Natural Resources and Environmental Issues

Volume 1 *Riparian Resources* Article 1

1994

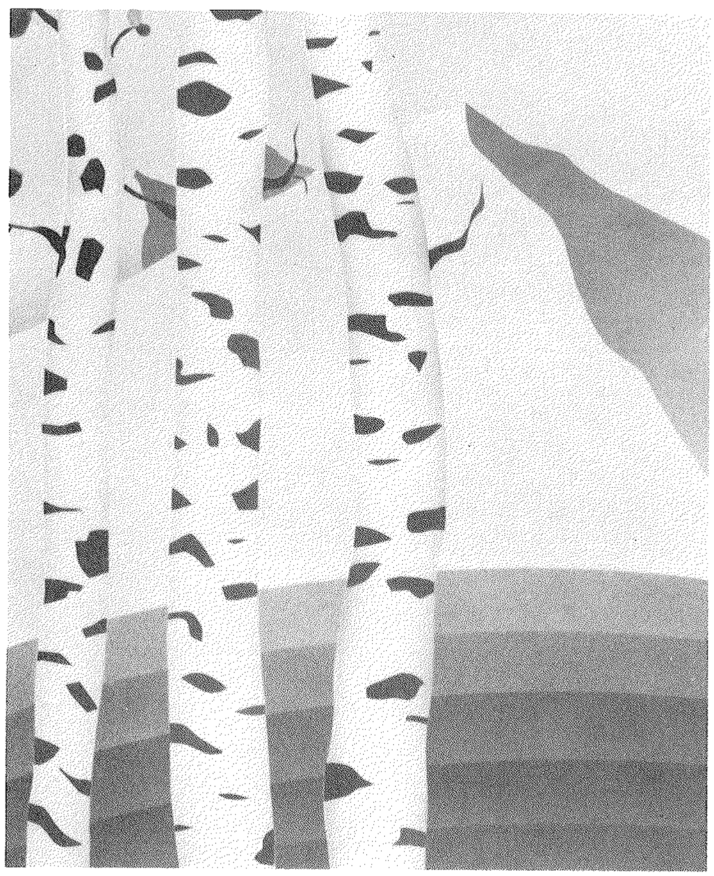
Riparian Resources: a symposium on the disturbances, management, economics, and conflicts associated with riparian ecosystems

G. Allen Rasmussen
College of Natural Resources, Utah State University, Logan

James P. Dobrowolski
College of Natural Resources, Utah State University, Logan

Riparian Resources

A Symposium on the Disturbances, Management, Economics, and Conflicts Associated with Riparian Ecosystems



Natural Resources and Environmental Issues

Volume I
1994

Natural Resources and Environmental Issues

Volume I
1994

Natural Resources and Environmental Issues is a series devoted primarily to research in natural resources and related fields. This series is published by the College of Natural Resources, Utah State University, Logan, Utah 84322-5200, and is distributed by the S. J. and Jessie E. Quinney Natural Resources Research Library.

Volumes of this series will be sent upon request. Single issues are $20.00 in the United States and $25.00 elsewhere. Payment must be made by check, money order, or purchase order, payable in U.S. dollars to the Quinney Library. Order information is located in the back of this publication.

ISSN 1069-5370

Foreword

The College of Natural Resources recognizes the important role it has in educating natural resources managers and leaders who can provide the guidance and knowledge needed to increase the production of the earth's renewable resources while sustaining and enhancing the global environment and the natural resources base. The College's teaching, research, extension, and service efforts focus on the many aspects of sustained multiple-natural-resources management and their relationship to man. Through its many programs, the College of Natural Resources focuses on solving local, state, national, and global problems to enhance a more efficient and contemporary use of the world's natural resources.

Since 1930 the College of Natural Resources has offered several publications of various kinds to disseminate technical and popular information about natural resources and the environment. These publications have included *The Utah Juniper* (1930–1970), which started as a technical publication and evolved into a popular format and ultimately into the College's yearbook; *The Edge* (1978–1980), which was intended to be popular in format and highlighted faculty research efforts; and most recently, *Resource Lines* (1989–present), a newsletter about the College of Natural Resources and its programs, faculty, students, alumni, and friends.

The publication begun in 1993, *Natural Resources and Environmental Issues (NREI),* is a technical series that addresses current topics relevant to natural resources and to the environment. The journal is published as a series of volumes, with at least one being issued each year as the proceedings of the Natural Resources Week symposium. Publication in *NREI* is by invitation only.

The management of global natural resources depends on our ability to obtain and disseminate pertinent information in a timely manner. Equally important, the information should reflect current issues of concern to natural resources and environmental managers as well as to the public. Through *NREI* the College of Natural Resources will provide information on timely topics of broad concern to professionals and to society as a whole.

Joseph A. Chapman, Dean
College of Natural Resources

Proceedings of the Symposium

Riparian Resources

April 18-19, 1991
Eccles Conference Center
Utah State University
Logan, Utah

Sponsored by

College of Natural Resources, Utah State University, Logan, Utah
Cooperative Extension Service, Utah State University, Logan, Utah
Utah Riparian Coalition, Salt Lake City, Utah

Riparian Resources

A Symposium on the Disturbances, Management, Economics, and Conflicts Associated with Riparian Ecosystems

Edited by
G. Allen Rasmussen
and
James P. Dobrowolski

College of Natural Resources, Utah State University
Logan, Utah

This volume is the result of the symposium held April 18–19 during College of Natural Resources Week, an annual event on the campus of Utah State University.

1991 Symposium Planning Committee

G. Allen Rasmussen, Chair
Department of Range Science

James P. Dobrowolski
Department of Range Science

Roger E. Banner
Department of Range Science

Charles P. Hawkins
Department of Fisheries and Wildlife

Michael P. O'Neill
Department of Geography and Earth Resources

Mary Lu Roskelley
Office of the Dean

Contents

Introduction
G. Allen Rasmussen vi

What Are Riparian Ecosystems and Why Are We Worried About Them?
Charles P. Hawkins 1

Natural Disturbance Effects on Riparian Areas
Fred Swanson 11

Agriculture and Riparian Areas
William C. Krueger 15

Forestry Effects on Riparian Areas
Art McKee 19

The Impact of Native Ungulates and Beaver on Riparian Communities in the Intermountain West
Charles E. Kay 23

Recreational Effects on Riparian Areas
G. Allen Rasmussen and Wayne Padgett 45

Management of Livestock in Riparian Areas
Alma H. Winward 49

A Framework for Evaluating the Economic Benefits, Costs, and Trade-offs Associated with Riparian-Area Management Practices and Strategies
Frederick W. Obermiller 53

Riparian Reform: Who Pays?
John A. Baden 65

Striving for Unanimity and Consensus: Finding the Common Ground in Conflict over Riparian Management
Mark L. Johnson 71

Building Consensus for Riparian Users: Toward the Twenty-First Century
William C. Krueger 77

Introduction

Riparian areas have moved to the forefront of natural resource management because of the increased knowledge of their importance in maintaining our natural resource systems. In the past, most natural resource managers did not concentrate their efforts in the riparian areas because these zones constituted such a small portion of the total area, and their importance to the entire system was not understood. This lack of attention was not an attempt to ignore the riparian resource but rather to deal with what were perceived as greater problems on the upland areas. As the knowledge of the function riparian zones play in ecosystems has increased, attention has been directed toward integrating the management of the riparian and upland areas. This integration requires an ecosystem perspective to effectively meld the management of these areas. All of the natural resource disciplines are required to work together for an ecosystem perspective to be beneficial. The greatest problem natural resource managers now face in integrating this management perspective is to put aside their prejudices about the other disciplines and to work together.

The purpose of this conference was to create a dialogue about the management of riparian areas and their associated systems. Specifically, this dialogue was intended to focus on the function these areas have in an ecosystem. There are many disturbances associated with riparian areas, ranging from natural landslides, which tend to be dispersed in time and space, to chronic disturbances normally associated with man's activities. While the natural disturbances can appear to be catastrophic, the recovery tends to be faster in areas that do not have chronic disturbances.

We brought together those individuals who helped develop unique and innovative management techniques to incorporate the upland and riparian areas together into a system approach and to mitigate or change the chronic disturbances. In addition, papers were presented on the costs associated with altering management of these areas and who should be paying those costs.

Riparian areas have become the focal point of many conflicts because of competing, or at least perceived competing, interests and uses. To address this area, the final two papers discuss how some groups are successfully dealing with these conflicts.

We would like to thank the conference participants for their comments and suggestions on riparian-area management.

G. Allen Rasmussen
Department of Range Science
College of Natural Resources
Utah State University
Chair, 1991 Symposium Committee

What Are Riparian Ecosystems and Why Are We Worried About Them?

Charles P. Hawkins
Director, Watershed Science Unit
Department of Fisheries and Wildlife
Utah State University
Logan, UT 84322-5250

Abstract

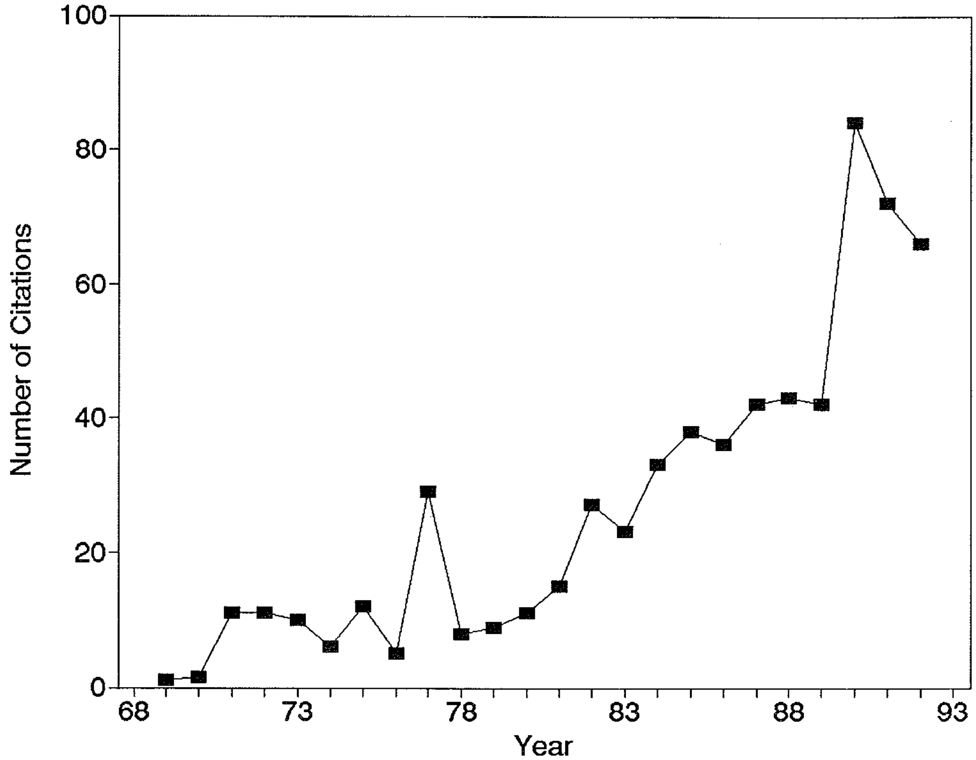
Riparian areas represent less than 2 percent of all terrestrial ecosystems, but they are functionally one of the most important features within natural landscapes. They are characterized by high biotic production and diversity; they moderate flood intensity and store water; and they maintain high water quality by acting as nutrient and sediment sinks. These ecological functions make them valuable areas for a variety of human uses including agriculture, timber and livestock production, recreation, and housing. Human use, however, has resulted in severe degradation of the functional health of many riparian ecosystems. Recognition of the value of the systems and the magnitude of existing and continuing degradation has generated a concerted effort by natural resources managers and researchers to develop strategies to protect and restore riparian areas. Issues requiring particular attention are (1) development of a generally accepted definition of riparian ecosystems, (2) development of a functionally useful classification scheme of riparian areas, (3) quantification of the specific ways that human use causes ecological dysfunction, (4) collection of data from which we can objectively prioritize efforts to preserve extant systems, and (5) development of ecologically sound strategies for the restoration of degraded areas.

INTRODUCTION

Riparian ecosystems have attracted an increasing amount of attention from scientists and natural resources managers during the last two decades. This attention has been due to two developments: (1) recognition by scientists that these ecosystems play a profoundly important ecological role within natural landscapes and (2) recognition by natural resources managers that many riparian areas have been lost or severely degraded. The growing interest in riparian ecosystems is reflected in the number of scholarly articles published since 1969 (Figure 1A). Of the more than eight million papers indexed by BIOSIS between 1969 and 1992, 629 had the word *riparian* in either the title or the list of keywords. Only one of these papers was published in 1969; but since then, the number of riparian-related articles published per year has progressively increased, peaking in 1990 with eighty-four papers. A simple increase in the absolute number of papers published on a specific topic may say little about how society judges that topic's relative importance because the total number of scientific papers published has steadily increased since 1969. However, the relative number of riparian citations (number of riparian citations/total citations) also has increased with time, suggesting that interest in riparian ecosystems is continuing to increase (Figure 1B).

This paper provides an overview of what we know about riparian ecosystems. Specific objectives are to

1. Discuss the ecological functions that riparian ecosystems perform within the context of the surrounding landscape



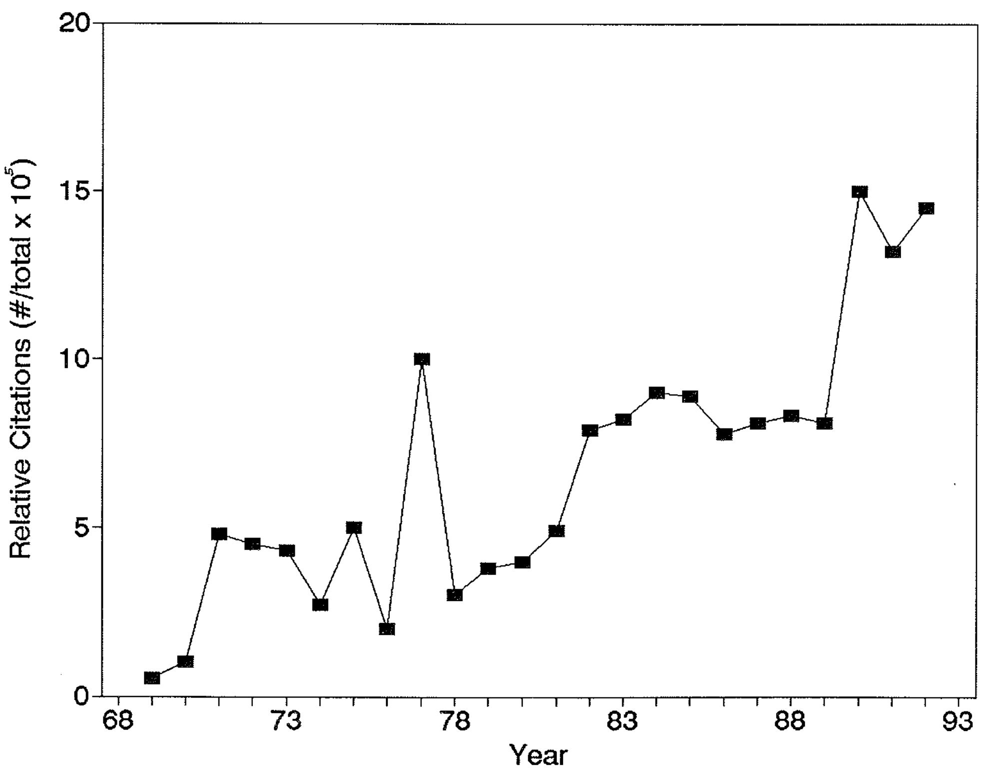


Figure 1. Number (figure 1A, top) and relative number (figure 1B, bottom) of articles indexed each year between 1969 and 1992 in BIOSIS that contained the word *riparian* in either the title or keywords. The relative number of citations was calculated as the number of riparian articles divided by the total number of articles indexed each year. Values of (B) are multiplied by 10^5 in the figure.

