Y081241 - Assessing the sensitivity of streams to riparian changes: Does channel geomorphology determine how tightly forests and small streams are linked to downstream reaches?

Project start date: May 2007
Length of project: 3 years (first year completed)
Former project numbers or funding sources that apply: None

Project purpose and Management Implications

The food webs of small streams and the adjacent riparian forests are inextricably linked. Riparian forests contribute substantial amounts of material to small streams, including leaf litter, conifer needles, and terrestrial invertebrates. These terrestrial inputs dramatically increase the productivity of stream food webs, and can make up the bulk of energy assimilated by local stream insect and fish populations (Webster and Meyer 1997, Nakano et al. 1999). However, recent research has shown that headwater stream networks act as effective conduits for the downstream movement of terrestrially-derived nutrients (e.g. Wipfli 2005). Such materials from upstream may thus ‘subsidize’ several levels of downstream stream food webs, including not only fish and benthic invertebrates, but also fungi, bacteria, and aquatic plants. Indicators of the degree to which riparian management strategies directly influence the ecology of small streams, and how those influences are transmitted downstream, are needed as tools that allow managers to determine whether stream systems are being protected by current or alternative practices.

Where channels effectively retain inputs of terrestrial materials and downstream transport is limited, local ecological effects (i.e. effects in immediately adjacent reaches) will be more pronounced, while the downstream effects of riparian perturbations may be minimal. In contrast, if streams act as highly efficient conduits for the transport of materials downstream, perturbations to riparian zones upstream will have ecological effects far downstream. However, while numerous studies have shown that key geomorphological features of stream channels such as bed roughness and average channel slope influence the retention of sediment and water, we know little about the specific features of stream channels that act to retain coarse, suspended organic materials of different types (see Hoover et al. 2006). If the geomorphological features of stream channels act as crucial elements in the retention of terrestrial inputs, the strength of linkages between riparian forests, headwater streams, and downstream reaches will depend on the physical characteristics of the channel itself.

In coastal British Columbia, riparian management strategies that encompass timber harvesting, use by livestock, and road building are known to effect changes in riparian forests and the rates of forest-to-stream inputs to adjacent streams. The goals of the first year of this project were to determine (1) if riparian...
management history controls the rates and types of organic matter (OM) input to small streams, and (2) if geomorphological factors (e.g. bed roughness) influence the amounts of OM that are retained in streams. The first year of the project focused on several different types of terrestrial OM that function as important forest-to-stream subsidies in coastal watersheds: red alder (*Alnus rubra*) leaf litter, red-cedar (*Thuja plicata*) fronds, conifer (e.g. Douglas-fir *Pseudotsuga menziesii*) needles, and wood fragments.

**Methodology**

We conducted two studies to quantify the physical processes that link riparian forests with the food webs of adjacent forest streams.

In the first study, we determined the amount of terrestrially-derived OM that entered small coastal streams with different riparian management histories. In the Alouette and Pitt River watersheds, we recorded OM input rates in streams with four different riparian management histories: (1) recently logged to the bank, (2) recently logged with riparian leave strips of coniferous trees, (3) older logged streams with riparian stands of red alder, and (4) unlogged (primarily coniferous riparian canopies). Daily fluxes of OM entering five replicate streams of each riparian condition were measured using pan traps suspended above the stream surface for 48-hour periods. The samples were then separated into their component fractions (conifer needles, red-cedar fronds, woody debris, flowers, etc.), and dried for 24 hours in a drying oven at 60 °C.

