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news

Focus:
The aquatic environment – what it provides and what it needs

Editorial

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Water for ecosystem function

From our everyday experience, we are all familiar with the central role that water plays in our lives. We depend on water resources for drinking water and hygiene, for recreation and transportation, and many other direct uses. Worldwide, about 20 per cent and, in Switzerland, 60 per cent of electricity is generated from hydropower. We are often unaware, however, of the many indirect ecosystem services that are provided by the water environment. These include rain-fed agriculture, which constitutes 80 per cent of agriculture worldwide and nearly all in Switzerland. The productivity of aquatic habitats supports not only fisheries, but also waterfowl and terrestrial wildlife. The provision of ecosystem services depends on the integrity of the ecosystem; the highest level of ecosystem services is usually associated with near-natural conditions.

Human activities exert substantial pressures on the water environment. Morphological conditions have been altered by dam construction, river channelization and the draining of wetlands. Water quality is affected by urban and agricultural run-off, which can contain pathogens, nutrients and micropollutants. Ecological integrity is affected by both morphology and water quality, as well as by the introduction of invasive species and practices such as fish stocking. For the effective management and conservation of aquatic ecosystems, it is critical to understand how they respond to such pressures, or conversely, to be able to assess their resilience and adaptive capacity.

In its Development Plan for 2012–2016, Eawag has identified Water for Ecosystem Function as one of three focal topics for this planning period. Eawag will address critical questions regarding the effects of human-induced environmental change at the population and ecosystem level, the linkages between biodiversity and ecosystem function, and the opportunities for effective restoration and remediation of degraded aquatic ecosystems. Eawag will direct its own resources to support these efforts and, in particular, is developing two strategic activities. The programme Fliessgewässer Schweiz (Swiss Rivers) will provide scientific support for the implementation of the revised Water Protection Act, and the project EcoImpact will examine the consequences of reducing the load of micropollutants in the effluent of wastewater treatment plants on ecosystem functioning.

These new activities will be based on a strong platform of ongoing research, which is described in this issue of Eawag News. Topics include: the development of concepts and assessment methods in environmental toxicology, field studies of the effects of nutrient inputs in lakes, approaches for sustainable water management in the face of climate change and conflicting interests, modelling for predicting effects of different management strategies on ecosystems, and the role of hydropower in our future electricity production. Most of this research is based on monitoring data, which shows the importance of monitoring programmes. Eawag is committed to providing the scientific basis that will allow direct human needs for water to be met while safeguarding the capacity of the water environment to provide valuable ecosystem services.

Cover photo: The Verzasca has carved out its path through the gneiss of the Ticino Alps. (Photo: Michel Roggo)

Content

Focus: The aquatic environment – what it provides and what it needs

In brief

eawag aquatic research

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How aquatic ecosystems are altered by nutrients

The reduction of phosphorus loads in Swiss lakes is a positive outcome of water pollution control efforts. But now, in order to increase fish yields on Lake Brienz and other waterbodies, members of the fishing community have called for phosphorus elimination to be reduced at local wastewater treatment plants. However, increases in phosphorus inputs to nutrient-poor lakes can lead to the extinction or merging of species, producing irreversible changes in aquatic ecosystems.

The past few decades have seen a marked decrease in eutrophication of Swiss lakes, thanks to the construction of wastewater treatment plants (WWTPs), a ban on phosphates in detergents (enacted in 1985) and additional phosphorus precipitation at WWTPs. As a result, water quality has improved substantially and habitats and species compositions have returned to a more natural state. But the subject of phosphorus inputs has recently been raised once again, in particular because some people believe that a lack of this nutrient is partly to blame for declining yields of fish from certain lakes. Accordingly, it has been proposed in two parliamentary motions (tabled in the National Council and the Council of States) that inputs of phosphorus to Lake Brienz should be increased as part of a pilot project. The supporters of this plan argue that fish yields would then rise as a result of higher primary production (algal growth) [1]. Similar ideas are under consideration for Lake Lucerne and other waterbodies.

As part of "Projet Lac", researchers investigated biodiversity in Lake Brienz. The survey revealed the presence of small whitefish species adapted to deep-water nutrient conditions.

Stefan Kubli

Displacement and merging of species. In the absence of nutrients, surface waters would be inhospitable to any form of life. To be able to exist in a lake, organisms require a certain minimum level of nutrients, which enter waters via natural processes of erosion and decomposition. Nutrient availability also determines how many organisms an ecosystem can support – i. e. how productive it is. Growth is generally limited by the least abundant nutrient. In our latitudes, the limiting nutrient for algal growth is almost always phosphorus. Algae, the main primary producers, represent a vital source of food for other aquatic organisms within the lake food web. A certain amount of phosphorus and other nutrients is thus indispensable for a functioning freshwater ecosystem. Just how much is required varies from one lake to another, depending for example on the catchment. The availability of nutrients also influences species composition.

After the Second World War, as the use of phosphate detergents and fertilizers rose sharply, many Swiss lakes were exposed to unnaturally high inputs of phosphorus from municipal wastewater and agricultural run-off. This led to the proliferation of algae (algal blooms) and, consequently, to oxygen depletion and fish kills. Today, the nutrient content of various lakes has returned to pre-pollution levels (Fig. 1).

As well as adversely affecting chemical water quality, the eutrophication of lakes altered aquatic ecosystems. In some respects, these changes are still apparent today. For example, in a number of studies, Eawag reconstructed how the composition of water flea *(Daphnia)* species changed as a result of eutrophication. These zooplanktonic crustaceans feed on algae and are an important source of food for fish. For many whitefish, for example, they are the primary food source.

With the aid of genetic analyses of resting eggs retrieved from the sediments of lakes exposed to various degrees of pollution, we found that, prior to anthropogenic nutrient inputs,

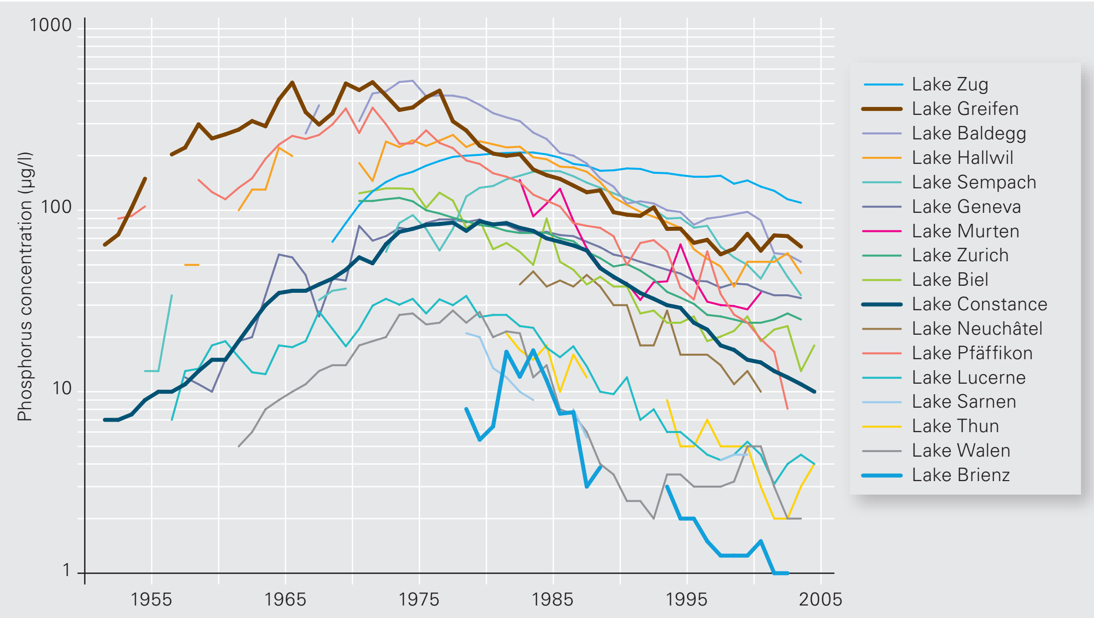
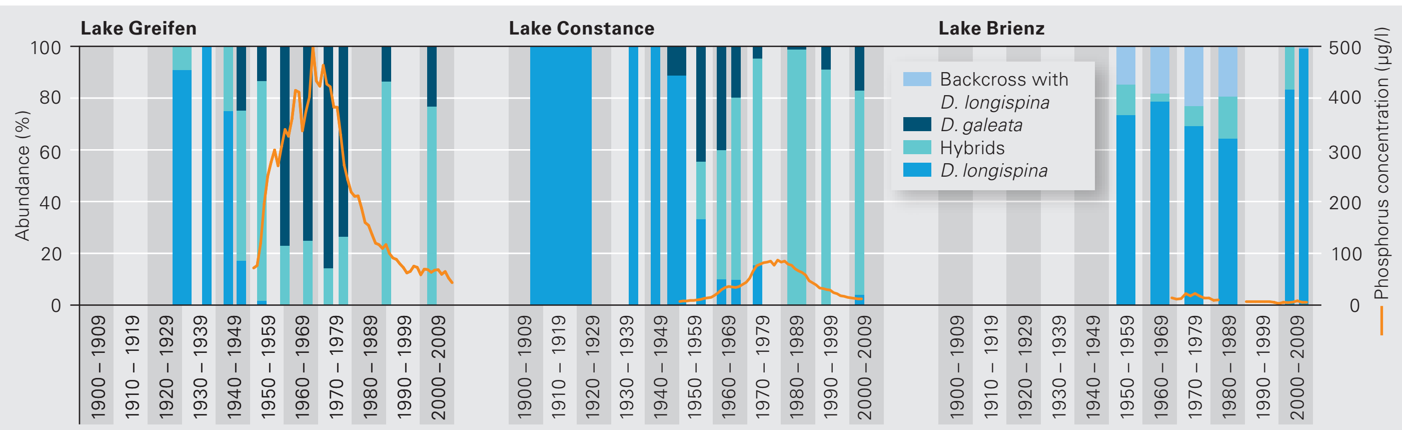


Fig. 1: Phosphorus concentrations in Swiss lakes declined as a result of water pollution control measures.

D. longispina had been the predominant water flea species in all the Swiss lakes studied [2, 3]. During the period of eutrophication, the invasive species *D. galeata* became established in many lakes – including Lakes Constance and Greifen – and displaced *D. longispina*. In some cases, these two species also merged, forming hybrids (Fig. 2). Today, as a result, *D. galeata* and the hybrid form are the only *Daphnia* species occurring in many lakes, even where the nutrient status has returned to normal. In waterbodies such as Lake Brienz, which naturally contain very little phosphorus and were less exposed to nutrient inputs, populations of *D. longispina* have tended to survive. Here, however, backcrossing has occurred between the hybrids and *D. longispina*. Current *D. longispina* individuals therefore also contain genetic material from *D. galeata* – in many lakes, the species *D. longispina* no longer exists in its original genetic form. In other words, changes of this kind may be permanent and irreversible.

Loss of ecological niches. Recently, we also experimentally demonstrated the mechanisms underlying changes in species composition. In the laboratory, we compared the fitness of clones of the two *Daphnia* species from various lakes reared under nutrient-poor and nutrient-rich conditions [4]. While *D. longispina* fared better with a sparse food supply typical of oligotrophic lakes, *D. galeata* performed better with eutrophic food. This also explains why *D. longispina* was not displaced from all Swiss lakes: in sediments from the small number of lakes minimally affected by eutrophication, we found only a few or no resting stages of *D. galeata*. This means that this species almost never occurred in Switzerland's cleanest lake – Lake Brienz – although it is found in neighbouring Lake Thun. In fact, the studies indicate that no permanent *Daphnia* populations existed in Lake Brienz before 1950. A population of *D. longispina* only became established with the onset of (relatively low) phosphorus inputs.

Fig. 2: *Daphnia* species composition was altered as phosphorus concentrations changed.




Eawag

A sediment core is retrieved from Lake Greifen: resting eggs recovered from sediments can be used to reconstruct how *Daphnia* species composition changed over time as a function of phosphorus concentrations.

As Eawag scientists have shown, the disappearance and merging of species induced by eutrophication is not confined to water fleas but can also be observed in fish. Recently, for example, Pascal Vonlanthen and Ole Seehausen of the Fish Ecology & Evolution department, together with colleagues from the University of Bern, demonstrated that – over a period of just a few decades – eutrophication has led to a 38 per cent reduction in the number of endemic whitefish species in Swiss lakes [5]. In the lakes studied, the higher the maximum phosphorus concentrations recorded, the greater the loss of species (Fig. 3a).

In seven lakes (Lakes Geneva, Murten, Sempach, Baldegg, Hallwil, Greifen and Pfäffikon), the original whitefish populations are now extinct and have been replaced by hatchery stocks. Only in deep perialpine lakes less exposed to nutrient inputs (Lakes Thun, Brienz and Lucerne) have the historical species been able to survive. In both Lake Walen and Lake Zurich, two of three historical whitefish species have survived, and four of five historical species are still found in Lake Constance. As the study also points out, there are at least 25 lakes in the European Alps which harbour one or more endemic whitefish species – i. e. species found exclusively in the lake in question.

