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Practical aspects of biotope mapping in cities: methods, problems and solutions. An example of Mainz, Germany

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'Biotope mapping of Mainz' - this is the name of a research project commissioned by the City of Mainz and carried out by an interdisciplinary group of geographers, biologists and environmental planners at Mainz University between 1993 and 1997. The project's goal was not only to gather, analyse and evaluate data relating to urban biotopes, but also to apply and - if necessary - modify the 'Basic program for biotope mapping in urban areas', which was set up by a working group at the German Federal Nature Conservancy in 1993. In conformity with the legal mandate, the work followed the strategy of integrated nature conservation, i.e. simultaneous protection of biotic, a-biotic and aesthetic resources, which is considered as an inevitable component of sustainable development in urban areas. Some of the methodological aspects recommended in the 'Basic program' and completed in the 'Biotope mapping of Mainz' are: the application of a well-structured biotope type reference key, the elaboration of a microsite key with relevance to flora, fauna and aesthetics, very detailed mapping and description of biotope types, subtypes and variations, as well as mappings and descriptions of the phenomena of nature, recreational activities and environmental impacts related to biotope types. Further, the 'Biotope mapping of Mainz' supplemented some new spatial aspects and assessment procedures that might eventually get planning authorities more adopted to the idea of sustainable land use in populated areas, such as the environmental zoning of the landscape within the city limits, the delimitation and description of 'urban landscape units' in detail (including climate, soil and water conditions, flora and fauna as well as historical and cultural features), the development of environmental quality targets and standards specified for each 'urban landscape unit', the assessment of the unit's biotope types with reference to the established environmental quality standards, and last, suggestions and recommendations for urban planning and environmental management. With the items mentioned, the research project 'Biotope mapping of Mainz' made its scientific outcome more accessible and understandable. As a consequence, it is reported that local planning authorities are applying the project's findings and giving a positive feedback of the results.

Praktische aspecten van stedelijke biotoopkartering: methoden, problemen en oplossingen. Een voorbeeld uit Mainz, Duitsland - 'Biotoopkartering in Mainz' is de naam van een onderzoeksproject dat door het gemeentebestuur van Mainz is opgedragen aan een interdisciplinaire onderzoeksgroep, bestaande uit geografen, biologen en milieukundigen. Het onderzoek werd aan de universiteit van Mainz uitgevoerd tussen 1993 en 1997. Het doel van het onderzoek was niet alleen het verzamelen, analyseren en evalueren van gegevens over stedelijke biotopen, maar ook om het 'Basisprogramma voor stedelijke biotoopkartering', dat in 1993 door een werkgroep van de Duitse federale natuurbescherming was opgezet, toe te passen en - waar nodig - te verbeteren. Conform de wettelijke voorschriften hield het onderzoek rekening met de gelijktijdige bescherming van biotische, abiotische en landschappelijke (of esthetische) waarden. Dit wordt beschouwd als een onlosmakelijk onderdeel van duurzame ontwikkeling in het stedelijk gebied. Enkele van de methoden die

worden aanbevolen in het 'Basisprogramma' zijn: de toepassing van een goed gestructureerde referentielijst van biotooptypen; de verfijning van een kleinschalige lijst van biotooptypen met betrekking tot flora, fauna en esthetica; een zeer gedetailleerde kartering en beschrijving van biotooptypes, subtypes en variaties daarop; de kartering en beschrijving van natuurverschijnselen, recreatieactiviteiten en milieukundige invloeden met betrekking tot de biotooptypen. Daarnaast heeft de 'Biotoopkartering in Mainz' nieuwe ruimtelijke aspecten en beoordelingsmethoden opgeleverd die er uiteindelijk voor kunnen zorgen dat meer rekening gehouden wordt met duurzaam grondgebruik in bevolkte gebieden. Voorbeelden: een milieu-zonering van het stedelijk landschap; de afbakening en beschrijving van stedelijke landschapseenheden (rekening houdend met het klimaat, bodem en water, flora en fauna, geschiedenis en cultuur); de ontwikkeling van milieukundige kwaliteitswaarden voor elk stedelijk landschapstype; de beoordeling van biotooptypen aan de hand van bestaande milieukundige kwaliteitseisen; en, tenslotte, suggesties en aanbevelingen voor stedenbouwers en milieumanagers. Met de genoemde punten is het onderzoeksproject 'Biotoopkartering in Mainz' qua wetenschappelijke resultaten toegankelijker en begrijpelijker geworden. Bijgevolg kan worden waargenomen dat de plaatselijke autoriteiten de resultaten van het project toepassen bij de ruimtelijke planning en er een positieve feedback over afgeven.

