Fact sheet: Boreal mid-sized, single-thread, mid altitude rivers

General description

Valley- and planform	Low to medium gradient.
Hydrology	The runoff pattern consists of low flows during the winter months, high spring runoff from snow melt and decreasing discharge during the summer. Depending on the rain and the area another discharge peak may occur during the autumn. The hydrological conditions are stable in the streams at lake outlets.
Morphology	Typically reaches are a series of alternating turbulent and tranquil sections. The turbulent sections have run, riffle, step-pool or cascade bedforms and are dominated by coarse till and bedrock from i.a. glacial deposits and eskers. The tranquil sections, pools and lakes, have slow flow and are dominated of peat and other fine sediments.
Chemistry	Depending of the proportion of organic soils in the catchment the humic content of the water varies a lot from very dark waters from peatland dominated catchments to clear waters partially fed from ground water sources and/or from mineral soils. Even though the rivers are generally quite oligotrophic, the nutrient levels as well as acidity vary greatly depending on the soil and bedrock type.
Riparian zone	The flood plain may be narrow or wide at certain conditions. The wide flood plains have usually fertile soils and have long history of agricultural use. It is occupied with decious species such as birch (*Betula pubescens, Betula pendula*), poplar (*Populus tremula*), willow (*Salix* sp.) and alders (*Alnus glutinosa*, *A. incana*) or coniferous species such as Norway spruce (*Picea abies*).

Pressures

Major pressures

Regulation of rivers and impoundment for hydroelectric power has changed the natural hydrological regimes. The channelization for timber floating in the 19th to mid 20th centuries and flood protection has been a major factor in degrading the riffle habitats, decreasing the water retention capacity of the river bed and altering the natural heterogeneous flow patterns in riffles. Diffuse load from agriculture and forestry is currently the major factor affecting water quality (nutrient levels, organic and inorganic sedimentation) and degrading the ecological status of the rivers.

Score of pressure level imposed on mid-sized, boreal single-thread, mid altitude rivers categorised according to pressure category and pressure, respectively (score in comparison to other pressures within this river type: No = no pressure/stress, L = low pressure/stress, M = moderate pressure/stress, H = high pressure/stress).

Pressure category	Pressure	Score
Point sources	Point sources	M
Diffuse sources	Diffuse sources	H
Water abstraction	Surface water abstraction	L
	Groundwater abstraction	L
Flow alteration	Discharge diversions and returns	L
	Interbasin flow transfer	L
	Hydrological regime modification including erosion due to increase in peak discharges	M
	Hydropeaking	L
	Flush flow	L
	Impoundment	M
Barriers/Connectivity	Artificial barriers upstream from the site	M
	Artificial barriers downstream from the site	M
Channelization	Channelisation / cross section alteration (e.g. deepening) including erosion due to this	H
	Sedimentation	M
Bank degradation	Bank degradation	M
Habitat degradation	Alteration of riparian vegetation	L
	Alteration of in-stream habitat	H
Others	Acidification	M
	e.g. Exotic species	L

Measures

The common restoration practice involves restoring the natural morphology of the channel, i.e. rearranging the stream bottom using boulders that have originally been removed from the channel during channelization and creating gravel beds for nursery habitat for salmonids. Returning the boulders to the channels can, in optimal case, restore the natural hydro-morphological conditions for aquatic organisms.

Score per measure category/measure of relevance, effect in-river, effect on the floodplain and costs the measure in comparison to other measures within this river type (No = no relevance or effect, L = low relevance or effect, M = moderate relevance or effect, H = high relevance or effect of the measure) and indication a prioritisation of measures (L = low priority, M = moderate priority, H = high priority).

Measure category	Measure	Relevance	Effect in-river	Effect floodplain	Costs	Prioritisation
Decrease pollution	Decrease point source pollution	M	M	L	H	M
	Decrease diffuse pollution input	H	H	M	M	H
Water flow quantity	Reduce surface water abstraction	L	L	L	M	L
	Improve water retention	H	H	H	M	H
	Reduce groundwater abstraction	L	L	L	M	L
	Improve water storage	L	L	L	H	L
	Increase minimum flow	M	M	M	H	H
	Water diversion and transfer	No	No	No	No	No
	Recycle used water	No	No	No	No	No
	Reduce water consumption	L	L	No	L	L
Sediment quantity	Add/feed sediment	No	No	No	No	No
	Reduce undesired sediment input	M	M	L	M	M
	Prevent sediment accumulation	L	L	L	No	L
	Improve continuity of sediment transport	No	No	No	No	No
	Trap sediments	No	No	No	No	No
	Reduce impact of dredging	H	M	M	M	H
Flow dynamics	Establish natural environmental flows	M	H	H	H	M
	Modify hydropeaking	M	M	M	H	M
	Increase flood frequency and duration	L	L	L	H	L
	Reduce anthropogenic flow peaks	L	M	M	H	M
	Shorten the length of impounded reaches	L	L	L	H	L
	Favour morphogenic flows	H	H	M	M	H
Longitiudinal connectivity	Install fish pass, bypass, side channels	H	M	No	H	H
	Install facilities for downriver migration	L	L	No	M	L
	Manage sluice, weir, and turbine operation	L	L	No	M	L
	Remove barrier	M	H	L	H	L
	Modify or remove culverts, syphons, piped rivers	L	L	L	M	L
In-channel habitat conditions	Remove bed fixation	L	L	L	No	L
	Remove bank fixation	M	M	M	M	M
	Remove sediment	L	L	No	M	L
	Add sediment (e.g. gravel)	H	M	L	M	H
	Manage aquatic vegetation	L	L	L	L	L
	Remove in-channel hydraulic structures	L	L	L	L	L
	Creating shallows near the bank	L	L	No	L	L
	Recruitment or placement of large wood	H	M	L	L	M
	Boulder placement	H	H	L	L	H
	Initiate natural channel dynamics	H	H	M	M	H
	Create artificial gravel bar or riffle	M	M	No	L	M
Riparian zone	Develop buffer strips to reduce nutrients	H	H	H	L	H
	Develop buffer strips to reduce fine sediments	M	M	M	L	M
	Develop natural vegetation on buffer strips	H	H	H	L	H
River planform	Re-meander water course	L	L	L	H	L