2. Describe how human use of riparian ecosystems depends on these functional attributes

3. Describe the extent of alteration and degradation that has occurred to riparian ecosystems within the United States

4. Illustrate some of the challenges scientists and managers face in developing an ecologically sound and operationally useful definition of a riparian ecosystem

5. Conclude by pointing to several issues that scientists and managers must address during the 1990s if they are to develop ecologically sound management practices

WHAT IS A RIPARIAN ECOSYSTEM? AN IMPRECISE DEFINITION

Nearly everyone has seen a riparian ecosystem even if he didn't recognize it. The word *riparian* is derived from the Latin *ripa*, which means riverbank. Used as a noun, the term *riparian* refers to a landowner whose property borders a stream. In the ecological literature, the term is used as an adjective to describe the location of a particular type of ecosystem.

Riparian ecosystems occur along the banks of streams. We normally, and most readily, recognize them in their unaltered state as the strips of green vegetation that occur from somewhere near water's edge outward to somewhere near the edge of the floodplain. Although vegetation is often the most conspicuous part of a riparian ecosystem, the entire ecosystem comprises a variety of life forms (microbes, plants, and animals) and abiotic environmental features that occur within a defined area.

ECOLOGICAL FUNCTIONS OF RIPARIAN ECOSYSTEMS

Riparian ecosystems are of great ecological interest because they are often functionally and structurally distinct from the upland ecosystems (e.g., forest, shrub, or grassland) that they dissect. Their ecological uniqueness is largely due to the effects of a single abiotic factor—the presence of large quantities of water. Near-stream environments are hydrologically and geomorphically dynamic in the sense that periodic flooding occurs that can scour floodplain surfaces in some areas and deposit material in others. The combination of periodic inundation and the proximity of the water table to the floodplain surface ensures that average riparian soil moisture is high relative to upland areas. Water either directly or indirectly influences all of the functional and structural attributes of riparian ecosystems.

Plant Production and Diversity

Availability of water is one of the most important conditions limiting plant growth in terrestrial environments. Because water is readily available in riparian ecosystems, plant growth may be much greater in these areas than in upland ecosystems. Differences between upland and riparian ecosystems in plant production may be especially noticeable in arid regions. For example, Reichle (1970) and Webb et al. (1983) showed that plant production in moist areas, like riparian ecosystems, was up to twenty-five times higher than that measured in drier regions.

The vegetation of riparian ecosystems also frequently exhibits high structural and taxonomic diversity (Brinson et al. 1981, Clary et al. 1992, Youngblood et al. 1985). Areas that support high plant production are often dominated by plant species that form either dense (shrubs) or high (trees) stands. Such stands are architecturally complex due to the range of sizes exhibited by different species (herbs to trees) and the branching and anastomosing growth patterns of individual plants of all sizes. Plant taxonomic diversity is also usually high due to the combined effects of readily available water and nutrients and the periodic scouring by floods that prevent potentially dominant species from monopolizing space (Day et al. 1988).

Wildlife Production and Diversity

Two ecological truisms are that (1) areas of high production at one trophic level tend to exhibit high production at higher trophic levels and (2) physical complexity tends to beget high ecological diversity. Wildlife abundance should, therefore, be correlated with plant production; and wildlife diversity should be correlated with plant structural complexity. These principles are clearly illustrated by contrasting riparian and upland areas. Average bird densities are approximately twice as high in riparian areas as they are in upland areas. Furthermore, more wildlife species use riparian areas than all other habitats combined (Brinson et al. 1981, Knopf et al. 1988). Wildlife congregate in riparian areas because these ecosystems provide abundant water, food, and shelter and provide forested corridors through which individual animals can migrate and disperse (Thomas et al. 1979).

Fish Production and Diversity

Stream systems that are surrounded by healthy riparian ecosystems also tend to have more productive and diverse fisheries than streams lacking riparian vegetation (Gregory et al. 1987, Karr and Schlosser 1977, Sedell et al. 1990). The reasons for this productivity and diversity are that riparian floodplains provide important nursery habitat for many fish species, function as a source of large woody debris (dead trees) that fish use for shelter, stabilize stream channels, and reduce summer and increase winter water temperatures. Riparian vegetation also appears to stabilize the invertebrate food base for fish by inputting organic litter into the stream during fall and winter. During this time period, algal production is usually low, and terrestrially derived litter may be the only food available to many invertebrates.

Flow Moderation and Water Storage

Riparian vegetation can reduce average water velocity and, hence, increase the length of time it takes a given volume of water to travel from an upstream to a downstream point (Elmore and Beschta 1987, Gosselink et al. 1990). During periods of flooding, the presence of vegetation acts to reduce stream efficiency and, thereby, reduces the peak stage heights of individual storms. Some of this water may be temporarily stored in floodplain soils or stored for longer periods as ground water. During periods of low flow, this stored water may be slowly released to the stream channel thereby augmenting base flows.

Water Quality

Riparian ecosystems regulate water quality in at least two ways. First, riparian vegetation decreases suspended sediment loads in streams by reducing bank erosion and by trapping sediment eroding from hillslopes (Elmore and Beschta 1987). Floodplains with abundant vegetation tend to store sediment and as a consequence have deeper soils than floodplains without vegetation. The combined effect of deeper soils and deep-rooted vegetation is to reduce the nutrient concentration of water entering the stream channel (Karr and Schlosser 1977, Lowrance et al. 1984, Whigham et al. 1988).

The shading provided by riparian vegetation also regulates water temperatures in some streams (Beschta et al. 1987). By blocking sunlight and insulating the near-stream environment, riparian vegetation can reduce summer maximum temperatures by as much as 16°C and increase winter minimum temperatures by as much as 2°C. In both cases, the daily range in temperatures is reduced.

THE VALUE OF RIPARIAN AREAS TO HUMANS

The functional attributes of riparian ecosystems just described give these areas a high value for numerous human uses (Table 1). Chief among these attributes is their potential to produce plants useful to human society. At one time, riparian ecosystems supported extensive floodplain forests. Many of these forests were harvested for their timber and converted to cropland. Now, much of this country's most productive farmland occurs on floodplains once covered with riparian forests. The agricultural productivity of these areas is sustained in part by the availability of water and by the tendency for sediment and nutrients derived from upstream or upslope areas to deposit onto low-gradient floodplains.

The potential of riparian areas has also been exploited to produce large quantities of high-quality water for both domestic and agricultural use. In many cases, the water has been diverted away from source areas for use in distant agricultural fields or cities; or reservoirs capable of storing more water than local soils and aquifers have been constructed on site.

Many riparian areas have high value as places to build residential or recreational homes. Most people wish to live in aesthetically pleasing environments, especially ones in proximity to a stream or lake. As more and more rivers have had their flows regulated by dams, the number of houses and business offices constructed within historical floodplains has greatly increased.

Human use almost always causes alteration or loss of at least part of the original ecosystem. Some uses are less damaging than others. Where riparian systems are largely intact, they provide recreational

Table 1. Ecological functions of riparian areas and their associated human uses.

Ecological Function	Associated Human Uses
Production of plant tissue	Cultivated farmland Timber production Livestock production Housing
Wildlife diversity and production	Hunting Aesthetics
Fish diversity and production	Fishing Aesthetics
Store water and moderate flow	Domestic water supply Irrigation Water for livestock
Trap and process sediment and nutrients	Domestic water supply

Table 2. Selected publications on riparian ecosystem ecology and management with emphasis on the Western U.S.

Karr and Schlosser (1977)	Johnson et al. (1985)
Johnson and Jones (1977)	Platts et al. (1987)
Johnson and McCormick (1978)	Salo and Cundy (1987)
Cope (1979)	General Accounting Office (1988)
Cowardin et al. (1979)	Abell (1989)
Brinson et al. (1981)	Gresswell et al. (1989)
Swanson et al. (1982)	Minshall et al. (1989)
Anderson et al. (1982)	Mereszczak et al. (1990)
Warner and Hendrix (1984)	Gregory et al. (1991)
Youngblood et al. (1985)	

opportunities for hunters, fishermen, hikers, and naturalists. In some cases, however, even recreational use can alter the potential of an area to support certain ecological functions. An example is excessive camping and travel within the floodplain, reducing vegetation and wildlife.

LOSS AND DEGRADATION OF RIPARIAN ECOSYSTEMS

The uses described above have contributed to a startling loss of riparian ecosystems within the United States and other countries. Based on data in Brinson et al. (1981), most of the alteration to riparian ecosystems appears to occur within 100 years of settlement by nonaboriginal peoples (Figure 2). In the United States, up to 98 percent of the riparian ecosystems that existed prior to European colonization have been lost or significantly altered (Brinson et al. 1981, Swift 1984). Considering that riparian areas originally represented less than 2 percent of the overall landscape, the significance of these losses for wildlife, fisheries, plant species diversity, and water quality is profound. Of particular concern is that many riparian ecosystems may have become so small and fragmented that they will be unable to maintain viable populations of many plant and animal species on a long-term basis (Harris 1984, Harris 1988).

RESPONSE TO THE PROBLEM

The recognition that most of the original riparian ecosystems have been profoundly altered has initiated a strong response from the scientific community and resource-management agencies. Since about 1977, nineteen major symposiums or syntheses have been published describing the status, ecological properties of, or management of riparian ecosystems (Table 2). These studies have greatly advanced the understanding of the structural and functional properties of riparian ecosystems, although the greater task of first reducing and then reversing the ongoing destruction remains largely unaddressed.

IS A STANDARD DEFINITION OF *RIPARIAN ECOSYSTEM* NEEDED OR POSSIBLE?

As is true for most other ecosystems, it is difficult to provide an unambiguous and conceptually comprehensive definition of a riparian ecosystem that is both ecologically complete and operationally useful. There are three main reasons why a universally accepted definition has not emerged to date. First, ecosystems are seldom, if ever, discrete entities with clearly defined spatial boundaries. Most ecosystems grade into one another, and what we usually refer to as boundaries are areas where physicochemical gradients are steepest. For some riparian ecosystems (e.g., those in V-shaped valleys), gradients between the floodplain and hillslopes may be so steep that for all practical purposes discrete boundaries do exist. In areas of gradual topographic relief, however, the transition from one environmental complex to the next may occur over several and even hundreds of meters. Delineating boundaries in these cases is largely an arbitrary decision.

A second and equally difficult problem is that individuals may not agree on the functional and structural criteria on which to base a definition. For example, if one person emphasizes the presence of a certain type of vegetation and another weights the extent to which nutrients move among adjacent areas, these two people would almost certainly draw different boundaries. This problem is so fundamental that MacMahon et al. (1978) argue that the definition of an ecosystem should depend mainly on the question being asked, i.e., the concept itself is investigator dependent.

The problem is further confounded by the fact that scientists usually want as ecologically encompassing a definition as possible, whereas resource managers strive for a definition that can be easily applied under a wide variety of field conditions. To illustrate the extent of the problem, three of the definitions in use today follow:

Gregory et al. (1991:540) defined riparian ecosystems from a functional perspective as the "three-dimensional zones of direct interaction between terrestrial and aquatic ecosystems. . . . Boundaries of riparian zones extend outward to the limits of flooding and upward into the canopy of streamside

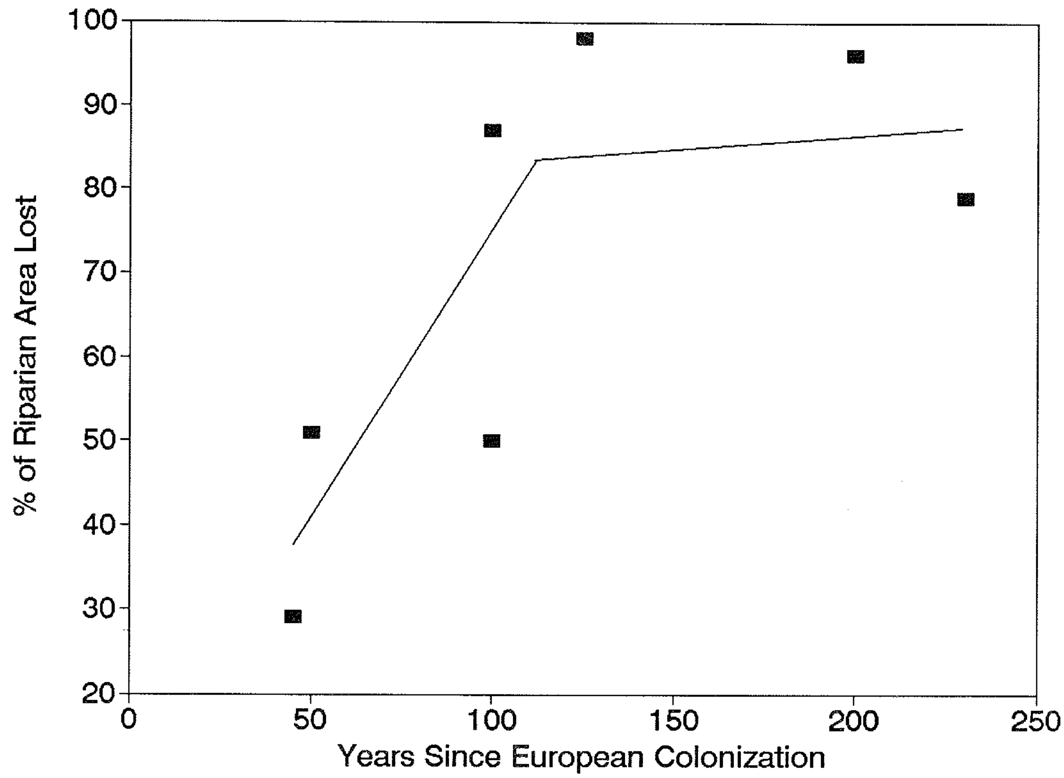


Figure 2. Loss of riparian area as a function of time in years since European colonization. Data points represent different major riparian ecosystems within the United States and were extracted from Brinson et al. (1981).

vegetation."

Cowardin et al. (1979) described riparian areas as one type of wetland and defined wetlands as (p. 3) "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered with shallow water. For purposes of this classification, wetlands must have one or more of the following three attributes: (1) at least periodically, the land predominantly supports hydrophytes, (2) the substrate is predominately undrained hydric soil, and (3) the substrate is nonsoil and is saturated with water or covered by shallow water at some time during the growing season of each year."

Cowardin et al. (1979) further defined riparian, i.e., palustrian, wetlands to include (p. 10) "all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 percent. The definition also includes wetlands lacking vegetation but with all of the following four characteristics: (1) areas less than 8 ha (20 acres); (2) active wave-formed or bedrock shoreline features lacking; (3) water depth in the deepest part of basin less than 2 m at low water; and (4) salinity due to ocean-derived salts less than 0.5 percent." In general, under this definition the riparian ecosystem is bounded on the aquatic side by areas that can support emergent aquatic vegetation and on the upland side by the high water line.

Federal agencies have attempted to apply a uniform standard for delineating wetland boundaries (Federal Interagency Committee for Wetland Delineation 1989) that is based on the definition of a wetland the U.S. Corps of Engineers uses when issuing permits for discharge of dredge and fill into wetlands (Section 404 (b)(1) of the Clean Water Act of 1977). Under this definition, wetlands include "areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support . . . a prevalence of vegetation typically adapted for life in saturated soil conditions."

