

## THE CUMULATIVE IMPACTS OF WATERSHED URBANIZATION ON STREAM-RIPARIAN ECOSYSTEMS

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**ABSTRACT:** Historically, watersheds of the Puget Sound lowland ecoregion contained an abundance of complex, diverse, and productive salmonid habitat in the form of small stream ecosystems and associated riparian ecotones. However, development of these lowland watersheds has significantly impacted the ecological integrity of their aquatic ecosystems. The cumulative effects of watershed urbanization have resulted in a loss of natural forest and wetland cover, as well as a significant increase in impervious surface area. Riparian forests, floodplains, and off-channel wetlands have also been severely degraded by the incremental encroachment of residential and commercial development. The decline in ecological integrity of the stream-riparian ecosystem begins at very low levels of watershed development and continues with increasing watershed urbanization. A conservation-based strategy for managing stream-riparian ecosystems in our urbanizing watersheds should be adopted if the remaining salmonid resources are to be protected and to facilitate recovery of those already in decline. Initial research indicates that maintaining natural riparian corridors around streams and wetlands can have a positive influence on ecological integrity even at moderate levels of watershed development. These results suggest that resource managers should place a high priority on preservation of remaining high quality stream-riparian ecosystems. In addition, our long-term objective should be to actively manage for natural riparian buffers throughout our watersheds.

**KEY TERMS:** Riparian Ecotone, Stream-Riparian Ecosystem, Urbanization, Forest Buffer, Salmonid Habitat.

### INTRODUCTION

In the Puget Sound lowlands (PSL), streams, wetlands, and their associated riparian areas, provide significant habitat for a myriad of fish and wildlife species. Historically these lowland aquatic ecosystems have provided important spawning and rearing habitat for native salmonid fishes (Nehlsen et al., 1991; Knutson and Naef, 1997; Naiman and Bilby, 1998). Most lowland stream systems can potentially support a diverse and abundant community of salmonids. Wild salmon and trout have significant scientific, cultural, and socio-economic value to the people of region. Although anadromous fish spend most of their life in the ocean, feeding and maturing to adulthood, the time spent in streams, wetlands, and nearshore areas, in close proximity to humans, is critical to their survival. During their freshwater life-history stages salmonids are coexisting with humans and can be affected by human activities in the watershed. These potentially damaging activities include timber harvest, road building, agriculture, and development (NRC, 1996). In the PSL region, the cumulative impacts of human activities, including watershed urbanization, over the past century, have resulted in a decline in salmonid abundance and overall biodiversity (Nehlsen et al., 1991; NRC, 1996; May et al., 1997; Lichatowich, 1999).

A wide, nearly continuous corridor of mature forests, off-channel wetlands, and complex floodplain areas (Naiman and Bilby, 1998) characterizes natural stream-riparian ecosystems of the PSL ecoregion. Native riparian forests of the region are typically dominated by a complex, multi-layered forest of mature conifers, mixed with patches of alder where disturbance has occurred in the recent past (Gregory et al., 1991). The riparian forest also includes a complex, dense, and diverse understory and groundcover vegetation. In addition, the extensive upper soil-layer of forest "duff" provides vital water retention and filtering capacity to the ecosystem. A typical PSL natural riparian corridor also includes a floodplain area, channel migration zone (CMZ), and numerous off-channel wetlands. Natural floodplains, CMZ, and riparian wetlands are critical components of a properly functioning aquatic ecosystem (Naiman and Bilby, 1998). Organic debris and vegetation from riparian forests also provide a majority of the organic carbon and nutrients that support the aquatic ecosystem food web in these small lowland streams. In short, the riparian community (vegetation and wildlife) directly influences the physical, chemical, and biological conditions of the aquatic ecosystem. Reciprocally, the aquatic ecosystem affects the structure and function of the riparian community. Anadromous salmonids provide rich, seasonal food resource that directly affects the ecological integrity of both aquatic and terrestrial food webs. The potential contribution of nutrients from decomposing salmon carcasses to the forest was historically quite significant (Cederholm et al., 1989; Knutson and Naef, 1997; Willson et al., 1998; Cederholm et al., 1999). The presence of this seasonally abundant nutrient resource has also had a hand in shaping the evolution of the stream-riparian ecosystem (Willson, et al., 1998). The aquatic ecosystems of the region are very closely linked, ecologically, with the surrounding terrestrial ecosystems. Therefore, any human impacts that destroy or degrade habitat in the stream-riparian corridor, or reduce the abundance and diversity of wildlife that are associated with anadromous salmonids, has the potential to weaken the ecological linkages in this complex ecosystem.

