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D9.2 Case Study 7 Report

Biodiversity management for rivers of the Swiss Plateau

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642317.

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Table of Contents

Figures

About AQUACROSS

The project 'Knowledge, Assessment, and Management for AQUAtic Biodiversity and Ecosystem Services aCROSS EU policies' (AQUACROSS) aims to support EU efforts to protect aquatic biodiversity and ensure the provision of aquatic ecosystem services. Funded by Europe's Horizon 2020 research programme, AQUACROSS seeks to advance knowledge and application of ecosystem-based management (EBM) for aquatic ecosystems to support the timely achievement of the EU 2020 Biodiversity Strategy targets.

Aquatic ecosystems are rich in biodiversity and home to a diverse array of species and habitats, providing numerous economic and societal benefits to Europe. Many of these valuable ecosystems are at risk of being irreversibly damaged by human activities and pressures, including pollution, contamination, invasive species, overfishing and climate change. These pressures threaten the sustainability of these ecosystems, their provision of ecosystem services and ultimately human well-being.

AQUACROSS responds to pressing societal and economic needs, tackling policy challenges from an integrated perspective and adding value to the use of available knowledge. Through advancing science and knowledge; connecting science, policy and business; and supporting the achievement of EU and international biodiversity targets, AQUACROSS aims to improve ecosystem-based management of aquatic ecosystems across Europe.

The project consortium is made up of sixteen partners from across Europe and led by Ecologic Institute in Berlin, Germany.

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1 Introduction and background

1.1 Problem statement

Throughout Europe, rivers have been heavily modified to increase so-called ecosystem services, such as flood protection, agricultural production or hydropower generation. These modifications include the construction of weirs and dams, channelization and modifications of floodplains for agricultural and urban use. This has led to morphological river degradation, reduction in lateral and longitudinal connectivity, to modified flow regimes and water pollution, but also to a loss of habitats and biodiversity, as well as a decrease of other ecosystem services such as recreational and aesthetic value. We developed methods to identify an ecosystem-based management plan to improve the management of biodiversity in rivers in the Swiss Plateau by maximising the ecological state within the constraints posed by other societal objectives in accordance with the AQUACROSS Assessment Framework (Deliverable 3.2).

1.1.1 Challenge

So far, efforts to rehabilitate river sections, reduce the impacts of hydropower plants, improve water quality by constructing wastewater treatment plants and decrease pollution from agriculture have shown many positive local effects. These improvements, however, were not yet able to revert the trends of declining habitat loss and biodiversity in Swiss rivers. This raises the question of whether water management could be improved to lead to larger positive effects on habitats and biodiversity. The goal would be to further raise the ecological status of the system with the same budget with a gain in "synergistic" ecosystem services (such as flood protection and recreational and aesthetic value) and without a considerable restriction of human activities, which are important of society but can have negative impacts on the ecosystem (such as hydropower generation and agricultural production).

1.1.2 Objective

In this study, we try to quantify the current state of knowledge on the dominant cause-effect relationships regarding the decrease in ecological status and biodiversity in rivers in the Swiss plateau. Furthermore, we use this knowledge to identify river management strategies that can be expected to have positive effects on the ecological state and biodiversity of rivers in the Swiss plateau, while also increasing the provision of some ecosystem services without significantly decreasing others. These objectives are addressed in close collaboration with stakeholders, primarily professionals from governmental agencies in the field of surface water protection, to profit from their knowledge and creativity and to support the design of alternatives that may have the potential of being implemented in Swiss river management plans.

1.1.3 Research Aims

In order to fulfil these objectives, we address the following research aims:

1. to quantify the current state of scientific knowledge about cause-effect relationships between natural and anthropogenic influence factors and the ecological status and biodiversity in rivers in the Swiss plateau;
2. to support the spatial planning of environmental management of river catchments in the Swiss plateau to improve the ecological status and taking into account the provision of ecosystem services.

1.1.4 Characterisation

The Swiss plateau (Figure 1.1), an area of ca. 11,000 km^2, is encompassed by the Jura Mountains in the North-West and the Alps in the South-East. It is the most densely populated region of Switzerland, covering about one third of the total area and inhabited by about two thirds of the population (on average about 380 inhabitants per km2). Land cover is heavily influenced by humans, with about 48% agricultural area, 23% forest, 19% urban settlements and 10% covered by surface waters.

1.1.5 Policy

The Swiss Water Protection Legislation (Gewässerschutzgesetz, GSchG, Gewässerschutzverordnung, GschV) states the main impairments to Swiss freshwater ecosystems and regulates the implementation of management alternatives. These include the structural restoration of stream and river habitats, the removal of barriers to enhance connectivity within stream networks, and the upgrade of wastewater treatment plants to remove micropollutants. The Swiss Biodiversity Strategy (Strategie Biodiversität Schweiz) foresees the conservation and restoration of biodiversity in general. Furthermore, we take into account a national action plan to reduce the current ecological risks of plant protection products from agriculture (Aktionsplan zur Risikoreduktion und nachhaltigen Anwendung von Pflanzenschutzmitteln).

As Switzerland is not part of the European Union, it is not legally obliged to comply with EU policy. However, its environmental legislation still strongly links to EU environmental policies. For example, the targets set by the Swiss legal system for water protection and management is comparable to those defined for EU Member States by the WFD. Nevertheless, the Swiss legislation differs from EU policy as it sets binding requirements including a set of national limits which must be met at all times, whereas the WFD is assessed within planning periods with targets set for these periods (EEA, 2010).

Furthermore, the Swiss Biodiversity Strategy (Strategie Biodiversität Schweiz) states that it is applying the Aichi Biodiversity Targets and the resulting EU Biodiversity Strategy to 2020. Hence, Switzerland is directly linking its national Strategy to the EU Strategy.

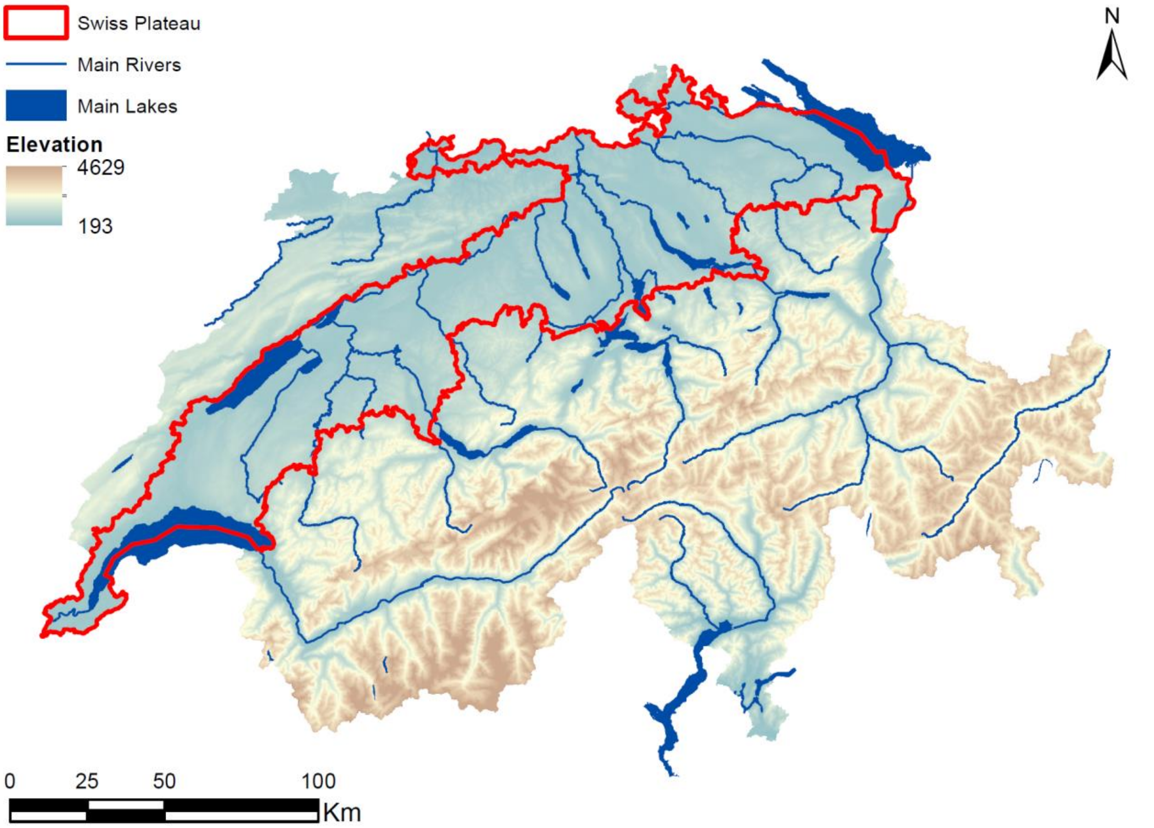

Figure 1.1 Map of Switzerland with main rivers and lakes, colours indicate height above sea level; the red line shows the perimeter of case study 7, the Swiss Plateau.

1.1.6 Stakeholders

An overview about important groups of actors for river management in Switzerland are given in Fig. 1. Our approach is driven mostly by policy, which has been agreed on at the political level, with support from the general public. Therefore, we consider our main stakeholders to be those responsible for planning the implementation of this policy. These stakeholders belong to both the federal level, as well as the cantonal level (the Cantons are the political first level subdivision of Switzerland). We consulted the federal stakeholders in three yearly meetings to get feedback on the policy situation, objectives, and scenarios and preliminary results. In addition, our approach is based on existing procedures to assess the ecological state of surface waters in Switzerland at the river reach scale. These assessment methods were developed in a long-term collaboration between representatives from the Federal office for the environment, from cantonal authorities responsible for surface water monitoring and management, consulting companies, and research institutes (including the authors). We extended these methods and discussed proposed extensions in bilateral meetings with representatives from cantonal authorities. In addition, The Federal Office for the Environment and cantonal authorities provided the monitoring data for the case study.

