# Ecological networks in river rehabilitation scenarios



# Rhine-Econet

## summary report

Ministry of Transport, Public Works and Water Management
Directorate-General for Public Works and Water Management
RIZA Institute for Inland Water Management and Waste Water Treatment

Ministry of Agriculture, Nature Management and Fisheries

DLO Institute for Forestry and Nature Research (IBN-DLO)
DLO Winand Staring Centre for Integrated Land, Soil and Water Research (SC-DLO)
VISTA, Bureau for Environmental Planning, Landscape Architecture & Ecology

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# Contents

# Introduction

Land and water management policies increasingly address the rehabilitation of river floodplains. Various actions plans aim at protecting, improving and developing habitats for plant and animal species.

Improving existing habitats or re-creating former ones, however, does not necessarily mean that animal species will settle. The size of the habitat units might be too small to support a viable population. Many species will only persist if habitat units are linked into a network system. If species are present in a part of the river system only or if they are absent altogether, it is important that new habitats create a network that enables them to expand. Consequently, local plans will probably be more successful if they are part of a strategy for the whole river system.

This summary report surveys the results of the case-study Rhine-Econet. Objectives of this study were:

- to clarify the importance of an ecological network of nature areas for a successful nature conservation and rehabilitation strategy;
- to elaborate scenario approaches into a method which can be applied in future studies on river rehabilitation.

The original study structure and process is depicted in Figure 1. The scenario approach has been adopted to illuminate various options for planning nature areas. Based on an analysis at the ecosystem level, which provided knowledge on suitability for nature rehabilitation, scenarios have been designed that differ in spatial distribution of ecotopes. To evaluate these scenarios in terms of their network function for species, models are used as tools to predict the impacts of the proposed future situations.

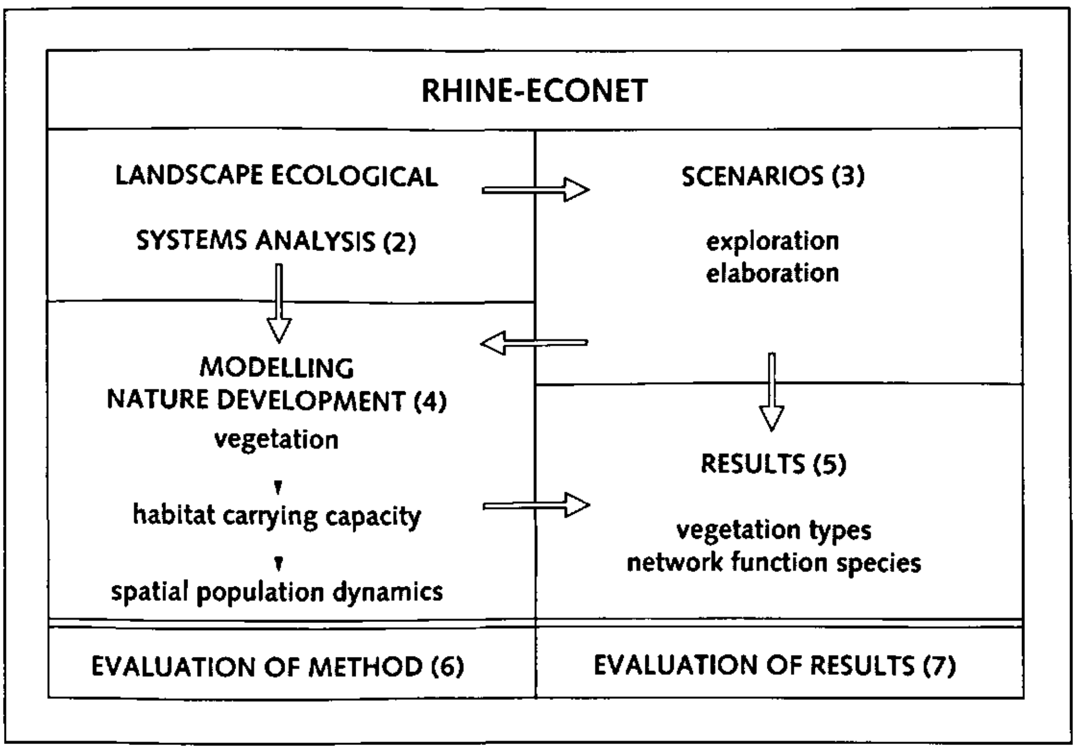
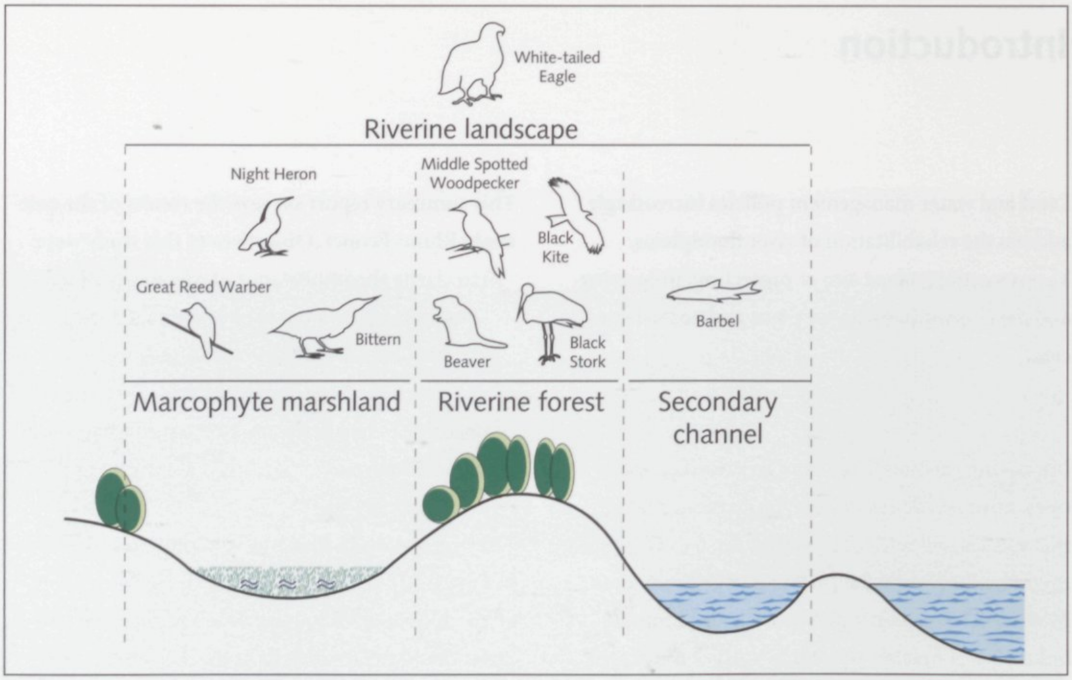



**Figure 1**
Outline of the study structure and process.

**Figure 2**
Target species and habitat types.




The case-study is focused on three habitat types: floodplain (riverine) forests, macrophyte marshes and secondary channels. Nature rehabilitation plans focus on these habitat types, since these are very small and strongly fragmented at present. To evaluate the network function, vertebrate animal species are selected which are characteristic for one or a combination of these habitat types (Figure 2). The lower part of the River Rhine system has been chosen as study area.