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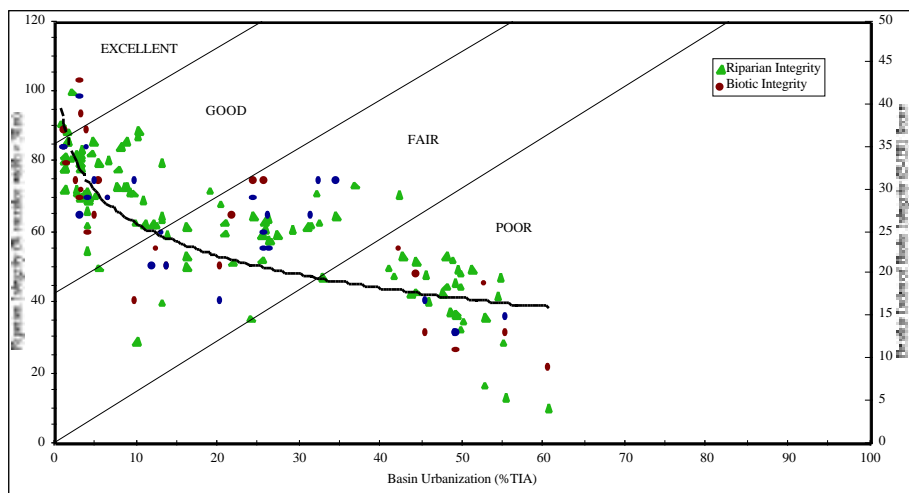
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In addition to the characteristics of the riparian forest described above, the most commonly recognized functions of the riparian corridor include (Gregory et al., 1991; Rapp, 1997; Naiman and Bilby, 1998; FISRWG, 1998):

- Providing canopy-cover shade necessary to maintain cool stream temperatures required by salmonids and other aquatic biota. Regulation of sunlight and microclimate for the stream-riparian ecosystem.
- Providing organic debris, leaf litter, and other allochthonous inputs that are a critical component of many stream food webs, especially in headwater reaches.
- Stabilizing streambanks, minimizing streambank erosion, and reducing the occurrence of landslides, but still providing stream gravel recruitment.
- Interacting with the stream channel in the floodplain and channel migration zone (CMZ). Retention of flood waters. Reduction of fine sediment input into the stream system through floodplain sediment retention and vegetative filtering.
- Facilitate the exchange of groundwater and surface water in the riparian floodplain and stream hyporheic zone.
- Filtering and vegetative uptake of nutrients and pollutants from groundwater and stormwater runoff.
- Providing recruitment of large woody debris (LWD) into the stream channel. LWD is the primary instream structural element which functions as a hydraulic roughness element to moderate streamflows. LWD also serves a pool forming function, providing critical salmonid rearing, flow-refugia, and enhanced instream habitat diversity.
- Providing critical wildlife habitat including migration corridors, feeding and watering habitat, and refuge areas during upland disturbance events. Primary habitat for aquatic habitat modifiers such as beaver and many other terrestrial predators or scavengers associated with salmonid populations.

