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Federal Department of the Environment,
Transport, Energy and Communications DETEC

Federal Office for the Environment FOEN
Water Division

Last revised: 15.03.2024; Version 1.03

Factsheet 7
Development of the framework

Publication details

Issued by: Federal Office for the Environment (FOEN)
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Citation: Weber, C., Sprecher, L., Åberg, U., Thomas, G., Baumgartner, S., Haertel-Borer, S. 2019: Development of the framework. In: Evaluating the outcome of restoration projects – collaborative learning for the future. Federal Office for the Environment FOEN, Bern. Factsheet 7, V1.03.

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This factsheet provides a variety of background information on the development of the framework for the STANDARD and EXTENDED outcome evaluations in the research project at Eawag.

7.1 Development of framework

The framework for the STANDARD and EXTENDED outcome evaluations was developed at Eawag, on behalf of the FOEN, between October 2015 and February 2018. In this process, a number of variants were outlined, strengths and weaknesses discussed, and cost estimates prepared. The framework was developed in close collaboration with three advisory groups (national, international and internal; see “Publication details”), comprising altogether over 30 representatives of various stakeholder groups (e.g. federal and cantonal authorities, consultancies, academia) and disciplines (e.g. ecology, river engineering, waters protection, geomorphology, social sciences and economics). After the completion of the initial development phase, the proposals were discussed with all the cantons represented at two Water Agenda 21 meetings (April and November 2018) and a workshop (September 2018). The concerns and criticisms expressed at these events were noted, and the framework was modified, e.g. with regard to the number of projects to be included in the STANDARD outcome evaluation. Approval and understanding were thus considerably enhanced as a result of these three events.

7.2 Typical goals of restoration projects

Restoration projects pursue a variety of goals – ecological, social or economic. With an outcome evaluation, the goals defined can be assessed. But which goals are most important for collaborative learning at the national level? During the development of the framework, typical goals of restoration projects were identified in several steps. First, possible restoration goals were collected with the aid of the three advisory groups and from the literature (e.g. Woolsey et al. 2005; Reichert et al. 2007, 2011). These can be grouped into an “objectives hierarchy” (see Fig. 7.2 below), which is a useful tool for providing a clear overview of goals with varying degrees of detail (Reichert et al. 2007, 2011). Next, four legal documents were systematically examined – the Waters Protection Act (WPA, SR 814.20), the Waters Protection Ordinance (WPO, SR 814.201), the Explanatory Report on the Amendment of the Waters Protection Ordinance (Explanatory Report on the Parliamentary Initiative on Protection and Use of Waters; BAFU 2011) and the Handbook on Programme Agreements (BAFU 2015) – and goals mentioned therein were inserted in the objectives hierarchy. Finally, in collaboration with the advisory groups, various filters were defined for the selection of priority goals – e.g. the number of mentions in the documents, the availability of indicators for goal assessment, or a goal’s amenability to influence by a restoration project. The result was a list of 9 typical goals at Level 4 of the objectives hierarchy, further characterised by the various sub-goals at Level 5.

7.3 Indicators

Indicators are measurable quantities which provide valuable information on the condition of an ecosystem and its relevant processes (Lorenz et al. 1997). Determination of an indicator thus has two components – measurement in the field and subsequent assessment of the results (= rating). Indicators can be used to assess goal attainment – i.e. they represent the actual tools from the objectives hierarchy and are correspondingly closely linked to the objectives. The development of the framework for the STANDARD outcome evaluation relied on indicators already described for Switzerland for which a value function (= step from measurement to rating) is available. Initially, a list of over 80 indicators was compiled from various sources, such as the Handbook for evaluating rehabilitation projects in rivers and streams (Woolsey et al. 2005) or the Modular Stepwise Procedure (http://www.modul-stufen-konzept.ch). In several steps, the available indicators were assigned to the objectives in the hierarchy and their suitability for measurement and rating was critically discussed (e.g. direct association with goals, sensitivity for the aspects to be assessed). At the end of this process, 22 indicators remained for the nine typical goals. These 22 indicators focus on abiotic, biotic and social aspects.

