Executive Summary for the Wider Public

“A conceptual framework for urban ecological restoration and rehabilitation”

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In recent decades, the value of urban green spaces for wildlife conservation, human welfare, climate change adaptation and other ecosystem services has been increasingly recognized. Still, most urban ecosystems remain highly modified and are impacted by urban stressors such as traffic or by intensive management such as frequent mowing. Some urban ecosystems completely lack a non-urban counterpart and have permanently modified biotic and abiotic properties, such as green roofs and canals with paved banks. Such ecosystems, which lack a reference ecosystem that indicates a good ecological state and could thus be used as a restoration target state, are called *novel ecosystems*. *Historic ecosystems* are small remnants of natural and semi-natural ecosystems such as forests and grasslands. They can be related to natural or semi-natural ecosystems outside cities. *Hybrid ecosystems* are strongly altered historic ecosystems, falling between novel and historic ecosystems.

In cities, we find all three types of ecosystems, i.e. novel, hybrid and historic. Restorative interventions that reintroduce native species and/or combat degradation to mitigate biodiversity loss and improve ecosystem functioning can be applied to all of them. In the publication, the authors propose the first conceptual framework for the ecological restoration and rehabilitation of all types of urban ecosystems and define goals that can also be applied to novel and hybrid ecosystems.

Goals for restoration or rehabilitation of a specific type of ecosystem should be based on its level of degradation and ecological novelty. *Ecological restoration* refers to recovering the ecosystem to a historical reference state and can be applied to hybrid and historic ecosystems. Novel ecosystems have been changed beyond this point or have been newly created and cannot be recovered to a reference state. Yet, improving their ecological quality and functioning can still result in increased ecosystem services and habitat conditions suitable for native biota.

Figure 1. Examples of different types of urban ecosystems and potential restoration and rehabilitation measures. (A) Deadwood in an ancient forest relict with reduced management (Picture credit: K. Kiehl); (B) Restoration of roadside vegetation (formerly species-poor lawn) by seeding native grassland species, Zurich, Switzerland (Picture credit: V. Klaus); (C) Rehabilitation of an urban creek under restricted spatial conditions, Zurich, Switzerland (Picture credit: V. Klaus); (D) Extensive green roof with heterogeneous environmental conditions, native wildflowers and a sand pile as nesting site for Hymenoptera in Germany (Picture credit: K. Kiehl).

Urban ecological restoration can be applied to a wide range of urban habitats (Figure 1). Remnants of ancient forests can often be restored passively by reducing management to a minimum and enriching deadwood (Fig. 1A). Hybrid ecosystems, such as lawns or road verges, can often be managed for higher biodiversity by removing cuttings, decreasing mowing frequency and stopping the use of fertilizers and herbicides (Fig. 1B).

Such measures can even lead to lower maintenance costs. In addition, the introduction of native plant species of local sources can be effective in restoring plant community composition. In novel ecosystems, restoration efforts should focus on some key ecosystem services, such as adding gravel or dead wood to canals for storm water retention and improved habitat conditions (Fig. 1C) or greening of roofs to support pollinators (Fig. 1D). Although urban ecosystem restoration might not necessarily require the (relatively costly) use of native plant species of local origin, these can better support native biodiversity, such as local insect populations.

Urban ecological restoration and rehabilitation measures can vary in their dimensions, from minimal to strong interventions, from large to small plot sizes and from historic to novel ecosystems. City planning needs to prioritize urban greenbelts as they improve air quality, mitigate climate change effects, and form networks that support biodiversity and recreational activities. Moreover, it is of the utmost importance to involve citizens and other stakeholders in planning and restoration processes, as their support is an important predictor of the success of the measures taken.

In conclusion, the authors argue that the restoration of urban ecosystems will come at a certain cost but can pay off by increasing urban ecosystem services and their links to improving biodiversity, reducing the effects of climate change and supporting citizens' quality of life. These benefits are further increased if we consider the long-term effects of environmental education and improved human-nature connections for citizens. The integration of restoration into urban planning can create cities with resilient and multifunctional green spaces that support biodiversity and improve the well-being of their inhabitants.