In addition to species loss, the decline in whitefish diversity is also due to the hybridization of formerly distinct species. As a result of massive phosphorus inputs between 1950 and 1990, the bottom and deep waters of many lakes became severely oxygen-depleted. Specialists which had evolved since the last ice age (around 15,000 years ago) and were adapted to feeding and spawning in deep waters were thus deprived of their ecological niches. (Deep, oligotrophic lakes in particular appear to be unique reservoirs of biodiversity, where new species can evolve.) With the loss of these niches, the whitefish moved to shallower waters, where they interbred with related species. As a result, they lost their genetic and functional distinctiveness within a few generations – a process known as "speciation reversal". In lakes with higher phosphorus concentrations, genetic differentiation among the surviving populations is now also lower than in oligotrophic lakes (Fig. 3b). Specializations to particular spawning times or types of feeding have thus also been lost, and phenotypic variation has declined.

Back to the "good" old days? The studies on water fleas and whitefish provide striking illustrations of how even slight nutrient enrichment can adversely affect the natural condition of lakes – with changes in species composition, losses of genetic differentiation and, possibly, extinctions. They also demonstrate that such alterations may be irreversible: the endemic whitefish

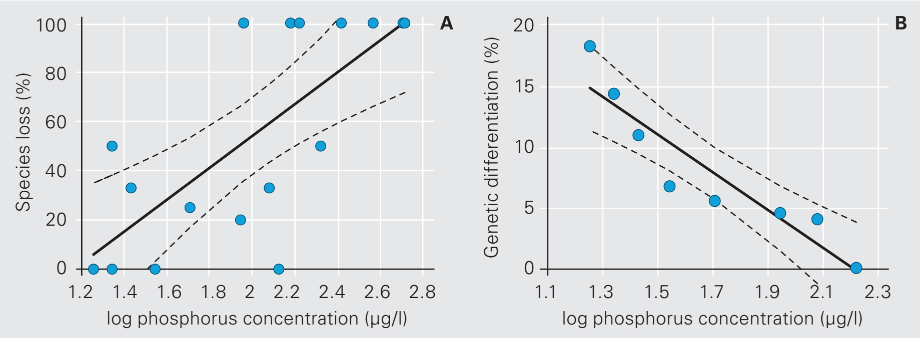


Fig. 3: In whitefish, higher phosphorus concentrations led to a greater loss of species (A) and to less genetic differentiation among different populations (B).

species which have disappeared or the original *D. longispina* cannot be recovered even in those lakes where nutrient levels have returned to normal.

Over the past three decades, as a result of the measures mentioned above, phosphorus loads have declined again in most Swiss lakes. In the cleanest – or most oligotrophic – waters, such as Lakes Brienz, Walen or Lucerne, phosphorus concentrations are now less than five micrograms per litre (see Fig. 1). From a water protection perspective, this represents a major success, but one which is now being called into question as the fishing lobby calls for nutrient elimination practices to be reconsidered.

The proponents of this idea have suggested, for example, that a phosphate limit of two to five micrograms per litre should be introduced for Lake Brienz, which corresponds to the conditions prevailing in the 1970s. In their view, this measure should once again permit "ecologically desirable plant and fish growth". According to commercial fishery statistics for Lake Brienz, while the annual whitefish yield averaged almost 15 kilograms per hectare during the period of increased nutrient inputs, it is now less than 1 kilogram [6]. The supporters of the parliamentary motions attribute this decline to a lack of nutrients in the lake. With the aim of achieving a renewed increase in algal production and hence fish yields, they are calling for WWTPs in the Lake Brienz catchment to reduce or even completely abandon phosphate precipitation. An increase in nutrient inputs would also be designed to prevent collapses of *Daphnia* populations, which have occurred regularly since 1999, thereby safeguarding the main food source for whitefish.

While *Daphnia* represented the primary food source for whitefish over the last 30 years, we did not observe any resting eggs in lake sediments from before 1950. The absence of water fleas is also mentioned in earlier studies of Lake Brienz plankton [7]. This suggests that the endemic whitefish species most likely managed without *Daphnia* as a constant food source. The recurrence of temporary declines in *Daphnia* populations should therefore be seen as a return to a natural state, rather than as a threat to whitefish.

Lower yields, but more endemic species. In the autumn of 2011, a systematic survey of fish species carried out as part of the Eawag/Bern Natural History Museum "Projet Lac" revealed that naturally spawning whitefish populations live in the depths of Lake Brienz. The low fish yields recorded by professional fishermen are thus not indicative of a general scarcity of fish in the lake. In fact, according to the Canton Bern Fishery Inspectorate, fishing effort has declined continuously since the end of the 1970s to just a fifth of the former level. The non-normalized commercial fish yield statistics thus give a distorted picture.

In the light of the above, the proposed phosphorus management measures would appear to be redundant. In addition, artificial nutrient enrichment of a natural lake would effectively reduce it to the status of a fish farm, which does not accord with the principles of sustainable use of natural resources. Switzerland has a number of highly productive, nutrient-rich lakes; the few naturally oligotrophic waters – and their unique biodiversity – should, however, be preserved, especially in view of the possible ecological consequences of eutrophication, based on the experience of the past 80 years. ○○○

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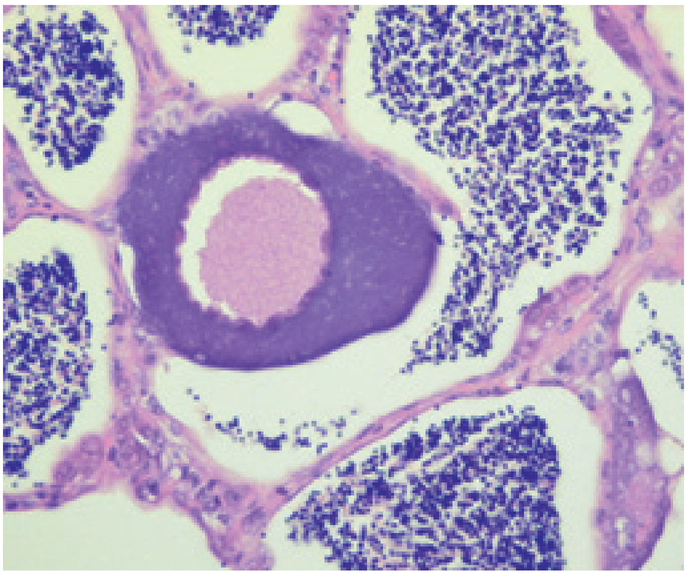
Endocrine disruptors: measurement, assessment and reduction

Endocrine-disrupting compounds, which enter surface waters mainly via wastewater discharges, can have adverse effects on aquatic organisms. Ecotoxicological test methods improve the measurement of these substances and the assessment of water quality, providing valuable decision support for reduction measures. For example, these methods can be used to evaluate additional treatment steps at wastewater treatment plants.

In the early 1990s, British researchers were puzzled by the discovery of hermaphrodite fish, i.e. individuals with both male and female sexual characteristics (Fig. 1). How were these abnormalities to be explained? The fish occurred particularly frequently in river stretches downstream of wastewater treatment plants (WWTPs), where treated effluent made up a large fraction of the river water. Subsequent investigations revealed that treated wastewater contained estrogenic substances which could lead to the feminization of male fish [1].

As well as natural estrogens of animal or human origin, estrogenic substances include synthetic compounds such as ethinyl estradiol (from contraceptives) or bisphenol A, which is widely used in the manufacture of plastics. These compounds act in a similar way to natural female sex hormones and can mimic or block their effects. Estrogenic substances adversely affect the development, reproduction and health of aquatic organisms. Fish, in particular, are affected, as their endocrine system is similar to that of humans. What is striking is that effects may be observed in fish even if the concentrations of estrogenic substances are very low – less than a nanogram per litre (the equivalent of a kilogram of active substance in Lake Biel).

Fig. 1: A cross section of testicular tissue from a male roach from Lake Geneva: an oocyte is visible in the middle of the image.



Daniel Bernet

Also a matter of concern in Switzerland. Endocrine disruptors enter surface waters from a variety of sources. The main source, however, is municipal wastewater, as in most cases these substances are not adequately eliminated at WWTPs. In the "Fischnetz" (Declining Fish Yields) project, estrogenic substances were identified as one of the factors that had contributed to a decline of more than 60 per cent in trout stocks in Switzerland since the early 1980s. A national research programme (NRP 50) carried out from 2002 to 2007 was designed to assess the risks of endocrine disruptors in the environment. It was found that estrogen concentrations were considerably higher downstream of WWTPs than upstream (Fig. 2). In some cases, elevated vitellogenin concentrations were also observed in male brown trout [2]. The occurrence of vitellogenin – an egg yolk precursor protein – in male fish indicates exposure to estrogenic substances. This protein is only produced naturally in mature female fish. Among the conclusions reached by NRP 50 were the following:

► endocrine disruptors represent a problem in Swiss rivers and streams where treated wastewater is insufficiently diluted;

► WWTPs in Switzerland are to be reviewed in terms of their elimination performance and technical optimization potential;

► support is to be provided for the rapid development of internationally standardized methods for the detection of endocrine disruptors and the assessment of water quality;

► for practical application, scientifically based quality criteria should be established for endocrine activity in the aquatic envir-

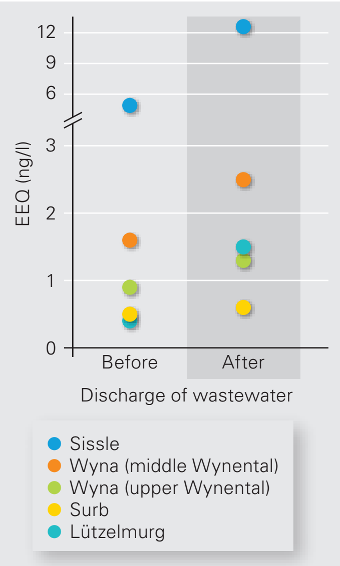


Fig. 2: Mean concentrations of estrogenic substances (EEQ = estradiol equivalents) in various Swiss rivers upstream and downstream of discharge points for treated effluent from WWTPs. Since 2004, when the study was carried out, discharges of effluent into the Sissle have been massively reduced.

onment, which should then be incorporated into the Swiss Water Protection Ordinance.

Over the past few years, some of these challenges have been addressed by the Ecotox Centre, in cooperation with the Federal Office for the Environment (FOEN), Eawag and other partners.

Assessing surface water quality in four steps. Although NRP 50 had shown that critical concentrations of estrogenic substances are likely to occur in some rivers downstream of WWTPs, no scientifically based procedure was yet available for assessing the contamination of surface waters with substances of this kind. This gap has now been filled: in collaboration with Eawag, as part of the FOEN "MicroPoll Strategy" project, we developed an evaluation concept for organic micropollutants [3]. Initially, on the basis of measurement and toxicity data, we identified 47 substances which are representative of the contamination caused by micropollutants from municipal wastewater. As well as various pharmaceuticals, biocides and industrial chemicals, the list of substances selected includes eight endocrine disruptors. To assess the ecotoxicity of these substances, we developed effect-based quality criteria, i. e. concentration limits which are not to be exceeded so as to ensure protection of the aquatic environment. The criteria were defined on the basis of acute and chronic toxicity data for algae, invertebrates and fish.

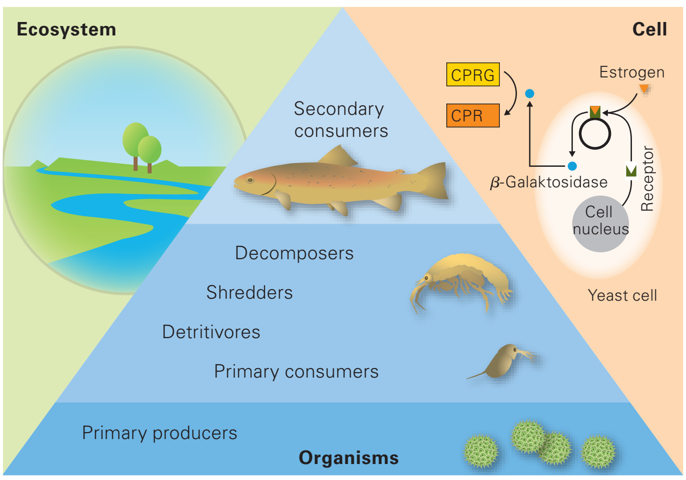
For the assessment of surface water quality, the evaluation concept offers a four-step procedure: firstly, potentially contaminated waterbodies are identified by estimating the wastewater fraction. If this fraction is above a certain threshold, the micropollutant load of the wastewater is then determined. Next, an ecotoxicological assessment is carried out: depending on the ratio of the environmental concentrations to the quality criteria, chemical water quality is assigned to one of five categories. In the final step, the main causes of contamination are to be ascertained and reduction measures proposed. With this procedure, it is possible to identify river stretches where critical concentrations of micropollutants occur and WWTPs where elimination of these substances needs to be improved.