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INTRODUCTION

With the 'Basic program for gathering, organizing and analysing data relating to urban biotopes' set up by the working group 'Methods of biotope mapping in populated areas' at the German Federal Nature Conservancy and the State Offices for Nature Conservation and Landscape Management in 1993 (Schulte *et al.* 1993), an important guideline was given to all those local communities that were able and willing to perform a biotope mapping project in their own city (see Werner 1999). In Mainz, a more than 2000 years old city situated at the northern edge of the upper Rhine valley, with a total area of about 100 km^2 and a population of 200.000 inhabitants, local authorities followed this idea and commissioned such a research project yet in 1993. Named 'Biotope mapping of Mainz', the project was carried out by an interdisciplinary group of geographers, biologists and environmental planners at the University of Mainz from 1993 until 1997 (Arbeitsgruppe Stadtbiotopkartierung Mainz 1996/1997). The project's goals comprised

- the supply, analysis and evaluation of data relating to all biotopes within the city limits of Mainz,
- a very detailed mapping and description of habitat structures, biotope types and landscape units,
- assessment procedures that might get planning authorities more adopted to the idea of sustainable land use in populated areas - as a contribution to the Local Agenda 21, and
- suggestions and recommendations for urban planning and environmental management.

The project's work was based entirely on the strategy of integrated nature conservation, which is considered as a fundamental basis of sustainable development in populated areas. After Pfadenhauer (1991), integrated nature conservation in terms of the German law 'Bundesnaturschutzgesetz' (§ 1) can be

defined as simultaneous integrated protection of

- biotic resources, i.e. the safeguarding and support of plant and animal species typical of a region, including their populations and relationships,
- abiotic resources, i.e. the protection and regeneration of the natural resources soil, water and air,
- aesthetic resources, i.e. the protection and/or development of landscape diversity, individuality and beauty in order to satisfy the needs of the people seeking relaxation and recovery in the landscape.

Finally, with the 'Biotope mapping of Mainz' some of the objectives and recommendations of the 'Basic program' had been transferred to the local situation and shortcomings within its methodological framework removed. The following paper gives an outline of the project's issues for possible further application.

A SYNOPSIS OF BIOTOPE MAPPING SCHEMES IN GERMANY

Table 1 provides a synopsis of two recent biotope mapping schemes, including the methodology of biotope mapping recommended in the 'Basic program', and, in the second column, an overview of the items completed or modified in the 'Biotope mapping of Mainz' (Frey 1998). Among the completed propositions are the application of a well-structured biotope-type reference key and a key of microhabitats; the thorough description of biotope types, subtypes and variations; as well as the mapping and description of phenomena of nature, recreational activities and environmental impacts related to biotope types. Some new aspects were supplemented with the zoning of the landscape within the city limits, the delimitation and description of 'urban landscape units', the development of environmental quality targets and standards specified for each 'urban landscape unit', the assessment of the unit's biotope types with reference to these standards, and, finally, with suggestions and recommendations for urban planning and environmental management in detail.

SOME FEATURES OF BIOTOPE MAPPING IN MAINZ

Delimitation of the area of investigation

From a scientific point of view, all biotopes of a comprehensive biotope mapping that reach beyond the city limits need not only be mapped in the parts lying within these boundaries, but also beyond. Despite this, the city that commissioned the project will merely pay investigations within its territory - this is also the case in Mainz. Furthermore, at least some industrial zones, military areas or railway tracks will remain inaccessible for scientists, so that from these places possibly important information may be lacking. And if the spectacular flora and fauna of the city's nature reserves are well analysed, the main task of a comprehensive biotope mapping is not to intensify such studies, but to integrate the given data and to focus on the sites yet unknown.

Basic information for biotope mapping in cities

As a second step, basic information about the area of investigation, its ecology, species, etc., is to be gathered and selected. In Mainz, floristic and faunistic data were available through publications, former mappings, unpublished species lists and species distribution maps, expert's reports (e.g. in environmental impact studies), expert knowledge, local literature and other local information from citizens. Further data were supplied by reports, plans and laws concerned with town planning, landscape architecture, landscape management, strategies of nature conservation, recreation, etc. For means of field cartography and digitalisation, air photographs (scales 1:5000, 1:1000), topographic maps (e.g. 'Deutsche Grundkarte' 1:5000), geological maps, soil maps, hydrographic maps, climatic maps as well as historical maps (scales 1:20000 to 1:25000) were needed. ArcInfo™ was applied as a geographical information system (GIS).

Table 1 Biotope mapping schemes in urban areas: the 'Basic program' and its applications and modifications in the 'Biotope mapping of Mainz' (after Frey 1998).