Synergies exist between numerous indicators, i.e. the surveys are similar, are carried out at the same site, or can be readily combined. Accordingly, the 22 indicators were grouped into 10 synergistic indicator sets, directly linked to one of the nine typical goals of restoration projects. There are four abiotic indicator sets, five biotic and one social. An additional indicator set (Set 11) exists which, in consultation with the FOEN, can be adapted to project-specific goals and requirements.
The indicators were in some cases modified or updated for the practice documentation; an overview of the modifications is given in Table 7.3 below.

7.4 Control and reference reaches

7.4.1 What are control and reference reaches?

Control reaches are sections of watercourses which reflect the conditions in the restored reach prior to restoration – i.e. degraded conditions (e.g. channelisation; Chapman 1999). In contrast, reference reaches exhibit scarcely degraded, near-natural conditions, such as are to be attained through restoration. If, in the outcome evaluation, surveys are performed not only on the restored reaches but also at the same time on control or reference reaches, then various conclusions can be drawn as a result at the project level. Firstly, natural variation can be quantified – i.e. it can be estimated to what extent a parameter varies naturally over time, even without the implementation of restoration measures. This provides an indication of whether an observed change in the restored reach is in fact attributable to restoration (= effect) or is due to other factors (e.g. extreme winter). Secondly, the direction of developments can be assessed. However, only a reference reach can genuinely indicate whether a development towards more natural conditions is occurring – the mere finding of divergence from conditions in the control reach says little about the desired effect.

7.4.2 How are control or reference reaches selected?

The selection of appropriate control or reference reaches is a crucial, but often underestimated task, presenting not just numerous opportunities but also risks. Points to be considered in the selection of control or reference reaches are discussed in the literature (Roni et al. 2013):

- *Similar temporal variability*: If the restored section and the control or reference reach are subject to the same environmental changes (e.g. in precipitation) over time, then a difference in the development of indicators in the restored section can be interpreted as an effect of restoration. Often, however, it is far from easy to confirm or assume similar variability.
- *Stability*: In the outcome evaluation, several years may elapse before the next survey. Particularly for control reaches, there is a “risk” that they will themselves be enhanced during this period. They will then no longer reflect the conditions which would be shown by the restored reach without restoration and will thus lose their value as a control. For reference reaches, in contrast, there is a risk of deterioration in their condition.
- *Geographical proximity*: If control or reference reaches are located too close to restored sections, they may possibly be influenced by them. Sites upstream of restored sections are therefore often chosen as control reaches. Here too, however, there is a possibility of influence, e.g. due to the migration of mobile organisms. Excessive distance between control and restored reaches can also be problematic, as the environmental conditions are then too dissimilar.

7.4.3 Why is routine sampling of control reaches not included in the STANDARD outcome evaluation?

Various study designs are used internationally to evaluate the outcome of restoration measures or other interventions in the environment (Roni et al. 2013). The most common are the BACI (Before-After Control-Impact) and the EPT (Extensive Post-Treatment) design. With BACI, the restored reach (Impact) is sampled before and after restoration (Before-After) and compared with a channelised (Control) reach (see Section 7.4.1). With the EPT design, older projects are sampled only after restoration (e.g. 5–10 years later) and compared with a channelised control reach. For both BACI and EPT, reference reaches (i.e. near-natural reaches, cf. Section 7.4.1) are also included in some cases.

The various study designs differ according to the goals, effort or duration, and all have different strengths and challenges – i.e. no one approach can do everything (Roni et al. 2005, 2013). They are also carried out at different levels – either project-specific, involving a single project (e.g. BACI), or cross-project (e.g. multiple BACI, or mBACI; Roni et al. 2018; Factsheets 1 and 4). The project-specific level is, however, much more common (Weber et al. 2017).

The various study designs can be combined, thus combining the individual strengths of each approach. This is also the case for the nationally standardised outcome evaluation for Switzerland from 2020: for the STANDARD outcome evaluation, a multiple before-after (mBA) approach is to be used, i.e. a before-after comparison involving a large number of projects without control reaches. As a result, the development of restored reaches will be monitored over an extended period and as far as possible across the entire spectrum of restoration measures, types of watercourse and regions. In addition, with the EXTENDED outcome evaluation for 2020–2024, an extensive post-treatment/ multiple post-treatment (EPT/mPT) approach is being pursued – i.e. an “after” comparison involving a sufficiently large number of older projects in small watercourses, and including control reaches. This means that specific questions concerning the development of restored reaches of small watercourses can be addressed in good time – it is not necessary to wait for more than 5 years for results to be available for the learning process.