## URBAN RIPARIAN MANAGEMENT

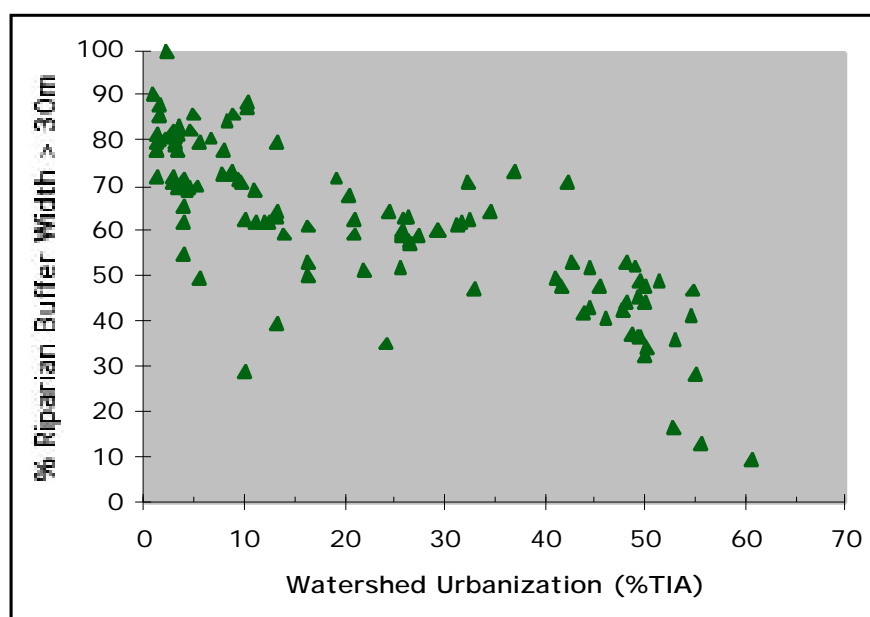
The effects of watershed urbanization on streams are well documented. They include extensive changes in basin hydrologic regime, channel morphology, and physicochemical water quality. The cumulative effects of these alterations produce an in-stream habitat considerably different from that in which salmonids and associated fauna evolved. In addition, development pressure has a negative impact on native riparian forests and wetlands, which are intimately involved in stream ecosystem functioning. Much evidence of these effects exists from studies of urban streams in the Puget Sound region (Richey, 1982; Scott et al. 1986; Booth and Reinelt 1993; Horner et al., 1997; May et al., 1997). During last of these regional studies of urbanizing watersheds, it became apparent that so-called riparian “buffers”, if designed and maintained so as to emulate natural riparian conditions, could have a significant mitigating influence on the ecological degradation of streams and wetlands in urbanizing watersheds of the PSL region (May et al., 1997). This was reflected in higher than expected levels of biotic integrity in those stream reaches with wide, continuous, and naturally vegetated buffers (Figure1).



**Figure 1: The relationship between biological stream quality and watershed development showing the potential benefits of riparian buffers in urbanizing watersheds. The suggested qualitative categories are shown based on Steedman, 1988.**

Based on the results of the initial PSL stream studies (May et al., 1997), the term, riparian integrity was adopted to describe the conditions found in natural PSL stream-riparian ecosystems. These “properly functioning conditions” should serve as a template for conservation and recovery of riparian areas. As used here, riparian integrity includes both structural and functional elements characteristic of the natural stream-riparian ecosystem.

