Maintaining lifelines – fully integrated, sustainable river basin management

Rivers are the lifelines of nature. They collect together the continents' water and transport it to the seas, they provide structure to landscapes and are a home for many different types of animal. They also fulfil a key economic function as transport routes, energy suppliers and sources of drinking water. When flooding occurs, it poses a risk to both life and property. Pollution also remains a problem in many regions of the world. This wide variety of aspects and their interaction can only be managed through sustainable river basin management.

River basin management refers to a water economy bordered by a natural drainage basin (rather than city, regional or other administrative borders). Its spatial field of activity is thus where the natural interrelations of the water cycle can be detected and where they have a direct impact.

A new understanding of water resource management

European Parliament and Council directive 2000/60/EC, generally referred to as the EU Water Framework Directive (WFD), came into force on 22 December 2000. It draws heavily on the idea of river basin management, its core objective being the protection of aquatic ecosystems with a view to sustainable environmental development. Unlike the previous method of categorising waters on a basis of usage, measures and sectors, the WFD places the focus on an all-embracing, integral view of the groundwater and surface water systems (watercourses, standing waters, transitional waters and coastal waters).

As such, water management in future will no longer be based on administrative borders but on river basins. This opens up the way to a fully integrated method of viewing natural water systems and their use from source through to mouth. A co-ordinated approach across state and country borders will serve to ensure waters are used sustainably and are protected.

Instruments for sustainable river basin management

These requirements make river basin management a complex task from both a scientific and practical perspective. The Federal Ministry of Education and Research (BMBF) is supporting research projects focussing on river basin management so that new handling guidelines can be developed within this field. As well as researching the complex interaction between rivers and their basins, land reclamation and conservation are other issues of scientific focus. Focal points from the last few years have included research on the Elbe ecology (project 1.2.01), river basin management (project 1.2.02), risk management for extreme flood events and integrated water resource management. The sediments in flowing waters were considered as part of the BMBF joint research project entitled "sediment dynamics and pollutant mobility in river basins" (SEDYMO) (project 1.2.03), the aim being to contribute towards ecological maintenance dredging of federal watercourses, sustainable management of contaminated flood sediment and the planning and implementation of sediment clear-ups to improve the structure and ecology of bodies of water. A joint research project funded by the BMBF and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) resulted in the requirements necessary for the successful reintroduction of sturgeon (project 1.2.04).

Funding has also been provided at European level, for R&D and networking projects on river basin management and integrated water resource management (IWRM) within EU research programmes. One such example is the EU "IWRM Net" project, representing 21 institutions from 14 countries including the BMBF with its two project co-ordinators in Karlsruhe (PTKA) and Jülich (PTJ). This project is pursuing training and intensification within European river basin management. IWRM Net gives the participating countries the opportunity to exchange both the conditions within their location and their experiences at European level, launch joint projects and even develop future concepts where necessary for co-operative research and development.

The Elbe basin – a research model for river management in the future

The Elbe river basin is an extremely exciting field of research for scientists in ecological disciplines. Whereas the quality of the Elbe's water was extremely poor some years back, the flood plains for the river formerly serving as an international border were able to sustain the versatile structure that most rivers of a similar size lose as a result of construction. This means the 1091 kilometre stretch of river and its basin◄ has the potential to survive as a near-natural river habitat in future. The Elbe basin therefore serves as a model region where experts can research usage conflicts and develop solution concepts.

The structure and history of the Elbe have made it the subject of many research activities within a whole host of different scientific disciplines – wholly within the intent of the EU Water Framework Directive◄. This directive demands river basin management◄ aimed at achieving sustainability. Development concepts for large-scale river habitats with their diverse forms of interaction have only emerged to some extent previously – including on an international front. In the meantime, it has become apparent that preservation of river habitats requires a fully integrated approach that must support a complex assessment of the ecological and commercial situation within the river basin.

