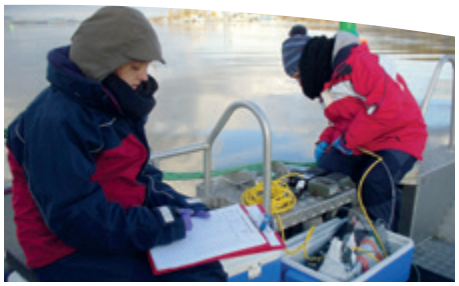
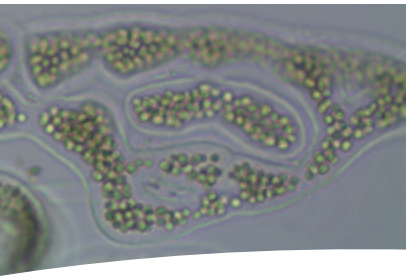
NaWaM
Sustainable Water Management
ReWaM

Regional Water Resources Management for Sustainable Protection of Waters in Germany







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FOREWORD

Intact rivers and lakes as well as clean groundwater fulfil a variety of functions and greatly benefit society. Water bodies are habitats for animal- and plant species, they are used as a water supply, to generate power or for recreation.

However, the various different claims placed on bodies of water with regard to their use often conflict with one another and with the water bodies' ecological functioning. Water quality is compromised by the input of nutrients and pollutants from residential and agricultural areas. Added to this is the structural modification of water bodies through straightening, building development or the deforestation of floodplain forests. Changes in land use in river basins can contribute to increased flood risk and can cause extreme events to have serious consequences.

We must exercise foresight in protecting our water bodies and we need regional approaches in order to deal effectively with the aforementioned issues. Furthermore, the European Water Framework Directive requires all water bodies to have a good ecological and chemical status. Considerable effort will need to be made to implement these standards, including by Germany. Their realisation will be based on a fundamental understanding of the processes involved and on the intelligent management of available resources.

This is the motivation behind the funding measure 'Regional Water Resources Management for Sustainable Protection of Waters in Germany – ReWaM' which was supported by the German Federal Ministry of Education and Research (BMBF) with almost 30 million Euros since 2015 within the framework of the funding priority 'Sustainable Water Management' (NaWaM).

Central to all the joint projects is the close collaboration between science and industry, i.e. the companies involved in the projects, but also the municipalities, public authorities and professional organisations – the same entities that are directly or indirectly responsible for water maintenance and management.

These collaborations and the implementation of the knowledge gained in model regions across the entire Federal Republic of Germany formed the basis for a targeted development of viable solutions and of services and methods which can be used over the long term. The results of the projects are presented in this brochure.

Dr. Karl Eugen Huthmacher
Federal Ministry of Education and Research

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WATER-RELATED DIRECTIVES: WORKING TO CLOSE IMPLEMENTATION GAPS

To protect and sustainably manage European water resources: That is the goal of the Water Framework Directive (WFD) approved by the European Parliament in the year 2000. The intention is to prevent the status of water bodies from deteriorating and to achieve a good chemical and ecological status by the end of 2015 – or till the end of 2027 at the latest. Since then German federal, state and local authorities have made a significant effort to improve the status of water resources. However, in 2015 only about seven percent of the water bodies subject to mandatory reporting achieved a 'good' status.

In addition to the WFD there are many water-related directives which specify how water resources are to be treated, managed and used: For example, they regulate the management of flood risks, the protection of species, or the quality of bathing and drinking water. Various different public authorities and water management practitioners are responsible for implementing the directives. This leads to water bodies often being seen and managed in a sectoral and not in an integrated manner. But the involvement of many stakeholders can also be an asset for water protection, which is the common objective of the various water-related directives. Different perspectives and a broad repertoire of specialised concepts and methods can allow flood risk management, species protection and other goals to be combined with the sustainable development of water resources. In order to achieve this, there needs to be a joint commitment from all stakeholders, and the respective underlying directives need to be interpreted and implemented accordingly.

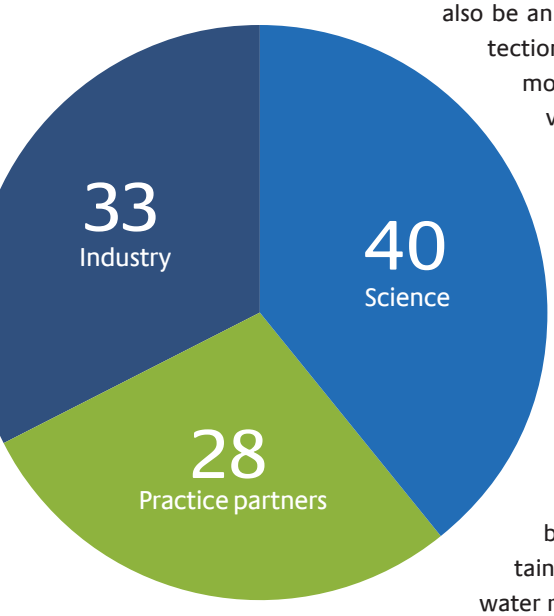

Fig. 1: 101 Partners from science, industry and practice partners (public authorities, municipalities, national federations and administrative bodies) are taking part in the BMBF-funding measure

RESEARCH GEARED TOWARDS PRACTICAL APPLICATION

Different requirements need to be fulfilled if activities implemented by water management practitioners are to be successful: a) A solid process understanding serves as a common knowledge base and as a basis for discussion for all the stakeholders involved and for the general public. b) A further requirement is scientifically validated indicators and methods which enable data to be generated that is relevant for decision-making. c) Application-related decision-making tools allow cross-sectoral assessment in order to reach a procedure which is accepted by all parties.

Against this backdrop, the German Federal Ministry of Education and Research (BMBF) launched the funding measure 'Regional Water Resources Management for Sustainable Protection of Waters in Germany' (ReWaM) in 2015. In total, the BMBF is funding 15 joint projects and an associated networking and transfer project. The projects' funding period will end in 2018 or 2019. ReWaM is part of the BMBF funding priority 'Sustainable Water Management' (NaWaM) within the framework programme 'Research for Sustainable Development' (FONA^3). Through ReWaM, the NaWaM topical focus area 'Water and the Environment' is underpinned by research geared towards practical application.

ReWaM's goal is to show how the various kinds of usage of water bodies can be reconciled with their protection so that the diversity and environmental performance of different aquatic ecosystems can be permanently preserved. This applies not only to rural, but also to suburban and urban regions. In order to ensure the transfer of the results into practical application and that the research and development work aligns with the needs of users, all ReWaM projects are transdisciplinary. The research, business and water management communities cooperate closely with one another in the joint projects. The BMBF is supporting 101 subprojects. These are being implemented by research, business and water management institutions in approximately equal parts. Other organisations and companies are also involved in the funding measure, as associated partners or via subcontracts.

All projects address the diverse challenges of regional water resources management in model regions. The model regions are located throughout the entire Federal Republic of Germany. This allows the transfer of the research findings to other regions in Germany and to neighbouring European countries.

PROJECT CLUSTERS

The joint projects cover a wide range of topics with different research approaches. The four project clusters illustrate the projects' joint remits:

- **Development and management of water bodies**
  The joint projects merged in this cluster address integrated development and action strategies for water resources management. The key focus is on reconciling flood management and development of water bodies. The emphasis is on water management in urban areas, urban water development, and on watershed management, as well as on the municipal water balance and on rainwater management.

- **Water monitoring**
  Innovative methods for monitoring the physical and chemical parameters in surface waters are what the joint projects of this cluster have in common. Water bodies are dynamic systems and react in different ways to the entry of substances and to change. To improve the way these processes are currently mapped, the joint projects are working on measuring systems for all relevant parameters with high spatial- and temporal resolution. In addition to traditional methods, (partly) autonomous measuring vehicles were developed.

- **Assessment methods for aquatic ecosystems**
  The joint projects of this cluster are focused on analysing and assessing ecosystem services. The research goal is to develop novel foundations for decision-making so that groundwater and surface waters can be managed sustainably. The projects focus on bioindicators and on services which a body of water and its adjacent areas provide, and which are used by humans.

- **Water quality management**
  The joint projects of this cluster study novel kinds of water pollution and develop risk assessment methods and new problem-solving strategies. The focus is on drinking- and bathing water quality and on the impact pathways between ground- and surface waters. The impact of pathogenic germs and of toxin-forming cyanobacteria on human health makes this especially relevant for society.

STEERING COMMITTEE

An associated body supports the work of the joint projects in the BMBF funding measure ReWaM: The Steering Committee is made up of representatives from public authorities and other institutions who are active in the field of water and the environment. In addition, the heads of the 15 joint projects as well as representatives of the networking and transfer project ReWaMnet, the BMBF and the project management agency are members of the Steering Committee. The Committee supports the projects with advice on practical applications and on further potential addressees for the insights gained. It also acts as a stimulus giver so that relevant cross connections can be made from the research projects and implemented.

PROJECT CLUSTERS	JOINT PROJECTS
Development and Management of Water Bodies	In_StröHmunG KOGGE NiddaMan StucK WaSiG
Monitoring of waters	BOOT-Monitoring HyMoBioStrategie RiverView
Assessment Methods for Aquatic Ecosystems	GroundCare RESI
Water Quality Management	CYAQUATA FLUSSHYGIENE MUTReWa PhosWaM SEEZEICHEN

Fig. 2: Allocation of the ReWaM joint projects to project clusters

USING SYNERGIES: WORKING ACROSS PROJECTS IN CROSS-CUTTING ISSUES

The projects overlap with regard to their methods, research questions and the types of water bodies being studied. In addition to the research work and the implementation of insights,

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the ReWaM consortia were involved in three cross-cutting issues (CCI) across projects as framed by the ReWaM Steering Committee. The task of ReWaMnet was to establish the framework for discourse and, together with the respective working group speakers, to prepare the meetings with regard to organisation and content. In total, ten meetings were held in the CCI.

- **CCI 1 'Transferring knowledge into practical applications'**
  The members of the CCI 1 addressed the issue of how research results get transferred into practical applications and can thus contribute to the implementation of the various water-related directives. In ReWaM, approximately 60 percent of the partners involved come from industry or water management. In order to benefit from this wealth of experience, the needs of water management with regard to knowledge transfer were surveyed during a workshop. To ensure that the results from the CCI would be available beyond the duration of the project, the insights were summarised in check lists. They are freely available and are designed to support a successful knowledge transfer between research and various target groups.

■ **CCI 2 'Sampling strategies and methods'**

The goal of CCI 2 was to compare methods and develop strategies allowing selected parameters to be measured and analysed more efficiently. The focus was on online probes, data validation methods, data management as well as recording the structure of water bodies. Two field trips were taken: In Rostock and Warnemünde the CCI members focused on the topics of morphometry, velocity and flow measurement, and continuous analytics. During a field trip to Lake Constance, the focus was on the topics of lakeshore restoration, river water as an inflow path, groundwater exfiltration and groundwater fauna.

■ **CCI 3 'Ecosystem services in water management'**

CCI 3 served as the basis for the methodological discourse between the projects working with the concept of ecosystem services. Within the CCI, two aspects were looked at in more detail: The goal of the working group 'nitrogen retention' was to collect the latest approaches for recording, quantifying and evaluating nitrogen compounds and nitrogen retention in different water body ecosystems on various scale levels. The members of the second working group 'View of ecosystem services across systems' concentrated on fleshing out the concept of ecosystem services for the water body systems which were relevant in the context of ReWaM, e.g. river-floodplain-systems, aquifers and standing water bodies.

THE NETWORKING- AND TRANSFER PROJECT ReWaMnet

The funding measure ReWaM is flanked by the networking and transfer project ReWaMnet. ReWaMnet supports the work of the joint projects in many different ways, with a focus on strengthening the collaboration between the projects. In addition to holding the three ReWaM conferences, the discourse was initiated and fostered in CCI. At the same time, both the project members and external experts receive information via a periodic newsletter and via brochures documenting the projects' progress.

Another priority is helping the projects transfer translatable results into day-to-day water management. To help achieve this, a comprehensive knowledge management system was established which is freely accessible in the form of a product library on the ReWaM homepage.

By utilising a variety of media, e.g. a touch table application which is used at trade fairs and events, presentation of the funding measure can be tailored to various target groups. Scientific articles were also placed in trade journals and special issues on various topics were organised. Information and updates about ReWaM are conveyed via the homepage and Twitter, and disseminated through cooperation with the local and trade press.

The German Federal Institute of Hydrology (BfG) was assigned to implement the networking- and transfer project by the BMBF. As a departmental research institute, the BfG is traditionally involved at the intersection between science and policy and is active on various federal and state government committees. In doing so it acts as a disseminator for the new scientific and practical insights of water management gained in ReWaM. The BfG's wide-ranging network and experience are essential in order to consolidate the insights and solutions from ReWaM and to transfer the exemplary implementation

and testing of measures in the model regions to other regions in Germany.

TRANSFER OF RESULTS AND INSIGHTS

The implementation in applied water management and thus the ultimate success of a funding measure can only be assessed several years after the research projects have been completed. Sometimes, the projects conducted research in their model regions tailored specifically to the local context. One characteristic of the funding measure is the transferability of methods and solutions which played a key role from the onset. That is why users in regions with similar problems are already benefiting from the wealth of experience which was gained. In order to consolidate the results from ReWaM, the joint projects are working together with ReWaMNet so that experts in the field learn about their research and it is integrated into guidelines and standards. Even while they were still ongoing, many projects provided their expertise to regulatory professional associations or counselled specialised policy makers on a regional, national and European level.

When the funding period is over, one priority will also be the cross-project findings synthesis. This is achieved by the joint projects combining their results on certain topics. In response to the ongoing discussions in the water sector, the projects involved address the topics identified by the Steering Committee and underpin them with insights from their own research work. Supported by ReWaMnet, appropriate formats are chosen in order to communicate the cross-project messages in a targeted manner.

This final brochure summarises the key insights of the projects. A comprehensive presentation and further findings can be found in the product library on the ReWaM homepage and in the final reports of the joint research projects.

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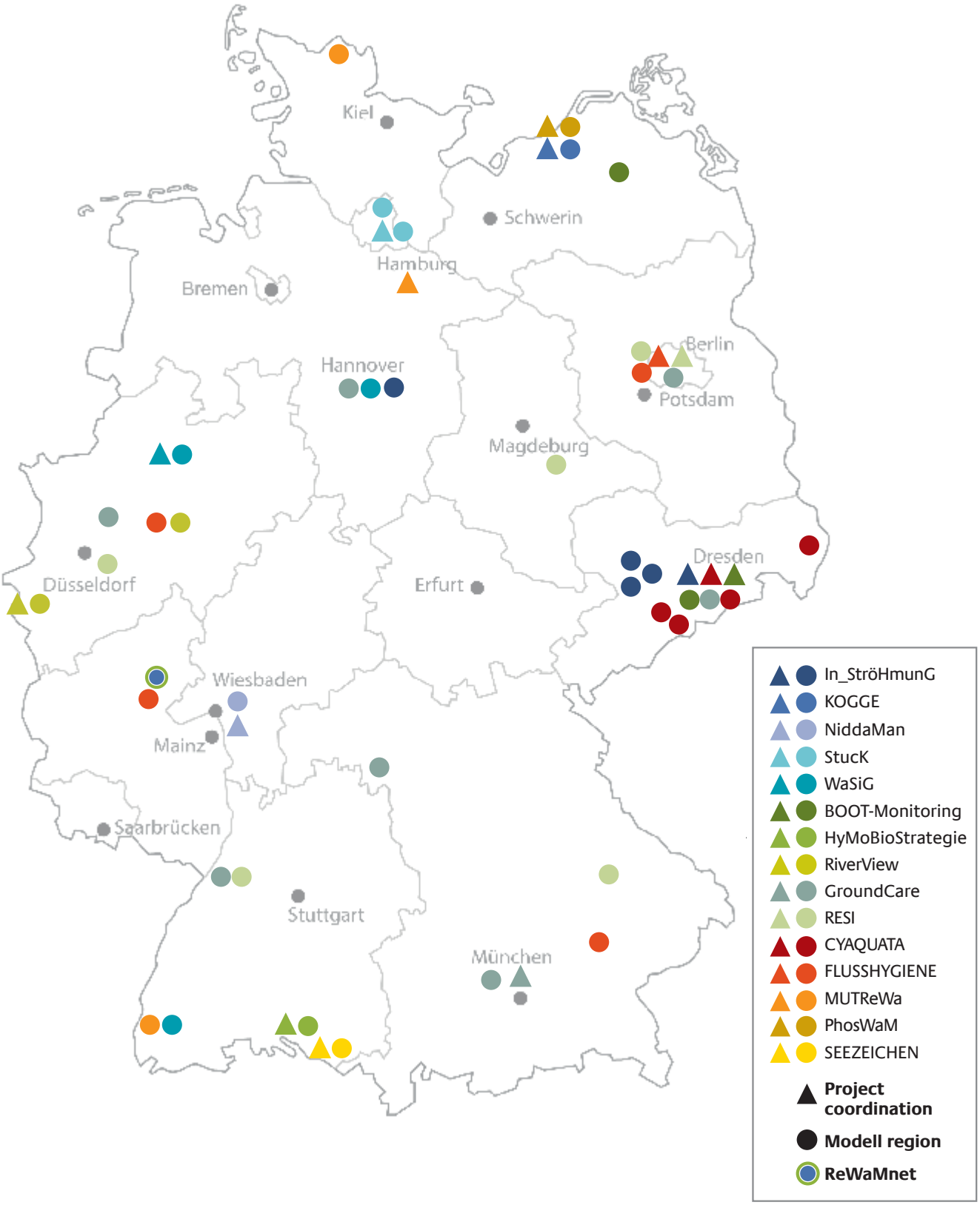

Fig. 3: BMBF funding measure ReWaM – Modell regions and locations of the project coordinations

KOGGE

My experience was one of exemplary and professional teamwork with the project partners. All partners involved in the project can be proud of their contribution to water body development in the Rostock region.

