Ecological Rehabilitation of the Rivers Rhine and Meuse: Progress report 1996-1997.

ABSTRACT

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An account is presented of the activities of a research programme in which five major research institutes in The Netherlands (RIZA, RIVM, RIVO-DLO, IBN-DLO, SC-DLO) cooperate. Research was done on water quality, sediment quality, habitats, invertebrates, fish, vegetation and management. Future policy-oriented research needs were examined in three workshops on water quality, sediment quality and habitats. All new literature is listed.

Key words: ecological rehabilitation, nature management, water quality, sediment quality, habitats, Rhine, Meuse.

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P.O. Box 17, 8200 AA Lelystad, The Netherlands
Phone: 31(320)298411; fax: 31(320)249218

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The project entitled 'Ecological Rehabilitation of the Rivers Rhine and Meuse' is a joint project of:

- the Ministry of Transport, Public Works and Water Management, represented by
  - the Institute for Inland Water Management and Waste Water Treatment (RIZA)
- the Ministry of Housing, Physical Planning and Environment, represented by
  - the National Institute of Public Health and Environmental Protection (RIVM)
- the Ministry of Agriculture, Nature Management and Fisheries, represented by
  - DLO Netherlands Institute for Fisheries Research (RIVO-DLO)
  - DLO Institute for Forestry and Nature Research (IBN-DLO)
  - DLO Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO)

The aim of the project is to contribute to the ecological rehabilitation of the Rivers Rhine and Meuse. One of the project's activities is the publication of a series of publications and reports on the project 'Ecological Rehabilitation of the Rivers Rhine and Meuse'.

Contents

Preface

This report provides an account of all activities undertaken within the framework of the programme 'Ecological Rehabilitation of the Rivers Rhine and Meuse' over the period 1996-1997.

Since five major research institutes in the Netherlands, cooperate in the programme, this report consists of a large number of contributions. The compilation has been coordinated by H.P. Wolfert, whilst the editing has been done by Ms. S. Kuster and H.E. Michel-Knaap, from SC-DLO. Their work was supervised by the members of the project steering group (see section 4.1).

The following persons have provided one or more accounts of their activities:

- C. Bakker, T. Buijse, H. Coops, N. Geilen, A.J. Hendriks, J. de Jonge, E. Lammens, A. Remmelzwaal, M. Schropp, J. simons, I. van Splunder, A. bij de Vaate and T. Vuling of RIZA;
- S. van Dijk, W. Ligtvoet and E. Timmers of RIVM;
- H. Pieters of RIVO-DLO
- P.J. van den Brink, W.C.Knol and H.P. Wolfert of SC-DLO;
- R.P.B. Foppen, W. Ma and R.C. Nijboer of IBN-DLO.

Addresses of contact persons are listed in Appendix 1.

1 Introduction

1.1 Cooperating institutes and aims of the programme

Ecological rehabilitation of the Rivers Rhine and Meuse requires an integrated management policy. Research aiming at supporting an integrated river management requires an interdisciplinary approach guarantering hat the research activities are coordinated and meet policy needs.

The programme 'Ecological rehabilitation of the Rivers Rhine and Meuse' (EHR) is a joint project of five governmental research institutes, all involved in ecological studies on the Rhine and Meuse river systems:

- Institute for Inland Water Management and Waste Water Treatment (RIZA)
- National Institute of Public Health and Environmental Protection (RIVM)
- DLO Netherlands Institute for Fisheries Research (RIVO-DLO)
- DLO Institute for Forestry and Nature Research (IBN-DLO)
- DLO Winand Staring Centre for Integrated Land, Soil and water Research (SC-DLO)

The aim of this programme is to contribute to the ecological rehabilitation of these river systems by (i) translating policy topics into general research items,(ii) planning and programming this research and (iii) disseminating the results.

All activities undertaken in the years 1996 and 1997 are presented in this report. Information on activities over the years 1988 to 1995 can be found in previous reports most of which have been published in the EHR series Publications and reports on the project 'Ecological Rehabilitation of the Rivers Rhine and Meuse'. These are listed in Appendix 2.

1.2 International context

The Dutch research programme 'Ecological rehabilitation of the Rivers Rhine and Meuse' is embedded in the 'Rhine Action Programme' (RAP). The partners work in subcommittees of the International Rhine Commission, implementing ecological research ativities initiated within the RAP framework. A similar programme is about to be started for the river Meuse.

1.3 Structure of this report

After this introduction, the research activities of the EHR members over 1996 and 1997 are presented in chapter 2. These include aspects of ecotoxicology, aquatic ecology and landscape ecology. Only activities which have been reported on in 1996 or 1997 have been incorporated. Chapter 3 provides an account of three workshops, organized to discuss future research needs. Some facts and figures on the organization, contributions and publications are presented in chapter 4. The adresses of the members of the Project Committee are given in Appendix 1. All publications in the series Publications and reports or the project 'Ecological Rehabilitation of the Rivers Rhine and Meuse' are listed in Appendix 2.

2 Research results

2.1 Ecotoxicology

2.1.1 Lindane: use, emissions and fate in the Rhine Basin

E. Timmers (RIVM)

The objective of this study was to estimate the use, emissions and aquatic fate of lindane in the Rhine Basin from 1985 to 2000. Estimations of the use of lindane in the Rhine Basin are based on its agricultural use in the five most important bordering countries, viz.: Germany, Switzerland, France, Luxembourg and the Netherlands for 1985 and 1990. Anticipative measurements on the different uses in these countries led to the conclusion that very little change was to be expected over the period 1990 - 2000. Monitored data up to 1993 more or less confirm this assumption. Six major emission pathways are distinguished: 1) agricultural applications, 2) erosion, 3) domestic use, 4) atmospheric deposition directly onto surface waters, 5) atmospheric deposition via non-paved areas and 6) runoff from urban areas. In 1985, agricultural and atmospheric deposition together comprised over 70% of all emissions, whereas in 1990 households and agriculture were calculated to be responsible for almost 80% of all emissions inside the Rhine Basin.

The aquatic fate in the Rhine Basin was calculated using the DELTAWAT water quality model. A comparison between the calculated and the observed water quality shows a general overestimation of the emissions in 1985 by a factor ranging from 1 to 2, whereas the estimates for 1990 were found to be fairly accurate. Since the monitored discharges showed unexplainable discrepancies, further analysis of the emission estimates was not very useful. Assuming an overestimation of the sources by a factor of 1 to 2 in 1985 and an accuracy of the 1990 emission estimates within a range of 50%, this would mean that the 50% emission reduction objective of the International Commission for the Protection of the Rhine (ICPR) in 1995 relative to 1985 has most likely already been met. Without additional measures, however, the water quality objective for the year 2000 will most certainly not be met or even be approached in most parts of the Rhine Basin.

In 1997, the integrated DeltaWat model was implemented for the part of the Rhine Basin upstream from Lobth, on a 1 to 1 kilometer grid cell base, in the PCRaster Geographical Information System in cooperation with Utrecht University. The model is designed to allow emissions, fate, water quality and discharge to be calculated for any location in the river system on the basis of general information on volumes applied, application methods, atmospheric deposition and a few substance properties.

2.1.2 Only marginal decrease in PCBs in eel

J. de Boer (RIVO-DLO)

Results of the 1996 monitoring programme on PCB contamination in

eel from Dutch freshwater show that there has been only a marginal decrease in PCB contents in eel from the rivers Rhine and Meuse over the last 20 years. Given a recent statement of the Dutch Health Council on the allowable level of dioxin toxicity in humans (1 pg/kg body weight) this development is cause for concern. Continuation of this trend would mean that consumption of such eel would not be possible for many years to come. Over the period 1996-1997, methods have been developed for the determination of nitro musks and polycyclic musks in fish, and for the determination of tris(4-chloro-phenyl)methanol and -methane. These compounds have all been found in substantial quantities in fish from the river Rhine, which shows that, in addition to PCB, a variety of other contaminants are still present in fish from this river.