As such, the BMBF provided around EUR 20 million of funding for 28 scientific projects within the joint research programme on the ecology of the Elbe between 1996 and 2005. Experts within the individual projects examined ecological and economic connections and developed solution concepts for the various usage requirements of farmland, conservation, water management and shipping.

Natural areas rather than administrative units

The researchers should not only gather scientific findings, they should also devise instruments and handling recommendations for politicians and planners. The requirements of the EU Water Framework Directive state that the river, its flood plains and the basin should be considered as a functional unit. The effects of the Elbe flood of 2002 and the extreme drought of 2003 have already clearly shown in dramatic fashion that ecological phenomena must be considered not within the confines of administrative borders but by those of natural areas.

View of the Elbe and its flood plains (Source: Federal Institute of Hydrology)

Three focuses for research

Topic 1: The ecology of flowing waters

Key phrases such as "creating retention basins◄ by installing dykes" and "guaranteeing minimum waterway depths through tailored river-engineering maintenance measures" are on everyone's lips in the wake of the floods. However, such measures have an effect on water levels, affect the hydrodynamics◄ and morphodynamics◄ of the waters and influence the living conditions of fish and micro-organisms. The micro-organisms in the Elbe are especially important for material conversion and thus for the quality of the water. The researchers investigated these connections by examining the morphological◄, hydraulic◄ and biocoenotic webs of interaction◄. The main focus was on which processes control the composition and dynamic of the living communities within the Elbe. The results of in-depth field tests and devised models provided the answer, the end product being a contemporary, comprehensive overview of the research on water quality, which also included decision-making supports for planning water engineering measures.

Topic 2: The ecology of the flood plains

Engineering rivers and changing land usage within flood plains are actions that have ecological consequences. Public discussion has seen an increased demand for the clearing of flood zones and the reclamation◄ of river flood plains. This poses the question as to what an environmentally appropriate development of the flood plains in the Elbe river basin might look like. The consequences for the affected farmland, the population and the flora and fauna must be taken into account. The projects within this topic indicate handling recommendations to ensure conservation and formulate overall concepts for the ecological development of flood plains while also factoring in eco-

The joint Elbe ecology research programme

nomic aspects. This meant that current research results on control factors, bioindication◄ and the prognosis for living communities within the Elbe and its flood plains had to be brought together. Alongside this, a considerable proportion of the work involved indicating the benefits and costs of intervention as this is ultimately what influences political decisions. So, for example, the results of the research have also provided key bases for planning procedures for dyke relocation around Lenzen. It is the largest national project of this type to date, and has since been implemented.

Topic 3: Land usage within the river basin

Diffuse nutrient loading from agriculture is one of the key negative factors in the quality of the Elbe's water today. The causes of this loading vary greatly from region to region due to the natural properties and usage structures within the Elbe river basin. The projects within this topic involved scientists examining how the water quality in the Elbe and thus also the North Sea could be improved through a modified use of the land or other agricultural procedures. They used water and matter balance models to show which measures are ecologically desirable and economically feasible for controlling land usage and the water balance in the Elbe basin. This was then used as a basis to develop and propose strategies for reducing water contamination. The conserving soil processing procedure is one worth particular mention: this management system has a positive effect on soil-physical, hydrological and biological properties, reduces soil loss and therefore also lowers the amount of phosphate entering the water.

Representation of the results in various media

The results of the joint Elbe ecology research programme were prepared in three types of media for varying needs:

- The Internet-based Elbe Information System (ELISE) provides information on the research into the Elbe's ecology and supports co-ordination of the project work.
- The five bands within the publication series on concepts for the sustainable development of a river landscape (entitled "Konzepte für die nachhaltige Entwicklung einer Flusslandschaft") summarise the findings across the projects and present concepts for use in practice (http://www.weissensee-verlag.de/verlagsprogramm/04_niw_flusslandschaft.htm).
- The "Elbe-DSS◄", a decision support system for river basin management, provides a basic structure for the specialist knowledge and the computer models and data relating to the Elbe basin. Such systems could help authorities to plan river management in future. They enable the complex effects of individual measures to be identified in advance in view of the objectives to be achieved. The Federal Institute of Hydrology (BfG) has made the developed prototypes for the Elbe DSS available free of charge over the Internet (http://elise.bafg.de/?3283).

