RHINE-ECONET

ECOLOGICAL NETWORKS IN RIVER REHABILITATION SCENARIOS: A CASE STUDY FOR THE LOWER RHINE
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  - Institute for Inland Water Management and Waste Water Treatment (RIZA)
- on behalf of the Ministry of Housing, Physical Planning and Environment:
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ABSTRACT


The significance of an ecological network of nature areas for a successful nature conservation and rehabilitation strategy of the Lower Rhine between Gorinchem (The Netherlands) and Duisburg (Germany) is indicated. A scenario approach is used to illuminate variations in the planning of 10,000 ha of new nature areas, focused on riverine forest, macrophyte marsh and side channels (LEDESS model). Each scenario is evaluated by determining the network function for nine characteristic fauna species. For Beaver, Black Kite, Black Stork, Night Heron, White-tailed Eagle and Barbel this is based on expert judgement (LARCH model), for Middle Spotted Woodpecker, Great Reed Warbler and Bittern on modelling spatial population dynamics (METAPHOR model). The results can serve as a conceptual framework for decisions about the ecological future of the Lower Rhine and probably also for other European rivers.

Keywords: ecological network, scenario approach, physiotopes, modelling vegetation development, fauna species, modelling spatial population dynamics, nature rehabilitation, nature management, river system, Lower Rhine.

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PREFACE

This study has been carried out by the DLO-Institute of Forestry and Nature Research (IBN-DLO), the DLO Winand Staring Center for Integrated Land, Soil and Water Research (SC-DLO) and VISTA, bureau for environmental planning, landscape architecture & ecology, in commission by the Research Institute for Inland Water Management and Waste Water Treatment (RIZA, project attendant E.C.L. Marteijn) and the Ministry of Agriculture, Nature Management and Fisheries, The Netherlands (project attendant J. van Baalen).

SC-DLO has been responsible for the landscape analysis (Chapter 2), the exploration and elaboration of the scenarios (Chapter 3) and the modelling of the vegetation development (sections 4.2 and 5.2). The exploration and elaboration of the scenarios has been carried out by VISTA consultancy. IBN-DLO has been taken care of the modelling of the habitat suitability, carrying capacity and the spatial population dynamics of the target species (sections 4.3, 4.4, 5.3, 5.4, 5.5 and 5.6). Owing to their expertise, IBN-DLO and SC-DLO each has been contributing to the conclusions of the study (Chapters 6 and 7).

The project has been coordinated by R. Reijnen (IBN-DLO, Department of Landscape Ecology) with assistance of W.B. Harms (SC-DLO, Department of Landscape Ecology). For SC-DLO contributions to the project has been made made by G.J. Maas (mapping physiotopes), H.P. Woltfert (landscape analysis and development), W.B. Harms (modelling vegetation development) and O. Roosenschoon (GIS) and for IBN-DLO by R.P.B. Foppen and R.Reijnen (modelling and results fauna), A.G.M. Schotman (modelling and results Middle Spotted Woodpecker), P.J.M. Bergers (habitat suitability Barbel), H.A.M. Meeuwsen (GIS-modelling fauna) and M. de Jong (GIS-modelling fauna and preparation of fauna maps). For VISTA consultancy S.J.M. Jansen and R. de Visser have been contributing to the project.

For the German part of the study area information on the flooding duration has been provided by the ‘Wasser- und Schiffahrtsamt in Duisburg, and information on the present vegetation by the ‘Landesanstalt für Ökologie, Bodenordnung und Forsten, Nordrhein-Westfalen (J.Rijpert).

The study has been advised by an Advisory Board which arranged seven meetings to discuss the progress reports and the penultimate version of this report. The Board consisted of E.C.L. Marteijn (chairman), M. Cals and R. Postma (RIZA), J. van Baalen and P. van de Reest (Ministry of Agriculture, Nature Management and Fisheries, The Netherlands), J. Rijpert (LÖBF, Landesanstalt für Ökologie, Bodenordnung und Forsten, Nordrhein-Westfalen) and G. Friedrich (LWA, Landesamt für Wasser und Abfall, Nordrhein-Westfalen).


P.M. Knaapen (Language Services) made corrections in the English text and translated the summary into German.
SUMMARY

The study aims at (1) clarifying the importance of an ecological network of nature areas for a successful nature conservation and rehabilitation strategy of the Lower Rhine and (2) elaborating scenario approaches which can be applied in future studies. This is carried out by comparing the network function for selected fauna species of different nature rehabilitation strategies using the same amount of nature expansion. Due to the methodological character of the study, the results cannot be used as a basis for developing concrete plans.

As study area, part of the Lower River Rhine system between Duisburg (Germany) and Gorinchem (The Netherlands) is chosen. It mainly comprises the River Waal and the River Rhine up to Arnhem. The study is focussed on riverine forests, macrophyte marshes and side channels, of which the present area is very small and the pattern strongly fragmented. To evaluate the network function of these habitat types the following target species have been selected: Beaver, Black Kite, Black Stork, Night Heron, White-tailed Eagle, Barbel, Middle Spotted Woodpecker, Great Reed Warbler and Bittern. Most of these species are very rare or absent at the moment.

Based on an analysis of the landscape ecological system of the River Rhine and general suitability for nature rehabilitation, river dynamics has been chosen as the leading concept for elaborating three scenarios. For the amount of new nature area 10,000 ha is taken (30% of the winterbed area), which is in line with the current policy aims. In each scenario nature areas are evenly distributed over the study area. The Rhine-Traditional scenario creates small forests and macrophyte marshes (± 100 ha) in the winterbed by pattern management, the Loire-River dynamics scenario medium sized forest-marsh-water (side channel) complexes (250-500 ha) in the winterbed by giving river processes more space, and the Mississippi-Spillway scenario mainly large-scale marshes outside the winterbed (1000-2000 ha) managed in a natural way, combined with some small forests in the winterbed.

To evaluate the network function of the target species for the three scenarios a modelling procedure is used, which consist of the following steps: (1) modelling vegetation development by using expert knowledge (LEDESS approach); (2) modelling habitat suitability and carrying capacity based on the expected vegetation development (expert knowledge); (3) modelling spatial population dynamics by using expert knowledge (LARCH approach, 6 species) or simulation models for spatially structured populations (METAPHOR approach, 3 species) in order to determine the following network parameters: population viability, population saturation (only METAPHOR approach) and stepping stone function.

Taking into account the size and shape of the study area and habitat available in the surroundings, 10,000 ha of new nature probably only can result in viable network populations for Beaver, Middle Spotted Woodpecker and Great Reed Warbler. One species, the Bittern has already a viable population in the present situation. In all species the amount of habitat in the surroundings of the study area largely determines the population viability.

Differences in the distribution patterns of new nature have great effects on the population saturation. Compared with the other distribution patterns, the best distribution pattern needs 40% less habitat (all three species) to achieve a similar population size. However, there is not one favourable pattern.
For Beaver and Bittern the stepping stone function can become optimal, which means that they are able to expand to all parts of the study area. On the other hand, Middle Spotted Woodpecker and Great Reed Warbler do not expand into the Dutch (western) part and German (eastern) part, respectively. Here, the amount of habitat in the surroundings of the study area seems very important: adjacent to the Dutch part there is almost no hardwood forest and to the German part no macrophyte marsh.

The results clearly show the importance of linking nature areas into a network system. They strongly support the present attention in nature policy for ecological networks as an important condition for a successful nature rehabilitation in the Lower Rhine area and probably also in other riverine areas. It should be emphasized that the network function also has to be considered in developing nature rehabilitation plans. For this the method presented in the Rhine-Econet study is a successful tool.
ZUSAMMENFASSUNG


Um die Vernetzungsfunktion für die Leitarten in den drei Szenarien zu ermitteln, wird ein Modellierungsverfahren eingesetzt, das folgende Schritte umfaßt: (1) Modellierung der Vegetationsentwicklung auf Basis eines Experten-systems (LEDESS-Ansatz); (2) Modellierung der Habitateignung und des Ansiedlungspotentials auf Basis der zu erwartenden Vegetationsentwicklung; (3) Modellierung der räumlichen Populationsentwicklung auf der Grundlage eines Experten-systems (LARCH-Ansatz, 6 Arten) oder Simulationsmodellen für räumlich strukturierte Populationen (METAPHOR-Ansatz, 3 Arten). Folgende Vernetzungsparameter werden bestimmt: Überlebungsähigkeit, Populationssättigung (nur METAPHOR-Ansatz) und die Trittsteinfunktion.

Wenn Größe und Form des Untersuchungsraumes sowie die im Umfeld vorhandene Habitat berücksichtigt werden, könnten mit 10.000 ha neue Naturgebiete nur für Biber, Mittelspecht und Drosselrohrsänger, überlebensfähigen vernetzten Populationen sichergestellt werden. Die Rohrdommel besitzt bereits heute eine überlebensfähige Population. Bei allen Arten bestimmt die Habitatmenge im Umfeld des Untersuchungsgebietes in hohem Maße die Überlebenschance der Population.
Die Unterschiede im Verteilungsmuster der neuen Naturgebiete üben einen erheblichen Einfluß auf die Populationssättigung aus. Für alle drei dieser Arten sind bei dem am besten geeigneten Verteilungsmustern der neuen Naturgebiete 40% weniger Habitatflächen erforderlich um die gleiche Populationsgröße zu erreichen wie bei den beiden anderen Verteilungsmustern.

Für Biber und Rohrdommel kann die Trittsteinfunktion optimal werden, dies bedeutet, daß diese Arten sich über alle Teile des Untersuchungsraumes ausbreiten könnten. Andererseits können sich Mittelspecht und Drosselrohrsänger nicht im niederländischen (westlichen) bzw. im deutschen (östlichen) Teil ausbreiten. Dies liegt vor allem an der Verteilung der Habitate im Umfeld des Untersuchungsgebietes: im niederländischen Teil fehlen im Umfeld die Hartholzwälder, im deutschen Teil die Sumpfgebiete.

Die Ergebnisse zeigen deutlich die Bedeutung, die einem vernetzten System von Naturgebieten zukommt. Sie fördern damit das heutige Interesse der Naturschutzpolitik an solchen Systemen und bilden zugleich eine wichtige Voraussetzung für eine erfolgreiche Naturentwicklung im unteren Niederrheingebiet und wahrscheinlich auch in andere Flußsystemen.

SAMENVATTING

Doel van de studie is (1) om het belang aan te geven van een ecologische netwerk van natuurgebieden voor een succesvolle natuurbeheers- en ontwikkelingsstrategie voor het Beneden-Rijngebied en (2) om een aantal scenario’s te ontwikkelen als basis voor toekomstige inrichtingsstudies.

Hiertoe is de netwerkfunctie van een aantal geselecteerde faunasoorten vergeleken voor verschillende natuurontwikkelingsstrategieën. Bij het ontwikkelen van de scenario’s werd dezelfde hoeveelheid ‘nieuwe natuur’ gehanteerd. Door het methodologische karakter van de studie kunnen de resultaten niet rechtstreeks gebruikt worden voor het ontwikkelen van concrete plannen.


Gebaseerd op een landschapecologische analyse van de Beneden-Rijn en de natuurontwikkelingspotenties in het studiegebied is de rivierdynamiek gekozen als het leidende concept voor de ontwikkeling van drie scenario’s. In overeenstemming met het huidige natuurbeleid is uitgegaan van 10.000 ha nieuwe natuur (30% van het winterbed). In ieder scenario werden de natuurgebieden evenwichtig verdeeld over het studiegebied. Binnen het Rijn-Traditioneel scenario levert patroonbeheer kleine bossen en moerassen op in het winterbed (± 100 ha), in het Loire-Rivierdynamiek scenario krijgen rivierprocessen deels vrij spel en dit levert redelijk grote bos-moeras-nevengeul complexen op in het winterbed (± 250-500 ha). In het Mississippi-Overlaat scenario wordt uitgegaan van natuurlijk beheerde overlaten buiten het winterbed en dit levert grote moerassen op (±1000-2000 ha) en tevens enkele kleine bosgebieden in het winterbed.

Om de netwerkfunctie voor de doelsoorten te evalueren in de drie scenario’s is een modelleringsprocedure ontwikkeld die bestaat uit de volgende stappen: (1) het modelleren van de vegetatieontwikkeling door het gebruik van een kennisysteem (LEDESS aanpak); (2) het modelleren van habitatgeschiktheid en de draagkracht gebaseerd op de vegetatieontwikkeling; (3) het modelleren van de ruimtelijke populatiedynamiek door het gebruik van een kennisysteem (LARCH aanpak, 6 soorten) of simulatiemodellen voor ruimtelijk gestructureerde populaties (METAPHOR aanpak, 3 soorten). De volgende netwerkparameters werden bepaald: de duurzaamheid van de populatie, de populatieverzadiging (alleen met METAPHOR aanpak) en de stepping stone-functie.

Als rekening wordt gehouden met de vorm en grootte van het studiegebied en de hoeveelheid habitat in de omgeving dan levert 10.000 ha nieuwe natuur alleen duurzame netwerkpopulaties op voor de Bever, Middelste Bonte Specht en Grote Karekiet. Eén soort, de Roerdomp, heeft al een duurzame populatie in de huidige situatie. Bij alle soorten bepaald de hoeveelheid habitat in de omgeving van het studiegebied in hoge mate de duurzaamheid van de populatie.
Verschillen in het verdelingspatroon van nieuwe natuurgebieden hebben een groot effect op de populatieverzadiging (alleen bepaald voor METAPHOR-soorten). Vergelijken met de andere patronen is er bij het beste verdelingspatroon voor alle drie de soorten 40% minder habitat benodigd om dezelfde populatiegrootte te bereiken. De optimale verdelingspatronen zijn echter verschillend voor de soorten. Voor de Bever en de Roerdomp kan de stepping stonefunctie optimaal worden, wat betekent dat de soorten zich tot iedere hoek van het studiegebied kunnen uitbreiden. De Middelste Bonte Specht en de Grote Karekiet kunnen zich daarentegen niet tot respectievelijk het Nederlandse (westelijke) deel en het Duitse (oostelijke) deel uitbreiden. Dat wordt vooral bepaald door de verdeling van het habitat in de omgeving van het studiegebied: om het Nederlandse deel van het studiegebied heen bevindt zich bijna geen hardhoutbos en om het Duitse deel geen (riet)moeras.

De resultaten tonen duidelijk het belang aan van een systeem van natuurgebieden gekoppeld in een netwerk. Ze steunen dan ook de huidige aandacht van het natuurbeleid voor ecologische netwerken en vormen een belangrijke voorwaarde voor een succesvolle natuurontwikkeling in het Beneden-Rijngebied en waarschijnlijk ook in andere riviergebieden. De netwerkfunctie moet nadrukkelijk worden meegenomen bij het ontwikkelen van natuurontwikkelingsplannen en hiervoor is de binnen de Rhine-Econet studie ontwikkelde methode een geschikt instrument.
1 INTRODUCTION
1.1 SCOPE

One of the aims of the Ecological Master Plan for the River Rhine (International Commission for Protection of the Rhine against pollution (1992) is "the protection, preservation and improvement of ecologically important areas". Among several actions to improve the conditions of habitats for plant and animal species (mostly protection measures), plans are mentioned for the rehabilitation of river floodplains along reaches of the Upper and Lower Rhine. At a higher scale level, this will increase the importance of the Rhine Valley as part of a future European Ecological Network (EECONET), which has been proposed as a solution for the increasing impact of landscape fragmentation at the recent conference "Conserving Europe's Natural Heritage, towards an European Ecological Network" at Maastricht (Bennett 1994).

Improving existing habitats or creating new habitats, however, does not necessarily mean that species will settle or survive. Due to local abiotic conditions, management strategies or practical restrictions, the size of the habitat units might be too small to support a viable population. This is especially to be expected for medium and large sized birds and mammals, which have large area demands, and probably also for fish species. Probably, these species only will persist when habitat units are linked into a network system, which might be locally unstable, but sustainable at the level of the network (Opdam et al. 1993, 1995; Verboom et al. 1993). The dispersal capacity of species largely determines the maximum distance at which habitat units can be linked.

Another aspect is the permeability of the Rhine Valley for expanding species. When species are only present in a part of the river or are absent, it is important that new habitats create a network that enables them to expand. This can be defined as the stepping stone function of a network.

So, the success of local plans for nature rehabilitation has also to be assessed in the context of the ecological complexity and connectivity at larger spatial scales. Also, the increase of the biodiversity of existing (semi-)natural areas is dependent on the size and the location of nature rehabilitation areas. In other words, local plans will be more significant if they are part of a plan for the whole Rhine Valley. However, there are many alternatives for the ecological future of the Rhine Valley. Decisions for a common nature conservation and rehabilitation strategy are made easier if supported by comprehensive information on the perspectives of the various alternatives. This information should integrate both the local potentials and the impact of the spatial arrangement of the nature areas.

1.2 OBJECTIVE AND GENERAL APPROACH

The main objectives of the study are:
1. to clarify the importance of an ecological network of nature areas for a successful nature conservation and rehabilitation strategy of the Rhine Valley;
2. to elaborate scenario approaches which can be applied in future studies on river rehabilitation.

This will be carried out by comparing the network function for selected fauna species of different spatial strategies for nature rehabilitation involving the same amount of nature-area expansion.
The study does not have the intention to develop concrete plans for nature rehabilitation but it aims at demonstrating that the method serves as a conceptual framework for decisions about the ecological future of the Rhine Valley.

1.3 PRINCIPAL CHOICES

1.3.1 Study area

For practical reasons the lower part of the River Rhine system has been selected for this study. Relevant knowledge on this part of the system was available from previous scenario studies on nature rehabilitation (Harms et al. 1994; Knol et al. 1994). The study includes the River Rhine from Duisburg to Driel and the River Waal downstream to Gorinchem (figure 1.1), thus excluding the urban river reaches in the ‘Ruhrgebiet’ and the downstream river reaches with strong tidal influences and barrages, and the River IJssel. Although, the River Meuse does not belong to the River Rhine system, a small part close to the river Waal for which a river rehabilitation project has was recently prepared, has been incorporated.

Laterally, the study area is restricted to the present floodplains, which enclose the area between the winter dikes (figure 1.2). An exception has been made for the ‘Rijnstrangen’ area, which is located outside the winter dikes but partly subjected to river dynamics. In developing one alternative for river rehabilitation, adjacent embanked areas within approximately 5 km distance from the winter dikes, have also been incorporated.

Fig. 1.1. Location of the study area in the drainage basin of the River Rhine, and the annual discharge at Lobith.
Mean discharge of the River Rhine in the centre of the study area is 2200 m$^3$/s, being the run-off from a drainage basin of approximately 225,000 km$^2$. Fed by rainwater in wintertime and melt water in spring the annual river discharge is bimodal (figure 1.1). The maximum discharge measured during the 20th century is 12,600 m$^3$/s. Flooding is restricted to the area between the winterdikes. Large parts of the floodplains are used for grazing; to protect the grasslands from flooding in spring, low summer dikes have been constructed on many locations (figure 1.2).

1.3.2 Habitat types and target species

The study is focused on floodplain (riverine) forests, macrophyte marshes and side channels. Nature rehabilitation plans focus on restoration of these habitat types, since at present the area is very small and the pattern strongly fragmented. Habitat sites in the surroundings of the study area which constitute similar conditions for the selected species are also considered, because they can be linked to the habitat network within the study area. These areas, however, are not varied in the scenario approach. To demonstrate the network approach, vertebrate animal species are selected which are characteristic for one or a combination of habitat types. It was aimed at selecting one fish species for the aquatic component of side channels. Species which are not present in the study area are not excluded, because they might return after nature rehabilitation plans have been carried out. The selection was based mainly on the following criteria:

1. available knowledge is sufficient to determine habitat suitability and carrying capacity, and to predict (simulation model) or estimate (expert judgement) the survival chance of spatially structured populations;
2. dispersal capacity is sufficient to maintain networks at the scale of the study area, and local habitat sites are almost always too small to support viable populations;
3. when possible, species which are characteristic for the same habitat type should have different area demands;
4. species mentioned in national policy plans and in 'red lists' are preferred.
Table 1.1 shows the results of the selection. For the aquatic component of side channels the Barbel appeared to be the best choice, but the available knowledge will only be sufficient to indicate areas which have suitable spawning grounds. Nowadays the species is rarely found in the Rhine between Duisburg and Gorinchem. Of the other eight species, of which seven are birds, only Great Reed Warbler and Bittern have regular occupied patches in the Dutch part of the study area. Night Heron occurs very rarely and irregularly in the Dutch part and Middle Spotted Woodpecker in the German part, while Black Stork and White-tailed Eagle are completely absent at the moment. The Beaver, the only mammal species, was recently introduced in the centre of the study area.

So, it can be expected that rehabilitation of natural areas may greatly improve the conditions for the species selected. For Great Reed Warbler, Bittern and Middle Spotted Woodpecker this can be translated into an estimate for the (potential) persistence in the study area by using spatial population models, for the other species (except Barbel) by using expert knowledge.

Table 1.1. Target species, habitat types and available knowledge to estimate the survival chance of populations.

<table>
<thead>
<tr>
<th>Species²</th>
<th>Riverine forest</th>
<th>Macrophyte marshland</th>
<th>Side channel</th>
<th>Riverine landscape¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beaver</td>
<td><em>Castor fiber</em></td>
<td><em>Acrocephalus arundinaceus</em></td>
<td><em>Barbus barbus</em></td>
<td><em>Haliaeetus albicilla</em></td>
</tr>
<tr>
<td>Middle Spotted Woodpecker</td>
<td><em>Dendrocopus medius</em></td>
<td><em>Botaurus stellaris</em></td>
<td>(X)</td>
<td>X</td>
</tr>
<tr>
<td>Black Kite</td>
<td><em>Milvus migrans</em></td>
<td><em>Nycticorax nycticorax</em></td>
<td>(X)</td>
<td>X</td>
</tr>
<tr>
<td>Black Stork</td>
<td><em>Ciconia niger</em></td>
<td>(X)</td>
<td>(X)</td>
<td>X</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species²</th>
<th>Estimation of survival chance of spatially structured populations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expert knowledge</td>
<td>Simulation model</td>
</tr>
<tr>
<td>Beaver</td>
<td>X</td>
</tr>
<tr>
<td>Middle Spotted Woodpecker</td>
<td>X</td>
</tr>
<tr>
<td>Black Kite</td>
<td>X</td>
</tr>
<tr>
<td>Black Stork</td>
<td>X</td>
</tr>
<tr>
<td>Great Reed Warbler</td>
<td>X</td>
</tr>
<tr>
<td>Bittern</td>
<td>X</td>
</tr>
<tr>
<td>Night Heron</td>
<td>X</td>
</tr>
<tr>
<td>Barbel</td>
<td></td>
</tr>
<tr>
<td>White-tailed Eagle</td>
<td>X</td>
</tr>
</tbody>
</table>

¹combination of all habitat types
²see Appendix 1 for German and Dutch names

1.3.3 Scenario approach

Scenario studies can be considered as information tools for policy makers who must cope with future uncertainties (Schoute *et al.* 1994). As the future of nature is uncertain, as are specific opportunities for nature restoration offered by social-economic or physical developments, scenario studies can help to determine an optimal nature policy.
Schoonenboom (1995) has introduced two types of scenarios: the projective or forecasting and the prospective or backcasting scenarios. Forecasting scenarios project present-day trends or expectations onto the domain of the probable future. In scenarios of this type mainly one variable is expected to vary in the future. As dose-effect relations play an important role, these scenarios can also be appointed as dose-effect scenarios.

Other scenarios design possible alternatives and confront them with the present situation in order to determine the most desirable alternative. This backcasting procedure prevails in physical planning. In this sort of approach scenarios are not determined by differences in a single factor. A complex of variables interrelated spatially is involved in the design of the prospective scenario alternatives. Whereas an analytical approach prevails in the projective scenario, a more holistic approach predominates in the prospective scenario.

This study belongs to that latter category: the backcasting scenarios. However, unlike a real planning procedure in which scenarios are used to delineate possible alternatives in order to choose the best one to be executed, in this study scenarios should be understood as tools illuminating differences in the network approach in planning new nature areas. So, the scenarios developed in this study are focused only on this objective of the study, i.e. to clarify the importance of an ecological network of nature areas for a successful nature conservation and rehabilitation strategy of the Rhine Valley. In this sense the scenario approach presented here is much more confined, restricted to this objective than usual in physical planning.

The scenario approach follows the planning cycle procedure (Harms, et al. 1993). Two stages are distinguished (figure 1.3):
- plan design: the exploration and elaboration of different scenarios;
- plan evaluation: the assessment of the scenarios.

In the design stage, based on a landscape ecological analysis, knowledge at the ecosystem or landscape level contributes to a creative solution of the problem. Concrete information about suitability for nature rehabilitation (building blocks) and spatial concepts related to different ecological objectives predominate in this stage.

In the plan evaluation, the scenarios are checked and assessed: is the alternative feasible and what are the ecological benefits of each plan? This means a validation of the scenarios at the species level, the target species. In this stage, models are introduced as tools to predict as accurately as possible the impacts of the proposed future situations and to compare them with the present situation. Since the stages are not completed consecutively but may alternate cyclically in the planning process the results of the evaluation are put into in a new planning cycle in order to adjust the scenarios and to re-evaluate them. Ultimately, a more comprehensive plan can be developed. In this study the scenario approach will be restricted to one planning cycle and three scenarios.

1.4 OUTLINE OF THE STUDY STRUCTURE AND PROCESS

The outline of the study structure and process is shown in figure 1.4 and explained below. The numbers between parentheses correspond to the chapters and paragraphs in this report.
LANDSCAPE ECOLOGICAL SYSTEMS ANALYSIS (2)
The analysis describes the development and present situation of drainage basin zones, river reaches and physiotopes within the study area. The present distribution of the vegetation is only considered when relevant for the target species. It provides a basis for the exploration and elaboration of the scenarios and determines the abiotic site conditions for vegetation development.

EXPLORATION AND ELABORATION OF SCENARIOS (3)
Scenarios are used to illuminate differences in the network approach in planning 10,000 ha of new nature areas. Based on the natural reference and general suitability for nature rehabilitation, river dynamics have been chosen as the leading concept to explore the scenarios. Three scenarios are distinguished which differ in river dynamics and their management. The elaboration has been carried out in terms of nature target types according to the aims of the scenarios.

MODELLING NATURE REHABILITATION (4)
To evaluate the scenarios the following modelling procedure has been used:
1. Modelling vegetation development by (a) distinguishing measurements in order to obtain the abiotic site conditions required for the nature target types and (b) determining the relationships between abiotic site conditions (physiotopes), management and vegetation types for each nature target type (LEDESS approach).
2. Modelling habitat suitability and carrying capacity of the selected fauna species based on the pattern of expected vegetation types.
3. Modelling the effect of spatial population dynamics to determine the network function for species by using expert knowledge (LARCH approach) or simulation models for spatially structured populations (METAPHOR approach).
RESULTS (5)
The expected pattern of physiotopes and vegetation types determined by the LEDESS approach is described and compared with the present situation. The consequences for the network function of the target species are shown and the influence of area of relevant habitat types and distribution strategy of new nature is discussed. Conclusions are made on the network function of the habitat types.

CONCLUDING REMARKS ON THE METHODOLOGY (6)
The method is discussed with respect to weak and strong points and recommendations are made for improvement. Attention is paid to the selection of target species, scenario approach, modelling vegetation development (LEDESS approach), modelling habitat suitability and carrying capacity, and modelling spatial population dynamics (LARCH/METAPHOR approach.