How can micropollutant levels be reduced? Inputs of micropollutants – and endocrine disruptors in particular – to receiving waters can be reduced by the integration of advanced treatment steps at WWTPs. As part of the "MicroPoll Strategy" project, the effectiveness of two such processes was assessed in a pilot plant – firstly, ozonation followed by a biological step and, secondly, powdered activated carbon treatment with downstream filtration. Using a number of bioassays (Fig. 3), various project partners investigated whether micropollutants are more effectively eliminated by these processes, and whether these assays are suitable for routine monitoring of the performance of advanced treatment steps at WWTPs [4].

Two types of bioassays were evaluated. With *in vitro* bioassays, specific effects on cell lines or unicellular organisms – and hence the presence of classes of chemicals such as estrogens – can be detected highly sensitively. However, such assays reveal very little about the effects of substances on whole organisms. In *in vivo* bioassays, whole organisms are used to study effects on biological functions such as growth, mortality, reproduction or induction of vitellogenin synthesis. While these assays detect the effects of all the substances contained in a wastewater sample, they often provide limited information on the substance classes responsible.

Wastewater samples collected at a number of points within the pilot plant were subjected to the various bioassays and to chemical analysis. As the *in vitro* tests showed, the toxicity of the wastewater was already reduced by the existing biological treatment step. However, micropollutants were not completely eliminated by this treatment. The wastewater still contained, for example, relevant concentrations of estrogenic substances. However, as shown by the specific *in vitro* bioassays, additional

Fig. 3: In the "MicroPoll Strategy" project, the effects of micropollutants were investigated at the cellular, whole-organism and ecosystem level. The higher the level of organization, the more difficult it is to attribute effects to individual factors.



Peter Schönenberger

Cornelia Kienle and Petra Kunz of the Ecotox Centre discuss the results of a YES assay.

treatment with ozone gas or activated carbon removed more than 80 per cent of the remaining micropollutants. These results were confirmed by chemical analysis.

Reduced toxicity thanks to the advanced treatment steps was also shown by the *in vivo* bioassays involving rainbow trout: hatching rates and embryo weight were increased and mortality was decreased. The other *in vivo* assays did not yield consistent results. This was partly due to the lack of sensitivity of these systems. A comparison of the bioassays evaluated indicates that there is no single test which could be used for an overall assessment of the toxicity of wastewater samples. However, for the monitoring of micropollutant elimination, the *in vitro* bioassays proved to be more suitable than the *in vivo* bioassays at the pilot plant studied. They are also easier to handle and can therefore be recommended for routine monitoring purposes.

The evaluation of the bioassays not only showed that ozonation or activated carbon treatment can eliminate a broad spectrum of micropollutants and significantly reduce concentrations of endocrine disruptors in wastewater. In addition, no evidence of stable transformation products of ecotoxicological concern was seen when ozonation was combined with biological treatment. Accordingly, to minimize the risks of such compounds being released into surface waters, ozonation should always be followed by a final filtration step with biological activity.

What kinds of measurements and monitoring are appropriate? In view of these findings, the federal authorities have decided that selected WWTPs should be upgraded in order to protect drinking water resources and aquatic organisms. Together with various partners, they have therefore elaborated a financing solution at the national level, in accordance with the "polluter pays" principle. Work on the necessary amendments to the Water Protection Act is currently underway.

Despite the upgrading of WWTPs, it will still be necessary to monitor surface water quality and carry out regular measurements of endocrine disruptors. As estrogenic substances are biologically active at extremely low concentrations, the scope for chemical detection of individual substances is limited. In addition, the value of chemical analysis is limited because different substances with the same mode of action can have additive effects. Thus, a combination of estrogens, each present in insignificant concentrations, may produce a biological effect overall. To permit sensitive detection of the overall effects of estrogenic substances, it is advisable to use *in vitro* bioassays in addition to chemical analysis.

On behalf of the FOEN, we are currently collaborating with representatives of the federal authorities, water protection agencies, academia and private consultancies to develop a concept for routine assessment of water quality based on bioassays. Tests which are suitable for the measurement of, for example, estrogenic activity need to meet numerous requirements: they should be sensitive, mechanism-oriented, easy to perform and inexpensive.

In an initial measurement campaign, we determined the concentrations of estrogenic substances in a number of Swiss rivers containing a high fraction of treated wastewater. For this purpose, we used two *in vitro* bioassays whose value had already been demonstrated in the "MicroPoll Strategy" project. The first of these was the yeast estrogen screen (YES): here, genetically modified yeast cells indicate estrogenic effects by undergoing a (yellow-to-red) colour reaction if an estrogenically active substance binds to the human estrogen receptor in the cell. This simple test is inexpensive, freely available and already widely used. The second bioassay is known as ER-Calux – a commercially available test based on a human cell line containing the gene for the human estrogen receptor. Because it involves cell lines, the ER-Calux system is more complex and costly to use than YES, but it is also more sensitive.

Essentially, both of these test systems were suitable for determining whether or not water samples complied with the ecotoxicologically based quality criterion specified for 17β-estradiol (0.4 nanograms per litre). This value represents the environmental quality standard proposed under the EU Water Framework Directive and recommended by the Ecotox Centre. With both tests, higher estrogenic activity was detected downstream than upstream of wastewater discharge points in the river sections studied. By contrast, it was not possible for water quality to be fully assessed in terms of estrogenicity by means of chemical analysis.

As a pragmatic approach for the measurement of estrogenic activity in surface waters, we recommend that the YES system should be used. With this value, the final concentration in receiving waters can be estimated on the basis of the dilution factor (Fig. 4). While YES is less sensitive than the ER-Calux system, it is suitable for assessing samples with relatively high concentrations of estrogenic substances. The main advantage of this method lies in its suitability for routine use: it is easy to apply and inexpensive.

The methods and concepts described here are very promising, and our studies show that bioassays are a valuable tool for the

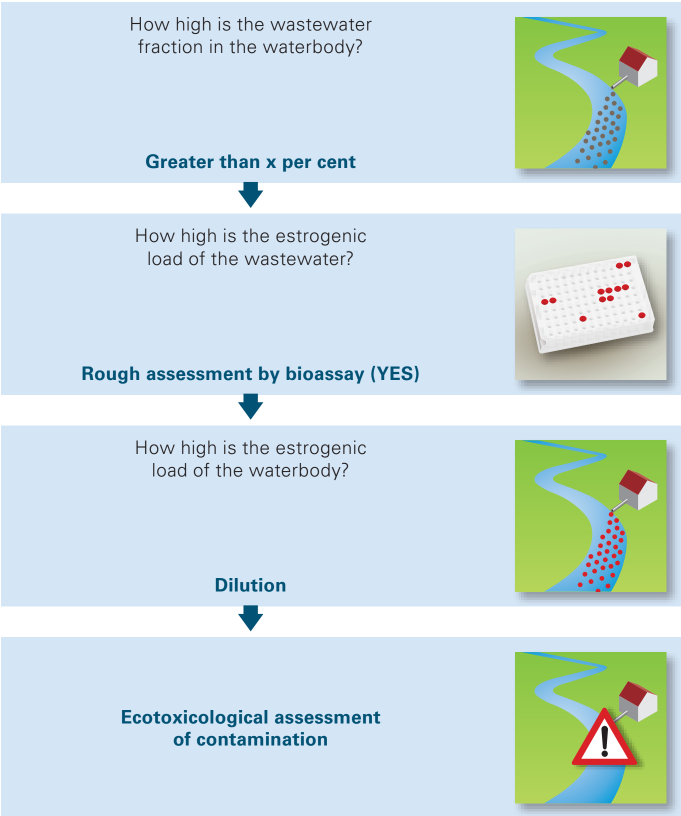


Fig. 4: Possible procedure for evaluation of estrogenic substances in surface waters.

assessment of estrogenic activity in rivers. However, further validation and standardization are required before they can be used by cantonal or private laboratories. Within the DIN Working Group on Hormonal Effects (Xenohormones), we are actively contributing to the initiation of ISO certification of the bioassays.

Addressing unresolved questions. Although large amounts of information on endocrine disruptors have been collected in Switzerland in recent years, numerous questions remain unresolved. For example, over the past 10 years, gonadal abnormalities have been observed in many whitefish from Lake Thun. Despite intensive research efforts, our analytical methods and knowledge of the effects of various chemicals have not proved sufficient to identify the cause of these malformations [5]. In addition, new findings suggest that, as well as affecting the reproduction of fish, endocrine disruptors may target their immune system, thus increasing their susceptibility to pathogens [6]. Such multiple mechanisms of action make it all the more difficult to predict effects at the population level. Interpretation is further complicated by the effects of other pollutants and stressors.

At the same time, our knowledge of ecotoxicological effects is constantly growing, and increasingly powerful high-throughput screening methods are being developed. This means that, in practice, our ability to measure estrogenic and other effects on aquatic organisms is improving. With high-throughput methods, however, the difficulty remains of establishing links between effects at the molecular level and on the whole organism. Here, hopes are pinned on "omics" methods, such as transcriptomics, proteomics and metabolomics. These techniques permit "all-at-once" analysis of an organism's genes, proteins or metabolites. They could help to identify metabolic pathways which lead from cellular interactions to impairment of health. It would then be possible to identify effect-specific biomarkers which could be used in routine analyses. If this vision is realized, we will – in the medium term – require considerably fewer animal experiments to predict risks to the environment and humans, and to protect the health of ecosystems. ○○○

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Time-zero data – the key to detecting changes

Eawag researchers Pascal Vonlanthen and Florian Altermatt are convinced that long-term monitoring programmes are an essential tool for the conservation of biodiversity and the protection of ecosystem services. Vonlanthen studies the evolution of fish in Swiss lakes and is currently coordinating a survey of fish biodiversity ("Projet Lac"). Altermatt is particularly interested in the dispersal and differentiation of macroinvertebrates along surface waters.

Interview: Andri Bryner

Why is it necessary to monitor biodiversity?

Florian Altermatt (FA) People have been doing scientific research for hundreds of years, but in most cases we still – in 2012 – don't know what the initial situation is. If there's no monitoring, we just keep on missing "time zero".

Pascal Vonlanthen (PV) And if data from an earlier period does exist, then it's often been collected in an uncoordinated way, which makes it difficult to compare with other datasets today. It's almost impossible to draw reliable conclusions about changes.

Is this really a federal responsibility?

(PV) Researchers are on the lookout for species diversity, for what's not yet known. Monitoring tracks changes in what's already known. Researchers should try to find out how and why these changes occur – how the processes work. For us, it's rarely possible – logistically, financially and time-wise – to actually carry out monitoring. But ultimately, of course, monitoring data is extremely important for research.

(FA) In the same way, it's not up to researchers to collect population data – births, marriages, immigration and so on. That's the state's job. And furthermore, the research landscape has changed: research is no longer satisfied with merely documenting existing conditions. I can't find any funding for that. From 1958, David Keeling monitored CO_2 levels at the Mauna Loa observatory in Hawaii on his own initiative. He carried out measurements for years before he received any money for it. Today, the Keeling Curve is one of the most important graphs in climate science. But the state can't just assume that there will always be researchers who are as courageous and intelligent as he was.

Biodiversity isn't just "nice to have". Ecosystems provide vital services.

What does "biodiversity" mean to each of you?

(FA) For me, biodiversity means variety and distinctive character. I don't always want to eat or see the same things. When we go away on holiday, we seek out diversity, we prefer wildflower meadows to monotonous cornfields.

(PV) But biodiversity is more than just "nice to have". The environment provides us with services which are vital: safe drinking water, the air we breathe and so on. And that's controlled by biodiversity. In my research field, it's quite simple: if the food web breaks down, then there are no more fish to be caught.

(FA) That's quite right. But at the same time there's a risk involved in the listing of ecosystem services – after all, safe water can also be produced by technological means. So we need to highlight the fact that near-natural waters and the organisms these habitats support are interlinked in complex ways, and that the end results consist of much more than just clean water.

And how is this diversity measured?

(PV) Generally, the individuals observed or captured are identified, and species abundance or biomass is recorded. Classifying animals and plants seems to be a human need. But in nature the boundaries aren't always so well defined. Often, the processes whereby new species evolve are continuous. So in our projects we aim to document the entire spectrum of diversity – not just in terms of form, colour or habits, but also genetic diversity. This is the basis for the development of new species, or the ability of existing species to adapt to environmental changes.

Pascal Vonlanthen (left) and Florian Altermatt explain the benefits of monitoring programmes.