In the STANDARD outcome evaluation, control reaches are thus not routinely sampled; sampling of control reaches is, however, possible in consultation with the FOEN (Factsheet 1). This decision was taken during the development of the framework – after intensive discussions with the three advisory groups (see Publication details) – primarily for the following reasons:

- *Coverage of project diversity to enable causal understanding:* Restoration projects are highly diverse (measures, project context). In order to gain a better understanding of the factors inhibiting or promoting the effectiveness of restoration projects, a large number of projects with different contexts need to be covered in the outcome evaluation (Factsheet 4). Accordingly, the allocation of resources needs to be balanced in such a way that a sufficiently large number of projects undergo a sufficiently comprehensive outcome evaluation.
- *Learning about development over time:* Information on temporal variability and on long-term development can be obtained at the project level above all by means of high temporal resolution (frequently repeated measurements) and comparison with control reaches. Such surveys provide very interesting results, as strikingly shown by a German study of river restoration involving 21 consecutive years of electrofishing (Höckendorff et al. 2017). At the same time, these surveys are costly, i.e. the cost per project is increased and fewer projects can be covered by an outcome evaluation with the resources available for this purpose at the national level. However, the temporal aspect can also be addressed using a cross-project approach – by comparison of multiple projects from different contexts and different years (Roni et al. 2018).
- *Difficulty of selecting control reaches:* The challenges involved in selecting meaningful control reaches are often underestimated, as shown by international studies, e.g. by advisory group member Phil Roni from the US (Roni et al. 2013). They are described in Section 7.4.2.

7.5 Unresolved questions from Swiss restoration practice

In a workshop at the Water Agenda 21 meeting held on 28 October 2016, the following question was discussed: In your view, what are the most pressing questions that need to be answered by national analyses of the effects of restoration measures? Examples of the issues mentioned by participants are given in Table 7.1.

Table 7.1: Unresolved questions from restoration practice, as formulated by cantonal experts at a Water Agenda 21 workshop.

Ecological processes
- *Degree of isolation of a reach:* How does this influence the effects of a restoration project?
- *Restoration of connectivity:* Can this have adverse effects on aquatic communities?

Project goals
- *Goal attainment:* What is a successful restoration? National consensus required with regard to goal attainment.
- *Significance of goal definition:* To what extent does the definition of goals influence the results of the outcome evaluation?

Spatial scale
- *Project size:* How does project size affect ecosystem recovery potential?
- *Project perimeter vs effect perimeter:* How far do the effects of a restoration project extend?

Temporal scale/duration
- *Duration of sampling:* How long does recovery take? How can one be sure of the results?
- *Effectiveness:* How many years are required for conclusions on effectiveness to be drawn?

Recovery potential
- *Morphology and water quality*: To what extent do successful restoration measures depend on these factors?
- *Other pressures*: How do regional and social developments (e.g. huge increase in recreational pressures and litter) affect the development of a restoration project?

Tools/indicators
- *Choice of indicators:* Which indicators are most suitable for assessing the effects of a restoration measure?
- *Applicability:* Can outcome evaluation for restoration projects also be applied to flood protection projects?

Societal benefits
- *Effectiveness from citizens' viewpoint:* How can the effectiveness of a restoration project be expressed (ecology per Swiss franc of taxpayers' money)?
- *Public satisfaction:* How is this related to the ecological effects?

Success/effectiveness
- *Intensity of restoration:* Where, and at what level of intensity, should restoration be performed?
- *Effectiveness:* What measures ensure the greatest effectiveness?

Implementation
- *Implementation:* How can one progress from strategic planning to specific projects?
- *Risks:* Is there not a risk that an analysis of the effectiveness of measures will lead to formulaic recommendations?

Learning/knowledge transfer
- *Exchanges among experts:* What degree of detail is required for fruitful exchanges?
- *Learning process:* What can we learn from other disciplines (e.g. water quality)?