Sebastian Foth,
Wasser- und Bodenverband
„Untere Warnow-Küste“

WaSiG

Collaborating with the WaSiG project was interesting and enhanced our expertise. However, it remains to be seen how the investment will pay off in the future.

Thomas Brendt,
BIT Ingenieure AG

NiddaMan

In addition to many practically relevant insights, the project has generated new questions e.g. on the relevance of silting and its impact on the ecological status of rivers.

Gerd Hofmann,
Regierungspräsidium Darmstadt

Development and Management of Water Bodies

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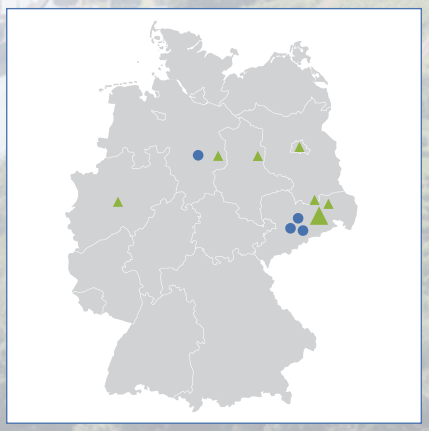

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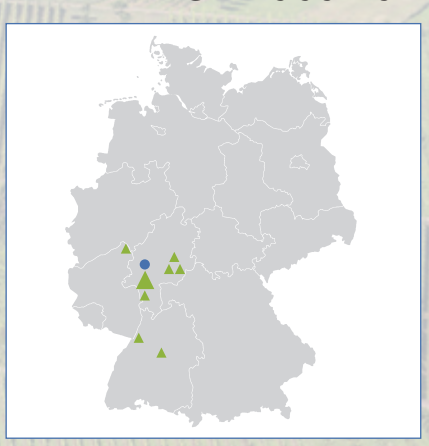

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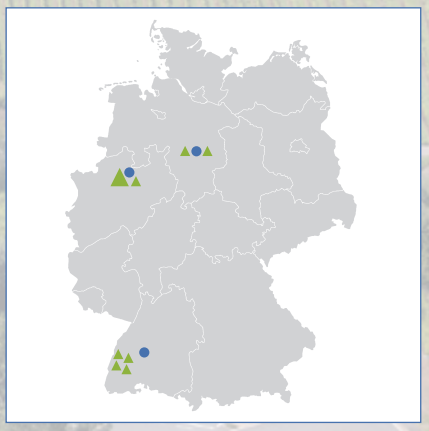

▲ Project coordination ▲ Joint project partners ● Model regions

In_StröHmunG

In order to enable the application of methods in daily practice, method development must take into account basic administrative processes and stakeholder contraints.

Dr. Bernd Spänhoff,
Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie

StucK

Firstly, the insights from StucK lead to immediate improvements in the warning service for inland flooding, thus improving operative flood protection in the Free and Hanseatic City of Hamburg. Secondly, ecological aspects are integrated into flood management which aim to combine flood management with the ecological enhancement of flood retention areas.

Dieter Ackermann,
Freie und Hansestadt Hamburg

In_StröHmunG – Innovative systems solutions for transdisciplinary and regional ecological flood risk management and natural watercourse development

The consortium has developed tools for the sustainable management of watercourses. The focus was on concepts and measures that support the goals of both the European Water Framework Directive (WFD) and the EU Flood Risk Management Directive (FRMD).

KEY MESSAGES

- Spatial and temporal flow diversity is the key factor with regard to the effectiveness of restoration measures. It is all the more important, the greater the pressures of water pollution and warming are. Natural levees reduce the amount of sediment deposited in the floodplain. They are shaped according to the density of the vegetation, and their ecological value is high. As long as natural levees do not impact flood protection, no measures are necessary.
- To improve the availability of land in order to successfully implement the development of watercourses in a near-natural state together with flood risk management, an adapted framework is required on all activity levels.
- Ecological improvement of watercourses and flood protection are to be planned and implemented in an integrated manner. In order to achieve this with sustainable watercourse maintenance, the water management software PROGEMIS® was developed.
- Surveys show that the local population values near-natural streams and wants watercourses to be more natural.

BACKGROUND AND RESEARCH QUESTIONS

The current water management system is geared towards the use of watercourses and their surroundings by humans. The exertion of influence, especially direct management through further development, use and maintenance, is mirrored in the inadequate status categorisation. This makes it necessary to transition towards an integrative and ecologically targeted development.

The In_StröHmunG project thus focuses on system solutions that view the watercourse as a natural system within an overall ecosystem. With a better understanding of the interrelationships between morphodynamics and ecology, approaches for management solutions are to be developed which can help the watercourses attain a significantly better quality.

RESULTS

In addition to water temperature and oxygen-consuming pollution, the flow diversity proved to be a key factor impacting the 'breathing habitat' conditions of the biocoenosis in the surveyed watercourses. That is why one of the essential requirements for achieving a good ecological status is to reach a type-specific flow diversity that is as natural as possible. However, it became evident that stressors such as 'pollution' and 'fine sediment deposits' have an excessive impact on the few near-natural micro- and mesohabitat structures, thus preventing a good ecological status from being achieved.

Physical flume experiments proved that riverbank vegetation increases the flow diversity, as well as the diversity of the riverbed substrate, if coupled with it. Thinning riverbank vegetation in a targeted manner (see PROGEMIS®) increases habitat availability for the macrozoobenthos (MZB) and for fish. Forecasting habitat availability can be achieved with the help of MZB habitat modelling (linking 2-D numerical methods with the reaction norms of certain organisms). Using the example of measures implemented on the Mortelbach, the method shows the improvement in habitat availability of several watercourse-specific species.

After discontinuing riverbank mowing along the model watercourses, an incipient self-reinforcing dynamic and structural changes started to become evident. However, till now this has not had a positive impact on the colonisation by the MZB. This is evidence of a poor re-colonisation potential and of further limiting factors. On watercourses that transport suspended riverbed material during flood events, natural levees often form. On the one hand, natural levees can negatively impact flood protection (profile loss), on the other hand, they reduce the amount of sediment deposited in the floodplain. Flume experiments showed that riverbank vegetation influences the shape of a natural levee, but is not a prerequisite for its formation. In principle, the formation of these levees is a natural process. That is why regular maintenance measures are required, in order to keep watercourses permanently free.

At larger watercourses, flood channels (artificial tributaries) serve to catch the runoff if a flood occurs. The project results indicate

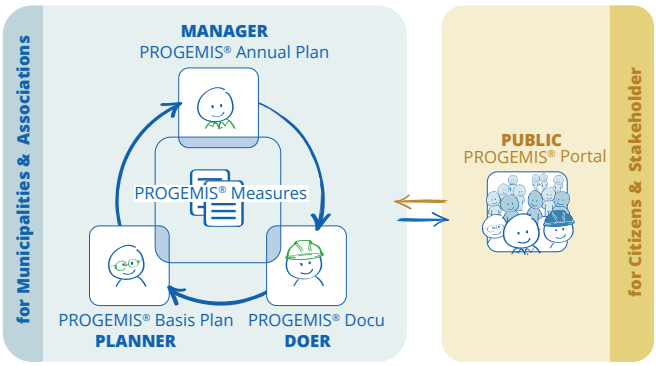

Fig. 1: Modules of the water management software PROGEMIS®. Graphics: Stowasserplan GmbH & Co. KG

that synergy effects which can be desirable to create ecologically valuable structures can be diametrically opposed to flood protection. It must be emphasised that these results are not transferable to natural old branch- and oxbow lake structures.

Areas adjacent to streams often cannot be used for natural development processes. Existing options for improving the availability of areas, e.g. acquisition or trading estates, often can not be fully exploited. Funding measures which guarantee compensation for reduction of crop yields can be used strategically as a temporary solution until permanent securing of land concepts are implemented, such as estate consolidation procedures or legal provisions.

The general public is open to watercourses which are more natural. The results from a choice experiment showed that approx. 75 % of people surveyed are even willing, in principle, to contribute financially to the costs of measures to improve watercourses.

Using the Mortelbach as an example, one approach to the step-by-step development of an 'integrated watercourse concept' was developed and is ready to be implemented. It systematically unlocks the synergies between watercourse development and flood protection and avoids conflicts. The method is easily transferrable and is available as a method- and result report with maps.

The PROGEMIS® software system was developed as a process-based watercourse management- and information system to efficiently manage data, goals, measures and stakeholders. It can use the goals and measures of an 'integrated watercourse concept' as entry data and is portable. An information- and dialogue option ensures that the process remains transparent.

CONCLUSIONS

The step-by-step but continual adaptation of the current watercourse management system is necessary in order to better factor

Fig. 2: Pilot project to measure water levels in the Mortelbach (modelled at a scale of 1:4) in the hydraulic engineering laboratory of the TU Dresden as part of a master's thesis. Photo: André Terpe, TU Dresden

in the morphodynamic and ecological foundations of a natural watercourse. Ecological watercourse development and sustainable flood risk management require space. To this end there needs to be a legal framework that fosters the development of watercourse functions to the benefit of ecosystems and landscapes. Like the ban on using arable land in the watercourse verges beginning on January 1st 2022, as mandated in the Water Law of the German state of North Rhine-Westfalia (§ 31 Abs. 2 Ziff. 2). With the management system PROGEMIS® a software tool is available which supports water maintenance stakeholders in the integrative planning, implementation and documentation of measures.

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More contacts and partners: page 52-53

KOGGE – Mutual development of municipal water bodies in urban areas

For the sustainable development of urban water bodies, a methodology was established and a city-wide water body development concept was developed using the city of Rostock as an exemplary model region.

KEY MESSAGES

- A city-wide water body development concept for Rostock was exemplarily developed.
- This was based on the establishment of an interdisciplinary collaboration. The amalgamation of relevant geoinformation as well as various water management, scientific and other models significantly facilitates the development of a joint understanding of processes and issues. It also necessitates data management based on common standards.
- Transferable analysis- and assessment methods for the hydrologic-hydraulic, ecological and sociocultural classification of small water bodies in mostly urban areas were developed. For water bodies not mandated for European Water Framework Directive (WFD) reporting there is a new bioindicative assessment procedure. By calculating water-related ecosystem services, development measures can be developed and justified in a more targeted manner.

BACKGROUND AND RESEARCH QUESTIONS

Watercourses fulfil a variety of functions in cities and communities. They serve as drainage for rainwater and thus as a protection against flooding, are a habitat for aquatic plants and animals, improve the micro-climate of residential areas and serve as recreational areas for the city's population. The goal of KOGGE was to systematically record these functions and use this information to develop an integrated water body development concept. The model region is the Hanseatic city of Rostock with more than 200 km of smaller watercourses, 400 standing water bodies as well as a 1,200 km long sewage system. Like in many other communities, the ecological status of the wetlands, flowing water bodies and standing water bodies is not known and their function as an experiential and recreational space is only limited. Simultaneously, the hydraulic load of the sewage system and flowing water bodies increases due to urban densification and development. Against this backdrop KOGGE was tasked with developing and implementing a transferable catalogue of methods from the analysis of the status quo to the planning of measures.

RESULTS

The basic approach during the KOGGE project is summarised in Fig. 1. The project partners fed all the available data and the results derived from them into a joint geodata infrastructure. For the subsequent collection of missing data (e.g. drainage areas, water body profiles, special structures) different methods (remote sensing with unmanned aerial vehicels, digitalisation, terrestrial surveying) were combined and further enhanced. Combined with a high-definition map of the actual land use, this approach allowed us to glean crucial information, particularly with regard to research questions pertaining to hydraulics and substances. At the same time, the requisite level of protection (recurrence interval of a potential flood) was specified in collaboration with the city of Rostock. This enables a consistent hydraulic risk assessment with the integration of land use, urban drainage systems and flowing water bodies, and the development of a city-wide integrated drainage master plan.

The structural quality of water bodies was mapped and assessed together with the sociocultural usability of a water body segment. Considerable potential for improvement was determined during this process. To ecologically assess the small flowing and standing water bodies not subject to mandatory reporting, an assessment approach was developed which uses macrophytes, macrozoobenthos and lepidoptera as bioindicators for the status of a water body and for probable causes for pollution. All of the information was consistently amalgamated in a digital water body- and wetland register, in which all relevant attribute data for 50 m flowing water body segments are accessible and which enables more detailed analyses through topological interconnections. The integrated water body development concept was developed on this basis, with development goals tailored to specific water body segments and with measures to achieve those goals. In addition, key water body functions with ecosystem services were assessed, thus substantially strengthening the significance of water bodies in the social discourse.

All of the results were collated in thematic maps targeting specific user groups and translated into sectoral plans by water management representatives and the municipality. The results feed into, among other elements, into the new land use plan and the environmental open space concept of the hanseatic city of Rostock. At the same time, the city developed an integrated drainage system master plan in close collaboration with

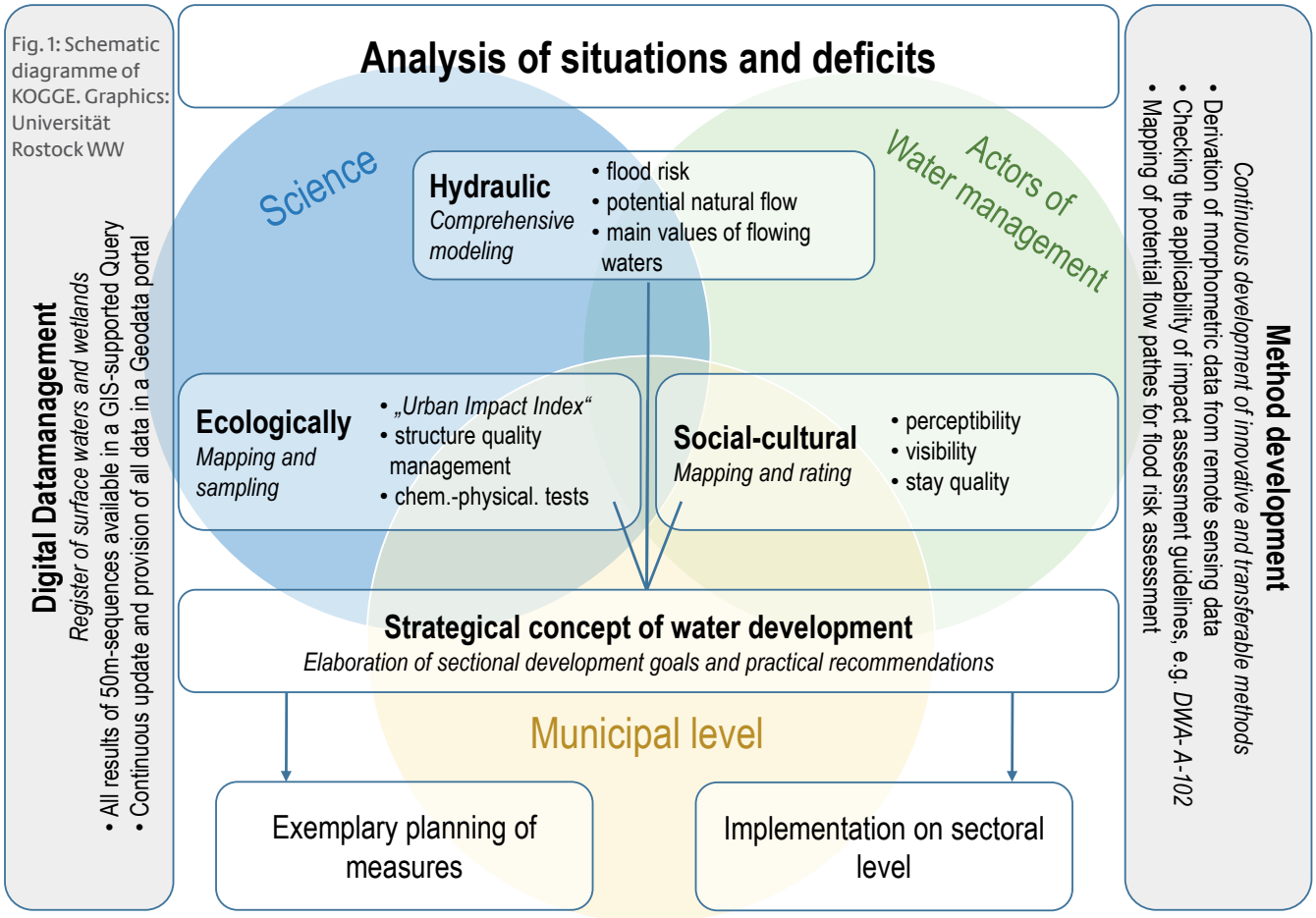

Fig. 1: Schematic diagramme of KOGGE. Graphics: Universität Rostock WW

KOGGE. It forms the basis for the future development of urban flowing water bodies and rainwater management. Exemplary integrated measures for flood prevention and water body improvement were planned, and some have already been implemented.