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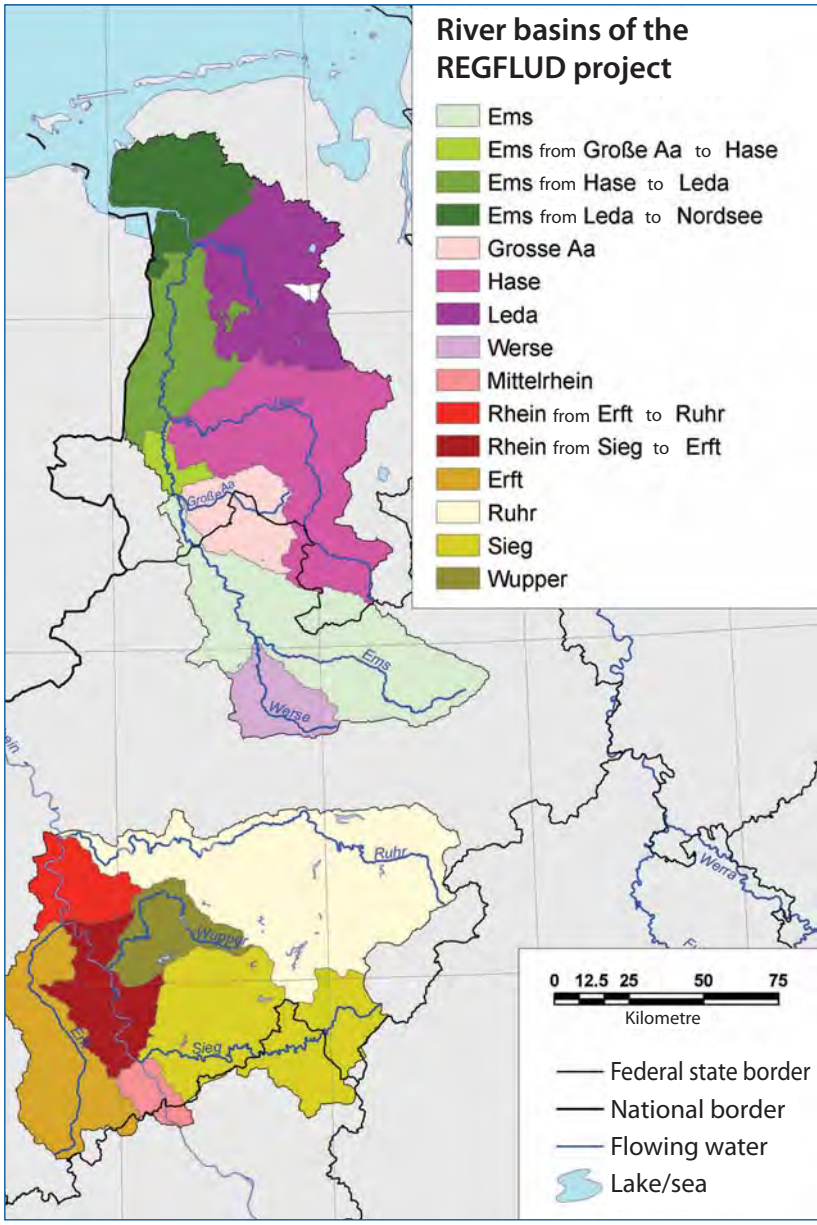
Examining the Rhine and Ems – management systems for water quality in river basins

Rivers form a crucial part of the water cycle. Among other things, they need to be protected from nutrient loading to guarantee their function in the long term. The European Water Framework Directive (WFD◄) calls for this safeguarding measure with the demand for corresponding environmental development. The REGFLUD project saw an interdisciplinary team tackle these requirements and adopt a scientific approach to studying the systematic management of regional river basins. Using the examples of the Rhine and Ems rivers, the experts investigated agricultural measures to improve the quality of the water.