Recommendations of the 'Basic Program'	**Applications (✓) and Modifications (• ...) in the Research Project 'Biotope mapping of Mainz'**
1. Delimitation of the area of investigation	• City limits of Mainz, incl. adjacent nature reserves
2. Analysis of available biotope data	✓
3. Comprehensive mapping of biotope-types (scale of 1:5000) with a given biotope-type reference key	• (partly) New systematization of the biotope-type reference key • Very detailed mapping of biotope-types, subtypes and their variations • Compilation of additional field notes
4. Representative mapping of sample biotopes Domains: • Flora / vegetation and fauna • Small-scale biotope features • Landscape aesthetics (scenery etc.) / Human contact with nature / Experience of nature • "Threats"	 ✓ • Mapping of biotope microsites with a special key of biotope microsites • Mapping of natural phenomena and recreational activities • Mapping of environmental impacts on biotopes
5. Evaluation of the data Description of biotope-types with regard to • their location/spatial distribution in the city • abiotic factors (geology, soil, climate) • small-scale biotope features • plant and animal species to be found • their "significance for the experience of nature" • "the reasons and causes of threats" *Description of the biotope-types' specific value for nature conservation* *Delimitation of 'important areas' for nature conservation* *Recommendations for protection, development and management of 'important' biotope-types* Zoning of the cityscape according to geographical and ecological criteria	 ✓ ✓ ✓ • Characteristic vegetation (plant communities, specialized and endangered plants, lichens) • Variety of natural phenomena/recreational activites • Environmental impacts ! *Topics not to be presented in a descriptive, but in a normative context (see 6.)* • Zoning of the cityscape • Delimitation and description of 'urban landscape units' with regard to the items mentioned in the biotope-types' description as well as to 'artistic' aspects
6. Assessment of biotope-types with regard to species protection, human contact with and experience of nature and landscape aesthetics Explanation of assessment procedures (targets, criteria, gradation)	Confronting the guidelines for environmental development with the findings of the biotope mapping • Development of environmental quality targets and standards, individually specified for 'urban landscape units' in the domains of flora, fauna, "landscape and recreation", soil and climate • Comprehensive assessment of each unit's biotope-types with reference to the established environmental quality targets and standards
7. Handling of the project's results Recommendations for protection, development, management, etc.	• Synoptic tables of targets, strategies and measures for protection, development or management of biotopes within the 'urban landscape units' of Mainz

Mapping of biotope types and microsites

The attempt to apply the biotope type reference key as proposed by the 'Basic program' unfortunately revealed a few shortcomings within the key's methodology, such as the lack of a strict hierarchy, a numeration that is incompatible with GIS, or an imbalance between the specification of different biotope types. As a consequence, a modified biotope-type reference key was set up for biotope mapping at a scale of 1:5000, divided into 'groups of biotope types', 'biotope types', 'biotope subtypes' and 'variations of subtypes' (see excerpts in Table 2). For even smaller biotopes, e.g. the ones delimitated during the representative mapping of sample biotopes, a key of biotope microsites was elaborated (see Table 2). All of those microsites can be subordinated to biotope types. Figure 1 serves as an example for a biotope-type working map of the inner city of Mainz.

Table 2 Excerpt of the biotope type reference key and the key of biotope microsites as used in the biotope mapping of Mainz.

Groups of biotope types
1000 City buildings mainly used for housing: mansions, housing areas
2000 Buildings in (former) villages, rural buildings
3000 Industrial and commercial buildings, military areas
4000 - Parks, cemeteries, allotments, botanical & zoological gardens, sportsfields
5000 Rivers, canals, brooks, ponds, reservoirs
6000 Railways, roads, pathways, parking lots, airports
7000 Rural biotopes: fields, orchards, vineyards, grassland
8000 Woodland, shrubbery, hedgerows
9000 - Quarries, sandpits, dumps, Ruderal sites
0000 - Local biotopes: Sand dunes, Loess slopes, dikes, archaeological sites

Biotope-types (examples)
100 Historical buildings of the 'Old Town'
2300 Farmhouses
3100 - Factory buildings
4200 City parks
5100 Rhine river
6100 - Railway areas
7600 Orchards, fruit plantations
8100 - City woodland
9300 - Ruderal biotopes

Biotope subtypes and *variations of subtypes* (examples)
4233 - Old city parks *with an extensive management*
5521 - Semi-natural ponds, *temporarily dry*
6134 - Railway verge *with shrub vegetation*
7611 Fruit plantations with young trees and lawns, *intensively cultivated, on Loess soils*
8610 - Shrubs and hedges of indigenous species
9320 - Ruderal grassland

Biotope microsites (examples)
1/21 Roof trusses, open
2/21 Wooden fences, not treated with chemicals
2/43 Grass verges
3/20 - Abandoned chimneys
4/10 Flower beds / vegetable beds
5/51 - Reed spots, with *Phragmites communis*
6/12 Cobble stones, with narrow gaps
7/13 - Rough stone walls: topsides
8/12 Old solitary trees, on sandy soils (e.g. *Pinus sylvestris*)
9/50 Foul fruit
0/32 Loess walls

Figure 1 Biotope-type working map of the inner city of Mainz.