# Landscape ecology

The analysis of the river landscape ecosystem has been performed on three hierarchical levels: drainage basin zones, river reaches and river ecotopes. It aims at providing a basis for the exploration of scenarios for nature rehabilitation as well as for modelling future situations.

The investigated part of the River Rhine system is situated between the mountains in Germany and the North Sea (Figure 3). In the upstream half of the study area the River Rhine flows in a broad valley, being part of the transport zone of the river system. It is characterized by fluvial terraces, indicating incision by a meandering river. Downstream, the depositional zone or Rhine delta is characterized by a number of meander belts interspaced with large flood basins. Sediments were deposited by meandering or low-sinuosity distributaries of the Rhine, that changed their course repeatedly. Within both types of depositional styles mentioned, local differences in geological setting and river regime caused an ecotope pattern variability at the river reach level.

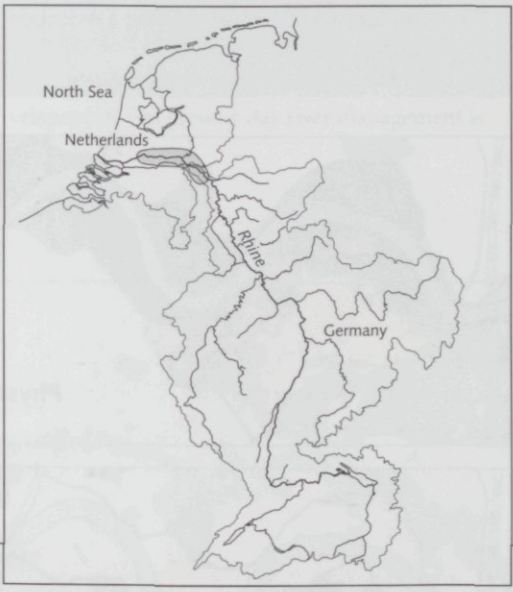
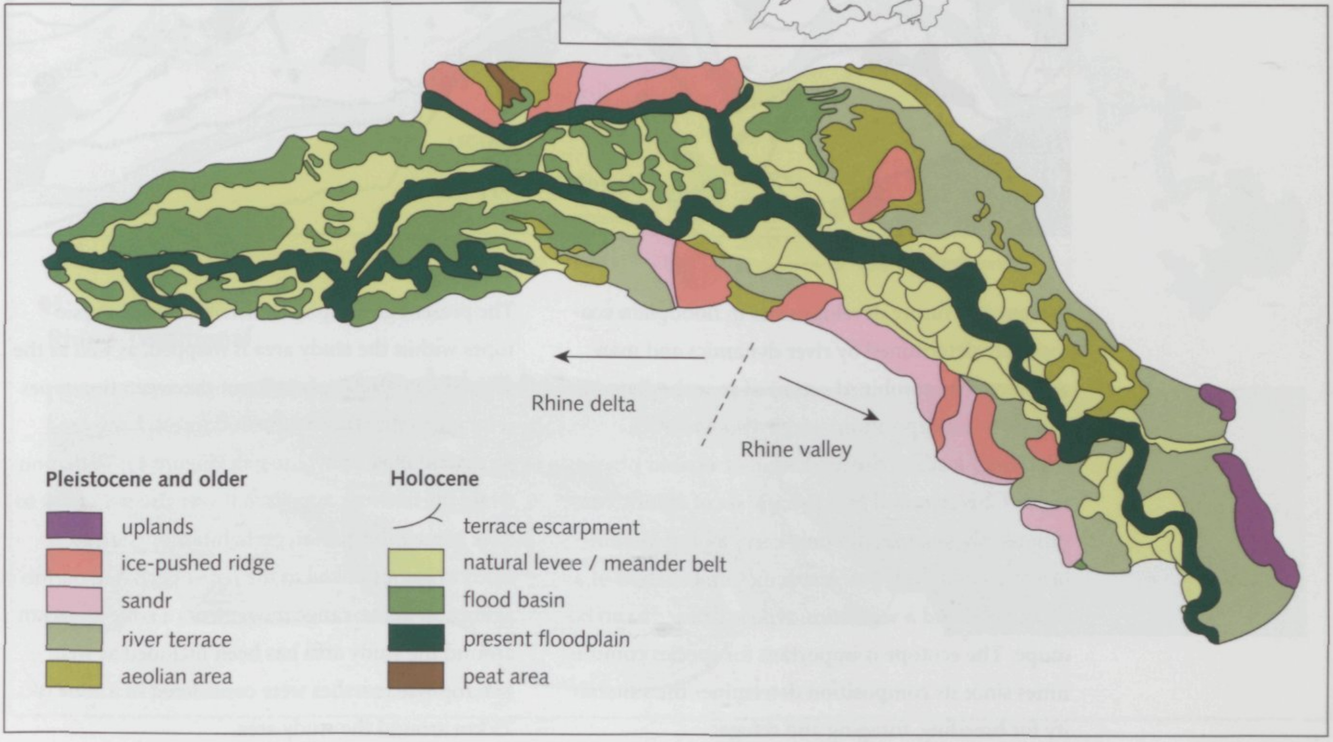



Figure 3
Physiography of the Lower Rhine area



## Historical changes

In the Middle Ages the Rhine and its distributaries were embanked. The flood basins and marshes were reclaimed for agriculture; hardwood forests were removed for settlements and orchards. Consequently, the morphology of the river channels and adjacent floodplains has altered completely. Increased sedimentation has raised the floodplain for several metres, causing a reduction in wetland area.

During the eighteenth and nineteenth centuries several meander loops were artificially cut off and finally the position of the entire river became fixed by means of groynes and revetments. Fixing the river bed meant the disappearance of features characteristic of migrating rivers, like mid-channel bars, gravel bars and secondary channels, and hence important habitats for wildlife. Furthermore, regulation has caused a strong tendency towards vertical erosion of the river bed, leading to further dessication of the wet floodplain ecotopes.