In the second study, we established a relationship between channel geomorphology (e.g. bed roughness) and reach-specific export and storage of OM. Eighteen stream sites were selected in low-order tributaries in the Pitt and Alouette River watersheds. The bed material of the 18 stream sites varied from gravel (median grain size diameter (D50) = 0.4 – 6 cm), to cobbles (D50 = 6 – 26 cm) and boulders (D50 = 26 – 410 cm). All 18 streams had mixed coniferous and deciduous riparian canopies. Pan traps were used to determine reach-specific input rates, while drift nets placed in the stream were used to determine the reach-specific flux rates of suspended OM. Streambed samples obtained using a net held downstream of a rectangular sampling quadrat of known area (0.00225, 0.04, or 0.0625 m², depending on the coarseness of the bed material) were used to determine the amount of detrital OM stored within the bed at each site. The macroinvertebrates associated with retained OM in the three channel types were identified from the streambed samples. A series of physical measurements were taken at each sampling point, including sediment grain size, grain protrusion, depth, and water velocity. Samples were obtained in early summer, late summer, and autumn in order to assess seasonal variation in terrestrial inputs and OM transport dynamics. All samples collected were separated into their component fractions (conifer needles, red-cedar fronds, etc.), dried, ashed at 550 °C, and re-weighed to obtain ash-free dry mass.
Interim Results, Conclusions, and Applications

There was substantial variation in the amount and types of OM inputs among streams with different riparian management histories (Figure 1). Recently logged (clearcut) streams had very little OM input, which was dominated by woody debris and the leaves of re-growing shrubs. Inputs of OM to streams with riparian leave strips of coniferous trees and streams with unlogged riparian canopies (primarily coniferous trees) were similar, although inputs of needles were higher in leave strips, possibly due to higher wind velocities in these canopies (Ruel et al. 2001). Streams with riparian stands of red alder experienced inputs from diverse sources.

![Figure 1](image-url)

**Figure 1.** Mean amounts of organic matter inputs to 20 small streams in south-western British Columbia with different riparian management histories (n = 5 for each management type, see text for more details). Error bars = standard deviation.

Channel geomorphology was an important factor in OM retention. However, the role of geomorphological factors varied among the different OM types (Figure 2). For example, the retention of coniferous debris (needles and red-cedar fronds) was very strongly related to sediment grain protrusion ($r^2 = 0.60$), while the retention of deciduous leaf material was not ($r^2 = 0.06$). While the retention of
woody debris appeared to be strongly dependent on grain protrusion ($r^2 = 0.59$), this trend was primarily due to two sites which retained large quantities of wood; when these two sites were removed from the analysis, there was little correlation between grain protrusion and wood fragment retention ($r^2 = 0.08$). The results suggest that there may be well-defined physical thresholds for the retention of OM in small streams; very little OM of any type was retained when grain protrusion < 3 cm, while substantial amounts of OM of all types were retained when grain protrusion > 7 cm.

**Figure 2.** Amounts of organic matter stored in streambed sediments in 18 stream sites in southwestern British Columbia in relation to sediment grain protrusion at the site. Relationships for three different organic matter types are shown; coniferous material (needles and red-cedar fronds), wood fragments, and deciduous leaves (red alder and other species). Error bars = standard deviation, dashed lines = regression lines. Note that the first regression coefficient reported
for ‘Wood fragments’ includes all data points, the second (*) excludes the two high-magnitude values on the right.

These results indicate that riparian management can potentially have substantial impacts on stream food webs by modifying rates of OM inputs to streams. While complete clearcutting can substantially reduce inputs of easily-processed OM types such as leaves, streams associated with riparian leave strips may actually experience higher rates of OM inputs. However, effects to stream communities will be mediated by the physical structure of the streams themselves. For instance, reductions in riparian canopy density may reduce rates of OM inputs, but in reaches with low retention (i.e. low bed roughness) many of the effects may be experienced by downstream reaches rather than those reaches immediately adjacent to the harvested area. In contrast, in those streams with coarse bed material, reductions in riparian canopy density may immediately reduce the availability of OM to stream detritivores, creating notable changes in community structure. Harvesting the timber immediately adjacent to fishless streams with fine bed material (i.e. fine gravels with grain protrusion < 3 cm) may have substantial effects on food webs in fish-bearing reaches downstream (including possible reductions in food available to fish), whereas similar timber harvesting adjacent to streams with very coarse bed material (grain protrusion > 7 cm) may have fewer effects on downstream food webs.

Research in the second and third years of this project will quantify the roles that detritus type and channel geomorphology play in food web dynamics both in upstream and downstream reaches. Because different OM types stored in the bed are utilized by stream organisms at different rates (see Richardson et al. 2004), changes to riparian canopies may produce a cascade of effects in stream food webs that is not easily predicted.

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References


