a negative effect on another group. It is therefore possible to use the measures to steer floodplain developments. This gives rise to the possibility and necessity of discussions about the measures to be taken. An important criterion in this regard is the "originality of the processes and species". In the target drawn up for the rivers (Postma *et al.* 1996), this is worked out for the various river stretches by determining the richness of opportunity for ecotopes and species. The measure of success in achieving the target of originality will be shown by the system's diversity and the occurrence of typical river species.

Design requirements

All kinds of measures for shipping have resulted in a decline in the natural river dynamics in the floodplains. The starting point for nature restoration projects is to bring about some degree of restoration of the dynamics (see chapter 2).

Constructing secondary channels, linking dead river arms on one side, and cutting through main channel embankments, are examples of measures intended to provide more opportunities for species that depend on systems with

Table 12.1
The effect (indicative) of design or management measures on the establishment and habitat opportunities for the organism groups discussed in this report.

Measure	Fish	Mammals	Ampfibians/reptils	Birds	Macrozoobenthos	Vegetation	Plankton
creation of gradual riverbank slopes (shallow and/or temporary waters)	+	+ (Water shrew)	+	+ (waders)	+	+ (pioneers, halophytes, softwood floodplain forest)	
creation of steep edge				+ (including Sand martin)	+ (snag inhabitants)		
construction of isolated vegetation-rich waters	+ (limnic)		+	+ (diving ducks, herbivores)	+ (vegetation-inhabitants)	+ (aquatic plants, riverbank plants)	+ (zooplanton)
construction of secondary channels (cutting through main channel embankments; flowing floodplain)	+ *(rheophilic)* (limnic)		-	+ (piscivores, herbivores)	+ (*riverine species*) - (limnic species)	- (macrophytes) + (pioneers, willows)	+
construction of waters that are joined to the river on one side (cutting through main channel embankment, higher inundation frequency)	+ (particularly limnic)		-	+ (piscivores, Great reed-warbler, Black tern)	- (limnic species)	+ (riverbank plants)	+
creation of pioneer situations (bare substrate)			+ (Natterjack toad)	+ (terns, plovers)		+ (pioneers)	
promotion of forest development	+	+ (Roes)	+ (Grass snake)	+ (tree breeders) - (herbivores)	+ (snag-inhabitants)	"+"	
extension of grazing management (more diversity in vegetation species)	+	+	+	+ (*seed-eaters, breeding birds*) - (graminivores)	+ (*vegetation inhabitants*)	"+"	
construction of places not reached by high water		+	+	+ (tree breeders)		+ (fluvial plants) + (hardwood forest)	
connection of habitats inside the dykes to the floodplains		+ (Red deer, Stone martin)	+				
construction of small stretches of water inside the dykes			+			+ (aquatic/riverbank plants)	
adaptation of old buildings (bricking up, maintaining piles of stones)		+ (bats)	+				
removal of hard bank revetments along waterway (creation of sand and sludge beaches)	+	+		- (diving ducks) + (waders, seed-eaters)	-	+ (pioneers)	

Explanation: Where only a + or a - is indicated, the relevant positive or negative response applies to all or a high percentage of the species in a group. Where a subgroup or species is indicated in parentheses, the effect is mainly or only on that subgroup. No indication means that the indicated measure has little if any effect on the presence of the group.

high dynamics. These measures are used in many nature restoration projects in the floodplains (Silva 1996). The starting point is usually a reference picture in which increasing the river dynamics in the floodplains plays an important role. The table shows that measures of this kind can have a negative effect on amphibians, macrozoobenthos and aquatic plants in particular. In the case of amphibians, the natural dynamics provide greater opportunities for land biotopes, however, the aquatic biotopes come under severe pressure. This should be taken into account in the planning, especially because the river area is a centre of prevalence for the distribution of a number of species of amphibians. Solutions may be found in the creation of biotopes in sections of the river with low dynamics and/or the encouragement of more amphibian biotopes inside the dykes, in the former basin areas.

This also applies to macrozoobenthos; monitoring nature restoration projects that are currently underway shows that when existing ponds with a large diversity of macrozoobenthos species are linked to the river, the level of diversity soon falls (Cals 1994). Unlike when flowing secondary channels are constructed, the species are not replaced by other characteristic river species (riverine species) because there is no flowing water in the ponds. Here too, various solutions are available, such as leaving the main channel embankments in tact in some places, developing comparable biotopes inside the dykes, or accepting that the diversity of the species concerned in the floodplains will become increasingly restricted to sections of the river with low dynamics.

In most nature restoration projects, the emphasis is on the originality of the species and processes. Although the presence of existing natural values is not denied, a choice is often made in favour of river-dependent species that occur in a dynamic environment. The less dynamic biotopes also occurred in the river area in the reference picture, the "original river system", but they were found in the basin areas, further from the channel with its high dynamics. In the dyked situation, these areas of the river are cut off and the dynamics in the remaining section increase. The differences in dynamics in the various stretches of the river can be employed to enable the development of biotopes with low dynamics in the floodplain, in the present system.

Photograph 12.1
A flowing secondary channel has been created in the Leeuwense Waard, along the river Waal, by joining existing ponds. The route of the future channel is marked by flags.

Another measure with results that are not all positive is the removal of the hard bank revetments along the river banks. Hard substrate provides a good habitat for macrozoobenthos species such as Zebra mussels. In their turn, these macrozoobenthos species are food for diving ducks. The removal of this material therefore affects the numbers of these species. The criterion "originality" is the motivation for deciding to remove these rip-rap revetments, even if this also leads to a reduction in species diversity. Rip-rap is a material that does not occur in lowland rivers. However, the groynes will be maintained along large sections of the river in connection with the river hydraulics.

The extension of pasture management and the development of more forest and marshland vegetation can result in a drop in the number of herbivorous water birds. Although natural vegetable food sources become more abundant (roots and seeds of aquatic plants), they are unlikely to provide an adequate alternative for the large numbers of birds. However, many breeding birds of marshy forest and brushwood covered wet pasture, such as Little bittern and Corn crake, will find better living conditions and migratory birds and seed-eating herbivores like the Pintail and Teal will profit from the new situation.

In many nature restoration projects, a more natural ecosystem with space for woodland is a deliberate choice.

Moreover, it is important in nature restoration projects to pay attention to the dyke itself as a possible ecological barrier. The closure of a road during toad migrations has become a familiar occurrence but other species also migrate between the floodplain and the area inside the dyke, such as Badger and Roe. With a few exceptions, nature restoration projects practically never pay any attention to the other side of the dyke.

Variation over space and time

The environmental requirements set by various species groups may be so conflicting that the species are unable to inhabit the same area. Spatial separation can be a means of giving the

photograph 12.2
Excavation work in the Gamerense Waarden: construction of the channels and partial excavation of the floodplain, so that various biotopes are created that no longer occur and are unwanted in the shipping channel. Examples of these biotopes are shallow sand and sludge beds, shallows that become clear of water, and riverbank vegetation.

various species groups an opportunity to co-exist. The scale at which the variation is introduced may, for instance, be in line with the natural variation in the morphodynamics and hydrodynamics, and the presence of existing natural history and cultural-historical values. Rademakers (Rademakers 1996) indicates where the various types of natural environment will be most likely to succeed on the basis of the altitude and dynamics. This water system report contains a number of concrete starting points for making a spatial division of this kind on the basis of the present natural values. For example, the best conditions for marshland plants are found in the downstream and weired stretches of the river. In the case of birds, the highest numbers of Black-tailed godwits in the spring are found in the Rhine/Lek area, and this is connected with the location of the brooding areas. Some species appear to be able to benefit from phasing activities (such as sand and clay excavation) in the floodplains. A number of species, for example the Natterjack toad, depend on the presence of bare substrate. In a natural river system, this occurs from time to time through natural erosion and sedimentation processes. The distribution that occurs over time with land clearance and the implementation of nature restoration projects enables these species to nevertheless continue to find enough bare substrate, even though there is less erosion and sedimentation.

In creating a varied system over space and time, it is important to take ecological networks into account (Reijnen *et al.* 1995). For example, the size of the populations, the distance between subpopulations and the presence of corridors are very important for the ongoing existence of species.