7.6 Explanatory variables

The outcome of a restoration project is influenced by numerous different factors – floods, catchment use, climate change, the measures adopted. One of the aims of nationally standardised outcome evaluation is to gain a better understanding of why a given restoration project has a certain effect while another does not. Such information on development potential is of major importance, e.g. for strategic planning (where are measures likely to be highly effective?). But cause-effect relationships can only be determined to a limited extent at the individual project level – rather, cross-project comparison is required.

In the scientific literature, a few examples can be found where explanatory variables are investigated in a meta-analysis (comparison of published studies). The findings of a study by Kail et al. (2015), for example, are shown in Figure 7.1: the authors analysed 91 European restoration projects to determine which variables best explained the observed effects. The results indicate that, among the eight variables considered, the biological effects measured were correlated in particular with project age, river width and agricultural area upstream. Reach land use and main measure were shown to be predictors of minor importance.

Relevant explanatory variables are to be integrated into the analysis of STANDARD and EXTENDED data. These are not determined in the field, but come from existing sources such as national geodata, other monitoring programmes, or the FOEN implementation evaluation of watercourse restoration projects. Examples of explanatory variables are given in Table 7.2.

Figure 7.1: Example of an extensive post-treatment analysis (Kail et al. 2015) synthesising the outcomes from 91 restoration projects in European rivers on fish, macroinvertebrate and macrophyte assemblages (richness/diversity and abundance/biomass). The relative importance (%) of eight variables (or predictors) on combined effects for all organism groups is shown. Box-plots indicate quartiles, range, and outliers of 10 replicate model runs (boosted regression tree model; total variance explained = 0.41; n = 353 response ratios).

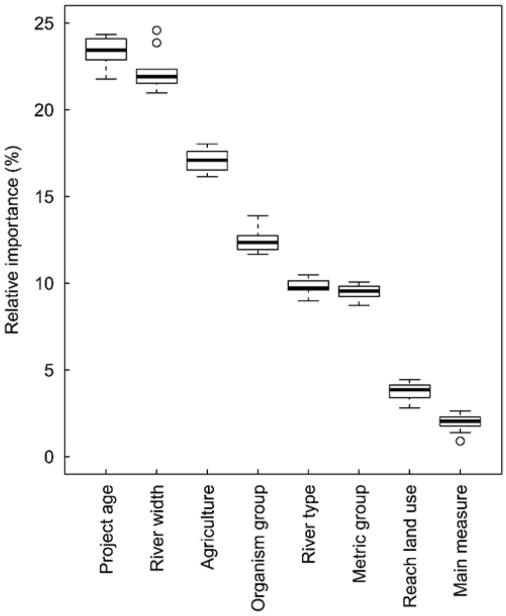

Table 7.2: Examples of explanatory variables which can be integrated into the centralised analysis of data from STANDARD and EXTENDED outcome evaluations.

Explanatory variable	Data source
Project characteristics • Project data (e.g. project setting, year construction completed) • Project classification (e.g. individual project, total costs) • General information (e.g. average bed width initially) • Set of measures (e.g. widening, deculverting) • Complicating factors (e.g. path relocation) • Financing (e.g. performance indicators, extended length)	*FOEN implementation evaluation*
Information on catchment • Catchment size • Elevation (project and average for catchment) • Geology	*Geodata* map.geo.admin.ch (catchment tool) map.geo.admin.ch (catchment tool) Typology (Schaffner et al. 2013)
Hydrology/morphology • River type • Stream order • Flow regime • Average flow (yearly, monthly)	*Geodata* Typology (Schaffner et al. 2013) Stream order (Pfaundler 2005) HYDMOD (Pfaundler et al. 2011) map.geo.admin.ch (catchment tool)/ average flows
Human influences • Hydropower (e.g. no. of plants up- or downstream; residual flow) • Land use (% forest, agriculture, settlement, etc.) • Water chemistry (e.g. nitrate, phosphate) • WWTPs in catchment • Degree of fragmentation • Population	*Geodata* Residual flow map FOEN; hydropower plant statistics (WASTA) Land use statistics Modelled values WWTP sites Ecomorphology Population_BFS_2014

Ecological status: • Data from nearby monitoring sites (surface water quality, biodiversity, habitat conservation) • Presence of protected areas	*Geodata/raw data* NAWA, BDM, WBS data Shapefiles of protected areas
Biological colonisation • Species distribution/abundance • River reaches with high level of biodiversity	*Geodata/raw data* Info from data centres (e.g. CSCF) ArtenV_NPA_Abs.shp (Schmidt & Fivaz 2013)