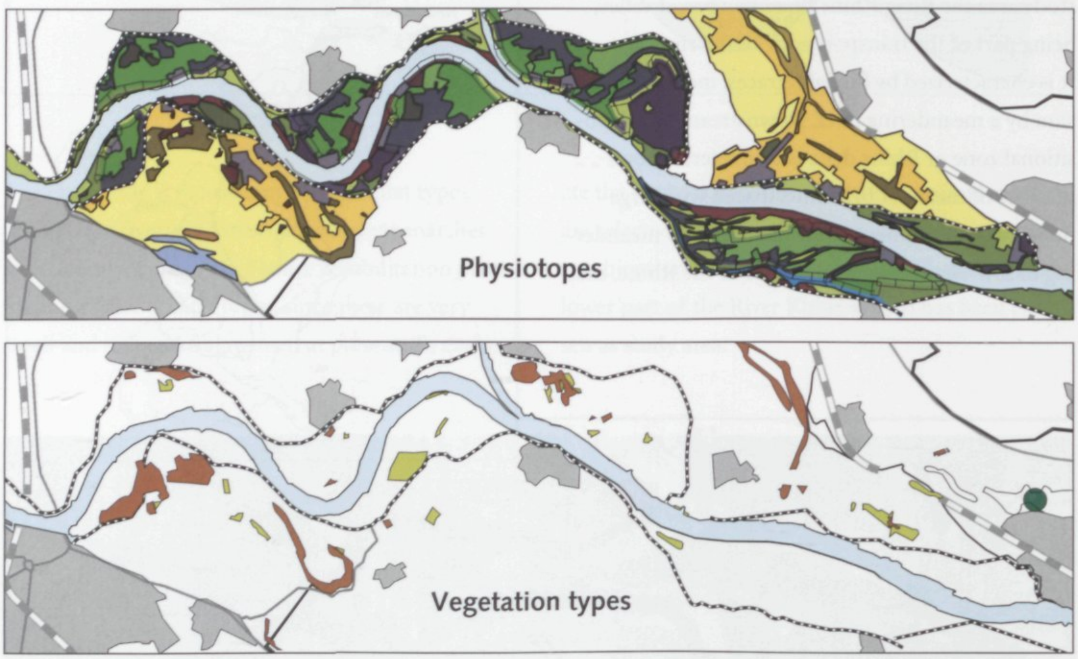



**Figure 4**
Maps of part of the study area presenting the present physiotopes and present vegetation.

Present and future developments in floodplain ecotopes are determined by river dynamics and management. The combined action of morphodynamics (erosion and deposition) and hydrodynamics (flooding) leads to the formation of various physiotopes. Characterized by a specific set of abiotic conditions, physiotopes can only carry a limited number of vegetation types. A specific combination of a physiotope and a vegetation type is defined as an ecotope. The ecotope is important for species communities since its composition determines the suitability for breeding, foraging and refuge.

The present geographical distribution of physiotopes within the study area is mapped, as well as the present distribution pattern of the vegetation types relevant to the study: softwood forest, hardwood forest and macrophyte marsh (Figure 4). To demonstrate the network approach it was also necessary to have some information on habitats outside the study area, but linked to the network. Based on foraging and home-range movements a zone of 10 km around the study area has been included as well. Macrophyte marshes were considered in a zone of 75 km around the study area.

# Scenarios

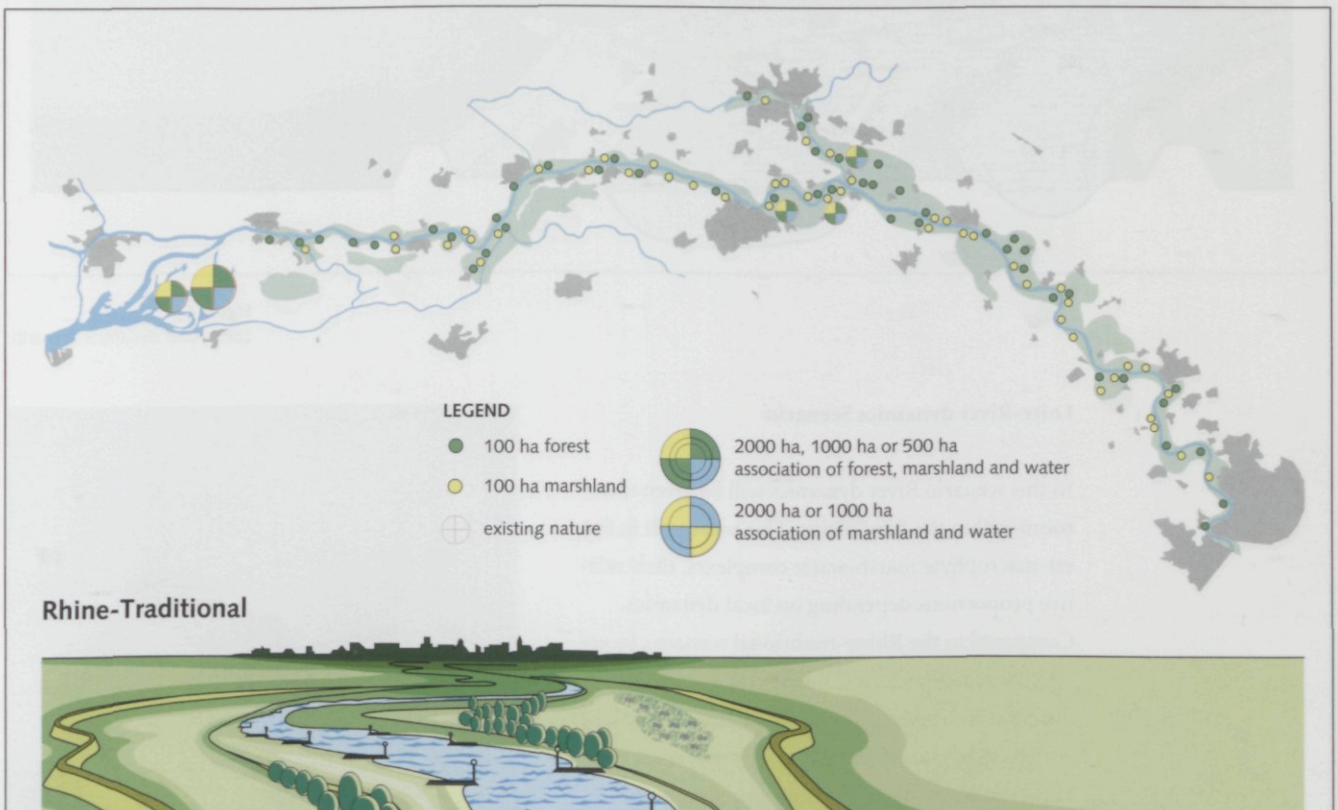
Inspired by the description of the systems' natural situation in historical time and based on the knowledge on the suitability for nature rehabilitation, three scenarios have been chosen, which differ in spatial distribution of ecotopes (Figures 5, 6 and 7).

The ecotope patterns are related to different intensities of river dynamics and management activities. These differences are expected to be reflected in the network function. The scenarios are named after river systems that can be considered, entirely or partially, as a contemporary reference.

**Rhine-Traditional Scenario**

Relatively small forests and macrophyte marshes will be spread evenly throughout the study area. Forests will be realized in the dry places. Sites for macrophyte marshes are only limited available at present, so excavations will have to be carried out to realize the scenario. This scenario allows mowing management and clay extraction in order to maintain the macrophyte marshes and favour Reed development. The present-day river management is continued.