CONCLUSIONS

Using the KOGGE approach and its underlying methodology, complex and sometimes conflicting demands towards water body development can be converted into a professional solution which is as integrated as possible. With the thematically differentiated status quo analysis of urban small water bodies, the consistent amalgamation in a GIS-based register, and the development concept derived from these, an integrated planning basis for practical water management and urban planning was established. The stated goal of all water management representatives and of the Hanseatic city of Rostock is to continue to maintain the results from KOGGE and to consistently integrate them into ongoing plans. The city is planning to create a new position in order to safeguard data availability and updates, as well as to educate future users on the methods and products developed during the project.

The final report will explain the methodological approach in a comprehensible manner, thus guaranteeing that it can subsequently be used in other municipalities. It will be made available as a download on the KOGGE homepage.

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Project duration: 01.04.2015 – 30.09.2018
More contacts and partners: page 53

NiddaMan

NiddaMan – Development of a sustainable water resources management using the example of the Nidda catchment

The project focused on studies on the relevance of trace substances, the effects on aquatic organisms and suitable measures for reducing pollution and the impact on surface water bodies.

KEY MESSAGES

- Measures to improve biological and chemical water quality should include streams and headwaters, even when these are not European Water Frame Directive (WFD) relevant, because these water bodies are a crucial source of biodiversity in aquatic systems.
- Isolated measures to renaturalise a river or to eliminate trace substances are by themselves not adequate to improve the chemical-ecological status of a water body.
- Embryotoxic and in vitro toxic activity potentials were already detectable in the rivers' headwaters, both in the water body and in the sediment. This is why measures should also be targeted at improving the quality of the sediment.
- Percentages of purified wastewater of ≥ 12 % in the annual mean (TITAN analyses) in the Nidda catchment area lead to changes in the species composition of the macrozoobenthos which do not conform to the reference conditions of the Surface Waters Ordinance provided for the defined types of water bodies. Above the calculated annual mean for wastewater, the abundances of particularly sensitive species drop abruptly. Through more effective, pollution-related wastewater purification, the critical percentage of wastewater can be increased.
- When planning water management measures, the participation of interest groups should be enlisted and communication with them should begin early, according to the principles of cooperation management.

BACKGROUND AND RESEARCH QUESTIONS

Renaturation of straightened, artificially engineered and unwooded river segments is often the method of choice when implementing the WFD and restoring rivers to a near-natural state. In this context it is largely unknown how much other negative factors, such as pollutants and plant nutrients, impact the status of the rivers and their biocoenoses. Using the Nidda as an example of an anthropogenically modified river characteristic of Central Europe, pollutants from point and diffuse sources were quantified and studied with regard to their impact on organisms and aquatic biocoenoses. In the process, renaturalised and non-renaturalised river segments were compared to one another in terms of the efficiency of water management measures, and a sustainable water resources management strategy was refined, while factoring in social-ecological insights.

RESULTS

The development of a water management strategy was based on linking various models (water balance model, urban- and rural precipitation runoff models, substance flow- and water quality model). Measures relating to urban drainage were developed according to a pollution-based approach. The development of measures related to sewage plants, mixed water, and drainage structures was achieved with the help of modelled discharge data and percentages of wastewater in the river. Thus, shortly after its closure, the biological effects of a category 1 sized sewage treatment plant were to a large extent no longer detectable in the river.

In most catchment areas in Germany, increased contamination with phosphorus can be traced back to agricultural emissions. In the catchment area of the Nidda, the situation is different: In the side stream Usa, for example, 90 % of the urban phosphorus contamination can be traced to sewage treatment plants. In another side stream, the Horloff, combined sewer overflows are another relevant route of entry for phosphorus alongside sewage treatment plants, contributing to approx. 25 % of contamination. In the case of carbamazepin, sewage treatment plants are the main source of contamination, with a percentage of > 90 % in both study areas.

Chemical tests on more than 150 anthropogenic trace substances, metabolites and transformation products mirror the typical situation with regard to the contamination of smaller rivers that have a higher percentage of purified municipal wastewater. During temporally highly defined monitoring campaigns in the study area it became evident that some of the polar substances (e.g. the analgesic diclofenac), which are relatively stable in the sewage treatment plants, are photochemically/biologically degraded in the river. Due to the large number of sewage treatment plants in the study area, however, and thus of sources of contamination, this often does not lead to a discernible decrease of concentrations through degradation processes in the river.

Fig. 1.: NiddaLife activities during Hessian Sustainability Day 2016.
Photo: Simone Ziebart. Universität Frankfurt

Fig. 2: Active monitoring at a sampling site on the Nidda.
Photo: Andreas Dieterich. Universität Tübingen

In part, more pronounced ecotoxicological effects were recorded in renaturalised river segments than in areas upstream from a measure. Further studies will concentrate on possible causes, such as e.g. an increase in the deposit of contaminated sediments in the renaturalised river segments.

The health of both abundant and exposed fish in the Nidda is alarming (especially chronic damage in liver tissue). Although the river's morphology is not changing, sensitive fish species are disappearing in short sections of the river. It also became evident that hydromorphological measures have only a limited effect (500-2500 m). This might be attributed to the fact that many substances have only a limited degradation capacity, as well as to a lack of potential for re-colonisation caused by the impact of further stressors (e.g. combined sewer overflows, silting up due to soil erosion).

Together with representatives of the NiddaMan stakeholder committee, a communication and participation concept was developed to plan and implement water management measures. The interactive knowledge map NiddaLand (http://www.niddaland.de/) was developed to enable a dialogue between researchers and the general public (citizen science) in the region.

CONCLUSIONS

In the Nidda catchment area a need for action to improve ecosystem health was determined. A limited substance retention through sorption and degradation processes and the unknown ecotoxicological potential of single substances/mixtures suggest the reduction of pollutants from municipal sewage treatment plants, combined sewer overflows und diffuse sources. So technical and/or structural drainage measures for improving the chemical-biological status of the river, as well as the choice and prioritisation of measures, should be implemented not only on the basis of sewage treatment plants' size categories, but should take into account the absorption capacity of the surface water body, sewage treatment plants of all size categories and combined sewer overflows in equal parts.

More efficient water management measures can be expected with an integrated, cross-sectoral (regulatory) approach to rivers. So, for example, the potentially positive impact of local measures can fail to appear or be prevented in a river's middle course, if there is a lack of corresponding activities in the river's upper- or lower course.

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More contacts and partners: page 54

StucK – Safeguarding drainage in coastal urban areas while factoring in climate change

In the StucK project, a comprehensive system analysis in two selected model regions in the Hamburg metropolitan area and an analysis of the hydrological interrelationships between high tides and inland flooding are completed. This enables the development of management strategies for the rivers being studied.

KEY MESSAGES

- An enhanced short-term and small-scale precipitation forecast, combined from radar measurements and model simulations (COSMO-DE-EPS), enables the running of an operational runoff forecast model for urban regions. Its results make Hamburg's warning service for inland flooding more precise, thus extending the room for manoeuver/response times in the case of a flood.
- Ecological flood protection concept for Hamburg: A targeted management of the flood retention basins enables an optimisation of flood protection, while at the same time exploiting the greatest possible ecological potential of the open spaces and creating ecologically valuable habitats.
- A procedure for the analysis of damage potential was developed. This enables the evaluation of different scenarios with a view to potential damage avoidance. The results can also be used to communicate with and sensitise the population.

BACKGROUND AND RESEARCH QUESTIONS

In coastal urban rivers, runoff is often compromised by backwater due to the tide – with a negative impact on inland drainage. Currently, the management of urban rivers is rarely viewed in an interdisciplinary manner, i.e. under ecological and economical aspects. In addition to other goals, the consortium in StucK studied drainage during extreme weather events, i.e. heavy rainfall leading to inland flooding and storm floods with flooding of the Elbe River. If these events occur simultaneously, flood managers of urban coastal areas are faced with an exceptional challenge. Thus, one of the key tasks was to develop a transferable concept. It integrates ecological aspects and factors in the economic assessment of individual options for taking action. Because StucK focuses strongly on the practical needs of the water management sector, the use and implementation of the results on a day-to-day basis is assured.

RESULTS

The procedure developed in StucK compiles combined precipitation forecasts. These are based on radar data for the 1st–2nd forecast hour. From the 5th forecast hour onwards, COSMO-DE-EPS data are used. In between (3rd–4th forecast hour), the radar- and COSMO-DE-EPS data are blended. The thus combined precipitation forecasts are compiled as an ensemble with 20 runs and significantly improve the forecast, especially for heavy rainfall warnings. The following products are produced for this purpose:

1. Continual time series of 20 ensemble runs, forecast time period 0–20 hours.

2. Continual forecast images of the precipitation intensity (mm/h), lead time 0–20 hours.

3. Forecast precipitation amounts of 20 ensemble runs as sums over various lead times: 0–2, 0–6, 0–12 and 0–24 hours.

The operational model for the runoff forecast in the Kollau model region is run with these forecasts. This model delivers a new runoff forecast every five minutes, thus creating more room for manoeuver for flood management. In connection with the precipitation forecast products, it enables more precise reporting from Hamburg's warning service for inland flooding.

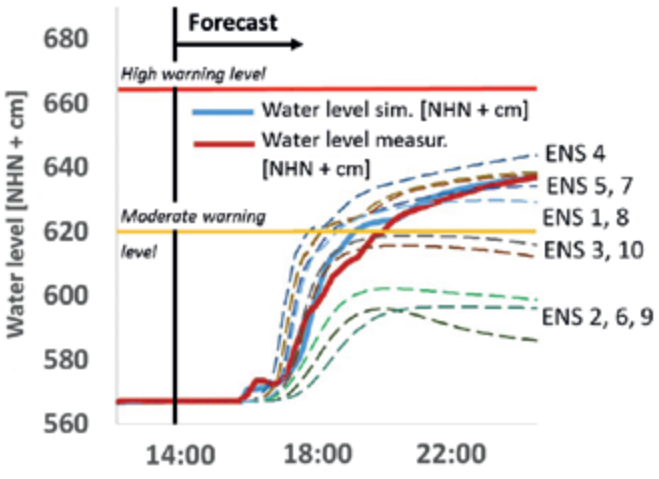

Fig. 1: Results of the operational model of the Kollau at the Niendorfer Straße gauge. The variance of the ensemble illustrates the variability of the results. Graphics: TUHH

Fig. 2 left: Flow measurements on the Kollau within the framework of StucK. Photo: LSBG
Fig. 3 right: Due to continuous rain flooded hiking trails along the Kollau on 06.10.2017. The water level at the downstream gauge Vogt-Kölln-Straße, which was established in 2015, reached the highest measured value to date. Photo: LSBG

For the Kollau model region, the modelling of land use and climate scenarios shows higher runoff peaks in the year 2035. Under the assumption of increased soil imperviousness – among other things through population growth and more housing construction/densification – runoff rises only marginally, at 2.5 %. If, to factor in the effects of climate change, the assumption is made that precipitation intensity will increase by 15 %, the runoff peaks in the year 2035 will rise significantly, at approx. 25 %. This in turn will lead to a larger overall area being flooded in the case of an event. Extensive measures are needed in the face of this significant increase, e.g. the optimal management of the model region's flood retention basins. This enables the increase to be reduced to only about 9 %, compared to today.

These results highlight the need to generate more room for manoeuver and more safety reserves in the future by implementing forward-looking activities. For the river system of the Kollau, which reacts quickly, a fitting management concept has been developed, based on the optimised precipitation forecasts and beginning 24 hours before a flood occurs. The flood retention basins are managed as dry basins so that they and the floodplains are ecologically upgraded. Thus, ecologically valuable habitats are created through flood protection measures. In the Dove-Elbe model region, the future management concept already begins six days before the occurrence of the flood event, since this catchment has longer flow times and thus a correspondingly earlier response is necessary in order to create the required retention volume. To this end, the management of the complex control structure is optimised by means of modelling, and combined with tide and precipitation forecasts.

In the Kollau model region, the damage potential is calculated to be approx. 1.6 million Euros in the case of a 100-year flood. A scenario which has been developed, called 'Future land use and climate surcharge', shows an increase in the flooded area. In this case, the damage potential can still be expected to rise. With these numbers, the costs of protective measures experience a new valorisation, which must also include the creation of ecologically valuable habitats.

CONCLUSIONS

StucK developed innovative action plans with regard to tide-dependent drainage and management options in densely populated urban areas. These extend the limited room for manoeuver which characterises urban areas due to a variety of competing uses. In the concepts which have been developed, flood protection is always assured. In addition, ecologically valuable habitats are created. The project results are presented in a summary and a detailed project report. Due to the large-scale scope of StucK since its inception, the concepts which have been developed can easily be transferred to other regions in Northern Germany. Specific plans for construction and the implementation of measures were not a part of StucK. It is currently being determined whether a realisation is possible after the project has been completed.

CONTACTS

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WaSiG – Water balance in urban areas: planning tools and management concepts

The goal of the project is to provide efficient planning tools for the sustainable management of storm water for municipalities and engineering companies.

KEY MESSAGES

- The observed storm water control measures (SCM) are reliable in the long-term and are mostly seen in a favourable light by the general public.
- The land requirements for the SCM must be taken into account as early as possible during the urban land-use planning. Based on their practical experience, experts from the German cities of Freiburg, Hanover and Münster have formulated recommendations for administrative and operational practice.
- Hydrological models for simulating SCM were improved, supplemented with a newly developed module to calculate the potential evapotranspiration in urban areas, and validated using observed data. They are freely available as open source tools for end users and providers of specialised software.
- The water balance is an important and suitable criterion of urban land-use planning. Based on freely available data and on a generally accepted water balance model, there is a new GIS-based calculation approach by which a reference condition for the near-natural water balance (predeveloped state) can be determined.
- Guidelines for a hydrometric monitoring have been developed to determine the effectiveness of SCM in terms of water management.

BACKGROUND AND RESEARCH QUESTIONS

In urban watercourses there are disruptions of the water balance, the hydrologic regime and the hydrologic dynamics due to soil sealing and the fact that storm water runoff is largely drained off. The problems, which by now have been recognised, have led to a paradigm shift in the management of storm water runoff in urban areas. Instead of complete and rapid drainage the new approach is designed for the avoidance, infiltration and delay of storm water runoff. However, this paradigm shift does not necessarily lead to urban watercourses aligning with a near-natural water balance, as required in order to achieve the good ecological status.

Fig. 1: Green roof test facilities with measuring systems in Münster (10 surfaces of 3 m^2 each). Photo: Isabel Scherer, FH Münster

The monitoring programmes and modelling studies in WaSiG contribute to a detailed analysis of the water balance of SCM and for provision of data on the impact of storm water management in already existing urban areas. The studies were conducted in selected neighbourhoods of the German cities of Freiburg, Hanover and Münster. The neighbourhoods are characterised by the fact that SCM have been implemented for up to 20 years.

RESULTS

In WaSiG a method was developed which is implementable across Germany. Based on this method, reference values are calculated for the water balance in urban areas, considering the current use of cultivated land without urban development. The GIS-based calculation approach combines freely available geological, climate and land use data with a commonly accepted water balance model. Monitoring data and other available water balance models were used for validation.