Quality

Ecotoxicological data show that the quality of the water, the suspended matter and the bed of the water course still present threats to the entire aquatic ecosystem. This particularly applies to the higher organisms. For example, the concentrations of cadmium and a number of PCBs measured in organisms are so high that as many as 50 % of the species may be detrimentally affected. Some of the toxicity still has to be explained and is attributed to, as yet, unknown substances.

A study of the ecological quality of a floodplain along the river Waal (AquaSense 1997) revealed a threat of secondary poisoning by cadmium and an increased biological availability of heavy metals. This partly explains the low population densities of riverbed fauna in current-sheltered locations.
Not much is known about the effects of contamination on the likelihood of biocoenoses developing in nature restoration areas. As yet, the quality of the water and soil does not appear to impede the establishment of new species. It is not clear whether they will be able to survive.
The quality of the river water does not appear to be a problem for most species in the river itself as far as the macronutrients are concerned. The short residence time of the nutrients in the flowing water means they are not fully utilized. However, this does not now mean that water quality can be ignored. If the river water enters into systems with low dynamics, such as floodplain ponds, lakes and estuaries, we see the effects of eutrophication such as algal bloom and fish death.

Policy

Space for the river

The importance of the discharge function of the floodplain during periods of high water became particularly apparent after the high water levels of 1993 and 1995. The policy known as "Space for the river" came into force in May 1996. The policy places major restrictions on the possibilities for using the floodplain for anything but river-related purposes. It indicates a wish to create extra space for the river during periods of high water. One possible way of achieving this is to lower the floodplain. If this is done in combination with nature restoration projects, it creates all kinds of possibilities for natural river life, but also has other consequences for natural values. It may result in a larger expanse of water, fewer possibilities for forest and less high ground. This new development will be worked out in more detail in the ensuing years. It will obviously affect the occurrence of various species groups. In particular, lower floodplains will result in fewer opportunities for species that live in less dynamic environments.

Recommendations

The present nature restoration projects are intended to increase the hydrodynamics and morphodynamics in the floodplains and to increase grazing. Creating possibilities for dynamic processes will give rise to characteristic river ecotopes. These are very likely to be populated quickly; fish and macrozoobenthos species from shallow flowing water are already present in very small numbers. Breeding birds will also benefit directly, as was apparent from the population of Corn crake and Corn bunting after the inundations of 1995. The same applies to bats, which profit from a larger and more varied food supply in the more varied vegetation. It has to be pointed out here that there are different levels of dynamics.

The isolated environments that only come into contact with the river through extremely high water or river seepage are always more dynamic than the areas inside the dykes and provide a habitat for rare and characteristic species. However, in the present situation, these areas are so close to the river that they would be unable to survive if the embankments were removed. Deliberately spreading areas with various levels of dynamics, for example by having low dynamic natural areas along the Lower Rhine, would provide places for amphibians, mammals, limnic fish and the macrozoobenthos of vegetation-rich waters. These species also belong in the river system but do not benefit from the removal of embankments and the silted-up floodplain soil. It is also important to increase the opportunities for these species inside the dykes by providing proper connection zones to the areas in the floodplain.

During the design phase, it is important to inventory the existing natural values, so that valuable areas can be kept. It is also advisable to examine the possibilities for creating adjoining biotopes inside the dykes. Finally, adapting the nature restoration projects to the morphological characteristics of the stretch of the river concerned will make it possible to achieve the most durable distribution of ecotopes with the greatest likelihood of success over the branches of the Rhine. In trying to achieve a varied natural floodplain, it is important to take into account the wish to provide more space for the river.

Monitoring

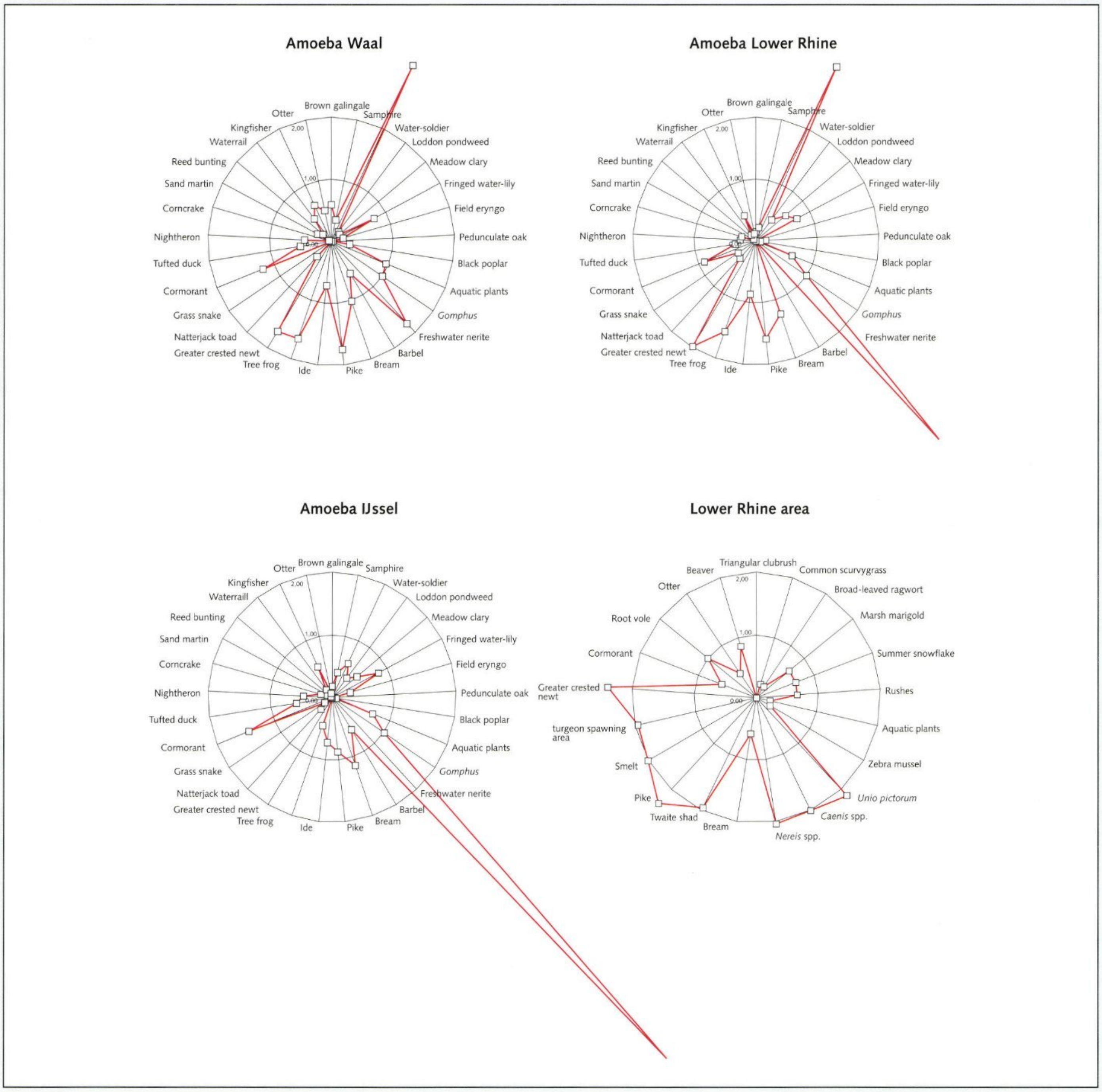
The aim is to achieve greater differentiation of the river branches and thereby to make greater use of the river's potentials. This also means taking measurements that enable the variation in ecotopes, vegetation and the associated species to be monitored. The ecotope mapping (area coverage) planned for 1999 in the next round of measurements for the Rhine, and the monitoring of the ecotopes of the main channel and the floodplain (a number in each branch of the Rhine) could provide the required information. It would therefore be worthwhile to also sample the isolated waters and to provide an idea of the area covered by floodplain forest, for example, and the developments taking place in it.

It is not possible to establish on the basis of the data whether and to what degree the river processes are still determining factors in the formation of the river landscape in the present situation. This will have to be determined by comparing the pattern of ecotopes in consecutive monitoring periods. It will also be necessary to pay more attention to the connection between morphological and hydrological developments, and ecological developments in the river.