7.7 Framework for collaborative learning

According to US geomorphologist G. Mathias Kondolf (1995), "each restoration project constitutes an experiment, so that a failure can be just as valuable to the science as a success, provided we can learn from it". Given the unique conditions and complexity of each local context, Kondolf stresses the importance of learning – i.e. long-term monitoring of the development of a restored watercourse and derivation of recommendations for future projects. Continuous learning reduces uncertainties and allows the most effective possible use to be made of often limited resources (Roni & Beechie 2013). According to Weber et al. (2017), collaborative learning is only possible within the following framework:

- *Standardised surveys:* Projects need to have a common denominator, i.e. monitoring and evaluation need to be sufficiently standardised (methods, sampling design) to enable cross-project comparison.
- *Decoupling of financing:* The financing of the outcome evaluation needs to be decoupled from that of the construction project, so that the effects of restoration can be observed over the long term (i.e. after completion of the construction phase).
- *Integration of explanatory variables:* Factors influencing the outcome of a restoration project need to be integrated into the analysis and interpretation as explanatory variables, including both local variables (e.g. length and width of restored reach) and factors operating over a wider area (e.g. bedload deficit, fragmentation). An overview of explanatory variables is given in Table 7.2.
- *Adaptability:* The limitations of existing approaches, methods or beliefs may need to be recognised and necessary adaptations made.
- *Stakeholder involvement:* A wide variety of stakeholders involved in the restoration of Swiss watercourses must be able to participate in collaborative learning.

Table 7.3: The most important modifications made when the indicators were updated (see also Section 7.3). References: [1] Woolsey et al. 2005; [2] Hunzinger et al. 2018; [3] Känel et al. 2017; [4] BAFU 2019.

Indicator (original source) and most important modifications

1.1 River bed structures[1]
- Comprehensive survey conducted along the entire restored reach
- Definition of the minimum area of a structure for the survey
- Digitalisation of results and calculation of areas using GIS

1.2 River bank structures[1]
- Replacement of structure types by separate determination of three attributes of bank structure – profile (3 qualities: linear, convex, concave), composition (5 qualities), slope (2 qualities)
- Digitalisation of results and calculation of lengths and overlay/ comparison of shorelines by means of GIS
- Longitudinal structures are no longer dealt with separately in the survey, but are characterised via the two attributes composition (permeable/impermeable structures) and profile (linear)
- Modification of the evaluation functions owing to the larger number of possible structures

1.3 Water depth[1]
1.4 Flow velocity[1]
- Reduction in the number of cross sections to be measured (15–20 instead of 20–25)
- No seasonal repetition of sampling

1.5 Presence of cover[1]
- Modification of types of cover, harmonisation with the types of structures surveyed in the IAM method (Indice d'attractivité morphodynamique; Vonlanthen et al. 2018)
- No field measurement, purely mapping
- Evaluation based on expert assessment instead of sampling of reference reaches
- Digitalisation of results and calculation of areas of cover using GIS

1.6 Substrate[1]
- Alignment of evaluation methodology with that of the guidance on bedload regime restoration (Hunzinger et al. 2018)
- Consideration of "substrate type" (as defined in Hunzinger et al. 2018) as one of two attributes of the substrate – mobilisability (plus composition -> not currently evaluable)

2.1 Temporal changes in diversity of geomorphic river bed structures[1]
- See modifications under Indicator 1.1 "River bed structures"

2.2 Temporal changes in the quantity and spatial extent of morphological units[1]
- See modifications under Indicator 1.2 "River bank structures"

2.3 Change in river bed elevation[2]
- Translation of evaluation classes from the guidance on bedload regime restoration into standardised values between 0 and 1

3.1 Inundation dynamics[1]
- Definition of the area referred to for the evaluation (-> minus water area at mid-flow)

3.2 Shoreline[1]
- Modelling only, i.e. no field surveys, e.g. at different water levels

4.1 Temperature[1]
Under discussion (autumn 2019):
- Required duration (whole year vs 2 hot summer weeks)
- Logger distribution: 1 logger per mesohabitat type (rather than logger distribution proportional to habitat distribution)
- For evaluation: comparison with channelised reach upstream would be appropriate.