CONCLUDING REMARKS ON RIVER REHABILITATION (7) IETS MEER AANSLUITEN? It is emphasized that when drawing conclusions from the results, the scope of the study should be considered. Three items are discussed: the importance of the network approach, application of the methodology in other rivers, and extrapolation of the results to other scenarios. Then, based on the results of the study, some remarks are made with respect to river rehabilitation policies and ecological networks.

<table>
<thead>
<tr>
<th>RHINE-ECONET</th>
<th>LANDSCAPE ECOLOGICAL SYSTEMS ANALYSIS (2)</th>
<th>SCENARIOS (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MODELLING NATURE DEVELOPMENT (4)</td>
<td>exploration elaboration</td>
<td>RESULTS (5)</td>
</tr>
<tr>
<td>vegetation</td>
<td></td>
<td>vegetation types</td>
</tr>
<tr>
<td>habitat and carrying capacity</td>
<td></td>
<td>network function species</td>
</tr>
<tr>
<td>spatial population dynamics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EVALUATION OF METHOD (6)</td>
<td>EVALUATION OF RESULTS (7)</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1.4. Outline of the Rhine-Econet study structure and process. Corresponding chapters and paragraphs are indicated in parentheses.
2 LANDSCAPE ECOLOGICAL SYSTEMS ANALYSIS

<table>
<thead>
<tr>
<th>RHINE-ECONET</th>
</tr>
</thead>
<tbody>
<tr>
<td>LANDSCAPE ECOLOGICAL SYSTEMS ANALYSIS (2)</td>
</tr>
<tr>
<td>MODELLING NATURE REHABILITATION (4)</td>
</tr>
<tr>
<td>EVALUATION OF METHOD (6)</td>
</tr>
</tbody>
</table>
2.1 INTRODUCTION

In this chapter the results of the analysis of the landscape ecological systems along the River Rhine are presented. The analysis was aimed at providing a basis for the exploration of scenarios for nature rehabilitation as well as for modelling future situations of these systems.

The analysis has been performed on the three hierarchical levels that are relevant for assessing potentials for future nature rehabilitation at the scale of this study: the levels of drainage basin zones, river reaches and river ecotopes (Rademakers & Wolfert 1994). Each of these levels is characterized by a specific set of elements and processes associated with a specific spatio-temporal domain. A distinction can be made between the characteristics of the drainage basin zones, which are mainly the result of natural processes during the Holocene, and the characteristics of the river reaches and river ecotopes, whose developments are strongly influenced by historic and present-day activities of mankind.

At the level of river ecotopes, physiotopes and vegetation are considered to be the central subsystems of the landscape ecological systems. Developments in species communities depend heavily on the ecotope vegetation, which determines the suitability for breeding, foraging and refuge. Similarly, developments in vegetation depend heavily on morphodynamics and hydrodynamics, which are clearly related to the spatial abiotic units named floodplain physiotopes (Knaapen & Rademakers 1990; Wolfert 1992; Harms et al. 1994).

In the next sections a description will be given of the development and present situation of drainage basin zones, river reaches and physiotopes within the study area, followed by an analysis of the present distribution of the vegetation relevant to the target species selected. Information on the distribution of vegetation in the past will be discussed in chapter 3.

2.2 DRAINAGE BASIN ZONES

The physiographic characteristics of the drainage basin zones within the study area are depicted in figure 2.1, which has been compiled from available information on geology, geomorphology and soils, published in various thematic maps of the study area (see Appendix 2). The investigated part of the River Rhine system is situated between the uplands in Germany and the North Sea, and is part of a continental gradient that is controlled by variables such as tectonics, climate and associated sea level rise. Two drainage basin zones can be clearly distinguished: the transport zone and the depositional zone.

TRANSPORT ZONE

The German part of the river system can be classified as transport zone: it is characterized by Holocene fluvial terraces, situated between glacial, aeolian and fluvial landscapes of older, Pleistocene age. The terrace sequence indicates degradation associated with incision by a meandering river: younger terraces are lower in elevation and narrower compared with older ones. In downstream direction the alluvial area broadens considerably, associated with a steady increase in thickness of Holocene fluvial deposits. The terrace intersection point, where the transport zone of the river systems ends, is situated near the ice-pushed ridges of Montferland and Kleve, an area also known as Gelderse Poort (Gateway to Gueldern). The terraces consist of fluvial gravels and sands, mostly covered by a thin layer of sandy silts. In abandoned
meanders, clayey silts are deposited. If situated close to a pronounced terrace escarpment or ice-pushed ridges, groundwater seepage locally caused the formation of peat.

DEPOSITIONAL ZONE
Downstream from the terrace intersection point, the river system can be classified as depositional zone. In this depositional zone aggradation by sedimentation dominated throughout the Holocene: the Pleistocene gravels and sands are covered by thick Holocene deposits. The alluvial area, also called the Rhine delta, is characterized by a number of meander belts interspaced with large flood basins. The sediments were deposited by meandering or low-sinuosity distributaries of the Rhine, that changed their course repeatedly. The deposition of sediments resulted in a decreasing size of the natural levees in the downstream direction associated with an increasing size of the flood basins. The natural levees consist of silty clays. In the flood basins heavy clays are found, often alternating with layers of peat. In the western part of the fluvial area, where deposition was strongly influenced by raising groundwater tables during the Holocene, peat dominates the sedimentary sequence within the flood basins.

Fig. 2.1. Physiography of the transport and depositional zones.

2.3 RIVER REACHES
The River Rhine and its present floodplains have been divided into several river reaches (figure 2.2), each of which is characterized by its specific spatial patterns of landforms and soils and associated processes. Some characteristics frequently used to distinguish river reaches within the Rhine/Meuse deltaic system are listed in table 2.1. The classification has been based on available geomorphological and soil maps (see Appendix 2), on historic maps depicting changes in river planform and other human interferences, and on literature on present phenomena of discharge, erosion and deposition (Gölz 1987; 1992). The variations in the floodplain characteristics of river reaches are part of a longitudinal gradient along the river, which can be abrupt due to
sudden changes in controlling variables such as the discharge of water, the discharge of sediment and the geological setting of the floodplain alluvium (Wolfert 1992; Wolfert et al. 1995).

Fig. 2.2. Distribution of classified river reaches (R = Rhine; W = Waal; N = Lower-Rhine; M = Meuse).

EMBANKMENTS
In the Middle Ages the Rhine and its distributaries were embanked, leaving only narrow zones of 2-3 km wide to be flooded, areas that now can be considered the floodplains of the river. In addition, the continuous process of land reclamation within the Rhine drainage basin, gradually changed the river regime. Consequently, the morphology of the river channels and adjacent floodplains has altered completely (Van Urk & Smit 1989). Enlarged sedimentation rates have raised the floodplain topography for several metres, causing a reduction in wetland area.

FLOODPLAIN CHARACTERISTICS
The most conspicuous feature is the change in the fluvial depositional style of the historic river, reflected in the landform patterns of the floodplains. Within the transport zone floodplain patterns originated from a river system in which channel migration had a strong lateral component, resulting in large meanders associated with only a few floodplain channels. Within the depositional zone, the river channel was of the low-sinusosity type, associated with a strong longitudinal component of river migration. Mid-channel sand bars, side channels and other wetland habitats were typical for this sedimentary environment (Wolfert 1992). In analogy to other river systems (Wolfert et al. 1995), these variations are contributed to the variations in valley slope and especially to variations in geological setting: the clayey sediments offer more resistance to lateral erosion, compared with the sandy deposits.
Local differences in geological setting caused a pattern variability within the two types of depositional styles mentioned above. For instance, within the transport zone meander cut-offs initiated a straightening of the river immediately downstream and an
increase in gravel bar formation. Within the depositional zone, crossings with old sandy meander belt deposits caused an increase in lateral erosion, and thus the formation of wider floodplains. The width of floodplains is an important feature, as it determines the quality of the lateral gradients within the floodplains. The wider floodplains are, the more wetland areas can persist in time. Differences, however, are not very noticeable within the drainage basin zones. The largest floodplain width is found in the Gelderse Poort area. From here, the floodplain width decreases in general in upstream as well as in downstream directions.

PRESENT RIVER CHARACTERISTICS
Some present differences in discharge and hydrological regime are associated with the river reach classification. The annual River Rhine discharge in the study area is bimodal, fed by rain water in wintertime and meltwater in spring. In comparison the discharge of the River Meuse is much smaller, and only fed by rain water, thus showing great differences between summer and winter discharges. Considerable differences are also seen when the Rhine distributaries are compared: the river Waal receives 2/3 of the discharge, while the Lower-Rhine receives only 1/9 of the total Rhine discharge. Furthermore waterlevels within the Lower-Rhine are regulated by means of barages. Tidal influences are noticeable in the most downstream part of the River Waal.

Bedding material and present processes of bed-erosion and deposition also give rise to some differences between river reaches. The subdivision into two drainage basin zones is still reflected in the bed material characteristics: in Germany most parts of the river have a gravel-bed; whereas in The Netherlands the entire river has a sand-bed. However, linked to the regulation of the river bed, the zone of erosion has been extending in downstream direction from the terrace intersection point in the natural situation near Emmerich towards Zaltbommel at present. Near Duisburg, sediment transport in the present river has been severely influenced by mining subsidence, causing entrapment of transported material and considerable vertical erosion downstream.

2.4 PHYSIOTOPES

The classification of physiotopes is presented in table 2.2. Information on the present geographical distribution of physiotopes within the study area, is given on the map Present Physiotopes (Annexes; Map 1). A detailed description of the mapping procedure and sources used is given in Appendix 2.

Information on the relationships between the selected physiotopes and the vegetation types relevant in this study are dealt with in chapter 4.

In the procedure of classifying physiotopes, the following criteria have been applied:
- the characteristics used to identify physiotopes should be relevant to the development of the vegetation types (i.e., hardwood forest, softwood forest, macrophyte marshland and side channels);
- it should be possible to translate measures for development of these target ecotopes into physiotope characteristics;
- the level of detail of the classification should be related to the level of detail applied in the elaboration of nature rehabilitation scenarios and the level of detail in the procedures for modelling;
- a map of physiotopes should be made that covers the floodplain area completely;
- this map should be compiled from already available information.
Table 2.1. Characteristics of river reaches.

<table>
<thead>
<tr>
<th>River reach</th>
<th>Floodplain characteristics</th>
<th>Present river characteristics</th>
<th>Other criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1 (km 780-803) Duisburg-Rheinberg</td>
<td>lateral migration</td>
<td>Rhine</td>
<td>gravel bedded; erosion</td>
</tr>
<tr>
<td>R2 (km 802-828) Rheinberg-Wardt</td>
<td>lateral migration</td>
<td>Rhine</td>
<td>gravel bedded; erosion</td>
</tr>
<tr>
<td>R3 (km 828-848) Wardt-Grieth</td>
<td>lateral migration</td>
<td>Rhine</td>
<td>gravel bedded; erosion</td>
</tr>
<tr>
<td>R4 (km 848-868) Grith-Pannerdene kop</td>
<td>transition from lateral to longitudinal migration</td>
<td>Rhine</td>
<td>gravel bedded; erosion</td>
</tr>
<tr>
<td>W1 (km 868-884) Pannerdene kop-Nijmegen</td>
<td>transition from lateral to longitudinal migration</td>
<td>Rhine; 2/3 Q</td>
<td>sand bedded; erosion</td>
</tr>
<tr>
<td>W2 (km 884-908) Nijmegen-Deest</td>
<td>longitudinal migration</td>
<td>Rhine; 2/3 Q</td>
<td>sand bedded; erosion</td>
</tr>
<tr>
<td>W3 (km 898-906) Deest-Ochten</td>
<td>longitudinal migration</td>
<td>Rhine; 2/3 Q</td>
<td>sand bedded; erosion</td>
</tr>
<tr>
<td>W4 (km 906-920) Ochten-Ophemert</td>
<td>longitudinal migration</td>
<td>Rhine; 2/3 Q</td>
<td>sand bedded; erosion</td>
</tr>
<tr>
<td>W5 (km 920-940) Ophemert-Hellouw</td>
<td>longitudinal migration; locally lateral migration</td>
<td>Rhine; 2/3 Q</td>
<td>sand bedded; transition from erosion to deposition</td>
</tr>
<tr>
<td>W6 (km 940-955) Helleuw-Horinchem</td>
<td>longitudinal migration</td>
<td>Rhine; 2/3 Q</td>
<td>sand bedded; deposition</td>
</tr>
<tr>
<td>N1 (km 868-880) Pannerdene kop-Arnhem</td>
<td>longitudinal migration</td>
<td>Rhine; 1/3 Q</td>
<td>?</td>
</tr>
<tr>
<td>N2 (km 880-891) Arnhem-Driel</td>
<td>longitudinal migration</td>
<td>Rhine; 1/3 Q</td>
<td>?</td>
</tr>
<tr>
<td>M1 (km 202-212) Lith-Kerkdriel</td>
<td>transition from lateral to longitudinal migration</td>
<td>large</td>
<td>Meuse</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>?</td>
</tr>
</tbody>
</table>

| Other criteria                      |                             |                  | artificial meander cut offs     |
Table 2.2. Hydrogeographical distribution of selected physiotopes.

<table>
<thead>
<tr>
<th>Not protected against flooding</th>
<th>Protected by summer dikes</th>
<th>Embanked area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aa River bed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ab Gravel bar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ac Side channel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ad Natural levee</td>
<td>Bd Natural levee</td>
<td></td>
</tr>
<tr>
<td>Ae Floodplain, natural</td>
<td>Be Floodplain, natural</td>
<td>Ce Former natural levee1</td>
</tr>
<tr>
<td>Af Floodplain, recultivated</td>
<td>Bf Floodplain, recultivated</td>
<td>Cf Recultivated area</td>
</tr>
<tr>
<td>Ag Tidal floodplain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ah Connected floodplain channel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ai Closed floodplain channel</td>
<td>Bi Stagnant floodplain channel/clay pits</td>
<td>Ci Stagnant abandoned channel/clay pits</td>
</tr>
<tr>
<td>Ak Connected gravel pit lake</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al Closed gravel pit lake</td>
<td>Bi Closed gravel pit lake</td>
<td>Cl Closed gravel pit lake</td>
</tr>
<tr>
<td></td>
<td>Bm High water free terrain</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cn Flood basin</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Co Back swamp</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cp River dune</td>
</tr>
</tbody>
</table>

1The nature of the former natural levees is different from the ones which are being developed at present; the height of the former natural levees is comparable to the height of the present floodplains.

RIVER REGULATION

Regulation and canalization of rivers during the eighteenth and nineteenth centuries implicated another change in developments within the landscape ecological systems. Along the German part of the river, several meander loops were artificially cut off. During the nineteenth century, the position of the entire river became fixed by means of groynes and revetments. Consequently, a much deeper navigable river channel has been formed in which erosion of the river bed is a still occurring process, possibly accelerated by sand extraction activities for navigation. Fixing the river bed meant the disappearance of physiotopes characteristic of migrating rivers, like mid-channel bars, gravel bars and side channels, and hence some important habitats for wildlife. In association with this new hydrodynamic situation, overbank deposition causes the formation of prominent but small natural levees along the river channel, which locally are transformed into small river dunes by wind action. Furthermore, regulation has caused a strong tendency towards vertical erosion of the river bed, leading to further dessication of the floodplain wetland physiotopes, such as floodplain channels. The present morphology is also severely influenced by other human activities, of which extracting clay and sand for the construction industry are the most important, creating large areas of recultivated floodplain land.
FLOODPLAIN PHYSIOTOPES
The classification of floodplain physiotopes occurring within the present river floodplains, has been made in analogy to the River Ecotope System (Rademakers & Wolfert 1994), which is appropriate for the aims and associated scale of this study. In the River Ecotope System, the occurrence and development of physiotopes is considered to be controlled by the abiotic variables morphodynamics (i.e. erosion and deposition) and hydrodynamics (i.e. flooding duration). Thus, the classification is related to lateral gradients within the river reaches: morphodynamics generally decrease with increasing distance from the river channel, whilst hydrodynamics generally increase due to the decreasing floodplain height. Morphodynamics and hydrodynamics are estimated and classified according to this system; morphodynamics in four classes (expressed in m/year vertical changes) and hydrodynamics in six classes (expressed in days/year flooding). Both morphodynamics and hydrodynamics have been estimated regarding the floodplain geomorphology and protection against flooding by summer dikes, based on experiences in other studies on floodplains in the Netherlands (Mulder et al. 1992; Harms et al. 1994). Additional information on the flooding duration for the German part of the study area was obtained from the Wasser- und Schiffrahrtsamt for nine selected cross section of the river and floodplains, representing a large range of physiotopes. The hydrogeographical distribution of the selected floodplain physiotopes is also given in table 2.2. The classification is summarized in table 2.3, which reflects the increase in dynamics along its x- and y-axes. A schematic presentation of the floodplain physiotopes is given in figure 2.3.

EMBANKED AREA PHYSIOTOPES
During the phase of exploring scenarios, parts of the embanked area were also incorporated in one of the alternatives for nature rehabilitation (see chapter 3). To be able to model the effects of measures in these parts of this area, their physiotopes were classified and mapped also. Instead of morphodynamics and hydrodynamics, which are not relevant in embanked areas, the classification of physiotopes occurring in this area were based on soil and ground water levels or water depths, modified from the classification method of Harms et al. (1994). The information was mainly derived from 1 : 50,000 soil maps. Groundwater levels are given in three classes (expressed in the depth of mean spring ground water levels); the depth of open waters is divided into two classes; soils are given in four textural classes. The classification of embanked physiotopes is given in table 2.4; a schematic presentation in figure 2.4.
Table 2.3. Classification of selected floodplain physiotopes.

<table>
<thead>
<tr>
<th>Hydrodynamics</th>
<th>Morphodynamics</th>
<th>Protected by summer dikes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not protected against flooding</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Very large (dm-m / y)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Large (cm-dm / y)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Moderate (mm-cm / y)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Small (mm / y)</td>
<td></td>
</tr>
<tr>
<td>Never flooded (&lt; 2 d/y)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seldom flooded (2-20 d/y)</td>
<td>natural levee</td>
<td></td>
</tr>
<tr>
<td>Periodically flooded (20-50 d/y)</td>
<td>floodplain, natural</td>
<td></td>
</tr>
<tr>
<td>Frequently flooded (50-150 d/y)</td>
<td>floodplain, recultivated; tidal floodplain¹</td>
<td></td>
</tr>
<tr>
<td>Shoreface (150-364 d/y)</td>
<td>gravel bar</td>
<td>closed floodplain channel</td>
</tr>
<tr>
<td>Permanently flooded (364-365 d/y)</td>
<td>side channel</td>
<td>connected floodplain channel</td>
</tr>
<tr>
<td>Deep water (&gt; 365 d/y)</td>
<td>river bed</td>
<td>closed gravel pit lake</td>
</tr>
</tbody>
</table>

¹Both morphodynamics and hydrodynamics of tidal floodplains are tide-influenced.

Table 2.4. Classification of selected embanked physiotopes.

<table>
<thead>
<tr>
<th>(Ground) water level (depth in spring)</th>
<th>Soil</th>
<th>Sand</th>
<th>Silt</th>
<th>Clay</th>
<th>Peat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry (&gt; 50 cm)</td>
<td>river dune</td>
<td>former natural levee</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moist (20-50 cm)</td>
<td>recultivated area</td>
<td>flood basin</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet (&lt; 20 cm)</td>
<td></td>
<td></td>
<td>back swamp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shallow water (&lt; 2 m)</td>
<td>seepage abandoned channel</td>
<td>stagnant abandoned channel/clay pits</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deep water (&gt; 2 m)</td>
<td>closed gravel pit lake</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Fig. 2.3. Schematic presentation of the distribution of the floodplain physiotopes. See for explanation of codes table 2.2.
2.5 PRESENT VEGETATION

Only vegetation types which are relevant to this study have been considered. This concerns soft wood forest, hard wood forest and macrophyte marsh. Soft wood forest comprises all willow and poplar stands. Forests in which Oak, Ash, Hornbeam or Elm are the main tree species are defined as hard wood forest. Owing to the habitat requirements of the target species (see section 4.3), they have been taken into account only if the diameter of these trees was on average >50 cm.
The distribution pattern of these vegetation types was established by using available information (see Appendix 3). Because the width of the study area is very small adjacent areas were included as well. Several target species, in particular the larger bird species, have large area demands and will therefore also use habitat patches outside the study area. Based on foraging and home-range movements of Black Stork (Dornbusch 1992), Night Heron (Hafner & Fasola 1992), White-tailed Eagle (Looft & Busche 1981) and Black Kite (Glutz von Blotzheim et al. 1971), a zone of 10 km around the study area was considered sufficient. Besides, to demonstrate the network approach using simulation models (see section 1.4), it was also necessary to have information on habitat sites outside the study area, which were linked to the network of habitat sites within the study area. Based on available information on dispersal distances, for the Middle Spotted Woodpecker the zone of 10 km was sufficient (Müller 1982), but for the Great Reed Warbler 20 km was needed (Beijer 1981) and for the Bittern 75 km (unpublished dat R. Foppen). Therefore macrophyte marshes were also considered in a zone of 75 km around the study area.

The distribution pattern of the vegetation types for the study area and the zone of 10 km around it are shown in Map 2 (Annexes). The distribution of macrophyte marshes in a zone of 75 km around the study area is presented in figure 2.5.

Fig. 2.5. Distribution of areas with macrophyte marsh in a zone of 75 km around the study area (shaded).
3 SCENARIOS FOR NATURE REHABILITATION
3.1 INTRODUCTION

In this chapter the scenarios for nature rehabilitation are initiated and elaborated. According to the two stages of the planning process (chapter 1) the attention starts focusing on to the stage of plan design. The results of the methods used in this stage are the different scenarios for nature rehabilitation. The way to develop scenarios can be delineated in two complementary approaches: the 'bottom-up' and the 'top-down' (Harms et al. 1991).

In the 'bottom-up' approach all factors determining the conditions for nature rehabilitation have to be taken into account in order to scan the relevant range of alternatives. The relevancy has to be derived from the objectives of the study. For this study the objective is the investigation of the network functions of the River Rhine. According to this approach relevant factors are:

- suitability of the physiotopes for nature rehabilitation, i.e. side channels, macrophyte marshes, soft- and hardwoods, etc. It means that all target nature types, derived from the habitat requirements of the selected species, have to be considered.
- types of nature management; a pattern oriented management may be followed, or a management aimed at restoring the natural processes, such as river dynamics and grazing.
- distribution pattern; nature (macrophyte marshes or forests) can be developed in small units evenly spread over the entire river area or in larger units further apart.
- total natural area to develop, i.e. the acrage of the total surface area of the river's winter bed, which may be designated as new nature. Part of this might be realized also outside the winter bed.

These single factors can be understood as the building blocks in the architecture of the landscape scenarios. Since all single factors in theory can vary a large number of alternatives can be distinguished. Not all alternatives make sense, however. Here the 'top-down' approach is coming into focus. This approach aims at a basic philosophy or leading concept for the design of scenarios, by which single factors fit together to a coherent and interrelated set of landscape elements. A holistic approach predominates here; the forces and processes that determine the landscape structure have to be taken into account, not the single factors. In this study the driving forces of the river dynamics in making the landscape is chosen as basic philosophy (including the river management). Thus, the 'top-down' approach steers the scenario development; the 'bottom-up' approach delivers the building blocks for the scenario and controls the consistancy of it afterwards.

In the following sections the scenario approach is elaborated. In section 3.2 the natural references for nature rehabilitation for the Rhine riversystem is delineated. The suitability for nature rehabilitation is described in section 3.3, the main building block for the scenarios. Before describing the scenarios in section 3.4 attention is paid to the main assumptions and restrictions. At last the scenarios are given in 3.4, the exploration, and 3.5, the elaboration.
3.2 NATURAL REFERENCES

For a better understanding of the river dynamics as the basic philosophy for the development of the scenarios a short survey is neccessary describing the natural conditions of the River Rhine used as the study’s reference point.

Since the river has been embanked and forests and marshes have been reclaimed almost completely, little is left of the original nature within the valley of the Rhine. Nature rehabilitation along the River Rhine offers possibilities of revitalizing ecological communities that are characteristic of the natural river system. An important source of inspiration is the landscape as it was at the beginning of the Christian era, being the result of natural processes during the Holocene. Thus, a fluvial area, little affected by man, and unprotected by dikes, is taken as our reference for the initiation of scenarios for nature rehabilitation.

The main elements of this landscape were forests, marshes and water. Ecologically, the forests and marshes which stretched from Germany to the westernmost part of the Netherlands, functioned as a related system.

There was, for instance, a relationship between the wet nature of the Pleistocene brook valleys, raised bogs and headwater regions and that in the fluvial region. The flood basins in the Dutch fluvial region were often vast marshes that were closely connected with the large marshes of the western and northern parts of the country. Therefore, Otter and Beaver could be found in brook valleys, fens and brackish peatbogs as well as in the fluvial region.

During the Holocene, the natural vegetation of the fluvial area within the transport zone of the river system, was a forest in which Oak (Quercus) dominated (Klostermann 1992). Some marshes, fed by seepage of groundwater originating from higher terraces or ice-pushed ridges, existed in abandoned river meanders. Within the depositional zone, the natural vegetation on the natural levees was a forest with mainly Oak (Quercus), Elm (Ulmus) and Hazel (Corylus). On the lower and wetter parts a forest with Willow (Salix) and Alder (Alnus) existed. In the flood basins macrophyte marshes of Reed (Poaceae) and Sedges (Cyperaceae) were found. As part of the normal succession those were partly replaced by Alder, when water levels dropped due to the accumulation of peat. On the other hand inundations led to an expansion of Reed and Sedges again (Hofstede et af. 1994). Drawing conclusions from paleobotanical research Steenbeek (1990) states that the prehistoric situation of the flood basins shows shallow open water conditions with locally very dense herbaceous vegetation cover with abundant Cyperaceae, Poaceae (Phragmites) and Umbellifereae. In the flood basins in the Western part of the fluvial area open water existed continuously in the lowest parts of the flood basins, with Reed near the margins (Van der Woude 1981).

The natural vegetation of the river floodplain consisted of Reed (Poaceae) and other helophytes and Willow (Salix), which could establish spontaneously on freshly deposited fluvial sediments. The natural levees, ice-pushed ridges, cover sands and terraces were wooded. Forest organisms of the extensive forests in Pleistocene areas, such as many woodpecker species, Red Deer and Wild Boar, could be found in the forests of the natural levees. There was also a relationship with flood plain forests far into Central Europe. River-accompanying species such as Black Stork and Black Kite could probably be found well into the Rhine delta area.
Nowadays the river is been embanked by dikes and the inundation of flood basins has been stopped. The flood basins and back swamps have been reclaimed for agriculture. On the natural levees the hardwood forests have been removed for settlements and orchards. The natural softwood vegetation has sometimes been transformed into a production forest and often on less frequent flooded areas meadows occur. Because of these changes in landuse and river management extended marshes and hardwood forests in the winter bed of the river have disappeared almost completely.

3.3 SUITABILITY FOR NATURE REHABILITATION

As stated before for the development of scenarios to begin ecological knowledge about the potentials of the study area concerned is needed, i.e. the abiotic suitability for nature rehabilitation.