Due to the specific characteristics of urban catchment areas, they need to be integrated accordingly into hydrologic models. These models subsequently serve as planning tools by simulating event-based and long-term water balances of urban areas with drainage, groundwater recharge and evapotranspiration. The simulation tools UrbanRoGeR and SWMM-RWB, which were further developed during the project and which are freely available, replicate the relevant hydrologic processes as well as various SCM (green roofs, semi-permeable asphalt areas, infiltration systems etc.) in a high temporal- and spatial resolution. Field tests and long-term measurements of climate variables

were combined with model calculations on solar radiation at an urban level. The findings serve as a basis for new approaches to determine the potential evaporation for urban areas. The transfer functions can be integrated into conventional urban-hydrological models.

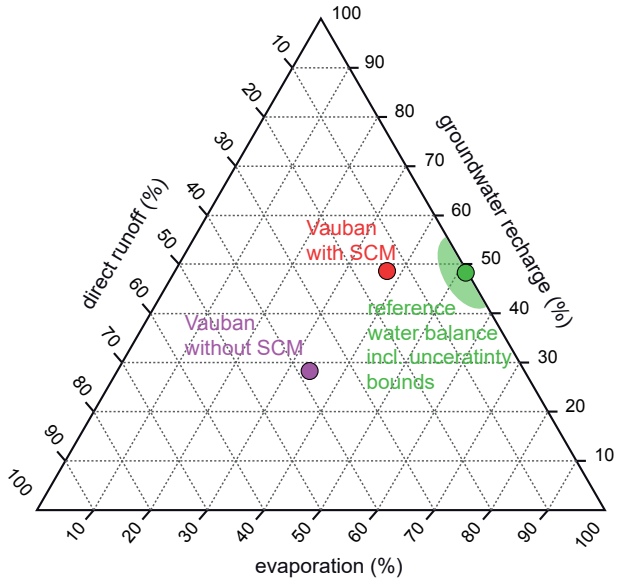

Fig. 2: Comparison of the water balance percentages (surface runoff, new formation of groundwater and evaporation) for the year 2016, between the Vauban neighbourhood in Freiburg (current situation with decentral stormwater management measures and a scenario without the measures) and the reference condition of the surroundings unaffected by residential areas.

Long-term simulations prove that most of the studied SCM can be safely operated – even when there are heavier rainfall events than those on which the assessment is based. On an operational basis, particularly swales, infiltration trenches and a combination of both, distinguish themselves through a high potential for inner-city flood protection. However, especially in the case of near-natural measures, maintenance details (e.g. swale geometry, mowing) should already be considered during the planning phase to avoid cost disadvantages later.

The SCM have proven to be successful after implementation. This results from an analysis of operational experiences together with a comprehensive monitoring programme in urban areas with water sensitive urban design. The observed swales, infiltration trenches, permeable pavements and green roofs in Freiburg, Hanover and Münster have been in operation for up to 20 years. Based on their experience, the cities have formulated recommendations on administrative processes and operational practice for other municipalities.

The overall technical and organisational analysis of the monitoring programmes as well as practical experiences have led to recommended actions for analysing the water management impact of SCM.

The evaluation of a household survey on the acceptance of SCM in 24 urban quarters of the three cities showed that the respondents were open-minded with regard to the measures implemented in their neighbourhoods and mainly reported having positive experiences. The acceptance analysis thus delivers an important data base for justifying future planning decisions.

CONCLUSIONS

WaSiG was able to show that the near-natural water balance in urban areas is important and suitable as a planning parameter. In future, using the findings and methods which were developed in WaSiG, it will be possible to better adjust the water balance in urban areas to the near-natural water balance.

The SCM have proven to be successful in practice. Operational experience and advice for efficient administrative action is available and ready to be implemented. The measures are largely supported by the general public. The type and impact of measures to increase evapotranspiration and to manage groundwater recharge can be determined thanks to the new methods, and should increasingly be considered during planning. If the reference condition ultimately cannot be reached, or cannot almost be reached, arrangements for substitute and compensation measures should be considered.

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BOOT-Monitoring

The journey from research result to marketable application is often more arduous than we think at the beginning of a project.

Achim Six,
Sächsisches Landesamt für Umwelt,
Landwirtschaft und Geologie

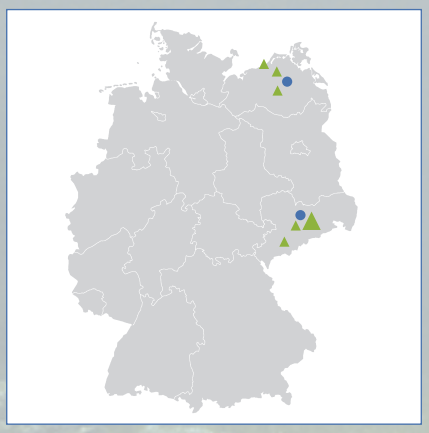
HyMoBioStrategie

The insights from HyMoBioStrategie about the effects of sedimentation in renaturated areas informed the ongoing implementation planning process.

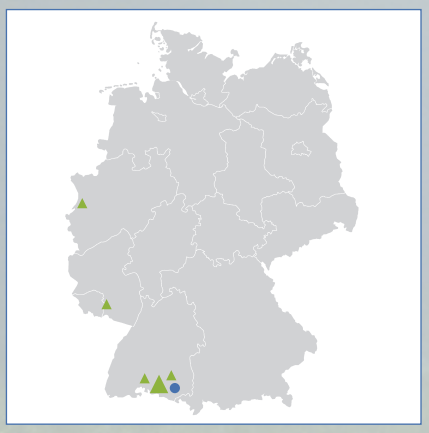
Lothar Heissel,
Regierungspräsidium Tübingen

Monitoring of waters

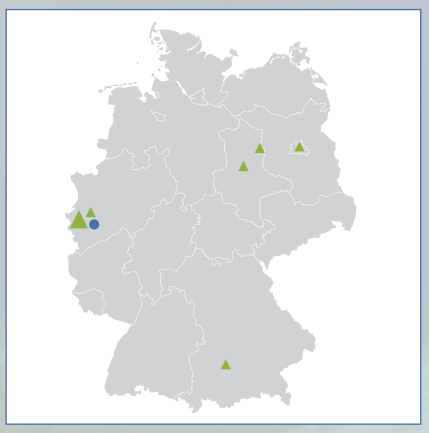
26 BOOT-Monitoring



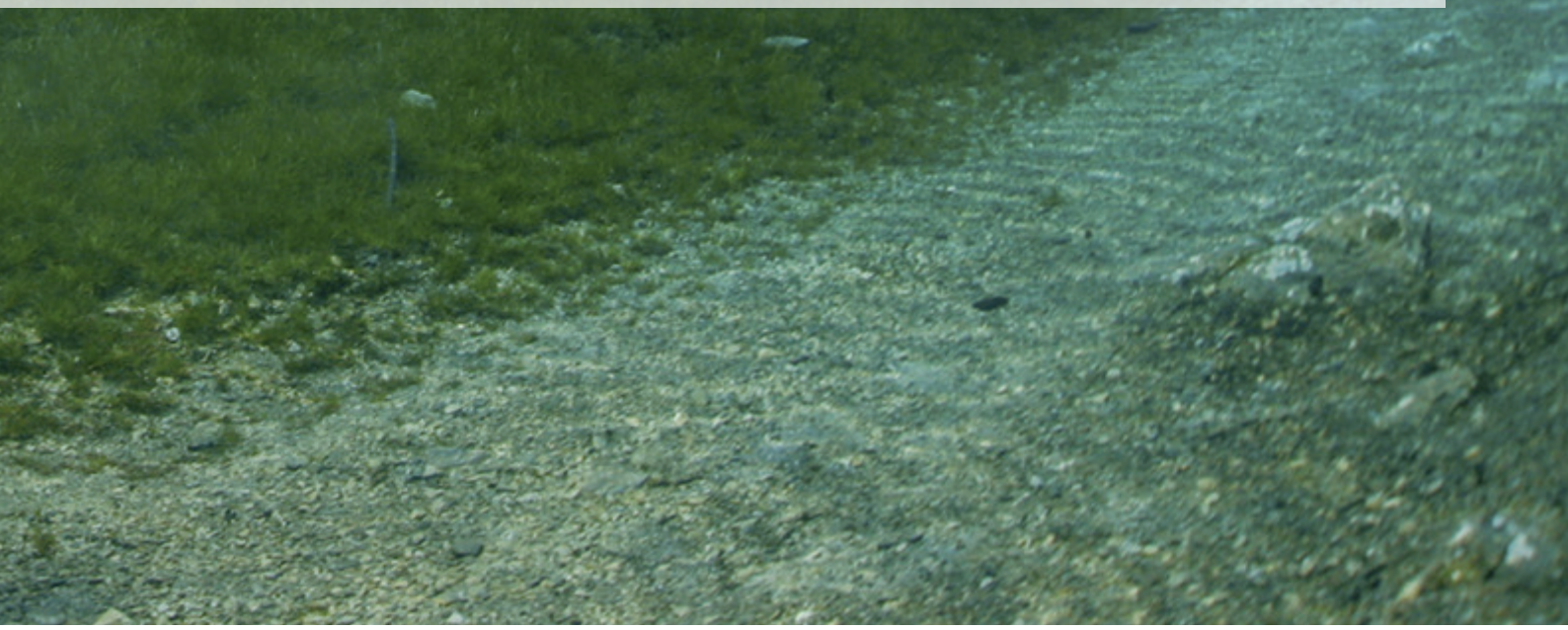
28 HyMoBioStrategie



30 RiverView



▲ Project coordination ▲ Joint project partners ● Model regions



RiverView

Monitoring results from rivers that have sufficient depth are utilisable for us and will inform the work of the Emschergenossenschaft and the Lippeverband.

Rolf Kemper-Böninghausen,
Emschergenossenschaft Essen / Lippeverband

BOOT-Monitoring – Boat-based measurement system to map the longitudinal morphometry, water quality and hydrology profiles of rivers as part of an integrated river monitoring system

An improved status description and -assessment of the small and middle-sized streams and rivers in Germany was the goal of the joint project BOOT-Monitoring.

KEY MESSAGES

- A monitoring concept was developed with which small to middle-sized streams and rivers can be navigated along their course, even when water levels are low or there is vegetal invasion. The monitoring system is structured in a modular fashion. If combined with an efficient navigation strategy, it can be adapted to specific evaluation criteria.
- The spatial-temporal high-definition measurement of physical-chemical water parameters allows specific point- or diffuse pollution sources to be identified and described, as well as determining degradation processes in the water body. This makes it possible to develop targeted measures to reduce pollution and to make water management more efficient.
- New evaluation algorithms to describe the river morphology on the basis of boat-based, georeferenced sensor technology and possibly drone- or satellite-based information enable improved evaluation of the structure of streams and rivers for the Water Framework Directive (WFD).

BACKGROUND AND RESEARCH QUESTIONS

Until now, assessing the environmental and chemical status according to WFD has been restricted to specific pre-determined sites along streams and rivers. When choosing a suitable measuring site, care should be taken that nutrient- and hydraulic loads in a given segment of a watercourse are captured in a representative manner. This leads to assumptions being made, which are often difficult to verify, about how data values may change between the measuring sites. In light of these facts we developed a monitoring boat with a modular structure, together with a monitoring concept. It uses an online measuring technique which can continuously map the water quality, channel morphometry and hydrology parameters along a river's course.

RESULTS

The monitoring concept which was developed closes a gap which cannot be bridged by remote-controlled monitoring units. It has a high load capacity so that a large number of measuring probes can be carried simultaneously, and can still be used when water levels are very low. Two different kinds of carrier systems were developed in order to meet the varying demands of the rivers. The Tollense River in Mecklenburg-Vorpommern, specified as a model region, is a lowland river characterised by low flow velocities and steady water levels. The Freiberger Mulde is a river in a region of hills and low mountain ranges with higher flow velocities, but very low water depths in places.

A consistently modular concept was implemented when choosing and positioning the measuring technology, which includes a broad range of measuring equipment for water quality and hydrometry. The sensors are chosen according to the expected measurement values of the watercourses being studied. Many parameters are captured redundantly to enable high data density and comparability of the results. In some cases, different instrumentation was used at the pilot watercourses due to different inquiry-based questions. In the river Tollense, a wet-chemical online-analyser was used for the first time which was able to very accurately measure nutrient concentrations outside of the measurement range of conventional online-measuring technology (Fig. 1). Thus, high-resolu-

Fig. 1: Monitoring concept for navigable watercourses (water is pumped onto the vessel via the measuring equipment), Photo: Wolfgang Klehr, Uni Rostock

Fig. 2: Monitoring concept for shallow watercourses (towing convoy with submerged sensors), Photo: Christian Koch, TU Dresden

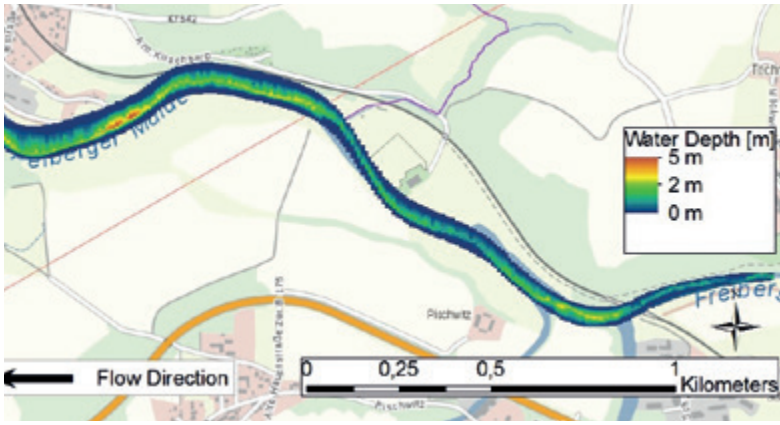


Fig. 3: River profile for a 4 km long segment of the Freiberger Mulde between Technitz and Westewitz during a monitoring campaign on August 15th, 2017, Graphics: Stefanie Wiek, TU Dresden

tion profiles of the phosphorus concentration were measured. At the Freiberger Mulde, a towing convoy was used (Fig. 2). The system guarantees measurements from a water level of 10 cm and enables obstacles to be circumnavigated quickly. On this carrier system, a single-beam echo sounder attached to a stepper motor was used successfully. By pivoting the echo sounder, data from the river bed across a breadth of 5 m can be collected. The acoustic signal is supplemented by the water depth measurements of an ADCP (4-beam-system), which are also recorded. Fig. 3 shows a river profile for a 4 km long segment of the Freiberger Mulde interpolated from this data. The resulting watercourse profiles are used to evaluate the structure of the river, but also to calculate the discharge and the ensuing longitudinal nutrient load profile.

In order to attain an image of the river bed which is as accurate as possible, the river must be navigated slowly and in the form of a sinus curve, whereas if only concentration profiles are needed, it is sufficient to navigate it longitudinally. Several monitoring campaigns in the Freiberger Mulde showed a gradual decrease in nitrate levels as proof of the river's self-cleaning potential. In addition, mixing processes due to tributaries' inflows can also be identified with low concentrations. The Zschopau tributary river has the largest impact along the 27 km long section of the pilot river which was navigated. Complex transport- and mixing processes were detected in the immediate vicinity of the confluence. In the Tollense River it was possible to quantify the diffuse input path via e.g. groundwater und associated nitrate load by flow rate development. In addition, the water and nutrient dynamics were simulated with an interlinked numeric 1D-model which enabled the assessment of the impact of local nutrient pollution.

The rivers' surroundings and longitudinal course were evaluated with satellite-, aerial view- and drone-backed remote sensing data. In combination with the depth- and cross sectional data of the monitoring boat, the metrics developed and adapted in the project could have been used to evaluate the individual parameters – river's curvature, river banks development, in-stream structures, depth variance, depth profile and width variance – according to the criteria of the 'LAWA on-site procedure'.

CONCLUSIONS

The boat-based monitoring system developed during the BOOT-Monitoring project to capture morphometric-, hydrologic- and water quality data is an innovative tool for environmental agencies. It provides the opportunity to efficiently consolidate information from middle-sized streams and rivers and to assess the impact of water management measures. It also enables an initial assessment of small streams and rivers as well as the identification of river segments with critical levels of pollution.

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HyMoBioStrategie

HyMoBioStrategie – Impact of the hydromorphological changes of lakeshores (Lake Constance) on the sediment budget, submerged macrophytes and macroinvertebrate communities with the goal of optimising mitigation strategies

Using an interdisciplinary approach, HyMoBioStrategie has identified the complex processes and interrelationships between a modified shore line structure and consequent hydromorphological conditions and biocoenotic structure, and has developed and implemented new monitoring- and modelling systems. Proposed solutions and strategies for improving the ecological status of lake shores and littoral zones were developed and recommendations for a sustainable management were made.

