NEW IDEAS FOR RIPARIAN AND STREAM MANAGEMENT: AN EVOLVING SCIENCE[1]

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Abstract: Early research such as the Alsea Watershed Study (1959-1973) showed that leaving riparian vegetation adjacent to streams greatly moderates immediate water quality impacts associated with logging. Observations about depleted dissolved oxygen levels associated with logging slash and possible fish passage issues further supported retention of riparian vegetation and led to excessive stream cleanouts. Wood recruitment is now recognized as an important riparian function for streams. There is emerging evidence that natural systems need disturbance in order to be productive. Research indicates that riparian disturbance, including harvesting, can be beneficial to fish where in-stream large wood is maintained or rejuvenated. One benefit of riparian management areas (RMAs) is a reduction of aerially applied chemical spray drift to streams, further decreasing potential for adverse environmental impacts. Unanticipated negative consequences of RMAs include unfavorable conditions for regeneration (long-term wood recruitment loss) or light-tight canopies that reduce in-stream primary production and fish productivity. Questions such as "How wide is wide enough?" for riparian management areas are complicated by multiple RMA dimensions and potential performance measures. RMAs are clearly effective for maintaining certain water quality parameters such as temperature and sediment, but they cannot completely overcome the lack of Best Management Practices in other portions of a watershed. Pollution trading schemes are often confounded by the non-conservative nature of water quality. The future for riparian and stream management should involve optimization to balance or improve stream conditions and values (both short and long term) and sustainable economic benefits.

INTRODUCTION

In an 1843 report to Congress, Patent Office Commissioner Henry Ellsworth stated, "*The advancement of the arts, from year to year, taxes our credulity and seems to presage the arrival of that period when human improvement must end*." This infamous assessment that everything that could be invented would someday be invented is a metaphor for our evolving understanding of riparian forests and their connections with forest streams. Here we will describe not a static view, but an evolving understanding of how riparian management areas function and can benefit from active management.

Areas with special protection adjacent to streams go by many different names, including buffers, equipment exclusion zones, filter strips, riparian management zones, riparian management areas, shade strips, stringers, and water course and lake protection zones. Throughout this paper we will refer to them as riparian management areas (RMAs).

The importance of an evolving view of RMAs cannot be overstated. An August 2009 letter from representatives of the National Oceanic and Atmospheric Administration (NOAA) and U.S.

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Environmental Protection Agency (EPA) sent to the administrators for Oregon Department of Environmental Quality (ODEQ) and Department of Land, Conservation and Development, addressing a review of Oregon's compliance with the Coastal Zone Management Act (CZMA), found that "*Oregon's forestry program lacks adequate measures for protecting riparian areas of medium, small and no-fish bearing stream…*" and for other perceived limitations for the forestry program under the Oregon Forest Practices Act (NOAA and USEPA 2009). This has precipitated potential lawsuits by environmental groups to halt federal funding unless revisions to the Oregon Forest Practices Act are made such that NOAA and EPA can approve Oregon's CZMA measures.

EARLY TEST OF RIPARIAN MANAGEMENT AREAS: THE ALSEA WATERSHED STUDY

As most foresters know, one of the first and most influential tests of alternative riparian forest management was the Alsea Watershed Study. The original Study (1959-1973) assessed the effects of timber harvesting on water, aquatic habitat, and salmonid resources (especially Coho salmon and cutthroat trout) using a paired-watershed approach[3] (Stednick 2008). Flynn Creek Watershed served as an undisturbed control. Deer Creek Watershed was patch cut and had RMAs left along fish-bearing reaches of the stream. Needle Branch was nearly completely clearcut and subsequently slash burned; no streamside vegetative buffer was left to protect it. Slash was initially felled across the stream and then removed; in some reaches equipment was operated in the stream channel.

Needle Branch experienced dramatic water quality changes for temperature and dissolved oxygen (see Stednick 2008 for a comprehensive review of results and updates on research conducted at these sites after termination of the original study). Changes in discharge, sediment, nutrients, and cutthroat trout populations were also measured. Dissolved oxygen deficits were believed to result from elevated stream temperatures and loading of fresh slash in the stream. In contrast, Deer Creek (with RMAs) experienced much less change in water quality and no statistically significant changes in fish. These results contributed to adoption of the Oregon Forest Practices Act in 1971 and development of rules to protect water quality and fish habitat in 1972.