Mapping of flora and fauna

The representative mapping of the characteristic flora and fauna of the sample biotopes mainly followed the principles of the 'Basic program' (Schulte *et al*. 1993: 508-513). However, the listing of plant communities was added for means of the description of biotope types (see below under 'Description of biotope types'). The species inventory of each sample area was recorded on a database compatible with GIS (KartASys®, see Arbeitsgruppe Stadtbiotopkartierung Mainz 1996a).

Mapping of natural phenomena and recreational activities

An important task of nature conservation in cities is the preservation of plants, animals and their habitats in order to make 'human contact with nature', i.e. 'human experience of nature' possible (Sukopp *et al*. 1980, Gilbert 1989). Since 'human contact with nature' is mainly achieved by perception and/or recognition of natural phenomena (forms, structures, patterns, processes, etc.) or while staying in natural areas for the purpose of leisure and recreational activities, the mapping focused on commonly known natural phenomena, everyday activities for leisure and recreation and their traces being found within biotope types (Frey 1997). Table 3 gives a brief selection of these features, which were mapped in about 50 sample areas in Mainz.

Description of biotope types

As shown in Table 1, each biotope type in Mainz, including its subtypes and variations, was described in detail, with regard to its location and spatial distribution, some abiotic factors (geology, soil), its biotope microsites, characteristic vegetation (plant communities,

Table 3 Natural phenomena (left hand column), recreational activities and activity traces (right hand column) related to biotopes (selected lists, after Frey 1997)

Natural Phenomena related to Biotopes
Scenic phenomena: sand dunes, pine forest, alleys, Rhine river, ...
Structural phenomena: big old trees, stone walls, hedgerows, slopes, ..
Aquatic phenomena: springs, water levels, waves, shorelines, aquatic wildlife, ...
Animal phenomena: songbirds, nests, rabbits, foxholes, dragonflies, glow-worms, ...
Seasonal phenomena: blossom, fruit aspects, colouring of the leaves, ...
Sound phenomena: woodpeckers, birds' chant, rustling of leaves, croaking of frogs
Olfactory phenomena scent of flowers, hay, mushrooms etc., stench of sewage etc., ...

Recreational Activities and Activity Traces related to Biotopes	
Activities	Activity Traces
walking, strolling / jogging	footpaths
biking	bike traces
playing: ball games, scouting games,	broken twigs / [illegible]
flower- or fruit-picking	cherry stones, nutshells etc.
picknicking	campfires
relaxing	lugged around sand and leaves
flirting ..	shacks ...

Table 4 Matrix of criteria for the delimitation of 'urban landscape units'.

Basic natural land use	Agriculture		Forestry	Housing				Commerce / industry	Leisure activities,
Human / historic development	Crops and vegetables	Growing of fruit and wine		Pre-20th century city or village centres	Younger districts		Urban fringe		nature conservation
Geological and geomorphological criteria					developed 1870-1914	developed after 1945			Former military units
Floodplains	• Rhine wetlands [illegible] • Rhine wetlands [illegible]	• [illegible]		Old villages • [illegible] • [illegible] • [illegible]	• (Neustadt)	• [illegible]			
Small valleys	• [illegible] • [illegible]			Old villages • [illegible] • [illegible] • [illegible]					
Sand areas		• [illegible] • [illegible]	• part of the [illegible]		• [illegible] • [illegible]			• Industrial, commercial and military areas in the former sand dunes of [illegible]	• protected sand dunes [illegible]
Loess areas	• fields [illegible] • fields between [illegible]	• [illegible] • vineyards [illegible]		Old villages • [illegible] • [illegible] • [illegible] • [illegible] • [illegible]		• [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible] • [illegible]	• [illegible] • [illegible] • [illegible] • [illegible]	• [illegible]	• former military area [illegible]
Areas with Tertiary sediments		• fruit growing area [illegible] • slope of [illegible]	• [illegible]			• [illegible] • [illegible]			
Areas with deposits of soil, debris etc.				• [illegible]	• [illegible] • [illegible]			• [illegible] • [illegible] • industrial area [illegible]	• [illegible] with remnants of the [illegible]

Table 5 Development of environmental quality targets for urban landscape units and assessment of the landscape unit's biotope types.