Although this definition goes far toward development of a standard that could be applied to riparian ecosystems as well as to other types of wetlands, its practical use is limited by (1) ambiguities regarding what constitutes "typically adapted" vegetation, (2) a poorly developed database describing the frequency and duration of saturation needed to support the hundreds of different species of wetland plants, and (3) the difficulty inherent in establishing how frequently and for how long soils are either inundated or saturated. As a consequence, the two federal agencies responsible for managing most of the riparian ecosystems in the Western U.S. (the Bureau of Land Management and the Forest Service) often use guide-lines that reflect local conditions or the particular biases of local riparian-resource personnel.

THE CHALLENGES AHEAD

As we move into the twenty-first century, we will be severely challenged to develop ways to sustain the ecological function of our remaining riparian ecosystems and, hence, their value to both human society and the world's wildlife. To manage these ecosystems intelligently requires that we address at least five general issues about which we presently know very little:

1. We need a *functionally* useful classification scheme of riparian ecosystems. This classification should be based, in large part, on the potential of specific riparian ecosystems to support different uses and the sensitivity of different systems to both natural and human disturbance.

2. We need a much better understanding of the role natural disturbance plays in influencing both structural and functional properties of these ecosystems. Because of their intimate connection to streams, these systems are naturally extremely dynamic. In what ways do different natural disturbances affect riparian areas, and what factors control the rate of ecosystem recovery following disturbance?

3. We need to quantify how different human uses affect dysfunction, especially in context of the effects of natural disturbance.

4. We quickly need objective data from which we can prioritize efforts to conserve extant systems. These data would include information on the size of different remaining fragments, their location within the overall landscape, their proximity to other types of ecosystems, the specific type of system in terms of taxonomic composition and functional attributes, and the uses they presently sustain.

5. We must develop ways to restore many of our currently degraded riparian areas. The loss of riparian ecosystems has been so great that conservation and preservation of the remaining areas is insufficient to ensure the persistence of these systems. This challenge is especially daunting for areas associated with large rivers. The costs of restoration will almost certainly be high. It is, therefore, important that the effectiveness of current restoration practices be rigorously evaluated. Considering the chances that an "engineered" fix may cause more damage than good in these dynamic systems, any proposed restoration practice should be evaluated in terms of what it will do, and how quickly it will do it, relative to natural recovery processes.

REFERENCES

Abell, D. L., ed. 1989. Proceedings of the California riparian systems conference: Protection, management, and restoration for the 1990s. September 22–24, 1988. Davis, Calif. U. S. Department of Agriculture, Forest Service General Technical Report PSW-110, Berkeley, Calif.

Anderson, A., G. Haugen, D. Duff, G. Taylor, D. Albin, D. Erman, D. Reiser, M. Bacon, T. Jackson, K. Overton, C. McAucliff, J. Griffith, and J. Cooper. 1982. The best management practices for the management and protection of Western riparian stream ecosystems. American Fisheries Society, Western Division.

Beschta, R. L., R. E. Bilby, G. W. Brown, L. B. Holtby, and T. D. Hofstra. 1987. Stream temperature and aquatic habitat: Fisheries and forestry interactions. Pages 191–232 *in* E. O. Salo and T. W. Cundy, eds. Streamside management: Forestry and fishery interactions. February 12–14, 1986. Seattle, Wash. Contribution (University of Washington, Institute of Forest Resources) No. 57. College of Forest Resources, University of Washington, Seattle.

Brinson, M. M., B. L. Swift, R. C. Plantico, and J. S. Barclay. 1981. Riparian ecosystems: Their ecology and status. U. S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services FWS/OBS-81/17, Kearneysville, W. Va.

Clary, W. P., E. D. McArthur, D. Bedunah, and C. L. Wambolt, eds. 1992. Proceedings—symposium on ecology and management of riparian shrub communities. May 29–31, 1991. Sun Valley, Idaho. U. S. Department of Agriculture, Forest Service General Technical Report INT-289, Ogden, Utah.

Cope, O. B., ed. 1979. Proceedings of the forum—grazing and riparian/stream ecosystems. Trout Unlimited, Denver, Colo.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services FWS/OBS-79/31, Washington, D.C.

Day, R. T., P. A. Keddy, J. McNeill, and T. Carleton. 1988.

Fertility and disturbance gradients: A summary model for riverine marsh vegetation. Ecology 69(4): 1044–54.

Elmore, W., and R. L. Beschta. 1987. Riparian areas: Perceptions in management. Rangelands 9(6): 260–65.

Federal Interagency Committee for Wetland Delineation. 1989. Federal manual for identifying and delineating jurisdictional wetlands: An interagency cooperative publication. U. S. Army Corps of Engineers, U. S. Environmental Protection Agency, U. S. Fish and Wildlife Service, and U. S. Soil Conservation Service, Washington, D.C.

General Accounting Office. 1988. Public rangelands: Some riparian areas restored but widespread improvement will be slow. GAO/RCED-88-105, Washington, D.C.

Gosselink, J. G., B. A. Touchet, J. Van Beek, and D. Hamilton. 1990. Bottomland hardwood forest ecosystem hydrology and the influence of human activities: The report of the hydrology workgroup. Pages 347–87 *in* J. G. Gosselink, L. C. Lee, and T. A. Muir, eds. Ecological processes and cumulative impacts: Illustrated by bottomland hardwood wetland ecosystems. Lewis Publishers, Chelsea, Mich.

Gregory, S. V., G. A. Lamberti, D. C. Erman, K. V. Koski, M. L. Murphy, and J. R. Sedell. 1987. Influence of forest practices on aquatic production. Pages 233–56 *in* E. O. Salo and T. W. Cundy, eds. Streamside management: Forestry and fishery interactions. February 12–14, 1986. Seattle, Wash. Contribution (University of Washington, Institute of Forest Resources) No. 57. College of Forest Resources, University of Washington, Seattle.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41(8): 540–51.

Gresswell, R. E., B. A. Barton, and J. L. Kershner, eds. 1989. Practical approaches to riparian resource management: An educational workshop. May 8–11, 1989. Billings, Mont. U. S. Department of the Interior, Bureau of Land Management BLM-MT-PT-89-001-4351.

Harris, L. D. 1984. The fragmented forest: Island biogeography theory and the preservation of biotic diversity. University of Chicago Press, Chicago, Ill.

Harris, L. D. 1988. The nature of cumulative impacts on biotic diversity of wetland vertebrates. Environmental Management 12(5): 675–93.

Johnson, R. R., and D. A. Jones, tech. coords. 1977. Importance, preservation and management of riparian habitat: A symposium. July 9, 1977. Tuscon, Ariz. U. S. Department of Agriculture, Forest Service General Technical Report RM-43, Fort Collins, Colo.

Johnson, R. R., and J. F. McCormick, tech. coords. 1978. Strategies for the protection and management of floodplain wetlands and other riparian ecosystems: Proceedings of the symposium. December 11–13, 1978. Callaway Gardens, Ga. U.S. Department of Agriculture, Forest Service General Technical Report WO-12, Washington, D. C.

Johnson, R. R., C. D. Ziebell, D. R. Patton, P. F. Ffolliott, and R. H. Hamre, eds. 1985. Riparian ecosystems and their management: Reconciling conflicting uses. April 16–18, 1985. Tucson, Ariz. U. S. Department of Agriculture, Forest Service General Technical Report RM-120, Fort Collins, Colo.

Karr, J. R., and I. J. Schlosser. 1977. Impact of nearstream vegetation and stream morphology on water quality and stream biota. Office of Research and Development, Environmental Protection Agency, Environmental Research Laboratory EPA-600/3-77-097, Athens, Ga.

Knopf, F. L., R. R. Johnson, T. Rich, F. B. Samson, and R. C. Szaro. 1988. Conservation of riparian ecosystems in the United States. Wilson Bulletin 100(2): 272–84.

Lowrance, R., R. Todd, J. Fail, Jr., O. Hendrickson, Jr., R. Leonard, and L. Asmussen. 1984. Riparian forests as nutrient filters in agricultural watersheds. BioScience 34(6): 374–77.

MacMahon, J. A., D. L. Phillips, J. V. Robinson, and D. J. Schimpf. 1978. Levels of biological organization: An organism-centered approach. BioScience 28(11): 700–704.

Mereszczak, I., J. Colmer, J. Oden, J. Almy, M. Hoppus, P. J. Ishikawa, H. Lachowski, J. Ward, and A. J. Oslin. 1990. Riparian area management: What can remote sensing contribute? U.S. Department of Agriculture, Forest Service, Engineering Staff EM 7140-19, Washington, D.C.

Minshall, G. W., S. E. Jensen, and W. S. Platts. 1989. The ecology of stream and riparian habitats of the Great Basin region: A community profile. U. S. Department of the Interior, Fish and Wildlife Service Biological Report 85(7.24), Slidell, La.

Platts, W. S., C. Armour, G. D. Booth, M. Bryant, J. L. Bufford, S. Jensen, G. W. Lienkaemper, G. W. Minshall, S. B. Monsen, R. L. Nelson, J. R. Sedell, and J. S. Tuhy. 1987. Methods for evaluating riparian habitats with applications to management. U. S. Department of Agriculture, Forest Service INT-221, Ogden, Utah.

Reichle, D. E. 1970. Analysis of temperate forest ecosystems. Springer-Verlag, New York.

Salo, E. O., and T. W. Cundy, eds. 1987. Streamside management: Forestry and fishery interactions. February 12–14, 1986. Seattle, Wash. Contribution (University of Washington, Institute of Forest Resources) No. 57. College of Forest Resources, University of Washington, Seattle.

Sedell, J. R., G. H. Reeves, F. R. Hauer, J. A. Stanford, and C. P. Hawkins. 1990. Role of refugia in recovery from disturbances: Modern fragmented and disconnected river systems. Environmental Management 14(5): 711–24.

Swanson, F. J., S. V. Gregory, J. R. Sedell, and A. G. Campbell. 1982. Land-water interactions: The riparian zone. Pages 267–91 *in* R. L. Edmonds, ed. Analysis of coniferous forest ecosystems in the Western United States. Hutchinson Ross Publishing, Stroudsburg, Pa.

Swift, B. L. 1984. Status of riparian ecosystems in the United States. Water Resources Bulletin 20(2): 223–28.

Thomas, J. W., C. Maser, and J. E. Rodiek. 1979. Riparian zones in managed rangelands: Their importance to wildlife. Pages 21–31 *in* O. B. Cope, ed. Proceedings of the forum—grazing and riparian/stream ecosystems. November 3–4, 1978. Trout Unlimited, Denver, Colo.

Warner, R. E., and K. M. Hendrix. 1984. California riparian systems: Ecology, conservation, and productive management. University of California Press, Berkeley.

Webb, W. L., W. K. Lauenroth, S. R. Szarek, and R. S. Kinerson. 1983. Primary production and abiotic controls in forests, grasslands, and desert ecosystems in the United States. Ecology 64(1): 134–51.

Whigham, D. F., C. Chitterling, and B. Palmer. 1988. Impacts of freshwater wetlands on water quality: A landscape perspective. Environmental Management 12(5): 663–71.

Youngblood, A. P., W. G. Padgett, and A. H. Winward. 1985. Riparian community type classification of eastern Idaho-western Wyoming. U. S. Department of Agriculture, Forest Service R4-Ecol-85-01.

Natural Disturbance Effects on Riparian Areas

Fred Swanson
USDA Forest Service
Pacific Northwest Forest and Range Experiment Station
3200 Jefferson Way
Corvallis, OR 97331

Abstract

Naturally occurring abiotic disturbances have a tremendous effect on riparian systems. Geomorphic and fluvial disturbances are discussed in this paper. These disturbances help form the complex habitats found in these systems. The type of geomorphic disturbance and the recovery of the riparian ecosystem depend on the geology of the area and on the extent of the disturbance. Fluvial disturbances are also constrained by the geologic strata. Natural disturbances tend to be distributed in both time and space. This leaves numerous undisturbed sites that act as inoculum sources to speed the recovery of the disturbed parts of the system. The aquatic portions of the riparian systems recover faster than the associated riparian vegetation, but both need the undisturbed areas to ensure recovery.

INTRODUCTION

Natural disturbances in riparian systems occur in three major categories: geomorphic, other abiotic, and biotic. This paper will focus on geomorphic and some of the other abiotic disturbance types. It will focus on their frequency, extent, and effect on riparian systems. Consideration of these disturbances is important when managing riparian areas.

To manage a riparian area, an ecosystem-function perspective is the most useful perspective because it provides for the management of the area by defining and utilizing objectives (Gregory et al. 1991). In forest riparian zones, the forest influences the stream through various functions such as (1) fine litter falling into the stream, which provides food for aquatic organisms, (2) large woody debris falling from the adjacent forest, which helps to structure the stream system, and (3) streamside forest shading the stream, which affects water temperature and regulates light available to fuel growth of aquatic plants. Depending on the objectives of the manager, various components of the stand can be managed to achieve those objectives. If fish habitat complexity is an objective, for example, attention would be focused on the woody-debris function. Within this framework, there are two major functional relationships between the vegetation and the aquatic organisms. Riparian vegetation influences the structure of aquatic systems through the influence of roots in stream banks, live stems in channels and floodways, and dead woody debris in the channel. It also influences the food resources both by regulation of light for primary production and by the amount of litter falling into the stream. There are cross linkages between these two functions in that the complex structures help retain floated food resources (litter) within the aquatic system. The influence of these two functions on the structure and food resources of an aquatic system is important to both intact riparian systems as well as to the recovery of disturbed systems that were altered by management or by natural disturbances.

GEOMORPHIC

The geomorphic features and processes, which transport sediment across landscapes, define and influence the riparian system. Landforms provide the physical stage on which biological and physical interactions occur. They constrain the behavior of the ecosystem. Geomorphic processes, such as lateral channel shifts and streamside landslides, can be viewed as one class of disturbance in the ecosystem. There are biotic and other types of abiotic disturbances as well. To understand how natural disturbances affect riparian systems, the geomorphic stratification of valley floors must be considered. This consideration also provides a basis for stratification of ecosystem functions from one segment of the stream to another, and it provides an understanding of human effects upon the riparian ecosystem.

Stream segments have individual functions and values. These characteristics are best explained in a hierarchical framework (Swanson and Franklin 1992). This hierarchy is divided among the various channel and valley-floor structures, starting with the finest scale of the individual particle of sediment or organic matter. Aquatic and invertebrate interests can be concerned with scales as fine as a boulder to determine which species use a particular side of the boulder as influenced by the flow regime over the boulder.

Two crucial scales used to evaluate disturbances are the channel-unit scale, such as pools and riffles, and the next coarser scale of resolution, the reach scale. Each stream reach contains numerous channel units in sequence. They are distinguished based on the type and degree of constraints on the channel and valley-floor structure by geologic agents. These constraints may be active, such as large landslides or alluvial fans growing at the mouths of sediment-productive tributary streams, or passive, such as hard-rock zones where the channel cuts a narrow gorge. Other reaches may be free of these constraints, resulting in a different structure often referred to as "unconstrained" reaches.

Examples of contrasting reaches are (1) a narrow, constrained valley floor with a single meandering channel and (2) a wide, unconstrained valley floor that has developed multiple channels. Constrained reaches form where alluvial fans composed of accumulations of bed load and debris-flow material are constructed at the mouth of tributary streams or where large, dormant, or active landslides have pinched the valley floor. All of these types of reaches and others can affect the same riparian system.

Narrow valley floors resulting from active or passive geomorphic processes are highly constrained and tend to have a reduced frequency and extent of the lateral movement of the stream channel. There can be some streamside landslides and small-scale, shallow, rapid sliding at the toe of the large landslides. These processes are generally rather restricted, but they do have persistent effects on channels, such as accumulation of large (up to car-size) boulders from the landslide. The boulder size depends on the debris associated with the landslide. Large landslides commonly push the channel against bedrock on the opposite valley wall. These areas have very restricted riparian habitat and recreational values.