5.1 Macrophyte community[3]
- The subreach for the survey should, if possible, be the same as the subsection selected for Indicator Set 1 "Habitat diversity".
- Determination of the parameters of Ecomorphology Level R is not mandatory, but it is recommended if the subreach lies outside the subsection selected for Indicator Set 1.
- The subreach must be documented by an aerial or eye-level photograph.
- If any macrophytes were planted, sowed or introduced with cuttings, this must be documented.
- With the new electronic template, there is no need for manual entry and read-in to the evaluation tool.

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6.1 Macroinvertebrate community[4]
- The subreach for the survey should be the same as the subsection selected for Indicator Set 1 “Habitat diversity”.
- 8 samples are to be collected, according to the method defined in the module.
- All samples collected are separately sorted, identified and analysed.
- The second (optional) sampling campaign is conducted in August/September rather than September/October at altitudes of over 1400 m.
- Species-level identification of ephemeroptera, plecoptera and trichoptera (EPT, as in biodiversity monitoring)
- Abundance is measured for all taxa, i.e. also for each EPT species.
- A quality control of the EPT-taxa is required.
- An evaluation of EPT species is still under development.
- Calculation of the IBCH quality index is not mandatory.
- Archiving is recommended, but optional.

7.1 Fish community[1]
7.2 Age structure of fish population[1]
7.3 Ecological guilds of fish[1]
- Quantitative survey, including use of barriers (rather than semi-quantitative)
- Electrofishing in a characteristic subsection (rather than mesohabitat-based electrofishing), in accordance with detailed mapping in Set 1
- Weighing of fish and consideration of biomass (rather than merely abundance/density)
- No seasonal repetition of electrofishing
- Assessment: not only sensitive (sentinel) species to be considered, but all typical species.

8.1 Plant species[1]
- New name (previously “Plant species typical of floodplains”)
- Increase in possible target species
- Guidance on selection of target species, with species list file (Ufervegetation_Ind.8.1_Empfehlung_Beispiele.xls)
- For at least three species, the number of individuals per unit area or the colonised area is determined for target species and/or neophytes.