Principal Ideas for the Sustainable Use of Land in the City of Mainz

The environment within the city limits of Mainz, as characterized by remnants of virgin landscape, diversified rural landscape and different types of urban-industrial landscape, is to be regarded as an *interdependent system* whose components have to be treated according to the principles of *integrated nature conservation* and the *sustainable use of land*. An important aspect in this case is the preservation of the landscape's individuality, diversity and beauty as a basis for quality of life.

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Guidelines for the Sustainable Use of Land in the Zones of Urban Landscape in Mainz

↓	↓	↓
Remnants of virgin landscape	Rural landscape	Urban-industrial landscape
Domains: Climate / Soil / Fauna / Flora / 'Landscape & Recreation'	*Domains: Climate / Soil / Fauna / Flora / 'Landscape & Recreation'*	*Domains: Climate / Soil / Fauna / Flora / 'Landscape & Recreation'*
↓	↓	↓
.....	.....	*Example:*

Urban-Industrial Areas of Mainz: Guidelines in the Domain of 'Landscape & Recreation'

- Preservation of areas with relevance to urban nature as well as to cultural history, i.e. as documents of historic-cultural and historic-natural interdependence in the urban-industrial landscape of Mainz.
- Preservation of (historic-)natural areas for recreation, enjoyment, inspiration, observation of urban wildlife & environmental education.
- Preservation of relics of rural or virgin landscape.

↓

Environmental Quality Targets for 'Urban Landscape Units' in Mainz

Example:

Urban Landscape Unit # 53 (Housing estates on sand dunes, northwestern suburbs of Mainz): Quality Targets for 'Landscape & Recreation'

- Presence of *dune landscape elements* as documents of natural history and individuality, as well as for inspiration, enjoyment, education and recreation in harmony with nature.

Quality standards / Quality criteria

Example:

Urban Landscape Unit # 53: Quality Criteria for 'Landscape & Recreation'

Presence of

- relics of calcareous sand dunes, sand mounds and sand flats
- relics of sparse pine wood and other indigenous tree species
- relics of orchards with thermophilous fruit trees, e.g. apricots
- dry grassland on autochthonous (sandy) soils
- dry lawn on autochthonous (sandy) soils
- wasteland on autochthonous (sandy) soils
- sandy slopes
- sandpits
- sandy paths and trails
- sandy embankments and verges

⇳

Assessment of the landscape unit's biotope-types

Assessment of the conformity of each biotope's structures with the required quality standards, i.e. with the required environmental quality targets

➢ „How does the biotope meet the specified environmental quality target ?" (4 steps; depicted in coloured maps)

Table 6 Targets and measures of biotope related environmental management in urban landscape units (as an example: 'Housing estates on sand dunes')

Targets of Environmental Management	Suggested Measures	Biotope-types
Preservation or regeneration of dune landscape elements (see Tab. 6)	Drawing up of a 'Landscape management plan for housing estates and common greenspace on calcareous sand dunes in the north-western suburbs of Mainz' comprising • the support of sandflora species through considerate and moderate cutting of dry lawns, embankments and verges • the planting of thermophilous, indigenous tree species like *Pinus sylvestris*, *Quercus robur*, thermophilous shrubs, tall fruit trees like apricots, plums, cherries, almonds etc. • the avoidance of deposits with allochthonous soil material and humus • the avoidance of fertilizers and pesticides • the support of small-scale biotope features (see Tab.3) • public information	• all biotope-types associated with buildings, esp. housing estates, churchyards, former military area 'Alte Kaserne' • biotope-type # 4100: playgrounds, verges of sportsfields • biotope-type # 6250: verges of parking lots (e.g. open air pool „Am Großen Sand")

specialised and endangered plants), variety of natural phenomena and recreational activities and, at last, environmental impacts. In Appendix 1 an example of such a description is presented. Figure 2 is a photograph of an example of this biotope subtype.

Environmental zoning of the landscape within the city limits

In order to get a reasonable basis for spatial description and assessment of biotope types in cities, the landscape within the city limits should be divided into different environmental zones. Following the basic principles of natural geography and geobotany (see e.g. Meynen & Schmithüsen 1962, Kowarik 1992), three zones are to be determined:

1 Area of remnants of virgin landscape: area characterised by ecological processes typical of virgin landscapes (in Mainz: sand dunes, floodplains),

2 Area of diversified rural landscape: area characterised by agriculture (growing of cereals, root crops, fruit, vegetables) and viticulture, with landscape elements like hedgerows, defiles, loess slopes, rough stone walls etc.,

3 Area of urban-industrial landscape: built-up area (city centre, former village centres, housing estates, industrial and commercial areas, etc.) with different types of urban greenspace (parks, cemeteries, allotments, wasteland, etc.) and characteristic small-scale biotope features (cobble gaps, solitary trees, etc.).

