The case for riparian reserves around small streams

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**Abstract**: Riparian reserves for the purpose of protecting fish and fish habitat from possible adverse effects of forestry have been in use for nearly 30 years. For the most part, streams lacking fish, particularly small streams, do not receive reserves. An increasing appreciation that small streams provide important ecosystem services, strongly influence downstream environments, and are a unique habitat in their own right, means that we need to consider how to bring their consideration into watershed-scale measures for protection. The direct effects on these habitats and now-obvious downstream effects of perturbations of small streams make it clear that these sites are vulnerable and their effects can be cumulative. Sustainable forest management will demand that we consider the roles of small streams and cumulative effects at the landscape level when we evaluate whether guidelines can achieve the objectives set for them.

**Keywords**: *streams, riparian, fish, water, headwaters*
Introduction

One of the objectives of sustainable forest management is the protection of aquatic resources, including clean water, healthy organisms, and ecosystem processes. The riparian zone, being the interface between the terrestrial and aquatic systems, plays an important role in controlling the impacts of land use activities, such as forestry, on aquatic resources. The most common approach to maintaining the integrity of the riparian zone is to leave reserve zones along streams, usually in the form of buffer strips. Many jurisdictions stratify stream protection primarily by stream size (Young 2000, Blinn and Kilgore 2001, Lee et al. 2004). While most jurisdictions require the retention of riparian forest cover along larger streams, prescriptions vary dramatically for riparian retention along smaller, usually non-fish-bearing, stream reaches. Some jurisdictions require buffers that extend up to and sometimes upslope of the perennial channel network and include intermittent streams (Blinn and Kilgore 2001), while others, such as British Columbia, do not require leave strips along non-fish-bearing streams (unless they are a designated community water source) or even the smaller fish-bearing streams (i.e., those less than 1.5 m bankfull width). Clearly there is a bewildering set of management guidelines used in North America, which only make sense when one considers the diversity of management objectives amongst jurisdictions.

Small streams are sometimes referred to as headwaters, but that term is often broadly applied and does not fully capture our notion of small streams. By small streams we mean those channels that have no perennial tributaries to them, and themselves may be intermittent or seasonal in surface flow (Moore and Richardson 2003). These small streams occupy the headmost position in a drainage, but are not necessarily at high elevation. They are more often steeper than downstream segments, but that is not a specific criterion. Several authors have demonstrated that these streams are underrepresented on maps of all scales, perhaps to the point of less than 25% of permanently-flowing small streams appearing on topographic maps at 1:50,000 scale (Sidle et al. 2000, Meyer and Wallace 2001).

Several arguments are commonly raised against the retention of buffer strips along small streams. Riparian leave strips can complicate access and yarding operations and incur opportunity costs to licensees. These costs can be considerable, given the high density of such streams in many landscapes; in extreme cases, buffers along headwater streams may overlap. A good example of opportunity costs associated with riparian buffers is the lower Nadina watershed in central British Columbia, where temperature sensitivity is a major management issue. To provide shade and thus reduce the potential for stream warming, extensive buffer strips are retained along small streams. It has been estimated that these buffers constitute 12% of the operable land base (D. Wilford, B.C. Ministry of Forests, pers. comm.). Another argument is that narrow buffer strips can be subject to significant blow-down, which may reduce their effectiveness (although this has not been tested experimentally) and can potentially generate significant sediment inputs via streamside soil disturbance (Grizzel and Wolff 1998).

The objective of this paper is to present the case for prescribing riparian reserves along small streams. We make this case by outlining the important services provided by small streams to downstream reaches, the important habitat values provided by small streams and their riparian zones, and how removal of streamside forest cover influences these services and values. We then
explore some possible alternative riparian management approaches that may help to protect aquatic resources associated with small streams while minimizing the costs associated with buffer strips.

**Services provided by small streams to downstream reaches**

Small streams are the primary input and storage zone for organic matter, which forms a large component of the basal resources for streams, both locally and downstream (Richardson et al. *accepted*). Input rates are reduced following clearcutting without buffers to less than 10% of pre-harvest inputs (P.M. Kiffney – *unpub. data*). Given that a large fraction of instream productivity in reaches downstream is dependent on this organic matter source, harvest-related decreases in OM inputs to small streams can have a significant impact on resource availability in downstream areas (Wipfli and Gregovich 2002). Storage and transport of wood and organic matter control the rates and times of year for which materials are delivered to downstream reaches where they support food web productivity.

Small streams originating from groundwater sources tend to be cool during summer (Mellina *et al.* 2002). They typically remain cool along their length as long as they flow under intact riparian forest cover, and can produce local cool-water areas where they flow into larger, warmer downstream reaches, and thus provide important thermal refugia (Bilby 1984). However, because small streams are shallow, they are sensitive to decreases in shade and attendant increases in solar radiation inputs. Such warming associated with harvesting without riparian reserves can reduce the value of cool-water areas at the mouths of small streams. In extreme cases where a significant proportion of small tributary streams are harvested without buffers, there is a potential for cumulative effects resulting in increased stream temperature in downstream reaches.

The banks and bed of small, steep streams tend to be made of large particles relative to channel depth, are usually not alluvial, and thus are relatively stable (Church in press). The transport of sediment from small streams has a profound influence on the geomorphic and habitat characteristics of downstream reaches. Changes to the spatial and temporal frequency of sediment inputs to downstream reaches can generate significant changes in downstream channel morphology and habitat that propagate through the channel network and persist for centuries (Miller *et al.* 2003).