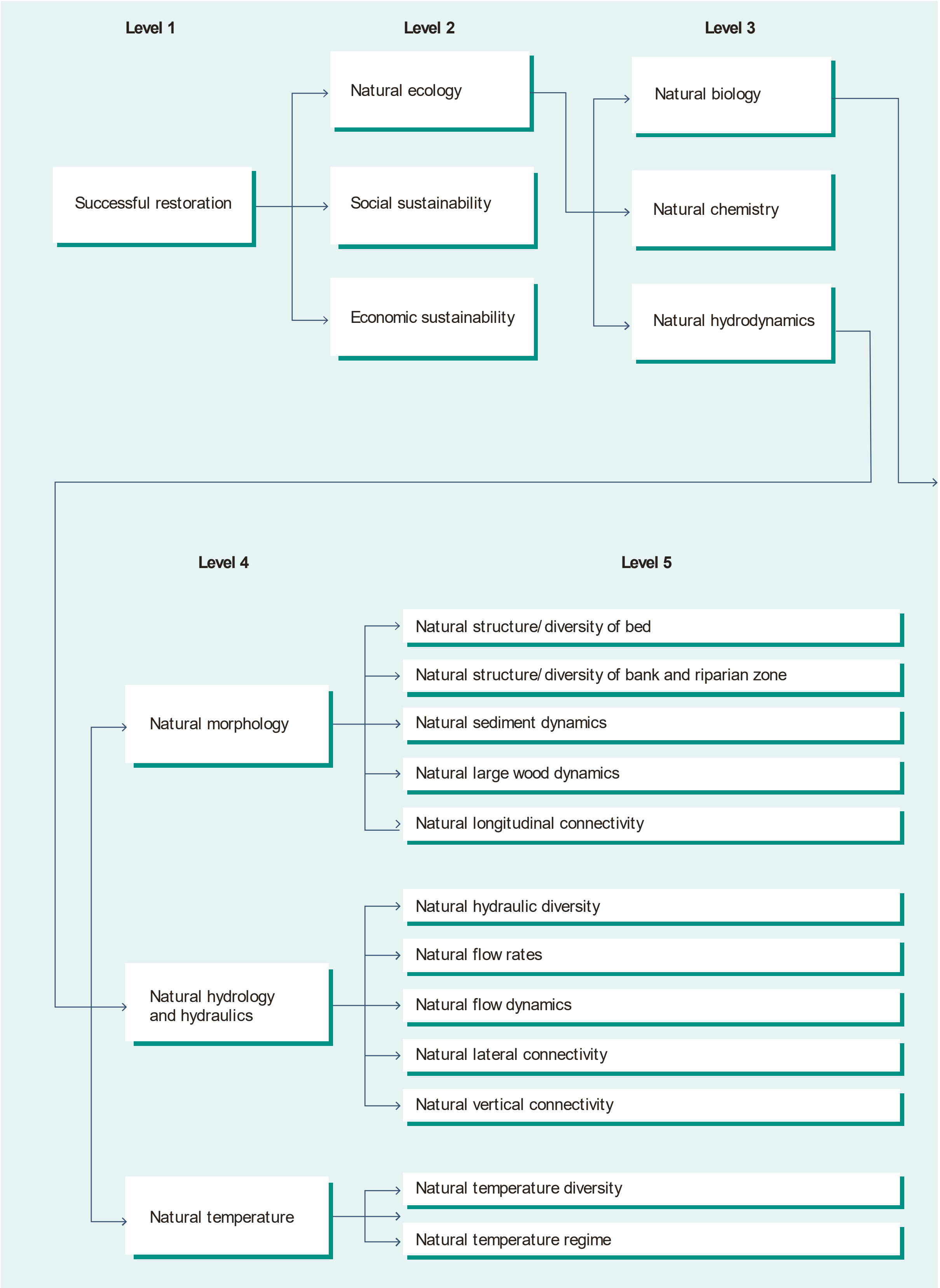
8.2 Plant communities[1]
- Survey based on the WBS (Monitoring the Effectiveness of Habitat Conservation in Switzerland) method, except that the permanently marked plots are not randomly distributed, but deliberately established
- A minimum of 5 permanently marked plots per (planned) plant community are set.
- Location and number of permanently marked plots remain the same before and after restoration
- The data from the phytosociological surveys can be used for two analyses, which are explained in more detail below - a comparison with the species lists of the Delarze habitats (analysis 1, mandatory) and the calculation of the score TypoCH of InfoFlora (analysis 2, optional).