Unconstrained reaches tend to be wide valley floors with multiple age classes and varied composition of vegetation, reflecting the complex disturbance history. In many forested systems in the Western United States, there are distinct upland conifer types indicative of past wildfires. In contrast, stream channel changes have been the dominant disturbance process in riparian zones. There are many secondary and tributary channels that flow through the forest to provide a very extensive zone of interaction between the terrestrial and aquatic environments. These provide extensive habitat for wildlife, aquatic, and human activities.

The geomorphic characteristics of the system help define reach structure and long-term geomorphic and biotic behavior. These reaches range from narrow, sediment-poor, stable, rock-defended channels with little room for meanders to sediment-rich reaches that have numerous lateral channel changes caused by sediment deposition. This conceptual framework of landform template and ecosystem functions allows the prediction of the extent and type of natural disturbances in riparian zones in reaches of passive and active constraints and in unconstrained reaches (Table 1).

The reach-type constraints control the frequency and extent of disturbance processes. If the geomorphic characteristics of a reach type are known, the disturbance regime can be predicted. In bedrock-constrained reach types, fluvial (lateral channel) adjustments have a very low potential but are frequent and dominant in unconstrained types.

Riverine systems are very dynamic in their long-term behavior. In forested mountain systems, there are narrow and wide reaches. In these systems, fluvial disturbances tend to be focused in the wide reaches where there is room for them to operate. In these areas, floods periodically reopen the riparian canopy over the channel. Evidence of earlier disturbances are commonly erased by the most recent disturbance.

In other systems, such as the meandering river systems (e.g., the Little Missouri River), the disturbance regime is very different. In some areas, the river is constantly eating away at a wide spectrum of forest age classes, leaving a zero-age-class substrate in its wake.

In a multiple-channel system with multiple live channels and bits of abandoned channels, such as oxbows, a different valley floor geomorphic and riparian dynamic occurs. Little lateral cutting is needed for one active channel to intercept another active channel or an abandoned channel, causing the main flow to move into another channel. This results in varied age classes and composition of vegetation and their associated influences on the stream ecosystem. These vegetation differences are caused by inherent differences in the geomorphic dynamics in each reach or system of river dynamics.

Flooding is the major process that can destroy riparian vegetation. Riparian vegetation has both positive and negative effects on the potential for this damage to occur. Woody debris floating down the channel can be lodged against standing trees and can serve as a tool to aggravate disturbance of riparian vegetation. However, the rooting of plants in the bank and gravel-bar material impede fluvial disturbance.

Landslides of a variety of types have important influences on the stability of riparian zones. One landslide class is large, periodically moving slides. The lateral encroachment of this slide type deflects a river's course and pinches it against the opposite valley wall. Areas of landslide movement greater than a few percent of channel width per year result in frequent streamside slides and severe bank erosion, keeping riparian vegetation from establishing and stabilizing the site in the short term.

Another class of landslide is large landslides at the heads of channels. This type is the major source of debris flows that move down channels affecting riparian zones. These are typical of the Wasatch Front area of Utah. In the steeper channel units, debris flows scour the channels. Where the channel gradient decreases to the point that movement stops, debris flow deposits accumulate, commonly on alluvial fans.

OTHER ABIOTIC DISTURBANCES

Riparian zones are subject to very high levels of natural disturbance. They are subjected to both the disturbances imposed by the riverine environment and to the disturbances imposed on the upland terrestrial environment. In some cases, there may be a decoupling of these disturbance regimes.

Wildfires often do not remove the vegetation structure in riparian areas where topography influences microclimate and fuel moisture and, therefore, fire behavior, impeding the movement of high-severity fires into valley bottoms. While wildfires may be the major disturbance on the upslopes, valley bottom disturbances are dominantly fluvial in many landscapes. Where the stream runs against the valley wall, the riparian zone is subjected to both the fluvial and upland disturbance regimes. Management must account for these various effects on the different stream reaches.

Different stream reaches have a role in the generation, propagation, and cessation of disturbances. Some types of reaches are very good at stopping the movement of disturbances through the system while others may facilitate disturbance movement. For example, large landslides that pinch the channel against the opposite valley wall often decrease the gradient above the landslide, which increases the deposition of sediment. This deposition of sediment then increases the opportunity of lateral channel changes above the slide.

In the landslide zone, small streamside slides are common, causing periodic outbursts of boulder and woody, debris-laden flood surges. These surges may damage the riparian zones downstream. This one feature controls the disturbance regime for a very long section of the channel in both upstream and downstream directions.

This type of disturbance also affects the biotic responses. In an altered forty-year-old hardwood stand, a large debris flow resulted in zones of scour and of deposition (Lamberti et al. 1991). The immediate effect on the physical system was that channel unit structure (size and spatial distributions of pools and riffles) became shorter, more disorganized, and more transient. Five years after the event, the physical system was still adjusting to this disturbance. In the areas with scouring, the channel was simplified, causing water to move through quickly, which reduced the potential for uptake of dissolved nutrients and opened up the vegetation canopy above the channel (Lamberti et al. 1991).

Table 1. Areal extent and frequency of riparian disturbances.

Disturbance Process	Reach type: Constrained		Unconstrained
	Bedrock	Earth flow	
Fluvial	very low	moderate	high
Streamside	very low	high	low
Debris flow	low	moderate	low

The immediate effect on the biotic system was catastrophic in the zone where the debris flow altered habitat completely. However, within the first year, primary production reached very high levels because of the canopy opening. This canopy opening allowed algae to flourish and to dominate the food base in the most disturbed segments of the channel. The macroinvertebrate community, in terms of its density and taxonomic richness, also came back within a year, though it was dominated by species grazing on the algae. Species dependent on stems and leaves were not present in these reaches.

The trout were originally decimated, but after one year the young-of-the-year trout were back to predisturbance densities. However, these populations have fluctuated from year to year, reflecting the instability of the system (Lamberti et al. 1991).

The quick recovery of the aquatic systems is related to the frequency and location of the natural disturbances. Many natural disturbances are episodic and scattered in space, leaving many undisturbed reaches in upstream and downstream areas. These undisturbed reaches create numerous refuges for the aquatic organisms and act as sources of inoculum to reoccupy severely disturbed sites (Anderson 1992). Channel complexity in this system has been recovering because woody debris was left in the system so that refuges of pool and slack-water habitats, at the scale of individual logs, were created. Recovery of riparian vegetation is much slower than recovery of the in-channel community.

An example in which disturbances provide a beneficial role in aquatic systems is the Elk River in southwest Oregon. This river is an important salmon fishery that requires rather specific water temperatures. Water temperature is an index of the habitat quality for native species. This fishery is maintained by two major areas in the river system, i.e., the "flat" reaches of low gradient and wide valley floor basins and the steep, narrow valley types. The flats have a high natural disturbance regime, resulting in an open canopy above the river. This open canopy allows high primary and invertebrate production but increases the water temperature. This increased primary and invertebrate production results in concentrations of salmon. The salmon in the flats benefit by the steep forested tributaries, since these reaches provide the cooler water required to keep the water temperatures in the basin within the salmon's tolerance. If disturbances removed tree cover over the steep tributaries, the system's fisheries value would decline.

Several of the flats on the Elk River have their origins in great, catastrophic disturbances. One of the best habitats is the product of a landslide out of a major tributary stream more than 100 years ago. This highly productive area is a very complex habitat resulting from abundant woody debris. The woody debris is derived from reworking the deposits, including logs, that were carried down with the landslide as well as from streamside slides bringing in new trees.

SUMMARY

The key to system recovery is maintaining the important elements of the system that help the system function. These elements include the vegetation, which regulates the food base and helps the physical stability of the system, and large woody debris. The pattern of disturbance is crucial. Many of our natural disturbance mechanisms tend to be scattered in both time and space, leaving many refuges. Some of our management practices tend to be more chronic or extensive in time and more pervasive geographically, thereby reducing refuges, recolonization, and recovery potential.

There is a high potential to predict the long-term system dynamics based on geomorphic considerations. Ecosystems have a high potential to recover from natural disturbances if allowed to do so with natural recovery agents, such as vegetation and large woody debris.

REFERENCES

Anderson, N. H. 1992. Influence of disturbance on insect communities in Pacific-Northwest streams. Hydrobiologia 248(1): 79–92.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41(8): 540–51.

Lamberti, G. A., S. V. Gregory, L. R. Ashkenas, R. C. Wildman, and K. M. S. Moore. 1991. Stream ecosystem recovery following a catastrophic debris flow. Canadian Journal of Fisheries and Aquatic Sciences. 48(2): 196–208.

Swanson, F. J., and J. F. Franklin. 1992. New forestry principles from ecosystem analysis of Pacific-Northwest forests. Ecological Applications 2(3): 262–74.

The immediate effect on the biotic system was catastrophic in the zone where the debris flow altered habitat completely. However, within the first year, primary production reached very high levels because of the canopy opening. This canopy opening allowed algae to flourish and to dominate the food base in the most disturbed segments of the channel. The macroinvertebrate community, in terms of its density and taxonomic richness, also came back within a year, though it was dominated by species grazing on the algae. Species dependent on stems and leaves were not present in these reaches.

The trout were originally decimated, but after one year the young-of-the-year trout were back to predisturbance densities. However, these populations have fluctuated from year to year, reflecting the instability of the system (Lamberti et al. 1991).

The quick recovery of the aquatic systems is related to the frequency and location of the natural disturbances. Many natural disturbances are episodic and scattered in space, leaving many undisturbed reaches in upstream and downstream areas. These undisturbed reaches create numerous refuges for the aquatic organisms and act as sources of inoculum to reoccupy severely disturbed sites (Anderson 1992). Channel complexity in this system has been recovering because woody debris was left in the system so that refuges of pool and slack-water habitats, at the scale of individual logs, were created. Recovery of riparian vegetation is much slower than recovery of the in-channel community.

An example in which disturbances provide a beneficial role in aquatic systems is the Elk River in southwest Oregon. This river is an important salmon fishery that requires rather specific water temperatures. Water temperature is an index of the habitat quality for native species. This fishery is maintained by two major areas in the river system, i.e., the "flat" reaches of low gradient and wide valley floor basins and the steep, narrow valley types. The flats have a high natural disturbance regime, resulting in an open canopy above the river. This open canopy allows high primary and invertebrate production but increases the water temperature. This increased primary and invertebrate production results in concentrations of salmon. The salmon in the flats benefit by the steep forested tributaries, since these reaches provide the cooler water required to keep the water temperatures in the basin within the salmon's tolerance. If disturbances removed tree cover over the steep tributaries, the system's fisheries value would decline.

Several of the flats on the Elk River have their origins in great, catastrophic disturbances. One of the best habitats is the product of a landslide out of a major tributary stream more than 100 years ago. This highly productive area is a very complex habitat resulting from abundant woody debris. The woody debris is derived from reworking the deposits, including logs, that were carried down with the landslide as well as from streamside slides bringing in new trees.

SUMMARY

The key to system recovery is maintaining the important elements of the system that help the system function. These elements include the vegetation, which regulates the food base and helps the physical stability of the system, and large woody debris. The pattern of disturbance is crucial. Many of our natural disturbance mechanisms tend to be scattered in both time and space, leaving many refuges. Some of our management practices tend to be more chronic or extensive in time and more pervasive geographically, thereby reducing refuges, recolonization, and recovery potential.

There is a high potential to predict the long-term system dynamics based on geomorphic considerations. Ecosystems have a high potential to recover from natural disturbances if allowed to do so with natural recovery agents, such as vegetation and large woody debris.

REFERENCES

Anderson, N. H. 1992. Influence of disturbance on insect communities in Pacific-Northwest streams. Hydrobiologia 248(1): 79–92.

Gregory, S. V., F. J. Swanson, W. A. McKee, and K. W. Cummins. 1991. An ecosystem perspective of riparian zones. BioScience 41(8): 540–51.

Lamberti, G. A., S. V. Gregory, L. R. Ashkenas, R. C. Wildman, and K. M. S. Moore. 1991. Stream ecosystem recovery following a catastrophic debris flow. Canadian Journal of Fisheries and Aquatic Sciences. 48(2): 196–208.

Swanson, F. J., and J. F. Franklin. 1992. New forestry principles from ecosystem analysis of Pacific-Northwest forests. Ecological Applications 2(3): 262–74.

Agriculture and Riparian Areas

William C. Krueger
Department of Rangeland Resources
Oregon State University
Corvallis, OR 97331-6704

Abstract

Agriculture has historically been based in the subirrigated riparian ecosystems. Often the engineering and agricultural practices have altered the systems and many of the associated ecological processes. In the Western United States, the most common agricultural practice affecting riparian systems has been livestock grazing. Effects have been both positive and negative. Lack of management has deteriorated many of these systems. Current research has shown what types of management have been successful in allowing grazing by livestock to improve the grazing capacity.

INTRODUCTION

Water is a fundamental basis of life and consequently is a major determinant of agricultural production. The proximity of riparian zones to water supplies has naturally led to intensive and extensive agricultural uses of these zones. The annual floods of the Nile River in biblical times left rich deposits of sediment that were the basis of major farming activities. Throughout the world, agriculturalists have used the rich and often subirrigated soils of riparian zones for intensive farming activities. The development of irrigation technology in modern times has allowed expansion of agriculture into uplands but has not diminished the use of riparian systems for intensive farming practices.

Most intensively farmed riparian zones are privately owned; and because of economic and social pressures, they are likely to remain farms. The impact of the farming systems on lakes and rivers will continue with inputs that degrade the natural processes in the riparian systems and inputs that enhance these river and lake systems. Nonpoint pollution problems of rivers and lakes are largely attributed to agricultural practices. The Environmental Protection Agency estimated that 64 percent of the nonpoint pollution in United States river systems was agriculturally based (Chaney et al. 1990). This pollution is caused by agricultural chemicals or unacceptable farming practices. As knowledge of agricultural effects increases, especially as related to water quality, practices will become more environmentally sound and will change to minimize pollution. Significant improvement will be seen in the 1990s.

The impacts of farming not related to pollution are also extensive. In the Western states, reclamation projects have built reservoirs that supply massive quantities of irrigation water. This water is applied to the land in the dry season and augments subsurface flows of adjacent river systems, a major force influencing late-season stream flows in heavily irrigated areas. Along with augmentation of water to farmland, frequently the streams and rivers have been constrained on reduced floodplains. Sometimes floodplains were entirely eliminated. Once a river system has been substantially altered by these and other practices, it should be considered an altered ecosystem. Since society is not likely to change the basic flood control and irrigation projects of the West, much of the lower elevation land area will remain as altered systems with altered ecological processes. The approach to understanding these systems should be in this context. Care should be given in applying ecological concepts derived from wildland systems in these altered ecosystems. The utilization of engineering practices and agricultural technology may well disrupt natural processes to the extent that a new body of theory will be required to accurately predict cause and effect relationships.

GRAZING

Extensive agricultural effects on riparian zones derive principally from grazing of livestock. Few riparian zones have remained ungrazed during the past century. Impacts of livestock grazing have been described as being both beneficial and devastating. However, observations of riparian zones in the Western states clearly indicate that livestock have substantially altered many of these systems. The result of this broad scale, poorly managed grazing has been well documented through description of soil compaction, stream-bank erosion, channelization, and loss of vegetation. In these same areas where extensive riparian zone alteration is apparent, there are examples of reversals of the alterations by changing management of the land and livestock. The research, demonstration, and management programs of the past fifteen years have allowed development of management strategies that will yield the desired objectives on the riparian area.