Photos: Andri Bryner

(FA) It's important that monitoring should be a long-term process, and that methods are not re-invented each time – for example, standard nets should be used for fish surveys. Unfortunately, monitoring initiated by individual experts tends to reflect their particular interests and areas of operation – holiday or work locations – rather than providing data comparable for Switzerland as a whole.

How long should monitoring be carried out for?
(FA) As a rule of thumb, a programme should at the very least cover one or more generation cycles of the species of interest, so that you have a baseline and data on changes. But essentially, of course, the longer the data series, the better the data base. In addition, with increasingly long data series, freely available monitoring data from public sources will inspire more and more research projects – and these don't need to be financed via the monitoring programmes.

Monitoring efforts often reflect experts' personal interests.

What use do you make of monitoring data?
(FA) One of the things I'm investigating in my projects is how species disperse along surface waters, and how barriers affect the differentiation of species. My aim is to draw conclusions for the whole of Switzerland, and that's not possible without data from the Biodiversity Monitoring Switzerland (BDM) programme. But we also supplement the BDM indicators with our own studies, especially genetic analyses.
(PV) Unfortunately, the data on fish is based almost exclusively on catch statistics. That gives us a distorted picture, because the species recorded are mainly those which fishermen like to catch. This is why we've launched our own monitoring programme – Projet Lac – based on methods recognized at EU level. But, in fact, our current research on the disappearance of numerous whitefish species would not have been possible if whitefish in Switzerland had not been recorded and described in great detail by a teacher over 50 years ago.

How does Eawag's research contribute to biodiversity monitoring?
(FA) Eawag was involved in the development of the new indicators for aquatic habitats – mayflies, stoneflies and caddisflies. In future, observation of ecosystem services will become increasingly important. Here, we can draw on experience from our research – for example, on an overall indicator for litter decomposition in waterbodies.
(PV) We will be making the Projet Lac data publicly accessible, and we hope that even more cantons will decide to participate. That would enhance the reference status of our survey of fish species in Swiss lakes. Fish populations in lakes should generally be monitored on a regular basis. That's the only way of preventing the extinction of species. ○○○

At the 2012 Eawag Info Day, Pascal Vonlanthen of the Fish Ecology & Evolution department and Florian Altermatt of the Aquatic Ecology department discussed the subject of biodiversity monitoring with National Councillor Franziska Teuscher. A video of the half-hour discussion (in German) is available at: www.eawag.ch/infotag.

Monitoring: part of a broader strategy

In April 2012, the Swiss Biodiversity Strategy was adopted by the Federal Council. By 2014, an action plan is to be elaborated via a participatory process involving cantons, communes and the private sector, setting out how the goals defined for 2020 are to be achieved. One of the ten strategic goals calls for the development of a monitoring system – based on existing programmes – to cover all levels of biodiversity, i. e. ecosystem, species and genetic diversity. In addition, indicators are to be introduced which allow ecosystem services to be assessed in quantitative terms – for example, purification processes in near-natural waters or the protective function of forests. Among the groups actively supporting the new strategy was the Swiss Academy of Sciences Biodiversity Forum (www.biodiversity.ch), on which Eawag is represented. The Swiss Biodiversity Strategy can be downloaded (in French/German/Italian) from: www.bafu.admin.ch/publikationen

Biodiversity Monitoring Switzerland (BDM) is one of a number of federal environmental observation programmes. Launched in 2001, it uses standardized methods to collect data on the occurrence of species of plants, mosses, molluscs, breeding birds and butterflies at more than 2000 sites across Switzerland. Since 2010, mayflies, stoneflies and caddisflies have also been included as indicators of species diversity in aquatic habitats. The BDM programme deliberately focuses, not on threatened species, but on common species widely found in "normal" landscapes. It thus complements other programmes which monitor rare species. The costs of the programme currently amount to over CHF 3 million a year. www.biodiversitymonitoring.ch

Nele Schuwirth, hydrogeologist, develops ecological models and decision support techniques for environmental management.
Co-author: Peter Reichert

Predicting the occurrence of macroinvertebrates

The habitat requirements of macroinvertebrates vary widely. Eawag is developing a model for the prediction of benthic community composition in surface waters. In the future, the model could be used to support integrated river management and to predict the possible consequences of different management options or climate change.

In the coming decades, the state of our surface waters will be strongly influenced by warming of the climate and changes in land use. As a result of warming, water temperatures in rivers will rise and water flows will be altered; social and demographic changes will affect inputs of pollutants from agriculture, urban areas, industry and transport. The impacts of such changes on freshwater ecosystems and organisms are not yet fully understood. However, with the aid of computer models, available knowledge of the processes occurring in surface waters can be integrated and described in quantitative terms. Modelling can thus help to predict the effects of environmental changes on ecosystems. Here, we use the example of an invertebrate community model to illustrate how predictive models are constructed, what difficulties are encountered during their development and how uncertainties can be accounted for.

Key role of macroinvertebrates in surface waters. The term "macroinvertebrates" covers a wide variety of organisms visible to the naked eye, including insect larvae, freshwater amphipods, mussels, snails, leeches and many others. Macroinvertebrates, which generally live on the river bed or in sediments, serve important functions within the ecosystem: they shred leaf litter (converting it into a usable form for other organisms), filter organic particles from the water or graze algae. They also represent a vital link in the food chain, providing a food source e. g. for brown trout.

These fascinating organisms also contribute to the biodiversity of freshwater ecosystems. The various species have adapted to widely differing environmental conditions. Some species only occur in particularly clean water, while others tolerate high levels of pollution with organic matter or have special properties enabling them to cope better with pesticides. Some species prefer

Mark Honti

The particular macroinvertebrates occurring in a river or stream will depend on its nature and state.

strong currents or slow-flowing waters; others are generalists, capable of tolerating a wide range of environmental conditions. Macroinvertebrates also vary in their feeding habits. Grazers feed on periphyton (e.g. algae), shredders break down leaf litter, and other species feed on organic particles which are suspended in water (filterers) or deposited in sediments (collectors). Also found among the macroinvertebrates are species which feed on other invertebrates (predators) and generalist feeders (omnivores).

Macroinvertebrates are especially important from a river management perspective, as they play a key role in the maintenance of ecosystem services (self-purification of natural waters, fisheries, recreational functions). At the same time, because of their differing habitat requirements, they are also suitable for use as indicators of water quality and of natural or degraded environmental conditions. For this reason, they are a crucial element in methods of assessing the ecological status of waterbodies, such as the Swiss Modular Concept for stream assessment (www.modul-stufen-konzept.ch).

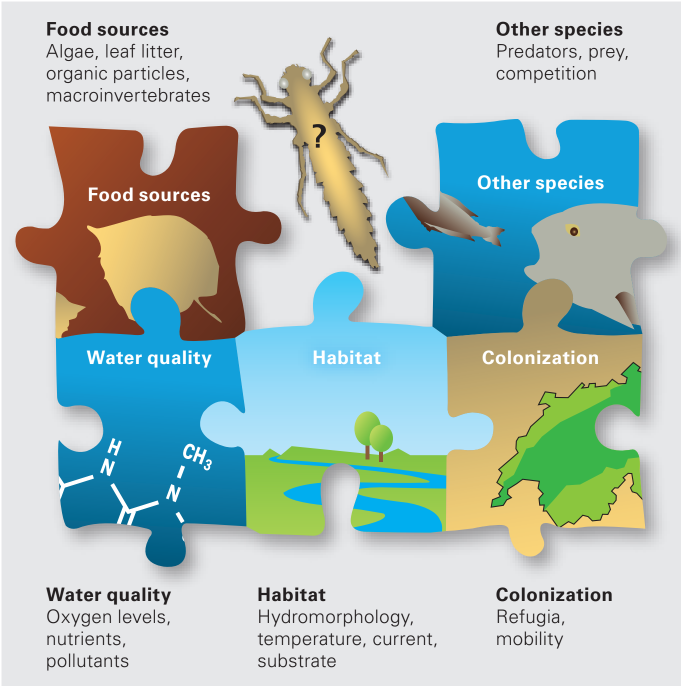

Fig. 1: A wide variety of factors determine whether or not a species occurs in a given habitat.

Predicting effects on species. In order to estimate in advance the ecological changes likely to occur in surface waters e.g. as a result of restoration efforts or upgrading of a wastewater treatment plant (WWTP), it would be useful to be able to predict effects on macroinvertebrate species. As part of the iWaQa project – carried out under the National Research Programme "Sustainable Water Management" (www.nfp61.ch) – we are therefore developing and refining methods which should allow such predictions to be made in the future.

The Ecological River Model (ERIMO), which we previously developed, combines invertebrate species into functional groups based on their food source and describes the abundance or biomass of these groups over time as a function of discharge and water temperature [1, 2]. This model is well suited for analysing the temporal dynamics of the invertebrate community and its functions within the ecosystem (e.g. grazing of algae or breakdown of leaf litter). However, it does not capture other factors which are important for assessing the ecological status of a waterbody, such as biodiversity or the occurrence of particularly sensitive species. Our "Streambugs 1.0" model now goes one step further by seeking to describe individual taxa (species, genera or families, depending on data availability) [3]. This has initially necessitated compromises with regard to temporal aspects. So far, we have focused on the occurrence or non-occurrence of species at a particular site. While the temporal dynamics of the

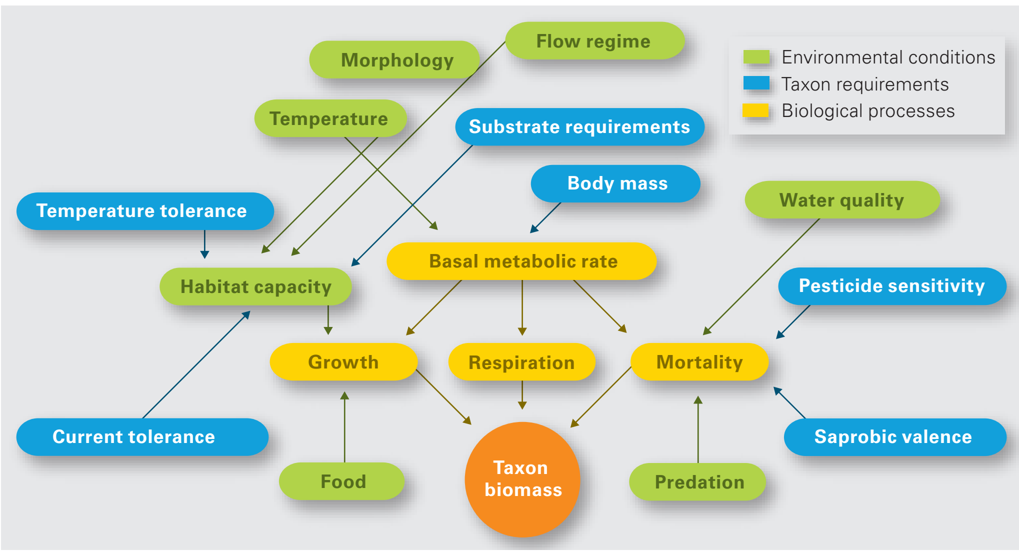

Fig. 2: On the basis of fundamental processes and influencing factors, the "Streambugs 1.0" model simulates the occurrence of a taxon, or the development of its biomass, at a particular site. *Habitat capacity* refers to the maximum number of organisms that a habitat can support. *Saprobic valence* indicates the degree of tolerance to pollution with degradable organic matter.

abundance or biomass of the various taxa could in principle also be predicted (as with ERIMO), this would require extensive testing and possibly also further refinement of the model.

Whether certain species occur at a given site or not depends on numerous factors, e.g. various environmental conditions (Fig. 1). Taking these influencing factors into account, our model simulates the most important processes that determine the occurrence of taxa, or increases or decreases in taxon biomass – growth (through food intake and reproduction), respiration (conversion of biomass into energy) and death rates. These processes depend on the basal metabolic rate (i.e. the amount of energy expended at rest). They are also influenced by the specific requirements of the various taxa and by environmental conditions (Fig. 2).

As complex as necessary, as simple as possible. Models of this kind always involve gross simplification of highly complex natural systems. The art, therefore, is to find an appropriate compromise between simplicity and complexity (i.e. an approximation to reality). Simplicity is desirable as it makes a model easier to apply. For example, it is useful to limit the amount of input required – ideally to data which has already been collected or which can be estimated from available information. A simpler model also requires less computing time, which is an important consideration in the application of methods for quantifying uncertainties or sensitivity analysis. The latter is used to evaluate the robustness of a model by showing how small changes in input parameters affect the results.

The complexity of a model can only be increased – providing a more realistic picture – if it is possible to describe the relevant interactions and influencing factors quantitatively. And greater complexity is only desirable if the predictive capabilities or universality of the model are thereby increased – i.e. if it is transferable to different situations or sites. For example, we can develop a model which effectively describes the occurrence of macroinvertebrates in the Mönchaltorfer Aa catchment. If this model also delivers good predictions for the Gürbe and Thur rivers, then not only is it more useful for practical purposes, but we can also be more certain that the individual processes are correctly represented. In this case, the model can more readily be used to predict the effects of changes in environmental conditions. However, there are always limits to such "universality". It would be unreasonable to expect a model to work for rivers of all types – for the Rhine at Basel and also for a mountain stream in the Alps.