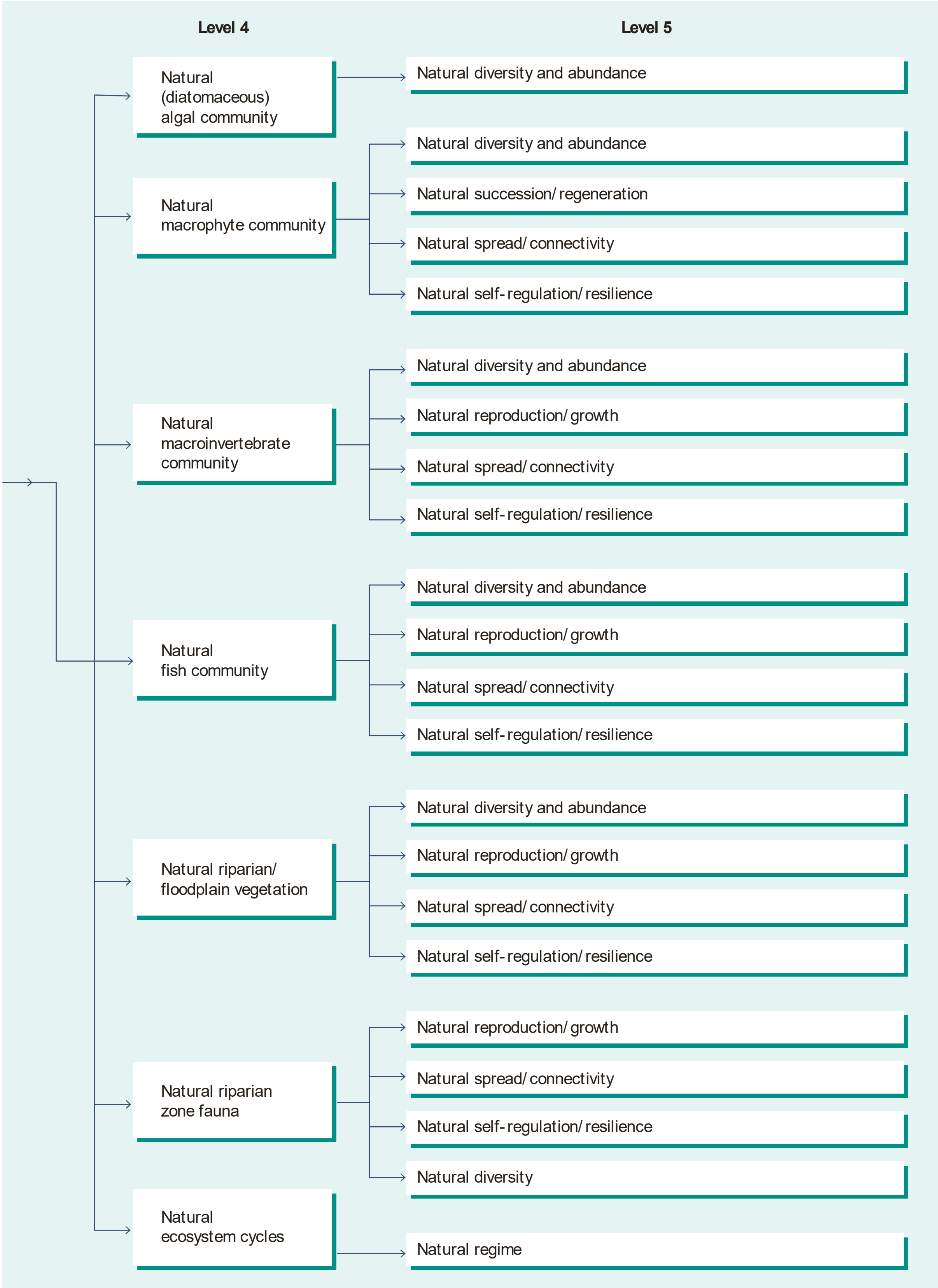
8.3 Temporal shift in the mosaic of floodplain vegetation categories[1]
- The step “Verification of the map of floodplain formations in the field” is now mandatory.

9.1 Bird species[1]
- The survey and mapping of avifauna is based on the standardised method for the Swiss Breeding Bird Atlas, the common breeding bird monitoring (MHB) programme and Indicator Z7 of Swiss Biodiversity Monitoring (BDM Coordination Office 2014); it is undertaken in collaboration with the Swiss Ornithological Institute.
- No assessment is to be carried out at present, until initial data from the restoration outcome evaluation is available.

10.1 Stakeholder acceptance[1]
- Modification of the time point of the second “after” survey (in year +1/+2 rather than +10/+12)
- Development of a questionnaire with 5 standardised questions to document the acceptance level.
- A value between 0 and 5 is assigned to each question, with 0 indicating very low and 5 very high approval.

Figure 7.2: Objectives hierarchy, with five levels




Level 4
Level 5
Natural (diatomaceous) algal community
Natural diversity and abundance
Natural macrophyte community
Natural diversity and abundance
Natural succession/ regeneration
Natural spread/ connectivity
Natural self-regulation/ resilience
Natural macroinvertebrate community
Natural diversity and abundance
Natural reproduction/ growth
Natural spread/ connectivity
Natural self-regulation/ resilience
Natural fish community
Natural diversity and abundance
Natural reproduction/ growth
Natural spread/ connectivity
Natural self-regulation/ resilience
Natural riparian/ floodplain vegetation
Natural diversity and abundance
Natural reproduction/ growth
Natural spread/ connectivity
Natural self-regulation/ resilience
Natural riparian zone fauna
Natural reproduction/ growth
Natural spread/ connectivity
Natural self-regulation/ resilience
Natural diversity
Natural ecosystem cycles
Natural regime

List of modifications

Relevant changes are marked in green.

Date (mm/yy)	Version	Change	Responsibility
4/2020	1.02	Correction of spelling errors, minor terminological modifications	Eawag
3/2024	1.03	Adaptation of table 7.3 in accordance with the updates in the technical sheets of sets 6 and 8	Eawag