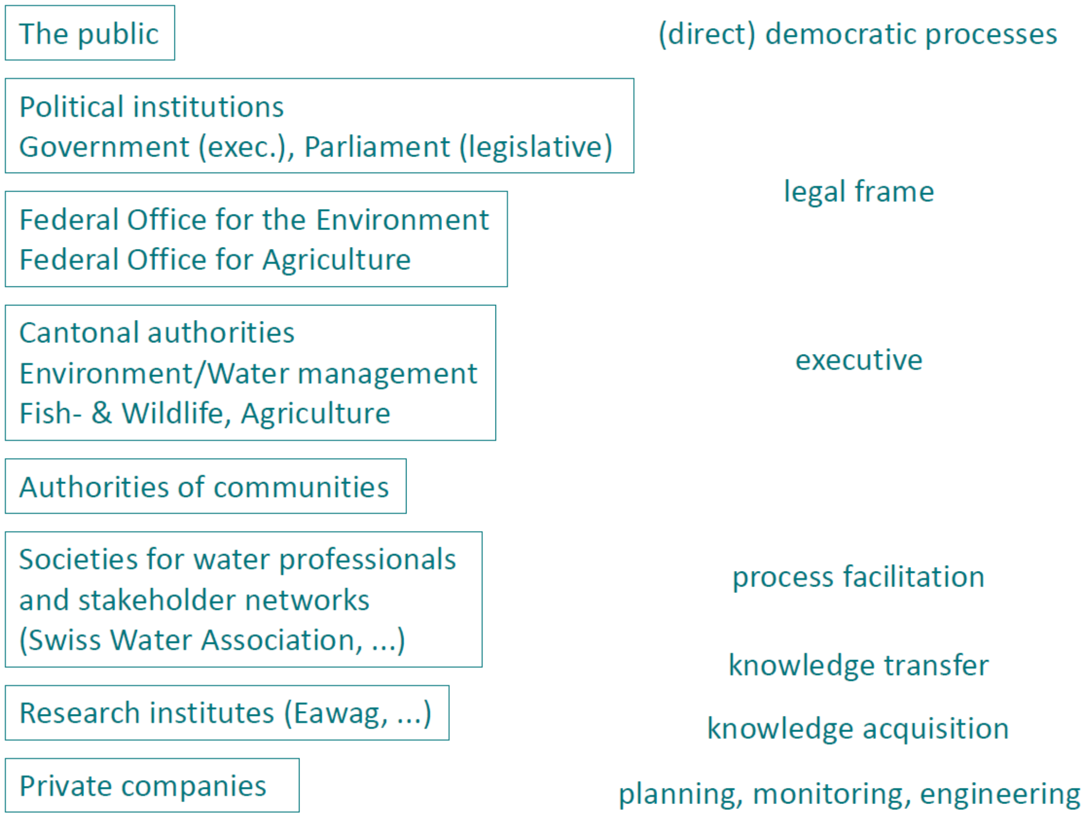

Figure 1.2 Overview about important actors/stakeholders for river management in Switzerland.

1.1.7 Approaches

To address our first research aim, we consider aquatic macroinvertebrates, as these are key aquatic organisms for biodiversity monitoring and assessment of the ecological status in Switzerland (Michel et al., 2017) and the EU (Birk et al. 2012). We construct a statistical model of the dependence of the occurrence of macroinvertebrate taxa on natural and anthropogenically modified environmental influence factors. This model is based on a combination of information about habitat requirements of macroinvertebrate taxa from existing trait databases and observed data. With this approach, we aim to assess the predictive power of the model based on existing trait knowledge. In addition, we can update and complement the existing knowledge by inferring habitat requirements from the observed data. This can stimulate the improvement of biological indices for ecological assessment. We will investigate to which degree we can expect to see effects of different human impacts on biodiversity and ecological status based on the current state of data availability and knowledge.

The second research aim is addressed by analysing the properties of the stream network in the Swiss plateau at the spatial scale of river catchments. The assessment of the ecological status of river reaches is mostly based on existing Swiss assessment methods for surface waters (http://www.modul-stufen-konzept.ch), which include abiotic (hydromorphology, water quality) and biotic components (macroinvertebrates, fish, diatoms). These methods assess the ecological state of river reaches (i.e. sections of the river network) or sites. However, to support the spatial planning of management strategies, we need spatial criteria at the catchment scale that can integrate biotic and abiotic components at the reach scale and allow for spatial integration to describe the ecological status of the whole catchment. To this end, we propose spatial criteria that take into account the resilience and connectivity of the ecosystem, e.g. regarding fish migration. The reach scale assessments serve as input to the catchment scale assessment. Based on the availability of data, all or only selected abiotic or biotic components of the reach scale assessments can be included to calculate the catchment scale criteria. This flexibility is important to ensure that catchment scale criteria can be applied across the Swiss Plateau.

We apply these catchment scale criteria to selected catchments in the Swiss plateau to evaluate their current state and to analyse current deficits. Based on feedback from representatives of the Federal Office for the Environment, we developed scenarios for different management strategies based on current policies. We then explored potential effects of these management strategies on the ecological state of the catchments and potential implications for other management objectives such as budget constraints and the provision of ecosystem services. During stakeholder meetings, we presented and discussed preliminary results leading to a revision of spatial criteria and management scenarios.

1.2 Solutions proposed

Compared to a baseline of current policy, we propose and assess ecosystem-based management plans. These EBM management plans differ from baseline by accounting for the principles of EBM (Gómez et al 2016). In particular, regarding the joint consideration of ecological/biodiversity aspects and ecosystem services, the scale of consideration (catchment scale, political boundaries, across the whole plateau), stakeholder participation and policy coordination. With this in mind, we summarize the current state of knowledge about important causes for biodiversity and habitat loss dealt with in the Swiss Plateau, as well as their co-benefits and trade-offs to ecosystem services.

1.2.1 Opportunities

The management strategies proposed in Swiss policies aim at improving the ecological status of surface waters through morphological river restoration and removal of impairments by barriers. The cantonal authorities supported by the Federal Office for the Environment developed a strategy for a spatial prioritisation of these rehabilitation measures based on budget constraints imposed by current policy decisions. These strategies serve us as a baseline. We estimate the effect of these baseline strategies for different socio-economic scenarios. To develop EBM strategies, we consider the same budget constraints, but also consider ecosystem service flows, and search for a spatial arrangement of rehabilitation measures that maximises the ecological state of the catchment (applying the proposed spatial criteria).

2 Establishing objectives

2.1 Identifying policy objectives

2.1.1 Management objectives and attributes measuring their fulfilment

The Swiss Water Protection Law (Gewässerschutzgesetz, GSchG) was put into effect to protect the water bodies from impairments due to excessive use. In particular (among other objectives), it requires the conservation of natural habitats for plants and animals, the protection of surface waters as landscape elements and for recreational use, and the support of the natural water cycle. On the other hand, it allows sustainable water use for drinking water provision and for irrigation in agriculture. The Water Protection Ordinance (Gewässerschutzverordnung, GschV) sets more concrete goals for the ecological state, water quantity and quality, and discharge of wastewater.

While these regulations set the water management legal framework, current water management is strongly guided by more concrete action plans that deal with measures to achieve the overarching goals. Of particular importance are the following action plans:

- **Enforcement plan for the rehabilitation of rivers** (Vollzugshilfe Renaturierung der Gewässer) and corresponding strategic plans for restoration, supporting fish migration, reducing hydropeaking, and supporting gravel transport:
  Goal: Rehabilitation of one quarter of the degraded rivers within the next 80 years, installation of infrastructure for fish migration and support of gravel transport at hydropower plants.
- **Extension of sewage treatment plants to better eliminate micropollutants**:
  Goal: Adding an additional treatment step to selected sewage treatment plants to more completely eliminate micropollutants.
- **Action Plan for the reduction of pesticide pollution from agriculture** (Aktionsplan zur Risikoreduktion und nachhaltigen Anwendung von Pflanzenschutzmitteln).:
  Goal: Reduce pollution of water bodies with pesticides from agriculture by 50%.

In addition, there are more generally formulated plans to support ecosystems, such as the Swiss Biodiversity Strategy (Strategie Biodiversität Schweiz), which supports conservation and restoration of biodiversity in general and aims to achieve the same targets defined by the EU Biodiversity Strategy, as stated in the Swiss Strategy text. The specific actions plans listed above contribute to achieving these goals.

As mentioned in chapter 1.1.5 above, the Swiss Water protection Law (Gewässerschutzgesetz, GSchG) is based on similar targets as defined by the EU WFD. However, Switzerland’s ambitions to target micropollutants through its extension of sewage treatment plants is going beyond what is requested by WFD quality standards and therefore Switzerland is exceeding EU policy in this regard.

A good river management strategy has to balance various policy goals, including costs, compliance with regulations, and various ecosystem services (e.g. drinking water production, agricultural food production, hydropower generation, flood protection, recreation, waste- and storm water disposal, carbon sequestration). In particular, trade-offs between costs, provision of ecosystem services, and maintaining or re-establishing a good ecological state of surface waters and their biodiversity are relevant. In the setting of this case study, these trade-offs have to a large degree been decided politically by establishing and financing the action plans listed above. For this reason, the main challenge of this case study is to support the development of combinations of measures that maximise the ecological state of the catchment resulting from the investment. The basic measures will be listed in section 2.1.2 before, in collaboration with the stakeholders, establishing a procedure to find the optimum combination of measures for each catchment to optimise its ecological state within the given budget constraint.

2.1.2 Management alternatives (EBM measures) considered

In the present case study, the types of management measures to be implemented have been predefined by the action plans listed in section 2.1.1. According to these plans, the following management measures are considered in the baseline and the proposed EBM solutions:

- **Ecological restoration of stream sections**: Out of the roughly 15,000km of stream networks in Switzerland that are considered to be in a bad ecological state, approx. 25% will be subject to restoration measures in the next 80 years with planning periods of 20 years that are revised every 12 years. Financing of the measures (bound to certain restrictions) has been guaranteed for the full time period. The initial focus is on resorting a near-natural morphology and hydrology that encourages and facilitates the recolonisation of a rich and diverse fauna and flora (Göggel, 2012).
- **Reducing impairments by barriers**: The Swiss law strives to re-establish the migration corridors for fish, both up and downstream (Könitzer et al., 2012). There is a large variety of infrastructure in river networks, which obstruct the free passage of migrating fish, including hydropower dams, and a large number of smaller drops and weirs. The most common restoration measures are fish ladders and diverse designs of artificial bypasses. However, these require some volume of water, reducing the river discharge available for other purposes (hydropower, abstraction).