AMOEBE's in de Rhine

(Winfried Laane)

In the AMOEBE study for the major rivers, rules of thumb are used to convert the distribution of ecotopes (see elsewhere in this chapter) into potential numbers of species, known as target variables, which have been examined in the "Water System Survey" project. The conversion rules are based on the habitat approach: a determination per species is made of how much suitable habitat will be available in the future ecotopes. The numbers of species in the present situation are derived from existing figures.
The present situation in the water systems of the Rhine and its branches are shown in the figure as pie diagram sections vis-à-vis the nature restoration target on the circle, which gives rise to what are known as the AMOEBEs.
As far as possible, the same target variables have been used for the different branches of the Rhine. The species for the Lower Rhine area (Noordrand and the freshwater tidal rivers, Vanhemelrijk, being printed) display the greatest departure owing to the dominant effect of salt and the effect of the tides in the area.



Along the river, there are, for example, Kingfisher brooding habitats around the secondary channels, dead river arms and ponds. In the nature restoration target for the Waal, Lower Rhine and IJssel rivers, the total area of brooding habitat has increased sharply and, instead of the present 3-4 brooding pairs, there are 520 brooding pairs (Duel 1996). In the lower river areas there is a larger area available for the Root vole, for example, which is a species found in moist reedland. The present incidental visitor then becomes a permanent resident in the area.

Photograph 12.3
Riverine landscape along the Lower Rhine - Lek.

13. References

1. Introduction

1. Ministry of Transport, Public Works and Water Management (1996). Nota watersysteemverkenningen: Toekomst voor Water. Ministry of Transport, Public Works and Water Management, The Hague.
2. Ministry of Transport, Public Works and Water Management (1997). Water Kader: Vierde Nota Waterhuishouding, Regeringsvoornemen. Ministry of Transport, Public Works and Water Management, The Hague.
3. van der Weijden, M.H., P. Jesse, K.H. Prins, W-H. Mulder (1995). Milieumeetnet Zoete Rijkswateren. RIZA, report 96.005, Lelystad.

2. The Rhine water system

1. Breukel, R.M.A. (1993). De Rijn en Rijntakken. Verleden, heden en toekomst. RIZA, report 93.004, Lelystad.
2. Breukel, R.M.A. & A. bij de Vaate (1996). Ecologische effecten van waterkwaliteitsveranderingen in de Rijn. RIZA, report nr. 96.015, Lelystad.
3. Brilhuis, R. (1988). Enkele hydraulische en morfologische parameters van de Nederlandse Rijntakken DBW/RIZA, report nr. 88.003.
4. Commissie Uitvoering Wet Verontreiniging Oppervlaktewater (1988). Ecologische normdoelstellingen voor Nederlandse oppervlaktewateren. CUWVO, Working group V-1.
5. Duel, H.,G.B.M. Pedroli & G. Arts (1996). Watersysteemverkenningen 1996, een analyse van de problematiek in aquatisch milieu. Een stroom natuur, Natuurstreefbeelden voor Rijn en Maas. Background document B: Ontwikkelingsmogelijkheden voor doelsoorten. RIZA, report 95.173X.
6. Isarin, R.F.B., H.J.A. Berendsen & M.M. Schoor (1995). De morfodynamiek van de rivierduinen langs de Waal en de Lek. Reports of the project 'Ecological rehabilitation of the rivers Rhine and Meuse' nr. 49-1995.
7. Postma, R., M.J.J. Kerkhofs, G.B.M. Pedroli & J.G.M. Rademakers (1996). Watersysteemverkenningen 1996, een analyse van de problematiek in aquatisch milieu. Een stroom natuur, Natuurstreefbeelden voor Rijn en Maas. RIZA, report 95.060, Arnhem.
8. Rademakers, J.G.M. (1993). Deelprogramma Natuurontwikkeling; Natuurontwikkeling uiterwaarden & ecologisch onderzoek; een verkennende studie. Institute for Forestry and Nature Research, Wageningen. NBP-research report 2.
9. Rademakers, J.G.M., G.B.M. Pedroli & L.H.M. van Herk (1996). Watersysteemverkenningen 1996, een analyse van de problematiek in aquatisch milieu. een stroom natuur, Natuurstreefbeelden voor Rijn en Maas. Background document A: kansrijkdom van ecotopen. RIZA, report 95.172X.
10. Rademakers, J.G.M. & H.P. Wolfert (1994). Het Rivier-Ecotopen-Stelsel: Een indeling van ecologisch relevante ruimtelijke eenheden ten behoeve van ontwerp- en beleidsstudies in het buitendijkse rivierengebied. Reports of the project 'Ecological rehabilitation of the rivers Rhine and Meuse' nr. 61-1994.
11. Silva, W. & M. Kok (1996). Integrale Verkenning inrichting Rijntakken. Main report: Een weegschaal voor rivierbeheer. IVR, report 1. Ministry of Transport, Public Works and Water Management.
12. Sorber, A. (1997). Oeversedimentatie tijdens de hoogwaters van 1993/1994 en 1995. RIZA, report 97.015.
13. Vanhemelrijk, J.A.M. & J.E.W. de Hoog (1997). Amoebe's Beneden rivierengebied. Studie naar ecologische ontwikkelingsrichtingen. RIZA, report 96.004.

3. Macrophytes

1. van den Brink, F.W.B. (1990). Typologie en waardering van stagnante wateren langs de grote rivieren in Nederland, op grond van waterplanten, plankton en macrofauna, in relatie tot fysisch-chemische parameters. Reporten of the project 'Ecological rehabilitation of the river Rhine' nr. 25, Univ. Nijmegen, DBW-RIZA.
2. Coops, H. (1996). Helophyte zonation: impact of water depth and wave exposure. Dissertation Univ. Nijmegen. RIZA, report 96.013, Lelystad.
3. Doef, R.W. (1995). Waterplanten in de Duursche Waarden 1994 en 1995. RIZA, report 95.193X, Lelystad.
4. de Graaf, M.C.C., H.M. van de Steeg, L.A.C.J. Voesenek & C.W.P.M. Blom (1990). Vegetatie in de uiterwaarden: de invloed van hydrologie, beheer en substraat. Reports of the project 'Ecological rehabilitation of the river Rhine' nr. 16, Nijmegen.
5. de la Haye, M.A.A. (1995). Evaluatie biologische monitoring (1992-1994). RIZA, report 95.067X, Lelystad. Aquasense, Amsterdam.
6. de la Haye, M.A.A. (1996). Biologische monitoring zoete Rijkswateren. Operationele uitwerking waterplanten en ecotopen. RIZA, report 96.004X, Lelystad.
7. Knaapen, J.P. & J.G.M. Rademakers (1990). Rivierdynamiek en vegetatieontwikkeling. Staring Centrum, report 82, Wageningen.
8. Lemaire, A. (1994). Water- en oevervegetatie: Zomerbed. Periode 1993 - 1994. Netherlands Institute for Ecological Research, Heteren; RIZA, report BM93.25, Lelystad.
9. Lemaire, A. & T. van der Kooi (1994). Water- en oevervegetatie: Winterbed. Oude rivierarmen in het winterbed van Maas, Waal, Rijn-Nederrijn-Lek en IJssel. Periode 1993 - 1994. Netherlands Institute for Ecological Research, Heteren; RIZA, report BM93.24, Lelystad.
10. Smit, G.F.J., E.J.F. de Boer, T.J. Boudewijn & S. Dirksen (1993). Inventarisatie van de ecologische kennis van de riviertak het Spui. Bureau Waardenburg bv, report 93.32, Culemborg.
11. Willink, G. (1995). Inventarisatie van de Zwarte populier (*Populus nigra* L.) in de uiterwaarden van Bovenrijn, Waal en Boven-Merwede. Ecologisch adviesbureau STL, report 95-15, Nijmegen.