**Figure 5**
Rhine-Traditional Scenario.



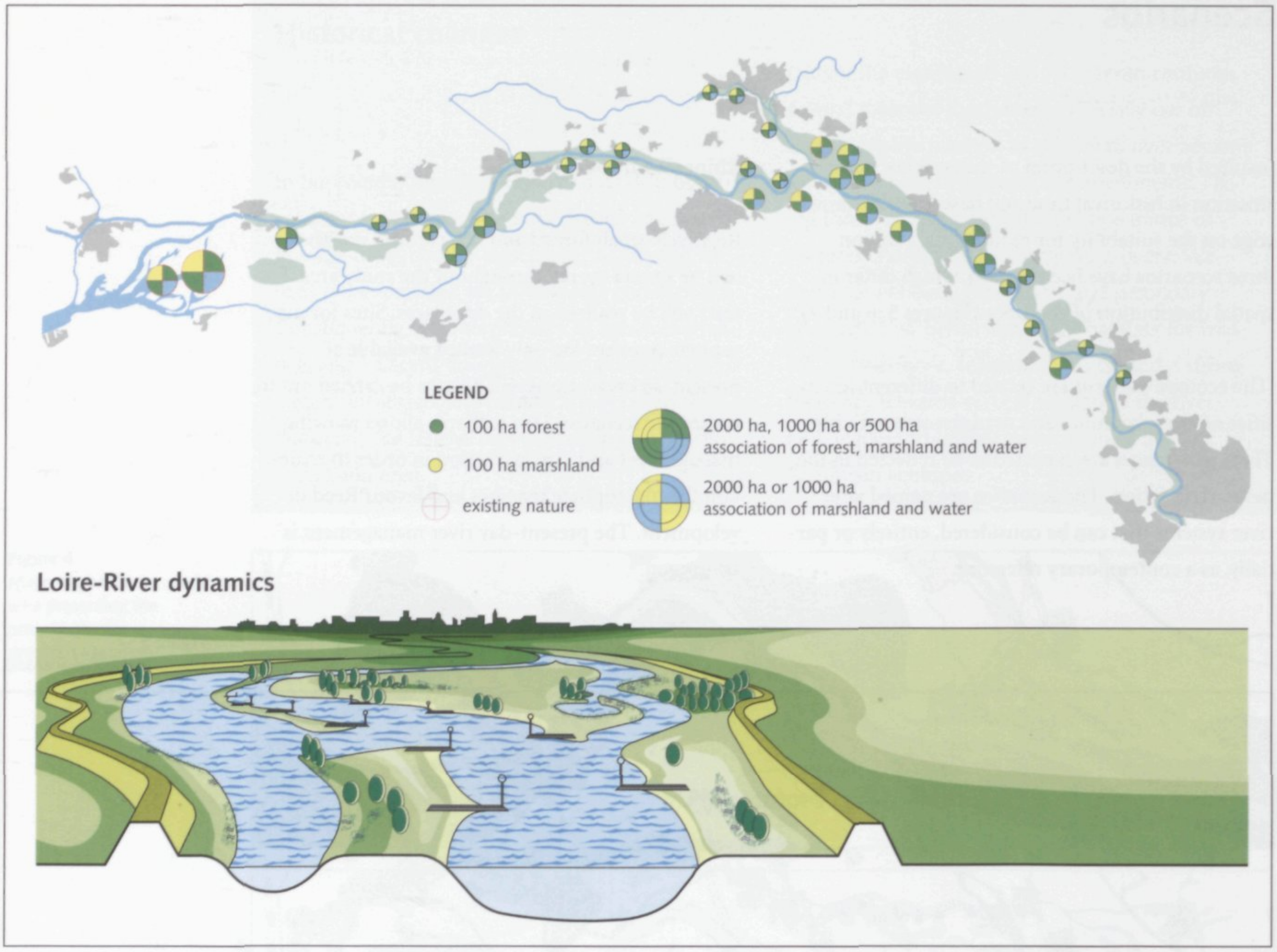



**Figure 6**
Loire-River dynamics Scenario.

**Loire-River dynamics Scenario**

In this scenario River dynamics will be given more room within the floodplains. This will result in forest-macrophyte marsh-water complexes, their relative proportions depending on local dynamics. Compared to the Rhine-traditional scenario, larger units of nature areas will be the result, with larger distances in between. The forest component will often predominate. Mowing management is excluded. However, extensive grazing, digging secondary channels or other excavation activities do fit in well. The secondary channels will have to be realized within river reaches that offer enough space and offer the appropriate river dynamics for maintaining open inflow points.