  Sediment transport is also modified through barriers. Such modifications in riverbed load budget are to be corrected according to Swiss law (Schälchli & Kirchhofer, 2012). Diverse management alternatives are possible, ranging from alternative procedures in the operation of dams to structural changes to large barriers such as dams. A further side effect of large dams is the alterations to the hydrological regime due to their operation. Usually these include considerable and sudden changes in river discharge, from very low flows, to very heavy flows (hydropeaking). This has a significant effect on the biota of freshwater ecosystems. Planned restoration of rivers in Switzerland considers reducing the effects of hydropeaking through the construction of additional infrastructure (i.e. retention basins) or through improved operation (i.e. reducing the flow peaks) (Baumann, Kirchhofer & Schälchli, 2012).

- **Upgrade of wastewater treatment plants (WWTP)**: Many different polluting organic substances present in municipal WWTP effluents contribute significantly to water pollution. With the current infrastructure, WWTPs are not capable of removing these pollutants. The concrete management measure is to add a treatment step such as powdered activated carbon adsorption or ozonation to some (ca. 15%) of the larger existing WWTPs in Switzerland (Abegglen & Siegrist, 2012).
- **Reduction of pesticide pollution from agriculture**: Agrochemicals are used for different purposes in agriculture (pesticides, herbicides, fungicides), but have negative impacts on ecosystems and biodiversity. The Swiss legislation aims to reduce the risks associated with their usage by 50%. The goals specifically aim to protect freshwater ecosystems, proposing the reduction of river sections not complying with water quality standards by 50%, as well as reducing potential risks to organisms by 50%. A large number of measures is proposed to achieve this goal, many of which relate to either abstaining from or reducing the use of agrochemicals. Other measures suggest a safer usage of the chemicals. In general terms, the goal is to lower pesticide usage and reduce pesticide emissions (Aktionsplan Pflanzenschutzmittel, 2016).

The challenge for the development of the EBM solutions in this case study is to develop restoration strategies that optimally combine these measures to maximize the ecological state of catchments under the given budget constraint.

2.2 Co-design

As mentioned above, in this case study, the funding for improving the rivers has already been decided and the challenge is to find the combination of measures that maximises the ecological state by combining measures under the given budget constraint.

Such a maximization can only be done if the ecological state of the rivers can be quantified as a function of ecosystem attributes. As such a quantification requires ecological knowledge as well as subjective judgment, it has to be co-developed by partners from authorities, consulting, non-governmental organisations, and scientists. This aligns with the principles of EBM, which call for transparent management and stakeholder engagement (Deliverable 3.2). We describe below how this was done for river reaches (sections) and catchments (which are networks of river reaches).

2.2.1 Ecological valuation at the river reach scale

Procedures for the ecological assessment of river reaches (sections) have been co-developed by partners from the Federal Office of the Environment, cantonal authorities, consulting companies and scientific institutes in an ongoing long-term collaboration with several working groups and expert panels. Fig. 2.1 summarises the key elements of the structure of the Swiss procedure for stream assessment (http://www.modul-stufen-konzept.ch).

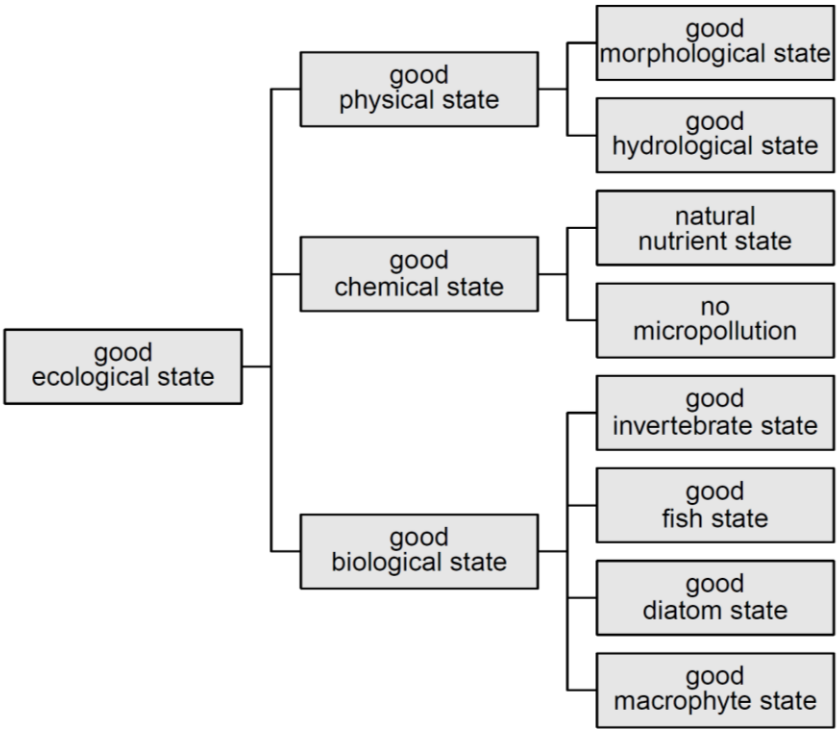

Figure 2.1 Objectives hierarchy for the good ecological state at the reach scale (modified after Haag et al., in press). The objectives at the lowest level of the hierarchy (i.e. right side) correspond to assessment modules, which already exist or are currently under development (www.modul-stufen-konzept.ch).

The fulfilment of the objectives at the lowest level is described with measurable attributes (not shown in the figure) and assessed using multi-attribute value theory (Reichert et al. 2015). A value function links the attribute level to a universal scale from 0 (objective not fulfilled) to 1 (100% fulfilment of the objective). The fulfilment of the higher-level objectives is then calculated by aggregating the values of the lower level objectives. For this study, the original formulation of the assessment modules has been "translated" to this decision-oriented framework and extended for micropollutants, a module that is not yet finally developed. Note that the biological modules include measures of biodiversity.

2.2.2 Ecological valuation at the catchment scale

Restoring one quarter of the degraded rivers within 80 years obviously requires spatial prioritisation. River reach scale ecological valuation is important but not sufficient for this task. A major innovative element of this case study is to propose an assessment method to quantify the ecological state of catchments (river networks). It consists of ecological objectives, measurable attributes and value functions, as described in the previous section. Because the catchment scale assessments are spatially explicit, we also refer to them as spatial criteria. The spatial criteria are based on the reach scale assessments, which are used as input. Figure 2.2 illustrates the suggested objectives hierarchy (Kuemmerlen et al., in press). These proposed spatial criteria were already discussed in bilateral meetings with a few representatives from cantonal authorities and the Federal office for the Environment. However, it would still need a wider consultation of practitioners and experts until they may become part of the Swiss assessment methods and used for strategic planning.

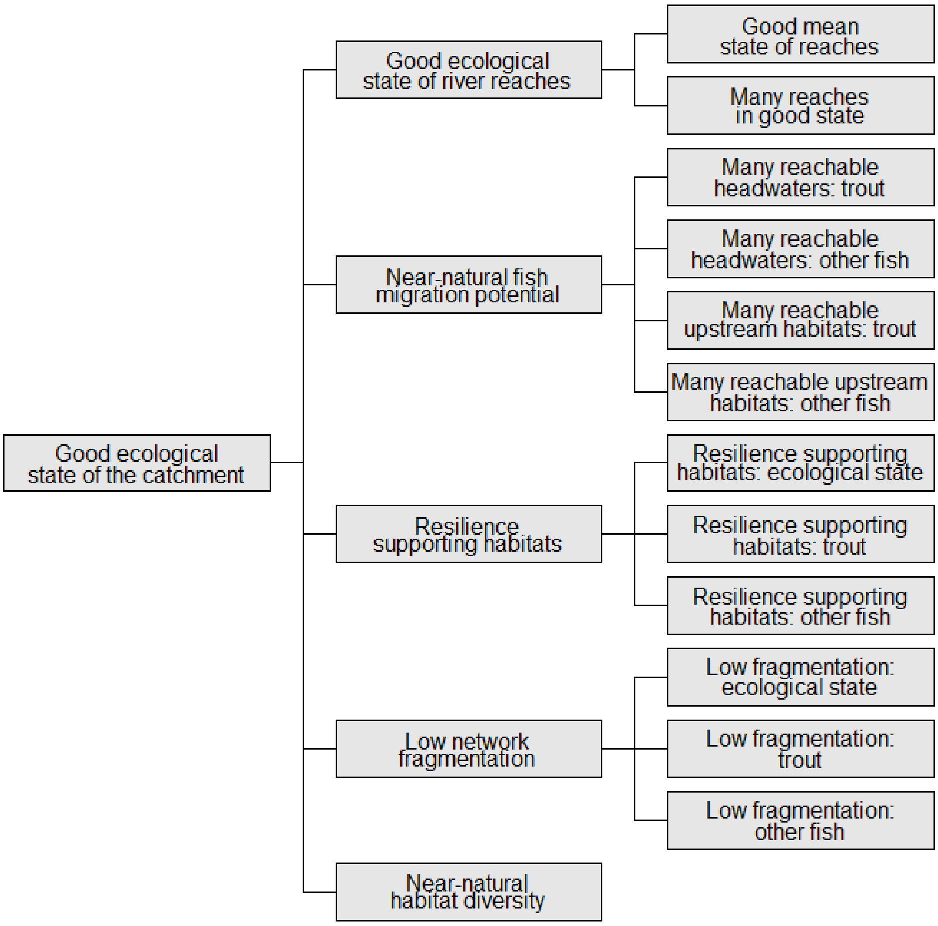

Figure 2.2 Objectives hierarchy for the good ecological state of a river network, from Kuemmerlen et al. (in press).

As these spatial criteria are a new element in the ecological assessment of rivers (Kuemmerlen et al., in press), we describe the objectives in detail.

The good ecological state of a catchment is described by the following sub-objectives:

Good ecological state of river reaches

The good ecological state of a catchment depends on the ecological state of all river reaches (sections) in the catchment. We propose to quantify the mean ecological state of the river reaches with a weighted average that takes into account the length and stream order of each river section. In addition, we consider the fraction of river reaches that are in a good state (value $>= 0.6$, which means that legal requirements are fulfilled.).

Attributes: weighted mean state and fraction of river length in a good state

As described in section 2.2.1 before, the ecological state of a river section is defined by the physical, chemical and biological state (Fig. 2.1), in accordance with the Swiss modular concept for stream assessment (SMC; Bundi et al. 1998). Combining the three different aspects should yield an integrative and more robust assessment.

Near natural fish migration potential

The presence and distribution pattern of fish communities in a natural catchment is largely defined by the connectivity between its tributaries. Anthropogenic barriers like drops and weirs impair the connectivity. We value the reachability of headwaters and the size of the reachable upstream region.