4. Phytoplankton

1. Admiraal, W., L. Breebaart, G.M.J. Tubbing, B. van Zanten, E.D. de Ruyter van Steveninck & R. Bijkerk (1994). Seasonal variation in composition and production of planktonic

communities in the lower River Rhine. Freshwater Biology 32: 519-531, 1994.
2. Admiraal, W., G. van der Velde, H. Smit & W.G. Cazemier (1993). The rivers Rhine and Meuse in The Netherlands: present state and signs of ecological recovery. Hydrobiologia 265: 97-128, 1993.
3. Buijs, P.H.L. (1991). RIWA Meetcampagne Maas. ICWS, report 92-05, Amsterdam.
4. de Hoog, A.W., H. Coops, A.A. Storm, M. Ohm & K.H. Prins (red.) (1997). Biologische Monitoring Zoete Rijkswateren; Watersysteemrapportage Haringvliet, Hollands Diep, Biesbosch 1994. RIZA report 96.032, Lelystad.
5. Klink, A. (1991). Ecologisch relevante factoren bij het inrichten van een nevengeulcomplex in de Rijn. Hydrologisch Adviesbureau Klink bv, report nr. 36.
6. Tubbing, G.M.J., A.E. Dommering, W. Admiraaal, H.W. Balfoort & L. Breebaart (1993). Effects of copper on planktonic communities from the river Rhine; changes in interacting populations of phytoplankton, zooplankton and bacteria. Dissertation Univ. Utrecht.
7. Turpin, D.H. (1994). Physiological mechanisms in phytoplankton resource competition. In: C.D. Sandgren (ed), Growth and reproductive strategies of freshwater phytoplankton. Cambridge University Press, Cambridge.
8. World Wide Fund for Nature (1993). Living rivers. WNF, Zeist.

5. Zooplankton

1. van den Brink, F.W.B., G. van der Velde & A. bij de Vaate (1993). Ecological aspects, explosive range extension and impact of a mass invader, *Corophium curvispinum* Sars, 1895 (Crustacea: Amphipoda), in the Lower Rhine (the Netherlands). Oecologia, 93: 224-232
2. Dekker P. (1995). Zoöplankton. In: K.H. Prins, M. Klinge, W. Ligtvoet & J. de Jonge (red.), Biologische Monitoring Zoete Rijkswateren: Watersysteemrapportage IJsselmeer en Markermeer 1992. RIZA, report 94.060, Lelystad.
3. van Dijk, G.M, B. van Zanten & F.G. Wortelboer (1995). Using XAD-resins to study the effects of reduced organic micropollutant concentrations in the River Rhine and Meuse water on phytoplankton growth. Neth J. Aquat. Ecol. 29: 151-156
4. Gosselain, V.C. Joaquim-Justo, L. Viroux, M. Mena, A. Metens, J.P. Descy & J.P. Thomé (in press). Laboratory and in situ grazing rates of freshwater rotifers and their contribution to community grazing rates. Hydrobiologia.
5. Neumann, D., Chr. Seidenberg-Busse, A. Petermeier, St. Staas, F. Molls & J. Rutschke (1994). Gravelpit lakes coonected with the river Rhine as a reserve for high productivity of plankton and young fish. Water Sci. Tech. 29: 267-271.
6. Peelen, R. (1975). Changes in the composition of the plankton of the rivers Rhine and meuse in the Netherlands during the last fifty-five years. Verh. Internat. Verein Limnol. 19:1997-2009
7. Tubbing, G.M.J., A.E. Dommering, W. Admiraal, H.W. Balfoort & L. Breebaard (1993). Effects of copper on planktonic communities from the river Rhine: changes in interacting populations of phytoplankton, zooplankton and bacteria. Dissertation Univ. Amsterdam p. 143-166
8. Winner, J.M. (1975). Zooplankton. In: B.A. Whitton (ed.), River Ecology, p. 155-169. Blackwell, Oxford

6. Macrozoobenthos

1. Anonimus (1996). Das Makrozoobenthos des Rheins 1990-1995 im Rahmen des Programms "Lachs 2000". Report International Rhine Committee, Koblenz.
2. Armitage, P.D., D. Moss, J.F. Wright & M.T. Furse (1983). The performance of a new biological water quality score system based on macroinvertebrates over a wide range of unpolluted running-water sites. Water Res. 17 (3): 333-347.
3. Breukel, R.M.A. & A. bij de Vaate (1996). Ecologische effecten van waterkwaliteitsveranderingen in de Rijn. RIZA, report.96.015, Lelystad.
4. van den Brink, F.B.W., G. van der Velde & A. bij de Vaate (1989). A note on the immigration of *Corophium curvispinum* Sars, 1895 (Crustacea: Amphipoda) into the Netherlands via the river Rhine. Bull. Zool. Mus. Amsterdam 11 (26): 211213.
5. van den Brink, F.B.W., G. van der Velde & A. bij de Vaate (1993). Ecological aspects, explosive range extension and impact of a mass invader, *Corophium curvispinum* Sars, 1895 (Crustacea: Amphipoda), in the Lower Rhine (The Netherlands). Oecologia 93: 224-232.
6. Frantzen, N. (1991). De kwaliteit van Maas- en Rijnwater in de periode 1983-1989. Beoordeling met behulp van macro-evertebraten. Report RIWA, Amsterdam.
7. Gledhill, T., D.W. Sutcliffe & W.D. Williams, 1993. British freshwater Crustacea Malacostraca: a key with ecological notes. Freshw. Biol. Ass., scientific publ. nr. 52.
8. Greijdanus-Klaas, M. (in prep.). (Re)Kolonisatie gevoelige macro-evertebraten in het Nederlandse Rijnstroomgebied: literatuurrecherche en veldinventarisatie. RIZA, Lelystad.
9. Greijdanus-Klaas, M. (in prep.). Methodebeschrijving berekening dominantie, aantal taxa en BMWP/ASPT index. RIZA, Lelystad.
10. Habraken, J.M.P.M. & B.H.J.M. Crombaghs (1997). Een vondst van de Rivierrombout (*Gomphus flavipes* (Charpentier)) langs de Waal, Brachytron 1, vol 1: p 3-5.
11. Hellawell, J.M. (1986). Biological indicators of freshwater pollution and environmental management. Elsevier, London & New York.
12. Klink, A. & A. bij de Vaate (1996). *Hypania invalida* (Grube, 1860) (Polychaeta: Ampharetidae) a freshwater polychaet in the Lower Rhine, new to the Dutch fauna. Lauterbornia 25: 57-60.
13. Mol, A.W.M. (1984). Limnofauna Neerlandica. Een lijst van meercellige ongewervelde dieren aangetroffen in de Binnenwateren van Nederland. Newsletter European Invertebrate survey - Nederland nr. 15
14. Moller Pilot, H.K.M. & R.F.M. Buskens