Due to the differences between river reaches, as far as elements and processes are concerned, differences in potentials for nature rehabilitation occur as well (Wolfert 1992). Some nature targets relevant to the planning process will be assessed below. In this section the assessment is performed on the level of river reaches. A more detailed assessment related to the suitability of physiotopes and changes in physiotopes by measures will be given in section 4.2 concerning the modelling of nature rehabilitation with the LEDESS-model.

**Side channels**
River reaches R2, R3, R4, W2, W3, W5, W6, N1, N2 and M1 have good potentials for the sustainable development of side channels. In those river reaches deposition of overbank deposits is relatively small, minimizing the process of entrapment of sand in the side channel. Moreover problems for navigation due to a relatively shallow river bed do not occur in the river reaches mentioned.

**Gravel bars**
River reaches R2, R3 and R4 have good potentials for gravel bars, due to a combination of a relatively strong vertical erosion and the occurrence of gravelly material below the river bed. Entrainment of gravelly bed material is favoured in those reaches where artificial meander cut-offs stimulated bed-erosion, such as near Xanten, Rees and Emmerich.

**Marshes**
River reaches R2, R3, W1, W3, W5, W6, N1, N2 and M1 have good potentials for the development of marshes. Closed and stagnant floodplain channels can best be developed within relatively broad floodplains which have more room in low elevated terrain. Therefore the rather straight and narrow river reaches are less suitable for the development of marshes. Strong vertical erosion of the river bed can entail dessication of marshes; barrages and tidal influence on the other hand can enlarge the possibilities for marshes.

**Forests**
River reaches R2, R3, W1, W3, W5, N1, N2 and M1 have good potentials for forests. This is mainly due to the fact that in comparison to the present situation forests will enlarge the resistance to water flow considerably, so that the development of forests will increase the risk of inundation of embanked areas. This risk is
smallest in those river reaches where the width of the floodplain is very large and low flow velocities during periods with large discharges occur. The increase in resistance can partly be compensated by measures on locations nearby, such as sand, gravel and clay extraction, where the topography of the floodplain is lowered.

Groundwater seepage
Groundwater seepage only rarely occurs within the floodplains. Potentials for the development of ecotopes influenced by seepage can be found in floodplain channels along high elevated landforms, such as terraces and ice-pushed ridges.

3.4 ASSUMPTIONS AND RESTRICTIONS

Pursuing the 'bottom-up' approach requires further assumptions and restrictions be made concerning the different factors that have to be taken into account. The assumptions and restrictions determine the margins for the development of the scenarios. The following issues have been considered:

Extraction of clay
When, for nature rehabilitation purposes, the soil surface has to be removed physiotoles with potential for clay extraction are preferable in order to cover the execution costs. Physiotoles Ae, Be, Ah and Ai have a good potential for the extraction of clay for industrial purposes. All finely textured sediments deposited within the floodplains are suitable for the extraction of clay. There are some exceptions, however: the contents of sand and humus should not be too high, and the deposits should be thick enough. Therefore the natural levees consisting of sandy overbank deposits, the stagnant floodplain channels in which terrestrialization takes place, and the sand bedded seepage floodplain channels are considered to have no potential for the extraction of clay. In addition, extraction will not be possible on terrains where part of the clay layers have been extracted already.

Total acreage
The total acreage at the disposal of nature rehabilitation will be 10,000 ha, to be distributed over a length of some 220 km. This is 30% of the study area if only the winterbed is considered (±30,000 ha) and 21% if also adjacent areas are included (±47,000 ha). The 30% level is in line with the policy aims for nature rehabilitation in the Rhine river system in both countries. At present only approximately 5% of the area is covered by natural vegetation.

Habitat distribution
According to the objective of the study the distribution of new nature is focused on enhancing the dispersal and survival of a selected number of species. Of the total acreage, 5000 ha have to be designated as forest and 5000 ha as marshland in order to equally favour the species of forests and marshland. According to the habitat requirements of the selected species the distribution of new natural areas should be based on modules with units varying from 100 to 2000 ha. This range of unit modules is derived from the expert knowledge of the species concerned.
Existing nature areas
Existing nature areas will be maintained and the new natural areas will fit as much as possible into the existing abiotic features.

River management
Nowadays river management is continued as most as possible. This means that safety from flooding has to be guaranteed by maintaining the winter dikes and that the transport function of the river will not be hindered by nature rehabilitation. In the scenarios combinations should be found for the three main functions of the river: nature, safety and shipping.

3.5 EXPLORATION OF SCENARIOS

The natural reference conditions as outlined above, indicate what ecological communities were characteristic of the fluvial region. It also sketches a picture of the ecological connections in the river area. The challenge in drawing up scenarios lies in exploring the possibilities of developing marshes and forests, given the current state of the landscape and present day river management.

Based on the inspiration of the natural reference (3.2) and the knowledge about the individual building blocks for nature rehabilitation (3.3), a concept has been chosen that distinguishes scenarios in the river’s dynamics and their management. Three options are distinguished:

1. the current river management, in which the river is strongly regulated by groynes, minor dikes and dikes; the flood plains provide the water storage;
2. river management in which minor dikes are cut in some places, in order to allow the river its own way in the winter bed; side channels may be formed and the flood plain is exposed to erosion and sedimentation processes;
3. river management in which the area outside the winter bed is also included: in the German part, side channels outside the dikes are reintroduced as spillways and water storage; in the Netherlands, several flood basins are reintroduced as spillways.

A closer examination shows that these three approaches determine the scale on which nature can be developed and the extent to which the process approach can be applied. Therefore, different ways of managing the river can be translated into three nature rehabilitation scenarios with possible different effects on the network and stepping stone functions. The potentially suitable sites vary for each scenario as well.

Although the scenarios refer to different stages of river management (or non-management) in the history of the River Rhine the scenarios are named after riversystems that can be considered, entirely or partially, as a contemporary reference.

Table 3.1 gives an overview of the main characteristics of the three scenarios, whereas table 3.2 provides more detailed information per river reach. Map 3 (Annexes) delineates the results of the exploration in an outline of the scenarios.

SCENARIO 1: RHINE-TRADITIONAL
Our first approach optimizes, through pattern management, an even distribution of the reference condition throughout the winter bed. Forests and macrophyte marshes of 100 ha each will be spread evenly throughout the study area. Forests
will be realized in the dry places. Because sites for macrophyte marshes are only limited available now, excavations will be carried out. This scenario allows mowing management and clay extraction in order to maintain the marshes by which Reed is favoured. The present-day river management is continued and minor dikes and main dikes are maintained. Due to the on-going dominant, agricultural influence on the landscape pattern of the floodplains of the River Rhine the scenario is called "Rhine (traditional)".

SCENARIO 2: LOIRE-RIVER DYNAMICS
The second approach is based on the river dynamics. An attempt will be made to give the river processes more room within the winter bed, the so-called 'Ooievaar' approach (De Bruin et al. 1987). This will result in forest-marsh-water complexes, which will have different proportions depending on local dynamics. Compared with scenario 1 this scenario gives more room to large units of nature areas with larger distances between them. The forest component will, however, often predominate, since there are comparatively many high and sandy spots in the winter bed. Mowing management does not belong to this approach. However, integrated grazing, digging side channels or other excavation activities do fit in well with this scenario.

The upstream section of the river Loire, without any limitation to the natural impact of river dynamics on the floodplains, has been the reference for this scenario. The scenario leads to a search for several dozens of sites in the winter bed that offer enough space for creating inflow points and side channels, according to suitable river sections.

SCENARIO 3: MISSISSIPPI-SPILLWAY
The third approach focuses on restoring a chain of large-scale marshes between the Biesbosch and the upper reach. There is, however, no room within the winter bed downstream of the Gelderse Poort area. To solve this problem, the flood basins are connected to the river system to restore them as spillways (Heeling et al. 1986). This is feasible in places without villages, busy roads and railways, where large low areas may remain flooded nearly all year round. In the flood basins, the macrophyte marsh component is to become as large as possible by high water levels. This can be obtained by river-water inlet during high winter levels, or by excavations and embankments. Reed can also be encouraged by mowing or burning. In this Dutch part, forests are planned on the natural levees.

Upstream of the Gelderse Poort area, this scenario uses another approach. There, marshes are planned in the adjacent low terraces, outside the winter bed. Partially the terraces will be excavated by sand and gravel extraction in order to make the site more suitable for marshlands. These marshes will always have a considerable forest component.

The downstream section of the river Mississippi has some spillways, which drain the discharge of the waterbody into flood basins, back swamps and lakes. This is the reason the scenario is given the name Mississippi (spillway). To elaborate this scenario seven large, nearly vacant, low-lying sites outside the winter bed must be found for (with the exception of hardwood forests on natural levees).
Table 3.1. The scenarios represented schematically.

<table>
<thead>
<tr>
<th>SCENARIO</th>
<th>RIVER MANAGEMENT</th>
<th>NATURE</th>
<th>SPATIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Rhine-Tradiotional</td>
<td>The present day river management is maintained.</td>
<td>Forests on natural levees and sites not frequently flooded, marsh development in low, frequently flooded flood plains or by clay digging.</td>
<td>50 forests of 100 ha each, not more than 10 km apart. 60 marshes of 100 ha each, not more than 10 km apart.</td>
</tr>
<tr>
<td>2. Loire-River dynamics</td>
<td>In some places the river is allowed its own way within the winter bed, minor dikes are cut. Flooding duration is long and frequency is high.</td>
<td>In comparatively broad flood plains with room for larger complexes with marshes (whether or not along side channels) and forests. On sites where minor dikes may be cut or the soil surface may be lowered, after which the flooding duration is long and the frequency is high and large-scale grazing is possible. Variation resulting from river dynamics is the central point.</td>
<td>30 complexes of marshes and forests of 250-500 ha each, 10-20 km apart.</td>
</tr>
<tr>
<td>3. Mississippi-Spillway</td>
<td>In some places the river will have access to the land behind the winter bed (in flood plain channels and flood basins).</td>
<td>In the upper reach (Germany, Gelderse Poort) large-scale marshes (including forests) are located outside the winter bed if possible (in adjacent flood plain channels and terraces). In the lower reach large marshes are located in the flood basin area, preferably where an area may be used as spillway. The forests in this part are located on the natural levees.</td>
<td>10 forests of 100 ha each, not more than 10 km apart. 6 marshes including forests of 1000-2000 ha each, 20-30 km apart.</td>
</tr>
</tbody>
</table>
### Table 3.2. The scenarios elaborated per river reach.

<table>
<thead>
<tr>
<th>REACH (see table 3.1)</th>
<th>CHARACTERISTICS</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>narrow, high, bed subsiding, depositing, gradient-rich</td>
<td>Scenario 1: marshes through excavations</td>
</tr>
<tr>
<td>Duisburg - Rheinberg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2</td>
<td>broad, often adjacent to ice-pushed ridge or terrace, eroding, gradient-rich potential for side channel, gravel bar, natural levee, marsh and forest</td>
<td>Scenario 1: marshes through excavations Scenario 2: extending places (at least 250 ha) with long flooding periods through excavations Scenario 3: in very wet places on terraces</td>
</tr>
<tr>
<td>Rheinberg - Wardt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td>much resembling R2, fewer high terraces, broad, eroding, gradient-rich potential for side channel, gravel bar, natural levee, marsh and forest</td>
<td>Scenario 1: marshes through excavations</td>
</tr>
<tr>
<td>Wardt - Grieth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R4</td>
<td>narrower than R3 and W1, straight, between ice-pushed ridges, gradient-rich potential for side channel, gravel bar and natural levees</td>
<td>Scenario 1: marshes through excavations</td>
</tr>
<tr>
<td>Greth - Pannerdense Kop</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W1</td>
<td>broad, relief, overbank deposition, migrating bed, gradient-rich potential for side channel, marsh and forest</td>
<td>Scenario 1: extending existing elements (Digipoeder, Miltumerwaard)</td>
</tr>
<tr>
<td>Pannerdense Kop - Nijmegen</td>
<td></td>
<td>Scenario 2: ditches, extending places (at least 250 ha) with long flooding periods through excavations</td>
</tr>
<tr>
<td>W2</td>
<td>narrow, straight, dynamic, eroding, gradient-rich potential for side channel and natural levees</td>
<td>Scenario 1: marshes through excavations</td>
</tr>
<tr>
<td>Nijmegen - Deest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W3</td>
<td>broad, relief, sand bars potential for side channel, natural levees, marsh and forest</td>
<td>Scenario 1: marshes through excavations</td>
</tr>
<tr>
<td>Deest - Ochten</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W4</td>
<td>narrower than W3 and W5, comparatively great potential for natural levees</td>
<td>Scenario 1: marshes through excavations Scenario 2: extending places (at least 250 ha) with long flooding periods through excavations Scenario 3: a very large marsh in the Meuse and Waal basin</td>
</tr>
<tr>
<td>Ochten - Ophemerter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W5</td>
<td>broad, eroding = depositing bed potential for natural levees, marsh and forest</td>
<td>Scenario 1: marshes through excavations</td>
</tr>
<tr>
<td>Ophemer - Helleuw</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W6</td>
<td>narrow, in flood basin landscape, side slope, little dynamic potential for side channel and forest</td>
<td>Scenario 1: marshes through excavations Scenario 2: extending places (at least 250 ha) with long flooding periods through excavations Scenario 3: a large marsh in the Sommelerwaard flood basin</td>
</tr>
<tr>
<td>Helleuw - Gorinchem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flood plain channel being tilted up</td>
<td>Former flood plain round channel being tilted up</td>
<td>Scenario 1: extending existing elements (Rhine flood plain channels) Scenario 2: ditches, extending places (at least 250 ha) with long flooding periods through excavations Scenario 3: ditches, extending places (at least 1000 ha) with long flooding periods through excavations</td>
</tr>
<tr>
<td>Spikh - Angeren</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N1</td>
<td>partly dug, relief potential for side channel, marsh and forest</td>
<td>Scenario 1: marshes through excavations</td>
</tr>
<tr>
<td>Pannerdense Kanaal - Lower Rhine up to Amhem</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N2</td>
<td>at the edge of the ice-pushed ridge, dammed at low stage, one third of Pannerdense Kanaal discharge, gradient-rich potential for side channel, marsh and forest</td>
<td>Scenario 1: marshes through excavations</td>
</tr>
<tr>
<td>Amhem - Driel barrage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M1</td>
<td>broad, dammed, rain-fed river, little dynamic potential for side channel, marsh and forest</td>
<td>Scenario 1: extending existing elements (Fort St. Andries) Scenario 2: ditches, extending places (at least 250 ha) with long flooding periods through excavations</td>
</tr>
</tbody>
</table>
3.6 ELABORATION OF SCENARIOS

In order to connect the scenarios to the data processing procedures a typology is created of target nature types classified according to their lay-out and management. The scenarios have been elaborated in terms of these target nature types. The target nature types are defined in such a way that, within the margins of the physiotope, the optimal conditions are created (lay-out and management) to achieve the ecological objective. The target nature types in this study are in line with the target nature types recently established in nature policy (Bal et al. 1995). The following types are distinguished (between parentheses the code for the nature target type is indicated according to Bal et al. 1995):

N0 Present-day situation. The actual landscape pattern will be continued by means of the same management and land use.

N1 Softwood floodplain forest (Ri-3.10). The target nature type will be dominated by Salix species, vegetations is frequently overflooded, and there is no management.

N2 Forest with oak (Ri-3.11). Very poor overflooded vegetation is dominated by oak (Quercus robur) and other hard wood species. There may be either extensive management or none at all.

N3 Macrophyte marsh (Ri-3.3). Vegetation is dominated by (perennial) reed (Phragmites australis) and other rough herbage preferring differentiated winter mowing or local burning.

N4 Side channel (Ri-2.1; Ri-3.1). A side channel is constructed/developed mainly by connecting existing floodplain channels with the river, upstream and downstream, in river sections, which are morphologically suitable. The target nature type is always developed in combination with the riverine forest landscape.

N5 Floodplain channel (Ri-3.1). A floodplain channel is constructed/developed, connected downstream by digging clay in suitable physiotopes.

N6 Isolated water (Ri-3.2). Isolated water areas inside the dike are constructed/developed by digging clay or sand or by inlet water in flood basins and back swamps.

N7 Riverine forest landscape (Ri-2.1). ‘Guided nature’ has to be developed by the (re)introduction of natural processes, including natural grazing in the winter bed of the river.

These target nature types can only be realized under specific abiotic circumstances. In assessing the potential for target nature types the physiotope map was used as a basis. The physiotopes were classified into four groups. This classification was used in allocating the target nature types (see table 3.3).

Map 4.1, 4.2 and 4.3 (Annexes) gives a series of map sections of three parts of the study area. In one of the map sections the elaboration of the scenarios in target nature types is expressed.
Table 3.3. Classification of target nature types for the elaboration of the scenarios.

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Physiotopes</th>
<th>Target nature types</th>
</tr>
</thead>
<tbody>
<tr>
<td>open water</td>
<td>river bed; connected pit; closed pit</td>
<td>N4, N5, N6, N7</td>
</tr>
<tr>
<td>puddled, high flooding duration/frequency</td>
<td>side channel; tidal floodplain; connected floodplain channel; closed/stagnant floodplain channel; seepage floodplain channel; back swamp</td>
<td>N1, N3, N7</td>
</tr>
<tr>
<td>moist, moderate flooding duration/frequency</td>
<td>gravel bar; floodplain, recultivated; recultivated area; flood basin</td>
<td>N1, N7</td>
</tr>
<tr>
<td>dry, occasional floodings</td>
<td>natural levee; floodplain, natural; flood-free terrain; river dune</td>
<td>N2, N7</td>
</tr>
</tbody>
</table>

Riverine forest landscape (N7) can be applied as a combination of the four groups.

SCENARIO 1: RHINE-TRADITIONAL
A first approach optimizes, through pattern management, an even section from the reference in the winter bed. Forests and macrophyte marshes of some 100 to 200 ha each will be spread evenly throughout the study area. Forests will be realized in the dry places. Wetlands for macrophyte marshes are only limited available now. Therefore, excavations in combination with the cutting of minor dikes will be carried out. This scenario allows mowing management and pumping up water in order to maintain these marshes. In the elaboration on the map, four target nature types were distinguished in the legend:

N0 present-day situation maintained  
N1 softwood forest  
N2 hardwood forest  
N3 macrophyte marsh

This scenario is aimed at an even distribution of forests and macrophyte marshes along the entire reach. To this end the most suitable sites in the winter bed are selected every few kilometres. In any case, these are sites with at least 100 ha of connected floodplains. The procedures for forests and macrophyte marshes are described below.

Forest
Non-excavated floodplains and natural levees are very suitable for hardwood forests, hereafter referred to as ‘forests with oak’. The largest connected areas of these physiotopes are allocated to forests with oak. This implies that:
- the largest areas of dry physiotopes within the winter bed are selected and supplemented with wetter physiotopes until connected clusters of at least 100 ha were formed;
- the available 5000 ha are spread over the clusters as equally as possible: in the 220 km long river reach, the distance between any two forests is 10 km at the most. If clusters are too close to each other, the abiotically suboptimal cluster will be cancelled.
Under a do-nothing management approach, the relative dryer physiotopes will mainly produce hardwood forests with oak (Type N2). The wetter physiotopes will mainly produce softwood floodplain forest (Type N1).

**Macrophyte marsh**
The most frequently flooded floodplains and floodplain channels are suitable for macrophyte marshes and softwood floodplain forests. Macrophyte marshes are more restricted to very wet sites, so most floodplains should be excavated. In order to realize the required macrophyte marshes, a two-step procedure is followed:
- The wettest physiotopes are selected, up to connected clusters of at least 100 ha.
- The available 5000 ha are spread over the clusters as equally as possible: in the 220 km long river reach, the distance between any two marshes is 10 km at the most.

Under winter-mowing management, the wetter physiotopes will partly produce reed (Type N3). Such very wet physiotopes are occasional in the study area. But the floodplain and floodplain channel physiotopes can be changed into very wet physiotopes.

**SCENARIO 2: LOIRE-RIVER DYNAMICS**
In this scenario, the river is allowed its own way in many places inside the winter bed of the study area. This is achieved by cutting minor dikes; side channels may form and erosion and sedimentation processes may clearly leave their marks on the area. Large grazers will be introduced to give the landscape a park-like character.

Nature is adjusted by external management (water control, embankment, grazing density). Unpredictability is the fundamental choice here. Therefore, other target nature types are used than in Scenarios 1 and 3. Compound mapping units are chosen for the guided natural systems involved here. Water is distinguished separately, because this concerns specific layout measures: much water connected with the river, such as side channels or channels linked on one side. Therefore, the four units used on the scenario 2 map are:

N0 present-day situation maintained
N4 side channel (water)
N5 floodplain channel with downstream connection with the river
N7 riverine forest landscape (macrophyte marsh-grass-softwood-hardwood)

Target Nature Types N4 and N5 are applied to physiotopes that include open water or that have been recently filled in. Other floodplain physiotopes are intersected only if one searches for access to the river. This procedure completely minimizes the introduction of new geographical structures into the winter bed. This ensues from the basic principle of this study that the models should fit in with existing physiotopes as much as possible.

Sufficiently large areas with much open water and water that has been recently filled in are suitable for guided nature. A three-step procedure is followed:
- Larger areas with a high percentage of physiotopes classified as ‘floodplain channels’ and ‘sandpit’ are selected.
- The available 10,000 ha are spread over the suitable areas as equally as possible: in the 220 km long river reach, the distance between these units may not exceed 10 km.
- Side channels are planned in river sections suitable for side channel construction according to the current river dynamics regime.

**SCENARIO 3: MISSISSIPPI-SPILLWAY**

This scenario creates spillways. Areas outside the winter bed will have a function in catching peak discharges. This is feasible in flood basins and in abandoned floodplain areas without villages, busy roads or railways, where large low areas may remain flooded all year round. In such areas, the macrophyte marsh component is to become as large as possible by high water-levels. This is obtained by river-water inlet during high water-levels, possibly in combination with excavations and embankments. The natural levees in the winter bed will be the best sites for forests with oak.

Almost the same target nature types can be used as in scenario 1 with water basins for river water inlet inside the dikes in addition. Forests with oak will be located on natural levees in the winter bed. So the units of the scenario 3 map are:

N0 present-day situation maintained
N1 softwood forest
N2 hardwood forest
N3 macrophyte marsh
N6 isolated water (inside the dike)

If river management permits, optimum conditions for macrophyte marsh can be created in the back swamps, which implies:
- a relatively low winter level (a few decimetres under the average soil surface) to allow the reed to be mown;
- a relatively high spring level (a few decimetres above the average soil surface) to prevent damage caused by insects and to advance reed growth;
- a summer level that is favourable for marshland birds (important to species that nest on the ground) and advances reed growth (puddled).

It is obvious that in practice these conditions should be handled flexibly, depending on the river management.

Two options for macrophyte marsh development by water inlet with spillways can be elaborated:
- the first option (figure 3.1) is the more natural way without artificial lay-out measures and intensive mowing management. One has to accept a smaller part of macrophyte marsh and a larger amount of softwood forest. Although little literature is available which clarifies the natural vegetation of fluvial basins and back swamps, some evidence about the reference is given by Steenbeek (1990), see section 3.2. Although circumstances have been changed, the newly created situation with a spillway can be close to the prehistoric one. Probably the reed surface can be extended by partly burning the vegetation cover.
- the second option (figure 3.2) gives the best conditions for optimal macrophyte marsh, but it is also a very artificial way. The best way to realize these conditions is the following:
  - minor dikes are built in spillway areas
- pumps are installed
- a pool or the river acts as reservoir and buffer.

Although the more artificial way of management gives the best guarantee for macrophyte marsh in which Reed will be dominant, the first option is chosen (scenario 3), i.e. the more natural way without the minor dikes and pumps.

In order to find suitable large-scale marshes, which can also be used as spill-ways, a two-step procedure is followed:
- large areas of flood basins are selected outside the present winter bed, which lie lower than the floodplains and which have hardly any buildings or infrastructure, with a surface area of at least 1000 ha.
- the available 9000 ha are spread over the suitable areas as equally as possible: in the 220 km long river reach, the distance between any two units is 20 km at the most. In the west, the Biesbosch is our starting point.

For forests with oak in the winter bed, the following procedure is followed:
- The larger units of the high-lying physiotopes are selected, with a preference for the natural-levee types.
- The available 1000 ha are spread over the suitable areas as equally as possible in the 220 km long river reach with units of 100 ha.

![Fig. 3.1. Example of a more natural alternative for the spillway system.](image)
Fig. 3.2. Example of the artificial alternative for the spillway system.
4 MODELLING NATURE REHABILITATION

<table>
<thead>
<tr>
<th>RHINE-ECONET</th>
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<tbody>
<tr>
<td>LANDSCAPE ECOLOGICAL SYSTEMS ANALYSIS (2)</td>
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<tr>
<td>MODELLING NATURE REHABILITATION (4)</td>
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<tr>
<td>EVALUATION OF METHOD (6)</td>
</tr>
</tbody>
</table>

| SCENARIOS (3) |
| RESULTS (5) |
| EVALUATION OF RESULTS (7) |
4.1 INTRODUCTION

According to the two stages of the planning process (chapter 1) the scenarios for nature rehabilitation, initiated and elaborated in the stage of plan design (previous chapter), have to be evaluated in the next stage: the plan evaluation. In this stage the ecological impacts will be determined. For this a modelling procedure is used which consist of the following steps:

1. Modelling vegetation development (LEDESS approach) by determining the relationships between abiotic site conditions (physiотopes), management and vegetation (section 4.2);
2. Modelling habitat suitability and carrying capacity of selected fauna species (GIS-modelling) based on expected vegetation types (terminal vegetations)(section 4.3);
3. Modelling spatial population dynamics of selected fauna species (LARCH/METAPHOR APPROACH) to determine the network function (section 4.3).

The models are implemented in a polygon-oriented GIS (Arc/Info). Owing to its GIS basis, the modelling procedure can be used for analysis, interpretation and presentation and finally provides polygon maps.

4.2 MODELLING VEGETATION DEVELOPMENT: THE LEDESS APPROACH

4.2.1 Outline

The LEDESS model, i.e. Landscape Ecological DEcision-Support System (Harms 1994), is a knowledge-based system coupled to a geographical information system (GIS). A previous version, the so-called COSMO-model (see Harms et al. 1993), has been improved for riverine areas and applied to a part of the study area, the Gelderse Poort in the Dutch part (Harms & Roos-Klein Lankhorst 1994) and the German part as well (Knol et al. 1994). Basically the same model is applied now for the total study area of this project.

The model is based on a deterministic concept of vegetation dynamics dependent on physiotope, target vegetation and management. The model provides a systematic way to use available, ecological knowledge. The two main operations in this study are:
- checking the ecological feasibility through confrontation with the abiotic site conditions,
- determining the terminal vegetation, based on the expected vegetation development.

The operation process is shown in figure 4.1. The scenarios are translated into target nature types and transferred to the GIS map. The first evaluation concerns the suitability of the abiotic state factors (the physiотopes) for the objectives chosen. If a target nature type does not correspond with the prevailing present abiotic conditions, the model can propose measures to change the physiotope in a way suitable for the development of target vegetation (e.g. raising the water-table or removing the topsoil). It is also capable of proposing alternative target vegetations. The planner can choose either solution, or both.

Consequently, vegetation development is simulated in accordance with the target vegetation, starting from the current or adapted abiotic conditions and vegetation.