KEY MESSAGES

- Development of a sediment transport model as a forecast tool to help plan future measures on shorelines and assess their impact on the hydro- und morphodynamics in the littoral zone of lakes.
- New methods characterising and quantifying the sediment transport in the littoral zone of lakes have been established and are available for use.
- Development of the universally applicable, autonomous monitoring vehicle Hydrocrawler, e.g. for the high-resolution, comprehensive survey of the lake bottom topography and sediment stratigraphy.
- Improvement of the methods used to assess the ecological status of lake shores in line with the European Water Framework Directive (WFD) using the two biotic indicators macrophytes and macrozoobenthos.
- Further refinement of the quality- and monitoring standards in the course of lake shore renaturations based on the renaturation guideline of the International Commission for the Protection of Lake Constance (IGKB).
- Recommendations for a sustainable management of littoral zones of lakes while considering the existing intensive usage claims and sustainability conflicts.

BACKGROUND AND RESEARCH QUESTIONS

The shores of many German lakes are subject to a significant structural impact. Shoreline construction and various forms of lake uses lead to changing hydrodynamic conditions in the littoral zone, which can affect the transport and balance of sediments as well as aquatic plants and benthic organisms. Little is known about the process interrelationships between shoreline construction and hydrodynamic conditions on the one hand, and the biocoenotic structure in the littoral zone on the other hand. In addition, it has become evident that there is an increasing erosion of littoral sediments in many alpine lakes. Erosion particularly affects archaeological underwater monuments, which are on the UNESCO World Heritage list and which have to be preserved.

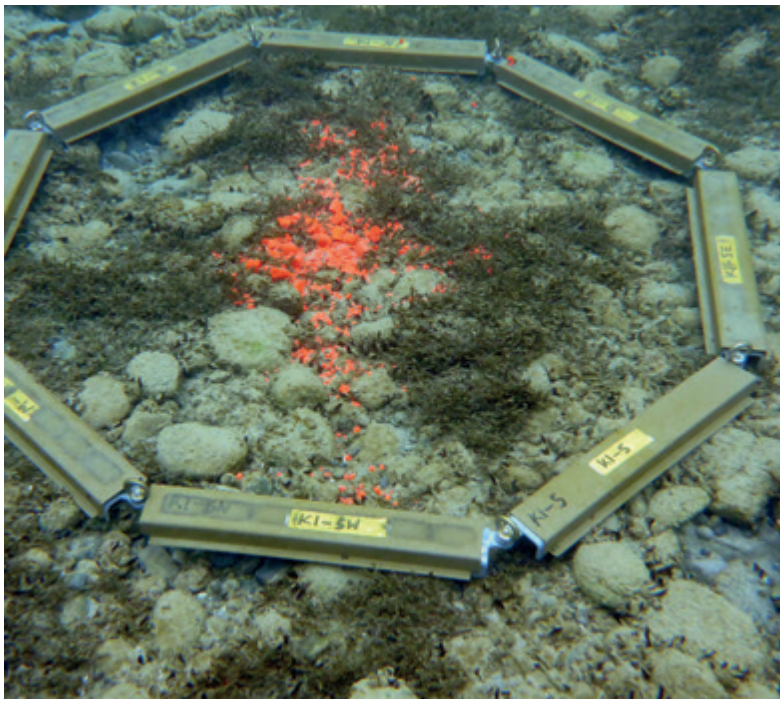

Fig. 1: Circle of eight magnetic traps with red tracers which were transported orthogonally to the shoreline by wave-induced motion. Photo: Dr. Wolfgang Ostendorp, LAD

RESULTS

The hydro- and morphodynamics in the littoral zone are a function of the kind of structural impact they are subject to, and of the hydrodynamic exposition. In particular, harbour facilities, elongated bank reinforcements and jetties lead to changes in the properties of the surface wave- and current field, thus affecting the patterns of sediment transport. The effects are greatest in shore sections with a high wave exposure, with water level fluctuations exerting a significant impact. In addition to the energetically dominant wind waves, waves and currents

induced by ships can lead to large redistributions of sediment locally, e.g. at jetties. The net sediment transport in the littoral zone of lakes usually occurs along-shore and is of small magnitude (< 5 cm a-1 on average in Lake Constance). However, it is subject to high spatial- and temporal dynamics. The sediment transport model which was developed in the project can describe these spatial- and temporal dynamics, can depict the effects of shore constructions on the morphodynamics, and is transferable to other large lakes.

Both relevant quality components of the WFD, macrozoobenthos and macrophytes, are suitable as indicators for a structurally impacted shoreline and for substrate characteristics in the littoral zone (< 2 m). Based on the vegetation-zone concept, a clear link was established between the shoreline structure and the species composition as well as the abundance of macrophytes. In contrast, the macrozoobenthos is less a function of the shoreline structure than of the properties of the substrate, but also of the magnitude of the water level fluctuation and the hydrodynamic exposure. Renatured shore sections and erosion protective structures at the UNESCO World Heritage site are rapidly recolonised by the macrozoobenthos, while macrophytes recolonise them only after several years due to the lack of fine sediment.

HyMoBioStrategie has developed and implemented new techniques for measuring particulate suspension- and bedload transport, the erosion- and/or accumulation behaviour of the surface sediments (e.g. boulder- and gravel tracers, cost-effective erosion markers); as well as acoustic methods (e.g. multi-beam echosounder, sub-bottom profiler, underwater georadar).

The cost-effective erosion markers and the boulder- and gravel tracers have already been integrated into the monitoring programme to protect UNESCO World Heritage underwater monuments. With the Hydrocrawler, an extremely accurate and autonomously operating monitoring vehicle for high-resolution, comprehensive surveys of lake bottom topography and sediment stratigraphy was developed, which can also be used to inspect dams and sheet pilings or to look for missing persons.

CONCLUSIONS

The outcomes of HyMoBioStrategie play a key role for the evaluation of hydromorphological changes on lake shores in line with the WFD and for the development of future lake shore valorisation programmes at larger lakes in Germany and in the circum-alpine region. In addition, new monitoring- and modelling systems were developed, which enable the characterisation of the hydromorphological process interrelationships in the littoral zone under consideration of the shoreline structure, the hydrodynamic exposure and seasonal water level fluctuations. They support the planning of future measures on lake shorelines and contribute to the protection of the UNESCO World Heritage. With the autonomously operating Hydrocrawler, a universally applicable monitoring vehicle is available for use in the field.

Fig. 2: Universally applicable, autonomous monitoring vehicle Hydrocrawler. Measurement run of the Hydrocrawler for the high-resolution, comprehensive survey of the lake bottom topography and sediment stratigraphy on Lake Constance.
Photo: Christian Degel, Fraunhofer IBMT

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More contacts and partners: page 52

RiverView – River status monitoring and management

The goal of the project is to further develop an autonomous measuring boat (RiverBoat) as a carrier platform for hydrophysical and -chemical measuring sensors (RiverDetect) and optical and sonar-based 360° river scanning units (RiverScan). The collected river data are fed into a bimodal geo-database management system (RiverAdmin), visualised with the help of various interfaces (app, web portal), and made available to the end user (RiverWorks).

KEY MESSAGES

- In the RiverView project, integrated and spatially referenced hydromorphology, water quality and image data are collected using a mobile carrier platform equipped with modular sensor technology.
- Representative and high-resolution data for water management planning and monitoring processes are available for practical application (e.g. industrial and municipal discharges).
- By using an autopilot, recordings can be made at different points in time on exactly the same measuring section, so that river development processes can be understood and documented.
- Further processing of 360°-above- and underwater images to a panoramic pictorial world with virtual reality elements is available – just like 3D-models as tools for communicating hydraulic engineering measures.

BACKGROUND AND RESEARCH QUESTIONS

River monitoring is essential for water management planning processes aimed at fostering a positive development of rivers. Especially since the introduction of the European Water Framework Directive (WFD), but also against the backdrop of flood protection, the integrated approach is becoming increasingly important. To date, river data are being collected mainly at stationary monitoring gauges and through time-consuming on-site inspections. In RiverView, a monitoring system for rivers is being pursued which collects river data in high temporal and spatial resolution and in a georeferenced and reproducible manner, thus making an important contribution to finding measures for managing water resources. The project focused on recording small- and medium-sized rivers.

RESULTS

The carrier platform – the RiverBoat – has software (Neptus) which was refined during the course of the project, allowing data to be tracked in real time and the trajectories of the autopilot to be programmed and monitored. The carrier platform was made entirely of lightweight components so that the system could be flexibly transported to the site where it was to be deployed (Fig. 1).

Fig. 1: RiverBoat with modular camera module and trailer. Photo: FiW e.V

The monitoring system records the structure of the river by using a combination of optical and acoustical methods. This is how – using the above-water mapping-unit developed in the project, which consists of a camera, a global navigation satellite system (GNSS) and an inertial measurement unit (IMU) – it is possible to get a spatially referenced image of the river's surroundings on the one hand, and measurements using a structure-from-motion (SfM) method on the other hand. The images are used for the purpose of visualisation and offer information about the vegetation and infrastructure. Conventional river imaging can thus be optimised using objective visual data. The generated point clouds which are used for measurement purposes (e.g. constructions, shoreline). Starting at a water depth of 35 cm, the riverbed is mapped using sonar technology. The system is supplemented by an optical underwater mapping unit consisting of underwater cameras and line lasers. This allows the mapping of sections of the river which cannot be reached by the sonar, depending on the prevailing light and visibility conditions. The scatter plots are also generated by the SfM method. If there are no distinctive visual elements to proceed from, the platform is extended using a line laser, whereby the depth of the riverbed is determined via a geometric method for

measuring distances (triangulation). By combining above and underwater mapping and sonar technology, a continuous digital 'printable' elevation model can be created.

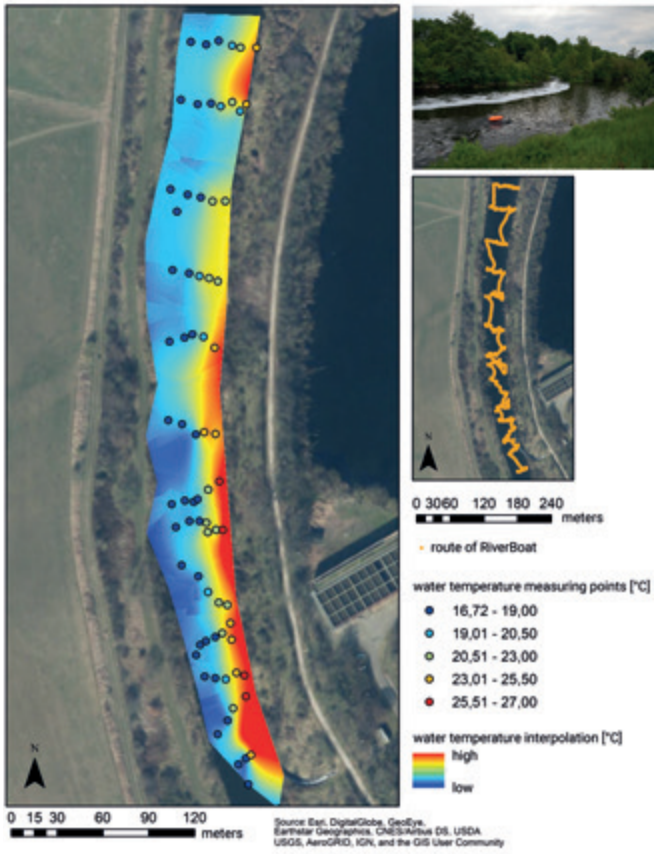

Fig. 2: Discharge plume of a wastewater treatment plant on the river Rur, visualised using the water temperature (Image taken on: March 17th 2017). Photo: FiW. e.V.

A multi-parameter probe to determine water quality parameters is available to further enhance these methods. When monitoring the mixing characteristics of rivers after point discharges, the probe can be attached directly to the boat. To take depth profiles, the multi-parameter probe is lowered from a trailer using a winch. Data transmission is wireless. Recording of quality parameters, i.e. temperature, oxygen, or turbidity, occurs with high temporal and spatial resolution due to the further refined measuring frequency of 20 seconds (Fig. 2). The riverbed is examined using an impulse-neutron-neutron-probe which determines the substance composition of the riverbed via the neutron decay curve.

In case GNSS reception is disrupted, e.g. by too much vegetation or structures like bridges, the exact position of the recorded monitoring data is confirmed in the project by using image orientation or tachymeter tracking.

To store the collected data, a bimodal database management system is used which was developed to meet the needs of the project with regard to recording large image data and heterogeneous sensor data. Through a web portal with an integrated 'panorama viewer', the data are made available to various user groups. The river can be experienced virtually through the point clouds and videos of the above and underwater images, enhanced by virtual reality elements. This allows the visualisation of planning processes and can be used within the framework of participation events (citizen participation).

CONCLUSIONS

The RiverView system enables the status of rivers above and underwater to be objectively recorded. By integrating a variety of different methods, sources of pollution can be identified and needs-based planning of measures can be implemented. In addition to creating a tool for implementing the maintenance goals of rivers, with the development taking place within the framework of the project a step has also been taken towards digitalising water management against the backdrop of water management 4.0.

The RiverView system enables high-resolution monitoring of structural developments and the spread of plumes after point discharges. It can also record further parameters which allow inferences to be made about other processes taking place in rivers. The project is preparing the integration of further elements (e.g. samplers) to determine the degree of pollution in the water and sediment.

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Project duration: 01.06.2015 – 30.09.2018
More contacts and partners: page 56

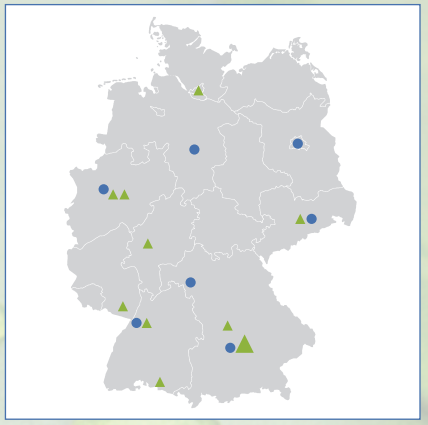
GroundCare

My message to researchers: New methods are practically viable when the cost-benefit comparison is positive, the transferability to other regions is possible, and the effort involved is reasonable. The GroundCare project is well on the way to step-by-step practical application.

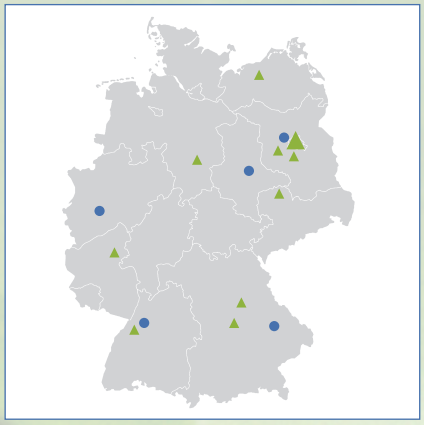
Martin Böddeker,
GELSENWASSER AG

Assessment Methods for Aquatic Ecosystems

34 GroundCare



36 RESI



▲ Project coordination ▲ Joint project partners ● Model regions

RESI

It became evident that in effect, many ecosystem services of rivers and floodplains can actually be evaluated on a region-by-region basis. The RESI index offers us a much broader set of options for determining value.

Kai Deutschmann,
Bayerisches Landesamt für Umwelt

GroundCare – Parameterisation and quantification of ecosystem services as a basis for sustainable groundwater management

The goal of the joint project GroundCare was to evaluate the functional capacity of groundwater ecosystems and to identify ecological parameters which are suitable as indicators. In addition, the project partners developed application-oriented biological-ecological criteria and methods for integrated monitoring in the groundwater.

KEY MESSAGES

- A set of ecological assessment- and monitoring criteria for groundwater was developed based on methods for surface water bodies which comply with WFD requirements. This includes integrated microbiological parameters as well as a characterisation and assessment of the groundwater fauna.
- Amendment of aspects missing in established sampling guidelines, i.e. molecular-biological analyses and the collection of groundwater fauna.
- The ecological reference status for selected aquifers in Germany was defined with the aid of microbiological and faunistic criteria.
- A market-ready biomonitor for the groundwater-specific ecotoxicological assessment of acute- and chronic pollutant contamination and for online quality monitoring is available.
- A sequence databank and DNA barcoding protocols were set up for selected groundwater metazoa.
- The development of a pressure-retaining sampling system for the extraction of groundwater to address specific research questions under groundwater conditions was concluded.