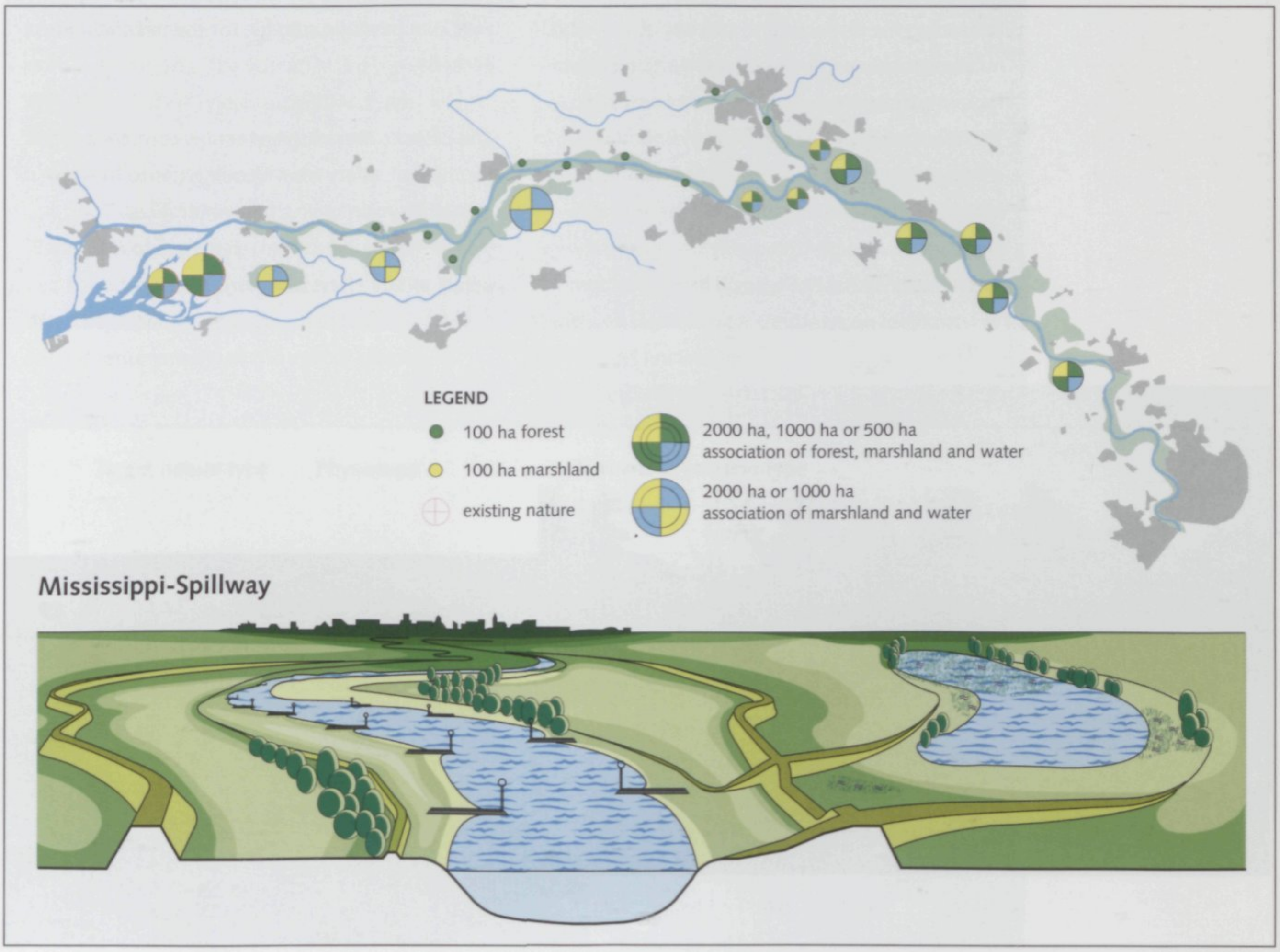
**Mississippi-Spillway Scenario**

A chain of large-scale macrophyte marshes will be restored. Within the Rhine delta, the former flood basins are connected to the river system to restore them as spillways. This is only feasible in places without villages, main roads and railways, where large low-lying areas may remain flooded nearly all year round. In the flood basins, the macrophyte marshes are to become as extensive as possible. This can be realized by river-water inlet during large winter discharges.

Within the Rhine valley, macrophyte marshes are also planned outside the present floodplains. Here they are to be realized within the adjacent river terraces. These terraces will be partially excavated by means of sand and gravel extraction in order to create a more suitable site for macrophyte marshes. The macrophyte marshes in this part of the river system will always be accompanied by forests.

In both parts of the river sytem forests are planned on the natural levees within the floodplains.

Figure 7
Mississipi-Spillway Scenario.



## Principles and restrictions

Pursuing the scenario approach requires stating principles and restrictions for physical planning. For the River Rhine system these are:

The total acreage at the disposal of nature rehabilitation will be 10,000 ha, to be distributed along a river length of some 220 km. This is 30% of the study area if only the floodplains are considered. The 30% level is in line with the policy aims for nature rehabilitation in the River Rhine system in both countries. At present only approximately 5% of the area is nature area. Existing nature areas will be maintained.

The distribution of new habitats is focused on enhancing the dispersal and survival of a selected number of species. An equal distribution of habitat units similar in size will be most favourable. Therefore, new nature areas are distributed accordingly. Of the total acreage, 5000 ha is designated as riverine forest and 5000 ha as macrophyte marsh in order to equally favour the species of both habitat types. The distribution of new natural areas is based on modules with units varying from 100 to 2000 ha.

The new habitats will fit as much as possible into the existing abiotic structures. However, should the floodplain physiotope not be suitable for the target nature type desired, measures can be taken to change the physiotope, such as removing summer dikes or digging shallow water resulting in an increase in river dynamics. Excavating will be done preferably in locations where the soil material is suitable for use in the construction industry. There it is economically valuable, and hence it can partially cover the execution cost of nature rehabilitation. Not all physiotopes, however, can be made suitable for the new habitats desired.

The present river management is continued. This means that safety from flooding has to be guaranteed by maintaining the winter dikes. The transport function of the river is not to be hampered by any effect of nature rehabilitation.

# Vegetation development

Automated processing of the scenarios has been enabled by using the Landscape Ecological DEcision-Support System (LEDESS), a knowledge-based system coupled to a Geographical Information System (GIS).

## Target nature types and terminal vegetation

Elaborating the scenarios requires a typology that fits in with the data processing. A distinction has been made between target nature types and terminal vegetations. The scenarios are translated into target nature types: vegetation types, which correspond to a certain type of management and a range of suitable physiotopes.

The type of vegetation that can be actually expected is the terminal vegetation type. The terminal vegetation typology corresponds to the habitat requirements of the animal species involved in the study. Beside the vegetation aimed at, other terminal vegetation types will develop. Within the physiotopes, the covering by terminal vegetation types is determined for each target nature type, expressed in percentages of physiotope area. An example of the final dataset is given in Table 1. In case the physiotope is not suitable for the target nature type desired, measures are incorporated to change the physiotope. When measures make no sense, this is also indicated. All relationships are based on literature and expert knowledge.

| Target nature type | Physiotope | Terminal vegetation type | | | | |
|---|---|---|---|---|---|---|
| | | Softwood forest | Hardwood forest | Macrophyte marsh | Open water vegetations | Grasslands |
| Softwood forest | Floodplain, natural | M7 | M7 | M7 | M7 | M7 |
| | Stagnant floodplain channel/clay pits | 40 | 0 | 10 | 50 | 0 |
| Hardwood forest | Floodplain, natural | 0 | 90 | 0 | 0 | 10 |
| | Stagnant floodplain channel/clay pits | M- | M- | M- | M- | M- |

**Table 1**
Terminal vegetations for some selected combinations of target nature types and physiotopes, expressed in percentage of the physiotope area (selected physiotopes are protected against flooding by low summer dikes; M7 = measure can be taken to change the physiotope: lowering the soil surface by clay digging; M- = no measures possible).

The two main operations of LEDESS are:

- checking the ecological feasibility through confrontation with the abiotic site conditions;
- determining the terminal vegetation, based on the expected vegetation development.

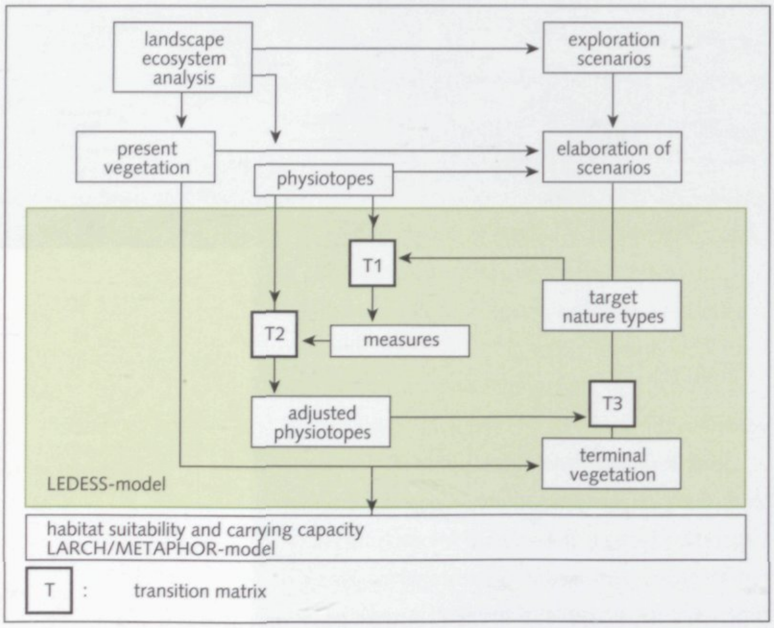



**Figure 8**
Operation process of the LEDESS system.

The scenarios are translated into target nature types and transferred to the GIS map. The first evaluation concerns the suitability of the physiotopes for the objectives chosen (Figure 8). If a target nature type does not correspond with the prevailing present abiotic conditions, the model can propose measures to change the physiotope. 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 and the present or adjusted physiotopes.