HOW WIDE IS WIDE ENOUGH?

One of the most divisive issues related to assessing forest practice rules or Best Management Practices (BMPs) is the question, "How wide is wide enough?" for an RMA. In reality, this cannot be answered because RMAs must be defined in at least three dimensions: width; reach extent (length); and management practice limits established (Ice et al. 2006). In turn, effectiveness can be measured using multiple metrics from fish productivity to various water quality parameters (Ice 2005a). Efforts to synthesize our understanding of how RMA width affects riparian functions include Castelle and Johnson (2000) and CH2M Hill and Western Watershed Analysts (1999). One of the key findings is that there tends to be a law of

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[3] Use of a pre-treatment calibration period between control and treatment watersheds so that post-treatment impacts can be estimated; impacts are estimated as the difference between observed values and values predicted from the control watershed using the relationship between control and treatment watersheds prior to treatment

diminishing returns and the greatest benefits to streams are secured from the portion of the riparian forest nearest the stream.

RMA width is a poor predictor of performance for some functions. Brazier and Brown (1973) found that timber volume and buffer width were poor criteria for controlling stream temperature. Instead, effective shade or "…*canopy density along the path of incoming solar radiation*…" was the key riparian forest parameter influencing stream temperature. A meta-analysis of nutrient removal (Mayer et al. 2007) found that "*wide buffers (>50 m) more consistently removed significant portions of nitrogen entering a riparian zone than narrow buffers (0–25 m)*," but also that "*buffers of various vegetation types were equally effective at removing nitrogen*…" This is significant because most forest harvests will temporarily change vegetation types, but the new conditions may be equally effective at removing nitrogen. Westside RMAs in Oregon are often dominated by nitrogen-fixing alder, and these conditions lead to high nitrate-nitrogen concentrations in streams.

RIPARIAN MANAGEMENT AREAS CANNOT OVERCOME ALL IMPACTS

There sometimes seems to be a perception that RMAs can overcome all upslope impacts. While RMAs often dramatically reduce such impacts, they cannot be the only BMP applied in a watershed. Deer Creek in the Alsea Watershed Study provided a good example. While temperature and dissolved oxygen were largely protected in Deer Creek, sediment outputs increased as a result of forest management activity even though RMAs were used. The cause is believed to have been sidecast road failures in the upper basin (Beschta and Jackson 2008). A contemporary study in the H.J. Andrews also experienced extensive road failures that scoured Watershed 3 to bedrock in some reaches and caused massive sediment delivery downstream despite the presence of RMAs (Levno and Rothacher 1967). Pollock et al. (2009), studying stream temperatures in coastal Washington, concluded that "*...forest harvest activity is in some way contributing to stream heating other than by exposing the stream surface to direct solar radiatio*n" and that "…*reestablishment of riparian forest alone will not be sufficient to return stream temperature regimes to natural conditions*." Ice et al. (in press) reviewed that paper and concluded that debris flows that scoured and exposed the channels were likely to be the cause of temperature increases and were directly related to riparian forest conditions. In fact, many studies have found that when RMAs fail, especially in maintaining temperature regimes, it is due to blowdown or beaver activities that increase solar exposure.

CAN STREAMS BENEFIT FROM RIPARIAN DISTURBANCE?

The Alsea Watershed Study and subsequent research taught us that riparian buffers can significantly reduce impacts to sediment, temperature, and dissolved oxygen by maintaining cover and shade, reducing soil disturbance near the stream, keeping fresh slash out of the stream, and maintaining forest floor conditions that allow for trapping and settling of sediment. Early concerns about depressed dissolved oxygen concentrations, as well as concerns about fish passage, led to stream cleanouts. Subsequent research found that in-stream large wood was important in providing pools and fish habitat (Bisson et al. 1987). More recent work in small streams identified the importance of wood for hiding cover. Today the benefits of in-stream large wood are widely accepted. One of the most remarkable and controversial findings in this era was that some (but certainly not all) debris flows that deposit material from tributaries can provide beneficial habitat for fish (Everest and Meehan 1981; Miller and Benda 2000). There are curious anomalies in research findings related to fish and their responses to riparian forest conditions. In many, perhaps most, cases where streams are exposed to direct solar radiation, fish populations actually increase as long as streamwater temperatures remain below harmful levels and in-stream wood is not removed.

