An Ecological Basis For the Management and Recovery of Riparian Zones

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INTRODUCTION

Riparian zones are likely the most productive yet mismanaged, the most diverse yet degraded, and the most valuable, yet least studied of wildland ecosystems. Mismanagement has resulted in a precipitous decline in the ecological potential of western range riparian resources including values of terrestrial wildlife, native salmonids, forage, and water. These losses pose a tremendous challenge and opportunity for resource managers today. Ecological restoration will be necessary to recover these ecosystems. However, in many cases, the scientific understanding to effectively restore degraded ecosystems is limited or does not exist. Hence, there is a critical need for research so that sound ecological principals can be incorporated in the management of riparian zones.

An value of riparian zones lies in their inherently high levels of biological diversity that characterize them. For example, along a 3 km reach of Catherine Creek in Northeastern Oregon, more than 255 plant taxa have been identified (Green 1991). This is equivalent to ~17 percent of all species found in the 932,000 ha Wallowa Whitman National Forest. Along Meadow Creek, we identified more than 120 species of plants existing on gravel bars that were created by a flood three years prior to sampling. In addition to species diversity, there is a high level of structural diversity present within and among riparian plant communities (Kauffman et al. 1985 and Case 1995). Due to a diverse gradient of communities dominated by conifers, hardwoods, wet meadows, dry meadows, willows, other shrubs, and herbs that occur along the river continuum. Knowledge of the multitude of geomorphic, hydrologic, and biotic features that shape species and structural diversity of the riparian zone will be necessary for undertaking restoration.

The inherently high biotic diversity of riparian zones is related to frequent natural disturbance processes that create high levels of edaphic and hydrological diversity (i.e. the physical variables of ecosystem diversity). Of particular importance is the occurrence of seasonal high flows that vary in magnitude, timing, and duration from year to year. Recognition of the linkages and interrelationships between natural disturbances, physical diversity, and biotic diversity is necessary in the restoration of riparian ecosystems. In addition an understanding of how, and to what degree, human land use activities (e.g. cattle grazing) alter ecosystem attributes of composition, structure, and function is important.

ECOLOGICAL APPROACHES TO GRAZING MANAGEMENT

Management of riparian zones is reflective of societal values which, similar to natural ecosystems, are in a continual state of change and evolution. While human values change with time, basic ecological processes that influence riparian zone structure, composition, and function do not. The challenge among scientists and natural resource managers is to continually increase our understanding of the ecological, hydrological, and physical properties of riparian zones in order to maintain ecosystem integrity or restore degraded ecosystems. Clearly, we have much to learn.

To be successful, riparian management objectives must have an ecological basis from which to take appropriate actions (Table 1). For example, on lands where livestock production is the primary management objective, an ecological approach to the optimization of net productivity of desirable plant species should be implemented. A knowledge of the inherent productivity of the land and plant species as well as the ecological impacts of herbivory on the environment is necessary. Management strategies must include not only the direct effects of grazing (e.g., defoliation, trampling, soil compaction, etc.) but also the indirect and long-term effects (e.g., influences on riparian vegetation structure, vegetation competition, changes in fire patterns, and influences on hydrology, streambank morphology, and biogeochemistry). From this knowledge-base, managers could develop grazing prescriptions that are specific to the biotic composition and soil/geomorphological features of the ecosystem.

When formulating management or restoration activities, caution should be made to avoid implementation of projects which, rather than result in recovery, actually exacerbate ecosystem degradation. Based upon untested management paradigms, many riparian/aquatic enhancement attempts have increased the degree of riparian degradation rather than facilitated recovery (Beschta et al. 1991, Kauffman et al. 1993, Beschta et al. 1994). For example, managers in the past recommended clearing cottonwoods (*Populus trichocarpa)* and other streamside vegetation with the hope of increasing available forage or surface water. However, because the influences of riparian hardwoods on soil stability, channel roughness, microclimate, wildlife habitat, nutrient cycling, and channel function were ignored, their elimination resulted in dramatic declines in riparian productivity and biodiversity.

ECOLOGICAL APPROACHES TO THE MANAGEMENT OF FISHERIES AND WILDLIFE HABITATS

An ecological approach is also needed to restore or maintain riparian resources for terrestrial wildlife. At Catherine Creek, we quantified high levels of avian and mammalian diversity that are characteristic of intact riparian ecosystems for the upper Grand Ronde River (Kauffman et al. 1982). Given the importance of riparian zones for the vast majority of wildlife species in semiarid ecosystems, their restoration should be a major responsibility that range and other natural resource managers must not ignore or minimize. In later studies on Catherine Creek, we discovered that a complex suite of biotic, edaphic, and hydrological factors are responsible for the high levels of biological diversity on these sites (Green 1991 and Green and Kauffman 1989).