Attributes: Number of the headwaters that can be reached without having to move over a weir or drop higher than a given threshold and without having to move more than 50 m through a culvert, divided by the number of headwaters that could be reached if there were no artificial drops or weirs. Length of the reachable upstream sections divided by the length of the sections that could be reached under natural conditions (without artificial barriers). We distinguish two threshold heights of 0.5 m for trout and of 0.1 m for other fish.

Resilience supporting habitats

Sections in good and very good ecological state are more likely to promote a good overall ecological state in the catchment, if they are adjacent to each other, because larger ecosystems in a good state are more resilient against disturbance.

Attribute: Sum of the lengths of connected parts of the stream network in good or very good ecological state, l_i, divided by the product of the total length of the river network, l_{tot}, and the order of the sub-network in good state, i, if these subnetworks are ordered in sequence of decreasing size: $\sum_i l_i/(i \cdot l_{tot})$.

Stream sections in good state are still counted as adjacent if they are separated by a stream section in a worse state that is shorter than 50 m.

We distinguish three different sub-objectives just based on a good ecological state (e.g. for invertebrates) or additionally consider fragmentation by barriers of the two heights mentioned above.

Low network fragmentation

Some organisms may migrate between regions of good state in the sense of “Resilience supporting habitats”. For this reason, we also quantify regions in good state that are not further apart than 2 km. The implementation is analogous to the resilience supporting habitats just with replacing the threshold length of reaches in bad state of 50 m by 2 km.

Near-natural habitat diversity

Each catchment is unique in its combination of different types of streams: small catchments will likely contain fewer different stream types than large ones. Here we acknowledge these differences by expressing how much of that diversity of stream types is actually in a good ecological state.

Attribute: ratio of the river type diversity considering only sections in a good ecological state and river type diversity of all sections in the catchment, based on River Typology for Switzerland (Schaffner et al. 2013).

2.2.3 Optimisation

Extending the valuation of river ecosystems from the river section to the catchment scale allows us to search for the combination of measures (within the budget and other constraints) that maximises the ecological state at the catchment scale. The quantitative formulation of the catchment-scale objective thus allows us to identify optimal combinations of measures.

3 Description of the socio-ecological system

The Swiss Plateau has a very high demand for ecosystem services, of which some are in synergy (such as recreation or flood protection) while others are in conflict with ecosystem functions (such as hydropower use or land use for agriculture). There is an increased interest in restoring the ecosystem and its functions, leading to frequent monitoring, providing abundant data that make this analysis possible. However, as population continues to increase, land-use conflicts may become more frequent.

This can be analysed based on the concept of social-ecological systems by applying the AQUACROSS linkage framework (Teixeira et al., submitted; Borgward et al., submitted). The social side (i.e. demand side) describes social drivers of human activities that place pressures on the ecosystem state, which affect and are affected by the ecological-side (i.e supply side), which consists of ecosystem components and biodiversity supporting ecosystem functions that deliver ecosystem services, ultimately fueling drivers (D3.1).

3.1 Demand-side

3.1.1 Linkage Framework

The society-ecosystem interaction was characterised by identifying all pressures possibly triggered by human activities in the area within CS7 (Teixeira et al., submitted; Borgward et al., submitted). A total of 35 pressures potentially relevant to the Swiss Plateau were identified, each assigned to one of five pressure categories (physical, exogenous, energy, chemical & biological; Figure 3.1). These pressures stem from 45 different human activities, which were linked to 16 ecosystem components, considered to be affected by them. Here, the social system is represented by activities, ranging from agriculture (e.g. livestock grazing and crop farming) to recreation (e.g. usage of riverbed). The ecological system was defined based on the EUNIS habitat classification scheme (EEA, 2017), which in CS7 was described by two river habitats (lentic & lotic, including benthic biota) and eight habitats corresponding to the floodplain (wet grasslands) and other vegetation found in riparian areas (various grass- and woodland areas). In addition, the biodiversity components were represented by six highly mobile biota groups (Insects, Fish & Crayfish, Amphibians, Reptiles, Birds and Mammals) that inhabit one or several of the aforementioned habitat types.

The impact risk of individual activity-pressure combinations on ecosystem components and biodiversity was considered to be dependent on their dispersal, persistence, severity, frequency and extent. In an attempt to account for these factors, activity-pressure combinations were assigned weights for each one of these aspects. The impact risk is calculated as a factor of a spatial exposure, a temporal exposure and a severity value. Being a simple multiplication, each one of these elements is equally important for the impact risk. (see Annex 1). This means that exposure scores will be high if one or both of their constituents has a high value. In summary, the activity-pressure-component matrix linkages express a complex set of assumptions which consider spatial and temporal aspects, combined with their perceived severity.

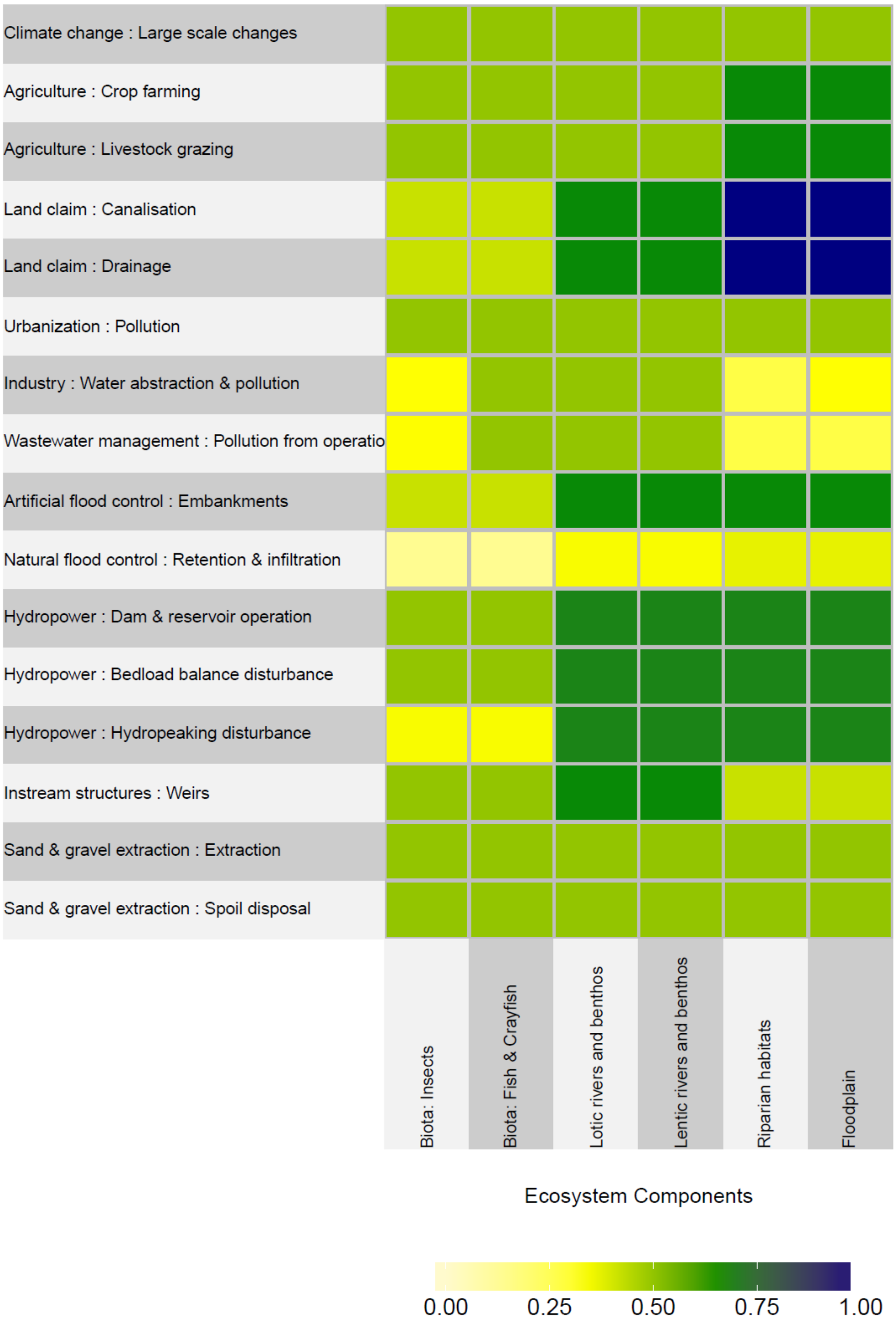

Figure 3.1 Impact risk from selected activities and their pressures with assigned weights based on extent, dispersal, exposure, Frequency and persistence.

Current efforts by the federal authorities, cantonal authorities and NGO's mostly address nutrient enrichment, contamination from micropollutants and structural (morphological) modification of streams and rivers (e.g. channelization and network connectivity). Many efforts are being implemented, as they have already received backing through recent policy changes and substantial financial support from the federal and cantonal governments. However, as shown in Fig. 3.1, additional relevant activities are those that generate pollution through diffuse or point sources, such as agriculture, manufacturing and urbanisation, in addition to activities associated with infrastructure that modify or impair natural river structure including artificial flood control, hydropower generation and instream structures.

To quantify the effects of water quality, hydromorphology and temperature on the macroinvertebrates (which are an important part of biodiversity in streams, due to their central position in the food web), we developed a trait-based joint species distribution model. The model makes use of prior knowledge of species' habitat requirements from ecological trait databases and monitoring data from a federal monitoring program (Vermeiren et al., in prep). While the different invertebrate taxa respond very differently to the various pressures, we found most pronounced effects from water quality and temperature (Vermeiren et al. in prep). For further analysis related to improving the restoration strategy in Switzerland, we pay particular attention to the physical, chemical and biological state of rivers at the reach scale, as well as to the ecological state at the catchment scale.