Information from online databases. The specific properties of the various macroinvertebrate taxa are obtained from databases which are available online. These were compiled using contributions from numerous researchers. For example, data on habitat preferences and feeding types is taken from the website www.freshwaterecology.info [4]. For the pesticide sensitivity of taxa, reference is made to the SPEAR (SPEcies At Risk) database [5].

The SPEAR system – based on biomonitoring data typically collected by water protection authorities – indicates the percentage of species at risk. If many sensitive species occur, it can be assumed that pesticide exposure is minimal at the site in question. If pesticide-tolerant species predominate, this suggests that pesticides represent a problem. In our model, we take this information on sensitivity into account by increasing the death rate for sensitive taxa at sites where we expect to see pesticide contamination. This is a highly simplified description of the influence of pesticides on communities. We adopt a similar procedure in the case of pollution with organic matter, which may lead to oxygen depletion in surface waters. For this purpose, we use the saprobic system, which is well established in Central Europe as a means of classifying water quality [6].

To date, we have tested the model at four sites in the catchment of the Mönchaltorfer Aa, a tributary of Lake Greifen in Canton Zurich. For these sites, we can use monitoring data collected over a period of years by the Cantonal Office for Waste, Water, Energy and Air (AWEL) [7]. This includes information on the occurrence and abundance of macroinvertebrate species, recorded in accordance with the Swiss Modular Concept of stream assessment (regional level). Also available for these areas is data on nutrients, pesticides, discharge and water temperatures. We are thus in a position to estimate the environmental conditions at the four sites which are required as input for the model (see Table).

Successful real-life tests. Many of the factors used as input for the model – e.g. taxon-specific growth or death rates – are uncertain. In such cases, we do not operate with fixed values but define, for each parameter, a probability distribution which reflects existing knowledge/uncertainty as to the value. In order to estimate the effects of these uncertainties on the overall uncertainty of the results, we use a mathematical method known as Monte Carlo simulation to generate a probability distribution. On this basis, we can calculate for each macroinvertebrate taxon the

Environmental conditions at four sites in the Mönchaltorfer Aa catchment.

	Site 1 Upstream of WWTP	**Site 2** Downstream of WWTP	**Site 3** Upstream of WWTP	**Site 4** Downstream of WWTP
Mean water temperature (°C)	10.3	12.4	9.6	11.4
Temperature regime	Moderate	Warm	Moderate	Warm
Mean leaf litter input (g/m^2/year)	170	260	500	420
Proportion of surface shaded (%)	15	26	90	95
Current regime	High	High	High	Moderate
Pesticide pollution	?	Yes	No	Yes
Water quality (saprobic class)	I: oligo-saprobic zone	II: β-meso-saprobic zone	I: oligo-saprobic zone	II: β-meso-saprobic zone
Mean phosphate concentration (mg/L)	0.01	0.03	0.05	0.04
Mean nitrogen concentration (mg/l)	3.3	8.0	2.1	7.6

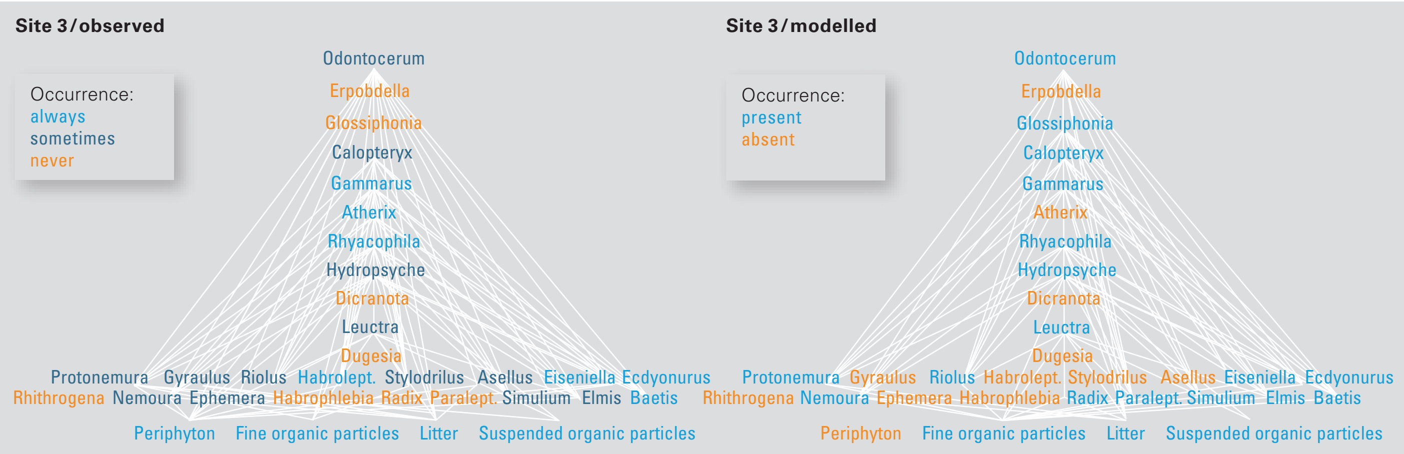

Fig. 3: Occurrence of macroinvertebrates at a site in the Mönchaltorfer Aa catchment, shown as a food web at genus level. Right: values predicted by the model; left: actual situation based on observational data.

predicted probability that it will survive at a given site or become extinct (e. g. as a result of unfavourable environmental conditions).

To assess how well "Streambugs 1.0" represents reality, we compared the predictions generated by the model with observational data on the occurrence of macroinvertebrates at each of the four sites in the Mönchaltorfer Aa catchment (Fig. 3). The initial tests – undertaken prior to calibration of the input parameters – were already very successful. As indeed we had expected, the simulation was not able to predict accurately the presence or absence of all taxa. Even so, the model did assign a high probability of survival to most of the taxa which, according to field studies, occurred at a site at all sampling times. Taxa which had never appeared in the monitoring data were generally assigned a low probability of survival by the model.

Assessing management options. As our example demonstrates, models can be helpful even if existing knowledge is incomplete. By providing the best possible predictions, they can support decision-making processes. However, to obtain realistic and credible estimates, it is important to quantify uncertainties. If a model of this kind is to be employed in practice, the following development steps are essential: testing of the model concept, application under the broadest possible range of environmental conditions, including improvements to the model, and implementation of user-friendly software.

«Streambugs 1.0» is currently in the first stage of development. The exceptional cases where the predictions were not in agreement with the observational data are of particular interest to us, as they can help to improve the model. As the next step, we will therefore test the model at further sites, to see whether the results are confirmed and to identify the reasons for any discrepancies. This should permit a more reliable assessment of the model›s universality and predictive capabilities and allow us to make further improvements.

In the future, we hope that recolonization after disturbance events can also be included in the model. This is an important process, which can help to determine the success or failure of restoration measures. Our goal is that, apart from the gain in scientific knowledge, the model should at some point be able to predict the possible effects of various management options or climate change on the occurrence of organisms in rivers and streams.

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Michael Doering, landscape ecologist in the Aquatic Ecology department, studies the relationships between ecosystem structure and function.
Co-author: Christopher T. Robinson

Water resource management: balancing protection and use

Freshwater ecosystems provide socioeconomic services, but their function is dependent on certain ecological requirements being met. Sustainable water resource management should therefore consider the needs of both humans and the environment. What this kind of approach could involve is shown by two research projects carried out on the Spöl and in the Sandey floodplain.

Climate change and growing human demands are affecting the availability of water resources. As a result of excessive water withdrawals (around 4000 cubic kilometres per year worldwide), many large rivers now fail to reach the ocean, especially in arid regions. Globally, more than 500,000 kilometres of waterways have been altered for navigation, over 63,000 kilometres of canals have been constructed, and over 50,000 large dams are in operation. The latter store more than 6300 cubic kilometres of freshwater, and further major dam projects are planned – notably in developing countries [1]. Climate change is also associated with shifts in the timing and magnitude of precipitation, leading to increases in extreme events such as flooding and droughts.

Water – risk and resource. Taking Switzerland as an example, recent data and predictions suggest that the main precipitation period will shift to late winter and early spring. This will increase the risk of extreme spring flows, followed by low flows or droughts in the late summer. In the longer term, the situation could be exacerbated by glacier retreat. These developments will have direct consequences for flood control and also for the agriculture, energy and water supply sectors, where water is an irreplaceable resource.

As well as the changing climate, a variety of human uses will exert further pressure on freshwater ecosystems. In Switzerland, the planned phase-out of nuclear power is to be offset – in part – by an expansion of hydropower, which already accounts for around 55 per cent of the country's energy production. At the same time, efforts are underway to mitigate the adverse impacts of hydropower generation. The newly revised Water Protection Act, which came into effect in 2011, calls for remedial measures to reduce the impacts of hydropeaking operations, reactivate sediment transport and remove barriers to fish migration. In addition, over the next 80 years, about a quarter of the 15,000 kilometres of degraded river sections are to be restored [2].

While freshwater ecosystems are used as resources, providing various socioeconomic goods and services, they are also habitats which can only function if certain fundamental ecological requirements are met. In addition, they may pose risks to human life and infrastructure. These different, sometimes divergent demands and interests – accentuated by climate change – are a source of potential resource-use conflicts. Against this background, sustainable management of water resources is becoming an increasingly urgent task (Fig. 1). Sustainability involves giving due consideration to the needs of humans and of ecosystems. This means taking an integrated approach to economic, social and ecological concerns so as to achieve an appropriate trade-off of interests, acceptable to the various stakeholders. This requires interactive thinking, participative decision-making and long-term strategic planning.

Fig. 1: Sustainable management of freshwater systems seeks to integrate multiple ecological and socioeconomic interests (adapted from [3]).

Adaptive management to enhance sustainability. One tool which can promote sustainable use of water resources is so-called adaptive management. This involves a continuous development process, in which what is learned from the results of previous decisions is used to optimize future management actions, thus moving closer towards an ideal solution.

In two case studies – on the Spöl river in the Swiss National Park and in the Sandey floodplain of the Urbach valley in Canton Bern – we have investigated how, with an adaptive approach, multiple ecological and socioeconomic interests can be integrated

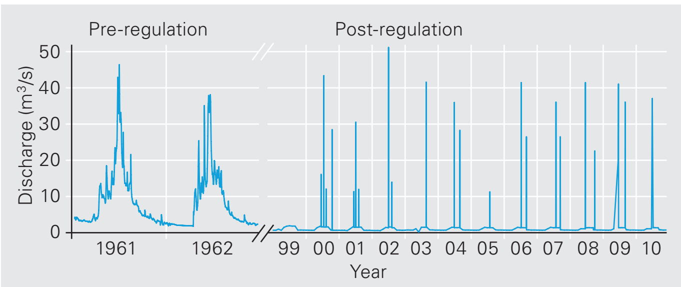
Since 2000 the constant residual flow of the Spöl is interrupted by experimental floods to test the potential for water reuse with respect to optimal ecological discharge.

into sustainable management of water resources. In the first of these two projects, the aim was to use experimental floods to improve the ecology of a regulated alpine river without adversely affecting hydropower production. In the second project, we studied the impacts of historical floodplain management and how planned restoration measures can be reconciled with flood protection and land use needs.

The Spöl originates from Lago di Livigno, a reservoir on the Swiss-Italian border. The pre-regulation discharge was 6–12 cubic metres per second (m^3/s), with peak flows up to 120 m^3/s; following regulation, the constant residual flow is 1.45 m^3/s in summer and 0.55 m^3/s in winter. Since 2000, this residual flow has been interrupted by one to three experimental floods per year, in order to re-establish a more natural flow regime (Fig. 2). The primary aim of the study was to determine whether implementation of this novel disturbance regime could produce positive effects on the Spöl ecosystem, where residual flows had remained at a relatively constant low level for over 30 years.

Optimal ecological discharge is defined in terms of the minimal base flow requirements and the timing, duration, magnitude and frequency of high flow and flood events that are most suitable for creating a sustainable habitat for resident biota – even under changing climatic conditions.