Thus, the challenge of the wildlife manager is to appreciate, approach, and implement management that will perpetuate those ecosystem processes that are responsible for the high levels of biotic diversity in the riparian zone. Ecosystem processes include the presence of frequent disturbances in riparian zones (e.g., fire and floods), and the complex interactions between groundwater, soils, and plants (e.g., redox processes, sedimentation, undercut formation, etc.).

Salmonid production has been among the most economically, socially, and spiritually valuable of range resources in the Pacific Northwest. Therefore, the restoration of anadromous and resident salmonids is among the most important challenges and responsibilities facing range and natural resource managers today. Many restoration attempts have failed to take an ecological approach resulting in minimal, if any, positive responses (Beschta et al. 1991, Kauffman et al. 1993, Beschta et al. 1994). Clearly, engineering approaches to stream restoration are no substitute for ecological functions provided by intact riparian ecosystems.

Management of salmonid habitats does not begin at the streambank, but rather at the ridgeline. A landscape approach that recognizes the linkages of the terrestrial, riparian, and aquatic components of fisheries habitats, natural disturbance regimes, and those anthropogenic factors that contribute to habitat decline or prevent recovery is needed to restore depleted salmonid populations (Beschta et al. 1995 and Kauffman et al. 1995).

Just as arboreal vegetation is critical habitat for terrestrial wildlife, so is it critical for salmon and trout populations in the semiarid west. Trees in the riparian zone influence the aquatic biota through the amelioration of temperatures, reductions in anchor ice formation, and in the provision of energy and nutrients that drive instream productivity. Trees also function in the provision of habitat structure in the form of coarse wood debris and roots, the entrapment of sediments during flooding events, and influences on water chemistry and quality (Gregory et al. 1991 and Li et al. 1994). Recently, we have quantified the biomass and ecosystem structure of riparian forests associated with headwater streams of the upper Grand Ronde River. Total above ground biomass of undisturbed headwater forests may exceed 300 Mg ha^{-1} (Case 1995). In contrast, biomass of unconstrained meadow-dominated reaches ranges from ~2 to 9 Mg ha^{-1} (Kauffman et al. 1983). The important functions of these headwater riparian forests as sources of the coarse wood and nutrients for downstream reaches, as well as their influence on water temperature underscores the need to maintain these reaches in an intact state.

While forested headwater streams provide much of the organic nutrients and large wood debris for riverine ecosystems, unconstrained stream reaches dominated by wetlands or meadow vegetation provide other critical habitat features for both juvenile and adult salmonids. In unconstrained stream reaches below the forest reaches we hypothesize that the complex interaction of wetland vegetation, groundwater, soils, and the soil biota dramatically influence stream nutrients, water quality, and ecosystem productivity. For example, anoxic or anaerobic conditions in wet meadows result in lower levels of nitrates which influence water quality and hence, instream oxygen concentration, and productivity (Green and Kauffman 1989). Recognition of the distinct function and interconnections of each type of stream reach with respect to their influences on the productivity and diversity of the entire river continuum is of importance if we are to restore or manage riparian/aquatic habitats and salmonid populations.

LIVESTOCK INFLUENCES AND MANAGEMENT FROM AN ECOLOGICAL PERSPECTIVE

The livestock and range management professions must recognize that many past and ongoing management approaches to cattle production are principal factors in the decline of riparian ecosystems throughout the world. Restoration of degraded riparian habitats or depleted salmonid populations will necessarily entail improved and innovative livestock management approaches. Rather than taking an advocates view, managers must view livestock impacts in an ecological context. As with any disturbance regime, livestock impacts can be quantified in terms of the severity of the disturbance, the areal extent of the disturbance, and the frequency of disturbance. Disturbances can also be viewed at several spatial and temporal scales. Management and research should view livestock impacts at landscape or ecosystem scales. The impact from a single cow walking through a riparian zone (while significant at microscales of individual plants or soil peds) is likely undetectable at the landscape level. Yet, the cumulative impacts of thousands of AUM's (animal unit months) over many years can be dramatic.

Influences of herbivory are not uniform on ecosystem components. Soils, plant communities, and associated biota are differentially influenced by grazing at different intensities and seasons of use. At moderate levels of utilization, the persistence of the herbaceous components of riparian zones is greater than that of cottonwoods and willows (Green 1991). For example, while late season grazing at moderate stocking levels had few influences on the productivity and structure of meadow communities at Catherine Creek, dramatic differences in the structure and development of adjacent alder (*Alnus incana*) and cottonwood communities was measured.