Buffer width or extent (% corridor > specified width) is often the sole criteria by which most stream-riparian corridor management areas are generally defined. Buffers can be “fixed” or “variable” in width. Fixed-width buffers are generally the products of political compromise between protecting a natural resource and minimizing the impact on development and private-property rights. Buffers of this type, unless conservatively designed and managed, often fail to support all the ecological functions of the riparian corridor. Variable-width buffers have the potential to be more ecologically based, but are difficult to administer by jurisdictions. Impacts of human activities on stream-riparian ecosystems are numerous and highly variable. The complex mosaic of land use in developing watersheds results in a multiple stressors impacting the stream-riparian ecosystem. The characteristics of the stream-riparian ecosystem will also influence the extent and intensity of the human-induced disturbance. Streams in watersheds dominated by rural development will have different impacts than those in suburban or urban watersheds. Variables such as stream size, location within the watershed, stream gradient, valley configuration, watershed topography, soil type, and others all combine to make some stream-riparian ecosystems more or less sensitive to surrounding human impacts. For example, a stream with an extensive floodplain area or active CMZ will react quite differently than a stream within a deep, steep-walled ravine. It stands to reason then, that appropriate buffer size will depend on the spatial area necessary to maintain the desired riparian functions and on the land-use activities that are influencing the stream-riparian ecosystem. For example, a wider buffer may be required in situations where high-intensity land-use is found, than in areas of low-intensity land-use. Similarly, all else being equal, a sensitive tributary stream used by salmonids for spawning and rearing may require larger buffers than does a mainstem stream used only as a migration corridor. In general, urban riparian buffers have not been consistently protected or well managed (Schueler, 1995; Wenger, 1999; Moglen, 2000). This is certainly true of the PSL region (Figure 2).

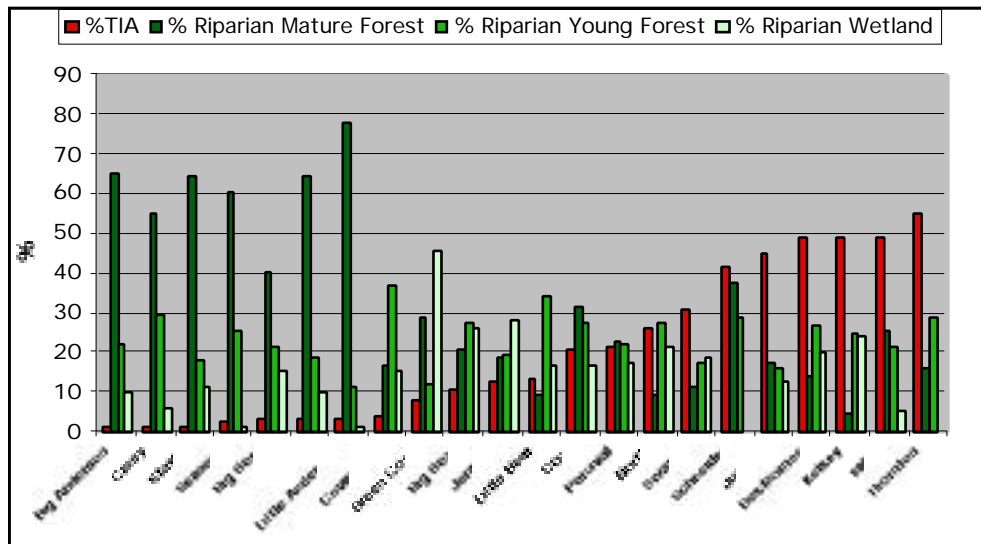


**Figure 2: The relationship between riparian buffer width and watershed development in Puget Sound Lowland (PSL) streams. A riparian buffer width of 30 meters is used as a measure of riparian extent (May et al., 1997).**

Of equal importance to the width or extent of the riparian corridor is the quality of the riparian area in terms of vegetation type, species diversity, physical condition, and maturity. Ideally, the riparian corridor in a developing or developed watershed should mirror that found in the natural ecosystems of that region. Due to the cumulative impacts of past and present land-use, this is often not the case (Figure 3). The riparian quality of the stream corridor is as important as the width or extent in determining how well a particular riparian area performs all of the functions required of it. The current vegetative composition and maturity should be factored into any riparian management or buffer width design effort. Areas dominated by mature, naturally complex forest have a much higher conservation potential than disturbed areas, young stands of native forest, or exotic vegetation. These mature and naturally diverse riparian areas also perform their required functions more efficiently and tend to be more resilient in recovering from disturbance (Naiman and Bilby, 1998). Past land-use activities in the PSL (timber harvest, road construction, and agricultural activities) have significantly impacted the riparian forests of the region (Horner and May, 1999). As a result, many riparian forests in urbanizing watersheds are dominated relatively young stands of alder and maple rather than the mixed-mature forests that characterize natural riparian communities of the PSL.