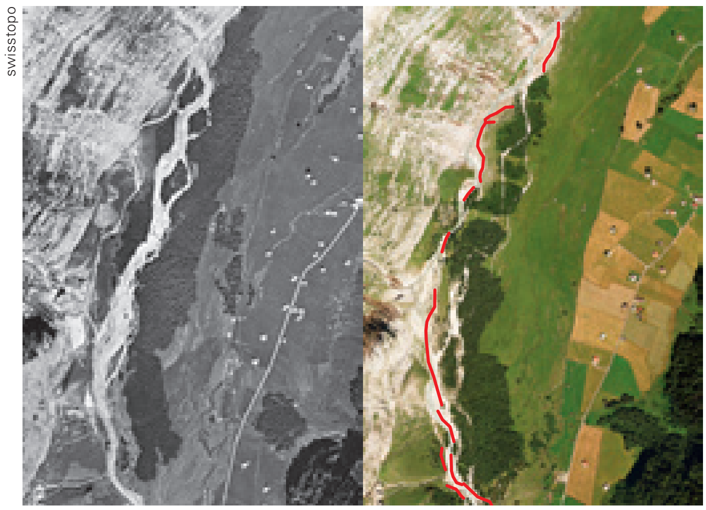
Fig. 2: Until 1970, the Spöl had a natural flow regime (left). Under regulated conditions, residual flows were continuously limited to approximately 2 m^3/s. Since 2000, regular experimental floods (up to 40 m^3/s) have been used to create a more natural flow regime.



Shift towards a more natural regime. The floods had little effect on the physicochemistry of the river, since the water source – hypolimnetic releases from the dam – was unchanged. However, they reduced the armouring of the stream bed and increased the porosity of bed sediments. The sediments were scoured and attached moss was dislodged within the first two years. The floods also reduced benthic organic matter in the river. Standing stocks of primary producers (e.g. periphyton) likewise declined. Although the Spöl is nutrient rich, the floods maintained low periphyton biomass by scouring filamentous algae from bed sediments.

The floods reduced benthic macroinvertebrate density and diversity, leading to changes in species composition, with higher proportions of smaller organisms and a lower biomass. There was a decrease in the abundance of disturbance-prone species, such as the large-bodied, sessile amphipod *Gammarus fossarum,* and an increase in the abundance of more resistant species, such as the small-bodied, highly mobile mayfly *(Baetis* spp.). Overall, after

Fig. 3: Aerial images indicate how the character of the Sandey floodplain changed between 1940 and 2007. Red lines mark the location of levees.



the ecosystem regime shift, greater variation was observed in the composition and morphology of the organisms studied.

At this point, it can be concluded that, as a result of the experimental floods, the habitat conditions and species composition in the Spöl are more similar to those of a comparable natural alpine stream. At the same time, the example of the Spöl demonstrates that it is possible to reconcile ecological and economic interests, as the water released for the floods can be diverted and used for power production in other catchments, with virtually no impact on economic costs [3, 4].

Involvement of stakeholders. The Sandey floodplain project (Fig. 3) – initiated in partnership with the hydropower company Kraftwerke Oberhasli AG and the Federal Offices for the Environment and for Spatial Development – combines field assessment, hydrological modelling and remote sensing/geospatial data to quantify and simulate the effects of historical floodplain management and of planned restoration measures such as selective opening of levees. Also to be taken into account are the maintenance of flood protection and existing land use needs. The project aims to promote sustainable management by providing a scientific basis for dialogue among stakeholders and supporting transparent decision-making for future floodplain management. The inclusion of reference studies from other river systems and the involvement of various actors at the regional, national and international level are designed to ensure that the findings are transferable to other situations.

The Sandey floodplain – around 3.5 kilometres long, with an area of 118 hectares – is characterized by a high degree of structural heterogeneity, containing habitat types which are typical of natural riverine floodplains, such as islands, alluvial forest, main channels and gravel bars. As an alluvial zone of national importance, it is a priority area for conservation. Socioeconomically, the floodplain is used for livestock grazing and for various private purposes. About 30 per cent of the average annual discharge of the Urbach river is abstracted from the system for hydropower production in a different catchment by an upstream dam built in 1950. In addition, especially in the 1990s, numerous levees were constructed to provide flood protection in the active floodplain.

Historical aerial images reveal the extent to which the floodplain has changed over time. The relative abundance of habitat types, as well as channel complexity, has fluctuated greatly, which is not a typical pattern for natural riverine floodplains. Compared with the near-natural state mapped in 1940, the area is now less heterogeneous, and certain typical habitats have become less abundant (Figs. 3 and 4). This is probably due to the effects of water abstraction and, in particular, to the constraints on hydrological dynamics imposed by the installation of levees [5].

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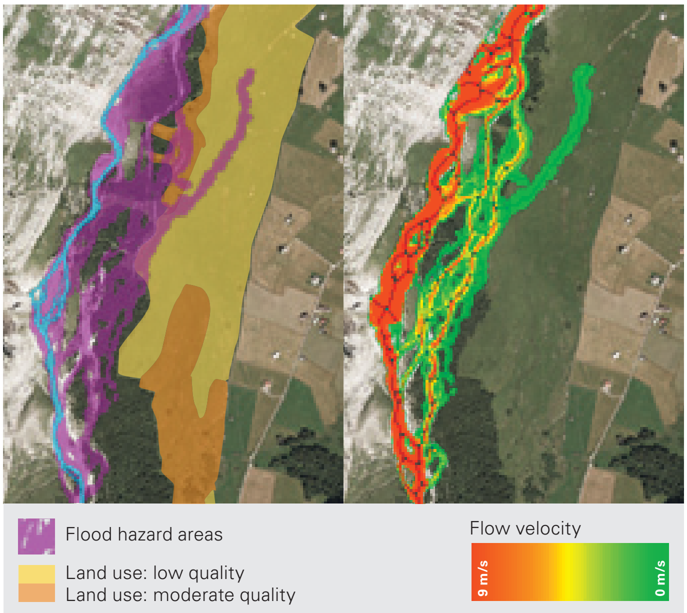
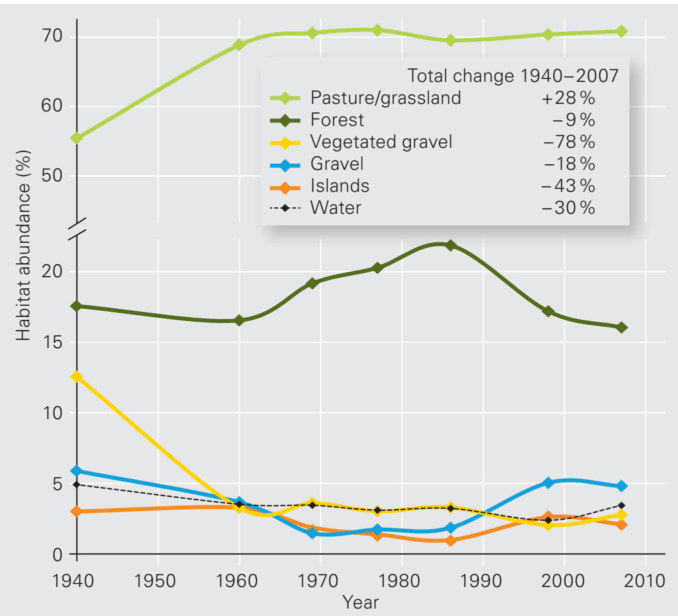


Fig. 5: Computer models can be used to simulate the socioeconomic and ecological consequences of various management scenarios for the Sandey floodplain. For example, it can be predicted how the opening of levees would affect land use, river networking and flow velocity.

Fig. 4: Changes of habitat abundance in the Sandey floodplain between 1940 and 2007. Data were derived from historical aerial images.



Impacts on ecosystem processes. We carried out field investigations of respiration rates – a proxy for carbon turnover – in the various habitat types. On the basis of habitat-specific respiration rates and the former extent of each habitat, we also calculated the historical carbon turnover. Comparison with current values revealed a significant shift in the total carbon budget for the floodplain over the last 70 years. These findings indicate that structural and functional floodplain properties can respond relatively rapidly to changes in the hydrological regime. The restoration of more natural hydrological dynamics could therefore enhance habitat heterogeneity and biodiversity, contributing to more natural floodplain ecosystem processes.

In a heavily used area such as the Sandey floodplain, changes to hydrological dynamics – brought about, for example, by the opening of levees – may be associated with increased flood hazards for humans and property. However, thanks to recent advances in landscape modelling, it is now possible to generate high-flow scenarios in conjunction with restored floodplain connectivity so as to simulate the rejuvenation of habitat features while minimizing risks of damage. By applying this model, we can assess which areas of the Sandey floodplain are likely to respond best, in ecological terms, to a high-flow management programme, with flood risks being kept to a minimum (Fig. 5). Initial results suggest that the opening of more side-channels could in fact reduce or mitigate the risks associated with more extreme high flows, while enhancing floodplain habitat heterogeneity and biodiversity.

The model can also be used to simulate how discharge is affected by climate change or changes in water use. The aim is to provide decision support for practitioners or policymakers in the planning of sustainable water management, ensuring a balance between ecological needs for floodplain functioning and the provision of socioeconomic services.

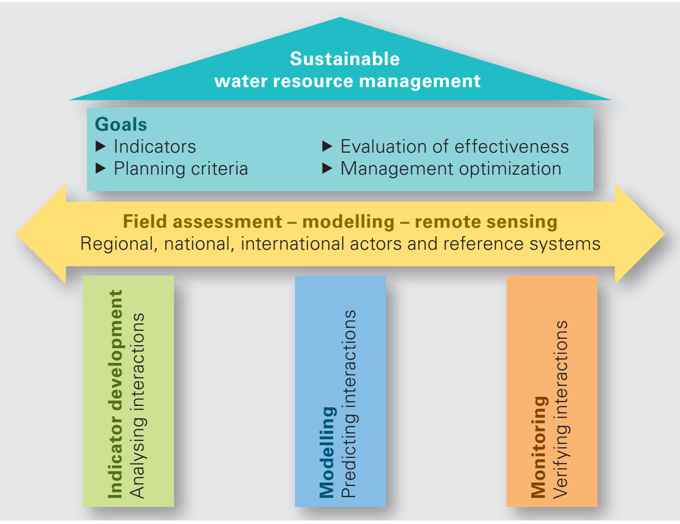
Importance of long-term monitoring. Sustainable water resource management is a complex task: as well as understanding the needs of freshwater ecosystems, the goal is to meet human demands for the goods and services provided by these systems without exceeding their overall carrying capacity. What requirements must be met if they are to remain intact and functional in the long term and thus capable of generating the services desired by humans?

The studies carried out on the Spöl and in the Sandey floodplain represent empirical and pragmatic approaches for achieving more sustainable water resource management, which recognize the complexity of the task and involve the relevant stakeholders (Fig. 6). The results obtained on the Spöl to date have been so convincing that experimental floods are now part of the regulatory framework for the river. In addition, the project has influenced similar experiments at the international level – e.g. on the Snowy River in Australia or on the Colorado River below Glen Canyon dam in the US. But the study also shows that long-term monitoring is essential for the assessment of changes and evaluation of the effects of management actions [6, 7].

The Sandey floodplain project has demonstrated how, with a combination of methods, changes can be quantified at the landscape scale and an integrative approach can be adopted to socioeconomic demands and ecological requirements. At the same time, the two studies have laid the foundations for a comprehensive monitoring programme involving remote sensing data. The aim is to evaluate the effectiveness and ensure the long-term success of restoration measures.

This broad, long-term perspective is essential for adaptive management and the restoration of freshwater ecosystems, so that it is possible to learn from unforeseen developments and, via an iterative process, move closer towards an optimal balance between ecological and socioeconomic needs. Water resource management should be considered a moral obligation vis-à-vis society and the environment, helping to assure the sustainability of ecosystem goods and services.

Fig. 6: An integrative approach to sustainable resource management: field assessment documents relevant parameters (indicators) in the study area, modelling simulates the effects of different management scenarios, and remote sensing permits long-term monitoring.



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Hydropower: potential for and limits to expansion

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Co-authors: Andreas Bruder, Armin Peter, Stefan Vollenweider

Switzerland's hydropower sector is facing billion-franc challenges. What is required to meet these challenges are economically and ecologically acceptable ways of optimizing peak-load production and storing surplus electricity from new renewable sources of energy. In both cases, the interests of Switzerland and Europe would be served – and ideally there could be benefits for aquatic ecosystems as well as the electricity sector.

Universal access to electricity may be taken for granted in Switzerland, but the planning of sustainable power supplies poses major challenges for policymakers throughout the world. This task has not become any easier since the Fukushima disaster in 2011. That same year, the Swiss Parliament and the Federal Council decided to phase out the use of nuclear power. What needs to be established now, as a matter of urgency, is how the future loss of capacity – around 24 terawatt-hours (TWh) per year – can be compensated for. The gap which will need to be filled over the coming decades by means of efficiency measures and new sources of energy is equivalent to 40 per cent of current electricity demand – and it continues to widen as a result of steadily rising consumption.

Realistically, there is a need for energy sources providing a total capacity of 30–40 TWh/year [1]. One option which might suggest itself is the use of fossil fuels to replace lost generating capacity. However, as Switzerland is committed to the emission-reduction goals of the Kyoto Protocol, alternative options must be sought among renewable energy sources such as wind, solar, geothermal or hydroelectric power. But what role can and should hydropower play in future energy provision?