(1990). De larven der Nederlandse Chironomidae (Diptera) deel C: autoecologie en verspreiding. Nederlandse Faunistische mededelingen 1C, publications EIS, Nederland.
15. Morris, L.A., R.N. Langmeier, T.R. Russell & A. Witt Jr. (1968). Effects of main stream impoundments and channelization upon the limnology of the Missouri River, Nebraska. Trans. Am. Fish. Soc. 97, 380-388.
16. Postma, R., M.J.J. Kerkhofs, G.B.M. Pedroli & J.G.M. Rademakers (1996). Een stroom natuur. Natuurstreefbeelden voor Rijn en Maas. RIZA, report 95.060, Arnhem.
17. Reinhold-Dudok van Heel, E. & P. den Besten (in prep.). Macro-evertebraten in verschillende ecotopen in het benedenrivierengebied van de Rijn. RIZA, Lelystad.
18. Rosenberg. D.M. & V.H. Resh (1993). Introduction to freshwater biomonitoring and benthic macroinvertebrates. In: D.M. Rosenberg & V.H. Resh (eds.), Freshwater biomonitoring and benthic macroinvertebrates. Chapman & Hall Publish., New York and London.
19. Schie, J. van (1996). Overleving en groei van *Theodoxus fluviatilis* (Zoetwaterneriet) in een stroomgoot aan de IJssel te Kampen. RIZA, report 96.039X, Lelystad.
20. Schleuter, M. & A. Schleuter (1994). *Jaera istri* (Veuille) (Janiridae, Isopoda) aus der Donau erreichtüber den Main-Donau-Kanal den Main. Lauterbornia 21: 177-178.
21. Schleuter, M., A. Schleuter, S. Potel & M. Banning (1994). *Dikerogammarus haemobaphes* (Eichwald 1841) (Gammaridae) aus der Donau erreicht über den Main-Donau-Kanal den Main. Lauterbornia 19: 155-159.
22. Smit, H., F. Heinis, R. Bijkerk & F.C.M. Kerkum (1992). *Lipiniella arenicola* (Chironomidae) compared with *Chironomus muratensis* and C. nudiventris: distribution patterns related to depth and sediment characteristics, diet, and behavioural response to reduced oxygen concentrations. Neth. J. Aquat. Ecol. 26: 431-440
23. Smit, H., P. Klaren & M. Snoek (1991). *Lipiniella arenicola* (Diptera: Chironomidae) on a sandy flat in the Rhine-Meuse estuary: population structure, biomass and production of larvae in relation to periodical drainage. Verh. int. Ver. Limnol. 24: 2918-2923.
24. Tittizer, T., F. Schöll & M. Schleuter (1990). Beitrag zur Struktur und Entwicklungsdynamik der Benthalfauna des Rheins von Basel bis Düsseldorf in den Jahren 1986 und 1987. Limnologie aktuell 1: 293-323.
25. van Urk, G. & A. bij de Vaate (1990). Ecological studies in the lower Rhine in the Netherlands. Limnologie aktuell 1: 131-145.
26. van Urk , G., F.C.M. Kerkum & A. bij de Vaate (1992). Caddis-flies of the Lower Rhine. Proc. 6th Intern. Symp. on Trichoptera: 89-94 (Lodz-Zakopne, 12-16 Sept. 1989).
27. bij de Vaate, A. (1994). Longterm changes in the macroinvertebrate fauna of the River IJssel, The Netherlands. Verh. intern. Verein Limnol. 25: 15631567.
28. bij de Vaate, A. & M. Greijdanus-Klaas (1989). Biomonitoring van grote rivieren met een kunstmatig substraat. RIZA, report 90.009.
29. bij de Vaate, A., A. Klink & F. Oosterbroek (1992). The mayfly *Ephoron virgo* (Olivier), back in the Dutch parts of the rivers Rhine and Meuse. Hydrobiol. Bull. 25(3): 237240.
30. bij de Vaate, A. & A.G. Klink (1995). *Dikerogammarus villosus* Sowinsky (Crustacea: Gammaridae) a new immigrant in the Dutch part of the Lower Rhine. Lauterbornia 20: 51-54.
31. bij de Vaate, A. & M. Greijdanus-Klaas (1995). De ongewervelde dieren. In: M.J.J. Kerkhofs & K.H. Prins (red.), Watersysteemrapportage Maas 1992. RIZA, report 95.001, Lelystad.
32. bij de Vaate, A., M. Greijdanus-Klaas & J. van Schie (in press). De ongewervelde dieren. In: N. Geilen & K.H. Prins (red.), Biologische monitoring zoete Rijkswateren: jaarrapportage 1995. RIZA, Lelystad.
33. Wilson, R.S. (1996). A practical key to the genera of pupal excuviae of the British Chironomidae (Diptera: Insecta), Mugley Elms, Wedmore, Somerset.

7. Fish

1. Cazemier, W.G. (1995). Überwachung der Fischmigration in den Niederlanden. Dritter Tätigkeitsbericht. Projekt "Rückkehr der Langdistanz-Wanderfische in den Rhein". Netherlands Institute for Fishery Investigations, report C052/95, IJmuiden.
2. Daan, N. (1996). Evaluatie vismonitoring zoete rijkswateren. Netherlands Institute for Fishery Investigations, report C007/96, IJmuiden.
3. de Groot, S.J. (1992). Herstel van riviertrekvissen in de Rijn een realiteit? 8. De Fint. De Levende Natuur 93: 182186.
4. Krekels, R.F.M. & P.J.M. Verbeek (ed.) (1994). Monitoring fauna oeververbeteringsproject Opijnen 1994. Bureau Natuurbalans, report 1994002, Nijmegen.
5. de Laak, G.A.J., J.C.A. Merkx & F.T. Vriese (1994). Visstandbemonstering in uiterwaarden. Pilot study naar de visstand in de uiterwaarden in relatie tot de inundatiefrequentie. Organization for the Improvement of Inland Fisheries, research report 1994-26, Nieuwegein.
6. Luiten, J.P.A. & J.T. van Buuren (1994). Watersystemen en doelvariabelen voor de watersysteemverkenningen. RIZA, report 94.019. RIKZ, report 94.016, Middelburg.
7. Natuurbeschermingsraad (1994). Vissen in schoon water: advies voor een ecologisch verantwoord beheer en gebruik van binnenwateren, toegespitst op zoetwatervissen. Natuurbeschermingsraad, Utrecht.
8. de Nie, H.W. (1996). Atlas van de Nederlandse zoetwatervissen. Media Publishing, Doetinchem.
9. Quak, J. (1994). Klassificatie en typering van de visstand in het stromend water. In: A.J.P. Raat (red.), Vismigratie, visgeleiding en vispassages in Nederland, p. 85-100. Organization for the Improvement of Inland Fisheries, Nieuwegein.
10. Schiemer, F. & H. Waidbacher (1992). Strategies for conservation of a Danubian fish fauna. In: P.J. Boon, P. Calow & G.E. Petts (eds.), River conservation and management, p. 363-382. John Wiley & Sons Ltd.

11. Schouten, W.J. & J. Quak (1994). De visstand in stromende Rijkswateren. RIZA, Lelystad; Organization for the Improvement of Inland Fisheries, report 1993-01, Nieuwegein.
12. Taverny, C. (1991). Pêche, biologie, écologie des aloses dans le système Gironde Garonne-Dordogne. CEMAGREF Ressources en eau 4.
13. Verbeek, P.J.M., R.F.M. Krekels & G. Hoogerwerf (eds.) (1995). Monitoring nevengeul Beneden-Leeuwen 1994/1995. Bureau Natuurbalans, report 199503, Nijmegen.
14. Wiegerinck, J.A.M., W.G. Cazemier & H.J. Westerink (1995). Biologische monitoring zoete Rijkswateren: samenstelling van de visstand in 1994/1995 op basis van korvangsten. Netherlands Institute for Fishery Investigations, report C040/95, IJmuiden.
15. Wiegerinck, J.A.M., W.G. Cazemier & H.J. Westerink (1996). Biologische monitoring zoete Rijkswateren: samenstelling van de visstand in 1995 op basis van vangsten met fuiken. Netherlands Institute for Fishery Investigations, report C018/96, IJmuiden.