In a second evaluation, the terminal vegetations of each scenario are checked. Although different in distribution patterns, all three scenarios must attain an equal total area of forests and macrophyte marshes (both 5000 ha) in order to be able to compare the impact of the habitat distributions on the network function for species. The total area of target nature types appeared to show an acceptable deviation of less than 10 %. However, being dependent on the suitability of physiotopes, the specific terminal vegetation types can deviate from the expected target nature type:

- In the Rhine-Traditional Scenario many physiotopes prove to be unsuitable for vegetations with a high percentage of macrophyte marsh. Besides, the target nature type Macrophyte marsh (with winter mowing), turns out to develop softwood forest and isolated waters as well. Consequently, the development of macrophyte marshes remains below the target area, whereas the development of softwood forests is beyond the target area.
- According to the Loire-River dynamics Scenario the isolated waters are mainly transformed into waters connected with the riversystem, such as secondary channels and connected floodplain channels. The Scenario will develop a mosaic of bare soil, softwood and hardwood forests and, due to natural grazing management, grasslands. The area of macrophyte marshes remains far below the expected 5000 ha. The forest part of the scenario is almost such as was aimed at.
- The Mississippi-Spillway Scenario shows the largest contribution to the development of macrophyte marshes. However, caused by the natural manner of back swamp management chosen, the macrophyte marshes are only one third of the total inland areas designated for nature rehabilitation. Most part of this target nature type will develop in softwood forest or isolated waters.

# Ecological networks and target species

To evaluate the network function for the target species in the three scenarios, at first the habitat suitability and carrying capacity are estimated. Then the spatial dynamics of the populations are modelled by using the LAndscape ecological Rules for the Configuration of Habitat (LARCH) system or the METAPHOR model. The LARCH approach relies on expert knowledge. The METAPHOR model simulates the dynamics of a spatially structured population mathematically; of which the three major components are recruitment, mortality and dispersal.

## Habitat suitability and carrying capacity

Modelling spatial population dynamics requires information on patterns of habitat units at the level of local populations and information on the carrying capacity of these units. In the assessment the following steps are made:

- determination of habitat requirements in terms of the terminal vegetation types and physiotopes considered in the study;
- algorithms to determine the minimal habitat requirements of one reproductive unit (breeding pair or family) and to estimate the carrying capacity: the maximum number of reproductive units which can be present in a habitat unit.

For example, the Beaver lives in natural forests very near to open water. One family group (up to 10 individuals) needs around its lodge 2000 - 3000 m edge of hardwood or softwood forest and river bed, secondary channel, floodplain channel or gravel pit lake. The expected vegetation development determines whether suitable habitat is available and what will be the carrying capacity. Edge situations are assessed in circles of which the diameter equals the home range size: a radius of 2 km for the Beaver (Figure 9).

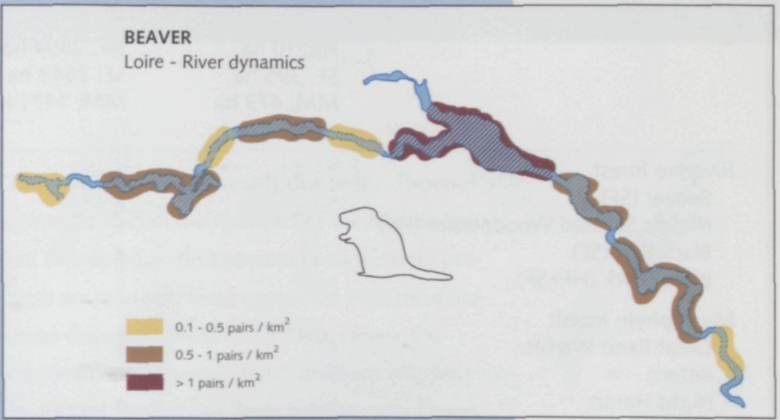



**Figure 9**
Estimation of suitable habitats and carrying capacity for Beavers in the study area in case of the Loire-River dynamics Scenario.

In general the mean expected size of a population will be lower than the carrying capacity of available habitats, due to variations in environmental factors. Reduction of a population increases the chance of local extinction.
As a result, the occupation chance of other small habitat units may decrease. As long as the distances between habitat units are not too large, recolonisations can occur due to exchange of individuals between patches (dispersal). The larger the distances are, the more probable it will be that the whole network population will become extinct: such networks cannot support a viable population.

The network function for the target species in the three scenarios is evaluated by means of the parameters: population viability, population saturation and stepping stone function. Depending on the available knowledge, the parameters are estimated by using expert knowledge or by simulating the spatial population dynamics. The population saturation can only be assessed with the METAPHOR model.

**Population viability**

Population viability is defined as the chance of a population surviving for a certain lenght of time, qualitatively assessed in the LARCH approach and expressed as extinction chance in the METAPHOR model.
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 study area has resulted in a viable network for only 1-2 more species. Depending on the amount of suitable habitat, Beaver, Middle Spotted Woodpecker and Great Reed Warbler can reach a viable population in one or more scenarios (Table 2). However, if habitats outside the study area are 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 the Barbel no conclusions can be drawn.

**Table 2**
Population viability of target species in the study area when developing 10,000 ha of nature areas (+ = viable; ± = marginally viable; - = not viable). Relevance for species and the total area of terminal vegetation types is also indicated (HF = hardwood forest; SF = softwood forest; MM = macrophyte marsh; SC = secondary channel).