RESEARCH

Riparian grazing research conducted at Oregon State University since the mid-1970s has led to generalizations that help explain the interaction between cattle grazing and mountain riparian systems (Krueger 1983). These studies have continued for more than fifteen years, evaluating several herds of cattle, a wide variety of management strategies, and thousands of hectares of mountain rangeland.

Under traditional grazing-management systems utilized on public and private land (e.g., season-long grazing, deferred rotation, rest rotation), riparian zones are frequently a focal point of cattle-grazing activity. When livestock are allowed selection between riparian zones and uplands, riparian zones are highly preferred. These mountain riparian zones are more abundant and productive than those in the high desert at lower elevations. Typically, the riparian zones were 2 to 3 percent of the land area and produced 20 percent of the available livestock forage in the area. Forage yield was generally about 2500 to 4000 kg/ha.

Livestock utilization of the riparian zones, using traditional grazing systems, was typically about 75 percent of current year's growth of herbaceous vegetation and 30 to 50 percent of current year's growth of shrubs. Even though riparian zones produced only 20 percent of the forage available, 80 percent of total forage consumption by cattle came from the riparian zone. At the same time, uplands were utilized at a rate of about 8 to 12 percent of current year's growth. The heaviest utilization measured on uplands was 30 percent. Obviously, there is great opportunity to change management practices to reduce grazing on riparian zones and increase grazing on uplands.

Riparian zones are exceptionally complex systems that yield varying responses to management among stands even in a small pasture. In the riparian zone of Meadow Creek in northeastern Oregon, 44 different plant communities were found on 45 ha. The stream bed itself occupied more total area than any single plant community. Nearby on Catherine Creek, the situation is even more complex. In an area about 50 by 3500 meters, 60 discrete plant communities, about 260 stands of vegetation, 400 plant species, 81 species of birds, and 20 species of mammals have been identified. Both of these riparian systems are considered representative of the region.

The relationships of these riparian zones to livestock grazing are probably indicative of what can be found in mountains of the Northwest. The riparian zone provides a high-quality forage in late summer and fall that is equal to or better than that available in the uplands. In dry years, the riparian zones are nutritionally superior. In fall, cattle grazing in riparian zones produced calves 18 to 25 kg heavier than cattle confined to upland pastures. This weight difference accrued during the last three weeks of the grazing season (September).

Early in the season, cattle tend to voluntarily use uplands more than they do later in the summer. In general cattle prefer, in order, riparian meadows; grasslands; clear-cut areas (especially when seeded to exotic grasses); logged forests; and mature forests. Cattle made heavy use of roads to move about the summer range. Diets of cattle were typically 85 to 95 percent grasses and sedges. Browse was not used until green grass was limited in availability.

The effect on specific plant communities in riparian systems was variable. Of ten plant communities studied intensively for four years in one meadow, only four were measurably affected by cattle grazing, with average utilization about 60 percent of available forage. In the spring, growth starts earlier in grazed areas; and in high-producing stands, grazing stabilizes fluctuations in forage yield by reducing the mulching effect of residual plant material. Generally, grazing tended to dry the meadows by inducing vegetation changes to less hydric vegetation. Development of vegetation adapted to dryer conditions appeared to enhance the productivity of cattle and encourage aerobic rather than anaerobic soil conditions.

Clearly, these systems are complex and management will be equally complex. When consideration is given to the necessary interdependence of riparian zones to the uplands that make up the other 97 to 99 percent of the watershed, the complexity increases. However, riparian zones cannot be effectively understood unless the interconnection with uplands is likewise understood. The watershed is the minimal interactive unit that can function as a single entity. When long-term upland changes are evaluated, particularly west of the Rocky Mountains, the problems faced by society are nearly overwhelming. The widespread increases of woody vegetation in the sagebrush, juniper, pine, and mixed-forest zones during the past fifteen years will probably cause further drying of riparian systems. The causes of this woody plant expansion are many. The result of this expansion is a continued decrease in range condition and a devaluation of multiple-use values, especially those that depend on concentration of water, i.e., riparian zones.

STRATEGIES FOR MANAGEMENT

Development of management strategies that permit or enhance the natural functioning of watersheds should result in sustainable management practices. The site-specific nature of watersheds and the riparian zones within watersheds prohibit selection of generalized management strategies to yield universal results. Barrett et al. (1991) have developed an approach to management of watersheds that guides development of site prescriptions. Their fundamental premise is that a watershed should capture, store, and safely release the precipitation that falls within its boundaries. If precipitation is captured, it has an opportunity to move into the soil. If it is retained by the soil and moved through the soil by gravity into springs, streams, rivers, and lakes, the watershed will function in a sustained way. Any practice can be examined by how well it will allow the capture, storage, and safe release of water. An entire watershed must be managed. Paying attention primarily to the riparian zone cannot compensate for a lack of attention to the upland component of the watershed.

Buckhouse and Elmore (1991) have developed a conceptual model that facilitates evaluation of the effects of management on any specific stream system. Their generalized model is illustrated in Figure 1.

If a system is inherently stable, it can withstand a greater stress due to some form of management than if it is naturally unstable. Natural stresses include climate, gradient, soil, rock, and water flow. Management stresses include grazing intensity, season of use, logging practices, road systems, and recreation, among others. The combination of stresses from natural and/or management sources can lead to recovery of a deteriorated system or to decline as stresses exceed the capability of the system to maintain its natural functions.

Riparian systems must have disturbance at some points to maintain their natural functioning. This disturbance may be periodic flooding, burning, or perhaps man-induced actions. Without disturbance

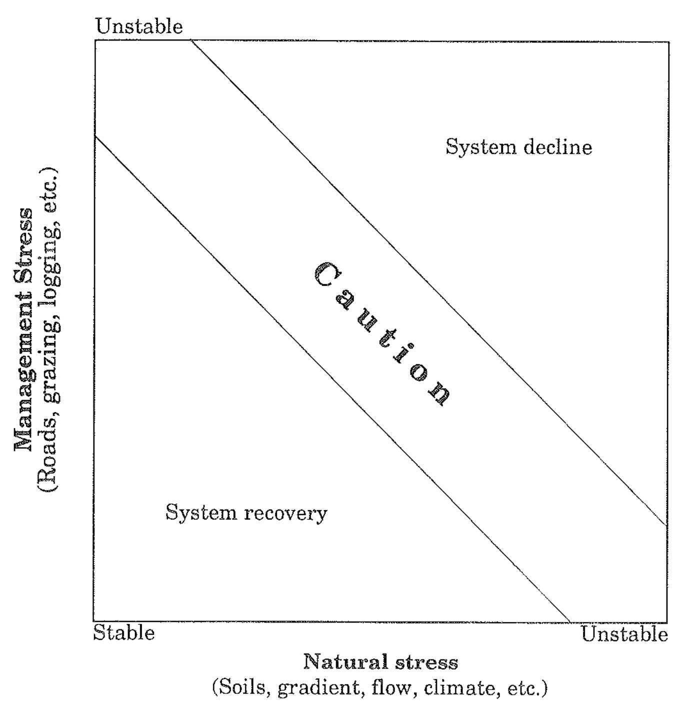


Figure 1. Generalized relationship between natural and induced (management) stresses.

the system will age and reduce its abilities to perform the many processes required to yield clean water, healthy fisheries, and wildlife habitat; and other natural features of wildland riparian systems will be impaired. A system that functions in response to disturbance should have a degree of resiliency. Through understanding the capacity of each system to buffer stresses from agricultural practices, it is possible to develop productive, sustainable agricultural uses of riparian systems as components of a total watershed.

REFERENCES

Barrett, H., T. E. Bedell, J. Buckhouse, T. Deboodt, W. Elmore, S. Fitzgerald, C. Jacks, and P. Test, eds. 1991. Watershed management guide for the interior Northwest. Oregon State University Extension Service EM 8436, Corvallis.

Buckhouse, J., and W. Elmore. 1991. Grazing practice relationships: Predicting riparian vegetation response from stream systems. Pages 47–51 *in* H. Barrett, T. E. Bedell, J. Buckhouse, T. Deboodt, W. Elmore, S. Fitzgerald, C. Jacks, and P. Test, eds. Watershed management guide for the interior Northwest. Oregon State University Extension Service EM 8436, Corvallis.

Chaney, E., W. Elmore, and W. S. Platts. 1990. Livestock grazing on Western riparian areas. U. S. Environmental Protection Agency, Washington, D.C.

Krueger, W. C. 1983. Cattle grazing in managed forests. Pages 29–41 *in* B. F. Roche, Jr., and D. M. Baumgartner, eds. Forestland grazing: Proceedings of a symposium held February 23–25, 1983, Spokane, Washington. Office of Conferences and Institutes, Washington State University, Pullman.

Forestry Effects on Riparian Areas

Art McKee
Department of Forest Resources
Oregon State University
Corvallis, OR 97331

Abstract

Past forestry practices were developed and applied at the stream-reach scale. New forestry focuses on a landscape scale to provide wood products while maintaining ecosystem and community processes. The effect of all forestry practices (e.g., logging, road building, planting, thinning, and slash) on the riparian areas is considered since these areas are part of the landscape. In new forestry, more effort is directed in the planning effort to define site objectives and to understand the implications of each site objective at the landscape scale. This planning provides management with greater flexibility in applying forestry practices to all areas of the landscape as well as in the riparian areas. New forestry is implemented by using the different forestry practices to finesse the stream-reach scale to meet the established objectives in terms of the functional relationship at the landscape scale.

FOREST RIPARIAN HABITATS

Logging and other forestry-related activities have profound influences on riparian areas and streams. How important these riparian systems are with respect to the total forest can be summarized in terms of plant diversity, wildlife habitat, developed recreation, and lumber yield (Figure 1). The example describes the relative importance of riparian areas as natural resources that are typical for a forest on the western slopes of the Cascade Range. The potential for lumber yield is less in riparian areas when compared to good, mesic upland sites due to saturated soils late into the growing season or cobbly soils that tend to be overdrained.

An acceptable functional definition for riparian areas was presented in the paper by Hawkins.[1] Many of the functional relationships associated with riparian areas extend well beyond what would be considered a "normal" riparian-area boundary and up the hillslope. If the concept is to manage by objectives, then practical boundaries must encompass elements of the upland, e.g., the sources for coarse woody debris input to the stream.

[1]See Hawkins, this volume, page 3.

Functional links exist among upland elements, the riparian area, and the channel. Often these links between forest riparian vegetation and channel elements are illustrated in the context of an aquatic organism-centered model (Figure 2). Structural links also exist. Some of the attributes of a forest riparian area include diversity in physical structure that results in a richness of biological species. The vertical and horizontal diversity of physical structures provides an abundance of edges. These differences can be illustrated by comparison of narrow, deeply incised channels to wide valley channels with significant floodplains. The frequency of the disturbance regime in a wide valley contributes to the vertical and horizontal heterogeneity. Tree-stand ages differ markedly between riparian areas developed on contrasting geomorphic surfaces. Valley landforms influence stream ecosystems by providing a variety of physical substrates to produce riparian vegetation diversity, a longitudinal spatial distribution, and complex strata of riparian vegetation. Disturbance regimes associated with stream/riparian systems tend to be linear: upstream disturbance influences downstream structure and function. Thus we need to have a basinwide, rather than simply a stream-reach, perspective when considering the management of riparian areas.

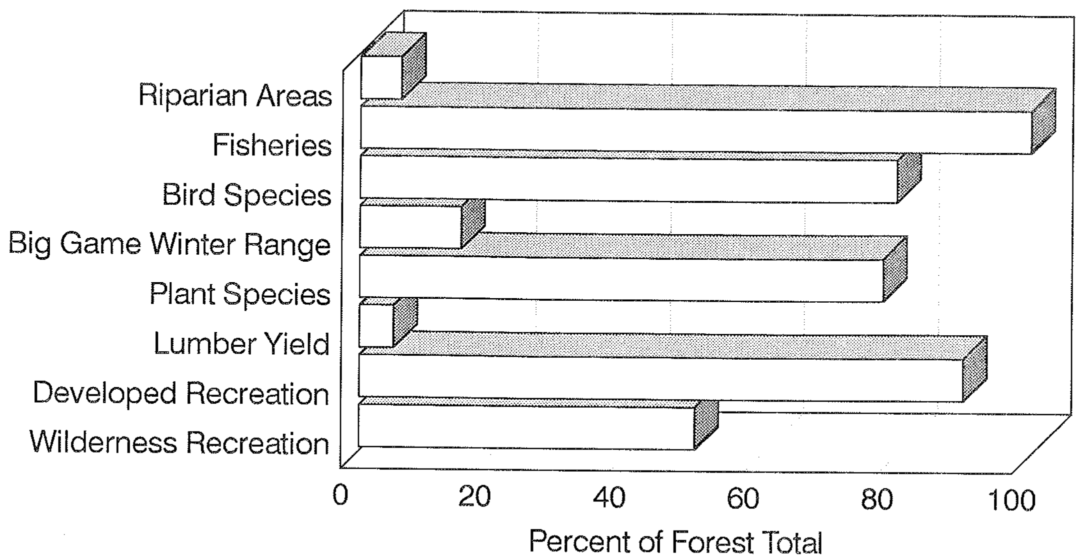


Figure 1

ECOSYSTEM FUNCTION AND ITS RELATIONSHIP TO FOREST PRACTICES

An important management concern is the influence of forest practices on some functional relationships of riparian areas. There are silvicultural treatments other than logging that need to be considered, such as planting or afforestation, thinning, and slash treatments. Forest practices that are possible in a riparian area include no logging, a perfectly acceptable management decision; control of slash by burning and/or piling; and the planting of trees, shrubs, and forbs that are common to thinning, commercial, and precommercial practices. These techniques can alter the physical structure and species composition of a system to meet management objectives.

One of the most obvious functional relationships is the shading of the stream by an adjacent tree stand. If there is a set of profound changes that logging has on a stream, it is the removal of adjacent vegetation that permits exposure of the stream to full sunlight. The greater solar radiation may increase stream temperatures and accelerate in-stream primary productivity.

Another effect of logging is to alter the type and timing of fine-scale organic inputs during the winter. This detritus provides primary production for the aquatic community and represents a significant portion of the energy base. By logging, certain species and their associated inputs can be removed. Other species with desirable properties can be introduced or reintroduced by forest practices. Since the rate of processing of organic inputs is plant-species dependent, it may be possible to regulate the mix of amounts, timing, and quality of organic inputs to the stream. This regulation may be accomplished by thinning without removal, logging, and planting.

The importance of organic inputs such as coarse woody debris in channel structure and integrity is discussed in other papers in this volume.[2] Coarse woody debris plays an important role in the retention of sediments, slowing of the movement of water out of the basin, and the capture of other organic material. The retention aspects allow processing of organic material by some organisms prior to a general energy availability or breakdown. If a riparian area occurs without roughness elements, i.e., with no coarse woody debris to capture the sediments or with no organic matter, energy is relatively rapidly exploited. By adding a few roughness elements, material begins to collect and riparian systems begin to rebuild. Streamside tree stands that deliver coarse woody debris provide habitat to endangered species such as the Pacific Giant Salamander. These riparian forests also provide habitat and migration corridors for a rich variety of wildlife, such as the spotted owl of the Northwest.

Riparian areas also capture nutrients that are transported from the hillslope. The filtering by riparian areas of water transported downslope has been likened to tertiary sewage treatment processes.

[2]See Hawkins and Swanson, this volume.

PROBLEMS OF SCALE

On the western slopes of the Cascade Range, the hydrology is altered by clear-cut patch logging. When patch cutting produces cleared areas over 40 to 50 percent of basins several thousand hectares in size, storm peak flows tend to be larger. This landscape-scale logging activity affects the riparian area by increasing the frequency with which the near-stream vegetation is disturbed by flowing water.