8. Amphibians

1. van den Bergh, L.M.J. & A.H.P. Stumpel (1975). Gegevens over de verspreiding en ecologie van de Rugstreeppad (Bufo calamita) in het gebied van de grote rivieren. De Levende Natuur 78: 104-111.
2. van den Bergh, L.M.J. & A.H.P. Stumpel (1977). Gegevens over de verspreiding en ecologie van de Groene kikker (*Rana esculenta* L.) in het gebied van de grote rivieren. De Levende Natuur 78: 84-91.
3. van den Bergh, L.M.J. & A.H.P. Stumpel (1978). Gegevens over voortplantingsbiotopen en trekactiviteiten van de Gewone pad (*Bufo bufo*) in het gebied van de grote rivieren. De Levende Natuur 81: 173-178.
4. Bergmans, W. & A. Zuiderwijk (1986). Atlas van de Nederlandse amfibieën en reptielen en hun bedreiging. Fifth herpetogeografical report K.N.N.V./Lacerta, Hoogwoud.
5. Bosman, W.W. (1994). Amfibieën in uiterwaarden. Amfibieën en overstromingsdynamiek. Report Working Group Animal Ecologie, Dept. Ecology, Univ. Nijmegen / Foundation ARK, Laag-Keppel.
6. Bosman, W.W. (1995). Amfibieën in uiterwaarden. Effecten van winteroverstromingen op amfibieën. Report RIZA / Working Group Animal Ecology Univ. Nijmegen / Foundation ARK, Laag-Keppel.
7. Creemers, R.C.M. (1991). Amfibieën in uiterwaarden. Een vooorbereidende literatuurstudie. Report Working Group Animal Ecology, Dept. Ecologie, Univ. Nijmegen / RIZA Lelystad / Foundation Ark, Laag-Keppel.
8. Creemers, R.C.M. (1994a). Amfibieën in uiterwaarden. Voortplantingsplaatsen van amfibieën in uiterwaarden. Report Working Group Animal Ecology, Dept. Ecologie, Univ. Nijmegen / Ministry of Agriculture, Nature Management and Fisheries, The Hague.
9. Creemers, R.C.M. (1994b). In: P.J.M. Verbeek & R.F.M. Krekels (red.), Monitoring nevengeul Benenden Leeuwen en monitoring amfibieën Druten. Bureau Natuurbalans / Limes divergens / RIZA, directorate Gelderland, Arnhem.
10. Creemers, R.C.M. & B.H.J.M Crombaghs (1995). De Knoflookpad in het IJsseldal. Een onderzoek naar het voorkomen van de Knoflookpad in het IJsseldal en de ontwikkeling van een soortbeschermingsplan voor behoud, herstel en uitbreiding van leefgebieden. Limes divergens / Natuurbalans / Foundation RAVON, Nijmegen.
11. Creemers, R.C.M. (1996). Basisrapport met voorstel voor de Rode Lijst van Reptielen en Amfibieën in Nederland. Foundation RAVON, Nijmegen.
12. Creemers, R.C.M., B.H.J.M. Crombaghs & R.F.M. Krekels (1996). Amfibieën en reptielen. In: J.G. Timmermans & K.H. Prins (red.), Biologische monitoring zoete Rijkswateren 1994, p. 42-46 RIZA, report 96009, Lelystad.
13. Crombaghs, B., H.J.R. Lenders & W.G.Vergoossen (1993). Reptielen en amfibieën in Nederland. Jaarboek Natuur 1993. De Vlinderstichting, Wageningen.
14. Crombaghs, B.H.J.M. & G. Hoogerwerf (1996). Leefgebieden van amfibieën in het dijkvak Weurt-Deest. Limes divergens / Polderdistrict Groot Maas & Waal.
15. Frigge, P.A.J. (1981). Amfibieën in de uiterwaarden. Provincie Gelderland, dienst Landinrichting en Landbouw, Arnhem.
16. Krekels, R.F.M & P.J.M. Verbeek (1994). Monitoring fauna oeververbeteringsproject Opijnen 1994. Bureau Natuurbalans / Limes divergens / Rijkswaterstaat RIZA and Rijkswaterstaat directorate Gelderland, Arnhem.
17. Lenders, H.J.R. (1989). Notitie over het belang van het rivierengebied voor de herpetofauna. Herpetologische Studiegroep Gelderland, Nijmegen.
18. PWS Utrecht (1988). De Utrechtse uiterwaarden van Neder-Rijn en Lek. Report No. 78. Summarizing report. Provinciale waterstaat Utrecht, dept. Ecologie.
19. Smit, G.F.J. (1994). Amfibieën langs de Zuidrand, de Oude maas, de Lek en de Afgedamde Maas. Bureau Waardenburg / Rijkswaterstaat directorate Zuid-Holland.
20. Willink, G. & H. Cuppen (1993). Vis- en amfibie-onderzoek De Gelderse Poort. STL, report 93-11, Nijmegen.

9. Birds

1. Adriaensen, F., P. Ulenaers & A.A. Dhondt (1993). Ringingrecoveries and the increase in numbers of European Great Crested Grebes Podiceps cristatus. Ardea 81: 5970.
2. Centraal Bureau voor Statistiek (1994). Milieustatistieken voor Nederland 1994. 's Gravenhage, Sdu publishers/CBS-publications.
3. van den Bergh, L.M.J., W.G. Gerritse, W.H. A. Hekking, P.G.M.J., Keij & F. Kuyk (eds.) (1979). Vogels van de Grote rivieren. Het Spectrum, Utrecht.
4. van den Brink, F.W.B., G. van der Velde & A. bij de Vaate (1993). Ecological aspects, explosive range extension and impact of a mass invader, *Corophium curvispinum* Sars, 1895 (Crustacea: Amphipoda), in the Lower Rhine (The Netherlands). Oecologia vol. 93: 224232.
5. van Dijk A.J., F. Hustings, H. Sierdsema, &

T. Verstrael (1996). SOVON-broedvogelverslag 1993. SOVON-monitoringreport 1996/02. SOVON Vogelonderzoek Nederland, Beek-Ubbergen.
6. van Eerden, M.R., M. Zijlstra, M. van Roomen & A. Timmerman (in prep.). The response of Anatidae to changes in agricultural practice: long-term shifts in the carying capacity for wintering waterfowl. Faune et Gibier Sauvage.
7. Erhart F.C. & J.F. Bekhuis (1996). Broedvogels van de Gelderse Poort 1989-94. Vogelwerkgroep Arnhem e.o/Vogelwerkgroep Rijk van Nijmegen e.o./NABU-Naturschutzstation Kranenburg.
8. de Graaf, M.C.C., H.M. van de Steeg, L.A.C.J. Voesenek & C.W.P.M. Blom (1990). Vegetatie in de uiterwaarden: de invloed van hydrologie, beheer en substraat. Laboratory Experimental Plant Ecologie, Univ. Nijmegen. Publication nr. 16.
9. van der Have T.M. & D.A. Jonkers (1996). Zeven misverstanden over Ooievaars *Ciconia ciconia* in Nederland. Limosa 69: 47-50.
10. Hustings F., F. Schepers & F. Ellenbroek (1995). De Grauwe Gors *Miliaria calandra* in de eerste helft van de jaren negentig. Limosa 68: 159-162.
11. Kon. Ned. Meteorologisch Inst (1985). Klimatologische gegevens van Nederlandse stations, No. 25. Het klimaat van het hoofdobservatorium De Bilt in de jaren 1901-1984. KNMI, De Bilt.
12. Koffijberg, K., G. Delacour, C. Dronneau, V. Keller, C. Sudfeldt & B. Wassmer, (1996). Waterbirds in the Rhine Valley in 1995. Results of a coordinated survey in January. Reports of the project 'Ecological rehabilitation of the river Rhine' 65-1996. RIZA, Lelystad.
13. Meininger, P.L., H. Schekkerman & M.W.J. van Roomen (1995). Populatieschattingen en 1%-normen van in Nederland voorkomende watervogelsoorten: voorstellen voor standaardisatie. Limosa 68:41-48.
14. Nienhuis, J. & M.J. Epe (1995). Feeding ecology of Bewick's Swans on five stop-over sites during spring migration. Zool. Lab. Univ. Groningen.
15. Osieck E.R. & F. Hustings (1994). Rode lijst van bedreigde soorten en blauwe lijst van belangrijke soorten in Nederland. Tech. Report Vogelbescherming Nederland 12, Zeist.
16. van de Steeg, H.M. (1992). Vegetatieonderzoek en vegetatiekartering van de Rijswaard bij Neerijnen. Report Working Group Experimental Plant Ecology, Univ. Nijmegen.
17. van de Steeg, H.M., C.W.C.J. van de Rijt, M.J. Reijnen & C.W.P.M. Blom (1989). Zonering van vegetatietypen en rumexsoorten in overstromingsgradiënten in het rivierengebied van Rijn, Waal en IJssel. Report Working Group Experimental Plant Ecologie, Univ. Nijmegen.
18. van der Winden, J., T.J. Boudewijn, M. van Wouwe & J.A.J. Tempelaars (1996). Watervogeltellingen op een aantal riviertakken in het Noordelijk Benedenrivierengebied 1985-1995. Bureau Waardenburg bv, report 96.31, Culemborg.
19. IJnsen, F. (1991). Karaktergetallen van de winters vanaf 1707. Zenit 18: 69-73.

