Restoring small streams: Effects on habitat complexity

Restauration de petits cours d'eau : Effets sur la complexité des habitats

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RÉSUMÉ

L'impact humain entraîne une simplification écologique, y compris dans les petits cours d'eau, où la complexité des habitats est considérablement réduite par la canalisation, le drainage des zones humides ou l'apport excessif de sédiments fins. Des mesures de restauration sont mises en œuvre dans le monde entier pour rétablir la complexité des habitats dans les rivières et les ruisseaux afin de préserver leur biodiversité bleue-verte exceptionnelle. Nous comparons ici 22 projets de restauration dans de petits cours d'eau de moyenne altitude en Suisse avec des tronçons de contrôle canalisés qui ont été étudiés à l'aide de méthodes standardisées. Nous utilisons des métriques paysagères pour évaluer la complexité des habitats en termes de composition du substrat, de structure du fond du lit et d'offre en abris préalablement cartographiés sur le terrain. Les métriques paysagères sont des outils couramment utilisés en écologie du paysage (= terrestre) et peuvent servir de substituts pour les caractéristiques de l'écosystème telles que la connectivité ou l'isolement de l'habitat, et la dispersion des organismes. Cependant, les métriques paysagères ont rarement été appliquées aux habitats aquatiques, et leur potentiel en tant qu'indicateurs pour l'évaluation des résultats de la restauration des rivières reste largement sous-étudié. Nos résultats préliminaires indiquent des effets positifs sur la restauration pour plusieurs des métriques paysagères utilisées, soulignant leur intérêt pour le contrôle des effets de la restauration des cours d'eau.

ABSTRACT

Human impact leads to ecological simplification, also in small streams, where habitat complexity is considerably reduced by channelisation, draining of wetlands or excessive fine sediment input. Restoration measures are being implemented worldwide to restore habitat complexity in rivers and streams to maintain their exceptional blue-green biodiversity. Here, we compare 22 restoration projects in small mid-elevation streams in Switzerland with channelised control reaches that were surveyed by means of standardised methods. We use landscape metrics to assess habitat complexity in terms of substrate composition, river bed structures and presence of cover previously mapped in the field. Landscape metrics are tools commonly used in landscape (= terrestrial) ecology and can serve as proxies for ecosystem characteristics such as habitat connectivity or isolation, and organism dispersal. However, landscape metrics have rarely been applied to aquatic habitats, and their potential as indicators for outcome evaluation of river restoration remains largely understudied. Our preliminary results indicate positive restoration effects for several of the landscape metrics used, highlighting their benefit for monitoring and evaluation of river restoration.

KEYWORDS

Collaborative learning, cross-project comparison, ecological simplification, landscape metric, outcome evaluation

Apprentissage collaboratif, comparaison entre projets, simplification écologique, métrique paysagère, contrôle des effets

1 RESTORING HABITAT COMPLEXITY IN SMALL STREAMS

Landscapes that have been intensively used by humans are characterised by ecological simplification, i.e., by a loss of structural richness and a decrease in habitat complexity (Peipoch et al. 2015). This phenomenon has been described for a wide range of ecosystems around the world, including wetlands, large rivers or small streams. Ecologically simplified landscapes are often not able to fulfil their ecosystem services, such as the provision of drinking water, for flood protection or as habitat for a diverse fauna and flora.

Ecological restoration aims at re-establishing habitat complexity and thereby ecosystem services. For rivers and streams, restoration includes a combination of measures such as local widening, placement of wood, deculverting or bank restructuring. For instance, Switzerland aims at restoring 4'000km of rivers and lake shores within 80 years (until 2090), what corresponds to 5% of its entire river network (Weber et al. 2017). A proper monitoring is required to learn as much as possible for future endeavours and to guarantee the implementation of the most cost-effective projects (Hoffmann et al. 2022). Such collaborative learning is fostered by standardised methods that allow for cross-project comparison (Weber et al. 2017; Roni et al. 2018). In Switzerland, a Swiss-wide monitoring system has been in place since 2020 (Weber et al. 2017; FOEN 2020).

Here, we compare 22 restoration projects in small mid-elevation streams in Switzerland with channelised control reaches that were surveyed by means of standardised methods. We use landscape metrics to assess habitat complexity, patchiness and connectivity in terms of substrate composition, bed structures and cover availability previously mapped in the field, e.g., by means of aerial imaginary on a handhold tablet.

Landscape metrics are measurable units of landscape composition that allow to determine whether spatial patterns have changed over time (Turner et al. 2015). They can serve as proxies for ecosystem characteristics such as connectivity, dispersal, or isolation. Up to now, landscape metrics have been mostly used by landscape ecologists, typically in terrestrial realms. In aquatic studies, landscape metrics have rarely been applied.

For our study we apply 9 landscape metrics (see Table 1 for a selection).

Table 1: Selected landscape metrics used to quantify habitat complexity in restoration projects in 22 small Swiss streams.