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4.2.2 Classifications

Elaborating the three nature rehabilitation scenarios requires a typology that fits in with the data processing. The elaboration in which the desired, ecological objectives are made more specific is based on the map of present physiotopes (Annexes, Map 1). In these scenario elaborations per physiotope, two issues are distinguished:
- target nature types: the desired nature, expressed as vegetation types with their corresponding management;
- measures that are advisable or necessary in order to achieve the target. These measures may concern:
  - the water management of larger (physiotope-exceeding) areas, mostly entire floodplains;
  - lay-out measures concerning individual physiotopes.

A systematic approach has been chosen to enable automated processing of the scenarios. A distinction has been made between target nature types (as indicated in the elaborated scenarios) and terminal vegetations, expressed as the percentage of covering by vegetation per physiotope that can be actually expected. This terminal-
vegetation typology corresponds to the habitat requirements of the animal species involved in the study.

The following classifications have been used: physiotope types (see chapter 2), measures (hydrological and lay-out), target nature types and terminal vegetation types. The latter will be discussed briefly.

MEASURES (HYDROLOGICAL AND LAY-OUT)
The following measures can be distinguished in order to adjust the physiotope to better abiotic site conditions for nature rehabilitation (i.e. target nature types):

M1 Removing dike.
Minor dikes (summer dike) will be removed in order to enhance the frequency and duration of inundation.

M2 Inlet of river water.
To create an inlet on behalf of a spillway and a water basin inside the dike.

M3 Constructing side channel.
To construct a side channel by digging, in order to connect existing floodplain channels with the river upstream and downstream as well, in river sections which are morphologically suitable.

M4 Making a downstream opening.
A floodplain channel or a sand/gravel pit will be connected downstream by digging clay.

M5 Digging shallow water.
Digging clay in order to provide optimal conditions for a side channel or macrophyte marshland development.

M6 Digging deep water.
Digging clay, sand or gravel to create a water basin for water inlet in combination with a spillway.

M7 Lowering the soil surface by clay digging.
Removing soil in order to create optimal conditions for softwood floodplain forest development.

TERMINAL VEGETATION TYPES
As was stated above, the terminal-vegetation types are based on the habitat requirements of the selected animal species. The following types are distinguished:

V1 Softwood floodplain forest.
Floodplain forest regularly flooded with Salix species predominating in the canopy vegetation layer.

V2 Forest with oak, hardwood (floodplain) forest.
Forest on natural levees or other seldom flooded sites with Quercus robur as the most characteristic tree species.

V3 Macrophyte marshland
Vegetation consisting of macrophytes (Poaceae and Cyperaceae), but dominated by Phragmites australis preferable on shallow water sites.

V4 Vegetations of open water (connected with the river)
Aquatic vegetations of permanent waters in connection with the main river, such as side channel, and floodplain channel, with an downstream and/or upstream opening.

V5 Vegetation of isolated water.
Aquatic vegetations of permanent water isolated from the main river, flooded (outside the winter dikes) or not flooded (inside the winter dikes).

V6 Grasses and rough pasture.
Pastures with natural grazing, consisting of grasses (Poaceae), herbs, roughs and shrubs, but mainly open landscape.
V7 Beach, gravel, mud.
  Mainly bare soil, frequently flooded, along riverbed, channels and lakes.

4.2.3 Transition matrices

For each terminal vegetation, the relationship between physiotopes and target nature types has been indicated, which resulted in 'transition matrices' (see Appendix 6). In these matrices the figures refer to the expected percentages of covering by vegetation per physiotope. In many cases, however, no fixed terminal vegetation will be established, but a cyclic succession will occur. Percentages of terminal vegetation are determined within the frame of the physiotope. The matrices are based on literature (Knaapen & Rademakers 1990; Rademakers 1993 and cited literature; Steenbeek 1990). When knowledge failed, experts were consulted: H. Coops (RIZA), P.W.F.M. Hommel (SC-DLO), H. Koop (IBN-DLO), M. Schoor (RIZA), Vrielink (SC-DLO), G. van Wirdum (IBN-DLO).

Often, lay-out measures have to be taken in order to make the physiotope suited for the ecological objective in question. This will be illustrated with the following example (see table 4.1): a floodplain inside minor dikes (Physiotope Be) is too dry to develop macrophyte marshland (N3); the clay layer will have to be removed until shallow water forms (Physiotope Bi). Table 4.2 shows which physiotope will be formed after the measure has been taken.

Table 4.1. Example of transition matrix: measures to be taken to implement target nature types (detail of Appendix 4). For explication see text.

<table>
<thead>
<tr>
<th>Target nature type</th>
<th>Physiotope Ad</th>
<th>Physiotope Be</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1 softwood</td>
<td></td>
<td>measure 7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(lowering soil surface)</td>
</tr>
<tr>
<td>N2 hardwood</td>
<td>measure 0</td>
<td>measure 0</td>
</tr>
<tr>
<td></td>
<td>(no measure needed)</td>
<td>(no measure needed)</td>
</tr>
<tr>
<td>N3 macrophyte marshland</td>
<td></td>
<td>measure 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(digging shallow water)</td>
</tr>
<tr>
<td>N4 side channel</td>
<td></td>
<td>measure 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(removing dike)</td>
</tr>
</tbody>
</table>

Table 4.2. Example of transition matrix: changes in physiotope types through measures (detail of Appendix 5). For explication see text.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Physiotope Ad</th>
<th>Physiotope Be</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure 4 (downstream opening)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measure 5 (digging shallow water)</td>
<td>physiotope Ai</td>
<td>physiotope Bi</td>
</tr>
<tr>
<td>Measure 6 (digging deep water)</td>
<td>physiotope Ai</td>
<td>physiotope Bi</td>
</tr>
</tbody>
</table>
Besides the terminal vegetation aimed at other vegetation types will develop in general. This is indicated in the terminal-vegetation matrices concerned. For example (see table 4.3): when a softwood floodplain forest (target nature type N1) is developed in a floodplain channel inside minor dikes (physiotope Bi), it is assumed that the terminal vegetation will include not only the intended softwood floodplain forest (V1: 40%), but also macrophyte marshland (V3: 10%) and open water (V5: 50%).

Table 4.3. Example of transition matrix: Percentages terminal vegetations (V) by target nature type (N) and physiotope type (details of Appendices 4.3). M, lay-out measure has to be taken. For explication see text.

<table>
<thead>
<tr>
<th>Physiotope</th>
<th>V1 Softwood</th>
<th>V2 Hardwood</th>
<th>V3 Macrophyte marshland</th>
<th>V5 Open water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physiotope Be</td>
<td>M</td>
<td>-</td>
<td>M</td>
<td>80%</td>
</tr>
<tr>
<td>Physiotope Bi</td>
<td>40%</td>
<td>-</td>
<td>-</td>
<td>10%</td>
</tr>
</tbody>
</table>

If the intended terminal vegetation does not develop according to a certain target nature type, a lay-out measure (M) has to be taken in order to change the physiotope. This refers to a previous transition matrix (see table 4.1). If a layout measure is not useful or not desirable, it is indicated in the matrices by ‘-’. For example (see table 4.1): a softwood floodplain forest (N1) cannot be developed on physiotope Ad (natural levee outside minor dikes) owing to the small chance of flooding. Furthermore, excavating is assumed to be not desirable, because the natural levee does not consist of sufficient clay. In such a case, the current situation must be continued (NO), or another target nature type must be chosen, e.g. hardwood floodplain forest (N2), if this fits in with the scenario.

The final outcome of the GIS-procedure through the matrices is a dataset containing the terminal vegetation types for each combination of physiotope and target nature type. In order to accomplish this task a number of steps has to be taken:

1. The first step is to check whether a certain target nature type on a physiotope is possible without the necessity to take any additional measures. In Appendix 4 all the possible combinations of physiotopes and target nature types are brought together, as shown in the table 4.1 example. Each combination leads to:
   - no additional measures are needed; target nature type can (partly) be developed on the physiotope concerned;
   - it is possible through measures, to change the physiotope in order to achieve the target nature type;
   - combination is not possible or desirable; another target nature type, better adjusted to the physiotope, has to be chosen.

2. If it is possible through measures, to change the physiotope to abiotic site conditions more in line with the target nature type, another matrix is used to produce the changed physiotope after the proposed measure has been implemented (Appendix 5 and illustrated in table 4.2). This matrix contains all the possible combinations of the original physiotopes and proposed measures.
   If no measure is needed, this matrix produces the starting physiotope.

3. It is possible that a second or even third measure is needed to produce a physiotope on which the target nature type can be developed. This means that the
procedure of step 1 and 2 has to be pursued again, until the combination of physiotope and target nature type makes additional measures unnecessary. In that case the next and final step can be taken.

4. A set of 7 matrices (one for each vegetation type) combines the final physiotope and the target nature type (Appendix 6 and illustrated in table 4.3). A specific combination produces a percentage of terminal vegetation cover. The addition of the percentages of each matrix (always 100%) accomplishes the total terminal vegetation cover on each physiotope for each target nature type.

The final outcome of the GIS-procedure are polygon maps of the terminal vegetation as will shown in chapter 5.
4.3 MODELLING HABITAT SUITABILITY AND CARRYING CAPACITY

4.3.1 General approach

To obtain a pattern of habitat units at the level of local populations and to estimate the carrying capacity of these units the following information is needed:

1. habitat requirements in terms of the terminal vegetation types and physiotopes considered in this study;
2. algorithms to determine minimal habitat requirements (one reproductive unit i.e. breeding pair, family) and to estimate the carrying capacity (the maximum number of reproductive units which can be present in a habitat unit);
3. procedure to distinguish habitat units which are concurrent with local populations.

Data to determine habitat requirements and algorithms are taken from the literature. Dependent on species, it also has been necessary to make use of expert judgement. Further details are species specific and can be found in section 4.3.2.

Different approaches are developed to distinguish habitat units:

1. species which have large area demands and mostly make use of two or more patches separated spatially;
2. species which have rather small area demands and are restricted to one patch.

To the first group belong Beaver, Black Kite, Black Stork, Night Heron, White-tailed Eagle and Barbel. The second group includes Middle Spotted Woodpecker, Great Reed Warbler and Bittern. The approaches are explained below.

HABITAT UNITS FOR SPECIES WITH LARGE AREA DEMANDS

To explore what parts of the study area (and adjacent surroundings) are suitable for the selected species a GIS coverage has been created with subunits about the mean size of the home range (see figure 4.2). Circles are used for the subunits, in which the diameter equals the estimated home range size. Depending on the species, either a circle with a 2 km radius or a circle with a 5 km radius has been chosen. Circles are drawn at distances of 2 km along the length of the river, starting from points in the middle of the study area. If the coverage of the study area was not complete additional circles were drawn.

At first it is determined for each circle whether there is enough habitat to support at least one reproductive unit (e.g. breeding pair). Then overlapping and adjacent ‘suitable’ circles are combined to achieve the final pattern of suitable areas. For these areas the carrying capacity is estimated. Whether the areas should be considered as different (local) populations is discussed in the results (chapter 5).

HABITAT UNITS FOR SPECIES WITH SMALL AREA DEMANDS

At first all patches of the required vegetation type are identified. Then patches are clustered when the distance between them is less than twice the home-range distance of the species. Clusters that have a carrying capacity of at least one reproductive unit (breeding pair) are considered as habitat units at the level of local populations. For these units the carrying capacity is estimated. See figure 4.3 for some further explanation.
Fig. 4.2. Determination of habitat units for target species with large area demands.
A. coverage of the study area with circles in which the diameter equals the home-range size (here 10 km).
B. determination of circles with suitable habitat (hatched).
C. determination of habitat units by joining overlapping 'suitable circles.
Fig. 4.3. Determination of habitat units for target species with small area demands.
A. identification of suitable habitat patches.
B. determination of a zone around patches which is concurrent with twice the home-range distance.
C. determination of habitat units by joining patches with overlapping zones.
4.3.2 Target species

BEAVER

Habitat requirements
The Beaver lives in natural forest (softwood or hardwood) very near to open water. It builds lodges along relatively steep edges between water and forest. Highly dynamic river reaches with pioneer vegetation on sand and gravel bars offer a suitable feeding ground in spring and summer. This makes sites alongside rivers and side channels, preferable. In general the conditions in the study area can be considered more favourable than the conditions in the Biesbosch (near the western border of the study area, Nolet pers. comm.). In this area the re-introduced Beavers have been studied very extensively. Beaver families use about 3000 m of edge vegetation around their lodge (Nolet 1994).

Algorithm
Based on the more favourable feeding conditions compared to the Biesbosch situation, one family group (up to 10 individuals) at a minimum needs only 2000 m edge of forest and open water (gravel pits, river, floodplain channels, side channels. The maximum edge length needed is the same as in the Biesbosch (3000 m). Edge situations were assessed in circles with a radius of 2 kilometres.

BLACK KITE

Habitat description
In Western Europe the Black Kite is a typical inhabitant of riverine areas. The species hunts above open water (river or gravel pits) and breeds in forest directly alongside the river (e.g., Kreuziger 1994). A density estimate is rarely found. Grimmett & Jones (1988) mention densities of 1 pair per 40-50 ha in comparable, suitable areas along the Rhine. In the northwest of Europe the species often nests in or next to Heron colonies (Glutz von Blotzheim et al. 1971). The area of forest and the area of open water seem to be the limiting factors of the habitat.

Algorithm
Only potential breeding sites are considered. It is assumed that along the Rhine there is enough open water for the Black Kite to forage. One pair of Black Kites in a circle of 5 kilometre needs at least 25-50 ha of softwood forest of which 5 ha should be continuous.

BLACK STORK

Habitat description
In the northwest of Europe Black Storks breed in old growth, almost primaeval deciduous forest (Bauer & Glutz von Blotzheim 1966). Large Oak and Beech are preferred nesting trees, but occasionally Poplar is used and particularly in the mountainous regions of middle and east Europe Pine (Creutz & Creutz 1970; Kalocsa 1993; Sackl 1985). The species is highly territorial and the minimum distance between nests is on average 1 kilometre (Kalosca 1993).
From literature, the picture emerges that in all of its geographical range the Black Stork is a bird of densely forested landscapes, although this probably is a condition on a local rather than on a regional level (Bauer 1952). Sackl (1985) analysed the
landscape in a 4 kilometre radius around Black Stork nests in Austria and stated that a Black Stork landscape usually contains about 50% forest (about 2500 ha) and that this is validated in other important breeding areas (e.g. Trebon region, Czech Republic; Nedbalova & Sevcik 1994).

The nest site is usually not further than a few kilometres from the preferred foraging sites (Dornbusch 1992). Black Storks forage in sheltered shallow waters, e.g. side channels bordered with forest, small streams and ponds in forests, wet forest meadows and moderately forested brook valleys. The food consists mainly of fish, amphibians and crustaceans (Bauer & Glutz von Blotzheim 1966; Cramp 1977). The minimum suitable foraging area can be expressed as the length of streams and brooks. The total length of potential foraging waters has to be at least 20-40 kilometres (Sackl 1985). Other authors mention a total area needed of at least 5000 ha (Dornbusch 1992).

**Algorithm**

One pair of Black Storks needs 1500-5000 ha of suitable habitat (forest and shallow water e.g. side channels) to forage and find nesting places. In a circle with a radius of 5 kilometre the amount of forest and open water has to be larger than 40% and 1500 ha respectively, and the size of the floodplain and side channel areas has to be larger than 500 ha (to ensure enough watersides to forage). Old growth hardwood forest should be present to build nests and the actual number of breeding pairs is determined by a minimum distance of 1 km between nesting sites.

**NIGHT HERON**

**Habitat description**

The Night Heron is a typical inhabitant of wet softwood forests. It usually breeds in colonies, often mixed with other heron species. Night Herons use branches of trees directly above open water, e.g. willows along the river or softwood forest standing in water as nesting and favourite roosting sites (Alieri & Fasola 1992). It mainly feeds on aquatic invertebrates, amphibians and fish caught in shallow waters, e.g. macrophyte marshland, softwood forest, side channels (Bauer & Glutz von Blotzheim 1986).

The size of the colonies depends on the one hand upon the size of the suitable breeding forests and on the other upon the area of freshwater macrophyte marshland in the neighbourhood. Data on the amount of freshwater macrophyte marshland in the neighbourhood of some colonies in southern France were used to develop a carrying capacity function by plotting area vs. number of breeding pairs (after data of Hafner & Fasola 1992).

Although foraging Night Herons can be found up to 10-20 km from the colony, most feeding movements are in a region of 5 kilometres (Hafner & Fasola 1992). Based on other results the relation between colony and forest size has been identified: large colonies (>10 pairs) need an area of 10 ha of suitable breeding forest (Alieri & Fasola 1992). Smaller numbers can be expected in areas with at least 2 ha suitable breeding habitat.

**Algorithm**

Circles (radius 5 km) with a total foraging area larger than 10 ha are selected. To calculate the carrying capacity in resulting suitable areas the total amount of feeding area is multiplied by 0.05 (minimum factor) and 0.125 (maximum factor). For foraging areas between 10 and 90 ha the largest softwood forest must be larger than 2 ha, otherwise the carrying capacity is considered to be zero. For areas larger than 90 ha the largest softwood forest must exceed 10 ha, otherwise the carrying capacity range
will be 5-11 pair (i.e. carrying capacity at 90 ha and forest size 2 ha). The mapped softwood forests are probably only in some cases of the preferred type. Age and exact location were not mapped, so predicted numbers are quite optimistic in view of the strong preference for waterbound breeding places.

WHITE-TAILED EAGLE

Habitat description
In central Europe the nesting sites of the White-tailed Eagle mainly consist of old, ancient trees (Glutz von Blotzheim et al. 1971). Oak, Pine and Beech are preferred nesting trees, usually in edge situations or solitary standing trees. Occasionally nests are found in relatively young and small trees like Willows and Poplars (see Helmer & Wittgen 1994 for references). For feeding, the White-tailed Eagle prefers open waters and marshes within 5 km of the nest, which have large concentrations of fish and large birds, like ducks and coots (Oehme 1961; Looft & Busche 1981; Helmer & Wittgen 1994). It is assumed that prey availability is sufficient in the study area (see also Helmer & Wittgen 1994). One pair needs 2000-5000 ha of suitable habitat (riverine forest, macrophyte marshland and shallow open water)(see Helmer & Wittgen 1994 for a review).

Algorithm
First, circles with a radius of 5 kilometres are selected with at least 2000 ha of suitable habitat. Suitable habitat consists of side channels, open water and macrophyte marshland. If the area of suitable elements within the boundaries of the study area is larger than 1000 ha the total area within these boundaries is considered suitable, since it is expected that the White-Tailed Eagle also makes use of other wet areas such as wet meadows and softwood forest if they are distributed fine-grained in the study area. The only circles included are those with old forest patches larger than 5 ha (usually embedded in a much larger forest). After clustering the selected circles the total amount of suitable habitat is calculated to derive the carrying capacity. The minimum value is 5000 ha suitable habitat and the density ranges from 1 pair per 2000 to 5000 ha.

BARBEL

Habitat description
The Barbel is a strictly rheophilic species, requiring oxygen-rich flowing water. It is also an indicator of the Barbel-zone of rivers. The River Rhine, upstream of Nijmegen has characteristics of a Barbel-zone, but at present suitable spawning grounds, e.g. side channels, are absent (Bergers 1991 and personal communication; de Groot 1991).

Algorithm
To distinguish suitable spawning grounds, circles with a radius of 2 km are used. Suitable spawning grounds are river reaches which have side-channels. Side channels in the Barbel zone are considered more important than outside this zone. It is not possible to make predictions on the carrying capacity because of the lack of knowledge concerning the autecology of the species.
MIDDLE SPOTTED WOODPECKER

General description
The Middle Spotted Woodpecker is a species living in old growth, deciduous forest. It prefers tree species with a rough bark, like Oak, Ash or Elm. The species has its highest density in hardwood riverine forest with mean tree diameters larger than 50 cm. In section 2.3 it is described which forest vegetation data have been collected for the present situation. Hardwood forest has been mapped and digitized in several categories (Oak stands, Beech stands, Mixed Oak-Beech stands) and these maps give a good description of the Middle Spotted Woodpecker habitat. Since from literature data it is clear that the dispersal range is limited (see e.g. Müller 1982) all suitable habitat, has been mapped in a radius of 10 km only. In case of the scenarios hardwood forest has been selected out of the terminal forest vegetation.

Algorithm
Based on literature data (e.g. Müller 1982; Flade 1994; Schmitz 1993) the following densities have been assumed:

- Oak forest 0.35 territories per ha
- Oak-Beech forest 0.10 territories per ha
- Beech-Oak forest 0.05 territories per ha
- Beech forest 0 territories per ha

The carrying capacity in a patch is the simple product of territory density and area of the patch. It is assumed that riverine hardwood forest developed in the scenarios equals 'Oak' forest.

GREAT REED WARBLER

General description
The Great Reed Warbler is an inhabitant of reed beds along open water. It prefers the reed standing in the water for breeding and often forages in other helophyte vegetation or in shrubs and bushes (e.g., Leisler 1981; Grüll & Zwicker 1993; Bauer et al. 1993; Teixeira 1979). As a result of the LEDESS procedure the amount of macrophyte marshland in the study area can be predicted under the conditions of a scenario. Regarding the specific demands of the Great Reed Warbler this is not a good measure for the amount of habitat. It is assumed that 75% of macrophyte marsh in riverine situations consist of reed. Furthermore 30% is regarded to be suitable for Great Reed Warblers i.e. old reedbeds in water (22.5% of total macrophyte marsh; based on data of Foppen for the eastern part of the Rhine Valley in The Netherlands). For reed areas in the present situation only the 30% rule is used.

Algorithm
Based on the data in literature an algorithm is used with two parameters: reed area and amount of surrounding non-reed marshland. In figure 4.4 the relation area of reed and carrying capacity (expressed as the number of breeding pairs) is shown. The larger the amount of surrounding marshland the larger the carrying capacity for a certain area. As a lower limit the size of the reed area has to be >0.25 ha.
Fig. 4.4. Relation between the area of suitable reed and the expected carrying capacity for the Great Reed Warbler. The different lines are for different amounts of surrounding marshland (expressed relative to the area of reed).

BITTERN

General description
The Bittern prefers large reed marshes with open water to forage and mostly wet and broad reedbeds to build nests (e.g. Gauckler & Kraus 1965; Cramp & Simmons 1977). All kinds of macrophyte marshland vegetations are used to forage. As a result of the LEDESS procedure the amount of macrophyte marshland in the study area can be predicted under the conditions of a scenario. It is assumed that 75% of macrophyte marsh in riverine areas consist of reed of which 60% is suitable for the Bittern (45% of total macrophyte marsh). For reed areas in the present situation only the 60% rule is used.

Algorithm
Based on the data in literature an algorithm is used with two parameters: reed area and the amount of surrounding other marshland. In figure 4.5 the relation between area reed and carrying capacity (expressed as the number of breeding pairs) is shown. The larger the amount of surrounding marshland the larger the carrying capacity for a certain area. As a lower limit the size of the reed area has to be >1 ha.
Fig. 4.5. Relation between the area of suitable reed and the expected carrying capacity for the Bittern. The different lines are for different amounts of surrounding marshland (expressed relative to the area of reed).

### 4.4 MODELLING SPATIAL POPULATION DYNAMICS: THE LARCH/METAPHOR APPROACH

#### 4.4.1 Introduction

Generally, the mean expected size of a population will be lower than the carrying capacity. This is due to the fact that environmental factors cause fluctuations in mortality and reproduction. If the numbers are low and/or the fluctuations large, a population might not even be viable because the chance of local extinction is very high (Goodman 1987; Shaffer 1987). In spatially structured or network populations which consist of small habitat units, this can lower the occupation chance of habitat units. As long as the distances between habitat units are not too large, recolonisations can occur due to exchange of individuals between patches (dispersal). With increasing distances between the units, however, the chance increases that the whole network population will become extinct (Opdam et al. 1993; Verboom et al. 1993). In that case, the network can not support a viable population anymore. Evidence for these effects on fauna species have been shown in several studies (Opdam 1991; Opdam et al. 1993, 1995).

In this study the network function is evaluated by the following parameters:
- population viability;
- population saturation, mean total population size divided by the carrying capacity;
- stepping stone function, to what degree can a species reach all parts of the study area.

Depending on the available knowledge, these parameters are estimated by using expert judgement (LARCH approach, section 4.4.2) or by simulating the spatial population dynamics (METAPHOR approach, section 4.4.3). The population saturation can only be assessed with the METAPHOR approach.
4.4.2 LARCH approach

LARCH (LAndscape ecological Rules for the Configuration of Habitat) is a decision-support system, developed by the department of Landscape Ecology of the IBN-DLO. The aim is to make available knowledge on habitat fragmentation applicable to a wide range of species and ecosystems.

VIABILITY
To estimate the viability of spatially structured populations, the system was updated by Kalkhoven et al. (1995). For populations of the target species in an isolated area, viable populations have at least 100-250 reproducing females. If the isolation is absolute the upper margin (250) will be valid, if once in a while there is some influx (e.g. one individual per generation) the lower margin (100) is probably more valid. If the influx is larger the population can be treated as part of a network. As a result, they can become viable if the number of reproducing females is at least 20, provided that the number for the network is 250 or more. The areas which support such local viable populations are defined as core areas. For every target species a choice has to be made whether the study area population is part of a network or has to be considered being isolated.

The number of reproducing females is estimated from the carrying capacity. Normally populations do not occur at the carrying capacity level but at lower levels. The actual percentage (degree of saturation) e.g. depends upon the vulnerability to catastrophes and the spatial configuration of the network. A range of percentages was chosen: 50-75%. To estimate the number of reproducing females, the lower level was multiplied with the lower range of the carrying capacity and the upper level with the upper range of the carrying capacity. The resulting figures have been used to derive the viability of the population:

1. viable (+), expected lowest number of reproducing females is above the upper limit value (20, 100 or 250);
2. marginally viable (±), expected largest number of reproducing females is above the and the expected smallest number below the upper limit (20, 100 or 250);
3. not viable (-), expected largest number of reproducing females is below the upper limit (20, 100 or 250).

Example: an area has 80 km of edge habitat between softwood forest and water. Following the algorithms for the Beaver this area can support 27-40 Beaver families. Using the saturation correction this leads to an expected population size of 14-30 Beaver families. When the population is part of an network (threshold value is 20), the viability will be marginal.

STEPPING STONE FUNCTION
The stepping stone function is absent when the population is not viable. For marginally viable and viable populations three classes were distinguished: high, moderate and low (see table 4.4).
Table 4.4. Estimation of the stepping stone function for LARCH species. Viability, + viable, ± marginally viable, - not viable. Stepping stone function: + high, ± moderate, - low, -- absent.

<table>
<thead>
<tr>
<th>Distribution of habitat in the study area</th>
<th>Viability</th>
<th>Stepping stone function</th>
</tr>
</thead>
<tbody>
<tr>
<td>West + Centre + East</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>±</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>--</td>
</tr>
<tr>
<td>Two of the three parts</td>
<td>+</td>
<td>±</td>
</tr>
<tr>
<td></td>
<td>±</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>--</td>
</tr>
<tr>
<td>One part or absent</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>±</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>--</td>
</tr>
</tbody>
</table>

4.4.3 METAPHOR approach

4.4.3.1 The METAPHOR model

METAPHOR MODEL STRUCTURE
METAPHOR (figure 4.6) simulates the dynamics of a spatially structured population. A spatial structured population is a set of local populations connected through dispersal. Males and females are taken into account and the population has an age structure, consisting of juveniles and adults. The three most important model components are recruitment, mortality and dispersal.