2.1.3 Assessing micropollutants by monitoring systems using Zebra mussels

H. Pieters (RIVO-DLO)

Assessment of the bioavailability of micropollutants in inland waters can be performed by active biological monitoring (ABM) using Zebra mussels. This method also provides indirect information on the impact of contaminated sediments on the water quality and on the efficiency of reconstruction measures to improve sediment quality.

Zebra mussels are very useful for active biomonitoring. The freshwater mussels have a long lifespan and are easy to collect and handle. Since the late 1970s, Zebra mussels have once more become widely distributed in the inland waters of the Netherlands. Furthermore, Zebra mussels are sedentary and have the ability to withstand high pollutant concentrations without appreciable mortality rates.

Over the period 1992 to 1996, ABM with Zebra mussels was used in 12 locations in the inland waters of the Netherlands. The Zebra mussels used were collected from a clean reference area in Lake Ysselmeer. Deployments started at the beginning of October and lasted for six weeks.

Surface waters in the Netherlands have been found to show considerable differences in bioavailability of micropollutants. The highest levels of micropollutants in exposed mussels were found in sedimentation areas of the River Rhine (Hollands Diep - Haringvliet and Ketelmeer), while lowest levels were found in the Wolderwijd and Ysselmeer lakes. Level ratios (high/low) varied from 15 for lead, 25 for ΣDDT and 30 for PCBs to 50 for PAHs.

Compared with the 1988 situation, concentrations of some micropollutants (Lindane, Dieldrin, ΣDDT, HCB and a-Endosulfan) in Zebra mussels exposed in the Rhine at Lobith were found to have significantly decreased, i.e. by a facter of two or more. Levels of Σ7PCBs remained relatively constant .

Active biological monitoring with Zebra mussels is a very useful method to reveal the bioavailability of accumulating micropollutants, to measure water quality differences

between surface waters as regards hydrophobic compounds and to investigate the impact of polluted sediments. Furthermore, this ABM method can easily be used for trend monitoring of organic micropollutants and heavy metals.

2.1.4 Toxic potency of fresh waters

W. Ligtvoet (RIVM)

Several methods are being used to obtain information on the "health status" of ecosystems. Chemical monitoring is one of the methods applied on a large scale to obtain information on the toxicological stress put upon ecosystems. One of the major disadvantages of this method is the limited number of substances which can be analytically dealt with.

In addition to chemical monitoring, biological research is being carried out to obtain detailed information on the health status of ecosystems. In most cases, however, it is difficult to relate observed ecological effects directly to causal factors like toxicity.

Nevertheless diagnosis of toxicological stress on ecosystems is a necessary tool to identify areas of toxicological concern or to evaluate regulatory actions. Therefore, a method has been developed to monitor toxicological stress on ecosystems. In 1996, a pilot monitoring project was designed, in cooperation with the Institute of Inland Water Management and Waste Water Treatment (RIZA) and the University of Amsterdam, Dept. of Aquatic Ecology. 15 stations were selected in the main watercourses in the Netherlands. These stations were sampled bimonthly. The organic pollutants contained in the water samples were concentrated and the toxicities were measured using a battery of small-scale aquatic toxicity tests. The test results were used to calculate the Potentially Affected Fraction (PAF) of species, a parameter designed to express the level of toxic stress in ecosystems. The PAF values measured generally did not exceed 5%.

2.1.5 Search for unknown substances continued

A.J. Hendriks (RIZA)

Environmental research and management are mainly confirmed 100-200 priority substances for which quality standards have been derived. RIZA-KIWA research has shown that only a fraction of the toxicity of the Rhine and Meuse water can be explained by toxicants that can be detected by chemical analysis. The rest is attributed to unknown compounds. Recent, studies by RIZA, RIVO and the Research Institute for Toxicology (RITOX) have suggested that this may also be true for accumulation.

The RIZA-KIWA study showed that the unknown substances are largely of a fat-soluble nature. As a result, this group of compounds has been extensively investigated in an analysis of mussel and eel by RIZA and RIVO. Again, the total level of all substances indentified in the organisms was only a fraction of the total level of accumulative compounds adsorbed to surrogate biological matter in a parallel RITOX-RIZA investigation. PAHs and PCBs showed the highest concentrations (fig. 1).

Other fat-soluble sompounds were detected in lower concentrations. Whether these levels are still harmful to the organisms and their predators is

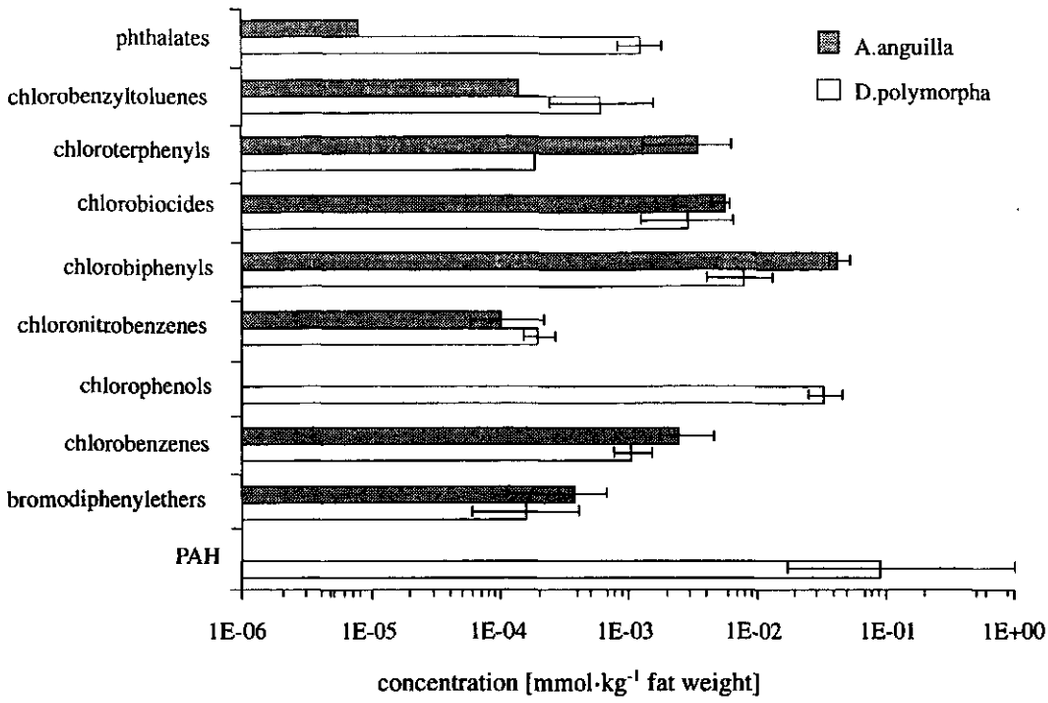

Fig. 1 Concentrations of fat-soluble compounds in zebra mussel and eel from the Rhine-Meuse basin. The highest levels are those of priority substances (PCBs, PAHs).

currently being investigated by RIZA Instituut voor Milieuvraagstukken (IVM). The methods are being discussed in a working group of the the Koninklijke Nederlandse Chemische Vereniging - Nederlandse Vereniging voor Toxicologie (KNCV-NVT). Their conclusions will contribute to additional selection of priority substances and monitoring parameters in the IRC.