A meta-analysis of 25 previous studies addressing stream habitat and salmonid density and biomass following streamside clearcut logging (Mellina and Hinch 2007) found that:

> *…the majority of the 25 studies reporting negative effects on [large wood] and pool habitat but positive ones for salmonid density and biomass. The greatest post-logging reductions in all response variables were generally associated with streams subjected to the removal of in-stream [large wood] (either deliberately or as a result of debris torrents)…*

This meta-analysis went on to find that short-term energy related benefits may be present during summer months, but may subsequently be "*…outweighed by a loss of critical over-wintering habitat…*"

Another odd observation from the Coastal Oregon Productivity Enhancement Program (Connolly and Hall 1994) was that:

> *[B]iomass of age 1+ or older resident cutthroat trout was generally higher (>1.4 g/m^2) in streams that had riparian zones with low levels (≤35 percent) of conifer in the riparian canopy and high levels (>15 pieces/100m) of LWD [large woody debris]. Percent hardwood in the riparian zone and level of LWD varied substantially among the three forest management classes examined, resulting in a dynamic picture of cutthroat trout populations in basins 20 to 60 years after logging. Unlogged basins had riparian zones that were dominated by conifers, had relatively low levels of LWD, and supported relatively low biomass of cutthroat trout. Basins logged 20 to 30 years ago had riparian zone that were dominated by hardwoods, had a highly dichotomous distribution of LWD, with a low (<15 pieces/100 m) and high (>35 pieces/100 m) group, and supporting the lowest and highest biomass of cutthroat trout encountered in the study. Basins logged 40 to 60 years ago had low to moderate levels of LWD, had moderate levels of hardwoods in the riparian canopy, and supported low to moderate biomass of cutthroat trout. Mechanisms that may explain variation in biomass of cutthroat trout include differences in light and nutrient input afforded by deciduous versus conifer trees in the riparian zone.*

A key observation from these studies is that more open or hardwood dominated riparian stands can provide "hot spots" for fish productivity (we think because more light leads to increased primary production and supports macroinvertebrates that can be food sources for fish, but perhaps also because fish can see prey easier), but this is most likely where there is sufficient in-stream large wood. The riparian conditions that contribute to large wood recruitment and relatively open canopy conditions do not generally occur with the same stand conditions (although there may be opportunities to thin riparian stands to focus growth on residual trees and simultaneously increase light to streams). Without active management of riparian stands we can not and should not expect to optimize conditions for fish everywhere at the same time.

Adding to this view that some riparian disturbance can be beneficial are observations from Mt. St. Helens and from wildfires where fish populations in streams exposed to elevated stream temperatures were surprisingly productive. Bisson et al. (2005) reported that following the 1980 eruption of Mt. St. Helens fish populations thrived in what would otherwise be considered undesirable stream temperatures due to the presence of abundant food supplies. Heck (2004) found growth in a forest watershed experiencing wildfire positively correlated with increased temperature: "*Contrary to the commonly held assumption that wildfire is detrimental to biota in aquatic systems, these results suggest that in the short term (≤ 3 years), fish in the study streams adjusted to environmental change caused by wildfire*." An early study by Murphy et al. (1981) in the Oregon Cascades found that "*…streams traversing open clear-cuts had greater rates of microbial respiration, and greater densities or biomasses of aufwuchs, benthos, drift, salamanders, and trout than did the shaded, forested sites…*"

Perhaps the most direct test of how active riparian management can affect fish populations is a study by Wilzbach et al. (2005). Using a replicated block study design, it tested whether adding salmon carcasses or opening riparian canopies affected trout populations. The riparian canopies were opened by cutting near-stream hardwoods. The authors found that opening the riparian forest resulted in an increase in trout biomass, but addition of salmon carcasses did not.

OTHER EMERGING CONCERNS ABOUT RIPARIAN MANAGEMENT AREAS

While foresters have embraced RMAs as an effective BMP to protect water quality, there are emerging concerns about their use.

At some point active management of riparian areas may be necessary to regenerate desirable forest stand conditions. For many years silviculturalists have warned that without active management buffers will suppress regeneration of trees along the stream corridor. "*Side light will allow the development of a shrub understory. As existing trees senesce, a gradual success to a shrub community will probably occur. No tree regeneration is likely in absence of deliberate efforts to secure it*" (Hibbs 1981). Newton and Cole (2005) found that regeneration of conifers was difficult with overtopping by shrubs. Principles for regeneration success found on upland sites (e.g., healthy, large seedlings; control of competition; full sunlight) can also be applied to regeneration of riparian forest stands.