Recruitment and mortality determine the local population dynamics (i.e. of habitat units). Population dynamics are stochastic, i.e. chance plays a role. There are two types of stochasticity. Demographic stochasticity is the effect of chance events due to individual fate and a small population size. Environmental stochasticity is modelled as a yearly fluctuation of mortality and recruitment rates.

Recruitment is modelled on a year to year basis and is the expected number of one year old individuals of a sex per patch (habitat unit). Recruitment is density dependent. Mortality is also modelled on a yearly basis. Each individual has a probability of survival depending on the yearly variation in expected mortality, age and local population density.

Dispersal consists of emigration, movement and immigration. Emigration from a patch depends on age, sex, density and patch area. The movement of birds has two aspects: where to go and whether or not to survive. The probability that individuals will arrive in other patches is calculated using a separate GIS model. After arrival in a patch, population size of the sex of the immigrating individual is compared with carrying capacity. If the patch is above carrying capacity, the individual gets a new opportunity to disperse with the patch of arrival as source patch. If it arrives in a full patch in its last dispersal attempt, it is assumed to stay there.


MODEL INPUT AND SIMULATION PROCEDURE
The input for METAPHOR consists of:
- a GIS-database which comprises the habitat pattern and characteristics;
- a species specific algorithm linking habitat characteristics to carrying capacity (see section 4.2);
- a GIS-database describing the dispersal probabilities between habitat units.
Each simulation takes 150 years and starts with all habitat units at carrying capacity and consists of 100 runs. Because populations need some time to reach equilibrium, the first 50 years are not taken in account.

OUTPUT
The primary output of the simulation consists of several statistics of which the following are used:
- the chance of occurrence per habitat unit (data and map);
- the mean total population size;
- the survival chance of the whole population (the percentage of runs in which the population did not become extinct).

These data are used to estimate the network parameters:
- viability of the population in three classes: + survival chance >90%, ± survival chance 50-90%, - survival chance <50%.
- saturation: mean total population size divided by the carrying capacity.
- stepping stone function in three classes: to what degree can a species reach all parts of the study area. See table 4.5.

![Fig. 4.6. Overview of METAPHOR approach (see text for further explanation)](image-url)
Table 4.5. Estimation of the stepping stone function for METAPHOR species. + high, ± moderate, - low, -- absent.

<table>
<thead>
<tr>
<th>Presence of habitat units with chance of occurrence &gt;90% in the west, centre and east of the study area</th>
<th>Stepping stone function</th>
</tr>
</thead>
<tbody>
<tr>
<td>West + Centre + East</td>
<td>+</td>
</tr>
<tr>
<td>Two of the three parts</td>
<td>±</td>
</tr>
<tr>
<td>One part or absent</td>
<td>-</td>
</tr>
</tbody>
</table>

4.4.3.2 Introduction to species models

GENERAL REMARKS
The species models used are existing models some of which have been slightly adapted. For a full description and explanation of these models, in particular the estimation of the parameter values, one can refer to forthcoming publications of the Department of Landscape Ecology of IBN-DLO. Here, only some general points are made.
By interpreting the results of the models one should take into account that the models are not yet validated. Nor it is possible at the moment to estimate the uncertainty in the output parameters of the models. Therefore, it is recommendable to use the results for a relative comparison of the alternatives and the present situation, and not to give small differences in output parameters too much value.

MIDDLE SPOTTED WOODPECKER
The model is derived from existing models for woodland birds. Model parameters are estimated by using data from the literature. Calibration has been carried out with data from north Switzerland (Müller 1982).

GREAT REED WARBLER
The model is based on a general marsh warbler model developed for a study that exploring different scenarios for marshland development in The Netherlands. Model parameters are estimated by using data of the Great Reed Warbler. Calibration has been carried out in two steps. First, available distribution data from around 1970 have been used to calibrate the model (van den Bergh et al. 1979). The population decreased drastically since then, probably due to detrimental drought effects in the winter quarters in Africa. An extra mortality has been introduced to simulate this effect. Present distribution data have been used to calibrate this last step (unpublished dat R.P.B. Foppen and SOVON).

BITTERN
The simulation model for the Bittern has been developed for a study that explores different scenarios for marshland rehabilitation in The Netherlands. The model has been calibrated with distribution data for the whole of The Netherlands (based on Teixeira 1979) and the immediate surroundings (including the Rhine-econet study area). The model has not been adapted further for this study.
### RESULTS

<table>
<thead>
<tr>
<th>RHINE-ECONET</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>LANDSCAPE ECOLOGICAL SYSTEMS ANALYSIS (2)</td>
<td>SCENARIOS (3)</td>
</tr>
<tr>
<td>MODELLING</td>
<td></td>
</tr>
<tr>
<td>NATURE</td>
<td></td>
</tr>
<tr>
<td>REHABILITATION (4)</td>
<td></td>
</tr>
<tr>
<td>RESULTS (5)</td>
<td></td>
</tr>
<tr>
<td>EVALUATION OF METHOD (6)</td>
<td>EVALUATION OF RESULTS (7)</td>
</tr>
</tbody>
</table>
5.1 INTRODUCTION

In this chapter the results of the modelling procedure are presented and explained. At first the expected ecotope pattern (in terms of physiotopes and terminal vegetations) of the three scenarios determined by the LEDESS approach is described and compared with the present situation (section 5.2). Then the consequences for the network function of species based on the LARCH approach (section 5.3) and the METAPHOR approach (section 5.4) are shown and the influence of area of relevant habitat types and distribution strategy of new nature is discussed (section 5.5). Finally, some general conclusions are made on the network function of the four habitat types (section 5.6).

5.2 ECOTOPES

5.2.1 Outline

The consequences of the three scenarios for the ecotopes of the river system are determined with the LEDESS model. In this section the results of the computation are focused to the question: can the patterns of target nature types in the different scenarios be realised and if the objectives are not attained what are the limitations. This will be discussed, firstly for the changes in physiotopes (5.2.2) and secondly for the changes in vegetations (5.2.3). The results are compared with the present situation.

5.2.2 Physiotopes

The physiotope cover in hectares is presented for the present situation and the three future situations according to the scenarios in table 5.1. Also the change in area compared with the present situation is indicated. The maps of changed physiotopes are given in a series of maps for three sections of each scenario (Annexes, Map 4). The changes in physiotopes reflect the elaborations of the scenarios mentioned in chapter 3. Small changes, often due to technical faults in the transport of the scenario design into the GIS, do not have impact on the final results and are neglected. The most important changes are as follows:

- In the Rhine-Traditional scenario, compared with the present situation the main change in physiotopes is due to the digging of shallow water in order to develop suitable sites for macrophyte marshes and softwood forests. The consequence is a shift from the recultivated floodplains (physiotope Af, Bf and Cf) to the closed floodplain channels (Ai, Bi and Ci respectively). Suitable sites are situated in non-protected floodplains or can be protected by minor dikes. A few sites are found on floodplains protected by main dikes. These sites are concentrated in the former Rhine-channel-area located in the Gelderse Poort area, the so-called "Rijnstrangen".

- In the Loire-River dynamics scenario, an obvious change in physiotopes occurs in favour of the restoration of side channels and connected floodplain channels. Due to measures, which connect isolated waters to the river, minor dikes are removed on several locations. The result is a shift from the hydrological unit B, physiotopes protected by minor dikes, to the unit A, non-protected physiotopes. The most suitable sites are found in the existing closed and stagnant floodplain channels and closed pits. There are no entirely newly dug side channels.

- The Mississippi-spillway scenario provides most changes in physiotopes protected
by main dikes. Flood basin (Cn), recultivated areas (Cf) and former natural levees (Ce) are converted into back swamps (Co) and pits (Cl) in order to retain the discharge of the waterbody by planned spillways during wintertime.

Table 5.1. Physiotope cover (ha) for the present situation and the scenarios. For the description of physiotopes see table 2.2 and Appendix 2.

<table>
<thead>
<tr>
<th>Phytotope</th>
<th>Present</th>
<th>Rheine-Tredionet change from Present</th>
<th>Loire-River change from Present</th>
<th>Mississippi-Spillway change from Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aa</td>
<td>8069</td>
<td>0</td>
<td>8069</td>
<td>8069</td>
</tr>
<tr>
<td>Ab</td>
<td>10</td>
<td>0</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Ac</td>
<td>0</td>
<td>0</td>
<td>3674</td>
<td>3674</td>
</tr>
<tr>
<td>Ad</td>
<td>2015</td>
<td>-1</td>
<td>2014</td>
<td>-1</td>
</tr>
<tr>
<td>Ae</td>
<td>4003</td>
<td>13</td>
<td>3872</td>
<td>-31</td>
</tr>
<tr>
<td>Af</td>
<td>4512</td>
<td>-1787</td>
<td>4399</td>
<td>-123</td>
</tr>
<tr>
<td>Ag</td>
<td>92</td>
<td>0</td>
<td>87</td>
<td>-6</td>
</tr>
<tr>
<td>Ah</td>
<td>471</td>
<td>0</td>
<td>1009</td>
<td>538</td>
</tr>
<tr>
<td>Al</td>
<td>438</td>
<td>1743</td>
<td>172</td>
<td>-264</td>
</tr>
<tr>
<td>Am</td>
<td>1933</td>
<td>-1781</td>
<td>172</td>
<td>-1781</td>
</tr>
<tr>
<td>Al</td>
<td>372</td>
<td>0</td>
<td>157</td>
<td>-215</td>
</tr>
<tr>
<td>Subtot.</td>
<td>21 913</td>
<td>-42</td>
<td>23 826</td>
<td>1712</td>
</tr>
<tr>
<td>Bd</td>
<td>277</td>
<td>0</td>
<td>277</td>
<td>0</td>
</tr>
<tr>
<td>Be</td>
<td>2307</td>
<td>-4</td>
<td>2303</td>
<td>-4</td>
</tr>
<tr>
<td>Bf</td>
<td>3501</td>
<td>-1464</td>
<td>3567</td>
<td>88</td>
</tr>
<tr>
<td>Bi</td>
<td>2163</td>
<td>1342</td>
<td>684</td>
<td>-1589</td>
</tr>
<tr>
<td>Bl</td>
<td>303</td>
<td>0</td>
<td>156</td>
<td>-147</td>
</tr>
<tr>
<td>Bm</td>
<td>42</td>
<td>0</td>
<td>42</td>
<td>0</td>
</tr>
<tr>
<td>Subtot.</td>
<td>8593</td>
<td>-128</td>
<td>8497</td>
<td>-1654</td>
</tr>
<tr>
<td>Ce</td>
<td>9719</td>
<td>0</td>
<td>9719</td>
<td>0</td>
</tr>
<tr>
<td>Cf</td>
<td>1396</td>
<td>-74</td>
<td>1396</td>
<td>0</td>
</tr>
<tr>
<td>Cl</td>
<td>672</td>
<td>123</td>
<td>572</td>
<td>0</td>
</tr>
<tr>
<td>Cj</td>
<td>101</td>
<td>0</td>
<td>0</td>
<td>-101</td>
</tr>
<tr>
<td>Cl</td>
<td>633</td>
<td>0</td>
<td>633</td>
<td>0</td>
</tr>
<tr>
<td>Cn</td>
<td>4826</td>
<td>0</td>
<td>4626</td>
<td>0</td>
</tr>
<tr>
<td>Cn</td>
<td>29</td>
<td>74</td>
<td>28</td>
<td>0</td>
</tr>
<tr>
<td>Cp</td>
<td>45</td>
<td>0</td>
<td>46</td>
<td>0</td>
</tr>
<tr>
<td>Subtot.</td>
<td>17 120</td>
<td>123</td>
<td>17 018</td>
<td>-101</td>
</tr>
<tr>
<td>Total:</td>
<td>47 828</td>
<td>123</td>
<td>47 588</td>
<td>-43</td>
</tr>
</tbody>
</table>

1The total acreage encloses the winterbed and adjacent areas.
5.2.3 Target nature types and terminal vegetations

One may ask whether the target nature types designated in the scenarios will be accomplished in the terminal vegetations completely or partly. According to the starting-points in the scenario approach (see chapter 3) for nature rehabilitation 10,000 ha are available. Dependent on the leading concept, suitable sites and claims about spatial distributions the target nature types are allocated in each scenario. The total areas for target nature types should be assigned as follows:

- Rhine-Traditional scenario: 5000 ha of forest (target nature types N1 and N2) and 5000 ha of macrophyte marshes (N3);
- Loire-River dynamics scenario: 10,000 ha riverine forest landscape (N7), including side channels and connected flood plain channels (N4 and N5);
- Mississippi-Spillway scenario: 9000 ha of inland macrophyte marshes (N3) managed on a natural way (including softwoods) and 1000 ha of hardwood forests (N2).

In table 5.2 an overview of the target nature types in each scenario is given.

Since the area available for nature rehabilitation will be withdrawn mainly from agricultural land the allocation of target nature types on existing non-agricultural land, as planning of side channels on isolated flood plain channels has to be subtracted. This concerns changes in nature management or in hydrological connections with the riversystem. For that reason Loire-River dynamics scenario is corrected for the assigned target nature types N4, side channel, and N5, floodplain channel. Eventually the total area of target nature types of each scenario has an acceptable deviation (<10%) from the starting-point of 10,000 ha for nature rehabilitation.

Table 5.2. Area (ha) of target nature types for the three scenarios.

<table>
<thead>
<tr>
<th>Target nature type</th>
<th>Rhine-Traditional</th>
<th>Loire-River dynamics</th>
<th>Mississippi-Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1 Softwood</td>
<td>2502</td>
<td>0</td>
<td>317</td>
</tr>
<tr>
<td>N2 Hardwood</td>
<td>2848</td>
<td>0</td>
<td>938</td>
</tr>
<tr>
<td>N3 Macrophyte marsh</td>
<td>4284</td>
<td>0</td>
<td>8436</td>
</tr>
<tr>
<td>N4 Side channel</td>
<td>0</td>
<td>251</td>
<td>0</td>
</tr>
<tr>
<td>N5 Floodplain ch.</td>
<td>0</td>
<td>413</td>
<td>0</td>
</tr>
<tr>
<td>N8 Isolated water</td>
<td>0</td>
<td>0</td>
<td>1107</td>
</tr>
<tr>
<td>N7 River,landscape</td>
<td>0</td>
<td>8798</td>
<td>0</td>
</tr>
<tr>
<td>Total:</td>
<td>10,834</td>
<td>9453</td>
<td>10,796</td>
</tr>
</tbody>
</table>

More interesting than the final distribution of target nature types in the scenarios is the expected terminal vegetations: does the scenario finally attain the targets? Although different in distribution patterns according to the assumption made (see chapter 3) all scenarios should attain an equal total area of forests and macrophyte marshes (5000 ha), for the impact of the habitat distribution on the network function of the fauna species has to be evaluated. So, in order to compare the results on an equal basis the areas of habitats have to be equal as possible in each scenario. Table 5.3 gives the expected terminal vegetations. The maps of terminal vegetations are given in a series of maps for three sections of each scenario (Annexes, Map 4).
Dependent on the suitable physiotope the terminal vegetation deviates from the expected target nature type. The results clearly show this.

In the Rhine-Traditional scenario many physiotopes are still not suited to develop vegetations with a high percentage of macrophyte marshes. The target nature type N3 turns out to develop softwood forest (V1) and isolated water (V5) as well as macrophyte marsh (V3). So, the development of macrophyte marshes remains below the expectation, whereas softwood forests is beyond.

### Table 5.3. Area (ha) of terminal vegetations in the present situation and for the three scenarios.

<table>
<thead>
<tr>
<th>Terminal vegetation</th>
<th>Present</th>
<th>Rhine-Traditional</th>
<th>Loire-River dynamics</th>
<th>Mississippi-Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td>V1 Softwood forest</td>
<td>396</td>
<td>2643</td>
<td>3219</td>
<td>4405</td>
</tr>
<tr>
<td>V2 Hardwood forest</td>
<td>10</td>
<td>2894</td>
<td>2043</td>
<td>842</td>
</tr>
<tr>
<td>V3 Macrophyte marsh</td>
<td>640</td>
<td>1471</td>
<td>113</td>
<td>2601</td>
</tr>
<tr>
<td>V4 Open water</td>
<td>2404</td>
<td>181</td>
<td>2824</td>
<td>0</td>
</tr>
<tr>
<td>V5 Isolated water</td>
<td>4580</td>
<td>2768</td>
<td>38</td>
<td>2840</td>
</tr>
<tr>
<td>V6 Grass/rough</td>
<td>?</td>
<td>386</td>
<td>4386</td>
<td>94</td>
</tr>
<tr>
<td>V7 Beach/gravel/mud</td>
<td>?</td>
<td>380</td>
<td>809</td>
<td>10</td>
</tr>
</tbody>
</table>

Due to natural grazing management the Loire-River dynamics scenario will develop a mosaic of grassland (V6), bare soil (V7), softwood (V1) and on less flooded physiotopes hardwood (V2). The area of macrophyte marshes remains far below the planned 5000 ha. According to this scenario the isolated waters are mainly transformed into waters connected with the riversystem (V4), such as side channels and connected flood plain channels. The forest part of the scenario is almost as planned (5000 ha).

The Mississippi-Spillway scenario shows the greatest contribution to the development of macrophyte marshes. However, caused by the natural manner of back swamp management chosen, the macrophyte marshes (V3) are only a third of the total inland areas planned for nature rehabilitation (N3). Most part of this target nature type will develop in softwood forest (V1) or isolated waters (V5).

So, in summary all three scenarios are unable to produce sufficient macrophyte marsh while staying within the 10,000 ha limit for nature rehabilitation. The forests target can be fulfilled, however.
5.3 FAUNA SPECIES: NETWORK FUNCTION LARCH APPROACH

5.3.1 Outline

At first the status of species in and around the study area is discussed. Based on this and on available data on the dispersal capacity for species which are not present at the moment, it is estimated whether there is a chance that they really will be able to settle in the area. Next the results for the scenarios are presented and evaluated.

The results for the present situation and each scenario are shown in a table and a figure. The table presents (1) the amount of suitable habitat, (2) the expected viability for the population and (3) the stepping stone function. The figure contains distribution maps of suitable habitat and carrying capacity. Furthermore the minimal and maximal numbers of breeding pairs expected at carrying capacity are given for the present situation and the three scenarios.

To judge the viability two options are considered:
1. the population is almost completely isolated. In this case the number of reproductive females needed for a viable population is 100.
2. the population can be considered part of a network. In this case the number of reproducing females needed for a viable core population within the network is 20.

To compare the scenarios the following aspects are discussed:
1. viability of the population;
2. stepping stone function.
5.3.2 Beaver

The results for the Beaver are presented in table 5.4 and figure 5.1.

PRESENT STATUS
The Beaver became extinct almost 100 years ago in The Netherlands, but has recently been introduced into several areas: In the ‘Biesbosch’, situated at the west border of the study area, and in the ‘Gelderse Poort’, situated in the center of the study area. In the ‘Gelderse Poort’ Beavers have been reintroduced in the Millingerwaard (3 families) and in an area just outside the study area in the Ooypolder (Groenlanden, 3 families). Furthermore there have been several reintroduction programmes in Germany, e.g. the Eifel. Some Beavers sighted just over the German border in the Dutch province of Limburg (about 60 kilometres from the study area) probably originate from these regions. It is doubtful whether the populations in the central part of the study area (Gelderse Poort) can have exchange with the Biesbosch ones. Nolet (1994) states that the distance between the two locations (100 km) falls just within the dispersal range of the species. Therefore, the lower limit for the number of families for a viable population should be 100.

There are two suitable areas which coincide very well with the places where Beavers have been reintroduced. However, the carrying capacity is too low to expect a viable population and there is no stepping stone function.

SCENARIOS

Viability
Owing to the distribution of suitable habitat, Beaver populations in the Rhine-traditional and Loire-River dynamics scenarios are considered to be part of a larger network. Therefore, the lower limit for the number of families for a viable population is considered 20. Using this criterium, one can expect a viable population in the Loire-River dynamics scenario and a marginal viability for the population in the Rhine-Traditional scenario.

Because the habitat pattern in the Mississippi-Spillway scenario is very similar to the pattern of the present situation, here 100 families is taken as the lower limit for a viable population. Although this scenario comprises the largest areas of softwood forest, the expected carrying capacity for the Beaver is much lower than in the other scenarios. Most of the softwood forest is not suitable, because it is situated outside the winterbed in back swamps. As a result the population is not viable.

Stepping stone function
Based on the distribution of suitable habitat it is assumed that in the Loire-River dynamics scenario the Beaver is present in most parts of the study area. In the other scenarios the stepping stone function is considered low (Rhine-Traditional) or absent (Mississippi-Spillway).
Table 5.4. Beaver: amount of suitable habitat, population viability (+ viable, ± marginal, - not viable) and stepping stone function (+ high, ± moderate, - low, -- absent).

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Present situation</th>
<th>Rhine-Traditional</th>
<th>Loire-river dynamics</th>
<th>Mississippi-Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edge length softwood forest and water (km)</td>
<td>12</td>
<td>107</td>
<td>150</td>
<td>49</td>
</tr>
<tr>
<td>Viability</td>
<td>-</td>
<td>±</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Stepping stone function</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>--</td>
</tr>
</tbody>
</table>

Fig. 5.1. Results for the Beaver. One map (upper left) showing areas with equal densities in the present situation and three maps (right side) for the scenarios. The numbers indicate the carrying capacity (minimum and maximum) of different parts of the area. The total carrying capacity (minimum and maximum) is shown in a high-low graph (middle of left page).
Fig. 5.1 BEAVER LARCH approach

PRESENT SITUATION

Suitable habitat and carrying capacity

- 0.1 - 0.5 pairs / km²
- 0.5 - 1 pairs / km²
- > 1 pairs / km²

Study area

Carrying capacity (number of pairs)

0 20 40 60 80

Present situation Rhine-Traditional Loire-River dynamics Mississippi-Spillway
5.3.3 Black Kite

The results for the Black Kite are presented in table 5.5 and figure 5.2.

PRESENT STATUS
The Black Kite is a very rare breeding bird in the study area. In the Rhine valley repeated breeding has been reported from areas just south of our study area (Mildenberger 1982). The nearest breeding places are less than 25-50 kilometres away. Studying the European distribution map gives the impression that the species is at the borderline of its geographical distribution in the study area. In the upper Rhine area the Black Kite is quite common and the numbers gradually decrease from south to north and east to west. However, this assumption is counteracted by the fact that there have been several cases of breeding records in the province of Flanders in Belgium (Devillers et al. 1988). The chance of colonisation of the study area is probably high, but the numbers will be low. So, under the present conditions the study area is quite isolated and has no chance of being part of a network. Therefore, to support a viable population the expected number of pairs should be 100.

Suitable habitat for Black Kites is only present in the central part of the study area ("Gelderse Poort"). The predicted carrying capacity, however, is too low to support a viable population and there is no stepping stone function.

SCENARIOS

Viability
Assuming that the area is quite isolated, populations in all scenarios reach a marginal viability. The Mississippi-Spillway scenario has the highest carrying capacity (89-179 breeding pairs).

Stepping stone function
Due to the marginal viability of the populations the stepping stone function is low in all scenarios.
Table 5.5. Black Kite: amount of suitable habitat, population viability (+ viable, ± marginal, - not viable) and stepping stone function (+ high, ± moderate, - low, -- absent).

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Present situation</th>
<th>Rhine-Traditional</th>
<th>Loire-River dynamics</th>
<th>Mississippi-Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of softwood forest (ha)</td>
<td>178</td>
<td>2730</td>
<td>3328</td>
<td>4493</td>
</tr>
<tr>
<td>Viability</td>
<td>-</td>
<td>-</td>
<td>±</td>
<td>±</td>
</tr>
<tr>
<td>Stepping stone function</td>
<td>--</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Fig. 5.2. Results for the Black Kite. One map (upper left) showing areas with equal densities in the present situation and three maps (right side) for the scenarios. The numbers indicate the carrying capacity (minimum and maximum) of different parts of the area. The total carrying capacity (minimum and maximum) is shown in a high-low graph (middle of left page).
Fig. 5.2 BLACK KITE
LARCH approach

PRESENT SITUATION

Suitable habitat and carrying capacity

- 0.01 - 0.075 pairs / km²
- 0.075 - 0.15 pairs / km²
- > 0.15 pairs / km²
- Study area

Graph showing carrying capacity:

- Present situation
- Rhine-Traditional
- Loire-River dynamics
- Mississippi-Spillway

Carrying capacity (number of pairs)

0 50 100 150 200

Present situation Rhine-Traditional Loire-River dynamics Mississippi-Spillway
BLACK KITE

SCENARIOS

Rhine - Traditional

Loire - River dynamics

Mississippi - Spillway

20 km
5.3.4 Black Stork

The results for the Black Stork are presented in table 5.6 and figure 5.3

PRESENT STATUS
It is unclear whether the Black Stork is a former breeding bird of the Netherlands but habitat was probably available, especially in riverine areas. Recently the species has shown a marked increase and comeback in areas in Germany and Belgium deserted a long time ago. In Belgium (the Ardennes) the species has increased in seven years’ time from 3 to 30 breeding pairs and is still expanding its range (Schepers 1995). In Germany the situation is comparable (Boettcher-Streim 1992). In the Eifel breeding pairs have been reported in recent years and they are probably also expanding. The nearest breeding places are less than 50 kilometres away. However, since the species is at the utmost border of its range in the study area it is probably not part of a network under the present conditions. Therefore, 100 pairs is used as the lower limit for a viable population.

At present suitable areas are absent. Particularly the amount of forest is too low. In view of its expanding range and the relatively short distances between the study area and the nearest occupied patches there is a good chance that dispersing Black Storks can reach the study area. However, there is almost no chance that the Black Stork will return under the present habitat conditions.

SCENARIOS

Viability
Suitable habitat is only present in the Rhine-Traditional and Loire-River dynamics scenarios (situated in the Gelderse Poort). Because the carrying capacities are very low (0-1), populations are not viable.

Stepping stone function
There is no stepping stone function.
Table 5.6. Black Stork: amount of suitable habitat, population viability (+ viable, ± marginal, - not viable) and stepping stone function (+ high, ± moderate, - low, -- absent).