The balancing function of hydropower. In Switzerland, hydropower is the main source of electricity production – accounting for more than 55 per cent of the total – but the remaining potential is limited. Estimates of the possible contribution of hydropower published by the Federal Office of Energy [2], the Swiss Association for Water Resources Management (SWV) [3] and environmental groups vary considerably. Realistically, net additional production could amount to around 1–3 TWh/year (Table 1). Allowing for the losses of production involved in complying with residual-flow requirements, the additional production resulting from operational optimizations and the construction of new large and small plants amounts to less than 10 per cent of current electricity generation [3]. Thus, hydropower cannot make up the future shortfall. As the potential contribution of wind power is limited and the future role of deep geothermal energy remains uncertain, it is clear that the largest contribution to the future electricity mix will have to come from photovoltaics.

Table 1: Potential for additional hydropower production [2–4].

Changes	Estimated potential (TWh/year)
Increased efficiency, optimization, renovation	1.0 to 1.8
New large plants	0.7 to 1.4
New small plants	0.7 to 1.7
Compliance with minimum residual flows	–2.0 to –1.4
Climate	± 0
Total	**0.5 to 3.5**

However, there are two ways in which hydropower can help to meet the huge challenges of electricity production in Switzerland and in Europe: (1) by providing energy at times of high demand (peak-load production) and (2) by storing energy at times of excess supply. With an installed peak capacity of 13.4 gigawatts (GW) and effective production peaks of around 10 GW, not only is Swiss hydropower extremely flexible and available at short notice, but – with an alpine storage volume of about four cubic kilometres – it also has a robust backbone for the provision of regulating and balancing power over a period of several months. Because in the past there was no significant overproduction of energy from stochastic sources in Europe (e.g. wind and solar energy, varying according to weather conditions and thus only partly predictable), only a few pumped-storage plants were constructed in the Alps for day/night load balancing. Here, major changes are to be expected in the near future, and Switzerland can make a significant contribution to the storage of surplus power from stochastic sources.

Hydropower for daily load levelling. If in the future more new renewable energy comes from wind (from Northern Europe) and from photovoltaics (from Switzerland), electricity production will become more irregular, with enormous daily – or even hourly – fluctuations in output (Fig. 1). How large will the excesses and deficits associated with the new renewables be, and how short the timescale of fluctuations? As a point of reference, we may take the above-mentioned shortfall in capacity of at least

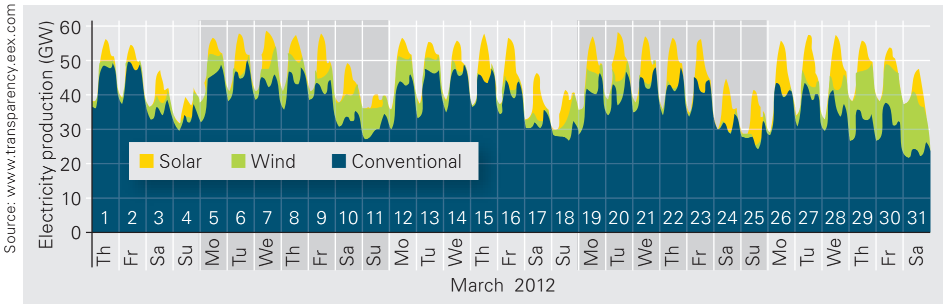


Fig. 1: Electricity production in Germany during the month of March 2012. Around midday on Saturday 31 March, electricity produced by wind and solar plants amounted to approximately 32 GW, i. e. more than 50 per cent of total electricity production. Pumped-storage plants should be able to absorb the surplus power generated at such times.

30 TWh/year, which ideally would be covered by photovoltaics. Practical experience in Germany suggests that the production of 30 TWh/year would require an installed peak capacity of around 40 GW [4]. Such a large proportion of photovoltaic energy would lead to short-term, weather-related fluctuations in output of up to 20 GW, which could not at present be fully compensated for by Swiss hydropower plants. While photovoltaic systems do offer the advantage that daily production maxima and minima largely coincide with the daily demand curve, and short-term fluctuations can be smoothed by smarter grids, it still appears likely that peak-load capacity will need to be increased.

If variation in the peak-load output of storage hydropower plants is further increased in the future – for example, owing to expansion of installed capacity – there will be massive fluctuations in discharges, particularly on weekdays, when turbined water is returned to rivers. These fluctuations lead to hydropeaking in downstream sections and thus to significant ecological impacts in the alpine rivers concerned (Fig. 2). Rapidly rising and high flow rates (surges) can destabilize the riverbed and wash away aquatic organisms such as insect larvae and small fish. This leads to a decrease in the abundance and biomass of these organisms and, ultimately, to changes in species composition (Table 2). As a result of declining and subsequently low flow rates, organisms (especially fish) may be stranded or restricted in their mobility. The abrupt start-up and shutdown of turbines and the huge variation in discharges thus produces a wide variety of adverse impacts on aquatic ecosystems and on the biocoenosis [5]. Especially for fish and macroinvertebrates, hydropeaking has devastating effects. The operation of pumped-storage plants, in contrast, does not involve hydropeaking, as rivers are not affected by exchanges between the lower and upper reservoirs.

Fig. 2: Example of hydropeaking on the Hasliaare, with a maximum/minimum discharge ratio of 10:1, typical of the winter months. Because of the higher baseflow, conditions are generally more favourable in the summer.

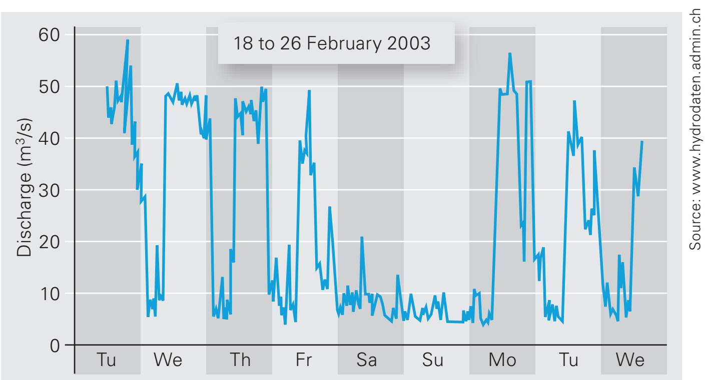
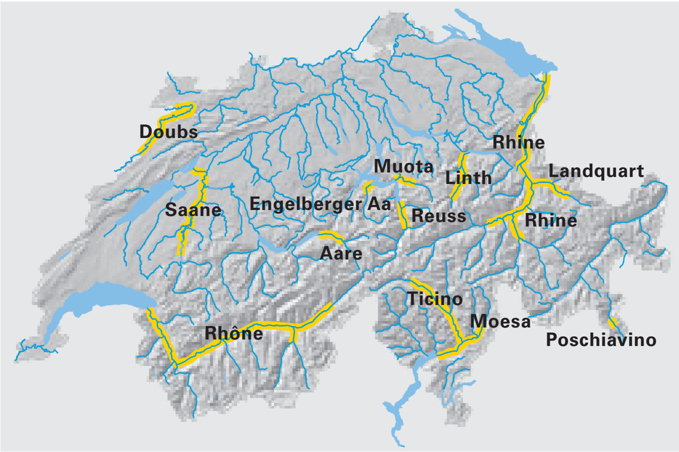


Table 2: Effects of hydropeaking.

	Phenomenon	Direct effects
Rapid rise in flow rate (surge)	Rapid increase in flow velocity	► Drift of aquatic organisms (exceeds compensatory upstream movements) ► Flight to low-current areas ► Wash-out of organic matter (resources)
	Mobilization of riverbed	► Mechanical damage ► Drift of aquatic organisms ► Removal of fine particles from upper sediment layer ► Increased turbidity
	Input and transport of suspended particles	► Increased turbidity ► Increased physiological stress ► Mechanical damage (skin and gills) ► Abrasion of organisms ► Reduced photosynthesis
During high flows	Shifting of bed layers	► Mechanical damage to substrate-dwelling organisms ► Reduced bed clogging
	Change in water temperature	► Drift of aquatic organisms ► Change in activity
	Change in geochemical composition of river water	► Exposure of organisms to different concentrations of oxygen, nutrients, and organic and inorganic content
Rapid fall in flow rate	Increase in dewatered area	► Stranding of organisms (drying-up, freezing of exposed areas and spawning redds) ► Trapping of organisms (unsuitable habitats)
	Rapid decrease in flow velocity	► Sedimentation of suspended particles ► Clogging of riverbed
During low flows	Reduced surface area, reduced water depth	► Usual residual-flow problems: altered water quality (reduced habitats and continuity, water temperature)
High variability in flow rates	Unnatural flow regime	► Altered morphology ► Changes in macroinvertebrate and fish behaviour



Source: Swiss Association for Water Resources Management

Fig. 3: Map of the most important river reaches subject to hydropeaking, mainly concentrated in the lower catchments of tributaries above prealpine lakes. Severely affected rivers include the Rhône above Lake Geneva and the Alpine Rhine above Lake Constance, as well as the Ticino, the Saane and the Doubs.

Measures to mitigate hydropeaking. Rivers subject to hydropeaking are to be found throughout the Alps, but the extent of affected reaches is striking in Switzerland, especially above prealpine lakes (Fig. 3). In view of the scale of the impacts and the upward trend in hydropower use, the Swiss Parliament decided – with the adoption of the revised Water Protection Act in 2010 – that substantial adverse impacts of hydropeaking operations are to be mitigated in future. The more stringent legal requirements are to be met primarily by means of structural measures, while operational measures are also possible on a voluntary basis. The cantons are currently developing a strategic remediation plan, which is to be coordinated with other measures (restoration projects) in the catchment, and they will subsequently order mandatory remediation steps.

Fig. 4: Visualization of a potential stilling basin [8]. Visible in the foreground (top right to bottom left) is the Hasliaare, which is joined by the Gadmerwasser at Innertkirchen. With a retention volume of around 50,000 cubic metres, the basin should allow the hydropeaking ratio to be reduced from 8:1 to 5:1.

Structural options for the mitigation of hydropeaking include stilling basins and equalizing reservoirs (Fig. 4). Whereas small stilling basins can moderate rising and falling – but not peak – flow rates, equalizing reservoirs have a considerably greater volume, so that maximum and minimum flows can be controlled by daily or weekly levelling. The extent and costs of the structural measures needed were estimated in a study commissioned by the Swiss Water Association (VSA) [6]: assuming a specified hydropeaking ratio of 5:1, the retention volumes required for the various main alpine rivers – Rhine, Rhône, Reuss, Aare, Ticino and Inn – ranged from several hundred thousand to several million cubic metres. The area of land required amounts to dozens of hectares, varying according to whether levelling is to be carried out on a daily or weekly basis or over a period of several months.

Equalizing reservoirs could additionally serve as small lower reservoirs of pumped-storage plants, thus providing further load-levelling capacity for intermittent new renewables. If the equalizing reservoirs were sufficiently large, stochastic wind or solar energy could be stored in higher-elevation reservoirs for a number of hours. Equalizing reservoirs on the order of several million cubic metres are, however, likely to encounter opposition because of the amount of space required. But they will be necessary if peak-load output is increased at existing plants where turbined water is released directly into a river.

Pumped-storage plants for longer-term balancing. Apart from equalizing reservoirs with pumping facilities, what will be needed above all to help compensate for fluctuations in new renewable energies will be additional newly constructed pumped-storage plants. Switzerland currently operates 14 mostly small pumped-storage plants, with a total installed pumping capacity of 1.4 GW (Table 3). This is a mere drop in the ocean, given the scale of the stochastic fluctuations to be expected within the European grid. Accordingly, various projects are at the planning stage or under regulatory review in Switzerland. Three large plants are currently under construction.

Do pumped-storage plants with alpine reservoirs represent an environmentally sound solution? Pumped-storage operations between existing reservoirs or using a very large prealpine lake as the lower basin can mitigate impacts on natural waterbodies, as long as pumps are appropriately equipped to prevent fish entrainment. Adverse impacts on fish have, however, been reported at the Geesthacht pumped-storage plant on the Elbe River, for example. A particularly critical view should also be taken of any mixing of the hydrology and freshwater ecology of different catchments. The use of small lakes as basins is to be avoided for ecological reasons (fluctuations in water levels, changes in temperature and turbidity). Here, the size of Lago di Poschiavo can be considered a borderline case [7]. The major ecological advantage of pumped-storage plants lies in the fact that peak production can be increased without causing additional hydropeaking impacts.

According to Table 3, when nuclear energy has been phased out, Switzerland could have a total installed pumping capacity of approximately 6 GW, which would comfortably suffice for daily and weekly balancing and additionally offer a service for Europe.