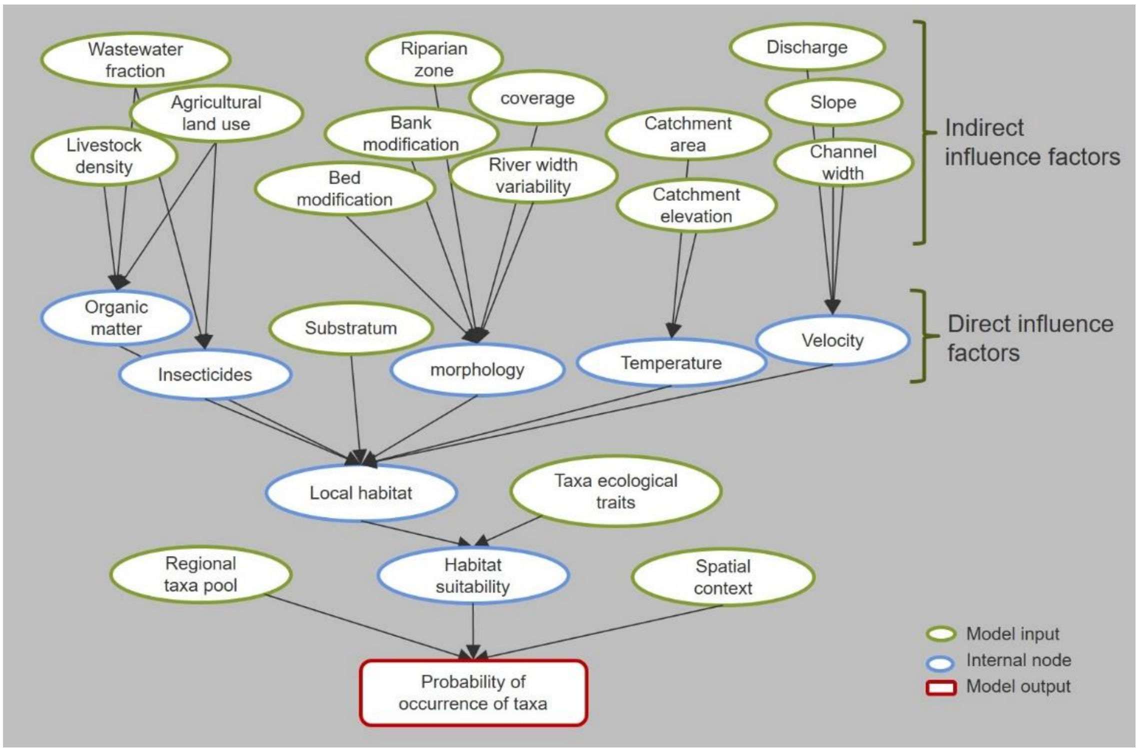

Figure 3.2 Schematic representation of the trait-based species distribution model for macroinvertebrate taxa (Vermeiren et al. submitted).

3.2 Supply-side

3.2.1 Case study-specific analysis: Biodiversity-Ecosystem-functioning (EF)-Ecosystem services (ESS) indicators, indices, and metrics

Based on our specific research objectives, the same six ecosystem components that were selected for the activity-pressure-component matrix (see Chapter 3.1.2; all riparian components summarized into a single one), were used in the specific assessment for both ecosystem functions and services (Fig. 2.1B).

This analysis has the potential to determine, which ecosystem components supply the most functions and services, but could also be used to explore where possible knowledge deficits are. These could be further explored in future research efforts. For this case study in particular, it may help pinpoint functions and services, which have not been accounted for previously and which could enhance the relevance of the results for conservation and policymaking.

3.3 The ecological system: links between the "supply" and "demand" side

From the selected ecosystem components and the weights assigned to the supplied ecological services and performed ecological functions, we conclude that both types of river habitats (lotic & lentic rivers), as well as the floodplain, including their benthic fauna and flora, play an important role for ecological functions and services (Fig. A2.2).

Moreover, the regulation or enhancement of ecosystem services through management such as restoration measures, has the potential to affect – among others – one or more ecosystem components. These effects, known as trade-offs and co-benefits, can arise from many activities utilising the ecosystem services and are plentiful. A detailed inventory was beyond the objectives of this study. Nevertheless, Table 3.1 shows potential interactions in the form of trade-offs and co-benefits along with an illustrative example, between the utilisation of ecosystem services and the ecosystem components relevant to this study. Future efforts aiming at re-establishing ecosystem services through restoration measures, need to be aware of trade-offs and co-benefits, evaluate them exhaustively and include them in the strategy formulation. An example of a trade-off is the production of drinking water, which may have negative effects on ecosystem components, if it leads to a lowering of the groundwater table. A co-benefit is exemplified by measures implemented to increase the attractiveness of rivers for recreation (e.g. recreational fishing), that may also have positive effects on ecosystem components.

					Ecosystem components					
				Example	Biota: adult insects	Biota: fish & crayfish	Lotic rivers & benthos	Lentic rivers & benthos	Wet grassland (floodplain)	Riparian habitats
Biologically mediated	Provisioning	Energy	Biomass	Extraction of wood					-	-
			Mechanical	n.a.						
		Materials	Biomass	Organic sediments		-	-	-	-	-
		Nutrition	Biomass	Recreational Fishing		±				
	Regulation	Maintenance	Lifecycle	Seed dispersal			±	±	±	±
			Disease control	Pest control	±	±				
			Soil formation	Weathering processes			±	±	±	±
			Water conditions	Chemical condition regulation			±	±	±	±
			Climate regulation	Temperature & humidity regulation			±	±	±	±
		Flows	Solid	Erosion buffering			±	±	±	±
			Liquid	Water flow buffering			±	±	±	±
			Gaseous	Carbon fixation			±	±	±	±
		Waste Mediation	Biota	Bio-remediation of substances	-	-	-	-	-	-
			Ecosystems	Fixation of substances			-	-	-	-
	Cultural	Interactions	Experiential	Health promoting activities	±	±	±	±	±	±
			Intellectual	Education facilitation	±	±	±	±	±	±
		Spiritual	Spiritual	Religious meaning		±				
			Other	Bequest value	±	±	±	±	±	±
Abiotic outputs	Provisioning	Energy	Renewable	Surface water energy			-	-		
			Non-renewable	n.a.						
		Materials	Water	Surface water as material			±	±	±	
			Metallic	Mineral substances as material						
			Non-metallic	Sand extraction			-	-		
		Nutrition	Water	Surface water for nutrition			±	±	±	±
			Mineral	n.a.						
			Non-mineral	n.a.						
	Regulation	Maintenance	Physico-chemistry	Regulation of inorganic processes			±	±	±	±
		Flows	Flows	Regulation of baseline flows			±	±	±	
		Waste mediation	Waste mediation	Dilution			-	-	-	
	Cultural	Interactions	Experiential	Health promoting activities			±	±	±	±
			Intellectual	Education facilitation			±	±		±
		Symbolic	Spiritual	Religious meaning			±	±		
			Other	Bequest value			±	±		

Table 3.1 Trade-offs [-]; co-benefits [+] and their combination [±] between the exploitation of ecosystem services and the protection/restoration of ecosystem components

Two important caveats apply to the interactions shown in Table 3.1. They do not account for the magnitude of the effects of exploiting ecosystem services, which may vary among the different habitat components. Also, they only illustrate direct links. Integrated management of rivers has to go further, considering the potential alternatives to the services mentioned above. For instance, if hydropower generation is to be reduced, alternative sources of electricity would have to be proposed, (e.g. electricity generation from fossil or nuclear -power sources), which could have even worse effects on ecosystems.

3.4 Assessing the knowledge base of the ecological system

The objective of the restoration strategy implicitly targets an aquatic community that is able to perform all functions and services expected from a healthy system. The assessment implemented here considers entire catchments and evaluates their ecological state based on the state of its river reaches. Specifically, the focus lies on four individual catchments, representing independent ecosystems. The insights gained on the specific objective from these should be applicable to all of the Swiss Plateau.

Restoration measures in the Swiss Plateau will be planned in stages, following the established cycles of planning and implementation (12 to 20 years). The approach implemented here can be used to evaluate restoration strategies under specific assumptions and scenarios (e.g. approximate restoration costs; population growth). Several such assumptions and scenarios will be tested to gain some insight into the sensitivity of the approach to uncertain future conditions.

The present approach does not evaluate each reach and barrier separately, but searches for optimal combinations among all reaches and barriers in a catchment and given a fixed budget that lead to the highest ecological benefit. While the approach focuses on river reach restoration and barrier removal, the catchment assessment takes into account complementary management measures such as the planned upgrade of the largest wastewater treatment plants and a pesticide usage reduction plan. Models will be run with and without these additional measures, to determine the importance of an integrated watershed management approach, in the context of developing strategic plans for freshwater ecosystem restoration.

4 The baseline and future scenarios

The aim of case study 7 is to evaluate the effect of diverse river restoration and water quality management measures. The main goal is to improve the ecological state of the freshwater ecosystem at large scales, while taking into account the costs of restoration measures and possible ecosystem service trade-offs.

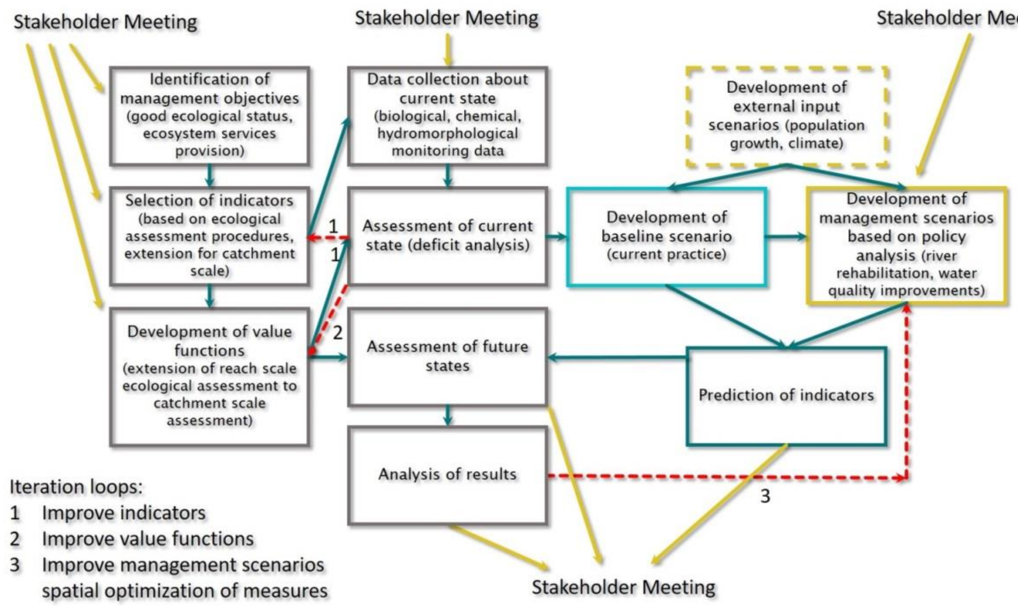

Figure 4.1 Workflow of model analysis (dark blue) and scenario development (baseline in light blue, policy/management scenarios/strategies in yellow) based on stakeholder input (yellow) for CS 7

4.1 Identifying gaps between baseline and objectives

The current ecological state of the four catchments at the Swiss plateau, evaluated by five spatial criteria, is poor to bad (Kuemmerlen et al., submitted). The current deficits in water quality and hydromorphology lead to a moderate to good mean state of the river reaches in the Mönchaltorfer Aa (Figure 4.2). The fragmentation of the longitudinal connectivity of the river network by many barriers and the low adjacency of river reaches in a good state lead to large deficits regarding fish migration potential and a reduced resilience capacity of the ecosystem.