2.1.6 Application of the OMEGA model identifies species that are vulnerable to toxicants

A.J. Hendriks (RIZA)

To address questions on toxicants raised by water quality management, the OMEGA model (Optimal Modelling for EcotoxicoloGical Applications) was developed at RIZA. OMEGA simulates the concentration kinetics of substances and the population dynamics of species. The model was built by integrating laboratory, field and literature data and needs only a minimum of information for an overall evaluation. It has been applied in the past to identify vulnerable species in the Rhine area, and more recently in a simulation of the population dynamics of cormorants and otters. In addition, it is being used for all kinds of short-term questions.

The core of OMEGA consists of a few tradional differential equations for the concentration kinetics of substances and the population dynamics of species. The model provides default values for most parameters. This is achieved by linking parameter values to well-known properties of substances, such as molecular weight, and of species, such as adult weight. If greater refinement is required,users can provide additional information on these parameters.

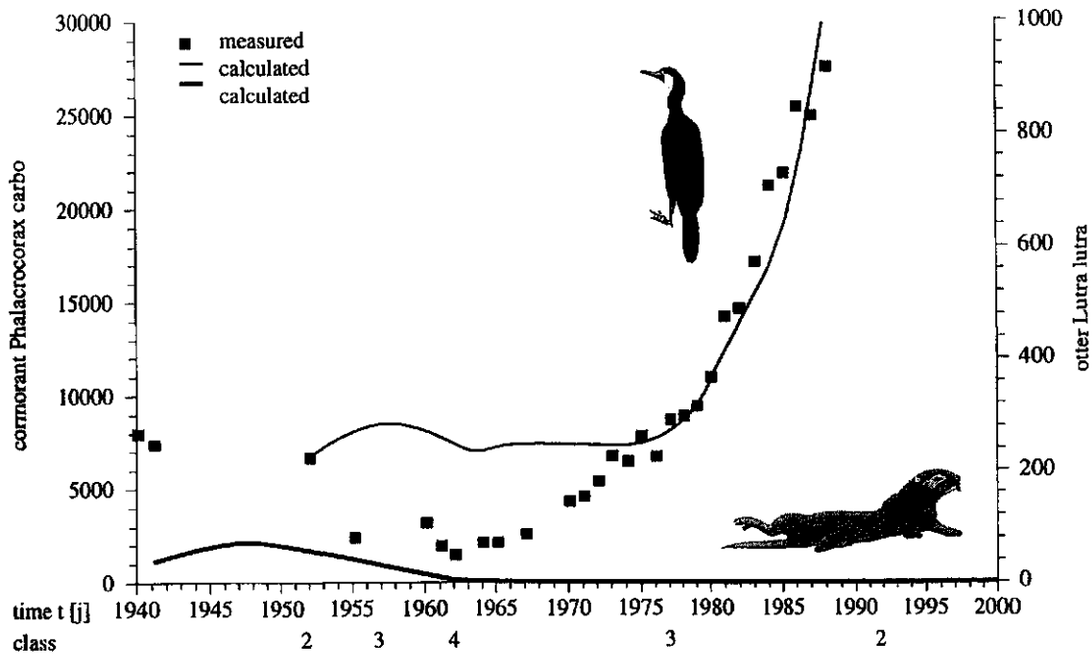

Fig. 2 Development of cormorant and other populations in the Rhine-Meuse delta simulated by the OMEGA model. PCB concentrations in the 1960s (pollution class 4) were high enough to suppress cormorant populations, as confirmed by other field data. Other populations are still unlikely to survive present PCB levels.

The model has been applied in several case studies in the Rhine-Meuse area. For instance, it was estimated that aquatic species mainly suffer from organochlorine, organophosphate and organonitrogen compounds, whereas terrestrial organisms are affected by metals. Field studies have so far confirmed the first but not the second estimation. Results of more detailed on cormorants and otters in the Rhine delta are shown in Figure 2.

This figure shows that cormorants nowadays no longer suffer from PCB stress while otters still do, as has been confirmed by field studies. The model is currently being used for the concentration kinetics of algal toxins and the population dynamics of phyto-zooplankton in the IJsselmeer area. In response to several requests, the model will be made more user-friendly, allowing to be linked to water quality models.

2.1.7 Soil pollution in riverine floodplains; a threat to terrestrial macroinvertebrates?

W. Ma (IBN-DLO)

Within the framework of nature development in floodplains, the problem of polluted soils and their effects on plants and animals is huge. Sanitation of polluted soils is expensive, and if it could be proven that detrimental effects are not to be expected, the money could be used more efficiently way. Experiments in the field and bioassays in laboratory have been executed to investigate possible effects on some key organisms in flood plains.
Field investigations have resulted in the observation of a highly characteristic floodplain biodiversity of terrestrial macroinvertebrates. There was no relation between biodiversity

and the level of pollution, expressed as the degree to which concentrations of heavy metals and organic micro-contaminants exceed the intervention values. The only exception was the family of Digger Wasps (Sphecidae), whose soil-inhabiting species showed a significant negative correlation with the level of pollution. Bioassays have been executed with only a few species and the level of pollution of the soil examined was not found to be extremely high. Further research with other species and heavily polluted soils (class IV) is recommended.

2.1.8 Comparing the ecological states of polluted river biotopes

J. de Jonge (RIZA)

On a commission by RWS-RIZA, Bureau Waardenburg has initiated a comparative study of the ecological state and chemical quality of the rivers Sajó and Grensmaas. The river Sajó is regarded as one of the most seriously polluted rivers in Hungary, but it has retained a more or less natural layout, including patches of floodplain forest. In 1994, the Hungarian research agency VITUKI surveyed the ecological and chemical state of the river Sajó. The river Grensmaas is also considerably polluted, but in addition has lost its natural layout. Data on this river has been gathered from a variety of reports.

The aim of the comparative study was to increase our understanding of the potential for ecological development in polluted Dutch rivers (such as the Grensmaas) after restoration of its natural layout, using the information obtained from the Sajó survey.

The study has shown the chemical state of the two rivers to be comparable. Both rivers are seriously polluted by heavy metals, though organic micropollution is less serious in the river Sajó.

Ecological state was found to be more difficult to compare, since the biological data sets did not match. Some findings do suggest, however, that restoration of the natural layout should enable recolonisation by interesting species, even in the presence of pollutants. An example would be the Loach (*Cobitis taenia*).

The study shows that analogy studies, i.e., comparing two rivers in order to assess the ecological potential of polluted rivers, are a useful tool as such. It is recommended, however, to focus such studies on a small number of biological groups only, and to monitor these groups in in both rivers in a similar way and during the same period, rather than to make use of large, but poorly comparable data sets.

2.1.9 Ecotoxicological reference rivers for the Rhine and Meuse

J. de Jonge (RIZA)

Ecological rehabilitation involves an assessment of the present ecological quality of the areas concerned as well as of the chances for new (or lost) species to establish themselves. This assessment uses exotoxicological techniques. Adequate interpretation of the data requires information derived from clean and polluted reference rivers, whose selection should be based on the presence of ecotopes corresponding to Dutch problem

locations as regards sediment composition, flow rate, depth, etc.

An explorative study to find suitable reference rivers was undertaken in 1997. The river Elbe (Germany) was chosen as a polluted reference river; collaboration was established with the *Bundesanstalt für Gewässerkunde* at Koblenz. The river Pripjat (Belarus) was selected as a suitable non-polluted reference river, collaboration having been established with the Turov nature reserve and the Minsk Zoological Institute.

In June 1997, RIZA collected sediment samples from the Elbe and Pripjat rivers for the purpose of macrofauna identification and chemical analysis, in order to assess whether both rivers met the criteria for macrofauna community composition and pollution levels. A report on this assessment will be published in November.

Currently, M. Zimmer of the *Büro für Umweltdokumentation* (Germany) is engaged in a comparative study of the impact of pollution on ecological developments and recovery in the rivers Rhine and Elbe and their flood-plains, based on literature data and interviews with experts. The findings will be presented in January 1998.