BACKGROUND AND RESEARCH QUESTIONS

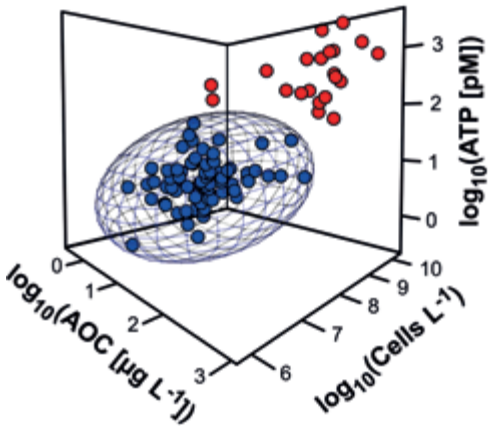
About two-thirds of Germany's drinking water is produced from groundwater. Thus, good quality groundwater is crucial to ensure the reliable supply of drinking water. But in many regions the quality of the groundwater is already compromised or under threat, due to the entry of pollutants from contaminated sites, the excessive use of fertilisers and pesticides, but also through trace quantities of waste water pollutants (e.g. pharmaceuticals). However, no standardised indicators and methods for assessing the ecological viability and stress tolerance of groundwater ecosystems currently exist. German- and European water legislation does not treat groundwater and surface water bodies equally. Although the European Groundwater Directive (2006/118/EG) declares groundwater to be an ecosystem, till now only physical-chemical properties and the groundwater quantity are taken into consideration during assessment and monitoring. That is why GroundCare has made it their task to develop an initial ecological assessment concept based on microbial parameters and the groundwater fauna. In the process, various aspects with regard to usage and contamination (e.g. production of drinking water, impact of contaminated sites and agriculture) as well as geographic and hydrogeological differences within Germany were taken into consideration. The primary goal was to provide environmental authorities and water suppliers with an initial tool box as a modular system and with a users' handbook.

RESULTS

Starting point for the activities in GroundCare was an increased awareness of the importance of groundwater as a habitat and, linked to this, an acceptance for factoring in ecological criteria.

Based on standardised microbiological and faunistic criteria, the ecological reference status of selected aquifers in Germany was defined and an initial modular assessment system for the characterisation and long-term monitoring of the ecosystem status was developed. The B-A-E concept which was developed capitalises on the quantification of the established microbiological parameters total cell count (=biomass), assimilatable organic carbon (=energy) and intracellular ATP (=activity) as sensitive indicators for the microbiological quality of groundwater. Using statistics (Mahalanobis distance), the three indicator parameters are calculated into one index score so that pristine groundwater and/or surface water bodies can be distinguished from contaminated ones in the assessment process (Fig. 1).

A comparable approach was also developed for the groundwater fauna. Sensitive indicator parameters, such as the ratio of genuine (stygobiontic) to invasive- and exotic (stygoxenic) species, are used for this assessment. DNA barcoding protocols were developed for taxonomic classification, and an initial sequence database for selected groundwater metazoa (e.g. amphipods, isopods) was established.



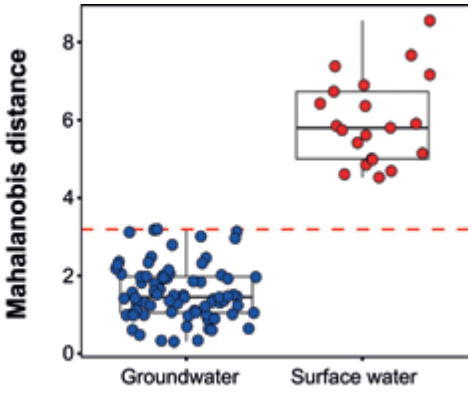


Fig. 1: The B-A-E-concept: The three established parameters total cell count (GZZ), ATP (adenosine triphosphate) and assimilatable organic carbon (AOC, see text) can be converted into one index score using the Mahalanobis distance, to distinguish clean from polluted ground and surface water when evaluating the data. Graphics: HMGU

The 'assessment tool box' developed in GroundCare is based on a sampling guideline, which also factors in molecular-biological and faunistic aspects. All parameters which were considered sound were adapted to groundwater conditions with regard to the analysis protocols and were validated in ring trials. A summarising collection of methods is available. For specific research questions regarding groundwater contamination (e.g. pathogens) and special groundwater conditions (e.g. oxygen-free), a pressure-retaining sampling system developed in GroundCare is available. Another newly developed product from GroundCare is an online biomonitor which enables groundwater-specific ecotoxicological substance assessment (tests on acute- and chronic toxicity) and groundwater quality monitoring (Fig. 3). New advances in the cultivation and conditioning of groundwater organisms also form a foundation for future ecotoxicological tests tailored to groundwater.

Fig. 3: Set up of the Ökotox Biomonitor manufactured by LimCo International GmbH. Photo: LimCo International GmbH

CONCLUSIONS

Groundwater deserves the same treatment as surface water bodies in German and European water legislation. Suitable criteria and concepts are then needed for the assessment and monitoring of ecological status and biological water quality. To this end, GroundCare has developed an initial tool box to make available to environmental authorities and water suppliers in the form of a handbook.

Fig. 2: The amphipod *Niphargus aquilex* is a typical inhabitant of the groundwater habitat. Photo: Nora Rütz, Universität Gießen

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More contacts and partners: page 51-52

RESI – River Ecosystem Service Index

In the project „River Ecosystem Service Index“ (RESI), an approach was developed to record and outline the services of river and floodplain ecosystems for society in an intersectoral way.

KEY MESSAGES

- The River Ecosystem Service Index (RESI) complements the current state-based assessment methods by a functional assessment based on ecosystem services (ESS).
- The RESI treats rivers and floodplains in a consistent manner and uses an integrative approach which visualises provisioning, regulating, and cultural ESS. Thus, the RESI enables to take an intersectoral view and to compare management options in a transparent manner.
- The methods developed to record and assess the selected ESS were summarised in indicator fact sheets which show how various monitoring data can be used and prepared in a targeted manner for decision-making processes.
- The RESI provides interfaces to complement existing planning tools and creates a communication basis for solving target conflicts in decision-making processes.
- A survey performed among practitioners shows that they appreciate the added value of the RESI approach, especially as regards interdisciplinary coordination and public outreach.

BACKGROUND AND RESEARCH QUESTIONS

Rivers and their floodplains are subject to various claims from society on their use, and as a consequence they have been heavily polluted and modified in many places. The negative impacts on these ecosystems limit their direct and indirect contributions to human well-being – the ESS. When developing and prioritising measures on rivers and floodplains, practitioners are often faced with the challenge of having to follow a variety of statutory frameworks, e.g. the EU Habitats Directive, the EU Water Framework Directive (WFD), the EU Flood Risk Management Directive, as well as factoring in additional interests (e.g. navigation, agriculture, tourism). In such complex decision-making situations, the ESS concept can contribute to a cross-sectoral and transparent comparison of water management options. Hence, in an inter- and transdisciplinary research process a) the ESS concept was adapted for rivers and floodplains as well as b) methods for the spatial recording and assessment of the ESS were elaborated and c) innovative approaches for visualising the index were developed.

RESULTS

With a view to the practical applicability to rivers and floodplains, 27 relevant ESS were identified and classified in three main groups: provisioning, regulating, and cultural ESS. For their assessment some key terms were defined based on existing ESS concepts. A distinction was made between a) available ESS, i.e. the performance of the ecosystem and b) used ESS, i.e. the part which has effectively been made use of. Thereby utilisation, especially of provisioning and cultural ESS, is substantially supported by human interventions (e.g. fertilisation, road and path network).

For all ESS treated in the project, the essentials of deduction, methods and databases of the RESI were documented in uniform indicator fact sheets in a clear and application-ready manner. Recording the offered cultural ESS (e.g. natural scenery, water-related activities, natural and cultural heritage) builds up on the density or number of specific landscape features and elements. These indicators were quantifiable in homogenous quality across Germany. The human contribution to the use of these ESS was quantified using the existing recreational infrastructure. Moreover, the appreciation of riverine landscapes was determined with the help of a choice experiment. In provisioning ESS, ‘cultivated plants’ and ‘plant biomass’, the availability is calculated via the usable area and the yield potential, whereas the used ESS results from the physical yield and the contribution margin (€/ha). Optionally, monetary effects of management alternatives may be calculated, too.

With regulating ESS, offered ESS equal the used ESS. For ‘habitat provisioning’, along with conventional assessments (e.g. threat), the particular site-specific features of the floodplain were used as indicators, and how its characteristics are shaped by hydrodynamics (groundwater dependence, floodplain-typical habitats). The self-purification of rivers is assessed based on the percentage of the retained load of nitrogen and phosphorus (‰-retention/km). By linking and refining the two models MONERIS and QSim, the effect of changes in land use on nutrient retention in a river-floodplain-section can be predicted. WFD data were repeatedly used to calculate the retention of greenhouse gases, flood and low water-regulation, as well as sediment regulation and cooling effect. These data were put into a function-oriented context through their combination, transfer into the RESI assessment scale and areal standardisation.

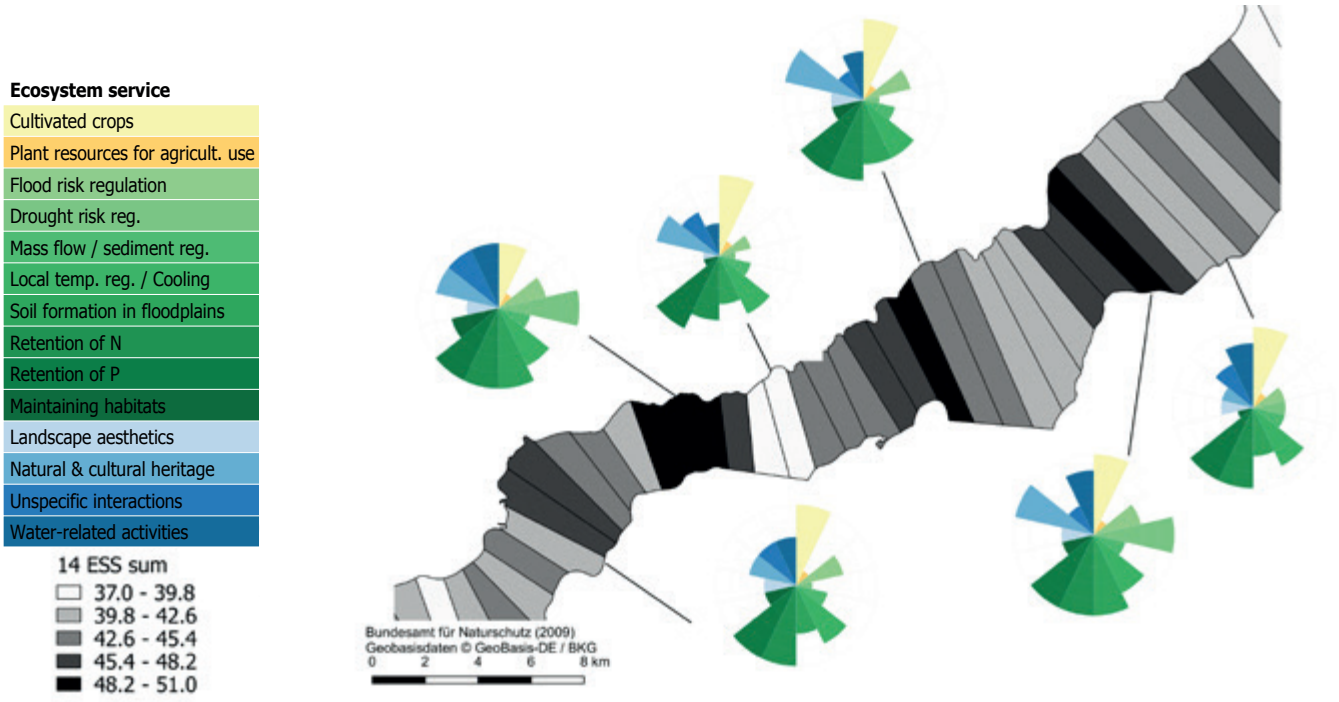

Fig. 1: Example of how RESI is used on the Danube River. Sum of ecosystem services per 1 km long river-floodplain-segment, including a detailed overview of minimum and maximum values. Graphics: Simone Beichler, IGB; RESI-Team

The RESI assessment scale was defined as having five levels, from 1 (very low to missing) to 5 (very high). All ESS were aggregated per 1-km river-floodplain-segments, whereby the index enables the visualisation of different spatial levels (entire segment or single components as river, morphological floodplain, active floodplain) and categorical levels (27 ESS, 15 subgroups, 3 main groups). The RESI was successfully tested in the model regions of the rivers Danube, Rhine, Elbe, Nahe, Wupper and Nebel. An online survey conducted revealed that experts from public agencies are only moderately familiar with ESS, but are very interested in using the concept for various phases of planning. The RESI is already being used to support a regional planning procedure for an 80 km long river landscape (Danube from Ulm to Donauwörth).

CONCLUSIONS

The ESS approach brings together methods from various scientific disciplines for their practical application, and therefore exhibits a number of interfaces to existing planning tools. As an overview procedure, the RESI approach allows practitioners in early stages of a project to use available data in order to evaluate the impacts of different measures and their respective societal benefits, and to communicate this to stakeholders and the general public. Through the modular structure, which is also documented in the RESI handbook, the RESI index may be adapted to specific regional conditions, and hence can be utilised in a wide variety of projects (e.g. river restorations, dike relocation, polder construction).

CONTACTS

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Project duration: 01.06.2015-31.10.2018
More contacts and partners: page 55

CYAQUATA

Only transdisciplinary projects can close the knowledge gaps that currently still exist.

Dr. Tilo Hegewald,
Landestalsperrenverwaltung des Freistaates Sachsen

FLUSSHYGIENE

Combining the expertise of universities, local authorities and companies paves the way for innovative solutions and new insights with regard to practical applications.

Annika Schönfeld,
Ruhrverband

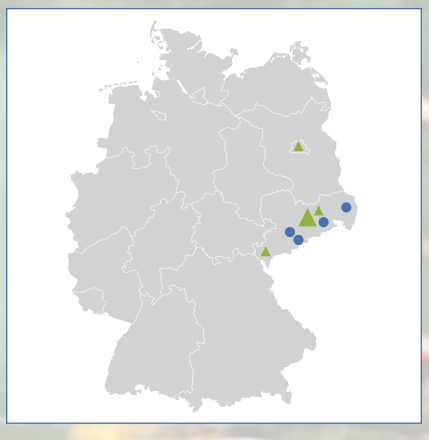
SEEZEICHEN

The groundwater modelling which was implemented within the framework of SEEZEICHEN is a good starting point for the planned state-wide modelling approaches of the Groundwater Department of the LUBW.

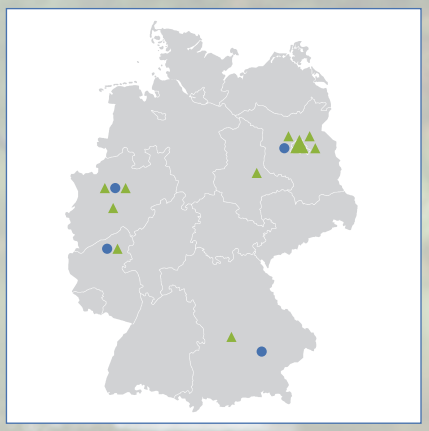
Thomas Gudera,
Landesanstalt für Umwelt Baden-Württemberg

Water Quality Management

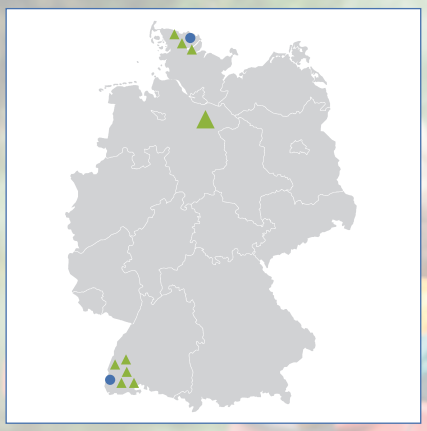
40 CYAQUATA



42 FLUSSHYGIENE

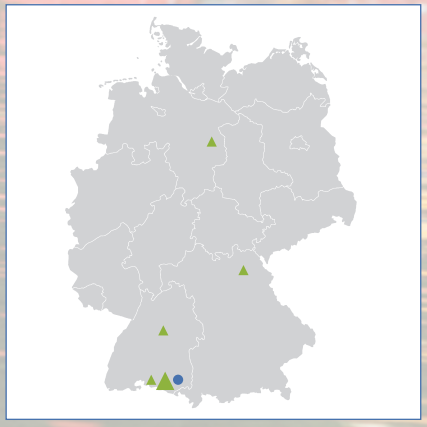


44 MUTReWa



46 PhosWaM

48 SEEZEICHEN



▲ Project coordination ▲ Joint project partners ● Model regions

MUTReWa

In addition to the project's tangible results, both the reputation gained from participating in a large BMBF joint project and the networks with various partners which have ensued are essential cornerstones for our future business activities.

