Links between riparian forest ecosystems and aquatic communities

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INTRODUCTION

The composition of riparian floral and faunal communities is strongly dependent upon the physical and chemical properties of the stream. Many of these properties are directly determined by the landscape surrounding the stream as well as the upstream landscape components. The retention of nutrients and autochthonous (produced within the stream) carbon sources in small streams located high in the watershed influences the macroinvertbrate community composition and can influence the energy flow patterns downstream and throughout the rest of the river (Vannote et al. 1980, Young 2000). As many small streams in forested areas are light limited which in turn limits primary productivity, clearcutting of riparian forest can drastically alter the dynamics of the food web. Increasing light availability to the site increases primary productivity which then impacts downstream communities. Removal of riparian forests near small streams can have many detrimental impacts to the aquatic communities by completely numerous chemical and physical properties of the stream including stream temperature, litter infall, nutrient and light availability.

Changes in community dynamics that affect the success of salmon spawning and rearing are of particular importance due to the economic, ecological, and recreational importance of anadromous fishes. Anadromous salmon (fish that migrate from the sea to freshwater to spawn) provide an important link between the river and ocean ecosystems by transporting energy of oceanic sources to interior riverine habitats. In addition, numerous studies have demonstrated the importance of salmon to terrestrial communities. Salmon contribute to the aquatic and terrestrial food webs in a variety of ways. They provide nutrients to trees and other vegetation [as post-spawning salmon carcasses degrade along stream banks], and provide food for birds, bears and even aquatic insects. The persistence of salmon in riverine habitats depends on the integrity of links between aquatic and terrestrial ecosystems. The Skeena River in British Columbia is a prime location in which to observe the healthy relationship between aquatic and terrestrial ecosystems. There have been very few disturbances such as clear cutting and development along the upper reaches of this river. This paper will examine potential effects on the terrestrial and aquatic ecosystem if poorly managed timber harvest practices were implemented along tributaries of the Skeena River.

The Problem from a Regulatory Perspective

British Columbia, like all regional governments in the Pacific Northwest, maintains guidelines that regulate forestry harvesting practices near riparian areas. British Columbia has restrictions on timber harvesting practices that protect all but the smallest (<1.5 m width) fish-bearing streams by requiring a 20 to 50 m no-harvest zone as a riparian buffer on either side of the stream (Young 2000). British Columbia (BC) has much more extensive areas of old growth forest than in the Pacific Northwest; therefore, the main goal in BC is to protect existing resources rather than to restore resources and to compensate for previous damage while preventing further damage. However, according to the 2004 report published by the David Suzuki Foundation (DSF), timber companies working in coastal BC are generally not voluntarily protecting small fish-bearing streams with unlogged buffers (Figure 1).

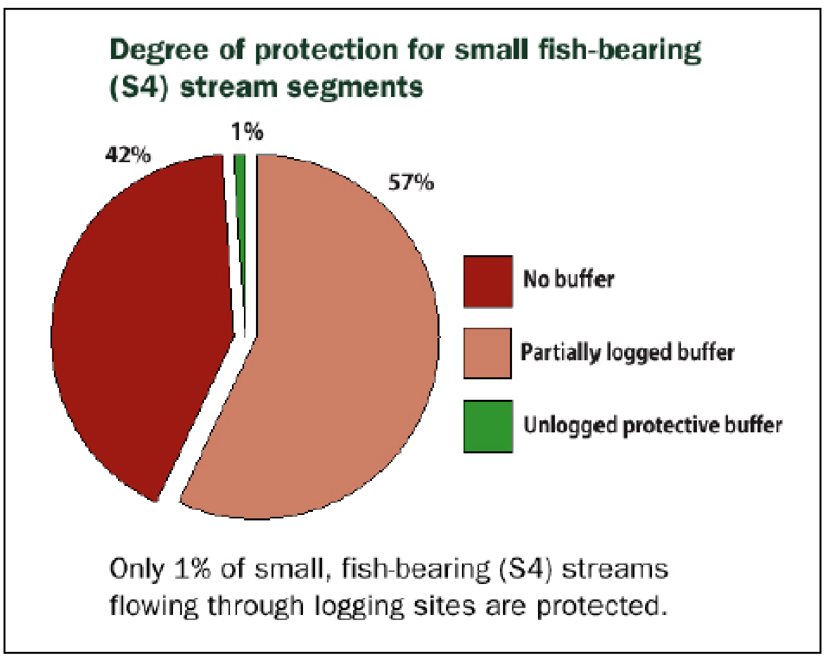

Figure 1. Between January 2003 and February 2004 unlogged riparian buffer zones were left on only 1% of small fish bearing streams located in logged areas of coastal British Columbia. (DSF 2004)

Companies are not legally required in this region to leave unlogged riparian buffers for streams less than 1.5 meters wide. Only one of the six companies investigated left a portion of unlogged riparian buffer around as small percentage of the small streams in their logging regions (DSF 2004).

