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Rehabilitation of Boreal Streams Channelized for Log Transport

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Introduction

Circumpolar boreal forests are an important source of timber products, as well as a significant global biome in the Northern Hemisphere. Historically, the structure and functioning of stream ecosystems of this forest region have been impacted by the practice of floating logs downstream as a means of transport. Rapids were destroyed when boulders and large woody debris were removed from the stream channel and placed in the riparian zone. Also, shallow riffle areas were dredged to produce a debris-free stream channel of uniform depth. The resulting lack of habitat heterogeneity produced faster stream velocities impacting a decline in stream species diversity and population sizes when compared to natural streams (Tikkanen et al. 1994; Kelso & Cullis 1996; Huusko & Yrjana 1998; Haapala & Muotka 1998; and Laasonen et al. 1998). Since the early 1980s this method of timber transport has been abandoned in Europe and Canada now that it is less expensive to truck logs directly to mills. Presently, there is a trend in both areas to rehabilitate impacted streams to resemble their original ecological structure (Kelso & Cullis 1996; Cowx & Welcomme 1998; Tikkanen et al. 1994; Laasonen et al. 1998; Scruton et al. 1998). The purpose of this paper is to describe: 1) criteria for determining target areas and species to be rehabilitated; 2) the physical and biological impacts of timber floating in streams; 3) methods used in rehabilitation projects.

Determining Targets for Stream Rehabilitation

Stream rehabilitation projects are implemented to improve the population size and structure of a target species by making planned structural improvements to specific sections of a stream. Realistically, species depend on complex ecosystems where many factors such as changes in light intensity, temperature, fluvial characteristics, and nutrient inputs regulate the structure and functioning of biotic communities. Therefore, stream rehabilitation methods need to be implemented in an effort to restore the complete physical and biological structure of the whole ecosystem to resemble the pre-disturbance condition (Hartman et al. 1996; Bradshaw 1997).

Stream improvement projects often target a fish species' population structure to enhance diversity of ages and sizes of individuals. In Finland and in Canada, enhancing suitable salmonid habitat was the criteria for determining rehabilitation sites (Tikkanen et al. 1994; Huusko and Yrjana 1998; Laasonen 1998; Hartman 1996; Scruton et al. 1998). Such species are selected because sport fishing generates economic benefits for governments and local communities. Also, salmonids are indicators of pristine environmental conditions due to their sensitivity to ecological stressors, such as destruction of spawning habitat by sedimentation.

Many stream species, like salmonids and the benthic macroinvertebrate insects they depend on as food, have life-histories which demonstrate specific adaptations to the cyclic changes and disturbances in streams. Selecting an appropriate target species requires an understanding of their life-history and habitat requirements (Hartman et al. 1996; Huusko & Yrjana 1998). Salmonids require different habitat structures at various stages of their development. Refuge cavities are the interstitial spaces created by stream structures (like rocks in shallow channels) that provide habitat preferred by younger trout. Older larger trout prefer the refuge of deep pools (Huusko & Yrjana 1998). Huusko & Yrjana (1998) also cited that a difference in hydraulic factors, created by complex structures in a stream channel, such as submerged woody debris and larger rocks, segregated three species of subyearling salmonids. Because of the complexity of energy flow and relationships within and among species, projects will necessarily consider impacts on multiple targets (Laasonen et al. 1998; Huusko & Yrjana 1998).

Before beginning the habitat improvement project the stability of upstream landscapes must be assessed. A restoration program in British Columbia uses a hierarchical implementation sequence which attempts to examine and rehabilitate hill slopes first, then riparian zones, followed by channels, and ultimately fish habitat in this order (Hartman et al. 1996). Another area assessment scale presented by Newbury and Gaboury (1993a, 26) is as follows: watershed (1000 m); stream segment (100 m); reach (10 m); pool/riffle (1 m); and microhabitat (0.1m). Coordinating a project by considering actions and conditions occurring within the watershed can safeguard a project from premature failure. Microhabitat improvement structures, like logs anchored into the stream bed, have been completely buried by sediment in one season of storm events due to the instability of slopes in the watershed (Hartman et al. 1996). Such an event occurred long after an area had been clearcut, due to landslides resulting as stump roots decomposed, allowing for more rapid water flow beneath the soil surface. Hartman et al. (1996) reported that a review of ~350 habitat improvement structures revealed that channel processes effected their stability and performance. Therefore, to ensure the success of a project one must have an understanding of the regional geomorphological and hydrological relationships within target area by viewing a project from a perspective of multiple scales (Newbury and Gaboury 1993a; Hartman et al. 1996).