Situations differ tremendously, and there is a considerable variation in these natural systems. For example, on the west side of the Cascades, summer base flows from recently logged areas have dropped to below prelogging levels. How long this effect will persist is not known, though it appears to be related to a shift in vegetation composition. Species in the earlier successional communities tend to be more profligate in their water use. By thinning, the species mix can be controlled. Selective planting can produce a species mix that is less apt to transfer water. These potential activities come under the general rubric of forestry. The forest riparian area provides material to strengthen the banks and roots that promote stream-bank integrity. Logging tends to destabilize the banks and thereby to destabilize the system.

The period of time it takes for different functions to recover to prelogging levels (e.g., inputs of nutrients and litter and shading along small third-, fourth-, and fifth-order streams) is relatively rapid (<500 years) (Figure 3). If the riparian forest is totally clear-cut, a long period of time must pass before large woody debris enters the channel in any significant amount through natural processes.

NEW FORESTRY AND FUNCTIONAL RECOVERY OF RIPARIAN AREAS

The promise of new forestry with "twice" the nutrient cycling power and "extra" animal ingredients involves the viewing of objectives and practices designed to meet those objectives in a slightly different way. The recovery time for many of these functions can be much shorter with the application of new-forestry principles. One of the primary objectives of new forestry is to provide, at a landscape scale, commodities such as timber and pulp and paper while simultaneously maintaining ecosystem and community processes, long-term site productivity, biological diversity, and aesthetic improvement. Visitors to the new-forestry units state that they are equally ugly when compared to the old "industrial strength" clear-cut, broadcast-burning approaches. These individuals are correct; but at the landscape scale, the visual effect is much softer. This kind of approach tries to maintain some of the ecosystem processes of the site, e.g., the retention of green trees, hard and soft snags, and a fair amount of woody debris on the forest floor. New forestry prescribes burning only a portion of the forest for slash cleanup and fire-hazard reduction rather than the more typical broadcast burning.

New forestry also prescribes the retention of a

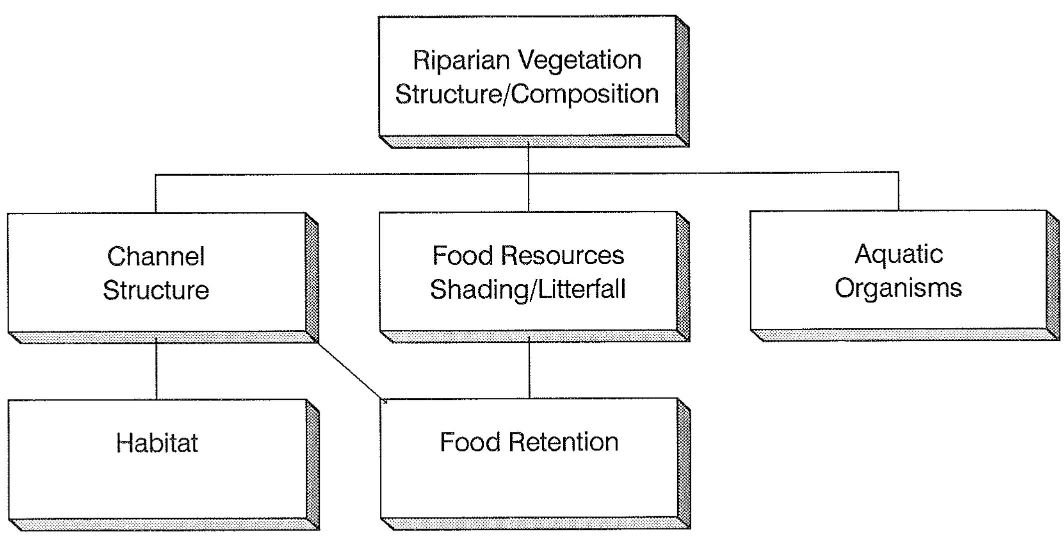


Figure 2

large portion of the overwood, which appears similar to a shelterwood logging activity to those familiar with traditional forest practices. These activities are accomplished for a slightly different set of objectives that must be clearly defined. In any reach-sized management plan or site plan, a site analysis must first be performed. The site analysis must provide site characteristics and scaling sensitivities. The greater share of the planning effort is spent defining your site objectives. Only then can a reasonable move be made from the site plan to a set of prescriptions that represents the best current working hypotheses related to the consequences of logging, other forestry-related activities, or any activity. After this effort, a reach where a stream is flowing can be entered and the riparian-management boundaries can be finessed to achieve the proposed management objectives in terms of the functional relationships discussed earlier.

The reach scale can be finessed, but it is important that the landscape scale be considered. Thus, whatever riparian-management program is constructed, the reach-scale prescriptions and objectives must be placed within the context of the complete landscape. The watershed should be the smallest unit of consideration. Management must be considered at a much larger scale than the reach scale. By thinking at the landscape scale, the decision may be to avoid the riparian forest or it may be something else entirely. The choice may be to enter the riparian forest to cut selected trees to enrich the stream with coarse woody debris because the reaches upstream or downstream are impoverished. A key element is the clarification of objectives, remembering that the narrow riparian area is profoundly enforced by adjacent uplands and that any riparian-management plans should be couched in terms of the overall landscape-management plan.

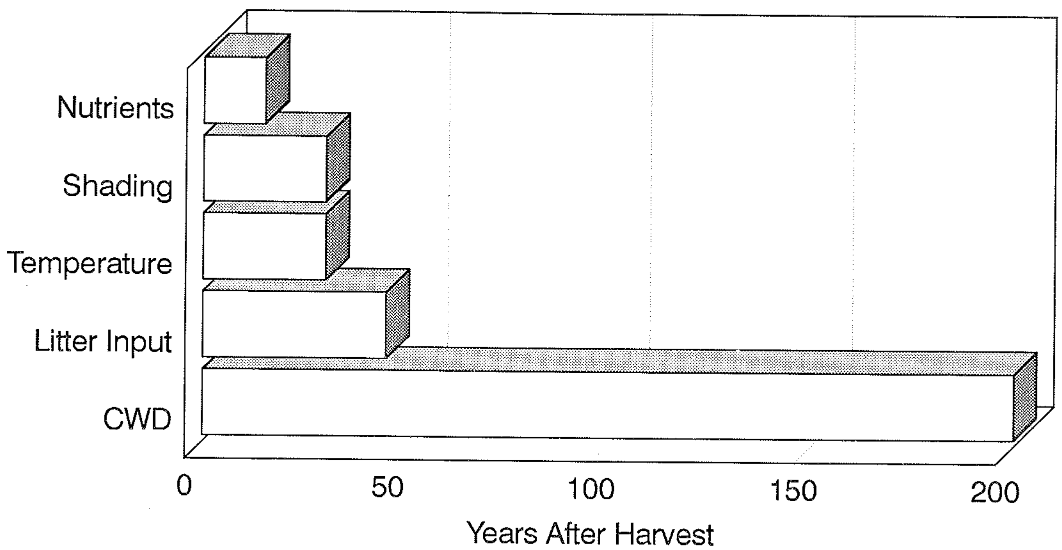


Figure 3

The Impact of Native Ungulates and Beaver on Riparian Communities in the Intermountain West

Charles E. Kay
Institute of Political Economy
Utah State University
Logan, UT 84322-0725

Abstract

This paper reviews the impact native ungulates, primarily elk and moose, and beaver can have on riparian communities in the Western United States. In Yellowstone National Park and in other areas where ungulates are not managed, repeated browsing has reduced tall willow, aspen, and cottonwood communities by approximately 95 percent since the late 1800s. Native ungulates can also severely reduce or eliminate palatable grasses and forbs from herbaceous riparian communities. By eliminating woody vegetation and security cover and by altering plant-species composition, native ungulates can alter bird, mammal, and aquatic communities. They can even negatively affect endangered species like grizzly bears for which riparian areas provide critical habitat. In many respects, excessive use by native ungulates is similar to overgrazing by domestic livestock.

Beaver is a keystone species that alters the hydrology, energy flow, and nutrient cycling of aquatic systems. Unlike ungula[illegible] which tend to degrade riparian habitats, beaver actually create and maintain riparian areas. Beaver dams [illegible] only impound water but they also trap sediments that raise the water table and allow the extension of riparian communities into former upland areas. By trapping silt over thousands of years, beaver have actually created many of the West's fertile valleys. Prior to the arrival of Europeans, Western streams supported large populations of beaver. During one five-day period in 1825, Peter Skene Ogden's fur brigade trapped 511 beaver. Today, state and federal land-management agencies are using beaver to restore damaged riparian areas. Beaver, however, can become a nuisance when they dam irrigation facilities, plug highway culverts, or fell streamside trees valued by landowners.

INTRODUCTION

Most classifications of intermountain wetland plant communities have failed to address what impact wildlife may have had on the species and structural composition of those riparian associations (Youngblood et al. 1985, Windell et al. 1986, Kovalchik 1987, Hansen et al. 1988, Padgett et al. 1989). While ungulate-induced reductions in tree and shrub canopy cover and growth have been widely reported for various upland plant communities (Pimlott 1965, Bobek et al. 1979, Stewart et al. 1987, Alverson et al. 1988, Tilghman 1989, Veblen et al. 1989, Brandner et al. 1990), only a few wildlife grazing studies have dealt specifically with riparian communities (Patten 1968).

This paper explores the impact native ungulates, primarily elk (*Cervus elaphus*) and moose (*Alces alces*), and beaver (*Castor canadensis*) have on riparian communities in the Western United States. Emphasis is placed on Yellowstone National Park—not because that area has unique wildlife/riparian relationships but because it is one of the few areas where researchers have concentrated on wildlife/riparian interactions. Chadde et al. (1988) classified wetland plant communities on Yellowstone's northern winter range, while Chadde and Kay (1988, 1991) recently reported on the impact of ungulate browsing on the park's willow (*Salix* spp.) communities. Barmore (1981), Houston (1982), Chase (1986), Despain et al. (1986), Chadde (1989), Despain (1989), and Kay (1990) provide additional information or different perspectives on how wildlife has affected Yellowstone's riparian communities.

Similar wildlife/riparian interactions occur in other Western national park, including Rocky Mountain, Olympic, Mount Rainier, Grand Teton, Banff, and Jasper, where ungulates have been allowed to concentrate in wetland areas. Similar conditions also exist in western Wyoming where large populations of elk are maintained by winter feeding (Anderson 1958, Beetle 1979, Strickland 1987, Boyce 1989) and where large numbers of moose winter in riparian areas (Bassett 1951, Rudersdorf 1952, Harry 1957, Houston 1968, Collins 1976).

UNGULATE IMPACTS

Willows

Until 1968 the National Park Service contended that an "unnaturally" large elk population, which had built up in Yellowstone during the late 1800s and early 1900s, had severely "damaged"[1] the park's northern winter range, including willow communities (Rush 1932, Kittams 1959, Pengelly 1963, Tyers 1981, Kay 1985, Chase 1986). However, agency biologists (Houston 1976, 1982) now believe elk and other animals in Yellowstone are "naturally regulated," being resource (food) limited.

A complete discussion of how the Park Service developed and formulated its "natural regulation" program is beyond the scope of this paper; but under "natural regulation," (1) predation is an assisting but nonessential adjunct to the regulation of ungulate populations. If wolves were present, they would only kill the animals slated to die from other causes, primarily starvation, and, thus, would not lower the ungulate populations; (2) if ungulates and vegetation have coevolved for a long period of time and if they occupy an ecologically complete habitat, the ungulates cannot cause retrogressive plant succession or range damage. The ungulates and vegetation will reach an equilibrium where continued grazing will not change plant species composition or the physical structure of the plant community; and (3) at equilibrium, competitive exclusion of sympatric herbivores due to interspecific competition will not occur. In Yellowstone this means elk have not caused a decline in the numbers of other ungulates or beaver.[2]

Park Service biologists now believe that elk and other herbivores and vegetation in Yellowstone have been in equilibrium for several thousand years (Despain et al. 1986). Any changes in plant-species composition since the park was created are believed to be due primarily to suppression of lightning fires, normal plant succession, or climatic change, not to ungulate grazing. Houston (1982:129) concluded that "while ungulates and other herbivores affected the rate of primary succession, changes in distribution of willow were mostly climatically determined." He (1982:131) also suggested that suppression of lightning fires may have adversely affected willows.

Houston (1976) indicated that if willow communities had actually declined on the northern range because of ungulate browsing this would be a basis for rejecting the "natural regulation" hypothesis. Because "natural regulation" is a global equilibrium model, grazing-induced changes in vegetation height or physical structure would also indicate the herbivores are not in equilibrium with their food resources. If ungulate browsing has changed what were once tall willow communities into short willow types, this would be additional grounds for rejecting "natural regulation."

To evaluate the effects of succession, climate, and ungulate browsing on Yellowstone's willow communities, the following data are presented on the historical distribution and abundance of willows in the park, ungulate-proof willow exclosures, and willow seed production.

Historical Distribution and Abundance. Kay (1990:229) made forty-four repeat photosets of willow communities on Yellowstone's northern range. The earliest sets date from 1871. Some photosets contained four photographs taken in 1893, 1921, 1954, and 1986–1988. In forty-one out of forty-four comparative photosets, tall willow communities totally disappeared. In three other photosets, only 5 to 10 percent of the original tall willows remained (Kay 1990).

In 1871 Captains Barlow and Heap (1872:40) toured Yellowstone Park. On the northern range, they reported "thickets of willows along the river banks." Norris (1880:613), Yellowstone's second superintendent, noted that the park was "well supplied with rivulets invariably bordered with willows." Norris (1880:617) added that there were "innumerable dense thickets of willow" in Yellowstone. Based on an analysis of pollen in the sediments from lakes and

[1]Terms such as *overgrazing, range damage,* and *unnatural* elk populations were used in nearly all early governmental reports about the northern range. Since these terms are value laden, they are used throughout this paper only in their historical context.

[2]See Kay 1990, Chapter 1, for a detailed analysis of how "natural regulation" was developed.

ponds on the northern range, Barnosky (1988) reported that willow pollen had declined since the early 1900s. Thus, the available evidence indicates that tall willow communities were once common on the northern range but that they are now virtually absent.

Historically, Yellowstone's Gallatin River drainage has had an elk situation similar to that on the northern range (Packer 1963; Patten 1963, 1969; Streeter 1965; Peek et al. 1967; Lovaas 1970). Patten (1968) reported vegetation along the Gallatin River changed rapidly from an area nearly devoid of willows near the park's boundary to extensive willow thickets a few kilometers upstream in the park. He (p. 1107) noted that "between these areas lies a transition zone of stunted and dead willows." The area with the fewest willows had the largest concentrations of wintering elk (Peek et al. 1967, Lovaas 1970). Where deep snow to the south or hunters north of the park limit elk use, willows grew taller (Kay 1990).

Kay (1990:236) made four photosets of willow communities on Yellowstone's Gallatin winter range. Three contained four pictures taken in 1924, 1949, 1961, and 1986, while the other included 1937, 1961, and 1989 photos. Tall willows declined markedly along this section of the Gallatin River and lower Daly Creek between 1924 and 1961. Since the 1970s, the Montana Department of Fish, Wildlife, and Parks has made a concerted effort to control this elk herd when it migrates from Yellowstone Park. By instituting late-season hunts, the department reduced the Gallatin elk population by at least 50 percent in recent years (Kay 1990). In apparent response to this decline in elk numbers, photos repeated in 1986 and 1989 show that willows have increased in height and canopy cover since the 1960s, but they still show more signs of browsing than willows did in 1924 (Kay 1990).