Existing			Total 1460
Grimsel 2	352	Ova Spin	52
Hongrin-Léman	256	Handeck	48
Mapragg	159	Zermeiggern	46
Robiei	157	Mottec	36
Nestil	140	Chatelard-Barbarine	32
Ferrera I	90	Sambuco-Peccia	24
Etzelwerk	54	Rempen	16
Under construction			**Total 2140**
Hongrin-Léman/Veytaux II, 2015	240	Nant de Drance/Emosson, 2017	900
Linth-Limmern/Muttsee, 2015	1000		
Under regulatory review			**Total 1630**
Lagobianco (Val Poschiavo)	1000	Grimsel 3 (KWO Plus)	630

Table 3: Installed pumping capacity (in megawatts) of Switzerland's existing and planned pumped-storage plants.

However, this capacity is not sufficient to provide a buffer for several weeks of very cold, hot or dry conditions, let alone for seasonal balancing. Nonetheless, electricity system services could generate considerable profits for the water industry, which could then be ploughed back into the necessary ecological compensation measures.

Hydropower expansion for seasonal balancing? If we assume that Switzerland will mainly use photovoltaics to compensate for the loss of nuclear energy, the question arises whether (existing) hydropower capacity could also meet seasonal balancing requirements. The German experience shows that spring and autumn account for around 50 per cent of total annual production of solar power, with summer 40 per cent and winter 10 per cent. For Switzerland, this means that photovoltaics would produce a surplus of 4–5 TWh in the summer, which would be lacking in the winter. This amount of energy could not realistically be stored with the existing storage volume, as this is already needed today for seasonal balancing. A rough calculation suggests that an additional volume of around one cubic kilometre would be needed to accommodate this additional amount of energy. This is roughly equivalent to the entire storage volume available in Canton Valais, with the huge reservoirs of Grande Dixence, Mauvoisin and Emosson. It is obvious that the construction of new reservoirs on this scale – new capacity could also be created by increasing the height of existing dams – would be highly controversial.

Research on sustainable water resource use. Given this vision for the development of hydropower, numerous practical questions arise concerning the ecologically acceptable conditions for peak-load production and energy storage. What changes – in terms of discharge and riverbed impacts – are to be aimed for in the remediation of river stretches subject to hydropeaking? How are stilling basins and equalizing reservoirs to be designed so as to make pumped storage and weekly balancing worthwhile? What are the minimum requirements – in terms of temperature, turbidity, water level fluctuations and fish habitat demands – which are tolerable for lower-elevation waterbodies used in pumped-storage operations? A research agenda involving goals of this kind is to be elaborated as soon as possible (see page 26).

Conclusions. In the future, by means of peak-load production and pumped storage, hydropower could play a key role in the integration of electricity from stochastic sources into the European grid. These modifications to Switzerland's hydropower – which could ideally lead to a win-win situation – will require billion-franc investments: (1) for the expansion of photovoltaics and (2) grid capacity, (3) for new pumped-storage plants and (4) the expansion and construction of alpine reservoirs, and (5) for stilling basins and equalizing reservoirs. While weekly balancing of supply and demand for electricity is achievable at a realistic cost, new alpine reservoirs are necessary for seasonal balancing. If this proves unacceptable to society, either fossil-fuel power plants or additional wind farms abroad will be needed to ensure secure supplies in the winter.

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Researchers and practitioners need to work hand in hand

In Switzerland, water researchers and practitioners are facing major challenges. According to Bernhard Wehrli, a member of the Eawag Directorate, these challenges can only be met in the coming years if researchers and water professionals join forces. By launching the "Swiss Rivers" applied research programme, Eawag intends to strengthen its links with partners across the water sector.

Interview: Andres Jordi

One of the three areas Eawag's research is focusing on is "Water for Ecosystem Function". Are Switzerland's aquatic ecosystems "functioning" as they should? The quality of our surface waters is good – Switzerland has made considerable progress on that front; in fact, with the recent publication of the Federal Council's plan to reduce inputs of micropollutants, the country is now among the pioneers. But unfortunately the same cannot be said of river habitats, which are heavily degraded as a result of flood protection structures and hydropower operations. That creates barriers to fish migration and has adverse effects on natural spawning. The implementation of measures to remediate residual-flow stretches is behind schedule. As long ago as 1992, the federal government required the cantons to ensure adequate residual flows, so as to mitigate the ecological impacts of hydropower generation. Here, the large Alpine cantons still have a lot to do. In most cases, they won't manage to complete implementation by the specified deadline of 2012.

We still lack a sound data base for aquatic biodiversity.

Doesn't that put a damper on the hopes attached to the latest revision of the Water Protection Act? The problem with residual-flow remediation is that measures have to be implemented in a cost-neutral way and cantons sometimes even have to forgo revenues from hydropower. But under the revised legislation, funding is available for restoration projects or for measures to mitigate the impacts of hydropeaking. Thanks to the fiscal equalization system and a levy on electricity transport, new money will be flowing into the cantons' coffers. For that reason, I'm optimistic that implementation will proceed more rapidly.

Won't implementation come under pressure if hydropower has to be expanded as nuclear energy is phased out? That is indeed a new issue which needs to be addressed. The Federal Office of Energy wants hydropower production to be increased by around 10 per cent. Apart from the optimization of existing facilities, half of the additional power is to come from large plants and half from small plants. The construction of certain large hydropower plants certainly makes sense. But new small plants in particular – of which quite a lot would need to be built – would run counter to the aim of improving river continuity and connectivity, and have major adverse impacts on aquatic habitats. Today, Switzerland is already using 90 per cent of its hydropower potential. It also needs intact river stretches so as to preserve biodiversity and ecosystem function. Here, there is a serious conflict of interests.

How can it be resolved? A good platform for constructive discussions is provided by the "Water Agenda 21" network, where all the players active in the water sector are represented – from Eawag and the authorities, through the water management industry, to environmental groups. In my view, it would also be useful if cantons assigned priorities to river stretches: where are additional uses possible, where should protection take precedence, and where do competing interests need to be weighed up? That would make it possible to avoid unnecessary efforts and reduce the number of disputed sites.

What else do researchers need to address? We still lack a sound data base for aquatic biodiversity. For water protection measures, biodiversity is always cited as an important goal, but it's not clear what exactly this comprises: what kind of diversity should be protected and where? How can this be achieved? Which species become established when we enhance habitats – is it in fact the rare, valuable organisms? It's also desirable to have a monitoring programme which captures biodiversity at the genetic level. Research can contribute to this by developing appropriate concepts and methods. Because the cantons have territorial rights over waterbodies, monitoring data is often patchy and not readily available. It would be important to make this data easier to access both for the public and for researchers.

But in the future there also needs to be closer cooperation between the fields of hydrology and biology. We don't yet know enough about how aquatic habitats function, or about the interaction between river morphology and organisms. But it's essential to understand the workings of these systems so as to ensure that remediation or restoration measures produce the maximum possible ecological benefits.

How can these deficiencies be remedied? In view of the challenges arising in connection with the revised Water Protection Act and the phase-out of nuclear energy, Eawag is currently developing a "Swiss Rivers" research programme. The aims of this programme include filling gaps in our knowledge of river restoration and fish migration, and promoting the development of more environmentally friendly hydropower generation. For example, while we know how to build fish ladders which enable fish to migrate upstream, downstream migration remains problematic. In these efforts, we'll be attaching particular importance to close collaboration with practitioners and applicability in the field.

Who will you be collaborating with? One key partner is the Federal Office for the Environment (FOEN), which supports us in our endeavours. Especially for knowledge transfer, we want to cooperate closely with the Swiss Water Association (VSA). The fishing community – as "lay researchers" – also play an important role. They know the rivers, and their feedback can help to define scientific objectives more sharply. We'd also like to involve the Water Agenda 21 stakeholders. In the research sector, Eawag will be pursuing its existing close collaboration with the Laboratory of Hydraulics, Hydrology and Glaciology (VAW) at the ETH Zurich, the Laboratoire de constructions hydrauliques (LCH) at the EPF Lausanne, and the Federal Institute for Forest, Snow and Landscape Research (WSL). Another partner is the Hydrological Commission (CHy) of the Swiss Academy of Sciences.

What's the timetable for these activities? At the moment, we're looking for a Programme Director, who'll be responsible for coordination and organization. We want someone with a scientific background and a lot of practical experience. They'll be responsible, above all, for transferring findings to practice. The programme is to begin at the end of 2012 and will run initially for three years, with a prospect of an extension. A time frame of six to eight years is necessary to establish and strengthen the network.

How is the programme being financed? There are various sources of funding. Eawag in partnership with the FOEN will provide the basic funding for the new position of Programme Director. The FOEN mainly finances practice-oriented projects; for questions of a scientific nature, the Swiss National Science Foundation can of course be approached. Certain projects could also be financed via the Commission for Technology and Innovation – the federal innovation promotion agency – in cooperation with the private sector. Lastly, through its internal funding programme, Eawag can help to get studies off the ground or provide additional support.

How can you ensure that findings are transferred to practice? My own experience of applied research projects has shown that

Peter Penicka

it's very helpful to collaborate directly with private-sector professionals. That way, you discover what practitioners really need and what problems they're confronted with. The practitioners, in turn, can easily access research findings. In the "Swiss Rivers" programme, the sharing of knowledge and experience is to be guaranteed by regular training events. We're very interested in receiving feedback from practitioners and we're dependent on open channels of communication: we want to hear about people's needs and concerns. From that point of view, "Swiss Rivers" aims to offer practitioners an open door. Very little time is available for planning and implementing the tasks we face. It can only be done by working hand in hand.

We want to hear about the needs of practitioners.

In brief

Agenda

Courses

3–4 October 2012, Eawag Dübendorf
Evaluation von ökotoxikologischen Tests

31 October – 2 November 2012, Eawag Dübendorf
VSA-Eawag-Kurs: Messen – Regeln – Überwachen in der Abwasserreinigung

7–8 November 2012, Eawag Dübendorf
Nanomaterialien in der aquatischen Umwelt

Events

28–29 June 2012, Eawag Dübendorf
1st European Conference on the Replacement, Reduction and Refinement of Animal Experiments in Ecotoxicology

14 September 2012, Empa Academy, Dübendorf
Herausforderungen einer nachhaltigen Wasserwirtschaft

22 November 2012, Landhaus Solothurn
5. Fachtagung ChloroNet

Further information: **www.eawag.ch/veranstaltungen/index_EN**

Just published

In May 2012, the Federal Council opened the consultation procedure on the revision of the Water Protection Act. Under this amendment, the upgrading of selected wastewater treatment plants for micropollutant elimination is to be financed on a nationwide basis according to the "polluter pays" principle. Eawag played a key role in developing and evaluating the concept and measures for the reduction of micropollutants from pharmaceuticals and chemicals. The findings have now been published by the Federal Office for the Environment, together with an English summary: **Micropollutants in municipal wastewater.** The report shows that water quality can be significantly improved by using advanced treatment processes such as powdered activated carbon adsorption or ozonation. http://tinyurl.com/micropoll-bafu

Factsheets and publications

On its website, Eawag publishes factsheets on a variety of topical issues. Recent additions to the series deal with "Water and energy", "Hydropower and ecology" and "Rainwater usage". **www.eawag.ch/medien/publ/fb/index_EN**

A database of all publications by Eawag researchers (including article summaries) is available online at: **www.lib4ri.ch/institutional-bibliography/eawag.html**
Open access publications can be downloaded free of charge.

New head of Process Engineering

At the start of 2012, **Eberhard Morgenroth** took over as head of the Process Engineering department. An environmental engineer, he studied at Hamburg University of Technology (TUHH) and the University of California. Having gained his PhD at the Technical University of Munich, he served as Assistant and then Associate Professor in the Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign. Since 2010 he has been Professor of Urban Water Management at the ETH Zurich. www.eawag.ch/forschung/eng/index_EN

Swiss Water Partnership

In February 2012, the **Swiss Water Partnership** was launched in Bern by representatives of 45 Swiss organizations from the spheres of government, research, private enterprise and civil society. This association aims to strengthen the international profile of the Swiss water sector and to create synergies between its members' activities. Representing Eawag on the Steering Board is Christian Zurbrügg, Director of the Department of Water and Sanitation in Developing Countries (Sandec).
www.swisswaterpartnership.ch

Awards

In 2012, the **Fundación Sodis** in Bolivia received a UN "Water for Life" Best Practices Award. This non-profit organization, founded by Eawag and the Swiss Agency for Development and Cooperation, promotes water and sanitation solutions in Latin America. Over the last eleven years, it has provided training on solar water disinfection (Sodis) for more than a million people, and it now also addresses hygiene and environmental sanitation issues. www.fundacionsodis.org

Fundación Sodis

Environmental microbiologist **Thomas Egli** has been honoured by the Swiss Gas and Water Industry Association (SVGW) for his research in the field of microbiological analysis of drinking water. SVGW President Mauro Suà compared Egli's pioneering use of flow cytometry to the invention of a "thermometer" for water supplies.