Lack of active riparian management can be a major problem if non-native noxious shrubs such as butterfly bush (*Buddleja davidii*) invade riparian areas (http://extension.oregonstate.edu/news/story.php?S_No=770&storyType=garde). Butterfly bush can form dense thickets that crowd out native plants in riparian areas. A list of a dozen invasive riparian plants developed for EPA's Ecological Monitoring and Assessment Program (EMAP) can be found at: www.epa.gov/.../EPA620R-06003EMAPSWFieldOperationsManualAppendixD.pdf.

We typically think that forest harvesting increases water yields by reducing evapotranspiration, but water supply concerns are increasing and RMAs could be a practice of concern. There are increasing concerns about water shortages, especially related to climate change. There is general agreement that warmer temperatures shift snowmelt patterns and result in earlier runoff in some locations (Rango and van Katwijk 1990). A report circulated by the Religious Campaign for

Forest Conservation argued that excessive timber harvesting along the West Coast was causing drought in the Interior West (Bacon 2001). Ice and Stednick (2002) found no evidence of this pattern. Luce and Holden (2009) analyzed long-term streamflow records for 43 basins in the Pacific Northwest. They found that:

> *Seventy-two percent of the stations showed significant (α = 0.10) declines in the 25th percentile annual flow, with half of the stations exceeding a 29% decline and a maximum decline of 47% between 1948 and 2006.*

Other research has indicated that streamflow may be reduced (Hicks et al. 1991) after an initial period of increased flow following timber harvesting. One mechanism for this decrease is exposure of RMAs to increased insolation with removal of the adjacent forest stand. RMAs have phreatophytes (such as alder) that have access to water during low soil moisture periods. In some water-short regions, such as the Southwest, there are proposals to remove invasive phreatophytes (e.g., saltcedar, *Tamarix chinensis*) that are using large amount of water. Diurnal fluctuations in streamflow are believed to be related to riparian forest evapotranspiration, but a recent experiment in Needle Branch, as part of the Alsea Watershed Study Revisited, failed to find a riparian evapotranspiration signal in streamflow.

Of course, another major concern is the economic impact of leaving RMAs. If rules require increasingly extensive and management-limiting RMAs there can be economic costs to landowners. Some have proposed that Oregon adopt rules similar to those in Washington or even federal forest lands. We calculated areas that would be in RMAs for Oak Creek in Benton County under the rules for private lands in Oregon, private lands in Washington, and federal forest lands in the Pacific Northwest under the President's Forest Plan (Ice et al. 2006). The portion of area in RMAs under these different rules ranged from 1.5% in Oregon to 47% for federal lands.

SPRAY DRIFT ATTENUATION BY RIPARIAN VEGETATION

The use of herbicides to control competition on forest lands remains a controversial topic for the public and state agencies despite the lack of any indication of ecological or human health problems (Ice and Dubensky 2004). ODEQ, for example, is organizing a cooperative monitoring effort that will screen for pesticides in streams draining watersheds with multiple land use activities, including forestry. Forest applications of herbicides tend to be infrequent, at low application rates compared to other land uses, and use chemicals that are not highly toxic and don't have other biological impacts at the concentrations commonly detected. Recent research (Stehr et al. 2009) and literature summaries (Tatum 2003, 2004) continue to support the conclusion that forest herbicides are not a water quality problem. One factor contributing to this low risk is the way that forest applications minimize loading of these chemicals in streams.

Historically, the highest concentrations of applied forest chemicals observed in streams occurred where there was overspray of streams or significant drift without any efforts to separate streams from an application (Norris 1967; Comerford and Mansell 1992). Avoiding overspray of streams and the use of drift reduction technology combine to reduce observed concentrations in streams. For some time we have suspected that riparian vegetation can attenuate drift (Teske and Ice 2002), but there have been scant data to support this hypothesis. A field study was carried out in the Oregon Coast Range near Alsea Fall to evaluate the effectiveness of RMAs (Thistle et al. 2009). The RMAs studied were typical of those used for small and medium fish bearing streams under the rules of the Oregon Forest Practices Act. A helicopter applied tracers across four transects running approximately perpendicular to the stream course and flight path. Twenty trials were conducted, resulting in over 1400 tracer samples. Results confirmed that the RMAs were effective in reducing drift over the stream. Reductions in deposition to the stream were estimated to average 92% and were greatest during adverse weather conditions when higher wind velocities blew toward the RMAs (see poster presentation on this topic). Reductions were less clearly identified in stable atmospheric conditions due to low wind speed and highly variable wind directions, but these are conditions that do not create high drift scenarios. Potential mechanisms for this high efficiency include boundary layer effects and impaction by understory vegetation.