In British Columbia, much of the timber harvest in the past has been confined to areas near the coast for ease of transport, but harvest is now more common in interior regions of the province. In February 2002, a symposium was held at The University of British Columbia to discuss the importance of small streams to the ecological health of a watershed and to identify levels of riparian vegetation retention required along small streams to protect aquatic ecosystems, riparian wildlife, and water quality (Moore and Richardson 2002). Results of this symposium are published in the August 2003 issue of the Canadian Journal of Forest Research. In several of these papers, the authors predicted that increased timber harvest pressures will be placed on boreal and sub-boreal forests in the near future (i.e. Fuchs et al 2003). Therefore it is essential that accurate ecological requirements be established for timber harvests that will maintain riparian environments to protect stream quality for salmon runs, mammal and bird habitat.

From a management perspective, it is difficult to ascertain a specific value for the minimum buffer width that is necessary to maintain a healthy linkage between riparian forests and streams. Many stream quality factors are affected by riparian forests including stream stability, channel morphology, stream temperature regulation, terrestrial inputs such as invertebrate infall, large and small woody debris inputs, sediment, and stream bed shading. Along some stretches of streams that are important for fish habitat, it is essential to establish a balance between ecological function and economic feasibility because ideal some timber harvest is inevitable. In other less impacted areas such as the Skeena River of British Columbia, logging has not yet become a major concern. The remainder of this paper will outline the potential impacts of timber harvesting in riparian forests on the aquatic environment. Impacts of timber harvest near riparian areas that have the potential to affect fish populations fall into 2 categories: physical changes and biotic changes. Each of these changes directly impacts the ability of fish, such as the anadromous salmonids, to survive and reproduce in the stream.

IMPACTS OF CLEARCUTTING RIPARIAN FORESTS

Physical changes

Inputs due to erosion and overland flow

Erosion and runoff often carry high loads of sediments (a.k.a. suspended solids) that may alter or impair the ability of certain fish, invertebrate, and plant species to survive in a particular reach of the stream. Sediments can settle onto aquatic vegetation decreasing the foraging ability of some invertebrates. In addition, suspended sediments can reduce the water quality and decrease suitable habitats for filter feeding invertebrates and fish in the river for great distances downstream. Runoff that is high in nutrients such as nitrogen and phosphorus can drastically alter productivity in downstream communities.

Macdonald et al. (2003) observed the changes in sediment loading to sub-boreal forests of a central, interior watershed of British Columbia that received several different levels of forest harvest. The goal of this project was to compare two riparian harvesting levels that are allowed in current British Columbia legislation. While timber harvest treatments of high retention (removal of merchantable timber >30 cm in diameter that are within 20 m of the stream), low retention (removal of all merchantable timber > 15 cm for pine and >20 cm in diameter for spruce within 20 m of the stream) and no harvest differed in initial sediment fluxes, suspended sediment levels returned to pre-harvest conditions within three years in both treatments.

Effects on stream habitat structure and availability

Maintaining riparian buffer strips is important for both decreasing erosion and runoff and also for maintaining the potential for terrestrial inputs into the stream in the form of small and large woody debris, leaf litter, detritus, and terrestrial invertebrates. Buffer strips of riparian vegetation that are 20-50 m wide should maintain about 50 to 80% of potential small and large woody debris sources (Young 2000). However, key tree species with the potential to become beneficial woody debris sources must be maintained. Some tree species result in greater amounts of invertebrate infall to the streams which is important for the diet of juvenile salmon (Hunt et al. 1975, Perry et al. 2003).

The periodic influx of large woody debris is essential for providing invertebrate and fish habitat. Tree falls, often attributed to windthrow, that block all or part of the stream result in extreme changes to channel bed morphology. They increase habitat opportunities by creating deep pools, facilitating mid-stream gravel bars, and by providing protected shady areas that foster invertebrate communities and protect fish from predators (Figure 2).