10. Mammals

1. van Apeldoorn, R. (1994). Zoogdieren en wetlands; wat zijn de problemen? Lutra 37(2): 63-80.
2. van Apeldoorn, R., H. Hollander, W. Nieuwenhuizen & F. van der Vliet (1992). De noordse woelmuis in het Deltagebied. Landschap 9(3): 189-202.
3. Broekhuizen, S., B. Hoekstra, V. van Laar, C. Smeenk & J.B.M. Thissen (1992). Atlas van de Nederlandse zoogdieren. 3e druk. Kon. Ned. Natuurhistorische Ver., Utrecht.
4. Dijkstra, V. (1996). Aantalsontwikkeling van de Bevers in het Nationaal Park Biesbos in 1995. VZZ, Utrecht, Institute for Forestry and Nature Research, Wageningen & State Forestry Service, Driebergen.
5. Hoekstra, B. (1992). Huisspitsmuis *Crocidura russula* (Hermann, 1780). In: S. Broekhuizen, B. Hoekstra, V. van Laar, C. Smeenk & J.B.M. Thissen (red.), Atlas van de Nederlandse zoogdieren, p. 49-54. Kon. Ned. Natuurhistorische Vereniging, Utrecht.
6. Hollander, H., T. den Boer & J. Reinhold (1990). Vleermuiswintertelling Zuidwest Veluwe 1990. Mammalaar 10 (1): 23-24.
7. Hollander, H. & P. van der Reest (1994). Rode lijst van bedreigde zoogdieren in Nederland. Vereniging voor Zoogdierkunde en Zoogdierbescherming, report 15, Utrecht.
8. Kerkhofs, M.J.J, W. Ma & W. Silva (1993). Zware metalen en organische microverontreinigingen in bodem, regenwormen en dassen in het winterbed van de Maas bij Grave. RIZA, Reports of the project 'Ecological Rehabilitation of the river Meuse' 14-1993, Arnhem.
9. van Laar, V. (1992). Waterspitsmuis *Neomys fodiens* (Pennant, 1771). In: S. Broekhuizen, B. Hoekstra, V. van Laar, C. Smeenk & J.B.M. Thissen (red.), Atlas van de Nederlandse zoogdieren, p. 37-42. Kon. Ned. Natuurhistorische Vereniging, Utrecht.
10. Lange, R., P. Twisk, A. van Winden & A. van Diepenbeek (1994). Zoogdieren van West-Europa. Kon. Ned. Natuurhistorische Vereniging & Vereniging voor Zoogdierkunde en Zoogdierbescherming, Utrecht.
11. Limpens, H., K. Mostert & W. Bongers (red.) (in prep.). Atlas van de Nederlandse vleermuizen. Stichting Vleermuis Onderzoek, Wageningen & Kon. Ned. Natuurhistorische Vereniging, Utrecht.
12. Lina, P.H.C. & G. van Ommering (1994). Rode lijst van bedreigde en kwetsbare zoogdieren in Nederland. IKC-Natuurbeheer, report 12, Wageningen.
13. Ma, W.-C. & S. Broekhuizen (1989). Belasting van Dassen Meles meles met zware metalen: invloed van de verontreinigde Maasuiterwaarden? Lutra 32(2): 139-151.
14. Martens, V. & K. Mostert (1991). Vleermuizen in het herinrichtingsgebied stadsrand Zwolle in 1990. Stichting Vleermuis Onderzoek, Wageningen.
15. Mostert, K. (1989). Kartering en betekenis van kleine landschapselementen in de Krimpenerwaard in 1987. NMF-Zuid-Holland.
16. Mostert, K. (1995a). Zoogdieren van Voorne in 1991. Vereniging voor Zoogdierkunde en Zoogdierbescherming, report 12, Utrecht.
17. Mostert, K. (1995b). Kleine zoogdieren in

Zuid-Holland. Zoogdier 6(2): 12-18.
18. Mostert, K. & J. Wondergem (1993). Tweekleurige vleermuis en Bosvleermuis op de Maasvlakte. Zoogdier 4(3): 12-14.
19. Niewold, F. (1993). Wordt de Woelrat zeldzaam? Zoogdier 4(4): 14-19.
20. Nolet, B.A. (1995). Verspreiding en aantalsontwikkeling van de Bever *Castor fiber* in Nederland in de periode 1988-1994. Lutra 38(1): 30-40.
21. Reinhold, J. & A. van Winden (1991). Zoogdierinventarisatie van de omgeving van Apeldoorn in 1988. Vereniging voor Zoogdierkunde en Zoogdierbescherming, report 5, Utrecht.
22. Wammes, D.F. (1992). Bosmuis *Apodemus sylvaticus* (L., 1758). In: S. Broekhuizen, B. Hoekstra, V. van Laar, C. Smeenk & J.B.M. Thissen (red.), Atlas van de Nederlandse zoogdieren, p. 289-291. Kon. Ned. Natuurhistorische Vereniging, Utrecht.

11. Ecotoxicology

1. Aldenberg, T & W. Slob (1991). Confidence limits for hazardous concentrations based on logistically distributed NOEC toxicity data. National Institure for Public Health and Environmental Protection, report 719102002, Bilthoven.
2. AquaSense (1996). Biologische Monitoring Zoete Rijkswateren. Meting effectparameters aan muggelarven in het veld; periode 1992 t/m 1995. RIZA, report 960321, Lelystad.
3. Beek, M.A. (1995). De risico's van normen. Een overzicht van de methodiek en afgeleide (eco)toxicologische risicogrenzen ter onderbouwing van Streef-, Grens-, en Interventiewaarden. RIZA, report 95.097X, Lelystad.
4. den Besten, P. (in prep.). Biotisch effectonderzoek ten behoeve van Nader Onderzoek Hollands Diep, Brabantsche en Dordtsche Biesbosch. RIZA, Lelystad.
5. Beurskens, J.E.M. & C. van de Guchte (1993). Dioxinen in de Ketelmeerbodem. RIZA report 92.041, Lelystad.
6. Eys, Y.A. (1996). De chemische en ecotoxicologische toestand van de zoete Rijkswateren. RIZA, report 96.016, Lelystad.
7. van der Gaag, M.A., M. van den Bergh, A. Brouwer, S. Dirksen, T. Boudewijn & G. van Urk (1989). Impaired breeding succes of some Cormorant populations in the Netherlands: the net tightens around compounds with a dioxine-like effect. In: The effects of micropolluttants on components of the river Rhine. Publications and reports of the project "Ecological Rehabilitation of the river Rhine". publ. no. 35 (1991).
8. Hendriks, A.J. (1993). Monitoring concentrations of microcontaminants in sediment and water in the Rhine delta: a comparison with reference values. European Water Pollution Control 3, 1: 33-38.
9. Hendriks, A.J., J.L. Maas-Diepeveen, A. Noordsij & M. van der Gaag (1994). Monitoring response of XAD-concentrated water in the Rhine delta: a major part of the toxic compounds remains unidentified. Water Research 28, 3: 581-598.
10. Hendriks, A.J. & M.D.A. Stouten (1993). Monitoring the response of microcontaminants by dynamic *Daphnia magna* and *Leuciscus idus* assays in the Rhine delta: Biological early warning as a useful supplement. Ecotoxicology and Environmental Safety 26, 3: 265-279.
11. Hoogeveen, P.M.T.C. (1994). Resultaten van het waterkwaliteitsonderzoek in de Rijn in Nederland. 1973 - 1992. RIZA, report 94.006, Lelystad.
12. Int. Rhine Committee (1987). Rhein Aktions Program (Rhine Action Program in French/ German), International Rhine Committee, Strasburg, FR.
13. Koeman, J.H. (1972). Side-effects of persistent pesticides and other chemicals on birds and mammals in the Netherlands. TNO-Nieuws.
14. van Leeuwen, C.J., W.J. Luttmer & P.S. Griffioen (1985). The use of cohorts and populations in chronic toxicity studies with Daphnia magna: a cadmium example. Ecotoxicol. and Environm. Safety 9, 26-39.
15. Leonards, P.P.E.G., M.D. Smit, A.W.J.J. de Jong & B. van Hattum (1994). Evaluation of dose-response relationships for the effects of PCBs on the reproduction of Mink (*Mustella vison*). IVM-report, R94/6.
16. Maas, J.L. (1993). Biologische Monitoring Zoete Rijkswateren. Operationele uitwerking ecotoxicologische parameters. RIZA, report 91.152FX, Lelystad.
17. Min. van Verkeer & Waterstaat (1994a). Saneringsprogramma Waterbodem Rijkswateren 1995-2010.
18. Min. van Verkeer & Waterstaat (1994b). Derde nota Waterhuishouding; Evaluatienota Water 1993; aanvullende beleidsmaatregelen en financiering 1994-1998. Den Haag
19. Mulder, M.A.A.J. (1993). TRIADE-Oost. Ecotoxicologische beoordeling van de waterbodemkwaliteit van vijf lokaties in Gelderland. RIZA, report 93.147X, Lelystad.
20. Noij, Th.H.M., M.A. Meerkerk, J. van Genderen, W. Hoogenboezem, H.A.M. Ketelaars & D. de Zwart (1996). Toxicologisch en ecologisch onderzoek van de Rijn in 1994. In relatie tot drinkwaterbereiding. KIWA SWO 95.218.
21. Noppert, F. & A.J. Hendriks (1995). Bewaking van oppervlaktewater met vissen en watervlooien. Praktijkervaringen op Rijn en Maas in de periode 1988-1992. H2O (28), 4; 112-114.
22. Pieters, H. & P. Hagel (1992). Biomonitoring of Mercury in European eel (*Anguilla anguilla*) in the Netherland, compared with Pike-perch (*Stizostedion lucioperca*): Statistical anlysis. In: J.P. Vernet (ed.), Heavy metals in the Environment II. Elsevier, Amsterdam.
23. Pieters, H., B.L. Verboom & V. Geuke (1996). Biologische Monitoring Zoete Rijkswateren: Microverontreinigingen in driehoeksmosselen - 1995. Netherlands Institute for Fishery Investigations, report C042/96, IJmuiden.
24. Reijnders, P.H.J. (1980). Management and conservation of the Harbour seal, *Phoca vitulina*, population in the international Wadden sea area. Biol. Conserv., 18, 1-13.
25. van der Valk, F., H. Pieters & R.C.C. Wegman (1989a). Bioaccumulation in Yellow eel (*Anguilla anguilla*) and Perch (*Perca fluviatilis*) from the Dutch branches of the