Landscape metric [unit]	**Quantification method**	**Ecological relevance (examples)**
Median Patch Size [m^2]	Median patch size	Habitat size
Edge Density [m / ha]	Sum of the total edge length divided by the total area.	Connectivity, patchiness
Mean Euclidean Nearest-Neighbour [m]	Distance from a patch to the nearest patch of the same type	Proximity/ isolation, dispersal
Patch Evenness [-]	Measures the degree of equal distribution of individual areas per habitat type	Dominance, spatial distribution

2 QUANTIFYING HABITAT PATCHINESS

Figure 1a shows the vector data (polygons) of the bed structure feature for one of the 22 projects and its respective control reach. To calculate the landscape metrics for this feature and the other two features (substrate composition, cover availability), polygons mapped in the field were transformed into raster data with a raster size of 15cm x 15cm. The landscape metrics were then calculated by means of the landscapemetrics package in RStudio.

Preliminary analyses of 16 out of the 22 projects show positive results in several of the landscape metrics. For instance. Figure 1c represents the response ratio for the landscape metric Edge Density calculated with the river bed structure feature (see Figure 1a and b for an example of control and restoration reach). For 13 out of 16 projects, the response ratio is > 0, representing an increase in edge density, what corresponds to more diverse and patchier river bed structures in restored reaches. Median increase was 2.6 (= response ratio of 0.9) and maximum increase was 54.9 (= response ratio of 4.1). In three out of the 16 projects, a slight reduction in edge density was observed (response ratio <0).

Our results highlight the suitability of landscape metrics for outcome evaluation of river restoration. First, landscape metrics are easy to calculate with the GIS mappings from the field. Second, they are straightforward and intuitive to communicate, also in an interdisciplinary context with colleagues from ecology and river engineering collaborating on a project. And third they are ecologically meaningful as they can be calculated with habitat data available at the patch-scale, i.e., the scale that is the most relevant from an organism's perspective (Bätz et al. 2023).

In a next step we will interlink the landscape metrics with data from the blue-green biodiversity surveys, e.g. on macroinvertebrate community composition, fish trait representation, macrophyte diversity or riparian vegetation abundance. Furthermore, we will extend application to other fields of river research and management, such as hydropower mitigation (Bätz et al. 2024). We are convinced that this comparison provides valuable and innovative input, e.g. for discussing cause-effect relationships etc.

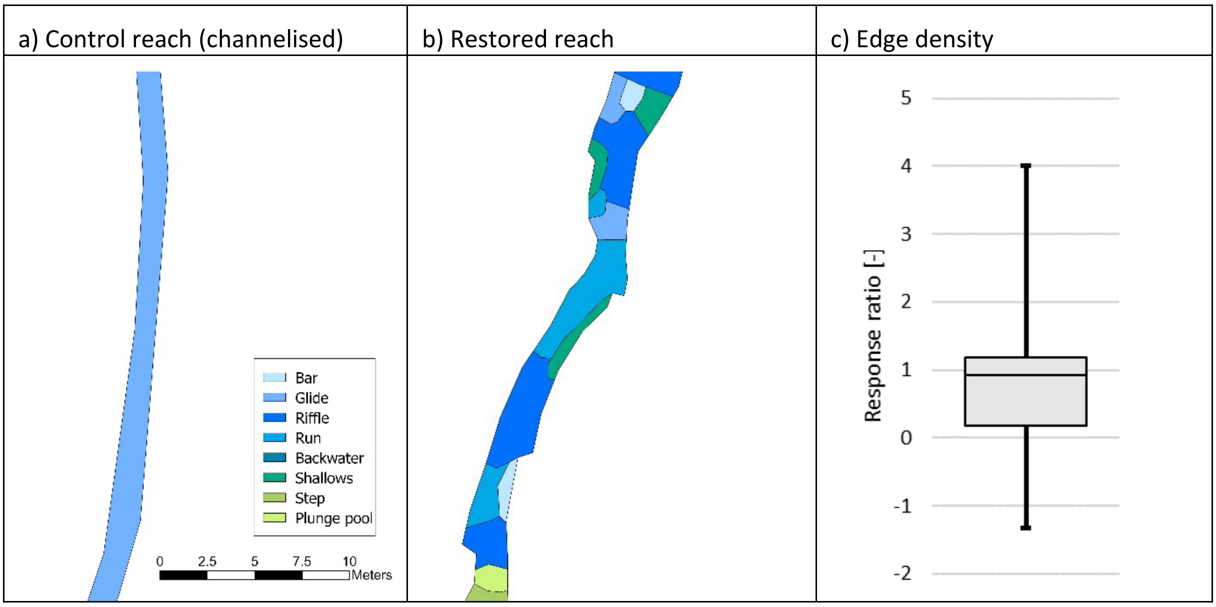

Figure 1: River bed structure in one of the 22 restoration projects in small streams in Switzerland (b) and its respective control reach (a). (c) Preliminary results for the landscape metric Edge Density for 16 of the 22 projects. The data are shown as response ratio (= ln(Edge Density restored reach/Edge Density control reach), with values > 0 indicating higher edge densities in restored reaches as compared to channelised control reaches. For the project shown in Figures 1a and 1b, a response ratio of 2.9 was observed which reflects an increase in edge density by factor17.2.

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