The aim is to carry out ecotoxicological surveys in four ecotopes in the spring over a period of 3 years, in order to obtain a clear overview of the macrofauna communities in both reference rivers.

2.1.10 Effect of chronic cpmined toxicity of pesticides on plankton in aquatic systems

P.J. van den Brink (SC-DLO)

This project aims at assessing the relation between the application of pesticides and the rehabilitation of the aquatic environment in the river system. The project started in 1996 and is conducted in cooperation with the Wageningen Agricultural University and RIVM. A validation of the current safety standards, based on the Uniform Principles, will be made for mixtures of different pesticides.

Twelve freshwater indoor microcosms (600 l) were used to study the effect of a chronic application of a mixture of the herbicides atrazine, metolachlor and diuron. The most sensitive endpoints were found to be photosynthesis efficiency, pH, oxygen concentration and the abundance of phytoplankton taxa. In a conservative approach, the safety factor proposed by the Uniform Principles failed to provide adequate protection for one of the taxons. All other variables observed were sufficiently protected against the mixture by the safety factors proposed in the Uniform Principles. A comparable experiment was conducted with a mixture of two insecticides (lindane and chlorpyrifos). Furthermore, an experiment in outdoor mesocosms was performed to observe the effects of an acute application of 10 and 20 pesticides at the level of their individual MTR concentrations.

2.2 Aquatic ecology

2.2.1 Source apportionment and quantification of nitrogen transport and retention in the river Rhine

S. van Dijk (RIVM)

This project, carried out in the period 1990-1996, constituted part of the project entitled 'An East-West perspective on riverine load of nutrients into the Baltic Sea'.

The main objective of the research effort described was to carry out a source apportionment of the observed nitrogen load (to the source – either point or diffuse) and to quantify nitrogen transport, emission and retention in the river Rhine and its main tributaries. The Rhine basin was investigated for comparison with the rivers discharging into the Baltic Sea. In addition, the applicability of the methods used in this type of research was tested. The Rhine basin upstream of Lobith was divided into 30 different sub-catchments. A substantial database, consisting of water quality data and geographic information, was compiled in cooperation with Utrecht University. Differences between the various sub-catchments in the contributions of diffuse and point sources of nutrients, as well as the (area-specific) emission of these sources and nutrient retention, were also investigated.

Source apportionment and emission estimation were determined using two fundamentally different methods. One of these methods is data-intensive with stringent requirements for the research area. An advantage of this method is the high spatial detail and the possibility to employ user-defined modelling concepts. The other method is more generally applicable and less data-intensive, making it very convenient for a quick determination of source apportionment and emission estimates with a relatively coarse resolution.

The emission of dissolved inorganic nitrogen (DIN) in the entire area upstream of Lobith was estimated at 361 $kt \cdot y^{-1}$; 47% of this originates from diffuse sources. The retention in the entire catchment upstream of Lobith was 32% of the total DIN emission. Estimates of source strength, emission and retention, obtained by means of both methods, showed differences between the various sub-catchments in the origin of the total load (from either point or diffuse sources), the unit area emission and the percentage of the total emission retained.

2.2.2 Plankton dynamics in the Rhine and Meuse rivers

W. Ligtvoet (RIVM)

The field work performed by RIVM focussed on plankton dynamics in the Rhine and Meuse. In 1996, plankton in the Meuse was monitored within the framework of Rijkswaterstaat's national biological monitoring programme. As had been found before, the upstream station of Eijsden was more strongly dominated bij green algae than the downstream stations. Cyanobacteria were more abundant there as well. This is most probably caused by the regulation of the upper Meuse with barrages, which increase the residence time of the water.
In 1996, a combined hydrological and ecological model of the Rhine was developed in cooperation with the Free University of Brussels, within the

framework of the EU project BINOCULARS (Biogeochemical Nutrient Cycling in Large River Systems).

Grazing experiments with water from the Rhine showed that the loss rate of phytoplankton due to grazing was of the order of 5 % of primary production per day, and hence not a significant factor in phytoplankton dynamics in the river Rhine, less so than for instance benthic filter feeders.

2.2.3 Plankton dynamics in a former riverbed

W. Ligtvoet (RIVM)

A field survey in a former riverbed and between two groynes along the river Waal aimed at an improved understanding of the plankton dynamics of aquatic systems adjacent to the main channel of a river. The water between the groynes did not differ from that in the main channel. In the former riverbed, however, zooplankton densities were more than 100 times higher than in the river. Chlorophyll-a levels were higher as well, and showed a highly dynamic behaviour.

This suggests that the grazing pressure on the phytoplankton is very high. The phytoplankton species composition in the dead arm showed a gradient towards a community dominated by green algae. The main conclusion is that the dead arm was much more productive than the main channel, despite the intense water movement caused by shipping traffic. Although at present the influence of dead arms and other low-flow areas on the river channel is small, expansion of such areas due to restoration measures may increase grazing pressure on the phytoplankton.

2.2.4 Habitat systems as aquatic graduators for large rivers

R.C. Nijboer (IBN-DLO)

Habitat systems are units of abiotic habitat characteristics and the biocommunity belonging to those habitats. Data sets from the period 1975-1995 have been analysed with the help of multivariate analysis techniques. The biocommunities were restricted to macroinvertebrate species composition, typifying species and biotic characteristics of these species.

The analysis shows characteristic habitat systems for the rivers Rhine, Meuse and Grensmaas. In the river Rhine, two brackish water habitat systems could be discerned and habitat systems from the Delta area were analysed separately.

The main discriminating features are substrate composition, current velocity and depth. The population density and numbers of macroinvertebrate species on stones in the river IJssel have increased since 1975. In several habitats of the river Rhine, an increase in the number of species could be attributed to non-characteristic imigrant species (neozoa). Despite the improved water quality, many critical species have not yet returned. Most probably, this is due to the lack of habitat diversity. Siltation is one of the main problems, enhanced by the presence of Corophium curvispinum.

In the rivers Meuse and Grensmaas, water quality has not improved, while siltation also plays an important role and the impoverished biocommunity has not recovered in the period studied.

In the Delta area, lack of variation has led to low diversity. Current velocity is very low, the natural tide has

disappeared, no transition exists between salt and fresh water and the sediment quality is poor. The biocommunity, therefore, shows low species numbers.

2.2.5 Opportunities for rheophilic fish

T. Buijse (RIZA)

Restoration projects along the rivers Rhine and Meuse comprise, among otherthings, the creation of secondary channels and floodplain lakes with downstream connections to the main channel. Their positive effect on the fish community is presumed, but has not yet been demonstrated. The project 'Opportunities for rheophilic fish species' evaluates these newly created water bodies for their functions for the fish community. Existing water bodies such as temporarily isolated floodplain lakes and connected deep sand-mining pits are used for comparison. The areas can serve as spawning, nursery and sheltering areas. The project started in 1996 and had its first full season of field work in 1997. The results are promising. Young rheophilic fish species have been caught in the secondary channels. The first results indicate that the secondary channels are used as nursery areas, which are regarded as an important habitat during the larval and juvenile stages. The channels appear to be too shallow for sheltering and the substrate too fine for spawning. The project will last until tje year 2000 and is a joint project of RIZA, Wageningen Agricultural University and the Organisation for Improvement of Inland Fisheries. Results will be submitted to peer-reviewed scientific journals.

2.2.6 Ecological studies in man-made riverside water bodies (OER)

H. Coops (RIZA)

Clay extraction will lead to the creation of many new lakes and channels in the floodplains of the main Dutch rivers. The OER project tries to predict how the development of aquatic wildlife in these new water bodies relates to the methods used in excavating them. The project will concentrate on ways to prevent the water bodies from becoming dominated by green algal 'soup'. Present knowledge of the functioning of aquatic ecosystems suggests that local depth, water level dynamics and degree of isolation are the main determinants of the type of aquatic wildlife which will develop. The OER project is to provide the knowledge required to aim for particular wildlife developments by selecting the right locations and layout for newly dug water bodies.