Figure 2 Example of biotope subtype '5520 - Ponds with slightly disturbed embankments'.

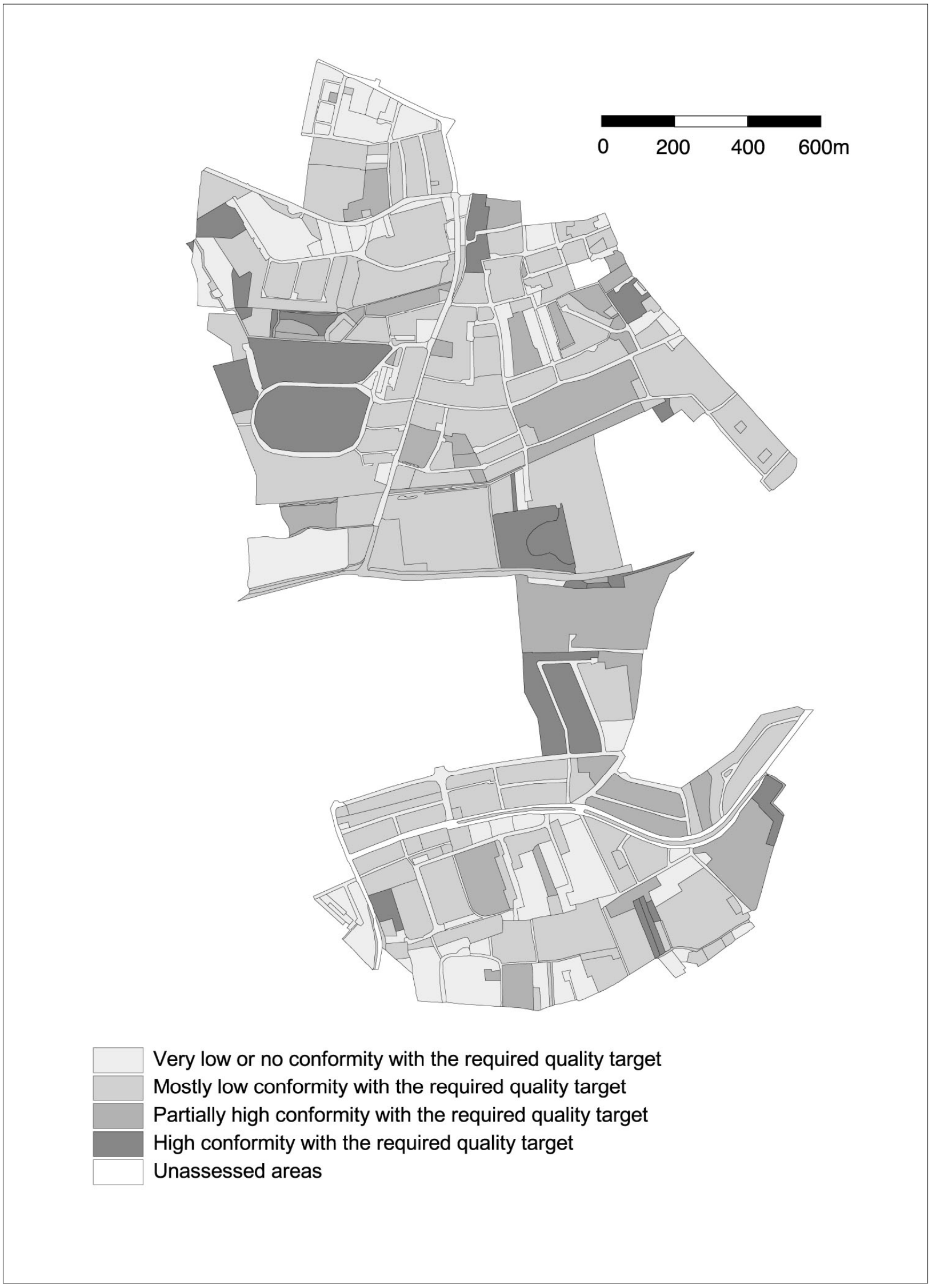

Figure 3 Assessment of a landscape unit's biotope types (as an example: 'Housing estates on sand dunes', northwestern suburbs of Mainz).