	Widening or re-braiding of water course	M	M	M	H	M
	Create a shallow water course	M	M	M	M	M
	Narrow over-widened water course	L	L	L	M	L
	Create low-flow channels	M	M	L	M	M
	Allow/initiate lateral channel migration	L	L	L	M	L
	Create secondary floodplain	L	L	L	No	L
Floodplain	Reconnect backwaters, oxbow-lakes, wetlands	L	L	L	L	L
	Create backwaters, oxbow-lakes, wetlands	M	M	M	M	M
	Lower embankments, levees or dikes	M	M	M	M	M
	Replace embankments, levees or dikes	L	L	L	M	L
	Remove embankments, levees or dikes	M	M	M	H	M
	Remove vegetation	L	L	L	L	L

Problems and constraints with common restoration practice

Despite of the extensive restoration programs, the biological responses to hydro-morphological restorations have generally been modest. However, the restoration of riffles has been shown to increase stream bed and flow pattern complexity. Impaired water quality due to land use (agriculture, forestry) in the catchment often prevents achieving the ecological goals of the habitat restorations. Moreover, natural hydro-morphological conditions are often only partially re-established and the natural flooding may not enabled which prevents the natural links between the stream and the riparian zone. The restoration measures also often involve using heavy machinery, which is a major disturbance for the stream ecosystem and has caused considerable reduction of bryophyte biomass. Since the mosses offer a habitat for other biota in the streams, their decline may have delayed the overall ecological recovery. Also minor investing in before-after monitoring has hindered identifying the best restoration practices, the long term responses of the biotic communities and causes of the biotic responses.

Promising and new measures

See the corresponding chapter for boreal small, single-thread, mid altitude rivers.

Monitoring scheme

Monitoring schemes should follow some basic principles that apply to all river types:

- Biotic as well as abiotic variables should be monitored. The restoration measures might have succeeded to create the desired habitats but the effect on biota might be limited due to other pressures at larger scales which have not been addressed in the restoration project.
- In-channel, riparian, as well as floodplain conditions should be monitored. Besides the biological quality elements relevant for the Water Framework Directive, restoration can also have positive effects on other semi-aquatic and terrestrial organism groups, like ground beetles and floodplain vegetation. Indeed, there is empirical evidence that effects on other organism groups can be larger.
- Monitoring has to be conducted at appropriate spatial and temporal scales that reflect (i) the habitat needs of the organisms (e.g. monitoring microhabitat substrate patches for macroinvertebrates, mesohabitat features for fish, consider habitats at river margins and in floodplain like side channels and ponds), (ii) all life stages (e.g. monitoring in-channel and riparian habitats for macroinvertebrates with terrestrial life-stages), (iii) the reproductive cycle as

well as dispersal abilities (long-term monitoring to also cover effects of restoration on long-lived species and weak dispersers), and (iv) seasonal changes and patterns that occur during the year.

- Looking at the spatial and time scale of many current restoration measures, macro-invertebrates are most suited for river monitoring. Fish population are strongly managed and reflect larger scale conditions, macrophytes bear a long history as they disappear only slowly and algae reflect to short time scales and very, very local conditions. Floodplains are large scaled and best be monitored by vegetation. The riparian zone can be monitored by using vegetation or carabid beetles.
- A Before-After-Control-Impact design should be applied to allow disentangling the effect of restoration from general trends in the whole river or catchment.
- However, the final selection of the organism groups, and spatial / temporal scales monitored strongly depends on the objectives and applied measures. Of course, it is reasonable to focus on the abiotic and biotic variables and scales that potentially have been affected by the restoration measures (e.g. in-channel habitat conditions by in-channel measures).
- Monitoring results should be used for adaptive management, i.e. to react on unanticipated effects and trends, and this should be included in the planning from the beginning ("Plan-B").

For further reading and practical guidelines we refer to the handbook of the River Restoration Centre (River Restoration Centre 2011).

The relevance of a variable at the scale of the river, riparian zone and floodplain scored in comparison to other variables within this river type (No = no relevance, L = low relevance, M = moderate relevance, H = high relevance)

Variable group	**Variable**	**River**	**Riparian zone**	**Floodplain**
River hydrology		H	H	H
In-river hydraulics		H	M	L
Floodplain morphology		L	L	M
In-channel morphology	Profile (longitudinal, transversal)	H	M	L
	Meso-/micro-structures	H	L	No
Chemistry	Nutrients	H	M	L
	Toxicants	H	M	L
	Others			
Biology	Algae	L	L	No
	Macrophytes	H	L	No
	Macroinvertebrates	H	M	No
	Fish	H	No	No
	Floodplain/riparian vegetation	L	M	M
	Terrestrial fauna	No	M	L