The strategic planning for river restoration has been delivered by the cantons for the next 20 years and will be updated every 12 years. The result from the first strategic planning period will serve as a baseline management scenario (Figure 4.3), against which we compare the proposed optimised river restoration scenarios. According to our assessment, only the objectives "near natural habitat diversity" and "low fragmentation based on the ecological state" will reach a good or high state in the baseline scenario.

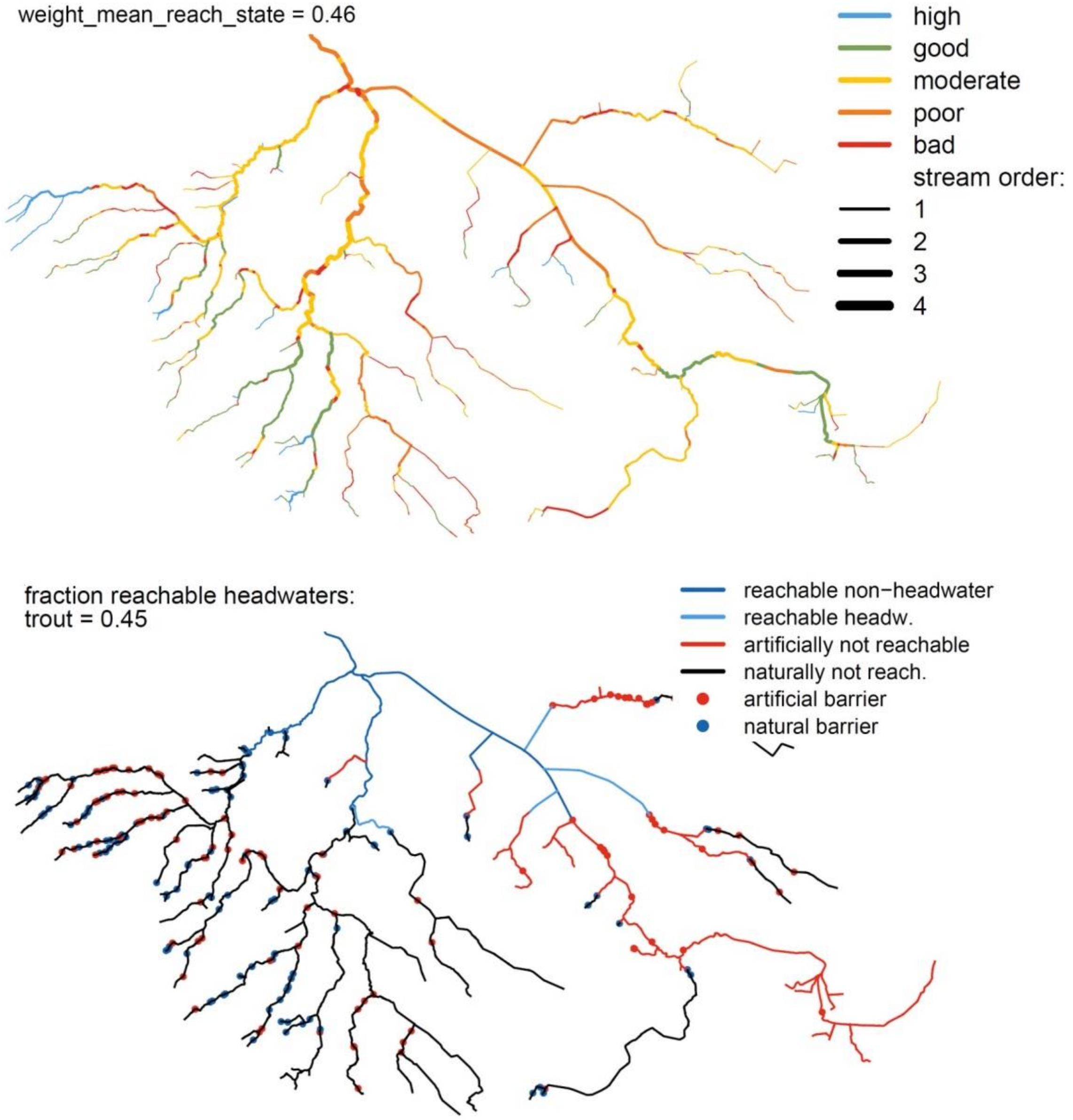

Figure 4.2: Mean ecological state based on water quality and hydromorphology (left panel) and fish migration potential for trout (right panel) of the current state of the Mönchalter Aa catchment in the Swiss plateau (from Kuemmerlen et al., submitted).

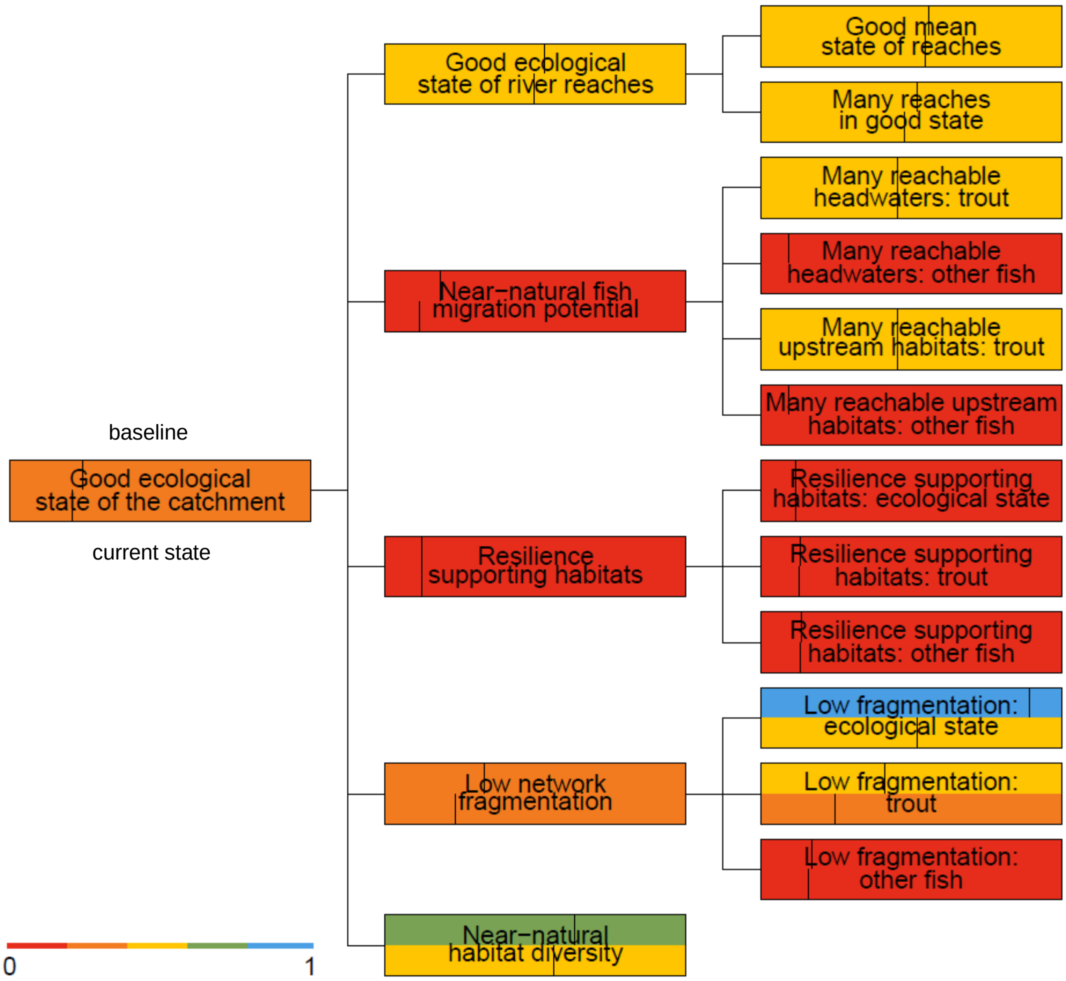

Figure 4.3 Baseline scenario for the Mönchaltorfer Aa catchment assessment for the year 2035 considering cantonal strategic planning, population increase external scenario and complementary management measures (upper half of the boxes) versus current state (lower half of the boxes); black vertical lines indicate the value between 0 and 1 on a horizontal scale, see legend on the lower left; colour coding indicates quality classes (see caption Fig. 4.2).

4.2 Scenario development

We expect the local management measures to improve the ecological state of a stream reach, which in turn improves the ecological state of the catchment it is part of. However, the fulfilment of the spatial criteria will largely depend on the location of rehabilitation actions in the stream network, because the spatial criteria aggregate the properties of the individual reaches to a summarised catchment assessment. This allows us to re-assess the state of a catchment again, once a series of management measures is assumed to be implemented, to analyse the ecological state reached by thethe management strategy under particular external input scenarios.

Several prioritisation strategies are being discussed with stakeholders who are responsible for the cantonal strategic planning for river rehabilitation. These strategies include the optimisation of each of the spatial ecological criteria (see Kuemmerlen et al., submitted) separately and in combination. In addition, several restrictions are considered based on other societal management objectives related for instance to the conservation of infrastructure, and the exclusion of ground water protection zones.

The management measures that will be evaluated are: (a) morphological restoration of stream reaches, (b) the removal of barriers, (c) the upgrade of wastewater treatment plants to remove micropollutants, (d) reduction of the impact of pesticide usage from agriculture by 50% (see chapter 5.1 for more details). Our goal is to optimise the management of freshwater ecosystems by assessing different management strategies for prioritising the locations of rehabilitation measures, under future external input scenarios (e.g. population growth). Particular focus will be given to the assessment of the ecological state at the catchment scale.