Hartman (1996) cites that the determination of an area to be restored is often made based on judgment or biological intuition about lotic species. In a large stream remediation project in Canada a decision was made to focus on providing cover for juvenile chinook salmon without research indicating that this life-stage had a limiting impact on population production (Hartman et al. 1996). The great economic cost incurred by successful rehabilitation stresses the importance of an interdisciplinary, systematic, and scientific approach for determination, implementation, and evaluation of the area and plan (Hartman et al. 1996). This approach incorporates design strategies that have the approval of hydrologists, geomorphological specialists, engineers, and biologists from specialized fields.

Impacts of Channelization on Stream Hydrology

Stream channel transport of logs produces a stream bed with homogeneous hydrologic and structural characteristics. Once boulders and large woody debris were removed, pools filled in with sediment and channels straightened, taking the form of a uniform log chute having a U-shaped cross-section and decreasing the ranges of depth (Huusko and Yrjana 1998). This resulted in greater stream velocities and floods, lower and longer-lasting minimum flows, and lower relative roughness and mean particle size of the streambed (Tikkanen et al. 1994; Huusko and Yrjana 1998; Laasonen 1998). Channelization produces a straight channel where the more rapid stream velocities favor the deposition of a narrow size range of cobbles and small boulders (Haapala and Muotka 1998). The natural structures impacted by channelization were uneven boulder assemblages, undercut banks and heterogeneous bank structure, large woody debris anchored into the channel, and a variety of depth and channel width regimes (Haapala and Muotka 1998). This structural heterogeneity produces turbulent flow which influences a dynamic meandering channel, creating seasonally changing areas of erosion and deposition within the stream channel (Haapala and Muotka 1998). With channelization, the uniform transport and deposition of gravels and sands destroys the quality of salmonid spawning and nursery habitats (Huusko and Yrjana 1998). The sum of these conditions adversely effected natural stream ecology.

Impacts of Channelization on Stream Habitat

The natural structures impacting stream hydrology, which were removed for channelization, also provide critical habitat for stream species and impact nutrient availability in stream microhabitats. The refuge cavities removed by channelization not only provide concealment for fish, but also serve as traps for detritus (coarse particulate organic matter, CPOM), and are colonized by benthic macroinvertebrates. Subsequently, channelized streams retained less leaf litter and supported lower densities of detritivore invertebrates than natural streams in the same area (Laasonen et al. 1998, Haapala & Muotka 1998). A comparison of research on detritus retention for a boreal stream in Finland and a subarctic stream in Alaska, having similar hydrologic patterns, revealed that while inputs were greater for the boreal stream, standing stock was greater in the subarctic stream (Haapala and Muotka 1998). Channelized streams do not retain sufficient CPOM to support an ecologically balanced and complete food web (Laasonen et al. 1998, Haapala & Muotka 1998). Tikkanen et al. (1994) cited that decreased stream structure corresponds with a decrease in abundance of salmonid species in streams where log drives have occurred. They stated that predatory species like sculpins (*Cottus gobio* L.), burbot (*Lota lota* L.) and minnow (*Phoxinus phoxinus* L.) that are not as desirable as sport fish increased in abundance. Haapala and Muotka (1998) reported that the highest densities and biomass of benthic macroinvertebrates, a major food for salmonids, occurred during the winter, just following the maximum addition of CPOM from autumn leaf fall. By spring the standing stock of CPOM had significantly declined and so had the populations of macroinvertebrates (Haapala & Muotka 1998). The overall densities and biomasses of macroinvertebrates in channelized streams are very low by comparison with intact natural streams (Laasonen et al. 1998, Haapala & Muotka 1998).

Besides relying on CPOM as a nutrient input, benthic macroinvertebrates depend on large woody debris (LWD) in the stream channel as critical to their habitat needs. Natural boreal streams, with a gradient of around one percent, are noted to contain accumulations of several kilograms per square meter of LWD having a diameter of 20cm or more (Haapala and Muotka 1998). As well as providing habitat for invertebrates, anchored woody debris offers cover for fish, retains CPOM, and increases the complexity of stream flow.

Stream Channel and Habitat Improvements

The goal of stream rehabilitation is to reverse the impacts of degrading influences, slow stream velocity, provide habitat for a diverse assembly of organisms typical of natural stream communities, and hasten their recovery to acceptable population levels (Hunt 1993). Local undisturbed sites serve as a reference for developing a plan as to which structural changes are to be implemented. Photographs and records of the pre-disturbance condition also serve as resources for developing a structural plan. A variety of structures, natural and artificial, are used in specific hydrologic/ geomorphologic situations to provide microhabitat for specific organisms and/or have a positive influence on the management goals for the stream reach.