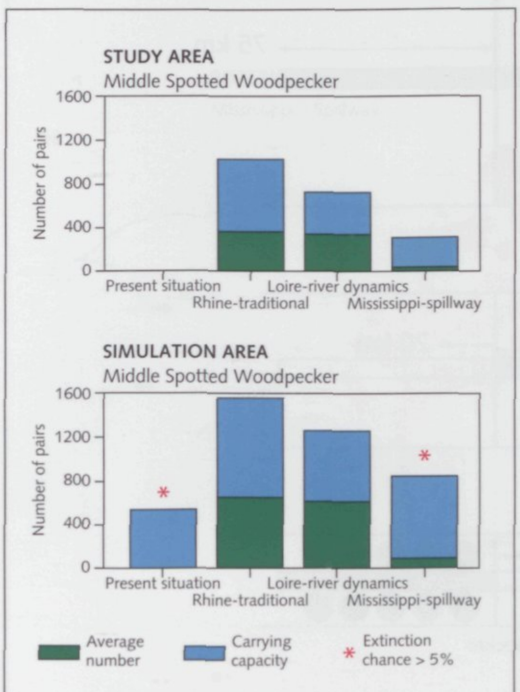
| Habitat types and species | Present situation | Rhine-Traditional Scenario | Loire-River dynamics Scenario | Mississippi-Spillway Scenario |
|---|---|---|---|---|
| | HF: 10 ha<br>SF: 395 ha<br>MM: 473 ha | HF: 2894 ha<br>SF: 2543 ha<br>MM: 1471 ha | HF: 2043 ha<br>SF: 3219 ha<br>MM: 132 ha<br>SC: 255 km | HF: 842 ha<br>SF: 4406 ha<br>MM: 2601 ha |
| Riverine forest | | | | |
| Beaver (SF) | - | ± | + | - |
| Middle Spotted Woodpecker (HF) | - | + | + | ± |
| Black Kite (SF) | - | ± | ± | ± |
| Black Stork (HF+SF) | - | - | - | - |
| Macrophyte marsh | | | | |
| Great Reed Warbler | - | + | - | + |
| Bittern | + | + | + | + |
| Night Heron | - | ± | - | ± |
| Secondary channel | | | | |
| Barbel | - | - | ? | - |
| Riverine landscape | | | | |
| White-tailed Eagle | - | - | - | - |

**Population saturation**

The population saturation is the mean total population size divided by the carrying capacity; in the METAPHOR model the number of breeding pairs realized in a simulation expressed as a percentage of the carrying capacity.

The evaluation shows a clear relationship between the saturation of viable populations and the distribution pattern of new nature areas as developed in the scenarios. The Middle Spotted Woodpecker has the highest population size in a pattern with relatively large habitats in combination with moderate distances (Loire-River dynamics Scenario), whilst a pattern with small habitats and short distances (Rhine-Traditional Scenario) is best for the Great Reed Warbler and the Bittern.

**Figure 10**
*The present and expected population size and carrying capacity for the Middle Spotted Woodpecker, evaluated for the study area and the simulation area, which also incorporates the surrounding habitats.*



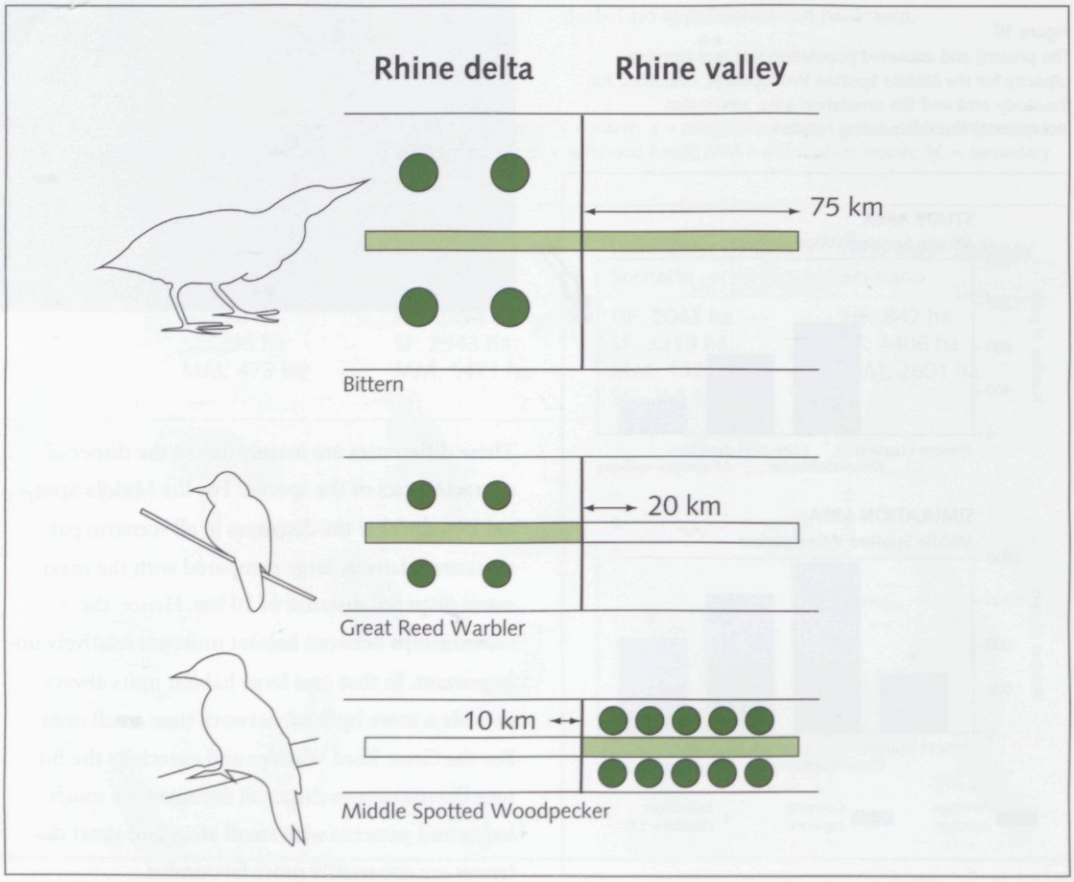

These differences are mainly due to the dispersal characteristics of the species. For the Middle Spotted Woodpecker the distances in all scenario patterns are relatively large compared with the maximum dispersal distance of 10 km. Hence, the relationships between habitat units are relatively unimportant. In that case large habitat units always provide a more optimal network than small ones. For the Great Reed Warbler and especially the Bittern the maximum dispersal distances are much larger and patterns with small areas and short distances are apparently more favourable.

## Stepping stone function

The stepping stone function is defined as the chance that species can spread from one side of the study area to the other. 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 habitats outside the study area. The stepping stone function does not always become optimal, if habitats are not equally distributed.

Thus, a moderate stepping stone function has been established for the Middle Spotted Woodpecker and the Great Reed Warbler (Figures 11 and 12), which means that the first species cannot expand into the western part of the study area and the latter cannot reach the eastern part. This is caused by the much smaller area of hardwood forest in the Rhine delta and of macrophyte marsh in the Rhine valley. Although for the Bittern the situation is similar to that for the Great Reed Warbler, here expansion in the Rhine valley does occur, probably due to the species' large dispersal capacity of up to 75 km. The Beaver has also a distinctly favourable response: within the floodplains it uses softwood forest, which is rather equally distributed. Moreover, the species can disperse over long distances of more than 100 km (Figure 9).

Figure 11
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.