German waters are not as heavily loaded with nutrients as they were in the past; they have undergone a substantial clean-up over the last few decades. The biggest contributions to this positive development are an improved procedure for cleaning up wastewater and a reduction in the amount of phosphates used in detergents. Despite this success in water protection, there are still equally large sections of water suffering to a greater or lesser extent from nutrient loading. The majority of nutrients in rivers originate from diffuse sources – i.e. they are impossible to pinpoint precisely – predominantly as a result of farming. Agricultural production introduces nitrogen and phosphorus, which have an impact on the ecological balance and the usability of water and seas. As a further step towards improving the water balance, the 2000 EU Water Framework Directive◄ calls for management systems to be established for all river basins.

New requirements

Many public bodies in charge of water usage and protection are entering new territory when it comes to diffuse nutrient loading. Unlike isolated loading, neither the cause nor the effect can be clearly identified. This is primarily due to the diverse natural conditions such as water balance and soil properties that affect the transportation, bonding and degradation of the nutrients underground and in the groundwater. In many cases, the authorities lack the tools and methods necessary to decide on efficient strategies or measures to reduce diffuse water loading through agriculture.



The river basins involved in the REGFLUD project

Different regions undergoing investigation

This is where the BMBF-funded REGFLUD research project stepped in to assist (full name: **"Management regionaler Flusseinzugsgebiete in Deutschland (REGFLUD) – Rahmenbedingungen und Politikoptionen bei diffusen Nährstoffeinträgen (Stickstoff und Phosphor) der Landwirtschaft"** – management of regional river basins in Germany – framework conditions and policy options for

diffuse nutrient loading (nitrogen and phosphorus) in agriculture). The aim of the project was to devise scientific methods that could be used to help determine efficient measures for reducing the diffuse nutrient loading of river basins as a result of agriculture. The investigations took place between July 2001 and October 2005 and focused on two river basins: a section of the Rhine basin between the Sieg, Erft, Wupper and Ruhr tributaries, and the entire basin◄ of the River Ems. The regions investigated differed in terms of both agricultural usage and local conditions.

Interlinking systems and models

The focus of the REGFLUD project was on interlinking the Regional Agricultural and Environmental Information System (RAUMIS) for Germany with the hydrological GROWA98 and WEKU models. RAUMIS enables the analysis of the regional effects of various agricultural and agri-environmental policy measures on agricultural land usage, production and income and on diverse agri-environmental relationships, e.g. excess agricultural nutrients. The GROWA and WEKU models use this as a basis – while factoring in a whole host of local conditions such as soil, climate and topography – in order to map nutrient loading of water by area. The deriving of efficient measures to reduce nitrogen loading from agriculture using the combined model was tested with a nitrogen tax and a restriction on livestock density.

Tailored measures required

The model results show that the different regional conditions lead to very different proportions of excess nitrogen from agriculture being found in the groundwater and surface water. The proven effects of a nitrogen tax and a restriction on livestock density, strongly deviating from each other within areas, document that only tailored measures to provide a sustainable solution to the nitrate problem will help in a given area. The integrated consideration of local conditions and the complex interaction through the combined model makes it possible to develop more efficient water protection measures.

Muck spreading in agriculture
(Source: www.oekolandbau.de)

Putting into practice

The AGRUM-Weser pilot project run by Germany and neighbouring countries is developing other regional solutions using the REGFLUD approach. The combined model has been expanded to include the MONERIS model, which factors in all relevant loading paths. The work is being conducted in collaboration with those responsible for executing the requirements of the WFD in the Weser river basin and also takes country-specific procedures into account. The aim is to analyse and evaluate operational measures for reducing the effects of diffuse nutrient loading from agriculture. As such, the decisive step has been taken to put the REGFLUD research project into practice.