ANTIDEGRADATION AND WATER QUALITY

Antidegradation policies for water quality standards (WQSs) are designed to maintain quality that exceeds water quality criteria. Section 303 of the Clean Water Act provides specific guidelines to states on what higher quality waters will receive special protection above the established water quality criteria. Highest protection goes to waters designed as Outstanding National Resource Waters, where no degradations are allowed. This component of WQSs has recently become an issue in a study of the effectiveness of the Oregon Forest Practice Act rules to protect stream temperatures. Preliminary findings of the Riparian Function and Stream Temperature (RipStream) Study are that current rules (RMAs) are protective of water quality criteria set to protect the beneficial uses (fish), but that the antidegradation policy (no change greater than 0.3°C) is sometimes violated. These findings are further complicated because these small changes in temperature are likely to be short lived (shade recovery) and should dissipate rapidly downstream. This treatment of water quality as a static value is in conflict with the resetting functions of disturbance discussed earlier and raises questions of ecological versus statistical significance.

POLLUTION CONTROL TRADING AND OPTIMIZATION

One emerging area of interest is the use of pollution control trading to minimize costs. The idea is to trade high cost pollution control solutions for lower cost controls. One of the water quality issues for the Willamette Basin is water temperature. Presumably, a company discharging heated water could trade with a forest company to provide an offset to thermal pollution by maintaining trees along a stream. The forest landowner would be paid for this pollution control and the discharger would save money over a costly diffuser or other pollution control practice. There are a few problems with this scheme: shade is already maintained under the Forest Practices Act rules; all water pollutants including thermal pollution are non-conservative, so they decay as flow moves downstream; and pollutants of interest may not be controllable by forest or riparian forest management alternatives.

The concept of optimization, while perhaps not often feasible for pollution trading strategies with other industries, is still an area of interest in most pollution control communities. Agriculture has been especially aggressive at trying to develop tools to simultaneously test BMP effectiveness and the costs associated with BMP alternatives. For example, the Comprehensive

Economic and Environmental Optimization Tool (CEEOT) (Hauck et al. 2005; Ice 2005b) has been used to weigh the economic costs and environmental benefits of alternative agricultural pollution control strategies. Because outputs can be valued differently by different people, CEEOT is usually used to optimize toward goals (e.g., minimize cost of achieving WQSs) rather than setting an optimum mix of outcomes. Similarly, EPA is developing the Visualizing Ecosystems for Land Management Assessment (VELMA) model that is designed to predict outputs for multiple ecosystem services and goods (McKane et al. 2007). VELMA outputs include timber volumes harvested, stream discharge and nitrogen concentrations, carbon sequestration, and wildlife habitat.

One example of optimization is a study by Weyerhaeuser Company that looked at the trade-offs of increasing RMAs along headwater channels while reducing RMAs along mainstem reaches so that no net increase or decrease in area in RMAs was realized. Could this strategy result in a balance that optimized environmental benefits with no additional cost to the landowner?

CONCLUSIONS

These observations can be summarized as follows:

- RMAs can reduce negative water quality impacts and retain large wood for future recruitment.
- RMAs cannot always reduce upslope impacts to acceptable levels and must be part of a watershed package of BMPs.
- RMAs do not necessarily represent optimal habitat conditions for fish. Recently logged stream reaches where the riparian forests have been removed can actually have elevated fish populations as long as large wood is not removed.
- There are potential long-term consequences of managing uniform buffers, such as creation of persistent riparian brush stands and possible reductions in streamflow, especially during low flow periods.
- There appear to be opportunities to increase fish productivity by opening some reaches and managing for a mixture of riparian canopy species, wood recruitment potential, and reach exposure levels.
- RMAs have been shown to significantly reduce drift of aerially applied chemicals.
- There are opportunities to explore optimization strategies that balance the economic costs of RMAs with their environmental benefits in ways that achieve water resource objectives.

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