2.2.7 Sea trout migration

A. bij de Vaate (RIZA)

The sea trout migration project started in 1996. The aim of the project is to investigate inland migration of salmonids (like the atlantic salmon and the sea trout) in the downstream area of the rivers Rhine and Meuse. A new telemetric method, the NEDAP TRAIL System®, was developed for this study. The method is based on inductive coupling between an antenna loop on the bottom of a river or canal and a ferrite rod antenna incorporated in a tag of the transponder type. The antenna loop is part of a detection station, 12 of which were built along possible migration

routes. Field tests have shown that the detection system functions well with a maximum antenna length of 550 m, a water depth of 15 m and a maximum passing speed of the tag of 5-6 m s^{-1}.

During the investigation (reference date: 31 December 1997) 160 fishes were tagged, amongst them 9 specimens of Atlantic salmon. Of the 151 sea trout tagged, 38 specimens were detected once or several times at the detection stations. Atlantic salmon have not yet been detected. A total of 23 sea trout, caught by professional or sports fishermen, were reported back. The number of registrations at the detection stations reflects the importance of the possible migration routes. As yet, however, the numbers were insufficient to provide a clear picture of inland migration in the downstream reaches of the rivers Rhine and Meuse.

2.2.8 Fish in the rivers Rhine and Meuse (The Netherlands)

W. G. Cazemier (RIVO-DLO)

Fish populations in the Dutch part of the rivers Rhine and Meuse are being monitored on a yearly basis using different fishing gear. The composition of fish stocks provides information about the ecological quality of the aquatic biotopes. Although the generalistic species form by far the main part of the riverine fish fauna, the number of more vulnerable rheophilic species is increasing. Special attention is being paid to the anadromous species, mainly lampreys, salmon, sea trout and twaite shad. These species have returned to the fish fauna. Monitoring the upstream migration of anadromous salmonids shows that cohorts are migrating towards the upper stretches of the rivers in two main periods each year. Adult and juvenile river and sea lampreys can be once again captured in coasiderable numbers in the Dutch part of the rivers. These recent developments all give evidence that the aquatic environment of our river basins is recovering under the serious policy of rehabilitation by different countries in the watershed.

A look at the data (Fig. 3) reveals that among the total number of 48 species captured in the last two years, about 50% belong to the ecological group of the non-specialists (generalists like roach, bream, white bream, perch, zander and ruffe). They constituted 83% of the total numbers captured during monitoring (Fig. 4). The group of rheophilic species is already represented by 14 species (like brook trout, grayling, bleak, asp, dace, chub, nase, barbel, bullhead) while the anadromous group includes 7 species (river and sea lamprey, twaite shad, Atlantic salmon, sea trout, rainbow trout, three-spined stickleback). Eel and flounder are the only catadromous species important in Holland. The presence of rheophilic and anadromous specie, has increased over the last decade.

Monitoring and tagging salmonids has shown that sea trout in Dutch rivers and in the coastal area partly originate from French rivers in Normandy, while others migrate to the German part of the river Rhine and its tributaries. Those tagged in the Meuse migrate upstream in this river. Atlantic salmon is still poorly represented in the rivers, compared to sea trout. Out of a total of 891 salmonids captured during 1994-1997,

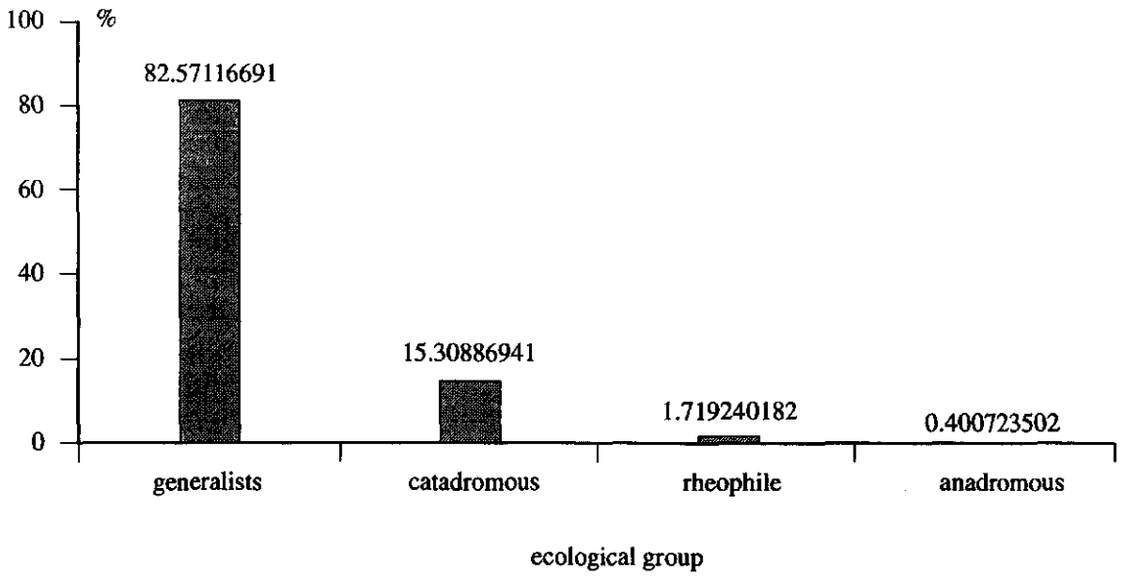

Fig. 3 Relative numbers of fish in the Dutch part of the rivers Rhine and Meuse

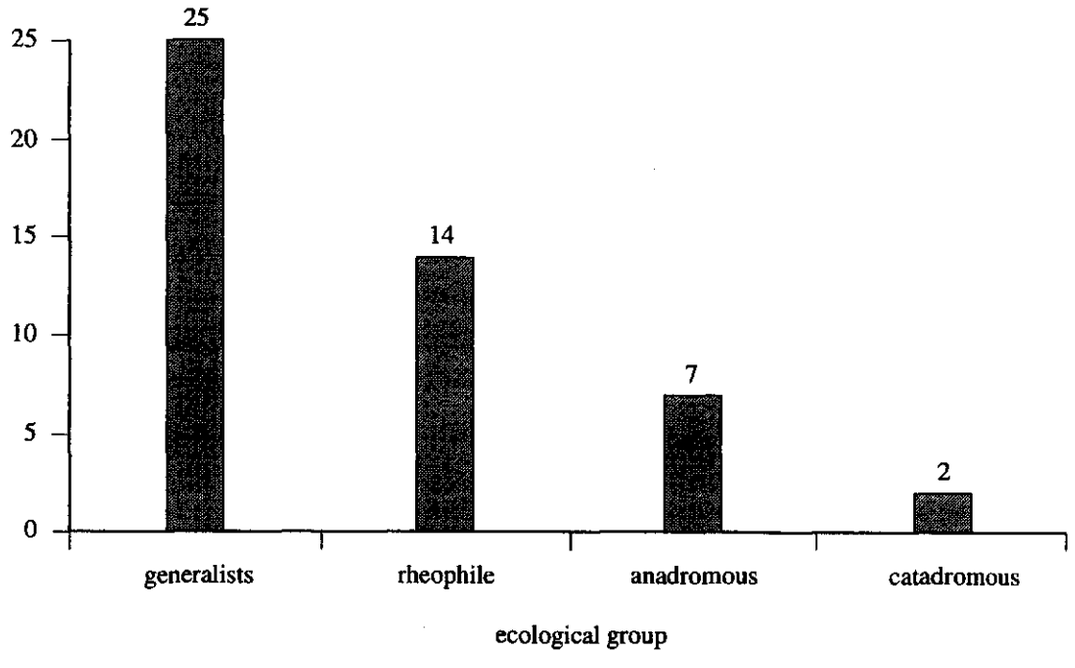

Fig. 4 Numbers of fish species in the Dutch part of the rivers Rhine and Meuse

97 (11%) were salmon. Weirs in the rivers Lek and Meuse still form serious obstructions for the migrating salmonids. Smolt migration has not been studied so far. Newly built fish passes in the river Meuse allow large numbers of fish to reach higher streches of the river.