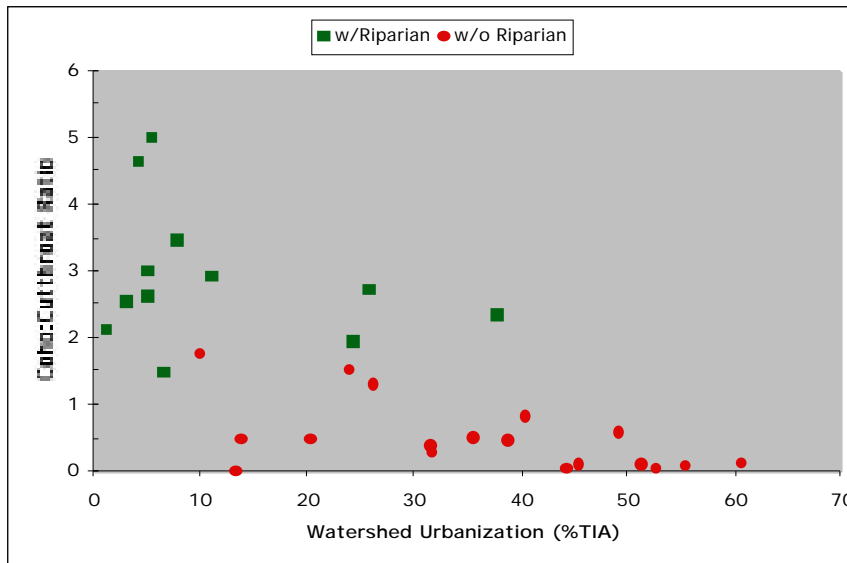
Floodplain connectivity is also critical to a properly functioning stream-riparian ecosystem (Rapp, 1997; Naiman and Bilby, 1998; FISRWG, 1998). This means that the active CMZ and floodplain should be included in the designated “riparian management zone” (RMZ). Both from an ecological and public safety perspective, development should be excluded

from the RMZ. In general, encroachment of developing areas should be prevented from impacting the structure or function of the stream-riparian ecosystem. This can be done via public education and by clear delineation of the RMZ (Schueler, 1995).