Alexander Krämer,
WWL Umweltplanung und Geoinformatik GbR

PhosWaM

Measurement programmes, measurement networks and research questions should be discussed with the practice partners beforehand if the results are to be successfully transferred into practical applications.

Dr. Ricarda Börner,
Staatliches Amt für Landwirtschaft und Umwelt Mittleres Mecklenburg

CYAQUATA – Study of the interrelation between toxin-producing cyanobacteria and water quality in reservoirs and development of a sustainable management strategy

The interdependency between water quality in reservoirs and the occurrence of toxin-producing cyanobacteria are the focus of the project. The goal was to identify key factors for the development of cyanobacteria and the formation of toxins in order to evolve sustainable management strategies, while considering the changing environmental conditions.

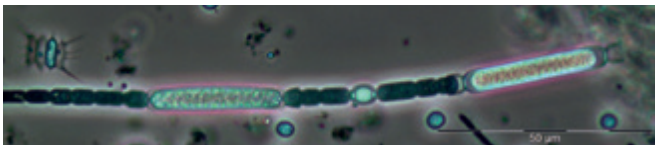
KEY MESSAGES

- Establishment and advancement of new methods for the specific detection of cyanobacteria: FluoroProbe for *in situ* monitoring and flow cytometry river restorations.
- A molecular biological method (PCR) is provided to detect the genetic potential for toxin production of cyanobacteria in water samples.
- Climate change led to prolonged summer stratification in lakes and extended the growth period for cyanobacteria.
- Strategies to prevent mass developments of cyanobacteria are: Further reduction of nutrients (especially phosphorus loading), prevention of extreme water level drawdowns in reservoirs, modification of pre-dam management (aiming at control of cyanobacteria export to the reservoir), and increase of epilimnetic turbulence and mixing depth (partial destratification).

BACKGROUND AND RESEARCH QUESTIONS

Phytoplankton concentration and taxonomic composition are key factors of the water quality of stagnant water bodies. Due to their potential for forming mass developments and their capacity for producing toxins, the occurrence of planktic cyanobacteria can restrict the use of water bodies, e.g. for drinking water supply or recreation. Mass developments of cyanobacteria are a recurring phenomenon all over Germany, particularly in eutrophic water bodies. However, increasing dominance of cyanobacteria was recently observed in oligo- and mesotrophic reservoirs as well.

Within the framework of CYAQUATA, different methods for detecting and evaluating the occurrence of cyanobacteria were combined in order to gain a better understanding of their development and the formation of toxins. In addition to an extensive monitoring of various reservoirs, this was achieved through field- and laboratory tests. By means of these acquired insights and enhanced analytical methods, forthcoming mass developments of toxic cyanobacteria can be detected earlier and measures to minimise problems associated with cyanobacteria can be implemented.



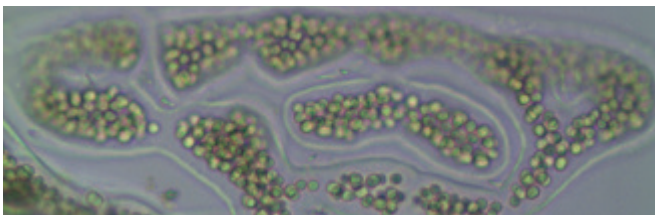


Fig. 1 top: *Aphanizomenon gracile* , sample from the Radeburg II reservoir taken on September 25th 2017, 400x magnification, phase contrast optical microscope. Photo: G. Paul, LfULG
Fig. 1 bottom: *Microcystis wesenbergii*, sample from the reservoir Quitzdorf on June 12th 2017, 200x magnification, bright field image, light microscope. Photo: G. Paul, LfULG

RESULTS

Different groups of phytoplankton can be photometrically detected and quantified based on their specific pigment pattern. An advanced version of the FluoroProbe (bbe Moldaenke) with an additional channel for the photopigment phycoerythrin was used, which enables significantly improved detection of cyanobacteria. Regular recording of depth profiles enables more targeted sampling and the optimisation of the depth-selective withdrawal of raw water from drinking water reservoirs (Fig. 2). The conventional microscopic method delivers a more precise picture of the phytoplankton composition but is significantly more time-consuming. With flow cytometry (Accuri C6) another method suitable for detecting cyanobacteria was established, which allows the analysis of phytoplankton cell sizes. Compared to the FluoroProbe, the taxonomic differentiation of the other phytoplankton groups by flow cytometry is restricted.

Cyanobacteria with the capacity of producing toxins pose a particular risk. Using molecular biological methods (PCR), gene segments crucial for the formation of cyanobacterial toxins can be detected in water samples, and hepato-, neuro-

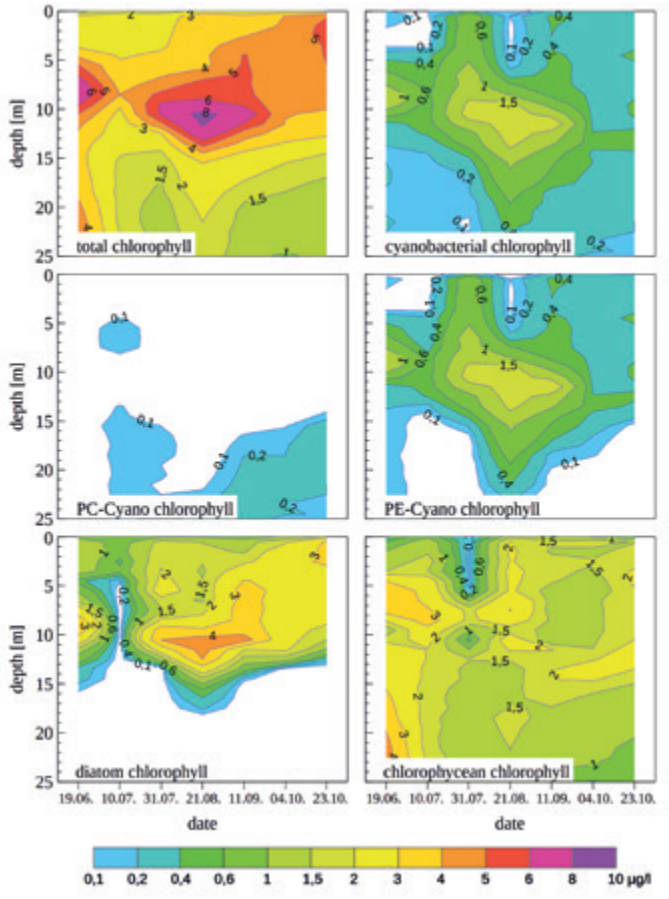


Fig. 2: Annual course of the chlorophyll concentrations for the phytoplankton groups at the Reservoir Gottleuba (measured with FluoroProbe II). The cyanobacteria chlorophyll depicted corresponds to the sum of the chlorophyll from the cyanobacteria which contain phycocyanin (PC-cyano-chlorophyll) and those which contain phycoerythrin (PE-cyano-chlorophyll). Graphics: LfULG

or cytotoxin-producing strains can be indicated. In case of positive results for these toxin genes, the project consortium recommends using immunoassays (e.g. ELISA) to detect the total concentration of a toxin group (e.g. microcystins) simply and quickly. For better risk assessment, the individual substances (e.g. microcystin-LR) should be characterised and quantified using LC-MS/MS analyses. Therefore, new analytical standards were established. Cell-based toxicity tests offer an even more comprehensive risk assessment. The sample's total toxicity is determined with the effect-based test strategy in order to detect additive effects or new and toxicologically relevant cyanotoxins. Within a guidance document, the project consortium will recommend an approach for monitoring cyanobacteria developments in stagnant water bodies and the selection of management strategies.

Both monitoring and field- and laboratory tests confirm the substantial impact of the availability of nutrients (especially phosphorus) on the development of cyanobacteria. Thus, sustainable control of external- and internal loading is crucial. Laboratory tests showed that the variation of climate factors such as temperature, light, or atmospheric CO_2 did not have consistent effects on cyanobacteria development or toxin formation. However, some cyanobacteria strains may benefit from climate change-related modifications, i.e. the increase in water temperature. Enclosure experiments confirmed that cyanobacteria benefit from stronger and prolonged thermal stratification. They also showed that the cyanobacteria development at the beginning of the summer stratification usually starts in deep water layers, most likely initiated from the sediment. In late summer, however, the import of cyanobacteria from pre-dams ('inoculation') seems to be meaningful in initiating subsequent mass growth. Thus, monitoring and targeted management of the pre-dams is necessary.

CONCLUSIONS

The monitoring methods tested during the project are reliable and offer the opportunity for monitoring at-risk areas, e.g. bathing sites. They enable quick vertical profiling and finding the optimum withdrawal layer. Early detection of cyanobacteria mass developments requires monitoring in short time intervals. Continuous automatic profiling is highly recommended. In addition to hepatotoxins, potential producers of neurotoxins were also detected in the studied reservoirs. The investigations currently show no critical concentration levels and only few toxicological findings. Nevertheless, neurotoxins constitute a potential risk often ignored so far. For preventative reasons, they should be monitored during mass developments. An increased occurrence of picoplanktic cyanobacteria was observed in oligotrophic drinking water reservoirs, which may cause problems during the drinking water treatment process due to their small size. In the literature, only a few cases of the production of hepatotoxins are described. However, further research is needed to develop appropriate abatement strategies.

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FLUSSHYGIENE – Hygienically relevant microorganisms and pathogens in multi-functional rivers and water cycles – sustainable management of different types of rivers in Germany

The development of transferable instruments to forecast short-term pollution in bathing waters is just as much a goal of the project as the long-term assessment of the effectiveness of measures in urban drainage systems and at wastewater treatment plants with regard to the hygienic water quality.

KEY MESSAGES

- In order to protect bathers from short-term pollution, early warning systems were developed as well as a robust procedure for their set-up, which transfer the risk-based assessment approach of the EU Bathing Water Directive (BWD) onto short-term forecasts.
- For pathogenic viruses as well as viral- and bacterial indicators, reference values for discharges from sewage treatment plants, combined sewer overflows- and storm water discharges, as well as for degradation- and reduction rates in the rivers were determined.
- A necessity for complementing the list of monitoring parameters regulated in the EU-BWD was not derived.
- To predict the effectiveness of management measures in the urban drainage system and at wastewater treatment plants on the hygienic water quality downstream of the point of discharge, a universally applicable hygiene module was developed for the water quality model QSim.
- A transferable willingness-to-pay model to determine the benefit side (cost-benefit-analysis) of new bathing waters is available.

BACKGROUND AND RESEARCH QUESTIONS

Many rivers in Germany are used for bathing. However, in many places the hygienic water quality is negatively impacted by entries from urban drainage systems and agriculture. For instance, heavy rainfall events led in part to massive short-term faecal pollution, which constitutes a risk to bathers. For river sections impacted by many different contamination sources there are no reliable methods to date in order to a) assess the relevance of the various entry paths, b) predict the effectiveness of measures and c) inform the population in a timely manner about the occurrence and duration of temporary pollution incidents. These conditions make it difficult to implement the EU Bathing Water Directive (2006/7/EG). River bathing also conflicts with other uses of the river and with water management goals. The FLUSSHYGIENE project was thus tasked with developing and implementing tools which would enable the responsible local authorities to manage bathing rivers with a variety of uses in a cost-efficient manner and with the highest possible degree of health protection.

RESULTS

The FLUSSHYGIENE research was performed at the structurally very different rivers Isar, Ilz, Rhine, Mosel, Ruhr, Spree and Havel. Analyses of specific DNA sequences showed that faecal

Fig. 1 left: Person swimming in Berlin. Photo: Pablo Castagnola, Berliner Wasserbetriebe
Fig. 2 top: Stentor (trumpet animalcule) dwells on any kind of substrate and feeds on bacteria from the open water. Photo: Universität zu Köln

contamination in the Isar is primarily of human origin, whereas on the river Ilz, faecal contamination from both urban drainage systems and agriculture plays a significant role. Event-based sampling at various discharge points in areas with separate sewer systems was used to quantify discharged faecal loads. The results showed that faulty sewage connections can be the main source of faecal contamination, with rainwater concentrations of 10^5-10^6 *Escherichia coli* MPN/100mL (comparison: rainwater without faulty sewage connections 10^3-10^4 *E. coli* MPN/100mL, effluent to municipal sewage treatment plants without disinfection 10^4-10^5 *E. coli* MPN/100mL). In Berlin, the reduction over time as well as the physical-biological degradation of faecal indicators and human-pathogenic viruses was quantified through two time proportional sampling campaigns of combined sewer overflows in the river. For the faecal indicators *E. coli* and intestinal enterococci, reduction rates between 0.025 and 0.045 h^{-1} were determined, for human adenoviruses 0.04 h^{-1}, for somatic coliphages 0.025-0.065 h^{-1}, for F-specific bacteriophages 0.01-0.08 h^{-1}. For noroviruses the recorded reduction rates of 0.02-0.022 h^{-1} are subject to considerable uncertainty due to the analysis method. As a specific degradation process, the microbial web, including the loss process 'grazing' by heterotrophic flagellates and ciliates, was studied at all rivers. The recorded consumption rates of protozoa on bacteria differed marginally between rivers, with a median of 0.01 h^{-1}. This corresponds to 22-40 % of the recorded reduction rates. A longer survival of viruses compared to bacteria was not determined at high temperatures during the summer.

With the help of a new assessment approach early warning systems were developed at all rivers. The systems use the 90th and 95th percentiles of the posterior predictive distribution of statistical regression models to assess bathing water quality on a daily basis, thus extending the classification approach of the BWD for short-term classifications. The assessment approach was presented at the European level during hearings on the review of the BWD, which is currently in progress.

Based on the quantified reduction rates a new module for the water quality model QSim was developed, which is suitable to predict the dynamics hygienic parameters. The module is used to quantify the effectiveness of measures in the urban drainage system and additional wastewater treatment on the bathing water quality in the river. The costs generated by the requisite measures were juxtaposed with the willingness of the population in Berlin to pay for them. The latter was determined in a representative telephone survey with 46 % of the surveyed population and an average cost of 33 € per person. Together with the results from the BMBF-project 'Sichere Ruhr' (Safe Ruhr), a joint willingness-to-pay model was established. A constellation analysis showed that for interested stakeholders, in addition to water quality, unclear demands and liability risks are the key constraints to establishing new bathing rivers.

CONCLUSIONS

Due to the many uses and the often strongly fluctuating water quality, implementing bathing area in rivers without specific requirements with regard to planning, monitoring and management puts bathers at risk. However, the tools developed in FLUSSHYGIENE enable:

1. to determine the origin of faecal contamination,
2. to predict the effectiveness of combinations of measures,
3. to protect the population from pollution situations through timely information, and
4. to assess new sites against the backdrop of different usages.

The results and methods generated in the project are available in condensed form as a manual on the management of short term pollution events and as a check list for opening new bathing areas on river banks.

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MUTReWa – Measures for a more sustainable management of pesticides and their transformation products in regional water management

The project focused on the impact of water management measures (WMM) on the mobilisation and transformation of pesticides from intensive agriculture and of biocides from urban areas.

KEY MESSAGES

- Many transformation products (TPs) were found for the pesticides and biocides being studied. TPs often have a comparable toxicity when it comes to bacteria and macrophytes, but have greater mobility and persistence than their parent compounds.
- Unlike the pesticides being studied, some TPs were detectable as long-term background contamination in the water.
- In some cases the contamination of groundwater, streams and lentic small water bodies with pesticide residues exceeds the environmental quality standards (EQS) and health reference values (HRV). There are no comparable standards for TPs.
- If end-of-pipe measures are chosen, then retention ponds can make contributions with regard to base flow, and wetland areas with regard to event runoff.
- In residential areas it is to be expected that biocidal active substances (e.g. facade paint) will leach into the groundwater by storm water infiltration systems. So the filter effect of existing systems should be monitored.

BACKGROUND AND RESEARCH QUESTIONS

When assessing WMM to improve the chemical- and ecological status of ground- and surface water bodies, the potential impact of an increased mobilisation of pesticides and especially their TPs has been neglected till now. The research thus focused on a) which processes for mobilising and transforming pesticides from agriculture and urban areas are relevant, b) the current state of water contamination in the study sites, c) which studied WMM reduce the infiltration of substances and d) which recommendations can be implemented into the regional water management programmes of the study areas.

RESULTS

In laboratory studies on the photolytic and biological degradation of four pesticides and four biocides, a total of 32 TPs were analytically accessible (of which 13 were hitherto unknown). The properties of these TPs deducible from the structural formula and the analytic behaviour led to the assumption that the majority of TPs are more mobile and persistent than their parent substances. Studies on genetic toxicity did not show any effect. However, bacteria toxicity tests showed anecdotal evidence of acute and chronic effects. In addition, studies on the occurrence of macrophyte species in lentic small water bodies (in the German state of Schleswig-Holstein) and on the effect of the studied pesticides clearly showed an ecotoxicological risk.