Yet, the delimitation of such zones does not fulfil the needs of a detailed spatial evaluation of biotope type data. According to geological, geomorphologic, historic-geographical and land use criteria, the three environmental zones can be subdivided into a variety of smaller landscape units, each of them having an individual environmental character within the city. In Mainz, 54 'urban landscape units' were distinguished and described in detail (Table 4, see Arbeitsgruppe Stadtbiotopkartierung Mainz 1996c).

Assessment of biotope-types with reference to environmental quality targets

Relating to the 'concept of environmental quality targets', which was officially recommended after the Rio de Janeiro Conference in 1992 (BMU 1993, RSU 1994), the 'Biotope mapping of Mainz' attempted to assess biotope types by comparing their biotic, abiotic and aesthetic inventory with criteria and standards required in environmental quality targets. Previously, specified principles, guidelines, quality targets and quality criteria were established for each 'urban landscape unit' in the domains of flora, fauna, landscape aesthetics, soil and climate (see details and examples in Table 5 and Figure 3). All propositions endeavoured to meet the idea of sustainable urban planning (DRL 1992, Stadt Mainz 1995, Diamond & Noonan 1996).

Suggestions and recommendations for environmental planning and management with reference to environmental quality targets

As a practical outcome of the detailed spatial description and assessment of the mapping, some advice for appropriate measures concerning biotope-type development in urban landscape units was supplemented. Table 6 gives an example of such suggestions. Firstly, 'targets of environmental management' had to be established in order to correspond with the proposed environmental quality targets. Secondly, all measures that could help to achieve the targets were listed, followed by a selection of the biotopes to be managed.

CONCLUSIONS

Adopting the currently discussed ideas of integrated nature conservation and sustainable use of land for the means of biotope mapping in populated areas, the research project 'Biotope mapping of Mainz' attempted to make its scientific results more accessible and understandable. As a consequence, it is reported that local authorities are applying the results of the project, including the GIS, for the purpose of environmental impact assessments connected with the construction of housing areas, roads, etc., as well as for measures of nature conservation, planning of recreational infrastructure and environmental planning in general.

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APPENDIX 1 Description of a biotope subtype in Mainz: '5520 - Ponds with slightly disturbed embankments' (after Allendorf *et al.* 1995, AG Stadtbiotopkartierung Mainz 1996b, 1997a). See also Figure 2.

Typology

5500 - Ponds and small reservoirs
5510 - Ponds and reservoirs with artificial and severly disturbed embankments
5520 - Ponds with slightly disturbed embankments
5530 - Ponds with undisturbed embankments

General information / Description of abiotic parameters

In the area of Mainz, which shows a comparatively dry climate and permeable subsoil conditions (sand, loess, limestone), there are no natural standing-waters, except for a few remnants of the Rhine's river branches (see biotope type 0200). The city is, however, studded with a number of artificially laid out standing-waters such as ponds and reservoirs (biotope type 5500), either with artificial and severly disturbed embankments (subtype 5510), with slightly disturbed embankments (subtype 5520) or with undisturbed embankments (subtype 5530).
Their area varies from about 250 m^2 to about 2500 m^2, sometimes 5000 m^2.
[...]
Subtype 5520 includes ponds located in the Rheine wetlands west of Mombach and several ones close to built-up areas. The ponds along the Rhine river have an age of about 50 years, wheras most of the others were created from the late 70s to the mid 80s. Some of the older ponds were formerly used for fishing, but most of them serve as amenity ponds, some-times also as balancing ponds for urban run-off. While the ponds' water originates from ground water and storm water, sometimes flood water (from annual floods of the Rhine) or brook water, the sediments suspended and deposited in the ponds are either river sediments, brook sediments with eroded soil (sand, silt) or solids from urban run-off. Most of the younger ponds are laid out by loam or concrete, smaller ones also by polythene. The ponds in Mombach appear to be more 'natural' ones: Located in the wetlands of the Rhine, their shape and ecological conditions depend on annual flood hazards. In a hidden location, they remain almost undisturbed by human activities. Despite their high diversity of species, their sediments are overloaded with nutrients, which is leading to a serious deoxygenation in summer. Most of the other ponds are located near settlements and reveal conditions typical of ponds in urban areas, such as fairly healthy oxygen levels with high diurnal amplitudes and a decrease towards the bottom due to daytime oxygen production by phytoplankton. Decay of detritus on the ponds' bottom is responsible for low oxygen saturation there. Their floristic and faunistic inhabitants can adapt to human disturbances. Thus, people - especially children - are given the feeling to be 'in nature', which might give the ponds a value in terms of recreation and environmental education.