Rhine - mercury, organochlorine compounds and polycyclic aromatic hydrocarbons. Netherlands Institute for Fishery Investigations, report MO 89-205, IJmuiden.

26. van der Valk, F., Q.T. Dao & J. Speur (1989b). Contaminant contents of freshwater mussels (*Dreissena polymorpha*) incubated at various locations in the river Rhine from Switzerland to the Netherlands. Netherlands Institute for Fishery Investigations, report MO 89-206, IJmuiden.
27. Verboom, B.L., H. Pieters & J. de Boer (1996). Biologische Monitoring Zoete Rijkswateren. Microverontreinigingen in Aal - 1995. Netherlands Institute for Fishery Investigations, report C008/96, IJmuiden.
28. Witteveen+Bos, Raadgevende ingenieurs b.v. (1995). Het bepalen van de toxiciteit van sediment en poriewater met behulp van bioassays. Fase 3: 1994 RIZA, report BM 94.09, Lelystad.
29. Witteveen+Bos, Raadgevende ingenieurs b.v. (1996). Het bepalen van de toxiciteit van sediment en poriewater met behulp van bioassays. Fase 4: 1995 RIZA, report BM 95.12, Lelystad.

12. Synthesis

1. AquaSense (1997). Ecotoxicologisch onderzoek Afferdensche en Deestsche Waarden. Situatie voor aanleg van een meestromende nevengeul t.b.v. natuurontwikkeling. RIZA, report 97.0817, Lelystad.
2. Postma, R., M.J.J. Kerkhofs, G.B.M. Pedroli & J.G.M. Rademakers (1996). Watersysteemverkenningen 1996, een analyse van de problematiek in aquatisch milieu. Een stroom natuur, Natuurstreefbeelden voor Rijn en Maas. RIZA, report 95.060, Arnhem.
3. Creemers, R.C.M. (1991). Amfibiën in uiterwaarden. Een voorbereidende literatuurstudie. RIZA Lelystad, Univ. Nijmegen, Foundation ARK.
4. Rademakers, J.G.M., G.B.M. Pedroli & L.H.M. van Herk (1996). Watersysteemverkenningen 1996, een analyse van de problematiek in aquatisch milieu. een stroom natuur, Natuurstreefbeelden voor Rijn en Maas. Background document A: kansrijkdom van ecotopen. RIZA, report 95.172X.
5. Reijnen, R., W.B. Harms, R.P.B. Foppen, R. de Visser & H.P.Wolfert (1995). Rhine econet. Ecological networks in river rehabilitation scenario's; a case study for the Lower Rhine. RIZA, Reports of the project 'Ecological rehabilitation of the riviers Rhine and Meuse' nr. 58-1995", Lelystad.
6. Silva, W. & M. Kok (1996). Integrale Verkenning inrichting Rijntakken. Main report ""Een weegschaal voor rivierbeheer" IVR-Report 1.
7. Vanhemelrijk, J.A.M. & J.E.W. de Hoog (1997). Amoebe Beneden Rivierengebied. Studie naar ecologische ontwikkelingsrichtingen. RIZA, report 96.004.

Photograph 13.1
River dune along the Waal at Millingen.

Rationale

BIRDS

Monitoring of waterbirds is coördinated by SOVON Vogelonderzoek Nederland (Cooperating Organizations Bird Census Work), Beek-Ubbergen. The operational scheme of waterbird monitoring is described in RIZA report BM 93.06.

FISH

Monitoring of fish is carried out in cooperation with the Netherlands Institute for Fishery Investigations (RIVO-DLO), IJmuiden. The operational scheme of fish monitoring is described in RIZA document 96.097x.

MACROZOOBENTHOS

Sampling of macrozoobenthos in the Rhine is carried out by Directorate East of the Directorate-General for Public Works and Water Management. Identification of benthos is supervised by the department IMLB of RIZA. The operational scheme of macrozoobenthos monitoring is described in RIZA document 96.002x.

ECOTOXICOLOGY

Monitoring of accumulation of micropollutants in Eel and Zebra Mussels is carried out in cooperation with the Netherlands Institute for Fishery Investigations. Monitoring of toxicity of surface waters is carried out in cooperation with the National Institute for Public Health and Environmental Protection. The operational scheme of monitoring of ecotoxicological parameters is described in RIZA document 91.152x.

FYTO- en ZOOPLANKTON

Sampling and identification of plankton is carried out by RIZA. In 1995 sampling and identification of plankton in the Rhine was carried out by the National Institute for Public Health and Environmental Protection at Bilthoven. The operational scheme of plankton monitoring is described in RIZA document 96.002x.

MACROPHYTES

The fieldwork for monitoring of the vegetation in and along the large rivers presented in this report was carried out by the Netherlands Institute for Ecological Research at Heteren. Since 1996 in the river Rhine this work is carried out in cooperation with Directorate East of the Directorate-General for Public Works and Water Management. The operational scheme of macrophyte monitoring is described in RIZA document 96.004x. Since 1996 monitoring of bank vegetation is carried out by the foundation FLORON.

WOULD YOU LIKE TO KNOW MORE???!

This report does not contain all the data collected within the scope of Biological Monitoring. A summary of the parameters determined in 1995 is provided in a report on the environmental monitoring network for national fresh waters (Milieumeetnet Zoete Rijkswateren, 92.051).

Upon the completion of "DONAR", the central data storage system of the Ministry of Transport, Public Works and Water Management, all the data will be stored in "DONAR".
Should you require any additional information about the data, please contact RIZA's monitoring co-ordination department (IMMM); the contact person is Mr P. Jesse.

The programme supervisor of Biological Monitoring is Mr K.H. Prins.

All the people referred to here are employed by RIZA, PO Box 17, 3200 AA Lelystad, The Netherlands, telephone +31 (0)320-298411.

Colophon

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Eric Marteijn (12.3)

illustrations:
Rob Felix (figure 8.2; 8.3)
Jeroen Helmer (Chapter 8, intermezzo 1)

translation:
Wilkens c.s.