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Present situation</th>
<th>Rhine-Traditional</th>
<th>Loire-River dynamics</th>
<th>Mississippi-Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of forest (ha)</td>
<td>0</td>
<td>429</td>
<td>384</td>
<td>0</td>
</tr>
<tr>
<td>Area of floodplain and side-channels (ha)</td>
<td>0</td>
<td>952</td>
<td>946</td>
<td>0</td>
</tr>
<tr>
<td>Viability</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Stepping stone function</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Fig. 5.3. Results for the Black Stork. One map (upper left) showing areas with equal densities in the present situation and three maps (right side) for the scenarios. The numbers indicate the carrying capacity (minimum and maximum) of different parts of the area. The total carrying capacity (minimum and maximum) is shown in a high-low graph (middle of left page).
Fig. 5.3 BLACK STORK
LARCH approach

PRESENT SITUATION

20 km

Suitable habitat and carrying capacity

Suitable habitat

Study area

Present situation Rhine-Traditional Loire-River dynamics Mississippi-Spillway
5.3.5 Night Heron

The results for the Night Heron are presented in table 5.7 and figure 5.4

PRESENT STATUS

The Night Heron is a very rare breeding bird in the Netherlands. In the study area birds are observed in the breeding season every year and there have been several claims of breeding pairs in for instance the ‘Ooypolder’, the ‘Marspolder’ near Lienden, the ‘Noordberg’ and the ‘Rijnstrangen’ area. Just outside the study area, in the Biesbosch, a breeding colony of several pairs has existed for many years. The present situation however is more complicated since at several places (Zwin, Zoos of Amsterdam and Arnhem) former captive birds are known to have founded colonies and bred young and this could have caused the increase in numbers of animals observed in recent years (see also Kurstjens in prep.). However, it seems that the number of colonies and breeding birds has decreased compared to some twenty years ago. As in other heron species a strong dependence is expected on population dynamics in southern Europe. The nearest important breeding areas outside the Netherlands are in the middle of France along the Loire and its tributaries. High population densities caused by favourable wintering conditions and high breeding success could irregularly cause an influx of individuals from these areas to Western-Europe. Since there are no heron rookeries with breeding Night Herons in the neighborhood of the study area the viability criteria for an isolated population probably will apply best (lower limit 100 pairs).

The estimated carrying capacity for the Night Heron under the present conditions is quite large and particularly the ‘Gelderse Poort’ (central part) and ’Kil van Hurwenen’ are (western part) strongholds. Still, this is not sufficient to support a viable population. As a result there is no stepping stone function.

Moreover, the numbers are probably overestimated due to some factors not incorporated in the habitat model:
1. most of the softwood is still too young
2. almost all softwood forest is easily accessible and therefore sensitive to disturbance. Night Herons primarily seek breeding places surrounded by water (Alieri & Fasola 1992).

SCENARIOS

Viability

Although the carrying capacity in the Mississippi-Spillway and Rhine-Traditional scenarios is relatively high, the viability of populations is marginal. Surprisingly, the population in the Loire-River dynamics scenario is not viable. This is caused by the fact that the amount of foraging sites available, e.g. macrophyte marsh, is very low. Possibly, this dependence on marshland foraging sites is somewhat exaggerated. If so, the numbers in the Loire-River dynamics scenario are underestimated. This could mean that the viability in this scenario might also be marginal.

Stepping stone function

In the Rhine-Traditional and Mississippi-Spillway scenarios the stepping stone function is considered low. In the Loire-River dynamics scenario the stepping stone function is absent.
Table 5.7. Night Heron: amount of suitable habitat, population viability (+ viable, ± marginal, - not viable) and stepping stone function (+ high, ± moderate, - low, -- absent).

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Present situation</th>
<th>Rhine-Traditional</th>
<th>Loire-River dynamics</th>
<th>Mississippi-Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of macrophyte marsh (ha)</td>
<td>1031</td>
<td>2176</td>
<td>638</td>
<td>3336</td>
</tr>
<tr>
<td>Viability</td>
<td>-</td>
<td>±</td>
<td>-</td>
<td>±</td>
</tr>
<tr>
<td>Stepping stone function</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Fig. 5.4. Results for the Night Heron. One map (upper left) showing areas with equal densities in the present situation and three maps (right side) for the scenarios. The numbers indicate the carrying capacity (minimum and maximum) of different parts of the area. The total carrying capacity (minimum and maximum) is shown in a high-low graph (middle of left page).
Fig. 5.4 NIGHT HERON
LARCH approach

PRESENT SITUATION

Suitable habitat and carrying capacity

- 0.01 - 0.075 pairs / km²
- 0.075 - 0.2 pairs / km²
- > 0.2 pairs / km²

Study area

Present situation Rhine-Traditional Loire-River dynamics Mississippi-Spillway
NIGHT HERON

SCENARIOS

Rhine - Traditional

Loire - River dynamics

Mississippi - Spillway

20 km
5.3.6 White-tailed Eagle

The results for the White-tailed Eagle are presented in table 5.8 and figure 5.5

PRESENT STATUS
The White-tailed Eagle was formerly a breeding species in the study area but it became extinct a long time ago. Nowadays a few individuals, mainly juveniles, can be seen during winter time. The breeding areas most nearby are in Germany (Schleswig-Holstein and the Elbe region) at about 250-300 km, however a ‘healthy’ and expanding population can only be found at 500 km distance in the Schwerin region (Helmer & Wittgen 1994). The chance of recolonisation is very low in view of the distance between the study area and the nearest expanding population. The dispersal capacity of the species seems to be limited up to distances of around 100 km (Helmer & Wittgen 1994). Considering the enormous distances between the study area and the nearest breeding localities the study area has to be treated as an isolated patch.

There are two potential suitable areas with sufficient foraging habitat: ‘St. Andries’ (in the west) and the ‘Gelderse Poort’ in the central part, which both can support 1-3 breeding pairs. However, taking into account that a suitable breeding area that consists of at least 5 ha of continuous hardwood forest leaves only one area suitable. The expected number of pairs is far below the limit for a viable population and the stepping stone function is absent.

SCENARIOS

Viability
Although there is room for some breeding pairs of this ‘top predator’ in the scenarios, the chances for a viable population are poor, even when the study area would be part of a large network. That is not surprising considering the enormous ‘area demand’ of one breeding pair. However, if the population in the study area is considered as part of a larger local population (including for example the Biesbosch area) it might be viable if linked to other populations in a network. According to the expected carrying capacity the Mississippi-Spillway scenario offers the best opportunities.

Stepping stone function
There is no stepping stone function.
Table 5.8. White-tailed Eagle: amount of suitable habitat, population viability (+ viable, ± marginal, - not viable) and stepping stone function (+ high, ± moderate, - low, -- absent).

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Present situation</th>
<th>Rhine-Traditional</th>
<th>Loire-River dynamics</th>
<th>Mississippi-Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suitable habitat (ha)</td>
<td>6063</td>
<td>13 017</td>
<td>7391</td>
<td>17 972</td>
</tr>
<tr>
<td>Viability</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Stepping stone function</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
</tbody>
</table>

Fig. 5.5. Results for the White-tailed Eagle. One map (upper left) showing areas with equal densities in the present situation and three maps (right side) for the scenarios. The numbers indicate the carrying capacity (minimum and maximum) of different parts of the area. The total carrying capacity (minimum and maximum) is shown in a high-low graph (middle of left page).
Fig. 5.5 WHITE-TAILED EAGLE
LARCH approach

PRESENT SITUATION

Suitable habitat and carrying capacity

- suitable habitat
- Study area

20 km

20 15 10 5 0

Present situation Rhine-Traditional Loire-River dynamics Mississippi-Spillway

Carrying capacity (number of pairs)
5.3.7 Barbel

The results for the Barbel are presented in table 5.9 and figure 5.6

PRESENT STATUS
The species was common in the major rivers in the last century but it nowadays is rarely found in the Rhine between Duisburg and Gorinchem (Böving 1981, Pelzers 1988, Lelek 1989, Heesen 1990, Schouten & Quak 1994). At present spawning grounds are absent. Although Barbels are caught in the study area it is thought that suitable spawning sites are situated outside the study area in Germany (pers. comm. W.Cazemier RIVO-DLO).

SCENARIOS

Viability
Spawning grounds for the Barbel are only developed in the Loire-River dynamics scenario. In this scenario many side channels are constructed. However, there are indications that only side channels along the Rhine between Millingen and Emmerich can function as optimal spawning grounds (presence of gravel as substrate). Due to the incomplete knowledge about the species no predictions can be made as to population size. Therefore, no predictions can be made as to the viability of the Barbel population in this scenario. For the other scenarios it is likely that populations are not viable.

Stepping stone function
It is not possible to value the stepping stone function for the Loire-River dynamics scenarios. For the other scenarios the stepping stone function is low or absent.
Table 5.9. Barbel: amount of suitable habitat, population viability (+ viable, ± marginal, - not viable) and stepping stone function (+ high, ± moderate, - low, -- absent).

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Present situation</th>
<th>Rhine-Traditional</th>
<th>Loire-River dynamics</th>
<th>Mississippi-Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of side channels (km)</td>
<td>0</td>
<td>0</td>
<td>265</td>
<td>0</td>
</tr>
<tr>
<td>Viability</td>
<td>-</td>
<td>-</td>
<td>?</td>
<td>-</td>
</tr>
<tr>
<td>Stepping stone function</td>
<td>--</td>
<td>--</td>
<td>?</td>
<td>--</td>
</tr>
</tbody>
</table>

Fig. 5.6. Results for the Barbel. One map (upper left) showing suitable areas in the present situation and three maps (right side) for the scenarios.
Fig. 5.6 BARBEL
LARCH approach

PRESENT SITUATION

Suitable habitat
- possible spawning ground
- spawning ground
- Study area

20 km
BARBEL

SCENARIOS
Rhine - Traditional

Loire - River dynamics

Mississippi - Spillway

20 km
5.4 FAUNA SPECIES: NETWORK FUNCTION METAPHOR APPROACH

5.4.1 Outline

At first the status of the species in and around the study area is discussed. Then a comparison is made between these empirical data on actual distribution and numbers and a simulation of the present situation using the METAPHOR model.

The results for the present situation and each scenario are shown in a table and a figure. The table presents (1) the amount of suitable habitat, (2) the expected viability of the population and (3) the stepping stone function. The figure contains global distribution maps which show the chance for occurrence and diagrams with the predicted mean population size and the carrying capacity for the simulation area (study area and surroundings) and the study area. Detailed maps on the chance for occurrence per habitat unit are inserted in Appendix 7.

To compare the scenarios the following aspects are discussed:
1. viability of the population
2. saturation (expected population size divided by the carrying capacity)
3. stepping stone function (based on the pattern of chance on occurrence)
5.4.2 Middle Spotted Woodpecker

The results of the Middle Spotted Woodpecker are presented in table 5.10, figure 5.7 and Appendix 7. The simulation area includes habitat units in a zone of 10 km around the study area.

PRESENT STATUS
The species is not present in the study area. Nearby populations are found 50 km to the east in Germany, north of the 'Ruhrgebiet'. The most recent breeding record inside the study area originates from 1966. Observations in Belgium and Germany show that the species is slowly increasing and expanding.
At present the habitat pattern for the Middle Spotted Woodpecker offers no possibilities for a viable population, although the carrying capacity is 500 breeding pairs. This is probably due to the very fragmented habitat pattern. The simulated mean population size is very low (around 10 pairs) and is concentrated in the German part of the study area. The stepping stone function is absent.

SCENARIOS

Viability
In the Rhine-Traditional scenario and Loire-River dynamics scenario Middle Spotted Woodpecker populations are viable. During the 100 simulation runs no extinction occurred. In the Mississippi-Spillway scenario, however, viability is marginal (chance on extinctions is almost 25%).

Saturation
The two scenarios that support viable populations have a similar mean population size but a different degree of saturation. If the amount of suitable habitat is considered the difference becomes very remarkable. The Rhine-Traditional scenario has 3000 ha of hardwood forest and the Loire-River dynamics scenario 2000 ha. This points to a much more optimal habitat configuration in the Loire-River dynamics scenario.
The very low degree of saturation in the present situation and the Mississippi-Spillway scenario is in agreement with the low viability chances and reflects the weakness of both habitat configurations.

Stepping stone function
The stepping stone function is moderate for the Rhine-Traditional scenario and Loire-River dynamics scenario. Habitat units with a good chance for occurrence are only present in the east and center of the study area. Apparently the pattern in the west is not strong enough for the species to persist. This can be explained by the fact that the area of suitable forest outside the study area in Germany (east part) is much larger than in the Netherlands (west part) (see Annexes, Map 2).
In the Mississippi-Spillway scenario (about 800 ha of riverine forest) the situation does not greatly improve compared with the present situation. Habitat units with a good chance for occurrence are not present.
Table 5.10. Middle Spotted Woodpecker: area of suitable habitat, population viability (+ viable, ± marginal, - not viable) and stepping stone function (+ high, ± moderate, - low).

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Present situation</th>
<th>Rhine-Traditional</th>
<th>Loire-River dynamics</th>
<th>Mississippi-Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area of hardwood forest (ha) study area</td>
<td>4</td>
<td>2911</td>
<td>2060</td>
<td>842</td>
</tr>
<tr>
<td>Simulation area</td>
<td>4000</td>
<td>6894</td>
<td>6038</td>
<td>4838</td>
</tr>
<tr>
<td>Viability</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>±</td>
</tr>
<tr>
<td>Stepping stone function</td>
<td>--</td>
<td>±</td>
<td>±</td>
<td>-</td>
</tr>
</tbody>
</table>

Fig. 5.7. Results for the Middle Spotted Woodpecker. One map showing areas with equal probability of occurrence in the present situation (upper left) and three for the three scenarios (right side). The histograms present the mean expected population size and the carrying capacity for the present situation and the three scenarios for the study area (upper) and the simulation area (lower). The percentage shows the degree of saturation.
Fig. 5.7 MIDDLE SPOTTED WOODPECKER

METAPHOR approach

PRESENT SITUATION

Probability of occurrence

- 1 - 50 %
- 50 - 90 %
- > 90 %
- Study area

Study area

Simulation area

- Average number
- Carrying capacity
- Extinction chance > 5 %
5.4.3 Great Reed Warbler

The results of the Great Reed Warbler are presented in table 5.11, figure 5.8 and Appendix 7. The simulation area includes habitat units in a zone of 20 km around the study area.

PRESENT STATUS
At present the species occurs in the study area and surroundings. There has been a strong decline in the past decades. Before 1960 the number of breeding pairs was 300-400 (Van den Bergh et al. 1979) and at the moment it is not more than 50, most of which in the central part (in 1994 22 pairs in Gelderse Poort). The species is very rare in the German part of the study area. The chance of extinction under the present conditions is considerable, which means that the population is not viable. There is no stepping stone function.

SCENARIOS

Viability
In the Rhine-Traditional and the Mississippi-Spillway scenarios the expected population size is about tenfold higher than in the present situation, due to the larger amount of suitable habitat. Accordingly, the extinction chance in both scenarios drops to practically zero. In the Loire-River dynamics scenario the future for the Great Reed Warbler remains very unsure because new habitat is hardly developed. The population is not viable (extinction chance >50%).

Saturation
The two scenarios that support viable populations have a similar mean population size in the study area but differ in the degree of saturation. If the amount of suitable habitat is considered the difference becomes very remarkable. The Rhine-Traditional scenario has 574 ha of suitable reed marsh and the Mississippi-Spillway scenario 878 ha. This points to a much more optimal habitat configuration in the Rhine-Traditional scenario. Still the degree of saturation is at a very low level (<50%). This is explained by the large influence of environmental stochastic factors in the METAPHOR-model reflecting catastrophies by drought in the winter quarters. The very low degree of saturation in the present situation and the Loire-River dynamics scenario is in agreement with the low viability chances and reflects the weakness of both habitat configurations.

Stepping stone function
In the Rhine-Traditional scenario and Mississippi-Spillway scenario there are almost no patches with a good chance for occurrence in the German (east) part of the study area. Apparently the pattern in the east is not strong enough for the species to persist. This can be explained by the fact that the area of reed marsh outside the study area in the German part of the study area is much lower than in the center and the west (see Annexes, Map 2). The situation for the Loire-River dynamics scenario is comparable with the present situation. The stepping stone function is absent due to the absence of habitat units with a good chance for occurrence.
Table 5.11. Great Reed Warbler: area of suitable habitat, population viability (+ viable, ± marginal, - not viable) and stepping stone function (+ high, ± moderate, - low).

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Present situation</th>
<th>Rhine-Traditional</th>
<th>Loire-river dynamics</th>
<th>Mississippi-Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area suitable reed marsh (ha)</td>
<td>173</td>
<td>574</td>
<td>101</td>
<td>878</td>
</tr>
<tr>
<td>study area</td>
<td>330</td>
<td>730</td>
<td>259</td>
<td>1020</td>
</tr>
<tr>
<td>simulation area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viability</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Stepping stone function</td>
<td>--</td>
<td>±</td>
<td>--</td>
<td>±</td>
</tr>
</tbody>
</table>

Fig. 5.8. Results for the Great Reed Warbler. One map showing areas with equal probability of occurrence in the present situation (upper left) and three for the three scenarios (right side). The histograms present the mean expected population size and the carrying capacity for the present situation and the three scenarios for the study area (upper) and the simulation area (lower). The percentage shows the degree of saturation.
Fig 5.8 GREAT REED WARBLER

METAPHOR approach

Present situation

Probability of occurrence

- 1 - 50%
- 50 - 90%
- > 90%

Number of pairs

Present situation: 7%
Loire-River dynamics: 1%
Mississippi-Spillway: 27%

Study area

Simulation area

Average number
Carrying capacity
Extinction chance > 5%
GREAT REED WARBLER

SCENARIOS

Rhine - Traditional

Loire - River dynamics

Mississippi - Spillway

20 km
5.4.4 Bittern

The results of the Bittern are presented in table 5.12, figure 5.9 and Appendix 7. The simulation area includes habitat units in a zone of 75 km around the study area.

PRESENT STATUS
At present the species occurs in the study area and surroundings. During the past decades the species has been at a rather low level. Numbers vary between 100 and 300 pairs in the simulation area and 20 to 75 in the study area (unpublished data SOVON and R.Foppen IBN-DLO). In the study area most of the breeding pairs are concentrated in the central part ('Rijnstrangen' area: 15-30 breeding pairs). The species is very rare in the German part of the study area.

The present habitat pattern can support a viable population. For a large part this depends on the situation outside the study area. Since habitat units with a good chance for occurrence are only present in the central part, the stepping stone function is low.

SCENARIOS

Viability
In all scenarios the population remains viable. Compared with the present situation, in the Loire-River dynamics scenario the number of breeding pairs is similar, but in the Rhine-Traditional and the Mississippi-Spillway scenarios the numbers increase almost fivefold.

Saturation
In the study area the saturation of the population is much higher in the Rhine-Traditional scenario than in the other scenarios and the present situation. So, the created habitat pattern in this scenario is apparently very efficient. The number of breeding pairs is only slightly lower than in the Mississippi-Spillway scenario (which has the highest numbers), but the amount of reed marsh is 60% lower.

On the other hand, for the whole area included in the simulation the habitat pattern of the Mississippi-Spillway scenario seems the most efficient. This indicates that this scenario offers the best conditions at a larger scale. Compared with the Rhine-Traditional scenario the larger size of the habitat units in the study area probably constitute a higher dispersal flow of birds towards areas outside the study area.

Stepping stone function
In the Rhine-Traditional and the Mississippi-Spillway scenario habitat units with a good chance for occurrence can be found in all parts of the study area. So, the stepping stone function can be valued high. The situation for the Loire-River dynamics scenario is comparable with the present situation.
Table 5.12. Bittern: area of suitable habitat, population viability (+ viable, ± marginal, - not viable) and stepping stone function (+ high, ± moderate, - low).

<table>
<thead>
<tr>
<th>Estimate</th>
<th>Present situation</th>
<th>Rhine-Traditional</th>
<th>Loire-river dynamics</th>
<th>Mississippi-Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area suitable reed marsh (ha)</td>
<td>286</td>
<td>1099</td>
<td>267</td>
<td>1708</td>
</tr>
<tr>
<td>study area</td>
<td>2643</td>
<td>3435</td>
<td>2574</td>
<td>4095</td>
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<tr>
<td>simulation area</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viability</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Stepping stone function</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
</tr>
</tbody>
</table>

Fig. 5.9. Results for the Bittern. One map showing areas with equal probability of occurrence in the present situation (upper left) and three for the three scenarios (right side). The histograms present the mean expected population size and the carrying capacity for the present situation and the three scenarios for the study area (upper) and the simulation area (lower). The percentage shows the degree of saturation.
Fig. 5.9 BITTERN METAPHOR approach

Present situation

Rhine-Traditional Mississippi-Spillway

Study area

Probability of occurrence
- 1 - 50 %
- 50 - 90 %
- > 90 %

Simulation area

- Average number
- Carrying capacity
* Extinction chance > 5 %

Probability distribution:
- 58%
- 73%
- 52%
- 57%

- 54%
- 59%
- 51%
- 66%
BITTERN

SCENARIOS

Rhine - Traditional

Loire - River dynamics

Mississippi - Spillway

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5.5 FAUNA SPECIES: NETWORK FUNCTION IN RELATION TO AREA AND DISTRIBUTION OF HABITAT

In this section the network function for the target species in the present situation and the three scenarios is related to the area of relevant habitat types and the distribution strategy of new nature. Viability and stepping stone function are discussed for all species, saturation only for METAPHOR species.

VIABILITY

Table 5.13 shows the viability of populations in relation to area and distribution of new nature. The results indicate that the viability of target species populations is mainly determined by the area of the relevant habitat types. This is not a surprising result, because the new nature areas are distributed according to the habitat requirements and dispersal capacity of these species (see chapter 3).

When taking into account the size and the shape of the study area and available habitat in the surroundings, ± 10,000 ha of new nature apparently only can result in viable populations for Beaver, Middle Spotted Woodpecker, Great Reed Warbler and Bittern. Without the presence of available habitat in the surroundings, it is even to be expected that viable populations for these species cannot exist either. The numbers for only the study area are probably too low to support viable populations.

Black Kite and Night Heron populations reach a marginal viability at their maximum and White-tailed Eagle and Black Stork numbers stay far below the lower limit for a viable or even marginally viable population. For the Barbel it was not possible to estimate the population viability.

SATURATION

Saturation of populations could only be assessed for METAPHOR species. Table 5.14 shows the relation between the saturation of viable populations and the distribution pattern of new nature. The results indicate that for the Middle Spotted Woodpecker ‘relative large areas and moderate distances’ (Loire-River-dynamics) is the best pattern and for Great Reed Warbler and Bittern ‘small areas and short distances’ (Rhine-Traditional). These differences are probably mainly due to the dispersal characteristics of the species. For the Middle Spotted Woodpecker distances of all patterns are relatively great compared with the maximum dispersal distance (10 km), which makes the relations between habitat units relatively unimportant. In that case large habitat units always provide a more optimal network than small habitat units. For Great Reed Warbler and especially Bittern the maximum dispersal distances are much larger and apparently ‘small areas and short distances’ (Rhine-Traditional) is a more favourable pattern than ‘large areas and great distances’ (Mississippi-Spillway).

STEPPING STONE FUNCTION

In table 5.15 the stepping zone function is shown in relation to area and distribution of relevant habitat types. As found for the viability of populations, differences in the stepping stone function are strongly related to the area of habitat types. This is not surprising as the stepping stone function is largely determined by the population viability (see section 4.4). An optimal stepping stone function can only be reached if populations are viable. Since new nature areas are equally distributed over the study area and present nature areas are quantitatively unimportant, one would expect that this is always achieved. Beaver and Bittern come up with this expectation, but Middle Spotted Woodpecker and Great Reed Warbler only reach a moderate stepping stone function. As discussed before (see sections 5.3.2 and 5.3.3), this can be explained by the fact that for Middle Spotted Woodpecker and Great Reed Warbler existing habitat outside the study area, which is non-equally distributed, largely determines the
viability of the populations. Although a similar situation is present for the Bittern, here
the stepping stone function can become optimal. Probably, the much greater dispersal
capacity of this species is responsible for this (see figure 5.10).

Table 5.13. Viability of target species populations (L = LARCH approach,
M = METAPHOR approach) in relation to area of relevant habitat types (total and
within the study area = S) and distribution strategy of new nature. Viability (V): +
viable, ± marginally viable, - not viable. Measures for viable populations are underlined.

<table>
<thead>
<tr>
<th>Species and habitat type</th>
<th>Present situation</th>
<th>Rhine-Traditional</th>
<th>Lorer-River dynamics</th>
<th>Mississippi-Spillway</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Habitat total area (ha)</td>
<td>Habitat % in S</td>
<td>Habitat total area (ha)</td>
<td>Habitat % in S</td>
</tr>
<tr>
<td>RIVERINE FOREST</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>softwood in winterbed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beaver (L)</td>
<td>- 396 100</td>
<td>± 2643 100</td>
<td>+ 3216 100</td>
<td>- 396 100</td>
</tr>
<tr>
<td>hardwood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle Spotted Woodpecker (M)</td>
<td>- 4010 0.2</td>
<td>+ 2694 42</td>
<td>+ 6042 28</td>
<td>± 4842 17</td>
</tr>
<tr>
<td>Black Kite (L)</td>
<td></td>
<td>± 2867 89</td>
<td>± 3632 91</td>
<td>± 4720 83</td>
</tr>
<tr>
<td>softwood + hardwood</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Stork (L)</td>
<td>- 405 100</td>
<td>- 6437 100</td>
<td>- 6262 100</td>
<td>- 6248 100</td>
</tr>
<tr>
<td>MACROPHYTIC MARSH</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Reed Warbler (M)</td>
<td>- 870 48</td>
<td>+ 1071 76</td>
<td>- 813 18</td>
<td>+ 3101 84</td>
</tr>
<tr>
<td>Bittern (M)</td>
<td>+ 5300 41</td>
<td>+ 5771 36</td>
<td>+ 4412 36</td>
<td>+ 6901 26</td>
</tr>
<tr>
<td>Night Heron (L)</td>
<td>- 802 69</td>
<td>± 1603 62</td>
<td>- 446 26</td>
<td>± 2833 87</td>
</tr>
<tr>
<td>SIDE CHANNEL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barbel (L)</td>
<td>- 0</td>
<td>- 0</td>
<td>± 3674 100</td>
<td>- 0</td>
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<td>RIVERINE LANDSCAPE</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>White-tailed Eagle (L)</td>
<td>- 17,889 84</td>
<td>- 21,226 87</td>
<td>- 16,137 84</td>
<td>- 28,712 88</td>
</tr>
</tbody>
</table>
Table 5.14. Saturation of target species populations in the study area in relation to the distribution strategy of new nature (METAPHOR approach). The scores are relative per species. Between parentheses: not viable populations.

<table>
<thead>
<tr>
<th>Species and habitat type</th>
<th>Present situation</th>
<th>Rhine-Traditional</th>
<th>Loire-River dynamics</th>
<th>Mississippi-Spillway</th>
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<tr>
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<td>Distribution of new nature</td>
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<tr>
<td></td>
<td>marsh + forest:</td>
<td>complex marsh/forest:</td>
<td>marsh: size 1000-2000 ha</td>
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</tr>
<tr>
<td></td>
<td>size ± 100 ha</td>
<td>size 260-500 ha</td>
<td>distance ± 10 km</td>
<td>distance 20-30 km</td>
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<tr>
<td></td>
<td>distance ± 10 km</td>
<td></td>
<td></td>
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<tr>
<td>RIVERINE FOREST</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Hardwood</td>
<td>(-)</td>
<td>±</td>
<td>+</td>
<td>(-)</td>
</tr>
<tr>
<td>Middle Spotted Woodpecker</td>
<td>±</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>MACROPHYTIC MARSH</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Reed Warbler</td>
<td>(-)</td>
<td>+</td>
<td>(+)</td>
<td>±</td>
</tr>
<tr>
<td>Bittern</td>
<td>±</td>
<td>±</td>
<td>±</td>
<td>±</td>
</tr>
</tbody>
</table>

Table 5.15. Stepping stone function (ST) of target species populations (L = LARCH approach, M = METAPHOR approach) in relation to area of relevant habitat types (total and within study area = S) and distribution strategy of new nature. Stepping stone function: + high, ± moderate, - low, -- absent. Measures for viable populations are underlined.