Biotope microsites

2/41 - herbaceous verges
2/43 - grass verges
5/22 - temporarily wet sites
5/24 - temporarily dry sites
5/41 - natural embankments (rare)
5/43 - sites with shallow water
5/51 - aquatic plants (see below)
5/52 - reed spots (see below)
8/13 - solitary trees: wetland species
8/33 - wetland shrubbery
8/34 - exotic shrubbery (not in the Rhine wetlands)
9/10 - old tree roots
9/20 - microhabitats at rotten parts of plants
9/30 - microhabitats at tree trunks, branches and leaves
9/40 - flowers with pollen and nectar
9/70 - birds' nests
0/20 - solitary stones

APPENDIX I (continued)

Flora and Vegetation
Aquatic vegetation (Pteridophyta, Spermatophyta)
Ceratophyllum demersum-community, *Lemna minor*-community, *Elodea nuttalii*-community (mainly in the Rhine wetlands), *Lemno minoris - Spirodeletum polyrhizae* (mainly in the Rhine wetlands)
Bankside vegetation
Reed communities: *Phragmitetum australis*; mainly in the Rhine wetlands: *Butometum umbellati*, *Caricetum rippariae*, *Glycerietum maximae*, *Oenantho aquaticae-Rorippetum amphibiae*, *Phalaridetum arundinaceae*; mostly cultivated: *Iris pseudacorus-community*, *Schoenoplectus lacustris*-community, *Typha latifolia*-community; *nitrophilous* communities: *Convolvulo-Epilobietum hirsuti*, *Urtica dioica-Convolvulus sepium*-community
Tree and shrub growth
Querco-Ulmetum minoris (mainly in the Rhine wetlands), mostly cultivated: *Salix alba*-/*Salix fragilis*-communities, *Prunetalia*-shrubs
[...]

Fauna (selection)
Mollusca - Gastropoda
Anisus vortex, *Bithynia tentaculata*, *Gyraulus alba*, *Lymnea stagnalis*, *Planorbarius corneus*, *Planorbis planorbis*, *Physella acuta*, *Potamopygrus antipodarum*, *Radix ovata*, *Stagnicola palu - stris*
Insecta
Diptera (larvae): *Chironomus* sp., *Culex* sp., *Dixa* sp.; *Ephemeroptera* (larvae): *Baetis* spp., *Cloeon simile* / *C. dipterum*; Heteroptera: *Gerris lacustris*, *Hydrometra stagnorum*, *Ilyocoris cimicoides*, *Notonecta glauca*; Coleoptera: *Hydaticus transversalis*, *Hyphydrus ovatus*, *Noterus crassicornis*; Odonata: *Aeshna cyanea*, *Aeshna mixta*, *Calopterix splendens*, *Coenagrion puella*, *Ischnura elegans*, *Lestes sponsa*, *Orthetrum cancellatum*, *Sympetrum sanguineum* / *S. vulgatum*.
Crustacea
Asellus aquaticus, *Gammarus pulex* (mainly in the Rhine wetlands)
Annelida - Hirudinea
Herpobdella octoculata
Amphibia
Bufo bufo, *Rana esculenta*, *Triturus cristatus* / *Triturus vulgaris* (mainly in the Rhine wetlands)
Pisces
introduced species: *Carassius auratus*, *Esox lucius* (rarely)
Aves
Acrocephalus scirpaceus, *Acrocephalus palustris*, *Anas platyrhynchos* s.l., *Ardea cinerea*, *Fulica atra*, *Gallinula chloropus* [...]

Natural phenomena
visual effects on the pond surface: reflections of light, water movements, wave ripples, water colour
water temperature
smell of water
aquatic animal wildlife (esp. fish, fowl, amphibians), insects (esp. dragonflies), snails
aspects of the embankments' vegetation (herbaceous verges, reed, blossom etc.)

APPENDIX I (continued)

wet and muddy spots
rustling of leaves and reed
willow and poplar seeds
birds' flight, birds' chant
croaking of frogs

Recreational activities
Ponds in hidden locations (Rhine wetlands): few activities (strolling, walking, watching, playing with dogs, riding);
Ponds near settlements: many activities (feeding of ducks, watching, resting, picknicking, strolling, playing with dogs, playing and trying to catch fish and other aquatic animals, flower-picking, flirting, bathing (rarely))
[...]

Impacts
discharge of water pollutants: organic matter, nutrients, pesticides, (rarely) sewage and mineral oil
eutrophication resulting from exotic animal species (goldfish, ducks)
discharge of sediments
deposits of waste material
recreational activities (see above)
pond management

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