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SEDYMO research project – effects of sediment dynamics on the quality of flowing waters

Many pollutants released by man into the environment end up in the water. The contamination directly discharged gathers together here, along with solids washed away by precipitation and floods and dissolved compounds. Some pollutants tend to bind to particles and are deposited with the sediments on the water bed. From there they can get back into the water, for example if they are stirred up by deepening of the waterways or flooding, or are re-dissolved as a result of chemical processes. A research project is tackling these important problems and working on supplying the currently lacking foundation and process knowledge.

Taking sediment samples at the Rhine

Using an in-situ erosion tester at the Elbe

Although the amount of contamination entering Germany's rivers is constantly falling, the sediments◄ they contain are still heavily loaded with environmental chemicals in many areas. These substances do not only enter the waters through wastewater; other causes of this pollution are contributions from the air, precipitation and floods, and contaminated solids from landfill sites and slag heaps. River mouths are especially affected by this, as this is where the pollutants from the entire course of the river gather.

Fine sediment is of particular interest to those researching water pollution. It contains relatively large amounts of pollution and the large particle surface makes it very reactive from a chemical and physical perspective. Pollution in this regard does not only relate to directly toxic environmental chemicals such as heavy metals and specific organic compounds; it also covers substances that can indirectly affect water quality, such as organic substances or nutrients such as nitrogen and phosphorus. The degradation processes and widespread algae growth reduce the oxygen levels in the water.

Dynamics of pollution release

Depending on the flow speed and the chemical and biological state of the water, solids and parts of dissolved substances transported by rivers are deposited on the riverbeds and flood plains. The sediments therefore also indicate the water pollution of the last few days, but their components can also be released again. If solids are present (mineral or organic particles), then either natural or artificial erosion processes are involved. Triggers include flood water, movement caused by ships or maintenance dredging to keep the waters navigable. Soluble pollutants that in the meantime have bound themselves to the sediment◄ can be released through (micro)biological and chemical processes.

Knowledge on the dynamics of pollutant-bearing sediments is becoming increasingly important with the implementation of the European Water Framework Directive (WFD)◄, which focuses on measures to improve water quality across entire river basins.

Statements to date on the means of pollution entering water have predominantly referred to known sources outside the water itself. This includes diffuse sources such as agriculture and isolated sources such as landfills and industrial sites. However, this approach omits an extremely important factor: the re-release of harmful particles within the sediment on the riverbed.

The BMBF **"sediment dynamics and pollutant mobility in river basins" (SEDYMO)** research project was launched in May 2002 to drive forward this aspect of sediment research. The project aims to make a contribution towards the ecological optimisation of maintenance dredging within federal waterways, the sustainable management of contaminated flood sediments and the planning and execution of sediment clear-up operations to improve the structure and ecology of the water.

Interdisciplinary approach

The research project co-ordinated by the institute of environmental technology and energy economy at the Hamburg University of Technology together with 12 other partners (see TUHH project website) combines two key issues: the dynamic erosion/depositing behaviour of the fine sedi-

Taking sediment samples at the Salzach

ment and the mobility of pollutants and loads in sediments and suspended matter. As the two aspects are closely interlinked in practice, a joint research approach between technical and natural-science disciplines is required.

The first phase◄ of the project saw the project team examining the erosion and transportation of fine-grained sediment using the Neckar and the Elbe as an example. The researchers used the flow channel, microcosm and turbulence column as measuring devices. The methodical work was accompanied by physical-chemical and microbiological analyses. Other sub-projects involved comparative investigations of the transportation of fine-grained sediment performed under near-natural conditions in docks and their inlets. Another sub-project investigated the mixture of fine-grain particles in the Elbe. The second phase primarily saw the scientists investigating the transportation of nutrients and pollutants. The interactions occurring in natural conditions between aggregates, pollutants, water and soil were quantified, classified as control factors of biological, sedimentological and chemical processes and consolidated into models. Six more sub-projects helped the scientists gain fundamental knowledge of the physical-chemical and biological properties of solids within water.