Houston (1982:276–77) suggested that willows were seral to conifers. In some instances, this is true but not for most willow communities on Yellowstone's

Table 1. Percent willow canopy cover on permanent transects inside and outside Yellowstone exclosures from 1958 to 1988. Adapted from Kay (1990) and Chadde and Kay (1988, 1991).

	Mean percent willow canopy cover*				
	Date of first measurement			Date of most recent measurement	
Exclosure-transect	1958	1962	1963	1986	1988
Mammoth					
Outside	7.5	—	—	—	12.3
Inside	4.5	—	—	—	109.2
Junction Butte					
Outside	—	6.6	—	—	21.0
Inside	—	16.1	—	—	93.2
Lamar-East					
Outside†	6.0	—	—	—	9.7
Inside	8.2	—	—	—	86.5
Lamar-West					
Outside†	—	5.4	—	—	9.7
Inside	—	1.7	—	—	92.0
Slough Creek					
Outside	—	—	20.0	28.0	—
Inside	—	—	46.0	114.0	—
Totals					
Outside		9.1		17.1	
Inside		15.3		99.4	
p ‡		n.s.		<.01	

*All permanent willow belt transects in Yellowstone Park contain some nonwillow communities. Those areas were excluded in the 1986–1988 measurements.

†The Park Service uses the same outside plot for both the Lamar-East and the Lamar-West exclosures.

‡Percentages were arc sine transformed; Student's t test.

northern range. Of the forty-eight repeat photosets of willow communities reported by Kay (1990), only two showed complete replacement by conifers. In three others, approximately 20 to 60 percent of the willow communities in the original photos were replaced by conifers. So only five of forty-eight photosets (10 percent) showed conifer invasion of what were once willow communities (Kay 1990).

Exclosures. Kay (1990:Chapter 6) and Chadde and Kay (1988, 1991) reported on willow communities inside and outside five ungulate-proof grazing exclosures on Yellowstone's northern range. Willows were taller and had greater canopy cover inside than outside each exclosure (Tables 1–2). Other less palatable shrubs, such as rose (*Rosa woodsii*) and river birch (*Betula occidentalis*) (Nelson and Leege 1982), exhibited the same pattern (Kay 1990). When pooled, these differences were statistically significant across all exclosures (Tables 1–2). Outside these exclosures, the mean height of all willow species was 51 cm while inside it was 279 cm. On average, willows had 17 percent canopy cover outside the exclosures but 99 percent canopy cover where ungulates were excluded. Thus, willow canopy closure was nearly complete inside the exclosures.

In addition, willows inside the exclosures increased significantly in height and canopy cover over time while those outside did not (Tables 1–2). Mean willow height outside the exclosures when they were first established (1958–1963) was 45 cm and only 51 cm when they were recently measured (1986–1988) (n.s.; Student's *t* test). Inside the exclosures, willows had a mean height of 54 cm in 1958–1963 and 279 cm in 1986–1988 ($p<.01$; Student's *t* test). At the date of first measurement (1958–1963), willows outside the exclosures had a mean canopy cover of 9.1 percent, which increased to 17.1 percent by 1986–1988; but that difference was not statistically significant. Inside the exclosures, willow canopy cover increased from 15.3 percent in 1958–1963 to 99.4 percent by 1986–1988 ($p<.01$; Student's *t* test on arc sine transformed percentages).

Inside three exclosures in the Gallatin River drainage, willows attained heights of 3 to 4 m with near-complete canopy closure while unprotected plants were all less than 1 m tall (Kay 1990:150). In Rocky

Table 2. Average height of all willow species on permanent transects inside and outside Yellowstone exclosures from 1958 to 1988. Adapted from Kay (1990), Chadde and Kay (1988, 1991), and Singer (1987).

	Mean height (cm)				
	Date of first measurement			Date of most recent measurement	
Exclosure-transect	1958	1962	1963	1986	1988
Mammoth					
Outside	28	—	—	—	22
Inside	64	—	—	—	316
Junction Butte					
Outside	—	56	—	—	35
Inside	—	29	—	—	210
Lamar-East					
Outside*	29	—	—	—	45
Inside	27	—	—	—	282
Lamar-West					
Outside*	—	32	—	—	45
Inside	—	28	—	—	287
Slough Creek					
Outside	—	—	80	100	—
Inside	—	—	120	300	—
Totals					
Outside	45			51	
Inside	54			279	
p†	n.s.			<.01	

*The Park Service uses the same outside plot for both the Lamar-East and the Lamar-West exclosures.
†Student's *t* test.

Mountain National Park, Gysel (1960) and Stevens (1980) noted that willows increased in canopy cover and height inside exclosures where elk were excluded. On elk and moose winter range in Banff National Park, Trottier and Fehr (1982) reported that willows inside an exclosure were significantly taller than those exposed to ungulate browsing.

In addition to the measurements of plant height and cover that the Park Service made over the years at Yellowstone's willow exclosures, they also photographed the permanent willow-belt transects each time they were sampled. Kay (1990) repeated those photographs in 1986–1988. The resulting multiple-image photosets confirm that willows inside the exclosures have increased in height and canopy cover since they were protected while willow communities outside the exclosures have not increased in height.

Those photographs also demonstrated that willows inside the exclosures now have the same height and physical structure that willows on the northern range had in the 1870s to 1890s (Kay 1990:150). So the conditions inside these exclosures more closely approximate the level of ungulate use that existed when Yellowstone Park was established in 1872 than conditions in the park today.

Seed Production. The Park Service believes that Yellowstone's present short-statured willows are ecologically equivalent to the tall willow communities that once existed on the park's northern range (Despain et al. 1986). To test one aspect of this assumption, Kay (1990) and Kay and Chadde (1992) measured willow seed production inside and outside Yellowstone exclosures. Outside the exclosures, no aments (male or female flowering parts) were present on any of the permanent willow-belt transects. Further, only eight male aments were found in an additional 1.13 ha of willow-dominated habitat that was searched adjacent to the four exclosures on Yellowstone's northern range. In contrast *Salix bebbiana, S. boothii, S. lutea,* and *S. geyeriana* produced an average, respectively, of 1445, 583, 694, and 1346 female aments per m² of canopy cover inside exclosures (Kay 1990:Chapter 7).

The number of seeds per m² of female willow canopy cover ranged from a low of around 109,000 for *S. geyeriana* to over 583,000 for *S. lutea* and averaged nearly 307,000 (Table 3). By combining the mean sex ratio, species canopy cover, and species seed production values, Kay (1990:185–91) estimated the total number of seeds produced inside and outside willow-belt transects. Approximately 5,857,000 seeds were produced on the willow transect inside the Junction Butte exclosure and zero outside; in the Lamar-East exclosure, 6,961,000 seeds were produced inside and zero outside; the Lamar-West exclosure had 7,016,000 seeds produced inside and zero outside; and in the Mammoth exclosure, 3,177,000 seeds were produced inside and zero outside.

Table 3. Mean number of seeds produced by willows inside and outside Yellowstone exclosures. Adapted from Kay (1990) and Kay and Chadde (1992).

	Mean number of seed per m² of female willow canopy cover	
Species	Outside exclosure	Inside exclosure
Salix bebbiana	0	318,854
Salix boothii	0	233, 142
Salix lutea	0	583,876
Salix geyeriana	0	108,972
Totals	0*	306,988*

*p<.001, Student's t test.

Kay (1990:191) reported that individual plants with a few stems beyond the reach of ungulates on Yellowstone's northern range showed an identical pattern. Willow stems above the browse height (2.5 m) produced an abundance of male or female aments while no aments were produced on that portion of the plant exposed to browsing (Table 4). Repeated ungulate browsing has virtually eliminated willow seed production on the northern range and other winter ranges within the Greater Yellowstone Ecosystem.

In a related study (Kay and Chadde 1992), willows protected for three growing seasons increased in

Table 4. Number of aments produced above and below the browse height (2.5 m) on individual willows in Yellowstone National Park near Geode Creek. Adapted from Kay (1990) and Kay and Chadde (1992).

Species-plant	Plant size (m²) canopy cover	Number of stems above browse height	Number of aments per plant	
			Below browse height	Above browse height
Salix lutea				
A - female	12	5	0	1680
B - female	2	1	0	78
C - female	2	2	0	170
D - male	3	9	0	1140
Salix geyeriana				
E - female	4	2	0	160
F - female	1	3	0	1351
G - female	3	5	0	600
Salix boothii				
H - female	2	2	0	182
Means			0*	670*

*$t = 2.80, p<.02$.

height but produced less than two male or female aments per m². It apparently takes several years for willows to reach their full reproductive potential once they are no longer subjected to ungulate browsing.

As a consequence, once the existing willows die of old age, disease, insects, or other causes they cannot be replaced by new plants produced from local seed. Under these conditions, willows will eventually disappear. Willows commonly colonize new habitats by producing vast numbers of wind-dispersed seeds. Yet during a three-year study to classify wetland communities on the northern range, Chadde et al. (1988) observed few willow seedlings on newly created gravel bars and mud flats, which normally provide ideal seed beds.

Without abundant seed crops, willows also cannot take advantage of recruitment opportunities produced by periodic large-scale disturbances such as fire (Despain 1989). Yellowstone's 1988 fires occurred under extreme burning conditions during an extended drought and are thought to be an event that occurs only every 100 to 300 years (Davis and Mutch 1989; Romme and Despain 1989a, 1989b; Schullery 1989a, 1989b). Hence, those fires were able to burn a limited number of normally wet riparian zones (Knight and Wallace 1989), many of which had thick sedge (*Carex* spp.) mats and accumulations of organic matter (Brichta 1987, Chadde et al. 1988). These areas, normally unfavorable to willow seed germination and seedling establishment, "were burned down to mineral soil, killing rhizomes and root systems" (Knight and Wallace 1989:704). This burning created bare mineral soil and ash substrates that had abundant soil moisture (especially after snowmelt in 1989), ideal conditions for germination and seedling establishment of willow (Brinkman 1974). Yet Kay and Chadde (1992) observed few willow seedlings growing in those areas.

The data would suggest that practically no willow seeds were produced on Yellowstone's northern range to colonize this newly created habitat. Reduction in seed production decreases the probability of plants colonizing new sites (Allison 1987). The virtual elimination of willow seed production by ungulates also suggests that herbivores and vegetation are not in equilibrium as proposed by the Park Service's "natural regulation" paradigm (Kay 1990:202).

Why Have Willows Declined? The Park Service has postulated that the observed decline in Yellowstone's tall willow communities is due to (1) normal plant succession, (2) climatic change, and (3) fire suppression but not to ungulate browsing (Houston 1982, Despain et al. 1986). According to Houston (1982:129–34), the willow decline may also have been due in part to the lack of new substrate for willows to colonize. He presented a 1974 photo of a newly formed gravel bar in the Gardiner River and a 1978 retake that showed willows had colonized that area.

Kay (1990:157) rephotographed that site in 1983, 1986, 1987, and 1988. In addition Chadde et al. (1988) established plots at that site as part of their riparian classification study. By 1983 willows were almost entirely absent from that gravel bar and had been replaced by grasses and other herbaceous plants.

So the area changed from bare gravel to willows to grass in only nine years. Not only is this much faster than normal plant succession but it is also contrary to expected successional directions. By the usual successional sequence in this area, colonizing willows would be replaced by other willow species and perhaps cottonwoods (*Populus* spp.) or eventually Engelmann spruce (*Picea engelmannii*) but not grasses, sedges, or forbs. Some willow communities on the northern range are seral; but on many sites, willows normally form stable or climax communities (Chadde et al. 1988). In nearly all instances, willows are not seral to grasslands unless there has been a change in hydrology (Chadde et al. 1988) that has not occurred at this site along the Gardiner River.[3]

The decline of willows on the northern range has also been attributed to climatic change, especially to the drought during the 1930s (Houston 1982:129–34). This suggestion, though, is not supported by data from the exclosures, where the climate is the same on both sides of the fence. The microclimate inside the exclosures is certainly different today, but that is an incorporated variable caused by the plants' response to elimination of ungulate browsing and is not the cause of the vegetation's response. Inside a small exclosure near Yellowstone's Tower Junction, willows grew vigorously during and after the 1930's drought while those outside did not (Kay 1990:158). Moreover, it is not climate that prevents the plants from growing to their full biological potential outside the exclosures. Measurements of subsurface water levels throughout the summer inside and outside the exclosures failed to show any less water available to the plants on the outside (Brichta 1987, Chadde et al. 1988).

The climate-change hypothesis also is not supported by photographic evidence and firsthand accounts. Willows started declining before the 1930's drought, and they have continued to decline in recent years. For example, willows in the western portion of Round Valley were severely hedged in 1949 but were still alive. By 1988 a major decline had occurred in those willows even though precipitation had been near normal during the 1949 to 1988 period, and there still are abundant springs and seeps at the site (Kay 1990).

Yellowstone's 2 ha Tower Junction willow exclosure was constructed in 1957; and by the late 1960s, the protected willows had significantly increased in height and canopy cover (Singer 1987). That exclosure was removed in the early 1970s and the protected plants exposed to ungulates. By the late 1970s and early 1980s, those willows were extensively hedged and were either dead or reverting to lower-statured plants (Kay 1990). Those changes certainly cannot be attributed to the 1930's drought. Climatic variation also appears to be unimportant since that area has abundant subsurface soil moisture (Brichta 1987, Chadde et al. 1988).

In recent years, the mean annual temperature on the northern range at Mammoth increased 0.5 to 1.0°C while the mean annual precipitation declined 1 to 2 cm (Houston 1982:101–7). No study, however, has demonstrated that a climatic shift of that magnitude will have a long-term impact on tall willows, especially since nearly all willow communities are subirrigated (Brichta 1987). Most perennial woody floras have so much biological or vegetational inertia that large-scale climatic changes of long duration are required before major shifts in plant species composition or stature occur (Smith 1965, Cole 1985, Davis and Botkin 1985, Davis 1986, Neilson 1986).

It has also been suggested that willow communities need to burn at frequent intervals if they are to persist on the northern range (Houston 1982) or if willows are to grow beyond the reach of browsing ungulates. Houston (1973, 1982:107) calculated mean intervals of 20 to 25 years between fires on the northern range during the 300 to 400 years before Yellowstone Park was established and the government began to suppress fires. Despite a policy that has been in effect since the early 1970s to let many lightning-caused fires burn, 1988 was the first year fire burned more than a small area on the northern range.

Despite what were considered the worst burning conditions in the park's history, riparian communities were not overly susceptible to the 1988 fires. Some willow communities did burn, but the fires commonly skipped over others because riparian areas and willows are generally too wet to burn (Romme and Knight 1981, Baker 1987).

Finally, there is no evidence to support the idea that burning will cause resprouting willows to grow so fast or to be so chemically defended that they can grow beyond the reach of elk and reform tall willow communities as has been postulated by park personnel (Kay 1990). Observations of experimental willow burns conducted by the Park Service on the northern range indicate that elk browsed all of the new sprouts and none were able to grow taller than 1 m except where physical barriers prevented elk use (Kay 1990:162). Stein and Price (1990:336) reported that in an experimental situation "elk fed primarily on [resprouted] willows that had been burned" as compared to unburned plants. Suter (1990:340) clipped winter dormant willows to simulate ungulate browsing and then measured proanthocyanidic tannins in twigs that grew the following year. She found that

[3]During the mid 1970s, a few tall willows were still alive above and below this gravel bar (Kay 1990). Those plants probably produced the seeds that became established on this gravel bar. Since that time, continued ungulate browsing, in combination with insects and pathogens, has eliminated those tall willows (Kay 1990).