<table>
<thead>
<tr>
<th>Species and habitat types</th>
<th>Present situation</th>
<th>Rhine-Traditional</th>
<th>Loire-River dynamics</th>
<th>Mississippi-Spillway</th>
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<td>Distribution of new nature</td>
<td>Distribution of new nature</td>
<td>Distribution of new nature</td>
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<td>marsh + forest:</td>
<td>complex marsh/forest:</td>
<td>marsh: size 1000-2000 ha</td>
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<tr>
<td></td>
<td>size ± 100 ha</td>
<td>size 260-500 ha</td>
<td>distance ± 10 km</td>
<td>distance 20-30 km</td>
</tr>
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<td>distance ± 10 km</td>
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</tr>
<tr>
<td>RIVERINE FOREST</td>
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<td>Softwood in winterbed</td>
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<tr>
<td>Beaver (L)</td>
<td>± 396 100</td>
<td>± 2643 100</td>
<td>+ 3218 100</td>
<td>± 386 100</td>
</tr>
<tr>
<td>Hardwood</td>
<td>± 4010 0.2</td>
<td>± 8884 42</td>
<td>± 8043 39</td>
<td>- 4842 17</td>
</tr>
<tr>
<td>Middle Spotted Woodpecker(M)</td>
<td>± 719 85</td>
<td>± 2667 88</td>
<td>± 3632 91</td>
<td>- 4720 93</td>
</tr>
<tr>
<td>Black Kite (M)</td>
<td>± 406 100</td>
<td>± 6427 100</td>
<td>- 5262 100</td>
<td>- 5248 100</td>
</tr>
<tr>
<td>Softwood + hardwood</td>
<td>± 970 48</td>
<td>± 1971 76</td>
<td>± 813 18</td>
<td>± 3101 84</td>
</tr>
<tr>
<td>Black Stork (L)</td>
<td>± 4300 11</td>
<td>± 5771 26</td>
<td>± 4413 3</td>
<td>± 6801 38</td>
</tr>
<tr>
<td>Great Reed Warbler (M)</td>
<td>± 862 58</td>
<td>± 1803 82</td>
<td>± 446 26</td>
<td>± 2833 87</td>
</tr>
<tr>
<td>Bittern (M)</td>
<td>± 3574 100</td>
<td>± 0</td>
<td>± 0</td>
<td>± 0</td>
</tr>
<tr>
<td>Night Heron (L)</td>
<td>± 17,969 84</td>
<td>± 21,228 87</td>
<td>± 16,137 84</td>
<td>± 26,712 89</td>
</tr>
</tbody>
</table>

118
Western part

Eastern part

Bittern

75 km

Great Reed Warbler

20 km

Middle Spotted Woodpecker

10 km

Fig. 5.10. Schematic presentation of the amount of habitat in the surroundings of the study area (circles) and the maximum dispersal distance on the stepping stone function of target species. The shaded part of study area (rectangle) reflects expansion capability.

5.6 FAUNA SPECIES: NETWORK FUNCTION OF HABITAT TYPES

For each habitat type general conclusions are made based on the results of the target species. The main objective is to obtain an indication of differences in the network function of species related to the three nature rehabilitation strategies reflected by the scenarios. An overview of the main results is given in table 5.13 (population viability), table 5.14 (population saturation) and table 5.15 (stepping stone function) of section 5.5.

RIVERINE FOREST

The Loire-River dynamics and the Rhine-Traditional scenarios offer the best conditions for species of riverine forests. The created forest habitat pattern supports viable or close to viable populations for three of the four species and the stepping stone function varies from low to high. In the Rhine-Traditional scenario, however, the conditions for the Beaver, due to the absence of side channels, are less favourable. Moreover, the results for the Middle Spotted Woodpecker indicate that the habitat configuration in this scenario is less optimal than in the Loire-River dynamics scenario, because the degree of saturation of the habitat is lower.

The Mississippi-Spillway scenario favours only two species of which the viability...
remains marginal, Middle Spotted Woodpecker and Black Kite. Here, for most species the forest is not suitable, which is due to the location in the spillways. For the species which has the greatest area demand, the Black Stork, none of the scenarios can support a (marginally) viable population and even suitable habitat is almost absent. In the present situation the conditions for all species are poor (not viable).

MACROPHYTE MARSH
The Rhine-Traditional and the Mississippi-Spillway scenarios offer the best conditions for species of macrophyte marshes. For all three species the created marshland habitat pattern supports viable (2) or close to viable (1) populations of which the stepping stone function varies from low to high. However, the results for the Great Reed Warbler and the Bittern indicate that the habitat configuration in the Rhine-Traditional scenario is more optimal than in the Mississippi-Spillway scenario, because the degree of saturation of the habitat is considerably higher. For the species which has the greatest area demand, the Night Heron, the scenarios can only support a close to viable population.

The Loire-River dynamics scenario does not improve the present situation. Here, only the Bittern has a viable population, but the numbers are much lower than in the other scenarios.

SIDE CHANNEL
Side channels only are present in the Loire-River dynamics scenario. Further conclusions cannot be made due to the lack of suitable target species.

RIVERINE LANDSCAPE
The results indicate that the size of the riverine landscape is not sufficient to support viable populations for species that have very large area demands, such as the White-tailed Eagle. Probably, these species might persist only if the study area is part of a network at a higher geographical scale (e.g. west Europe). The Mississippi-Spillway scenario offers the best opportunities, because it enlarges the study area by creating large marshlands outside the winterbed.
## 6 CONCLUDING REMARKS ON THE METHODOLOGY

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<td>SCENARIOS (3)</td>
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<td>MODELLING</td>
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<td>NATURE REHABILITATION (4)</td>
<td>RESULTS (5)</td>
</tr>
<tr>
<td>EVALUATION OF METHOD (6)</td>
<td>EVALUATION OF RESULTS (7)</td>
</tr>
</tbody>
</table>
6.1 INTRODUCTION

In this chapter the different steps of the presented method are discussed and recommendations are made for improvement (sections 6.2-6.6). Finally some general conclusions are drawn with respect to the applicability of the method (section 6.). The significance of the results of the study for river rehabilitation is discussed in chapter 7.

6.2 TARGET SPECIES

The approach is focused on species. This means that the choice of species is very important and selection criteria should be dependent on the research question. In this study it was very difficult to find useful target species for the aquatic component of the habitat type side channel. Even the choice for the Barbel appeared to be not very successful, since this species seems restricted to a small part of the study area. Moreover, it was also not even possible to apply the LARCH approach. As a consequence the aquatic component of the river system was not evaluated satisfactory. Since the aim of the study was to clarify the importance of the network approach and not to produce specific plans, this was not a serious problem. However, in future studies the aquatic component of river systems should get much more attention.

It is recommended to explore which species of the 'Amoebe' approach for rivers (Luiten & van Buuren 1994) can be used as indicators for the network function.

6.3 SCENARIO APPROACH

The scenario approach as applied in this study has proved to be a useful tool by delineating ecologically desirable future situations of the Rhine valley. Both the bottom-up and the top-down approach have turned out to be helpful in the exploration and elaboration of the scenarios. Although it is very difficult to limit the number of possible alternatives from the many that could have been chosen, the leading concept of river dynamics has helped to make a good choice of three interesting scenarios for nature rehabilitation.

The three scenarios and the results on the network function also give a good impression of the range of possibilities, of which the policymaker can be informed better. The approach does not indicate explicitly which scenario is the best. That answer depends on the objectives of the policy makers. The scenarios are exaggerated in the sense of consistent implementation of ecological targets and spatial lay-out. The scenarios have to be understood as an abstract framework, in which only three extreme corners have been surveyed. The projected consequences of these extremes enable policymakers to choose a feasible compromise.

As described in chapter 1, the procedure of the scenario approach is cyclical, with alternating stages of design and evaluation. In this study only one cyclic run of the planning procedure was made. In the planning practice the results of the evaluation would provide new input to another run in order to adjust and re-evaluate the scenario. The final result will be a more comprehensive plan and a better understanding of the consequences of the chosen objectives.
6.4 MODELLING VEGETATION DEVELOPMENT (LEDESS APPROACH)

The modelling procedure has been elaborated from previous studies on nature rehabilitation in the lowermost part of the River Rhine system (Harms et al. 1994; Knol et al. 1995). Thus, the knowledge incorporated into the LEDESS modelling procedure is based on knowledge of this very part of the system, having specific morphodynamic and hydrodynamic characteristics. When applied to other parts of the River Rhine system or to other European rivers, the classifications and the transition matrices used should be adapted to the local circumstances first. The procedure itself, however, is considered valid for any other landscape ecological system.

A crucial step in exploring the landscape ecological suitability of the study area was to determine the expected percentages of covering by the terminal vegetation types for the nature target types in the different physiotopes (see chapter 4). Because published data are hardly available, 'expert judgement' was used to fill the matrixes. The values chosen represent the prevailing opinion of the experts. This means that higher or lower values are possible, particularly for macrophyte marshland. It would therefore be interesting to investigate how sensitive results of the scenarios are to these uncertain factors. Besides, there is a great demand for further research to determine the vegetation composition of nature target types.

Another point of attention is the deterministic character of the approach. One can argue whether physiotopes are stable in space and time. In particular new developed physiotopes, such as floodplain and side channels, might not persist in the long run. However, at the moment this can only be investigated by monitoring nature rehabilitation plans.

The approach assumes that the environmental quality is optimal. This means that emphasis is put on restoring the structure of nature. Therefore for species for which an improvement of the quality of the actual environment is needed the potentials will be lower than predicted if that improvement lags behind.

6.5 MODELLING HABITAT SUITABILITY AND CARRYING CAPACITY

To determine the habitat suitability of the target species the terminal vegetation types were not always sufficient. For example, to determine the amount of suitable reed marsh for the Great Reed Warbler, two additional steps were made. First the proportion of reed of the terminal vegetation type 'macrophyte marsh' was estimated, after that the amount of old reed standing in deep water. This was possible because the knowledge needed was available. However, if one wants to consider a wider range of species than selected for this study, it is likely that the classification of terminal vegetation types in many cases should be more detailed. On the other hand, estimates for the coverage of these detailed terminal vegetation types will probably be very uncertain. It is expected that this will be more restrictive than the limited availability of data on habitat requirements and carrying capacity of species.
6.6 MODELLING SPATIAL POPULATION DYNAMICS (LARCH/METAPHOR APPROACH)

Spatial population models (METAPHOR) require knowledge of the population biology and the dispersal capacity of species. Moreover, it is often difficult to obtain data for both calibration and validation. So application will be possible for a small number of species only. As has been done in this study, models which are not yet validated can be used if emphasis is put on the comparison of scenarios. At the moment a procedure is being developed (IBN-DLO Department of Landscape Ecology) to estimate the uncertainty in the outcome of METAPHOR models (based on sensitivity analysis), which enhances the possibility of evaluating the absolute values of the output parameters.

To consider a wider range of species the LARCH approach has been developed, which provides rules and guidelines based on general and specific knowledge. The results are less specific than obtained with METAPHOR, but as shown in this study, the output of both approaches can be compared. The LARCH approach is currently incorporating new research results and the number of species that can be considered is growing.

6.7 GENERAL CONCLUSIONS

To explore and visualise the perspectives of future nature in the Rhine valley with varying efforts, the method presented in this study appears to be a successful tool. The method facilitates discussion and decision making about what nature policy goals for the Rhine valley are desirable and realistic.

In further studies, in particular concerning the development of concrete plans, a great deal of attention should be paid to the selection of target species. For this the ecological demands of specific target species (as mentioned in different policy documents) should be defined in a more accurate way. To obtain better data on the relationships between abiotic conditions, management and terminal vegetations is needed as well.
7 CONCLUDING REMARKS ON RIVER REHABILITATION

<table>
<thead>
<tr>
<th>RHINE-ECONET</th>
<th>LANDSCAPE ECOLOGICAL SYSTEMS ANALYSIS (2)</th>
<th>SCENARIOS (3)</th>
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<tr>
<td></td>
<td>MODELLING NATURE REHABILITATION (4)</td>
<td>RESULTS (5)</td>
</tr>
<tr>
<td></td>
<td>EVALUATION OF METHOD (6)</td>
<td>EVALUATION OF RESULTS (7)</td>
</tr>
</tbody>
</table>
7.1 INTRODUCTION

At first the scope of the study is considered (section 7.2). Three items are discussed: the significance of the network approach, application of the methodology in other rivers, and extrapolation of the results to other scenarios. Then, based on the results of the study, some remarks are made with respect to river rehabilitation policies and ecological networks (section 7.3).

7.2 SCOPE OF THE STUDY

7.2.1 Importance of the network approach

The results of the Rhine-Econet study clearly show the importance of linking nature areas into a network system. They strongly support the present attention to nature policy, as ecological networks are an important condition for a successful nature rehabilitation in the Lower Rhine area and probably also in other riverine areas. It must be emphasized that the network function should be taken into account when developing nature rehabilitation plans. The method presented in the Rhine-Econet study is a successful tool for that.

In this study, however, the significance of an ecological network of nature areas was demonstrated for a small number of characteristic vertebrate fauna species of riverine forest, macrophyte marsh and side channels. In consequence, one should be careful in drawing general conclusions from the results with respect to the network function of these habitats.

To evaluate the network function in nature rehabilitation plans it might be necessary to use a wider range of fauna species and possibly also plant species. There is much evidence that habitat fragmentation also effects small mammals, amphibians, butterflies and other insect species (see e.g. Opdam et al. 1993) and plant species (Ruremonde & Kalkhoven 1991; Ouburg 1993; Dzwonko 1993). To increase knowledge of the aquatic fauna should get much attention.

7.2.2 Application of the methodology in other rivers

The problem being studied here is typical for modern lowland rivers in densely populated areas, where the river manager has to meet several demands for space within the river system. Lost nature qualities will be rehabilitated at the expense of the agricultural use of floodplain lands, while safety against flooding and a navigable river have to be guaranteed. As such, the study area can serve as an example for many other large European rivers.

However, not all rivers are identical, nor are the problems of river managers. The identity of drainage basins and river reaches can vary strongly. In this study the nature rehabilitation targets are based on historical references of the landscape ecological system. It has been demonstrated that even within the Lower Rhine system several references can be described, depending on the drainage basin zone, or the river reach considered. Elsewhere, the historical natural references can be quite different. Thus, for application to other parts of the River Rhine system, or in other European river systems, other nature rehabilitation targets may have to be formulated.
The problems of river managers are related to the landscape ecological identity of the rivers considered. When the river and its floodplains are situated within landscapes that still have a high degree of naturalness, the network function does not depend on the spatial configuration of habitats within the river system as much as it does in the Lower Rhine area. In mountainous areas the river floodplains may not even be of the appropriate size, to change the network function by river rehabilitation measures alone. When applying the network methodology to another river, new choices have to be made with respect to the habitats and species to be considered, the boundaries of the area and other functions or boundary conditions that have to be taken into account.

7.2.3 Extrapolation of the results to other scenarios

As stated in chapter 1, the scenarios elaborated in this study should not be regarded as optimized ecological networks for any of the selected species. The scenarios have been chosen to illuminate the effect of different strategies on the network function. The choice of three scenarios meant three network approaches constructed of different sets of network related variables, such as total area and distribution of forest and macrophyte marshes. Although much more differences in the chosen variables and also other variables may be involved in the exploration of the scenarios, for practical reasons only three sets of variables have been chosen for elaboration. This forms a restriction of the study, which one has to bear in mind when general conclusions have to be drawn. It means that it is difficult to extrapolate the conclusions of the study beyond the scope of these three sets of variables. For instance, no accurate conclusion could be drawn if the area for nature rehabilitation were doubled in size. On the other hand, the results of the study contribute to generate new questions, which can be solved in an other cyclic run of the scenario procedure.

Another point of attention in drawing conclusions from the study is that other interests, apart from nature, have not or not enough been considered; like agriculture, mining, river management, recreation and landscape (historical, geomorphological or aesthetical aspects). That means that the study may not be seen as an integral planning approach. A more comprehensive approach was followed in a previous study for integrated river rehabilitation in the central part of the study area, De Gelderse Poort, on both sides of the German border (Harms & Roos-Klein Lankhorst 1994; Knol, et al. 1994) and in the Landscape Planning Rhine, which comprises all Rhine distributaries in The Netherlands (IVR-study, e.g. Silva & Kok 1995). In both studies, however, the ecological network function of the river system was or could not be considered.

Nevertheless, for this study some general remarks on river management and mining can be made. As far as river management is concerned, in the Rhine-Traditional and the Loire-River dynamics scenarios the areas of forest are very similar and amount to 16% of the area between the winter dikes. Wijbenga & Klaassen (1994) indicated that, owing to the safety of the dikes at high water levels, such an amount of forest can only be realized in combination with the creation of side channels and digging of clay. Further study is required to assess whether both scenarios meet these requirements. Moreover, one also should take into account that the forest areas are not evenly distributed over the study area. In both scenarios several river reaches do have much a higher proportion of forest (up to 30%). For the Mississippi-Spillway scenario no problems are expected. Because most of the forest is situated in spillways outside the winterbed, the amount of forest within the winterbed is only 4%. For river reaches
the percentage does not exceed 10%.

The amount of clay that will come available per scenario has been estimated. Due to the development of back swamps related to the spillways, the Mississippi-Spillway scenario delivers the largest supply of clay (about 45 million m$^3$). The Loire-River-dynamics scenario foresees clay excavation mainly in side channels (about 11 million m$^3$), whereas Rhine-Tradional would create a small supply of clay (0.5 million m$^3$).

As far as the demand of clay is concerned only The Netherlands could be considered. At present there is a demand for 1.2 million m$^3$ clay a year, which will decrease to 1.0 million m$^3$ a year in 2005 (van der Meulen et al. 1994). If we put the execution of the plans at a period of 50 years (see also Silva & Kok 1994) the total supply for clay (Dutch and German part of the study area) will not exceed the demand. But, one should bear in mind that a large area has been indicated for clay digging already (18.6 million m$^3$ in the province of Gelderland, of which 11.2 in floodplains of the Rhine system; van der Meulen et al. 1994). In the Mississippi-Spillway scenario, there is a chance that the supply of clay will exceed the demand.

7.3 RIVER REHABILITATION AND ECOLOGICAL NETWORKS

7.3.1 What does 30% nature area mean for river rehabilitation?

For one species, the Bittern, a viable population already exists in the present situation. The development of 10,000 ha of nature areas in the studied stretch of the Lower Rhine (is ± 30% of the winterbed area) resulted in viable network populations for only 1-2 species extra (out of a total of 9 target species). This concerns Beaver, Middle Spotted Woodpecker and Great Reed Warbler. Depending on the amount of suitable habitat, they can reach a viable population in one or more scenarios (see table 7.1). However, if habitat outside the study area is not taken into account, the population viability of all these species (including Bittern) will be questionable. For Black Kite and Night Heron, the habitat conditions are sufficient to support a marginally viable population only, and the carrying capacity of Black Stork and White-tailed Eagle stays far below the threshold for a marginally viable population (table 7.1). For the Barbel no conclusions can be drawn.

To improve the situation, (1) the scenarios can be applied to a much larger stretch of the Lower Rhine, (2) the % of nature can be increased or (3) both approaches can be combined. For the Rhine-Traditional and Loire-River-dynamics scenarios increasing the amount of nature seems only possible outside the winterbed. Because of the safety of winter dikes at high water levels, the proportion of forest in the winterbed is already at the maximum and potentials for macrophyte marsh are poor. In the Mississippi-Spillway most nature areas are situated outside the winterbed in back swamps.

If the scenarios are applied to the whole river system of the Lower Rhine (including the Rivers Lek and IJssel), the amount of nature areas will be roughly doubled. Possibly, this will result in a higher number of viable target species compared with the Rhine-Econet area. However, since in many species available habitat in the surroundings of the river area largely determines the population viability, it is difficult to give any further judgement.

By doubling the amount of nature in the studied stretch of the Lower Rhine one may expect that almost all species (except Black Stork and White-tailed Eagle) in each scenario will reach viable populations. The Beaver population in the Rhine-traditional scenario, however, will probably stay marginally viable and spawning grounds for the
Barbel can only be developed in the Loire-River dynamics scenario. Depending on the scenarios extra nature has to be developed within or outside the winterbed. By combining both approaches, it will still be difficult to obtain conditions which may lead to viable populations of Black Stork and White-tailed Eagle. The extra nature probably need amounts of more than 100,000 ha. Therefore, these species may only persist if the Lower Rhine becomes part of a network at a higher geographical scale (e.g. western Europe). For the White-tailed Eagle a general analysis for The Netherlands shows that the potential is poor (Foppen 1995).

However, these guidelines can only be used to indicate what might be possible and can serve as a framework for further study.

Table 7.1. Population viability of target species in the study area when developing 10,000 ha of nature areas. HF hardwood forest, SF softwood forest, MM macrophyte marsh, SCh side channel. Viability: - not viable, ± marginally viable, + viable

<table>
<thead>
<tr>
<th>Species and habitat types</th>
<th>Present situation</th>
<th>Development of 10,000 ha of new nature areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HF 10 ha</td>
<td>Rhine-Traditional</td>
</tr>
<tr>
<td></td>
<td>SF 395 ha</td>
<td>HF 2894 ha</td>
</tr>
<tr>
<td></td>
<td>MM 473 ha</td>
<td>SF 2543 ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MM 1471 ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SCh 265 km</td>
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<tr>
<td>Riverine forest</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beaver (SF)</td>
<td>-</td>
<td>±</td>
</tr>
<tr>
<td>Middle Spotted Woodpecker (HF)</td>
<td>-</td>
<td>±</td>
</tr>
<tr>
<td>Black Kite (SF)</td>
<td>-</td>
<td>±</td>
</tr>
<tr>
<td>Black Stork (HF + SF)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Macrophyte marsh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Great Reed Warbler</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Bittern</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Night heron</td>
<td>-</td>
<td>±</td>
</tr>
<tr>
<td>Side channel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barbel</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Riverine landscape²</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White-tailed Eagle</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1Situated outside the winterbed
2Combination of all habitat types

7.3.2 Is there a most favourable distribution pattern of nature areas?

The study was not designed to investigate the effect of the distribution strategy of new nature areas on the viability of species. New nature areas were distributed according to the habitat requirements and dispersal capacity of the target species. Therefore, it is only possible to make remarks on the saturation of viable populations (percentage of the carrying capacity which is realized) in relation to the distribution strategy. This is only possible for the three METAPHOR species.

Favourable distribution patterns differ for each species. For Middle Spotted Woodpecker (hardwood forest) the distribution strategy used in the Loire-River-dynamics scenario (size 250-500 ha, distance 10-20 km) gives the highest saturation and for
Great Reed Warbler and Bittern (macrophyte marsh) the distribution strategy used for the Rhine-Traditional scenario (size ±100 ha, distance ≤10 km). In terms of the amount of suitable habitat, the differences are very striking. Compared with the other distribution patterns, the best distribution pattern needs ± 40% less habitat (all three species) to achieve a similar actual population size. That result emphasizes the importance of the network approach.

So, if one develops characteristic habitat types, such as hardwood forest, the spatial pattern may influence the size of the expected populations of specific species considerably. By choosing the optimal spatial pattern, the profit will be raised considerably. That becomes extra important if the available area to develop new habitat types is limited. The choice of the optimal spatial pattern may then determine whether a species reaches a viable population or not.

However, one should be careful in applying the results of this study to other situations. The results are based on only a few distribution patterns. Relatively small differences in the size of and the distance between habitat units might give different results. General guidelines should be developed by comparing the results of a larger number of selected distribution patterns.

7.3.3 Can ecological networks in riverine areas function as a corridor?

Ecological networks can only have a stepping stone function for species if populations are viable. Whether the stepping stone function becomes optimal depends on the distribution pattern of the habitat units. An equal distribution of habitat units similar in size, will be most favourable. Therefore, in this study, new nature areas were distributed accordingly. However, for most species, which reached a viable population, viability is to a large extent determined by existing habitat outside the study area. As this habitat is not-equally distributed, the stepping stone function does not always become optimal.

A moderate stepping stone function has been established for Middle Spotted Woodpecker and Great Reed Warbler, which means that the first species cannot expand into the Dutch (western) part of the study area and the second species not in the German (eastern part). That can be explained by the much lesser abundance of hardwood forest in the surroundings of the study area in The Netherlands (Middle Spotted Woodpecker) and of macrophyte marsh in Germany (Great Reed Warbler).

Beaver and Bittern show a distinctly favourable response. The Beaver only uses softwood within the winterbed, which is rather equally distributed and the species can disperse over long distances (up to 100 km). Although for the Bittern the situation is similar as for the Great Reed Warbler, here expansion into Germany does occur, which is probably due to the great dispersal capacity (up to 75 km)(see also figure 5.10).

To improve the stepping stone function for Middle Spotted Woodpecker and Great Reed Warbler one has to create larger amounts of forest and macrophyte marsh in The Netherlands and Germany, respectively. That seems only possible outside the study area, because the proportion of forest is already at its maximum, because of the safety of winter dikes at high water levels and potentials for macrophyte marsh are poor. However, for macrophyte marsh one can argue whether this is concurrent with the landscape ecological identity of the landscape bordering the river system studied. Under former natural conditions, macrophyte marsh in Germany was only present in abandoned meanders and in some locations influenced by the seepage of groundwater, and were thus small in size and number. That means that in determining river
rehabilitation targets it is important to pay attention to the landscape ecological identity of the landscape bordering the river system.

7.3.4 Is there a best management strategy?

The management strategies in the scenarios are (1) managed nature in the winterbed (Rhine-Traditional), (2) restoring natural processes (river dynamics) in the winterbed (Loire-River dynamics) and (3) restoring natural processes in backswamps outside the winterbed (Mississippi-Spillway).

When nature is managed there is little uncertainty about the expected habitat types, and as a result forests (hardwood and softwood) as well as macrophyte marshes are represented in relative large areas. So, it is not suprising that most target species of both riverine forest and macrophyte marsh reach viable or marginally viable populations (see table 7.1). That management strategy leads to the highest network function for two of the three target species of macrophyte marsh, Great Reed Warbler and Bittern.

Restoring natural processes (river dynamics) in the winterbed results in relatively large complexes of riverine forest (hardwood and softwood), macrophyte marsh and side channels. However, because macrophyte marsh is not managed anymore, the area remains small. By consequence, only target species of riverine forest and side channels are favoured: three of the four forest species reach viable or marginally viable populations (see table 7.1) and suitable spawning grounds for the Barbel can only develop here. For Beaver, Middle Spotted Woodpecker and Barbel that management strategy leads to the highest network function.

Restoring natural processes in backswamps outside the winterbed creates large areas of softwood, macrophyte marsh and open water. Because there is little softwood forest in the winterbed and the area of hardwood forest is very small (some patches have been developed in the winterbed), only two species of riverine forest reach marginally viable populations (see table 7.1). For macrophyte marsh the number of species with viable or marginally viable populations is similar to 'managed nature' in the winterbed, the network function, however, is less than optimal.

So, when developing 10,000 ha of new nature, each management strategy can improve the network function for different target species. If nature is managed, more different target species can be favoured than if river bed or back swamps are ruled by natural processes. However, it should be considered that developing and maintaining large areas of macrophyte marsh in the winterbed is probably a rather artificial measure. Under former conditions the area adjacent to the river was predominantly covered by riverine forest and macrophyte marshes mainly occurred in abandoned meanders and back swamps at a greater distance. Due to the embankment of the rivers by dikes, almost all areas that have a natural potential for marshland are now situated outside the winterbed. So, in restoring natural processes in the river system, one can only approach the natural reference by including areas outside the winterbed of the river system.
7.3.5 Which type of evaluation can be given to current river rehabilitation plans?