Broad application range

The investigations showed that the speed at which the organic pollutants are sorbed (bound) to the sediment and then desorbed (released) depends heavily on hydrodynamic conditions. Conversely, changes to the hydrochemical composition of the flowing water, e.g. due to flood events, have less influence on the binding behaviour of pollutants than previously thought.

The instruments and models developed during the course of the project to characterise and predict the erosion stability of sediments has already been put to practical use. For example, areas flooded by the severe Elbe flood in August 2002 were examined. Scientists from the research programme have also taken part in the "Iffezheim barrage" risk assessment: the shifting of 300,000 cubic metres of heavily contaminated Rhine sediment has sparked an international controversy.

The SEDYMO results are also being directly input into the work of the technical committee on managing contaminated sediments at the German Association for Water, Wastewater and Waste (DWA) and the BMBF-funded "Risk Management of Extreme Flood Events" (RIMAX) programme. They will be of particular relevance when further measures are implemented in accordance with the WFD to combat pollution sources in waterways. Reducing emissions from historically contaminated sediments will be a key task within this work.

The publication entitled "Sediment Dynamics and Pollutant Mobility in Rivers – An Interdisciplinary Approach" is the frame of reference for the interactions in both technical engineering and natural sciences of contaminated sediment in flowing waters and was compiled as part of the SEDYMO project from the contributions to the "International Symposium on Sediment Dynamics and Pollutant Mobility in River Basins".

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The sturgeon is making a comeback – repopulation of a former river resident

The sturgeon was a typical resident of North-German rivers that then disappeared from these waters. Its eradication is a symptom of the conditions of the water: migrating fish in particular find it difficult to locate suitable conditions in obstructed and contaminated rivers. An ongoing research project conducted by the BMBF and the BMU has been working since 1996 to meet the necessary requirements for the successful repopulation of the sturgeon. The scientists have already established parent stock for North Sea and Baltic Sea sturgeon and released the first set of young into the Oder and Elbe as part of an experimental stocking measure. Fish from French and Canadian rivers constitute the germ cell for the offspring.

At the end of the 19th century, sturgeon were widespread along the entire European coast and they had spawning grounds in all the major European rivers. Today, this breed of fish is threatened with global extinction. The rivers have become obstructed and contaminated, destroying their habitat, and intensive fishing has simultaneously decimated the population. Individual catches of sturgeon were registered in Germany as late as 1992. After that, the sturgeon was deemed to have died out in Germany.

It is not just the sturgeon that has suffered the destruction of its habitat; other migrating fish have also been affected, e.g. the salmon, sea trout, houting, allis shad and twait shad. The experience gained in the reintroduction of the sturgeon and possible reclamation measures◄ is therefore also of benefit to other fish populations.

Residents of different waters

The sturgeon is a migrating fish that leaves the sea and moves far upriver in order to breed, laying over a million eggs in fast flowing water. Once the larvae have hatched and grown up among the pebbles, the offspring drift downstream to sections of the river rich in food. At the end of their first year, the fry progress to the brackish water of the river mouth and then go on to reside in the sea for the next two to four years. After 10 to 20 years, the sexually mature fish return to the river of their birth in order to breed.

Reintroduction research project

The quality of the water in rivers has improved greatly in the last 20 years – providing an opportunity to reintroduce sturgeon, which was seized by the Gesellschaft zur Rettung des Störs e. V. (society for saving sturgeon) in 1994. The federal ministries for research and the environment have given over EUR 1.8 million since 1996 to support a research project on the reintroduction of sturgeon to the feeder rivers of the North Sea and Baltic Sea. Entitled **"Genetische Populationsstruktur, Zuchtplan und künstliche Vermehrung einer süßwasseradaptierten Zuchtgruppe des Europäischen Störs** (Acipenser sturio) **als Voraussetzung einer erfolgreichen Wiedereinbürgung"** (genetic population structure, breeding plan and artificial reproduction of a freshwater-adapted breeding group of European sturgeon (Acipenser sturio) as a prerequisite for successful reintroduction), the project involves the German Federal Agency for Nature Conservation (BfN), the Berlin Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB), the Landesforschungsanstalt für Landwirtschaft und Fischerei Mecklenburg-Vorpommern (Mecklenburg-Western Pomerania state research facility for agriculture and fisheries) as well as other research facilities.