**Inherent habitat values of small streams and their riparian zones**

Many species are only found in or near small streams. One reason species might occur uniquely in small streams is that those streams act as a fish-free refuge for species that are vulnerable to predation by fish. The lack of fish in many small streams may also be associated with a lack of terrestrial or aquatic predators that may be shared in common with fish. There are amphibians found only in very small streams, for reasons that are not completely understood (Sheridan and Olson 2003). The geomorphology of small streams, with largely colluvial (non-alluvial) banks, which may be a product of small absolute flow peaks, might provide special habitats not found
downstream where alluvial reworking of the banks might cause excessive disturbance for the persistence of some species (Richardson et al. *in review*). Some examples of species that seem vulnerable to harvesting along small streams include an array of small organisms that many people know little about, e.g., liverworts, mosses, and small snails (Hylander et al. 2002, 2004). Others include poorly-known species like the shrew mole (*Neurotrichus gibbsi*) (Cockle and Richardson 2002). There are undoubtedly other species for which there has been little systematic sampling to determine their habitat specificities. Theoretical work indicates that the organisms that are restricted to small streams and their riparian areas may be the most vulnerable to local extinction of populations due to the lack of contiguous refuge areas that might support their recolonisation (Fagan 2002), as might be found in bigger channels.

**An experimental test of the effectiveness of riparian reserves**

We initiated an experimental trial of riparian management strategies along small streams in coastal British Columbia in 1996, with harvesting in 1998 (Kiffney et al. 2003). We used a before-after, control-impact (BACI) design to achieve more statistically powerful results by controlling for initial differences amongst sites. The treatments included clearcuts to the banks, 10 m reserves, and 30 m reserves, each replicated three times, and contrasted with control streams. Measured variables included streamflow, water quality, temperature, and aspects of the stream and riparian food webs. The results to date indicate that even with 30 m reserves, many properties of these small streams changed (Cockle and Richardson 2003, Kiffney et al. 2003, Gomi et al. unpublished data). Even up to 5 years post-harvesting, there were still differences from the controls in terms of water quality, algal productivity, stream invertebrates, amphibians, and terrestrial invertebrates. These persistent differences are not entirely unexpected, but have not been demonstrated previously.

We have recently initiated a second phase to our experiments with a study of the effectiveness of partial harvesting within riparian zones of small streams. In this case an additional 3 streams will have 50% of the basal area of trees within the riparian buffer removed. This will be contrasted with control streams and using a BACI design we can use the pre-treatment conditions in the harvested areas to control for prior differences. We expect to have results from this part of the study by 2006.

Evidence that streams and their riparian zones are strongly affected by forest harvesting, even with reserves of 30 m, demonstrates that if the objective is to minimise divergence from initial conditions, current guidelines are insufficient. However, streams also have the potential to recover quickly, and transient effects on stream systems are not necessarily long-lasting (Richardson 2004). The high number of small streams means there could be refuges for species that require these habitats. We need to determine the rates of recovery of these small streams relative to the rate at which they are disturbed across the watershed, to ensure long-term sustainability of these valuable ecosystems.
Possible management options for small streams

Given the large proportion of most watersheds that would be impacted by leaving reserves around small streams, it is clear that leaving substantial reserves will not be taken seriously as a management option. Moreover, narrow linear reserves are prone to windthrow, perhaps reducing their effectiveness (this remains untested). There are some options that may be practical and provide a modicum of protection to small streams, certainly more than most receive now.

In many parts of the world, forest companies are practicing some form of variable retention, from single stems to patches of up to a hectare. These green tree patches are usually left for future wildlife habitat supply in the regenerating stand. One option in headwater areas may be to disproportionately leave these tree patches in the riparian areas within a harvest block. In some places trials with retention of advanced regeneration or mature trees whose foliage overhanging a stream are being left along small streams as a modest concession to their protection.

In stream networks, one of the most dynamic locations can be at the confluence of tributaries, often because these are of different sizes and gradients, leading to formation of deltas of sediment and wood. These confluences are more physically heterogeneous (Rice et al. 2001) and may support higher concentrations of biodiversity than elsewhere in the stream network. For this reason it may be advantageous to consider placement of tree patches at confluences of small tributary streams where they merge with other streams.

In most places, even without leaving vegetated reserves around small streams, there is more than sufficient reason to maintain machine-free zones along riparian margins. The direct impacts through soil compaction and physical damage can affect hydrology and streambank stability (Keim and Schonholtz 1999). Most guidelines already accommodate this protection, but it really is an absolute minimum amount of protection for aquatic habitats.

Conclusions

The management of small streams in forested landscapes remains controversial. There is no doubt that reserves for small streams can potentially have impacts on large areas of production forests. There also can be no doubt that these parts of the stream network are vulnerable to current forest practices in many areas. The resolution of this quandary will not be simple. We need to be clearer about what objectives we are trying to achieve by way of protecting aquatic resources.

There is a great need to set up trials to evaluate whether riparian management guidelines are effective at achieving the objectives set for them. This is a rarer occurrence than most would think. Evaluation against alternatives and controls is needed, particularly comparisons with creative layouts beyond the narrow, fixed-width reserve approach still common around the world. Most of the studies referred to regarding the role of riparian management are often unreplicated case studies or uncontrolled surveys, which still teach us important lessons, but are not sufficient. Properly designed experimental (or adaptive management) trials should be put in
place at the same time as guidelines are implemented, with the explicit commitment to revisions if the trials show the guidelines not to be sufficiently successful.

Finally, we need to put small streams into context within the watershed scale, at which scale we consider sustainable forest management to be tractable. This will include studies at the site scale, but also consideration of cumulative effects at larger scales in time and space. The scaling up from local riparian protection to the consideration of whole watersheds will be a major challenge facing scientists, and ultimately forest managers. However, if we contend that we practice sustainable forestry, then this challenge is one that will require investment and ingenuity.

**Literature cited**