2.2.9 Fish in Lake IJsselmeer

W. Dekker (RIVO-DLO)

Lake IJsselmeer (52°40'N 5°25'E) is a former estuary with a surface area of 1820 km^2 in the Dutch part of the Rhine system. Since being closed by a dam in 1932, it has been functioning as the largest fresh water reservoir in the Netherlands.

The fish fauna has been dominated by the fresh water species like perch, pikeperch, ruffe, roach, bream; additionally, eel, flounder and smelt - entering the system through the sluices to the Wadden Sea - contribute significantly to the total fish biomass. The high density of these eight species (about a billion specimens) has enabled routine surveys. Additionally, the (direct and indirect) impact of the commercial fisheries is being monitored and assessed on a regular basis. The fisheries tremendously overexploit the stocks of eel, perch, pikeperch and smelt, while huge numbers of these and all other species are caught unintentionally.

Before the closure of the lake in 1932, it was the primary estuary of the Rhine system, housing euryhaline species like coastal herring, anchovy, eel and flounder, but also giving highly migratory species like salmon and trout access to the river. Since the enclosure, the marine herring and anchovy have completely disappeared, but salmon and trout are still found in the lake. In order to clarify and quantify the status of these migratory species, a monitoring programme for migratory species was started in 1994. Since their low numbers (ca. 1000 per year all, see below) make direct observations impossible, a catch-return programme for the commercial fisheries has been set up, yielding 750 salmonids in two years. A complicated statistical analysis model of return rates and catch volumes has been compiled, yielding estimates of a return rate of 75 % and an estimated total population of 1000 animals. Data on fatty acids, length distribution, seasonality and maturity suggest that most of these animals are of marine origin (several trout showing definitely marine prey organisms, suggesting they have crossed the Wadden Sea and the sluices in just a few hours time).

Although spatial concentrations occurred (amongst others places) near the entrance of a branch of the Rhine into the lake, the relation with potential spawning areas upstream was not evident.

2.2.10 The Rhine foodweb

E. Lammens (RIZA)

Integral river management requires knowledge of ecological processes in the main river basin and the connected floodplains. Predicting the consequences of river management for the dynamics of specific species requires more information on the structure and functioning of the food web. Even the most basic information

regarding the spatial and seasonal distribution of food production, how much is utilised and by which organisms, is lacking. As a consequence, effects of bioaccumulation of toxic substances, or carrying capacity for fish and birds cannot be calculated. Therefore a study is proposed to describe the food web structure of the Rhine branches.

The purpose of the study is to quantify the fluxes of production and consumption of the most abundant (groups of) organisms for different habitats, separately and in total, and to develop a model to show the consequences of management measures on these fluxes.

The first step in this study will be to set up a database of ecosystem parameters which are needed for the model as input parameters or for calibration and to choose the most strategic and information-rich locations. In 1998, parameters will be collected for three locations (Lobith, Kampen, Maassluis) parameters are collected and proposals for additional experimental and field work will be formulated, which should yield information needed for the model development. In the first two years, only the food web in the main channel will be studied, while a few strategic locations in the floodplains will be added in the third years. The second year will see the start of the field and experimental work and the preparation for the modelling. The project is being carried out in cooperation with IBN-DLO, KU Nijmegen and Delft Hydraulics.

2.3 Landscape ecology

2.3.1 Geomorphological suitability and draft guidelines for physiotopes

M. Schropp (RIZA)

Various proposals have been made to improve flood protection in the area of the main Dutch rivers. Some of these proposals allow the creation of physical preconditions for a rehabilitation of the riverine ecosystem. The morphological aspects are being studied by the MEANDER project. The first object is to indicate which stretches of the river Meuse and the various Rhine branches would be geomorphologically suitable for the creation of river dunes, levees, side channels, abandoned channels and marshes. For this purpose, the project has involved mapping sandy sedimentation in the floodplains after episodes of high water levels and a study of sand drift in the groyne fields.

In addition to an assessment of the chances of success, the project also aims to use research findings to generate draft guidelines for nature development, taking into account any available knowledge on ecological networks and on the effects of layout on the river's physical characteristics. The project is limited to the study of physiotopes and interventions with a largely morphological emphasis, viz., creating levees, river dunes, side channels, the lowering of floodplain levels and the removal of summer dykes and revetments.

The expertise is being developed on the basis of theoretical considerations, reference studies, models and pilot projects. These concern not only the effects within the actual floodplain, but also the consequences of the layout for the summer bed, including the distribution of the discharge over summer bed and floodplain and the rate of sedimentation in the summer bed.

2.3.2 Suitability for ecotopes examined by developing a classification of river reaches

H.P. Wolfert (SC-DLO)

In integrated water management, formulating policies for physical planning requires tools that indicate the physical suitability for ecotopes. Spatial and temporal variation in suitability was examined by developing a classification of river reaches in the Netherlands, combining ecological, geomorphological and river engineering characteristics.

A high-sinuosity meandering reach of the river IJssel (Westervoort-Zutphen) and a low-sinuosity meandering reach of the river Waal (Nijmegen-Tiel) were studied, representing the upper and middle parts of the Rhine-Meuse delta respectively. Historical maps were used to map ecotopes and physiotopes on a mapping scale of 1 : 25 000. For the river IJssel, the historical characteristics of 1750 and 1840 AD were analysed; for the river Waal, those of 1780 and 1830 AD.

The most important river engineering parameters were calculated for both reaches, for the historical situation of 1800 AD as well as for the present situation; current velocities and water flow diversions were calculated using the 1-dimensional SOBEK model for water movement. The comparison of all data yielded a consistent result. The two river reaches differ with respect to geomorphological processes and migration rates. The differences between the reaches have been reduced by 19th century river regulation.

The ecological characteristics of the river IJssel and Waal have been classified using the river engineering parameters width-depth ratio and Shields parameter, which (1) show a strong causal relationship with the differences in river dynamics and (2) can be changed by means of river management measures. Instead of the Shields parameter, the specific stream power may be used. Based upon this classification, it has been indicated which of the two river reaches is suitable for the development of certain ecotopes. This suitability is illustrated by schematic sketches indicating (1) development preconditions, (2) river reach suitability, (3) most suitable locations and (4) development measures and lay-out.

2.3.3 Side channels and natural riverbanks

J. Simons (RIZA)

Shallow running waters are nowadays scarce elements in Dutch rivers. Shipping optimisation measures and flood protection, interventions have destroyed many of these elements of natural river systems. In recent years several plans for restoring these physiotopes by means of side channels and river bank landscaping have been implemented.