In Finland, large boulders, which had been moved to the riparian zone, were returned to the stream channel according to a placement pattern viewed in a nearby undisturbed stream (Tikkanen et al. 1994; Huusko and Yrjana 1998; and Laasonen et al. 1998). Scouring pools were excavated as natural features that occur adjacent to large boulders. Boulder dams were recreated to increase the channel width, create ponded areas upstream, and aerate the stream. Creating wider stream channels promotes larger fish sizesby offering larger feeding territories which diminishes intraspecific competition (Huusko and Yrjana 1998). Boulders and LWD deflect current, create rapids that have greater flow heterogeneity (Cowx and Welcomme 1998), and reduce the stream velocity (Tikkanen et al. 1994). Other benefits include: collection and retainment of spawning gravels, LWD, and CPOM; formation of gravel bars; greater channel meandering; smaller localized sediment trapping; raised water levels; and cooler water temperatures (Tikkanen et al. 1994; Hunt 1993; Cowx and Welcomme 1998).

Successful replacement of LWD is problematic. Trees from the stream bank that fall into the channel, are anchored by an extensive root wad. The root wad itself is a structure that provides habitat for game fish and insects and traps CPOM. In nature, the erosion of bank side soil, causing tree falls, is a gradual process. Deliberately pushing trees into the stream adds an excessive pulse of sediment which could be counter productive to the restoration project. Restoration of stream LWD is accomplished with logs, or elevated half-logs split transversely, anchored in the stream bed by driving metal rods through them (Hunt 1993). Uprooted trees are also anchored to the stream bank with cable guy lines (Cowx and Welcomme 1998). Research in Alberta suggests that structures, like anchored logs, were more successful in low energy streams that were laterally and vertically stable (Hartman et al. 1996).

Tikkanen et al. (1994) assessed the short-term impacts of a small rehabilitation project with minimal disturbance of the stream bed substrate. A 20 ton bull dozer was used to return boulders to the stream bed in a reach of less than 30 meters during early summer low flow conditions. Disturbance to the substrate was comparable to a minor flood, and macroinvertebrate recolonization to the disturbed area was rapid. The recovery rate is dependent upon the severity of the disturbance, its areal extent, availability and life-histories of potential colonists, the heterogeneity of the disturbed area, and the timing of the disturbance (Tikkanen et al. 1994). It is difficult to measure the predictability and intensity of disturbances. Therefore, further rehabilitation experimentation is recommended to determine adaptiveness of stream biota to disturbance by researching: manipulations in small patches within otherwise undisturbed areas, long-term studies following community recovery from exceptional disturbance events, and comparisons of streams with differing disturbance regimes (Tikkanen et al. 1994).

The implementation of the variety of methods listed above influenced a more heterogeneous flow regime, reduced stream velocities, and provided habitat for a greater diversity of stream organisms (Hunt 1993; Tikkanen et al. 1994; Huusko and Yrjana 1998; Laasonen et al. 1998; Cowx and Welcomme 1998). Nutrient cycling and productivity enhancements, like anchoring LWD and creating greater uneven stream bed surface with various sizes of rock, aerate the stream; create flow complexity; and impact population increases in stream biota, especially fish (Hunt 1993; Cowx and Welcomme 1998).Simple changes in hydraulic conditions can influence segregation resulting in a variety of salmonid species colonizing a stream reach (Hartman et al. 1996; Huusko and Yrjana 1998).

Conclusion

> *You can disassemble a thing....without knowing much about it, but you Can't put it back together---that is, restore it----without understanding it pretty well, and also without having a clear idea about how you have affected it.* (Packard and Mutel 1997, p. xvi).

Logging has resulted in significant loss of habitat in streams (meanders, pools, and riffles) due to sedimentation, erosion of the banks and stream bed materials, and straightening of the meanders. Successful stream rehabilitation or enhancement designs must often recreate hydraulic conditions in all levels of stream definition (Newbury and Gaboury 1993b). Lotic ecosystems are dynamic. Consequently, projects designed to rectify human caused impacts are greatly limited in their capacity to restore streams to their pre-impacted condition. Therefore, project goals must be clearly outlined and evaluated to properly fit within the geomorphological, hydrological, biological, and economic factors that will determine the projectsÕ success. A complete stream rehabilitation project includes a systematic long-term evaluation to measure its success, and/or failure, which is communicated to the public and interested agencies.

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