Figure 2. Large woody debris can create vital habitat for salmon. (Oceanlink: Bamfield Marine Sciences Center 2003)

Clear cutting of riparian vegetation near the stream effectively eliminates the input of large woody debris into the stream. It is important to maintain trees with a diameter large enough to remain in place in the stream through a variety of small floods. In a comparison of clear cut and unimpacted streams in the Russian boreal landscape, the amount of large woody debris was 10 to 100 times greater in unimpacted streams than in streams with clear cut catchments (Lijamiemi et al. 2002). In addition, input of detritus was greatly decreased in the clear cut stream. Detritus is an important food source for many invertebrates and limited detrital inputs can decrease overall productivity in the stream.

Biotic changes

Changes in primary productivity

One of the most obvious alterations to stream habitats from clear cutting riparian vegetation is the change in canopy closure. Canopy closure determines the amount of light that reaches the stream for primary production. A change in canopy closure initiates a chain of events that may completely alter community dynamics in the stream. One such pathway is illustrated in figure 3. Extensive logging near stream beds actually can result in temporarily increased macroinvertebrate community biomass, diversity and density (Fuchs et al. 2003). Due to the higher light levels, photosynthesis within the stream usually increases which results in a greater amount of periphyton (the vegetation or algae that is attached to rocks or other stream bottom substrate) on which macroinvertebrates feed.

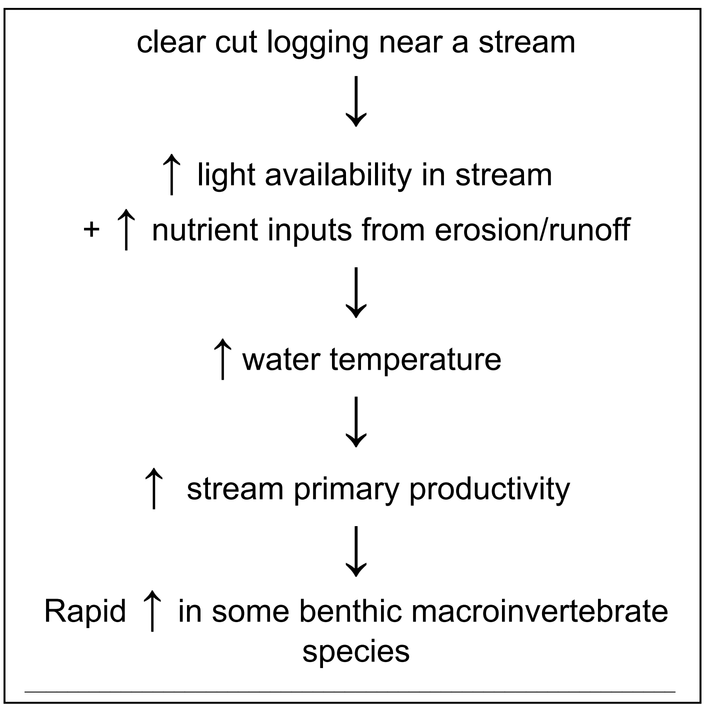

Figure 3. One possible pathway in which clear cutting near streams affects stream communities.

Aquatic macroinvertebrates are often classified according to the feeding guild to which they belong. Some researchers predict that increases in light availability will result in a shift in the most abundant feeding guild from shredders which tend to feed on detritus to scrapers which tend to feed on periphyton, though proof for this hypothesis is poorly documented (Liljaniemi et al 2002, Fuchs et al. 2003). The abundance and type of aquatic macroinvertebrates determines, in part, the availability of food for salmon and other stream fishes.

Water temperature is another important variable that is strongly influenced by the level of canopy closure. High amounts of vegetation covering the stream decrease the level of direct solar radiation that reaches the water surface and thereby maintain cooler less variable water temperatures. Modest water temperature changes can affect insect and fish populations through impacts to insect abundance, egg incubation, susceptibility to disease and fish rearing success (Macdonald et al. 2003a). Kiffney et al. (2003) found that solar radiation allowing photosynthesis increased directly in proportion to an increase in riparian buffer width. In regions of the stream with 30 m riparian buffer strips, they observed significant increases in photosynthetically active solar radiation, periphyton biomass, and water temperature (Kiffney et al. 2003). Johnson and Jones (2000) observed 7 degree C increases in maximum stream temperatures after clearcutting in an Oregon forest stream. Young et al. (1999) found that temperatures in non-anadromous cutthroat trout streams harvested to streamside margins crept to a maximum summer temperature of 30 °C, which may have resulted in the four-fold decline in fish density in this stream.