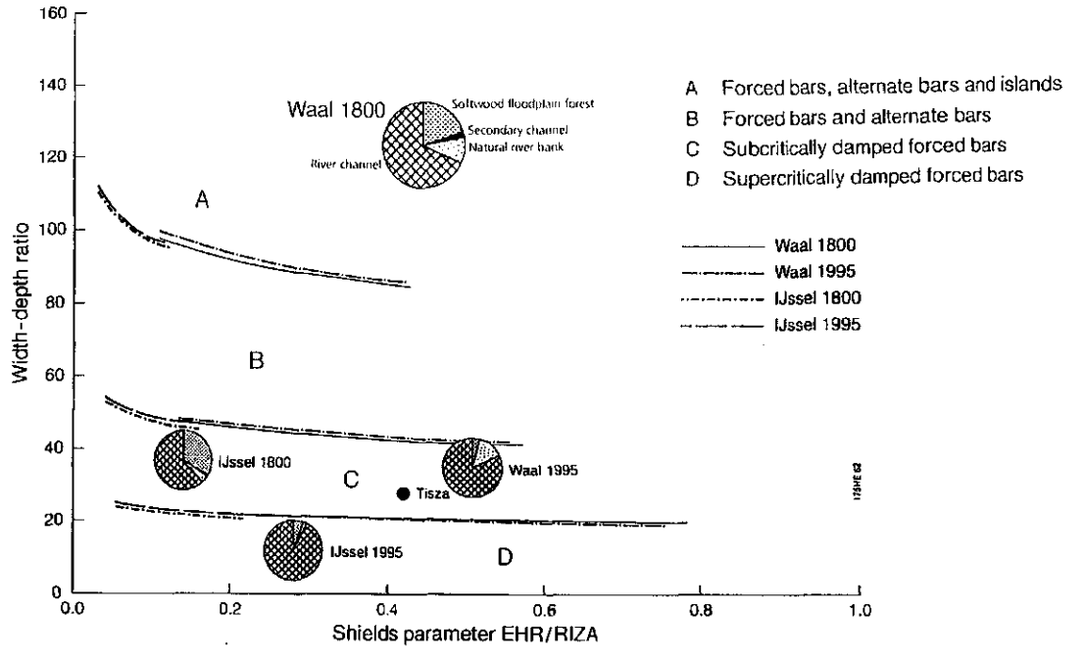

Fig. 5 Classification diagram, indicating morphodynamics of river reaches

Monitoring programmes of these projects indicate that several characteristic species (mainly fish, birds and invertebrates) have been able to invade these newly created habitats within a short period of time. Examples include young rheofilic fish like Barb in side channels and Sand Martin nesting in steep natural river banks. Detecting morphological changes due to river processes will require monitoring over a longer period of time.

2.3.4 Helophytes

H. Coops (RIZA)

The role helophytes can play in shore rehabilitation and shore protection against erosion has been elucidated in a previous study. The present study also resulted in a brochure (Helophytes) and a thesis by H. Coops, and was carried out by RIZA in cooperation with Road and Hydraulics Department (DWW), Delft Hydraulics, RWS Dir. Zuid-Holland, KUN and Bureau Waardenburg. In addition to ecological information on the habitat requirements of different species of helophytes, the interactions with physical aspects of water (e.g. water movement) were studied. Growth and development of helophytes proved to be strongly influenced by flooding and wave attack. Natural vegetation patterns on shore lines are based on differences between the species in their tolerance to flooding and wave attack. On the other hand, the presence of vegetational structures influences stream velocity and wave energy. Rooted soils are less vulnerable to erosion, while above-ground plant material acts as a wave barrier. Results from field, laboratory and wave tank experiments show that helophytes can play an important role in both shore rehabilitation and shore protection along those stretches of rivers which are suitable for helophytes.

2.3.5 Floodplain forest

I. van Splunder (RIZA)

The floodplain forest is one of the characteristic vegetation types in a natural river ecosystem. Because of human interference the floodplain forests along the Dutch rivers have almost completely vanished. Over the last few years, however, action has been taken towards the restoration of a more natural river landscape. The role of floodplain forests in river basin management is somewhat ambiguous. Although floodplain forests play an essential role in the river ecosystem, they also constitute obstacles in the riverbed, resulting in raised water levels. These and other questions concerning the role of floodplain forests within river management have led to the initiation of a large multidisciplinary research project, carried out by RIZA in cooperation with several other institutes (Bureau Stroming, CPRO-DLO, RWS Dir. Oost-Nederland, STL and KUN). The results of this project have been presented in a thesis (by I. van Splunder) and in a brochure entitled 'Foodplain forests'. Factors considered include the establishment of trees on the riverbank, ecological values of floodplain forests, measures to protect banks from erosion, wave attenuation by flooded forests, water level rises due to hydraulic roughness, and nature management.

2.3.6 Ecological network function

R.P.B. Foppen (IBN-DLO)

Landscape ecology uses methods and models to describe the spatial relationships between plants and animals in order to instruct management officers in nature development areas. Landscape elements like hedges, patches of shrub or linear water bodies form part of ecological webs (networks) along which organisms may move or be transported in such a way that sustainable populations can persist. At the moment it is impossible to include all species in the web, but selected target species are used to represent the main ecosysteem structure.

Models and a prototype expert system for management are being evaluated using some terrestrial and aquatic macroinvertebrates, fish, amphibians, birds and a few mammals in the nature development area called 'Zandmaas', along the river Meuse. The expert system being development is called GISRIA and consists of an ARCINFO/VIEW program, for which Department of Landscape Ecology of IBN-DLO has developed an automated procedure.

2.3.7 Ecological evaluation of the river Rhine

C. Bakker (RIZA)

Important information on the present state of ecosystems and evaluation of nature management policies is obtained by large scale monitoring programmes. Within the regular monitoring programme for Dutch waters, each water body is monitored in more detail every four years. In 1995, this was done for the river Rhine. In addition to an analysis of the individual biological parameters (like zooplankton, fish and vegetation), an overall analysis was made in which interactions between biological

parameters and abiotic processes were taken into account and river management is evaluated. The monitoring programme as a whole is carried out by RIZA (section IMM).

Water quality has greatly improved since the early seventies and is no longer a limiting factor for the presence of many species, although certain toxic effects are still being recorded for some aquatic species. Nowadays, habitat diversity is the limiting factor for the presence of many characteristic species, since certain typical ecotopes like floodplain forest, side channels and marshes are in short supply. Nature development measures aim to restore these ecotopes to the river systems. One of the remarkable results of the monitoring programme is the important role of exotic species, as regards both numbers of species and total biomass. One striking example is the mud shrimp (*Corophium curvispinum*). In 1996 the same detailed monitoring programme was carried out for the river Meuse. The data will be analysed and published in 1998.

2.3.8 Ecological network evaluation

N. Geilen (RIZA)

Nature development and river restoration are major topics in river management. It is not only the types and sizes of the natural amenities which determine the ecological potential of nature development along river systems, but also their spatial distribution. As habitat demands differ between species, nature development can be carried out in many ways. Estimating the ecological impact of certain development strategies by means of ecological network functioning (based on the habitat demands of species and the dispersion radius) allows guidelines to be formulated for optimising the implementation of nature development measures. In 1997, IBN-DLO carried out a project to evaluate the ecological network functioning of the Zandmaas, a stretch of the river Meuse. Future studies will eventually cover entire river basin areas.

Another method to evaluate the ecological potential of nature development has been used by Delft Hydraulics in its Environmental Impact Statement (EIS) for the "Zandmaas" project in the same stretch of the river Meuse. The consequences of three strategies for nature development have been evaluated regarding ecotope differentiation (in comparison with the desired situation), habitat suitability and potential for species development. These strategies include corridors (natural riverbanks), stepping-stones (many 'small' areas) and core areas (a few 'large' areas).

Both methods indicate the importance of the implementation of nature development measure and have proved to be useful in the planning and execution of such development measures.

2.3.9 An inventory of monitoring activities for the purpose of setting up an integrated monitoring programme

W.C. Knol (SC-DLO)

Nature development in river floodplains can be stimulated by

recording developments in natural amenities and other land use functions. Information on the monitoring activities of 37 institutes was gathered acquired using a questionnaire. Data on the structure themes and methods of more than 200 projects were stored in a data-base. The programmes' themes have been evaluated regarding their relevance for three aspects of land use, viz., natural amenities, agriculture and outdoor recreation. In addition, it was assessed with themes are not yet being monitored. It was found that present projects on aspects of natural amenities can be incorporated readily into a future monitoring programme, but that they require some expansion to cover the whole of the river system consistently. As regards aspects of agriculture and outdoor recreation, however, new projects will have to be set up. An essential requirement for any new programme is a sound philosophy for integrating all data on the various themes.