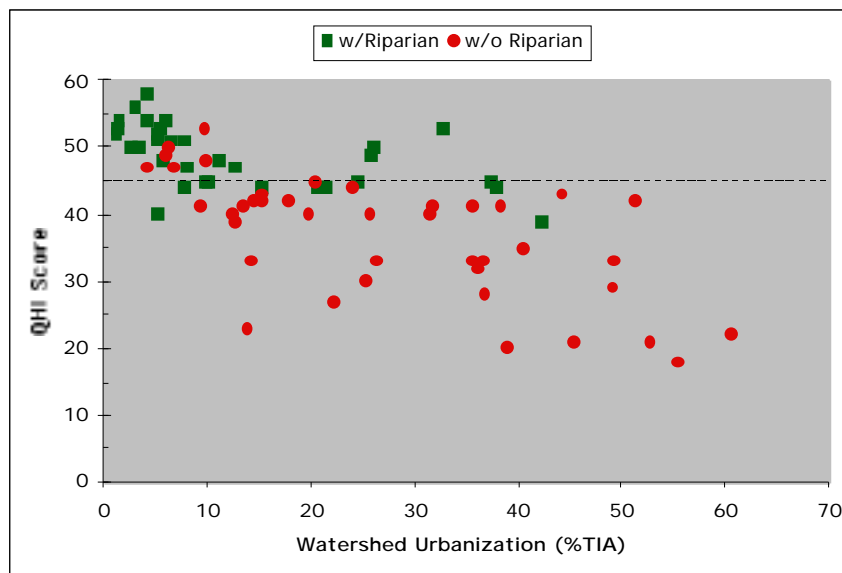


The second phase of research on the effects of development on PSL streams is underway. The focus of this phase is the efficacy of the best management practice (BMP) tools that urban water resource managers can apply in attempting to achieve aquatic resource protection and recovery goals. Specifically, its intent is to determine to what extent different types of BMPs mitigate the negative effects of watershed urbanization. Up to now, most jurisdictions have relied almost solely on structural BMPs designed to control the quantity of stormwater runoff or for pollutant removal, water quality treatment. In addition to the structural BMP approach, there has been a more limited use of what is frequently termed as non-structural BMP methods or the use of natural vegetation to treat stormwater runoff. Urban riparian buffers fall into this category of BMP. In their most widespread and effective form, the non-structural BMP approach preserves natural land cover through conservation efforts, land-use planning, and regulatory techniques. Available techniques include sensitive area ordinances, purchase of riparian or upland forest areas for open space, purchase of development rights in these areas, and incentive programs like impervious surface reduction, conservation design, and cluster development. There has been limited use in the Puget Sound region of non-structural controls in addition to structural BMP requirements.

development and could more easily be bought and put into protective status than upland areas. Riparian retention fits nicely with other objectives, like flood protection and provision of wildlife corridors and open space.



**Figure 4: The relationship between salmonid assemblage diversity (juvenile coho to cutthroat ratio) and watershed development in Puget Sound Lowland (PSL) streams showing the positive effects of natural riparian integrity. Sites “with riparian” refer to those sites with natural levels of riparian integrity (buffer width, corridor continuity, and maturity).**



**Figure 5: The relationship between instream habitat quality, as measured by the multi-metric habitat quality index (QHI), and watershed development in Puget Sound Lowland (PSL) streams (QHI of 45 was selected as the baseline level for properly functioning habitat). Sites “with riparian” refer to those sites with natural levels of riparian integrity.**

In order to determine RMZ and buffer dimensions, a comprehensive watershed and stream assessment must be conducted. This process will establish current conditions, identify threats to the ecological integrity of the stream-riparian ecosystem, and determine reference (historical or desired) target goals. In addition, riparian integrity must be evaluated and management goals established. When the analysis is complete, RMZ and buffer area should be delineated clearly both on maps and on the ground. This will reduce the possibility of inadvertent encroachment into the RMZ during on-going land-use activities or future development. It is important that a watershed approach be used in the RMZ delineation process so that both human (roads, agriculture, development, etc.) and ecological needs can be balanced as much as possible. Any modifications to RMZ or buffers to accommodate human activities should be based on a sound scientific foundation. The scientific principles that form the foundation for delineation of riparian management zones and buffers include the following:

- Maintain or restore the freedom of movement of stream channels to move and change within their natural CMZ based on environmental conditions.
- Maintain or restore the connection of the stream to its floodplain, including off-channel habitat, riparian wetlands, and side-channels.
- Allow natural regenerative processes to occur without undo human intervention. Restoration efforts should not conflict with natural processes.
- Protect or enhance biodiversity and habitat complexity within the stream-riparian ecosystem. Recognize and nurture the complexity and diversity of nature. Do not try to mold streams to suit human-based constraints.
- Support or reestablish the longitudinal connections within the stream-riparian corridor. The interactions of headwater areas, mainstem channels, tributaries, and estuaries are critical to the proper functioning of the watershed.
- Site-specific modifications must always consider the cumulative impact of that action and how the site plan fits into the watershed as a whole.

As the above discussion indicates, a “one-size-fits-all” buffer likely will not work. This would argue for a watershed-by-watershed, stream-by-stream, and site-by-site approach. This integrated, hierarchical approach may look to be a daunting and costly task, but it is necessary if we are to conserve our salmonid resources, protect of water quality, and improve our quality of life. The use of riparian buffers is only one component in an effective watershed management approach. Because of the diverse and pervasive nature of development impacts, buffers alone are likely not adequate. A combination of riparian buffers, land-use limits, and an aggressive stormwater treatment program may be the best strategy (Horner and May, 1999).

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