Effects on macroinvertebrate communities

Clear cutting within several dozen meters of a stream channel influences the aquatic plant and algae growth as well as detritus (leaf) inputs to the streamwater resulting in higher abundances, diversity and density of aquatic macroinvertebrates. In addition, the proximity of certain tree species to the stream has shown to influence the infall of terrestrial invertebrates to the stream. Terrestrial invertebrates can account for greater than 50% of the energy intake by stream fish and are often the preferred prey of juvenile salmonids (Wipfli 1997). Deciduous trees usually harbor more invertebrate species in a greater abundance than do conifers. Therefore, clear cutting practices should be designed to maximize invertebrate infall into streams by choosing tree species and tree sizes with the greatest potential benefits to the salmon food supply. Terrestrial inputs of invertebrates did not differ significantly in juvenile salmon diets between old growth and young forest growth (recently clear cut) sites (Wipfli 1997).

Time Scales for Recovery of Pre-harvest Conditions

While clear cutting riparian forests can result in drastic and abrupt changes in physical and biotic stream habitat conditions, many of these impacts may only persist for a few years or up to several decades depending on the stream characteristics. Hartman et al. (1996) explain that there are three time scales by which to measure recovery to pre-harvest conditions. These include the three to 20 year impacts that diminish with vegetation regrowth, the intermediate scale impacts of seen in 5-10 year flood events and the erosion associated with these floods, and the 10-20 year impacts with the low availability of large woody debris inputs. Initially, removal of vegetation primarily affects biotic components of the stream that are determined by light availability and terrestrial infall. For example, Fuchs et al. (2003) observed increased macroinvertebrate biomass due to increased primary productivity in young deforested stream segments, but this effect diminished within 20 to 35 years.

Effects from erosion may not be observed until a large flood event that generally recurs at 5 to 10 year intervals creates a large sediment influx that alters the stream channel morphology. Macdonald et al. (2003) determined that increases in suspended sediments after clear cutting only lasted about 3 years or less; however, their study measured initial changes and did not continue long enough to observe potential long term changes in channel morphology. Some long term impacts from clear cutting may not appear for several decades. For example, after clear cutting near stream banks, less large woody debris will be available to fall into the stream resulting in decreased availability of suitable habitat for fish and invertebrates over time (Hartman et al. 1996).

CONCLUSION

Clear cutting riparian forests close to stream beds can have drastic negative effects on fish habitat quality and fish survival. Some of these effects, such as increased water temperature, increased sediment loading, and decreased large woody debris inputs, can greatly reduce the ability of fish to persist in these areas. Maintenance of riparian buffer zones of uncut vegetation near the stream banks can often greatly decrease the impacts of tree harvesting depending on the extent or width of the buffer zone on either side of the stream. As Young (2000) described, the width of the riparian buffer strip is directly proportional to the benefits it is able to provide in terms of mediating effects of harvesting on the physical and biotic components of the stream.

The ideal buffer width that protects the majority of stream components has not been determined, and it is likely dependent on local conditions and habitat components. A variety of recommended buffer widths have been presented by various researchers, but each often focuses on only a few habitat components, such as the width necessary to control solar radiation or the width necessary to prevent excessive sedimentation in the stream (Lee et al. 2004).

Governmental requirements for riparian buffer widths differ greatly between the states and provinces in the Pacific Northwest. California and Washington do not require no-harvest riparian buffer zones near the smallest streams while Oregon requires 6 m buffers and British Columbia requires 20 m no-harvest zones around streams greater than 1.5 m wide (Young 2000). Increased protection of salmon rearing habitat is likely to be gained by requiring riparian buffer strips and increasing the required widths of these buffers. Many of the impacts of timber harvest can be minimized by buffer zones of only 20 to 30 m while zones up to 100 m may be necessary to fully eliminate all impacts of the tree harvest. A compromise between loss of economically valuable timber and the protection of terrestrial habitat functioning must be made to allow the fish that are environmentally, recreationally, and often economically valuable to persist in the streams.