The basic principals of range management (i.e., the proper timing, season, distribution and utilization by grazing animals) have close parallels to managing the temporal, spatial, and severity components of disturbances. Recognizing the effects of livestock as a perturbation to ecological processes and functions will facilitate the innovation of improved approaches to grazing management. When livestock grazing occurs in areas where the restoration of riparian zones is a management goal, steps must be taken to ensure that their influences result in minimal disruptions to natural ecosystem processes (e.g., competition, succession, erosion, and hydrological processes). Here is where expertise and innovation in grazing management is needed. Successful grazing strategies will be those that result in the restoration and continuation of ecological processes necessary for proper ecosystem function. Included in the range of grazing management strategies are exclosures and rest; the most rapid recovery rates of degraded riparian zones have been in areas where livestock were excluded (Elmore and Kauffman 1994 and Beschta et al. 1995). For example, following two years of rest from livestock grazing on Meadow Creek, riparian shrub density increased (Case 1995).

Developing prescriptions for the restoration of riparian zones is not a simple nor linear process; riparian zones are not uniform in the structure, function, or response to anthropogenic activities. If livestock were the only influence on riparian vegetation, management might be reasonably straight-forward. However, other herbivores can influence riparian composition and structure and they must be considered when establishing allowable limits of utilization. Livestock impacts will be additive to those of native herbivores. In the upper Grand Ronde River, deer, elk, and beaver have been shown to significantly affect regrowth rates of riparian willows and cottonwoods. For example, following the cessation of livestock grazing on Meadow Creek, willow biomass increased 142 percent in two years. However, in areas protected from wild ungulates as well as cattle, shrub biomass increased 506 percent (Case 1995).

CONCLUSION

Our knowledge of the complex suite of ecological patterns and processes that are characteristic of intact functional riparian zones is limited. This limited research base is a significant barrier to the design and development of riparian restoration strategies. However, it is known that riparian vegetation has reproductive and morphological traits that facilitate persistence in an environment of frequent fluvial and other disturbances. The inherently high resilience of riparian vegetation to recover following disturbance suggests a potential exists for the recovery of riparian wildlife and fisheries habitats following decades of unsustainable or improper land use. The recognition of the inherent capacity for riparian ecosystem recovery, and how activities such as livestock, wild herbivores, channel manipulations, and revegetation programs influence natural recovery is an important first step in riparian rehabilitation. This will require an interdisciplinary approach where the contributions of specialists in vegetation, hydrology, fish, and wildlife resources is imperative.

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Table 1. The ecological context of riparian management objectives.

Riparian Management Objectives	Ecological Interpretation or Considerations
1. Increase forage production, availability, and quality for livestock	-Positively influence net primary production of herbaceous and shrub layers. -Encourage species diversity of herbaceous and shrub layers.
2. Restore, enhance or maintain terrestrial wildlife resources	-Manipulate plant species and structural diversity of riparian vegetation. -Wildlife habitats (food, nesting, and thermal cover, etc.) -Increase the juxtaposition of aquatic and terrestrial plant communities.
3. Restore, enhance, or maintain fisheries resources	-Focus on ecosystem processes responsible for high levels of habitat diversity -biotic, physical, hydrological. • Vegetation productivity - allocthonous inputs (fines to CWD). • Functional interactions among riparian zone features - riparian soils, ground water, water column, benthos, hyporheic (water chemistry nutrient spiraling). -Minimize anthropogenic increases in sedimentation, erosion losses, and influences on streambank integrity (structure, erosivity). These are best accomplished through intact vegetation assemblages and CWD dynamics. -Allow riparian zone to function as a thermal buffer of the aquatic system: • Interchange with groundwater, hyporheic zones; • Recovery of channel diversity and structure; • Natural levels of vegetation cover • Allow beaver populations to occur. -Influence base flow-hydroperiods: • Linkages with intact uplands • Floodplain storage, soil resources management
4. Improve water quality and quantity	-Dissipate energy of flood events, high flows by increasing roughness element of vegetation, streambanks. -Interchanges with ground water, riparian vegetation, hyporheic zones, and the stream channel.
5. Alter timing of discharge	-Recovery of natural dynamic peak flows and base flows. -Maintain or reconnect linkages with intact uplands. -Facilitate storage within the floodplain complex.
6. Decrease streambank erosion, floodplain losses, and loss of streambank integrity (channel bank structure); allow for channel recovery	-Increase vegetation cover and structural diversity to facilitate sediment trapping-streambank rebuilding. -Maximize channel roughness diversity, and sinuosity.
7. Decrease or eliminate negative effects or alterations associated with livestock in riparian zones or use them to modify the environment for some specified use.	-Minimize or eliminate livestock influences on natural ecosystem processes (ecological physical, and disturbance). -Minimize anthropogenic degradation of streambanks (e.g., trampling damage). • Grazing strategies - intensity and seasonal presence. • Kind and class of animals. • Rest, exclosures
8. Restore or conserve the biological diversity of the riparian/stream ecosystem	-All of the above.