3 Future research needs

In 1988, EHR started a research programme with the aim of supporting the formulation and implementation of national and international policies for rehabilitating the rivers Rhine and Meuse. In its first phase, from 1988 to 1991, this programme largely focussed on research supporting policy measures to improve water quality, including risk assesment studies on toxicants, while basic knowledge of the status of different river biota was a secondary goal.

Gradually, the emphasis in policy development has shifted towards integrated management of rivers and floodplains. Therefore, the programme's second phase, from 1992 onwards, emphasised the geomorphological and hydrological conditions for habitat restoration and nature rehabilitation strategies in both rivers. For the years to come, the development of an ecological model integrating the impact of various factors was indicated as an important aim. At the same time, it became clear that there was no consensus among policy makers and researchers what other topics should be addressed. EHR therefore organised three workshops, in which representives of both groups were brought together to discuss future research needs. Each of the Dutch ministries involved hosted one of the workshops.

3.1 Water quality

The first workshop, on water quality, was hosted by the Ministry of Housing, Physical Planning and the Environment, on March 20, 1996, at The Hague. Convenor was Mr. H.W. Kroes of the Directorate-General for Environmental Protection.
Presentations were given by:

- H.W. Kroes: Developments in policy and research needs; the ministry's view;
- D.A. Donkers: Standards development and biodiversity;
- A.J. Hendriks: The rivers Rhine and Meuse are becoming cleaner, but are not yet clean enough.

The process of making choices for physical planning was discussed. Effects of water quality and other potentials for nature rehabilitation are best addressed in an integrated framework. This requires integrated research for specific riverine areas aiming at optimisation techniques. An ecological model, such as that aimed at by EHR, is certainly useful. Its development should start by defining its role in forecasting effects and risks. Policy makers and researchers must cooperate in defining realistic targets for river rehabilitation. It was stressed that the research agenda may deviate from fashionable topics, as it needs to anticipate on new questions in future.

3.2 Sediment quality

The workshop on sediment quality was convened by Mr. M. Ceruti from the Directorate-General for Public Works and Water Management. The workshop was hosted by the Ministery of Transport, Public Works and Water Management at The Hague, on November 26, 1996. Presentations were given by:

- J.E.M. Beurskens: Soil quality and nature; the state of affairs;
- W.H. Musters: Soil management policy;
- A. van der Wekken: The management of aquatic sediments.

As in the previous workshop, an important issue turned out to be the interference of soil management policies with nature rehabilitation aims. Laws on how to handle contaminated soils often prove to hamper the physical planning of new nature conservation areas. Solutions may be offered by research on the effects of contamination on the actual ecosystem, by recording and mapping the spatial variability of contaminated soils, and by developing instruments to compare the ecotoxicological effects of contamination with the ecological benefits of river rehabilitation measures.

3.3 Habitats

The final workshop, on habitats was organised by R. Postma of the Institute for Inland Water Management and Waste Water Treatment. The workshop was held at Wageningen, January 28, 1997 and was hosted by the Informatie- en Kennis Centrum Natuurbeheer.
Presentations were given by:
- M. Dirkson: Research needs of policy makers;
- J. van Baalen: Which types of nature are possible within the constraints of safety?
- A. Littel: Physical planning in riverine areas;
- R. Postma: Knowledge and lack of knowledge.

As regards policies on nature and protection against flooding, it appeared that knowledge was lacking on the role that references for nature rehabilitation should play in river rehabilitation plans, as well as on possibilities for water retention, and on food web relationships. It was stressed that not all questions can be answered at short notice, so that policy makers must try to find creative solutions for the time being, whilst researchers must aim at developing instruments that will be useful for solving future problems. Finally, it was stressed that the implementation of policies on ecological rehabilitation can benefit from contributions from the social sciences.

4 Facts and figures

4.1 Organisation and contributions

Members of EHR participate in two committees, the Steering Committee and the Project Committee. The Steering Committee is responsible for translating policy topics into general research items.

In 1996/97, the Steering Committee consisted of:
- Ir. A.H.M. Bresser, RIVM;
- Dr. J. van Baalen, Ministry of Agriculture, Nature Management and Fisheries;
- T. van der Wekken, Ministry of Transport, Public Works and Water Management;
- Dr. P. Hagel, RIVO-DLO;
- Dr. H.W. Kroes, Ministry of Housing, Physical Planning and the Environment;
- Dr. P. Leeuwangh, SC-DLO;
- Drs. E.C.L. Marteijn, RIZA;
- Drs. R.A. Bulthuis, RIZA.

The Project Committee is responsible for planning and programming the research topics, and for organising national and international workshops and symposia. It is also responsible for publishing the series of papers entitled Publications and Reports on the Project 'Ecological Rehabilitation of the Rivers Rhine and Meuse'. G. van Dijk left the Project Committee in 1996, while R. Postma and K. Beurskens resigned in 1997.

The P.C. currently constists of
- Drs. E.C.L. Marteijn (president), RIZA;
- Dr.ir. A.J. Hendriks, RIZA;
- Drs. N. Geilen, RIZA;
- Drs. W. Ligtvoet, RIVM;
- Drs. H. Pieters, RIVO-DLO;
- Dr. L.W.G. Higler;
- Drs. H.P. Wolfert.

Adresses are given in Annexe 1. EHR reports are listed in Annexe 2.

4.2 Publications

4.2.1 Ecotoxicology

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Hendriks, A.J. and C. van de Guchte, 1997. Optimal modelling and monitoring in ecotoxicological assessments: choosing instruments for management and applied research with examples from the Rhine-Meuse delta Environment Toxicology and Water Quality 12: 321-333.

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Annex 1 Addresses

E.C.L. Marteijn (president) (RIZA), P.O. Box 9072, 6800 ED Arnhem, phone 31(026)3688579, fax 31(026)3688678

A.J. Hendriks (RIZA), P.O. Box 17, 8200, AA Lelystad, phone 31(320)298529, fax 31(320)249218

N. Geilen (RIZA), P.O. Box 9072, 6800 ED Arnhem, phone 31(26)3688547, fax 31(26)3688678

W. Ligtvoet (RIVM), P.O. Box 1, 3720 BA Bilthoven, phone 31(30)2749111, fax 31(30)2742971

H. Pieters (RIVO-DLO), P.O. Box 68, 1970 AB IJmuiden, phone 31(255)564733, fax 31(255)564644

L.W.G. Higler (IBN-DLO), P.O. Box 23, 6700 AA Wageningen, phone 31(317)478753, fax: 31(317)424988

H.P. Wolfert (SC-DLO), P.O. Box 125, 6700 AC Wageningen, phone 31(317)474398, fax 31(317)424812

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Aanvragen/requests:
(RIZA): Institute for Inland Water Management and Waste Water Treatment, P.O. Box 17, 8200 AA Lelystad, The Netherlands.
(RIVM): National Institute for Public Health and Environmental Protection, P.O. Box 1, 3720 BA Bilthoven, The Netherlands.
(RIVO-DLO): Netherlands Institute for Fishery Investigations, P.O. Box 68, 1970 AB IJmuiden, The Netherlands.
(IBN-DLO): Institute for Forestry and Nature Research, P.O. Box 23, 6700 AA Wageningen, The Netherlands.
(SC-DLO): The Winand Staring Centre for Integrated Land, Soil and Water Research, P.O. Box 125, 6700 AC Wageningen, The Netherlands.