Trial stock in the Elbe river basin, young sturgeon (Acipenser sturio) with marking

Suitable sturgeon were bred

If the waterways are to be repopulated, it is essential to have sufficient numbers of fish that correspond to the former native breeds. A significant sub-project is therefore the establishment of a parent stock for producing a stock of offspring suitable for the respective habitat. The European Atlantic sturgeon (Acipenser sturio) from the Gironde in south-west France was selected for the offspring to be introduced to the North Sea and its feeder rivers. From a genetic perspective, this very small fish population is virtually identical to the fish that once lived in the North Sea. The IGB has been obtaining a few samples with the co-operation of Cemagref in France since 1996 in order to breed stocking fish for the Elbe and Rhine. As sturgeon are not sexually mature until the age of 10 to 12 at the earliest, the first offspring of fish formerly of

Ultrasound to determine gender in Born/Darß

French stock became available in 2007. The fish produced from this reproduction were marked, fitted with telemetric transmitters and released in the middle of the Elbe so that their migration could be tracked.

The sturgeon that once lived in the Baltic Sea differ from those of the North Sea both genetically and in appearance. They are the descendants of the American Atlantic sturgeon (Acipenser oxyrinchus), which migrated to this location around 1,000 years ago. A breed that is genetically very similar to the Baltic Sea sturgeon lives in the Rivers St. Lawrence and St. John in Canada. The Gesellschaft zur Rettung des Störs brought some sexually mature fish to Germany for breeding purposes in 2005 and 2006 with the aim of founding an initial parent stock. The release of offspring from controlled reproduction in Canada into the Oder river basin◄ has been taking place since 2006 for telemetric examinations and to determine the use of the habitat◄.

Offspring from controlled reproduction were reared in order to build up parent stocks. These fish were characterised using genetic screenings, particularly via microsatellites developed by the University of Potsdam, and breeding plans were created in order to optimise genetic diversity. 2010 saw the first successful reproduction from the A. oxyrinchus parent stock in Germany, so now early live stages can also be examined.

Catching an American Atlantic sturgeon (Acipenser oxyrinchus) for reproduction in Canada

Development of alternative fishery techniques

To ensure that the growing sturgeon population does not become a victim to fishing, the project has also driven forward the further development of gillnets for coastal fishing. The aim is to minimise the unintended catching (bycatching) of sturgeon and simultaneously to optimise the catching of zander and perch in the Szczecin Lagoon. Trials with newly developed nets have shown that the bycatching of sturgeon can be almost completely eliminated by implementing simple changes. But as the amount of target breeds entering the net was also somewhat lower, uptake within the fisheries is still rather low.

Sturgeon under observation

Once the sturgeon have been released, they remain under intense observation. Markings and transmitters are used in order to research the migration of the fish, the aim being to identify and describe suitable habitats and to determine the risks posed to them. This monitoring is to form the basis for further releases and possible reclamation measures in rivers. If the quality of the sturgeon habitats is improved, then other animals will also benefit. The sturgeon can therefore also become a precursor for the resettlement of other breeds with similar ecological requirements.

Leibniz Institute of Freshwater Ecology and Inland Fisheries (IGB)

The scientists at the Berlin IGB are dedicated to ecosystem research of limnetic systems (inland waterways). The findings serve as the basis for ecological restoration, remediation, management and protection concepts. At the IGB, hydrologists, chemists, microbiologists, limnologists, fish ecologists and fisheries biologists all work under one roof. www.igb-berlin.de

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