In current river rehabilitation policy great attention is paid to increasing the river dynamics in the winterbed, which was initiated by the plan ‘Levende Rivieren’ (‘Living Rivers’) made in commission by the World Wildlife Fund (Helmer et al. 1992). The Loire-River dynamics scenario in this study is also based on this idea and can, together with the results of the other scenarios, serve as a framework about decisions in developing concrete plans. Here, some comments are made on a first elaboration of the plan ‘Living Rivers’ for the Lower Rhine in The Netherlands (Silva & Kok 1994; Kok et al. 1994) and on existing nature rehabilitation plans for the stretch of the Lower Rhine covering the study area.

ELABORATION ‘LIVING RIVERS’ FOR THE LOWER RHINE IN THE NETHERLANDS
The objective of the WWF-plan ‘Living Rivers’ is to restore the natural character in in 90% of the area of the floodplains. In the elaboration (Silva & Kok 1994; Kok et al. 1994), the percentage of wood was restricted to 20 %, because of the safety of the winter dikes. This is not very different from the percentage of forest in the Loire-River dynamics scenario, which is 16%. The remaining part will consist of grassland (25%), other natural vegetations (24%) and open water (21%). Based on the analysis of vegetation development for the Loire-River dynamics scenario in this study, it is assumed that only a small part of the 24% of other natural vegetations will consist of macrophyte marshland. In both studies, the area of floodplains is very similar.

So, one could conclude that the results of the River dynamics-scenario, as far as it concerns riverine forest, marshland and side channels, are representative for the ‘Living Rivers’-plan. This means that elaboration of the ‘Living Rivers’ will improve the network function for species of riverine forests and side channels. The network function for species of marshland won’t improve. However, it should be mentioned that the ‘Living Rivers’ plan is restricted to the area between the winter dikes. In a natural river system, back swamps develop mostly at a longer distance from the river, where circumstances are less dynamic (see also section 7.3.4).

EXISTING PLANS IN THE STUDY AREA
For The Netherlands information gathered by RIZA for the project ‘Landscape Planning Rhine’ (Silva & Kok 1995) was used. For Germany the ‘Landesanstalt für Ökologie, Landschaftsentwicklung und Forstplanung Nordrhein-Westfalen’ provided us with the report ‘Gezamtskonzeption zur Erhaltung und Optimierung des Feuchtgebietes internationaler Bedeutung Unterer Niederrhein’ (see also Wolke & Verbücheln 1993; Rüpert & Schulte 1993). Only nature rehabilitation plans are considered. In the Dutch part the total area of the plans is about 3000 ha. Although further detailed information was not available there are indications that elaboration will be compatible with the Loire-River dynamics scenario. This also holds true for the German part of the study area, because there are plans to develop about 1500 ha of floodplain forest. The plans are equally distributed over the study area, but the total area is only 40% from that of the Loire-River dynamics scenario.

So, compared with this scenario expectations are that in the study area the network function for the target species will be less if the existing plans are carried out. Probably, only a marginal viability and a low stepping stone function can be reached for Beaver and Middle Spotted Woodpecker.
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GLOSSARY

These definitions are specific to the use of these terms in this document.

Carrying capacity
The maximum number of reproductive units that can be present in a particular habitat patch.

Chance of occurrence
The chance that a particular habitat unit (=patch) is occupied by individuals as assessed by a simulation model. Expressed as the number of times that a patch is occupied in 100 years.

Ecotope
Spatial unit of corresponding ecosystem. Combination of abiotic site conditions (physiotope) and related plant and animal community.

Extinction chance
The chance that a metapopulation will become extinct. Expressed as number of times that a population becomes extinct in 100 simulations of 100 years (METAPHOR-approach).

Habitat unit
A unit of vegetation that offers suitable breeding and feeding conditions for at least one pair of a species.

Hydrodynamics
The physiological or hydrological influence of water on site, vegetation and animals, here expressed as the duration of flooding of ecotopes in days/year.

LEDESS
Landscape ecological decision support system. A knowledge-based GIS-oriented deterministic model that provides changes in physiotopes and vegetation related to measures and management.

LARCH
Landscape ecological rules for the configuration of habitat. For an extensive description see section 4.4.2.

Macrophyte marsh
Marshland vegetations consisting of large helophytes like reed Phragmites australis, reed mace Typha spec., reed canary grass Phalaris arundinacea and reed grass Glyceria maxima etc.

METAPHOR
Mathematical model to simulate the dynamics of spatially structured populations. For an extensive description, see section 4.4.3.

Morphodynamics
The mechanical and physical influences of flowing water on substrate, vegetation and animals, here expressed in vertical changes of physiotopes in m/year.
Natural reference
Ecological characteristics of the natural river system.

Network
A spatial distribution of habitat patches among which relations of exchange exist.

Physiotope
A set of abiotic conditions with the same chances for vegetation development and the same habitat suitability.

River reach
Part of the river system characterized by a specific configuration of river and floodplain landform patterns.

Saturation (of network population)
A measure for the network function. In this case the number of breeding pairs realized in a simulation, expressed as a percentage of the carrying capacity.

Spatial population dynamics
Dynamics of demographical parameters e.g. number of reproductive units, recruitment and mortality of a spatially structured population (like metapopulation).

Stepping stone function
A measure for the network function. The chance that species can distribute from one side of the study area to the other. Expressed in three qualitative categories and dependent on viability and distribution of core areas.

Summer dike
Small dike constructed for the protection of floodplain grasslands against flooding in late spring and summer.

Target nature type
A characteristic and coherent unit of vegetation, flora and fauna which develops under specific abiotic conditions and due to certain construction or management measures.

Target species
Species which are characteristic for one habitat type or a combination and are susceptible to the landscape ecological scale level in this study.

Terminal vegetation
Expected vegetation, which will finally occur in a ecotope after the execution of a scenario.

Viability (of network population)
Measure for the network function. The chance that a population will survive for a certain amount of time, expressed as the extinction chance in the METAPHOR-approach and qualitatively assessed in the LARCH-approach.

Winter dike
Large dike constructed for total protection against flooding.
APPENDICES

APPENDIX 1. LIST OF NAMES OF TARGET SPECIES

<table>
<thead>
<tr>
<th>English</th>
<th>Latin</th>
<th>Dutch</th>
<th>German</th>
</tr>
</thead>
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<tr>
<td>Barbel</td>
<td>Barbus barbus</td>
<td>Barbeel</td>
<td>Barbe</td>
</tr>
<tr>
<td>Beaver</td>
<td>Castor fiber</td>
<td>Bever</td>
<td>Biber</td>
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<td>Bittern</td>
<td>Botaurus stellaris</td>
<td>Roerdomp</td>
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<td>Great Reed Warbler</td>
<td>Acrocephalus arundinaceus</td>
<td>Grote Karekiet</td>
<td>Drosselrohrsänger</td>
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<tr>
<td>Middle Spotted Woodpecker</td>
<td>Dendrocopous medius</td>
<td>Middelste Bonte Specht</td>
<td>Mittelspecht</td>
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<td>Night Heron</td>
<td>Nycticorax nycticorax</td>
<td>Kwak</td>
<td>Nachtreiher</td>
</tr>
<tr>
<td>White-tailed Eagle</td>
<td>Haliaeetus albicilla</td>
<td>Zeearend</td>
<td>Seeadler</td>
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</table>
APPENDIX 2. PHYSIOTOPES: MAPPING PROCEDURE AND DESCRIPTION

2.1. Mapping procedure

The present distribution of the selected physiotopes within the study area is presented on the map Physiotopes (Appendix; Map 1). The physiotopes have been mapped on a scale of 1 : 60,000; on this level all relevant information was available. Physiotopes have been mapped by hand on three transparent topographic map sheets; the sheet for the German area being a photographic reproduction of the published 1 : 50,000 topographic maps. This map was digitised into an ARC/INFO database.

Information on the abiotic variables of the study area, relevant for the classification of physiotopes (see chapter 2), has been derived from published maps and air photographs. The table summarizes which information has been used for the particular physiotopes.

For the Dutch part of the study area the following have been used:

1 - the Topographical map of The Netherlands 1 : 50,000, sheets 38 W/O, 39 W/O, 40 W/O, 44 W/O and 45 W (Topografische Dienst Emmen, 1992-1993);
2 - the Geomorphological map of The Netherlands 1 : 50,000, sheets 39 (Kleinsman et al., 1985), 40 (De Lange and Ten Cate, 1980) and 45 (Kleinsman et al., 1983);
3 - the soil map of the Netherlands 1 : 50,000, sheets 38 West (Markus, 1984), 38 West and Oost (STIBOKA, 1973), 39 West and Oost (STIBOKA, 1976), 45 West (Damoiseaux en Vos, 1987), 44 Oost (Harbers, 1980), 45 West (Bles et al., 1984) and 45 Oost (STIBOKA, 1976);
4 - the 'Uiterwaardenkaart van de grote rivieren' 1 : 50,000, Vereenvoudigde Geomorfologie, sheet 3, 4 and 6 (De Soet, 1976);
5 - the 'Milieutypenkaart Gelderse uiterwaarden' 1 : 50,000, sheet 1 t/m 6 (Drok, 1988);
6 - the 'Foto-atlas Gelderland', air photographs on scale 1 : 14,000 (Robas Produkties/ Topografische Dienst, 1989);
7 - the 'Rivierkaarten' 1 : 5000 (Rijkswaterstaat, Meetkundige Dienst)

The physiotopes and their delineation have been determined mainly from sources 1-4. The soil map (3) has been relevant only for mapping the (embanked) natural levees, former floodplains and back swamps. Natural levees which have been developing very recently have been mapped by means of the air photographs and the 'Overzichtskaart van de zandpakketten zoals afgezet tijdens het hoogwater van december 1993' (Van Menen et al., 1994). Source (4) has been used to map the tidal floodplains, and has been used as substitution of sheet 38 Oost of the Geomorphological map of the Netherlands, which has not been surveyed yet. In the other areas this map together with the sources (5),(6) and (7) has been used as 'second' or 'third opinion' next to sources (1) and (2). In cases where two or more sources gave contradictory information on the delineation of physiotopes, the most recent source has been chosen. In cases where differences in classification occurred a choice has been made according to our best professional judgement.

For the German part of the study area the following have been used:

8 - the 'Topographische Karte von Nordrhein-Westfalen 1 : 60,000', sheets L4102, L4104, L4302, L4304, L4306, L4504 en L4506 (Landesvermessungsamt Nordrhein-Westfalen, 1989-1990);
9 - the 'Topographische Karte von Nordrhein-Westfalen 1 : 25,000 (Luftbildkarte)', sheets 4102, 4103, 4203, 4204, 4304, 4305, 4405, 4506 en 4506 (Landesvermessungsamt Nordrhein-Westfalen, 1988);
10 - the 'Bodenkarte von Nordrhein-Westfalen 1 : 50,000', sheets L4102, L4104, L4302, L4304, L4306, L4504 en L4506 (Geologisches Landesamt Nordrhein-Westfalen, 1974-1989);
11 - the 'Geologische Karte von Nordrhein-Westfalen 1 : 100,000', sheets C4302, C4306, C4702 en C4706 (Geologisches Landesamt Nordrhein-Westfalen 1968-1987);
12 - the 'Hydrogeologische und Ingenieurgeologische Karte von Nordrhein-Westfalen 1 : 25,000', sheet 4506 (Geologisches Landesamt Nordrhein-Westfalen, 1991);
13 - the 'Biotopkartierung Nordrhein-Westfalen 1 : 50,000' (Landesanstalt für Ökologie, Landschaftsentwicklung und Forstpflanung Nordrhein-Westfalen, 1991)

Physiotopes in this part of the study area have been mainly mapped using information from sources (10) and (13). The latter was used only for the classification; the delineation of physiotopes has been derived entirely from the soil maps. Information on minor dikes, connected lakes and closed lakes has been derived from recently published topographical maps. Sources (11) and (12) gave additional information on dump sites of industrial and household waste on sites that would have been classified as recultivated floodplains when using the soil map information solely. The air photographs have been used to check our interpretations.
### SOURCES USED FOR MAPPING THE PHYSIOTOPES (see text for explanation of codes and numbers)

<table>
<thead>
<tr>
<th>Physiotope</th>
<th>Sources</th>
<th>Netherlands</th>
<th>Germany</th>
</tr>
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<td></td>
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</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
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<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Ae Floodplain, natural</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Af Floodplain, recultivated</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Ag Tidal floodplain</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Ah Connected floodplain channel</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Ai Closed floodplain channel</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Ak Connected gravel pit lake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Al Closed gravel pit lake</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Bd Natural levee</td>
<td></td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Be Floodplain, natural</td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Bf Floodplain, recultivated</td>
<td></td>
<td>x</td>
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</tr>
<tr>
<td>Bi Stagnant floodplain channel/clay pits</td>
<td></td>
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<td>Bl Closed gravel pit lake</td>
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<td>x</td>
<td></td>
</tr>
<tr>
<td>Bm High water free terrain</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Ce Former natural levee</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Cf Recultivated area</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Ci Stagnant abandoned channel/clay pits</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Cj Seepage abandoned channel</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Cn Flood basin</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Co Back swamp</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Cp River dune</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

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2.2. Description

**NOT PROTECTED AGAINST FLOODING:**

**Aa River bed**
- situation: river channel
- genesis: bedding processes
- morphodynamics: very large
- soils: gravel and sand
- relief: strongly undulating relief
- hydrodynamics: deep water
- water depth: deep

**Ab Gravel bar**
- situation: within river bed
- genesis: bedding processes
- morphodynamics: very large
- soils: gravel and sand
- relief: strongly undulating relief
- hydrodynamics: shoreface
- groundwater level: moist

**Ac Side channel**
- situation: behind gravel bar
- genesis: bedding processes
- morphodynamics: large
- soils: sand
- relief: shallow channel
- hydrodynamics: permanently flooded
- water depth: shallow

**Ad Natural levee**
- situation: along river banks
- genesis: overbank deposition
- morphodynamics: moderate
- soils: sandy clays
- relief: undulating
- hydrodynamics: periodically flooded
- groundwater level: dry

**Ae Floodplain, natural**
- situation: behind natural levees
- genesis: overbank deposition
- morphodynamics: moderate
- soils: sands with clayey top layer
- relief: flat
- hydrodynamics: frequently flooded
- groundwater level: moist

**Ah Connected floodplain channel**
- situation: often along main dikes
- genesis: abandoned river bed, still connected
- morphodynamics: moderate
- soils: sands with clayey top layer
- relief: shallow channel
- hydrodynamics: permanently flooded
- water depth: shallow

**Al Closed floodplain channel**
- situation: often along main dikes
- genesis: abandoned river bed, disconnected
- morphodynamics: moderate
- soils: sands with clayey top layer
- relief: shallow channel
- hydrodynamics: shoreface
- water depth: shallow

**A f Floodplain, recultivated**
- situation: often along main dikes
- genesis: overbank deposition, clay extraction
- morphodynamics: moderate
- soils: sands with clayey top layer
- relief: pronounced ridge
- hydrodynamics: permanently flooded
- water depth: deep

**Ag Tidal floodplain**
- situation: along river bed or along floodplain channels
- genesis: overbank deposition and accumulation of organic material
- morphodynamics: moderate
- soils: clays, sandy clays and sands
- relief: flat
- hydrodynamics: frequently flooded
- groundwater level: wet

**PROTECTED BY MINOR DIKES:**

**Bd Natural levee**
- situation: along river banks
- genesis: overbank deposition
- morphodynamics: small
- soils: sand
- relief: pronounced ridge
- hydrodynamics: periodically flooded
- groundwater level: dry

**Be Floodplain, natural**
- situation: behind natural levees
- genesis: overbank deposition
- morphodynamics: small
- soils: sandy clays
- relief: undulating
- hydrodynamics: periodically flooded
- groundwater level: dry

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Bf Floodplain, recultivated
situation: behind natural levees
genesis: overbank deposition, man-made
for clay extraction
morphodynamics: small by minor dikes
soils: sands with clayey top layer
relief: flat
hydrodynamics: periodically flooded
groundwater level: moist

Bi Stagnant floodplain channel / clay pits
situation: behind natural levees
genesis: overbank deposition, man-made
morphodynamics: small by minor dikes
soils: sands with clayey top layer
relief: shallow channel
hydrodynamics: frequently flooded
water depth: shallow

Bj Closed gravel pit lake
situation: along main dikes
genesis: abandoned river bed, disconnected, accumulation of organic material
morphodynamics: small
soils: sands with clayey/peaty top layer
relief: shallow channel
hydrodynamics: deep water
water depth: deep

Em High-water-free terrain
situation: along minor dikes
genesis: abandoned river bed, disconnected
morphodynamics: small
soils: gravel and sand
relief: plateau
hydrodynamics: never flooded
groundwater level: dry

Embanked area:
Ce Former natural levee
situation: along the main dikes
genesis: overbank deposition before embankment
morphodynamics: -
soils: silty clay soils
relief: shallow ridge
hydrodynamics: -
groundwater level: dry

Cj Seepage abandoned channel
situation: along pronounced terrace escarpments, often near ice-pushed ridges
genesis: abandoned river bed, groundwater seepage
morphodynamics: -
soils: sand
relief: shallow channel
hydrodynamics: -
water depth: shallow

Ci Close gravel pit lake
situation: no specification
genesis: man-made for gravel extraction
morphodynamics: small
soils: gravel and sand
relief: very deep depression
hydrodynamics: -
water depth: deep

Cn Flood basin
situation: behind former natural levees
genesis: flood basin deposition
morphodynamics: -
soils: heavy clay or clay on peat soils
relief: flat
hydrodynamics: -
groundwater level: moist

Co Back Swamp
situation: in the center of flood basins
genesis: flood basin deposition and peat formation
morphodynamics: -
soils: clay on peat or peat soils
relief: flat
hydrodynamics: -
groundwater level: wet

Cp River dune
situation: no specification
genesis: Pleistocen aeolian dune formation
morphodynamics: -
soils: sand
relief: pronounced isolated hillocks
hydrodynamics: -
groundwater level: dry
APPENDIX 3. PRESENT VEGETATION: MAPPING PROCEDURE

SOFT WOOD FOREST
Information on softwood forest (e.g. willow and poplar stands) was gathered up to 10 km from the borders of the study area. For the Netherlands the ‘4de Bosstatistiek’ was used, which describes the composition and age of forests larger than 0.5 ha (available on maps 1:10,000). Willow stands were only included if they had a height of >5 m. For Germany the ‘Biotopkartierung Nordrhein-Westfalen 1:25,000’ carried out by the Landesanstalt für Ökologie, Landschaftsentwicklung und Forstplanung (LÖBF) was a suitable source. All softwood riverine habitat and all forests consisting of Willow or other typical softwood riverine forest tree species were selected.

HARDWOOD FOREST
Information on hardwood forest (diameter of trees >50 cm) was gathered up to 10 km from the borders of the area. The same sources were used as mentioned for softwood forest. In Germany, however, the exact location of patches of hardwood was not available. It was only possible to map hardwood forest as a proportion of the area of larger forest patches. Hardwood riverine forest was labelled differently from other hardwood forest types since that represents optimal habitat.

MACROPHYTE MARSH
Information on macrophyte marshes which consist of reed vegetations was gathered up to 75 km around the study area. They were only considered if the size of the reed area was >0.25 ha for the zone up to 20 km (minimum area for the Great Reed Warbler) and 1 ha for the zone from 20-75 km (minimum area for the Bittern). For the Netherlands a GIS database of marshland areas was available, compiled by IBN-DLO (Department of Landscape Ecology). The proportion of reed of each area had already been indicated. For Germany the ‘Biotopkartierung Nordrhein-Westfalen 1:25,000’ (LÖBF) was used. With help of J. Rijpert of the LÖBF the marshes were selected and the proportion of reed estimated. This information was added to the existing GIS database.
APPENDIX 4. MEASURES TO BE TAKEN TO IMPLEMENT TARGET NATURE TYPES

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<thead>
<tr>
<th>Target nature type</th>
<th>physiotope</th>
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<tr>
<td>N0</td>
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<tr>
<td>N1</td>
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<td>N7</td>
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</tbody>
</table>

Nature target types

N0: maintaining the current situation
N1: developing softwood floodplain forest, no management
N2: developing wood with oak, no management
N3: developing macrophyte marsh (reed), winter mowing
N4: constructing/developing a side channel
N5: constructing/developing a floodplain channel (connected downstream)
N6: constructing/developing isolated water (inside the dike)
N7: developing riverine forest landscape, guided nature (with natural grazing)

Measures (hydrological and layout)
1 = removing dike
2 = letting river water in
3 = constructing side channel
4 = making downstream opening
5 = digging shallow water
6 = digging deep water
7 = lowering the soil surface by clay digging

0 = no measures needed
- = no measures possible
APPENDIX 5. CHANGES IN PHYSIOTOPE TYPES BY MEASURES (HYDROLOGICAL AND LAYOUT)

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</table>

Measures (hydrological and layout)
1 = removing dike
2 = letting river water in
3 = constructing side channel
4 = making downstream opening
5 = digging shallow water
6 = digging deep water
7 = lowering the soil surface by clay digging

O = no measures needed
- = no measures possible
Ac = new physiotope type
APPENDIX 6. PERCENTAGES TERMINAL VEGETATIONS BY TARGET NATURE TYPE AND PHYSIOTOPE TYPE

6.1. Terminal vegetation V1: Softwood forest

<table>
<thead>
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<th>V1</th>
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<th>N2</th>
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<th>N4</th>
<th>N5</th>
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<tbody>
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<td>M</td>
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<td>Bm High water free terrain</td>
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<td>Ce Former natural levee</td>
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<td>Cj Seepage floodplain channel</td>
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*M, lay-out measure has to be taken in order to change the physiotope*
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1M, lay-out measure has to be taken in order to change the physiotope
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¹M, lay-out measure has to be taken in order to change the physiotope
6.4. Terminal vegetation V4: Open water (connected with the river)

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*M, lay-out measure has to be taken in order to change the physiotope
6.5. Terminal vegetation V5: Isolated water

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'M, lay-out measure has to be taken in order to change the physiotope
6.6. Terminal vegetation V6: grass/rough pasture (resulting from natural grazing)

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1M, lay-out measure has to be taken in order to change the physiotope
### 6.7. Terminal vegetation V7: beach, gravel, mud

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*M, lay-out measure has to be taken in order to change the physiotope*
APPENDIX 7. RESULTS METAPHOR APPROACH: PATTERN OF CHANCE ON OCCURRENCE PER HABITAT UNIT

Present situation and scenarios

1. Middle Spotted Woodpecker
2. Great Reed Warbler
3. Bittern
1 - 1988 Ecological rehabilitation of the river Rhine: a proposal for a Netherlands research programme. (RIZA, RIVM, RIVO-DLO)


7 - 1989 Bioaccumulation in yellow eel (Anguilla anguilla) and perch (Perca fluviatilis) from the Dutch branches of the Rhine-mercury, organochlorine compounds and polycyclic aromatic hydrocarbons. F. van der Valk, H. Pieters and R.C.C. Wegman. (RIVO-DLO)


11 - 1989 Literature survey into the possibility of restocking the River Rhine and its tributaries with Atlantic salmon (Salmo salar). S.J. de Groot. (RIVO-DLO)

12 - 1989 Literature survey into the possibility of restocking the River Rhine and its tributaries with sea trout (Salmo trutta trutta). S.J. de Groot. (RIVO-DLO)


14 - 1989 Ecologisch herstel van de Rijnmakrofauna. B. van Dessel. (RIZA)


17 - 1990 Chemicals affecting the spawning migration of anadromous fish by causing avoidance responses or orientational disability, with special reference to concentrations in the River Rhine. T.C. van Brummelen. (RIZA)

18 - 1990 Biomonitoring with the larvae of Chironomiden en kokerveffers. F. Heinis en T. Kronmann. (RIZA)


21 - 1990 On the potential of based an ecological typology of aquatic sediments on the nematode fauna: an example from the River Rhine. T. Bongers and J. van de Haar. (RIVM)

22 - 1990 Monitoring the toxicity of organic compounds dissolved in Rhine water. D. de Zwart and A.J. Folkerts. (RIVM)

23 - 1990 The kinetics of the degradation of chlorof orm and benzene in anaerobic sediment from the River Rhine. P. van Beelen and F. van Keulen. (RIVM)

24 - 1990 Phases in the development of riverine plankton: examples from the rivers Rhine and Meuse. E.D. de Ruiter van Steveninck, B. van Zanten and W. Admiral. (RIVM)

25 - 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. F.W.B. van den Brink. (RIZA)


28 - 1991 Voedsellecologie van vissen in de Nederlandse Rijnvakten. P.J.M. Bergers. (RIZA)


31 - 1991 Inventarisatie van en verbeteringsplanning voor de fysieke belemmeringen voor de migratie van vis op de grote Nederlandse rivieren. A.W. de Haas. (RIZA)


33 - 1991 Nevengeulen - onderzoek naar de mogelijkheden, de consequenties en de te stellen eisen bij de aanleg van nevengeulen in de uiterwaarden. A.W. de Haas. (RIZA)

34 - 1991 The Asiatic clam, Corbicula fluminea (Müller, 1774), a new immigrant in the River Rhine. A. bij de Vaate (ed.). (RIZA)

35 - 1991 The effects of micropollutants on components of the Rhine ecosystem. Ed J.A.W. de Wit et al. (RIZA)


47 - 1992 Methode voor de schatting van milieurisico's in de Gelderse uiterwaarden (RIZA).


51 - 1993 Documentation of zooplankton species in the Lower River Rhine. B. van Zanten en P. Leentvaar. (RIVM)


53 - 1993 Worden groei, overleving en kieming van vlotterende Waterrankenkol (Ranunculus fluitans Lamork) in Maaswater beïnvloed door waterstandsfluxuaties? Semi-veldexperimenteren. M.A.A. de la Haye. (RIZA)

54 - 1993 Paal- en op royaltybeelden voor vis in de Maas. S. Semmekrot en F.T. Vrieze. (RIZA)


55B - 1993 Reports of the project "Ecological Rehabilitation of the river Meuse". Zware metalen en organische microverontreinigingen in bodem, regenwormen en dassen in het winterbed van de Maas bij Grave. M.J.J. Kerkhofs, W. Silva en W. Ma (RIZA)


62 - 1994 Reports of the project "Ecological Rehabilitation of the River Meuse". A. bij de Vaste en M. Gerysman-Klaas (RIZA)

63A - 1994 Ontwikkelingsmethoden voor zachtboutooibos in het zomerbed van de Grensmaas. N. Geelen (RIZA)


Aanvragen/requests:
(RIZA): Institute for Inland Water Management and Waste Water Treatment, P.O. Box 17, 8200 AA Leelystad, The Netherlands.
(RIVM): National Institute for Public Health and Environmental Protection, P.O. Box 1, 3720 BA Bilthoven, The Netherlands.
(IBN-DLO): Institute for Forestry and Nature Research, P.O. Box 9201, 6800 HB Arnhem, The Netherlands.
(SC-DLO): The Wimund Staring Centre for Integrated Land, Soil and Water Research, P.O. Box 125, 6700 AC Wageningen, The Netherlands.