One management scenario is evaluated and compared against the baseline scenario. Both scenarios are have the time horizon 2035 and assume population growth of 21% (external scenario; BFS, 2016), a 50 % reduction in the usage of agricultural pesticides (management measure; Bundesrat 2017), an upgrade of the most important wastewater treatment plants (management measure). The difference between both scenarios lies in the restoration strategy: the baseline scenario takes into account the restoration strategy defined by the canton of Zürich (HOLINGER AG, 2015), while the scenario implementing the EBM strategy consists of an optimised restoration strategy computed using the catchment assessment approach.

5 Ecosystem-based management plan evaluation

5.1 Detailed specification of relevant EBM solutions

According to the guideline for strategic planning of the Federal Office of the Environment (Göggel 2012), the current strategy for prioritising river sections to be restored is based on an individual evaluation of the rehabilitation potential of each river reach. The rehabilitation potential of a reach is assumed to be large if the morphological state is moderate to bad and rehabilitation would not be constrained by infrastructure, like roads and buildings. In a second step, it considers the ecological potential and importance for the landscape based on e.g. protected areas, rare species, which increase or decrease the priority for rehabilitation. In a third step the benefits for nature and landscape are assessed against the potential costs and synergies with flood protection, recreational value and requirements of space are considered.

Our suggested EBM inspired approach goes several steps further than the current strategy. First, spatial criteria that define the ecological state of whole catchments were developed based on the spatial arrangement of river reaches in good or bad ecological state (based on an integrated assessment of hydromorphology and water quality) and migration barriers. We then prioritise reaches to be restored (and barriers to be removed) by searching for combinations that optimise these spatial criteria. While automatically searching for optimal solutions, we consider constraints imposed for instance by a limited budget and due to infrastructure and ground water protection zones. With this strategy, we can consider the combined effect of all restoration measures that shall be implemented in a given period.

To consider water quality, we developed a simple model based on the land-use in the catchment of interest and the fraction of treated wastewater in the river network. This model allows us to extrapolate the chemical state from a few reaches, where measurements are available, to the whole catchment. The river-network-wide availability of this data enables us to consider scenarios for water quality management, such as the reduction of pesticide inputs from agriculture and the upgrade of wastewater treatment plants to remove micropollutants. It also allows us to consider external input scenarios of socio-economic development regarding population growth and land-use changes for the baseline as well as the management scenarios. This facilitates the coordination between water quality management and morphological rehabilitation, even though the funding and implementation of these measures are based on sectoral policies, which aligns with the EBM principle of supporting policy coordination and integration (D3.2).

In line with Piet et al (2017), we pre-screen EBM measures to ensure they fulfil the criteria of ecological sustainability, technological feasibility, financial feasibility, economical efficiency, ethical defensibility, cultural inclusivity, legal permissibility, and effective communicability. However there exist some reservations regarding political expedience and administrative achievability of river rehabilitation measures. While the decision for river restoration in Switzerland was based on a democratic process, in some cases there exists opposition against the implementation of local rehabilitation measures, mainly due to the potential loss of agricultural land. Furthermore, the implementation is slowed down in some cases due to personnel limitations at the cantonal agencies responsible for project planning and rehabilitation measures implementation and due to difficulties with land acquisition.

5.2 Setting the evaluation criteria

In the following, we develop the example of one of the four catchments investigated: the Mönchaltdorfer Aa, located in the canton of Zürich. Our focus lies on the cantonal restoration planning currently under implementation, which outlines the measures to be taken during the first planning period between 2015 and 2035 (HOLINGER AG, 2015).

We evaluate the effect of the restoration strategy, in addition to complementary restoration measures (e.g. pesticide usage reduction) on the possible future state of the catchment. Furthermore, using our tool for catchment assessment, we search for optimal combinations of reaches to be restored and barriers to be removed. The goal is to learn from the exercise and improve decision making in the future, particularly when following phases begin and new restoration measures have to be planned beyond the year 2035.

5.2.1 Evaluating effectiveness

The main objective is to attain a good ecological state at the reaches that are subject to an ecological restoration measure. Such measures target the morphological properties of the river channel, previously modified through anthropogenic impairment, in an effort to return them into a near-natural state. However, this is frequently insufficient as other aspects may be deficient, preventing a good ecological state to be reached (e.g. high nutrient concentrations). The approach implemented here builds on the ecological assessment of individual reaches and can be used to assess whether restoration serves the purpose of raising the ecological state of the reach to a good state. Figure 5.1 shows for the Mönchaltdorfer Aa that the baseline strategy is effective in improving the ecological state of most of the restored reaches through morphological restoration and improvement of the micropollutant state. This result highlights the importance of complementary management measures to attain the objective of a good ecological state.

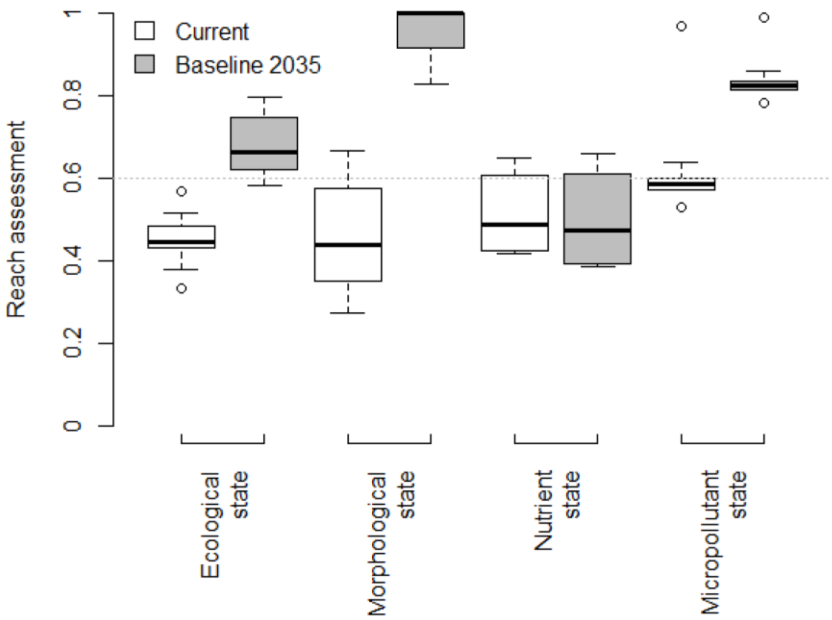

Figure 5.1 Boxplots showing the ecological, morphological, nutrient and micropollutant state for 33 river reaches of the Mönchaltdorfer Aa catchment, in the current and the baseline scenario.

Moreover, the proportion of good reaches in the catchment (Annex 2) can be used as an indicator of effectiveness at the catchment scale. If there is an increase of reaches in good ecological state, one of the main goals of the restoration program will be reached.

5.2.2 Evaluating efficiency

Efficiency is evaluated in terms of the improvement in ecological state at the catchment scale for a given budget. In the particular case of the case study Swiss Plateau, the investment by the government (at the federal, cantonal and local levels) is relatively fixed. A particular budget is allocated for a 20-year planning period in order to implement a number of management measures. However, in our approach we intend to find alternative implementation plans for the management measures, which do not exceed the budget, but which can maximise the positive impact of the restoration strategy on the ecological state, its biodiversity and services. That is, if we consider just the direct costs of restoration, which are fixed by the budget constraint, an increase in benefits increases efficiency.

The costs considered here correspond to the direct costs of the physical intervention of the river channel. On the one hand, the cost of ecological restoration per meter of river is taken into account, with cost being assumed as proportional to river size (measured as stream order). On the other hand, the cost of removing a barrier in the river network is assumed to be fixed, regardless of river size (Kuemmerlen et al. in press). The cost estimates will be refined if more information about the dependence of the costs on size and other criteria becomes available.

Next to the costs explained above (which remain fixed), we approximate the benefits – for the effects of this example – in terms of the overall ecological state of the catchment and in terms of the fish migration potential. The former has the objective to assess the efficiency of the full restoration plan, while the second one specifically addresses the topic of longitudinal connectivity in the catchment.

Beyond the improvement in ecological state, there are significant co-benefits, as well as trade-offs, stemming from the systematic restoration of river networks, which should be considered to fully evaluate efficiency. Several benefits are well known, in particular those related to recreational activities along restored river reaches. However, there are many more positive aspects arising from restoration. For a more detailed analysis on co-benefits, see Table 3.1 in Chapter 3. There are also trade-offs stemming from river restoration, one of the most well-known being the limitations to the exploitation of hydro electrical power. Much research is needed to accurately define costs and benefits for ecosystem services. Only then will these be accounted for in the evaluation of the baseline scenario and for optimisation of restoration strategies.

5.2.3 Evaluating equity and fairness

The restoration of rivers in Switzerland was initiated through a law and policy in the year 2009. Funding for the financing of the restoration, as well as complementary measures, is allocated mostly by the central government, with additional contributions from the cantons. In this way, the costs are distributed across all taxpayers (participatory budgeting), providing a basis to assume there is equity.

Moreover, the location of the restoration measures is a heavily debated topic. This is why already the cantonal baseline strategies were developed with participatory elements, which varied between cantons. As rivers are valuable components of the landscape, both for practical and aesthetic reasons, securing areas to restore significant stretches of rivers has become challenging. Most extensive restoration projects are implemented in areas of agricultural land use, as acquiring large properties is much more accessible than in urban areas. This has risen the awareness around the topic of fairness. On the one hand, mostly farmers are faced with the decision to give up their land and sell it for the purpose of river restoration. On the other hand, the urban population tends to benefit less frequently from these measures. While this is a topic in discussion, it has not been addressed yet in detail in this study.

5.3 Results (comparing scenarios / measures)

The baseline scenario was defined as the expected state of the catchment in the year 2035, assuming that a) restoration has taken place in accordance with the cantonal strategic planning (HOLINGER AG, 2015), b) the pesticide reduction action plan was successful in preventing the usage and leaching of 50% of agricultural pesticides (Bundesrat 2017), and c) population in the canton of Zürich has increased by 21% (BFS, 2016).

The EBM management scenario includes the pesticide reduction action plan and considers population growth. Restoration measures are, however, not determined by the cantonal strategic planning, but through optimizing the spatial criteria describing the ecological state of the catchment. Currently, several optimisation algorithms are being developed and tested. The preliminary results shown here stem from testing thousands of replicates representing an alternative restoration strategy, comparable in costs to the cantonal plan.