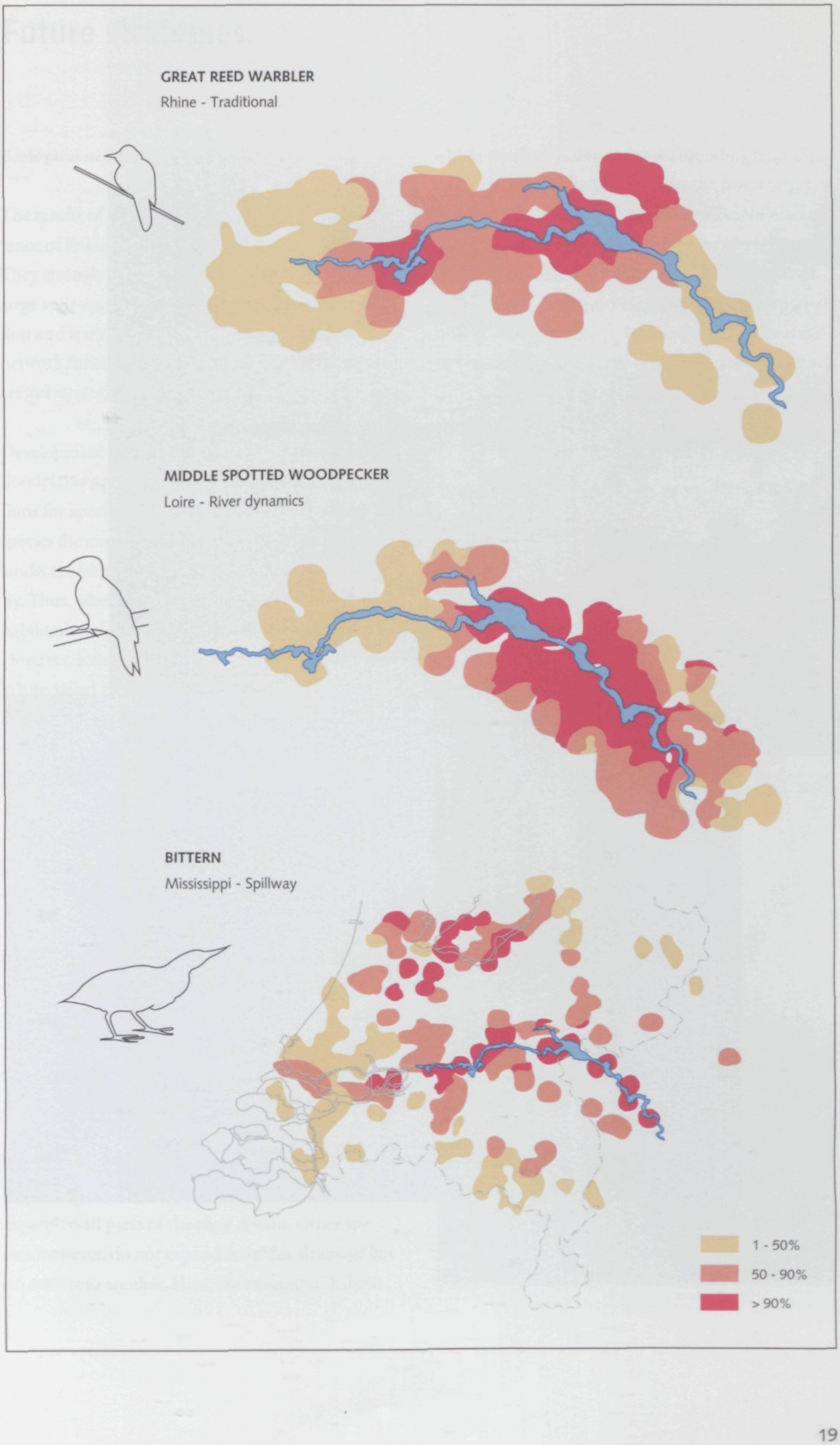



**Figure 12**
Distribution maps of Middle Spotted Woodpecker, Great Reed Warbler and Bittern in the Loire-River dynamics, Rhine-Traditional and Mississippi-Spillway Scenarios respectively.

# Future strategies

## Ecological network

The results of this study clearly show the importance of linking nature areas into a network system. They strongly support the growing attention for large scale approaches, such as river basin rehabilitation and transboundary river management. The network function is an important condition for successful strategies.

Development of nature areas within 30% of the floodplains only results in viable network populations for species with small area demands. For all species the amount of habitat in the surrounding landscape largely determines the population viability. Thus, when developing strategies for nature rehabilitation these areas must be taken into account. However, some species, like the Black Stork and the White-tailed Eagle which have very large area demands, will only persist if the nature areas within the river system are part of a network on sub-European scale.

Variations in the distribution patterns of new nature areas have large effects on the population saturation. Compared with the other distribution patterns, the best distribution pattern needs 40% less habitat to achieve a similar population size. However, there is not one single favourable pattern. Consequently, the success of the strategies will be raised considerably by choosing the optimal spatial pattern, especially where the available area to re-create former habitats is limited.

For some species the stepping stone function can become optimal, which means that they are able to expand to all parts of the river system. Other species, however, do not expand from one drainage basin zone into another. Here, the amount of habitat within the floodplains or the surrounding landscape is crucial. All three scenarios meet the forest target, but prove to be unable to produce sufficient macrophyte marsh. Suitable physiotopes for macrophyte marsh within the floodplains are only limited available, nor can they be developed within the transport zone of the river system. Attuning rehabilitation targets to the river landscape ecosystem characteristics reduces the risk of failure of strategies.

### Research methodology

To explore and visualise the perspectives of future nature with varying efforts, the methodology elaborated in this study appears to be a successful tool. Its results facilitate discussion and decision making about which nature policy targets are desirable and realistic.

The problem being studied is not specific for the River Rhine, but typical for modern lowland rivers in densely populated areas. Several demands for space within the river system have to be met: lost nature qualities are to be rehabilitated at the expense of the agricultural use of floodplains, whilst safety in case of flooding and in many cases a navigable river have to be guaranteed. As such, the study may well serve as an example of how to approach nature rehabilitation along other floodplain rivers.

When applied to other floodplain rivers or other ecosystems, the selection of target species, the exploration of scenarios and the classifications and datasets used, must be adapted to the local circumstances first. It may also be necessary to use a wider range of fauna species and possibly also plant species. The procedure itself, however, is considered valid for any other landscape ecological system.

# Colophon

The project Rhine-Econet was commissioned by:
- RIZA Research Institute for Inland Water Management and Waste Water Treatment;
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The project was performed by:
- DLO Institute for Forestry and Nature Research (IBN-DLO), PO Box 23, 6700 AA Wageningen, The Netherlands
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| | |
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| D. van Dijck | Bittern (p. 4) |
| I. van Splunder | riverine forest (p. 6) |
| P.P. de Nooyer | Black Kite (p. 10) |
| R. Noordhuis | secondary channel (p. 12) |
| J.C. Klees | Barbel (p. 12) |
| R. Doef | Black Poplar (p. 13) |
| L. Vogelenzang | back swamp (p. 14) |
| W. Wisniewski | Beaver (p. 15) |
| F. Cahez | Middle Spotted Woodpecker (p. 17) |
| A. A. Blok | White-tailed Eagle (p. 20) |
| P.P. de Nooyer | river landscape (p. 20) |
| P.P. de Nooyer | Great Reed Warbler (p. 21) |
| P.P. de Nooyer | marshland at sunset (p. 22) |

English linguistic corrections:

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