RELEVANCE TO THE SKEENA RIVER

As the Skeena River provides habitat for at least five salmon species, as well as dolly varden trout and steelhead, maintaining suitable reaches for spawning in terms of temperature, large woody debris, insect prey, and water quality are of great concern in this entire watershed. Timber harvesting near the river edges can have strong negative impacts on the salmon rearing success directly at the site as well as potentially impacting habitat quality in reaches far downstream from the disturbance. As the need for timber continues to expand in interior British Columbia, great care must be taken to protect regions that can influence headwaters and small order tributaries of the Skeena River in order to allow salmon populations to persist. Unlike many rivers in British Columbia, the Skeena has been protected from dam construction in order to allow salmon runs to continue. Similarly, timber harvesting should be managed to require protected no-harvest riparian buffers and restricted to areas where negative impacts to the Skeena River aquatic communities will be limited.

REFERENCES CITED

Allan, J.D., M.S. Wipfli, J.P. Caouette, A. Prussian, and J. Rodgers. 2003 Influence of streamside vegetation on inputs of terrestrial invertebrates to salmonid food webs. *Canadian Journal of Fisheries and Aquatic Sciences* 60: 309-320.

Bamfield Marine Sciences Center. 2003. Oceanlink website: Accessed 28 May 2004: oceanlink.island.net/oceanmatters/salmon.html

David Suzuki Foundation (DSF). 2004. Canada's Rainforests: Status Report. pp 1-34. www.canadianrainforests.org date accessed: 5/25/04.

Fuchs, S.A., S.G. Hinch, and E. Mellina. 2003. Effects of streamside logging on stream macroinvertebrate communities and habitat in the sub-boreal forests of British Columbia, Canada. *Canadian Journal of Forest Research.* 33(8): 1408-1405.

Johnson, S.L. and J.A. Jones. 2000. Stream temperature responses to forest harvest and debris flows in western Cascades, Oregon. *Canadian Journal of Fisheries and Aquatic Sciences*. 57(Suppl. 2):30-39.

Hartman, G.F, J.C. Scrivener, and M.J. Miles. 1996. Impacts of logging in Carnation Creek, a high-energy coastal stream in British Columbia and their implication for restoring fish habitat. *Canadian Journal of Fisheries and Aquatic* Sciences 53 (Suppl1) 237-251.

Kiffney, P.M., J.S. Richardson, and J.P. Bull. 2003. Responses of periphyton and insects to experimental manipulation of riparian buffer width along forest streams. *Journal of Applied Ecology* 40:1060-1076.

Lee P., C. Smyth, S. Boutin. 2004. Quantitative review of riparian buffer width guidelines from Canada and the United States. *Journal of Environmental Management* 70:165-180.

Liljaniemi, P., K. Vuori, B. Ilyashuk, and H. Luotonen. 2002. Habitat characteristics and macroinvertebrate assemblages in boreal forest streams: relations to catchment silvicultural activities. *Hydrobiologia.* 474:239-251.

Macdonald, J.S., P.G. Beaudry, E.A. MacIsaac, and H.E. Herunter. 2003. The effects of forest harvesting and best management practices on streamflow and suspended sediment concentrations during snowmelt in headwater streams in sub-boreal forests of British Columbia, Canada. *Canadian Journal of Forest Research*. 33(8): 1397-1407.

Macdonald, J.S., E.A. MacIsaac, and H.E. Herunter. 2003a. The effect of variable- retention riparian buffer zones on water temperatures in small headwater streams in sub-boreal forest ecosystems of British Columbia. *Canadian Journal of Forest Research*. 33(8): 1371-1382.

Moore, R.D. and J. S. Richardson. 2003. Progress towards understanding the structure, function, and ecological significance of small stream channels and their riparian zones. *Canadian Journal of Forest Research.* 33(8): 1349-1351.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. *Canadian Journal of Fisheries and Aquatic Sciences*. 37:1259-1269.

Wipfli, M.S. 1997. Terrestrial invertebrates as salmonid prey an d nitrogen sources in streams: Contrasting old-growth and young growth riparian forests in southeastern Alaska, U.S.A. *Canadian Journal of Fisheries and Aquatic Sciences*. 54:1259-1269.

Young, K., S. Hinch, and T. Northcote. 1999. Status of resident coastal cutthroat trout and their habitat. *North American Journal of Fisheries Management* 19: 901–911.

Young, K.A. 2000. Riparian zone management in the Pacific Northwest: Who's cutting what? *Environmental Management* 26:131-144.