The optimised restoration strategy (management scenario) outperforms the cantonal strategy (baseline scenario) in the indicator for effectiveness (Good ecological state of river reaches) and in one of the indicators for efficiency (Good ecological state of catchment; Figure 5.2, 5.3). The latter represents the overall ecological state of the catchment, being the most important indicator that summarises all information in the catchment, while balancing the different ecological processes taken into account.

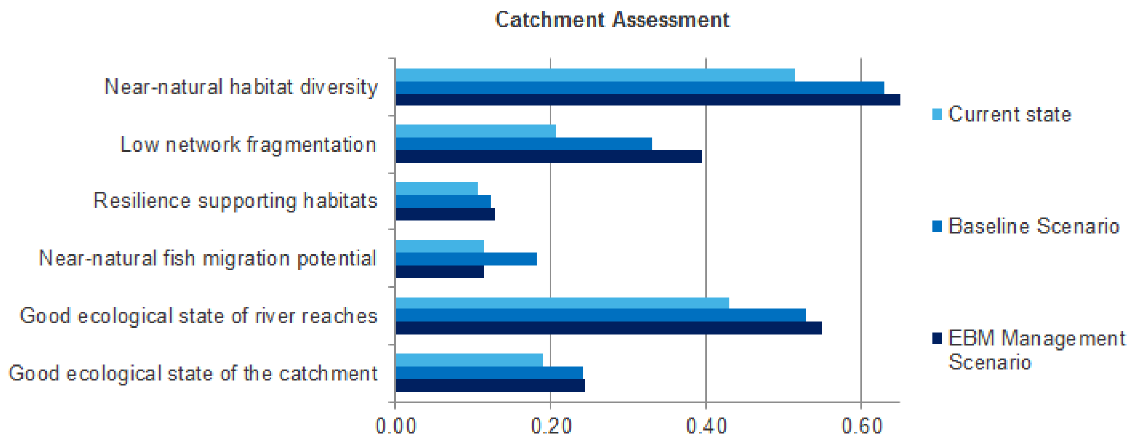

Figure 5.2 Catchment assessment in terms of ecological state and several ecological processes for the Mönchaltdorfer Aa catchment.

The optimised restoration strategy is, however, not able to provide a better outcome in terms of fish migration potential. In this aspect, the restoration strategy planned by the canton, partially focused on restoring connectivity in the stream network, designing the strategy accordingly. The results indicate the cantonal planning provides a quite good strategy already.

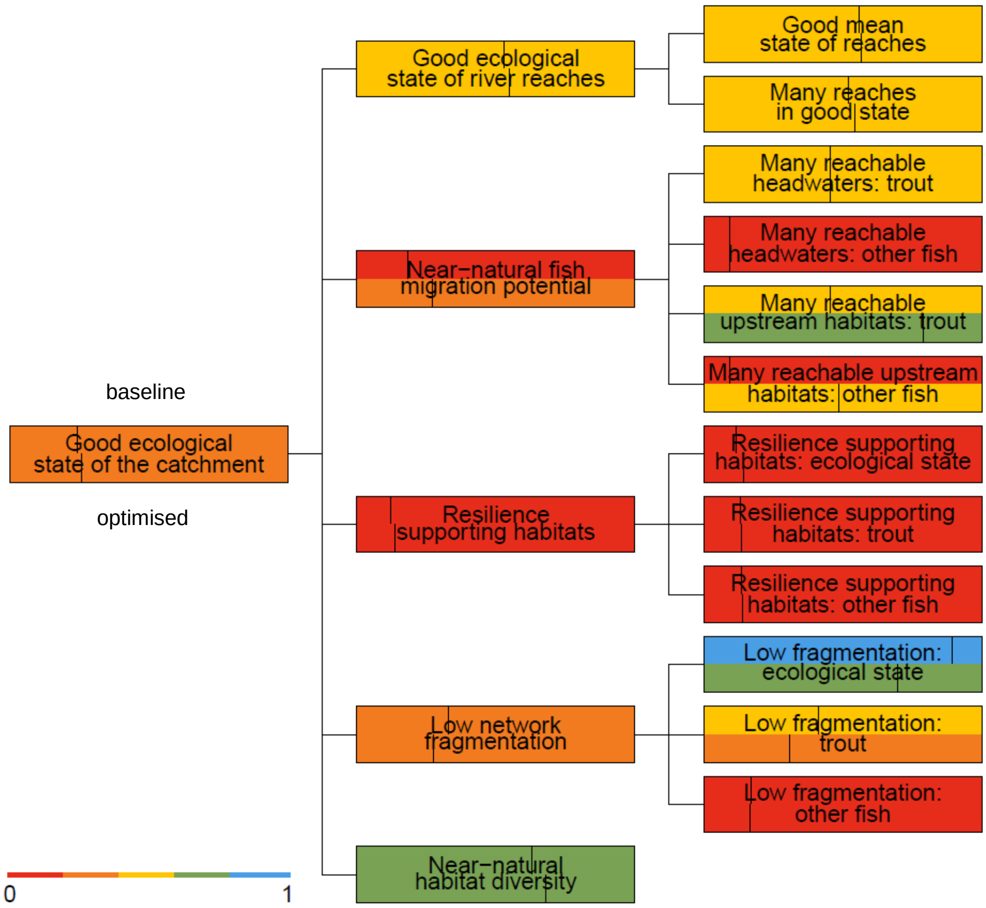

Figure 5.3 Objectives hierarchy with the catchment-scale assessment of the baseline (upper half of the boxes) versus the proposed optimised management scenario (see Fig. 4.3 for more explanations).

There are significant sources of uncertainty associated with this analysis. Remote sensing data usually have a margin of error, sometimes relatively large, if data was not ground-truthed. Data recorded through surveys is prone to differences associated to the surveyor. Further, it is uncertain if the external scenario of population growth will occur as predicted and also whether the pesticide reduction plan will be successful in halving pesticide usage. In addition, the estimations of nutrients and micropollutants are based on simple linear interpolations, which are also a source of uncertainty. Many of these sources are quantifiable, however only some of them will be pursued in the near future.

The EBM approach followed here has several strengths compared to the baseline scenario:

- It takes into account nutrients and micropollutants next to river morphology when assessing the state of individual reaches.
- Reach assessments are aggregated by taking in to account their spatial situation in the stream network through five spatial criteria that stand for different ecological processes that are highly relevant to freshwater ecosystems.

- Optimisation of the restoration strategy includes the effects of complementary management measures, which have important effects on the outcome of the assessment.
- Catchments of very different sizes and properties can be compared with each other.

The results show that it is possible to propose additional, better performing restoration strategies and that incorporating complementary management measures has a significant effect on the outcome of the catchment assessment (Figure 5.2). In addition, the analysis of the outcome allows us to identify easily which ecological aspects require particular attention ( )

There is still important work to be done in order to implement algorithms that can improve specific objectives. For instance, improving fish migration potential may have to be addressed differently than raising the ecological state of the entire catchment.

Further, a purely in-silico optimisation is likely to ignore important aspects of restoration which are not evident from the data itself. Strong stakeholder involvement will be necessary to continue improving the catchment assessment procedure and to test the outcomes of the optimised restoration strategies. This will prove challenging, considering the four chosen catchments have quite different properties and stakeholders.

5.4 Pre-conditions for successful take off and implementation of “qualified” EBM solutions

The implementation of the catchment assessment approach will be an on-going process that may take several rounds of revisions with stakeholders. In addition, automating the optimisation of restoration strategies will require several rounds of discussion itself. However, the current requirements of conservationists and managers show a clear demand for such tools to support their decision-making.

The further development of this approach requires high-quality, spatially explicit data. It has to be handled by GIS specialists and introduced into a programming language. These processes require much detail and care. These are arguments that can reduce interest in such an approach. Also, it would be very useful to introduce better nutrient and micropollutant data, but these are products that need to be developed by other users and groups of interest.

Additional criteria from several fields can be introduced in the approach to make it more realistic. There are several pressures for freshwater ecosystems, which are not accounted for yet (e.g. temperature, pH, microplastics, etc.). Not all important ecological processes are included yet. Restoration can be hindered by additional issues, which are not accounted for yet (e.g. land ownership). These are many improvements, which will require considerable effort, but could prove to be a valuable improvement.

In the current form, this approach can already make important contributions to the cantonal restoration strategies in Switzerland. As the objective of restoring 25% of the degraded river reaches is a long-term one, this method may profit from many years of implementation experiences.

6 Summary and Conclusions

In this study, we developed methods for the spatial optimization of river management actions aligned with the AQUACROSS Assessment Framework to apply Ecosystem based management in the Swiss Plateau. Its main advantages, compared to the current strategic planning, is the more integrative perspective that allows for a better coordination of management actions across different sectors (e.g. water quality management, morphological restoration, removal of fish migration barriers). We proposed spatially explicit criteria to assess the ecological state of catchments in the current state and for baseline management scenarios. They can be used for the spatial prioritisation of management actions that increase the effectiveness while complying with budget and other constraints. The approach was tested on four catchments at the Swiss plateau and illustrated here for one of them: the Mönchaltorfer Aa.

Dissemination of the new methodologies is based on courses, stakeholder interaction platforms, collaborations for policy implementation and collaborative projects with the Federal Office of the Environment and cantons. This requires long-term collaboration that builds trust and supports mutual understanding of scientists and practitioners. Our institute has a long and successful collaboration with practitioners in this respect. Many management measures are currently and will continue to be implemented in Switzerland until the year 2090. The integrative planning of all measures can help to increase the efficiency of this process.

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Vermeiren, P., Reichert, P., Schuwirth. N. (submitted): Pushing prediction boundaries by combining joint species distribution models with ecological trait information.

Annex

All annexes are available on the AQUACROSS website Case Studies page.

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ACTeon – Innovation, Policy, Environment (ACTeon) | France

University of Liverpool (ULIV) | United Kingdom

University College Cork, National University of Ireland (UCC) | Ireland

Royal Belgian Institute of Natural Sciences (RBINS) | Belgium

Stockholm University, Stockholm Resilience Centre (SU-SRC) | Sweden

Danube Delta National Institute for Research & Development (INCDDD) | Romania

Eawag – Swiss Federal Institute of Aquatic Science and Technology (EAWAG) | Switzerland

International Union for Conservation of Nature (IUCN) | Belgium

BC3 Basque Centre for Climate Change (BC3) | Spain

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