The detection of 17 TPs in the ground- and surface water made evident that there was a shift with regard to pesticides and their TPs which sometimes led to the HRV being continuously exceeded in the groundwater (e.g. for metazachlor-TP in Schleswig-Holstein). In all study areas, the number and concentration of detectable pesticide residues in flowing water bodies were clearly dependent on rainfall events and application rates. In addition, it became evident that TPs also entered the water bodies as residues from previous year applications. The studied lentic small water bodies, which are at particular risk because they are located in the middle of agricultural areas, also showed this behaviour. The relevance of individual infiltration paths still needs to be studied.

Biocides and their TPs leach into the groundwater as a result of urban rainwater infiltration, as was shown in the German city of Freiburg. The barrier effect of the studied swale-trench-system with regard to the biocide contamination of the groundwater is thus insufficient. Tests show that system aging might influence the retention of substances. The relevance of other infiltration pathways as well as the generalisation still need to be tested. With the 'FReWaB Plus-Model' a simple and efficient tool for detecting biocide discharges from roof- and façade surfaces (rainwater run-off) was developed and tested. It can be used in urban planning across all the study sites.

In an intensively cultivated wine-growing area, a stream with an accompanying flood retention pond was redesigned with the support of the municipality of Eichstetten. It became evident that the created wetlands showed a retention and dilution effect mainly during discharge events. Additional tests (e.g. OTIS-model) showed that the open water surface worked most effectively. Results for a retention pond in the catchment of Kielstau (Schleswig-Holstein) also show a retention of pesticides in the longer-lasting basic runoff.

Fig. 1: Tests with watering down façades to determine local biocide leaching. Photo: Jens Lange, Albert-Ludwigs-Universität Freiburg

The test results and opportunities for reducing pesticide contamination were discussed with land and water management representatives. It became evident that there are many reservations due to economic drawbacks and that more acceptance is contingent on legal obligations. In Eichstetten on the Kaiserstuhl, approx. 150 winegrowers were informed about the results of MUTReWa during a mandatory 'Advanced Training on Professional Plant Protection' immediately prior to the application season. Subsequent chemical monitoring gave some indications for more conscientious pesticide use and thus for the positive impact of the communications activity.

CONCLUSIONS

Although pesticides and TPs have been detected in water bodies, sometimes in high concentrations, under the current legal framework a need for action can only be derived from the ban on deterioration of the European Water Framework Directive. Various benchmarks for the maximum concentrations of TPs in the groundwater exist, which are not harmonised. To date there are no EQSs for TPs in surface water bodies. Thus standardised threshold values are needed, particularly for the implementation, in a legally binding manner, of measures to reduce contamination.

The number of potentially environmentally relevant substances was quadrupled through the detection of TPs. Because of the range of substances which will need to be taken into account and the increase in those substances which can also be expected in the future, and because there will be a corresponding growth in expenditure for testing, determining relevant trace substances and the risk assessment necessary to do so quickly reaches its limits. It also became evident that end-of-pipe measures have only a limited effect. On the contrary, activities should focus on measures at the source to minimise contamination, and more substances should be used which are better degradable and do not form questionable TPs with unknown properties.

Various minimisation strategies for using biocides are available for urban areas (e.g. alternative façade design or newly developed paints). A legal obligation, e.g. for city planners, companies and architects to educate themselves about the topic could lead to increased awareness and buy-in. Based on the insights from MUTReWa, first measures (e.g. banning direct infiltration of rooftop runoff, subsidising facade renovations with uncontaminated products, controllable central rainwater infiltration in urban planning) were also successfully implemented in the study sites.

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PhosWaM – Phosphorus from source to sea – Integrated phosphorus and water resources management for sustainable water protection

Since the joint project PhosWaM was launched later than the other projects of the funding measure, the interim results are presented below.

BACKGROUND AND RESEARCH QUESTIONS

Phosphorus (P) is one of the key elements for the growth of terrestrial and aquatic plants. While there is often a deficiency of the nutrient in arable land due to the removal of biomass, which is offset by fertilisation, in many water bodies there is an excess of P, leading to eutrophication. This is still one of the major issues when it comes to water protection, not only with regard to inland water bodies, but also in the Baltic Sea. Phosphorus compounds reach the sea via various routes, passing along lakes, rivers and estuaries.

By studying processes and making use of models, PhosWaM is examining the sources, transport routes, transformation processes and retention measures of P compounds in the catchment area of the river Warnow (second largest German Baltic Sea catchment area) and adjacent coastal waters. Based on these studies, proposals are to be drawn up for optimising the monitoring plans and action programmes targeted towards reducing the P concentration.

INTERIM RESULTS

In order to supplement the selective sampling and be able to calculate scenarios (P reduction measures, climate change), an ecohydrological model was drawn up for the river Warnow (SWAT – Soil and Water Assessment Tool). By modifying the model (taking into account P in drainage systems) it was possible to precisely map the specific pathways (surface runoff, drainage systems, groundwater, and sewage treatment plants) of P loads in their seasonal dynamics at the sub-catchment scale over a period of 20 years. At the same time, a regional Baltic Sea ecosystem model (ERGOM – Ecological ReGional Ocean Model) was drawn up and expanded. By coupling the models, P transport and P turnover from simulated riverine inputs of the Warnow can be tracked into the Baltic Sea. In addition, a P index for the catchment area is currently being modified and used. This index enables practitioners on site to assess the risk of diffuse P losses and to evaluate the effectiveness of measures. To complement this, fertilisation tests are being carried out to determine the impact of e.g. digestates on diffuse P losses.

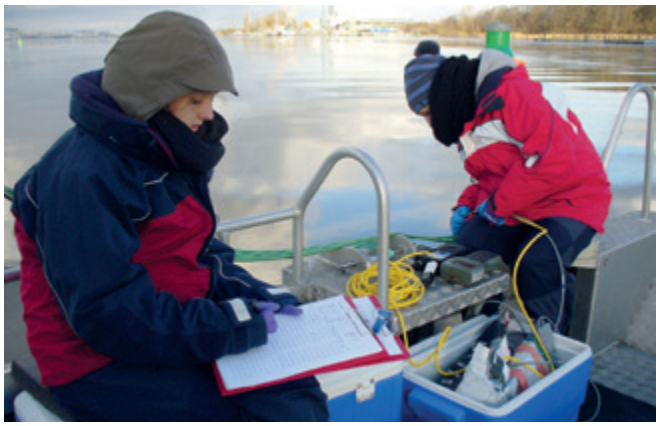
Since mid-2016 there has been extensive sampling along the entire length of the Warnow water system and up into the coastal waters, and all P fractions in their seasonal and spatial variation are being studied. The fractions are defined according to their behaviour in the so-called molybdenum blue method: dissolved reactive P (DRP), dissolved nonreactive P (DNP), particulate reactive P (PRP) und particulate nonreactive P (PNP). The total P composition differs according to emission sources as well as along the river's length, depending on precipitation and seasons. This should e.g. be taken into account when choosing which nutrient retention measures to implement. There are particularly elevated levels of P during periods of high precipitation, but also during summer when P is released from lake sediments. It became evident that not only DRP (also called phosphate), but other P fractions also are a source of nutrients for algae. Significant amounts of P are retained in the Unterwarnow (estuary of the Warnow). For rivers and lakes a methodology is being devel-

Fig. top / bottom: Taking a water sample in a small stream in the catchment area of the Warnow, upstream of a piped section, in order to later analyse the P-fractions in the lab, among other things. Photo: Lisanne Petry, IOW; Inga Krämer, IOW

oped to characterise the sediments with regard to their P dynamics and to identify the environmental conditions through which they turn into sinks or sources of P. Since total phosphorus (TP) and organic carbon are closely linked in these water systems, tests are being done to determine whether the organic content, which is easier and more cost-effective to measure, can be used as a gauge for the P load of water bodies.

To support agricultural measures aimed at achieving political P reduction goals, options for reducing P levels in watercourses are being investigated. The controlled drainage trial shows that the peaks of more extensive drainage events and thus the TP loads are being reduced. However, the loads subsequently increased again, so that in total there was no large reduction effect. For the use of a filter box at the drainage outlet, various filter materials were tested in the laboratory with regard to their suitability for P reduction, and one was chosen for the now following field test. In the study area there are >3,500 culverted watercourses with a total length of 950 km (14 % of the river network), primarily on arable farmland. We are using open and culverted segments of watercourses to study how these differ in terms of P retention and transformation and what would change if they were opened. Small sewage treatment plants (< 10,000 population equivalents) are not mandated by law to have P elimination, so in sparsely populated regions they are implicated in P emissions. For the approx. 85 sewage treatment plants in the Warnow catchment area, a transferable approach for the prioritisation of plants with an especially urgent need for optimisation was developed. To demonstrate how this works, the appropriate measures will now be implemented at selected plants. In addition, data and publications on further P reduction measures in watercourses are being analysed and compared. Using the models, the results will be extrapolated to the entire region.

Fig. top / bottom: Taking water samples with the 'Klaashahn' in the Unterwarnow (estuary area) to 'track' phosphorus from the catchment area of the river Warnow to the Baltic Sea.
Photo: Christoph Kamper, IOW



OUTLOOK

When the series of measurements have been analysed, the results will be integrated into the activities which will now follow. There will be consultations with the modelling experts in order to extrapolate the results to the catchment area. When the project is completed, we can then submit detailed input on the status assessment of watercourses and standing water bodies with regard to their P load, insights on controlling the release and retention of P in the sediments of watercourses and standing water bodies, as well as the appropriate proposals for suitable measures to reduce P concentrations in watercourses and standing water bodies. In addition, the results will provide information on how far existing monitoring and modelling approaches focusing only on TP and/or phosphate are adequate when it comes to the P load and to measures in a system of water bodies, and what potential for eutrophication there is in the fractions of the P pool, which have not been precisely determined before.

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SeeZeichen

SEEZEICHEN – Tracer methods to identify groundwater- and inflow stratification and its impact on water quality and drinking water production

The project focuses on the key immission pathways of water constituents in lakes, particularly on groundwater inflows, river water plumes and surface inflows. Through the combination of measurement, analysis and model concepts, these are to be detected and quantified, and impact zones are to be designated. The project's main research focus is on activities in Lake Constance. The Ammersee and the Steisslinger See are also being studied, with a focal point being the immission pathway groundwater.

KEY MESSAGES

- To generate a comprehensive description of the transport paths of substances in lakes, a coupled model system consisting of a numerical groundwater model and a high-resolution three-dimensional hydrodynamic model of the lake was developed for the first time. It serves to study and quantify inflows, transport paths, residence times and areas of interaction in a hydrogeological context and in the lake itself.
- A method tool box for the detection and quantification of groundwater in lakes was developed. It can be used to identify, localise and quantify groundwater inflows.
- The concept of water body signatures ('fingerprints'), which are formed from the biological, chemical, physical and isotope-analytical properties of a water body, plays a key role in the study of different inflow routes.
- High-resolution three-dimensional hydrodynamic models were used, among other things, to interpret in situ point measurements, to determine distribution paths of water constituents and to gain a process understanding for the complex mixing and transport processes.

BACKGROUND AND RESEARCH QUESTIONS

Like both of the other lakes being studied, the Ammersee and the Steisslinger See, Lake Constance is under considerable anthropogenic pressure with regard to its use. So it is essential to preserve these unique natural habitats over the long term through preventative water protection. This is also the basic requirement for a sustainable drinking water supply.
Lakes are generally embedded in a complex hydro(geo-)logical system. The various inflow routes, such as rivers, groundwater inflows, and atmospheric inflows, significantly impact the water quality of lakes through the composition of their water-borne substances.

The goal of the SEEZEICHEN project is to identify the impact zones of these various inflow routes and designate them as such, to characterise them, and to assess their importance with regard to water protection and the drinking water supply. The project's working hypothesis is that each inflow route differs physically, chemically and biologically from the lake water, i.e. has a specific water body signature ('fingerprint'). These specific water body signatures can be used to describe the interaction between the respective inflow routes and the lake, and to quantify the transport and mixing processes.

RESULTS

Based on the implementation and validation of a groundwater model for Lake Constance which spanned the catchment area, the project was able to determine for the first time that the groundwater exfiltration for the entire lake is approx. 3 m^3/s.

This was the first time that a groundwater model was operatively coupled with a three-dimensional hydrodynamic model of the lake. This allows an integrative model-technical view of the entire system and of the hydrogeological context (see Fig. 1).

With extensive measurement campaigns, the hydrogeological context and the tributaries of Lake Constance were studied more closely, and the temporally highly variable water body signatures for key inflow routes – surface inflows and aquifers – were determined.

Both through lake-wide measurement campaigns and through spatially highly-resolved measurement rasters near estuaries, we were able to record both the lake-wide distribution pattern and the transport and mixing processes taking place on a small space-time scale for the water constituents which enter the lake via various inflow routes. With the help of the water body signatures and using the qualitative and quantitative statistical methods and chemical simulation model (PHREEQC), the transport and mixing processes of water constituents are analysed.

In Lake Constance in the two very different regions of Birnau (escarpment, tertiary aquifer) and Mehrerau (shallow water zone, quaternary aquifer) tools from the 'method tool box groundwater' (measurement methods, evaluation concepts

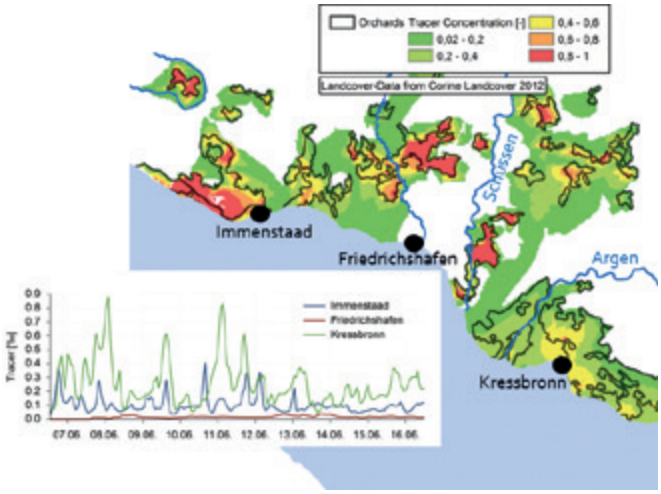

Fig. 1: Calculated percentage of newly-formed water from vineyards and orchards in the catchment area of Lake Constance and calculated percentage of groundwater at three sites close to the shore of Lake Constance. Graphics: SEEZEICHEN-Team

Fig. 2: Looking for groundwater exfiltrations in Lake Constance with the research ship 'Kormoran'. Photo: LUBW

and numerical models) were implemented, and groundwater inflows were detected. In order to set the in situ point measurements into the spatially and temporally highly variable context of the lake's dynamics and to be able to interpret them better, a three-dimensional hydrodynamic model (grid size dx=10 m) was set up for these locations. This can also be used to visualise the very small-scale inflow and transport processes in the area of the groundwater exfiltrations in Mehrerau at two excavation holes (Fig. 2). With a three-dimensional hydrodynamic model the groundwater inflow was determined, with an inverse simulation ensemble, to be approx. 100 l/s. This value tallies well with the local results of the catchment area-based groundwater model, which have yielded a groundwater exfiltration of approx. 400 to 500 l/s for the Bregenz-Mehrerau region.

The stable isotopes $\delta^{18}O$ and δD have a large potential for the detection of river water plumes in a lake-wide context. With a coupled model system (three-dimensional hydrodynamic and tracer transport model), transport and mixing processes of river water bodies can be simulated in a lake-wide context. There is also the option of simulating the distribution for very different substance classes in a detailed manner with tracer cascade simulations. Based on these simulations, impact zones with high concentrations and/or long exposure times for certain water-constituents can be designated. This methodology is being adapted and implemented for the operative online information system BodenseeOnline (www.bodenseeonline.de).

CONCLUSIONS

The SEEZEICHEN project has implemented a wide range of measurement, evaluation and model concepts at three very different lakes – Lake Constance, Ammersee and Steisslinger See. The combinations of methods studied were developed to detect the key immission pathways for water constituents into lakes and to be able to quantify the corresponding transport and mixing processes and to identify impact zones. A 'method tool box groundwater' offers a wealth of informative material to analyse the complex topic of 'groundwater exfiltration in lakes' in a qualitative and quantitative manner, and is available for further use in day-to-day water management practice. In future, a compact documentation of the results and further dissemination among water managers will take place within the framework of the newly founded DWA-working group 'groundwater-lake interactions'.

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