"after two repeated clipping treatments in successive years, tannin levels decreased at all clipping intensities." She noted that "at extreme clipping levels plant reserves [were] not large enough to meet the demands of both a compensatory growth response and increased tannin production." Suter (1990) concluded that "a rapid growth response [was] an ineffective deterrent to future browsing."

Based on this evidence, Kay (1990) and Chadde and Kay (1991) concluded that frequent, repeated ungulate browsing was primarily responsible for the decline of tall willow communities on the northern range. Browsing by elk and moose presently prevents the willows that do exist on the northern range from expressing their full biological height and canopy cover. From 1970 through 1978, willow utilization on the northern range averaged over 91 percent (Houston 1982:149) and has not decreased in recent years (Kay 1990:163). Likewise, Barmore (1981:358) concluded that willows had declined on the northern range due to repeated ungulate browsing, not to climatic change.

During the late 1950s and early 1960s when the Park Service believed that an "unnaturally" high population of elk was causing "range damage" in Yellowstone, the herd was reduced by trapping, transplanting, and killing elk (Kay 1990:Chapter 1). Barmore (1981:357) noted that "by the late 1960s, the growth form and condition of *Salix* spp. on most of the winter range began to more closely resemble the less heavily browsed conditions of the late 1800s and early 1900s. This change was associated with major reduction of the northern Yellowstone elk herd suggesting that the decline in the distribution and condition of *Salix* spp. from the 1920s to the early 1960s was at least partly due to heavy browsing by elk."

On the Gallatin River, willows declined only where wintering elk concentrated (Patten 1968). The willows upstream and downstream from the main elk wintering area have not declined and commonly exceed 3 m in height. Climatic or hydrologic conditions could not be primarily responsible for the decline near the park boundary since all sections of the river were subjected to the same physical factors. Patten (1968) found that willows farthest from the river had the highest grazing-induced mortality rates. He concluded that plants subjected to physiological stress were less able to withstand grazing pressure. It was ungulate browsing, though, that actually caused most of the mortality and reduction in plant growth form. Neilson (1986), who worked on a similar climatic-change versus grazing problem, concluded that the vegetation would have persisted despite drought; but the additional stress of grazing completely altered the flora.

Repeated ungulate browsing can change tall willow communities into grazing-maintained short willow types and can also eliminate willows entirely. Unrestricted browsing by large populations of wild ungulates has the same impact commonly associated with "excessive" livestock grazing in riparian zones (Knopf and Cannon 1982, Cannon and Knopf 1984, General Accounting Office 1988, Schulz and Leininger 1990). After examining riparian communities in Yellowstone National Park, Dr. William Platts, U.S. Forest Service (USFS) riparian researcher and past president of the American Fisheries Society, stated that Yellowstone contained some of the worst overgrazed riparian areas that he had ever witnessed. He added that if this had occurred on Bureau of Land Management- (BLM) or USFS-administered lands with domestic livestock those agencies would have revoked the grazing permits.

Elk have also altered riparian communities in several other Western national parks including Rocky Mountain in Colorado (Stevens 1980, Braun et al. 1991) and Olympic in Washington (Houston et al. 1990). As in Yellowstone, the National Park Service contends that those altered areas are zootic climaxes that are "natural" and that they are not a sign of overgrazing. Based on an extensive analysis of historical journals and archaeological faunal remains, however, Kay (1990) demonstrated that large populations of elk did not exist anywhere in the Intermountain West over the last 8,000 or so years. Instead, today's herds are a recent phenomenon associated with park management. Of more than 52,000 ungulate bones identified at more than 500 intermountain archaeological sites, only 3 percent were elk and only one moose bone was unearthed (Kay 1990).

Aspen and Cottonwoods

Various species of cottonwood (*Populus* spp.) and aspen (*Populus tremuloides*) commonly grow in riparian settings throughout the Intermountain West (Youngblood and Mueggler 1981, Youngblood et al. 1985, Windell et al. 1986, Baker 1987, Mueggler 1988, Padgett et al. 1989). Heavy livestock grazing has long been recognized as a detriment to reproduction of cottonwoods (Crouch 1979) and aspen (Clary and Medin 1990) situated in riparian zones, but few studies have addressed the impact ungulates may have on cottonwood- or aspen-dominated riparian communities.

Late 1880s photos of Slough Creek and the Lamar River on Yellowstone's northern range show dense cottonwood and aspen riparian forests (Kay unpub. photos). Photos of those same areas taken during 1986–1988 show that the riparian gallery forest trees have declined approximately 90 percent since the park was established (Kay unpub. photos).

The few large cottonwoods (*Populus trichocarpa* and *P. angustifolia*) remaining along waterways in

Yellowstone Park produce abundant seeds, some of which establish on gravel bars along rivers and streams. Virtually none of those plants, however, has been successfully recruited into their sexually reproducing populations over the last eighty or so years because repeated ungulate browsing has prevented the young cottonwoods from growing taller than 1 m (Chadde et al. 1988, Kay unpub. photos). As the older trees die from various causes, they are not replaced by new trees grown from seed; and under present conditions, ungulate browsing will eventually eliminate cottonwoods from the park.

Kay (1985, 1990) conducted a detailed analysis of aspen communities on Yellowstone's northern range and throughout the Greater Yellowstone ecosystem including riparian aspen types. He utilized inside/outside park comparisons, repeat photographs, as well as exclosures in his study of aspen ecology. He concluded that, as with willows, ungulate browsing—not normal plant succession, climatic change, or fire suppression—was primarily responsible for the decline of aspen throughout the Yellowstone area. He noted that under the present levels of ungulate browsing once the remaining older aspen trees die communities with an aspen-tree overstory will be eliminated from the park and much of the Yellowstone ecosystem because repeated ungulate browsing has suppressed aspen regeneration for the last eighty or so years. Except where elk and other ungulates are physically excluded, repeated browsing prevents aspen suckers from growing taller than 1 m, including aspen growing in riparian zones (Kay 1990).

Herbaceous Riparian Communities

Tiedemann and Berndt (1972), Hanley and Taber (1980), Bradley (1982), and Edgerton (1987) concluded that grazing and trampling by elk on upland sites limited shrubs and tall forbs while favoring grasses, sedges, and low-growing forbs. Since elk and other ungulates have a preference for mesic habitats, it appears reasonable to assume that ungulates would have a similar impact on riparian understory plants and herbaceous riparian communities, though few researchers have specifically investigated this subject.

As part of his aspen ecology study, Kay (1990) measured understory species composition in aspen stands on Yellowstone's northern range. He compared understory species composition in the park with that of aspen stands immediately outside the park in Eagle Creek where fewer elk winter. He reported that the understories of aspen stands in the park were dominated by plants resistant to grazing or ones that are less palatable, while understories in Eagle Creek were dominated by shrubs and tall forbs sensitive to grazing and trampling. For example, cow parsnip (*Heracleum lanatum*) had an average canopy cover of 12.3 percent in Eagle Creek aspen communities and only 0.5 percent in park stands ($p< .001$, t-test on arc sine transformed data) (Kay 1990:75). Cow parsnip had a constancy (the percentage of total measured stands containing the species) of 73 percent in Eagle Creek and 24 percent in the park.

Cow parsnip is readily eaten by ungulates, and elk in Yellowstone select cow parsnip even in summer when other forage is abundant. Moreover, cow parsnip is very susceptible to trampling damage. Simulated elk trampling research has shown that tall forbs are the class of plants most severely affected by trampling (Bradley 1982). Since cow parsnip is very sensitive to herbivory (Youngblood and Mueggler 1981:12, Stivers 1988) and there have been substantially fewer elk outside the park (Kay 1985, 1990) where cow parsnip is more abundant, it appears reasonable to attribute the observed differences to elk grazing.

Although commonly found in riparian areas throughout the West, cow parsnip is rarely found in wetland plant communities on Yellowstone's northern range (Chadde et al. 1988). In the park's riparian zones, cow parsnip is often found growing only where it is physically protected from ungulate browsing. For instance, cow parsnip has been observed growing inside clumps of dying willows where dead branches apparently act as nurse plants to protect the umbel from elk (Kay unpub. photos).

Most aspen communities in the park have understories dominated by non-native grasses such as timothy (*Phleum pratense*) or Kentucky bluegrass (*Poa pratensis*). On average, timothy had a canopy cover of 33.4 percent in park aspen stands but only 2.6 percent in Eagle Creek ($p< .001$, t-test on arc sine transformed data) (Kay 1990:75). Houston (1982:415) indicated that timothy dominated "about seventeen percent" of the aspen stands he measured in the park but provided no other data. In the park, Kay (1990:75-76) reported that timothy had average canopy covers of 42.4 percent and 36.5 percent respectively with constancies of 88 percent and 77 percent in his North and South Lamar study areas. Timothy is resistant to grazing and tends to increase with grazing pressure or disturbance (Chadde et al. 1988). Elsewhere, aspen and riparian communities dominated by non-native grasses have been classified as grazing disclimaxes (Youngblood et al. 1985, Mueggler 1988, Padgett et al. 1989.)

Chadde et al. (1988) and Chadde (1989) reported a similar pattern in riparian communities throughout the northern range. Undergrowths tended to be dominated by grasses while palatable shrubs and tall forbs were rare. This trend is also clearly evident at the Lower Beaver Meadows exclosure in Rocky Mountain National Park. There, a herbaceous riparian community inside the exclosure is dominated by cow parsnip, white angelica (*Angelica arguta),* and tall blue bells (*Mertensia* spp.), while grasses and sedges predominate on the outside (Kay unpub. photos).

In Isle Royale National Park, Michigan, browsing by moose completely altered the species composition and understory structure of the forests (Hansen et al. 1973, Krefting 1974, Janke 1976, Snyder and Janke 1976, Risenhoover and Maass 1987, Moen et al. 1990) and is even eliminating balsam fir (*Abies balsamea*) from most of the island (Brandner 1986, Brandner et al. 1990). In addition, Aho and Jordan (1979) and Jordan (1987) noted that grazing by moose had a marked negative impact on aquatic plants (*Nuphar variegatum, Nymphaea odorata,* and *Potamogeton* spp.) over the entire island, while Fraser and Hristienko (1983) reported that moose had eliminated much of the aquatic vegetation in Sibley Provincial Park, Ontario.

Hiding or Security Cover

Hiding or security cover, another measure of vegetation height and plant density or spacing, is important to many wildlife species. For instance, grizzly bears (*Ursus arctos*) seldom use a food source far from cover (Kay 1989). Loft et al. (1987) demonstrated that hiding cover for mule deer (*Odocoileus hemionus*) fawns in willow, aspen, and herbaceous riparian habitats was significantly reduced with heavy livestock use.

Kay (1989) measured security cover in willow and aspen habitats inside and outside Yellowstone Park exclosures, as well as along Montana's East Front. He noted that the security cover offered by willows on Yellowstone's northern range was only 11 percent while it was 100 percent inside willow exclosures and in East Front willow communities. He also reported a similar trend in aspen types. Kay (1989) concluded that grizzly bears in Yellowstone seldom use low-elevation riparian and aspen communities in the park, in part because repeated ungulate browsing has drastically reduced the security-cover value of those habitats. Where security-cover values are high, such as along the East Front, grizzlies show a decided preference for low-elevation willow and aspen communities (Aune et al. 1986, Aune and Brannon 1987, Aune and Kasworm 1989).

Summer Range

Houston (1982:131) argued that ungulates were not primarily responsible for the decline of willows in Yellowstone because willows had also declined outside the park as well as on Yellowstone's summer ranges. Willows have in fact declined throughout the West since European settlement; but that has been primarily due to agricultural practices such as irrigation dewatering, channelization, and livestock grazing, not to climatic change (Meehan and Platts 1978, Dobyns 1981, Myers 1981, Marcuson 1983, Platts et al. 1983, General Accounting Office 1988). A recent study of 262 miles of streams in southwest Wyoming found that since the 1850s 83 percent of the streams and their associated riparian areas had been severely altered by livestock grazing (Shute 1981). Furthermore, moose and elk feed upon willows on Yellowstone's summer ranges (McMillan 1950, 1953); and until exclosures are built in those areas, there is no way to determine what impact summer ungulate utilization is having on those communities.

In Western Canada, Morgantini and Hudson (1989) reported that elk shifted their diet to willows on summer ranges. In Rocky Mountain National Park, Stevens (1980:14) concluded that "willow forms a major part of the summer diet for elk, about 21 percent." He (1980:139) reported that on the park's summer range "53 percent of the elk were observed on willow types." Moreover, he found that elk grazing caused willows to decline on the park's summer range. "*Salix brachycarpa* decreased an average of 55 percent on three of the four transects, with an overall decline from 20 percent cover to 9 percent. *Salix planifolia* declined from 37 percent to 29 percent cover" (Stevens 1980:135). These reductions occurred in only eight years as the elk herd built up in that park (Stevens 1980:136). Reporting on a continuation of that study, Braun et al. (1991) noted that from 1971 to 1989 willow canopy cover on permanent plots in Rocky Mountain National Park's alpine zone decreased from 49 percent to 36 percent while willow canopy cover on subalpine plots declined from 57 percent to 27 percent due to reported elk browsing.

Bradley (1982) reported that summering elk had severe impacts on wetland communities in the subalpine zone of Washington's Mount Rainier National Park. He reported that a combination of elk grazing and trampling caused extensive soil erosion that eventually destroyed many riparian zones in elk summering areas. As noted previously, this is not surprising since nearly all habitat-use studies have shown that summering elk have a decided preference for mesic areas (Skovlin 1982; Edge et al. 1987, 1988).

A large segment of the southern Yellowstone or Jackson Hole elk herd once summered in Wyoming's Teton Wilderness, including Big Game Ridge (Anderson 1958, Houston 1982, Boyce 1989). Croft and Ellison (1960) reported that grazing and trampling by large numbers of elk on Big Game Ridge caused extensive soil erosion that was so severe that huge boulder-choked mudflows descended several miles down from the ridge and completely buried miles of riparian habitat. This destruction could not be blamed on domestic livestock, as they had never been allowed in that area (Croft and Ellison 1960).

Cole (1969), Gruell (1973), and Boyce (1989) questioned this interpretation. They believe that the situation on Big Game Ridge is "natural" and claim that large herds of elk have summered there for the last several thousand years. They insist that excessive soil erosion began when the area was burned during the 1880s and then subjected to extensive pocket-gopher-induced (*Thomomys* spp.) soil disturbance. Croft (1974) and Beetle (1974) criticized this reinterpretation.

This area was once part of the Teton State Game Preserve, and hunting was not permitted from 1905 to 1942. During the thirty-eight years when hunting was not allowed, large numbers of elk summered on Big Game Ridge. Range damage on Big Game Ridge was first reported in 1951, and by 1960 massive soil erosion had occurred (Croft and Ellison 1960). As more and more hunters used the area, though, fewer and fewer elk summered on Big Game Ridge. Today relatively few elk summer there, and mudflows have not occurred since the late 1960s despite a continued abundance of pocket-gopher activity.

Moreover, Kay (1990) reported that despite extensive archaeological surveys and excavations not a single elk bone has been unearthed from any of the several hundred known archaeological sites in Jackson Hole. Wright (1984), who made an extensive study of aboriginal subsistence patterns in northwestern Wyoming, concluded that native peoples who inhabited Jackson Hole for the last 10,000 or so years subsisted mainly on vegetal foods and that there was no evidence that large herds of elk or other ungulates summered or wintered in that area until after European influences. It appears that the soil erosion, which completely buried miles of riparian habitat at some distance from Big Game Ridge, was not natural but occurred when elk concentrated in an area closed to hunting.

BEAVER IMPACTS

Negative Impacts

Unlike ungulates, which tend to negatively affect or eliminate riparian habitats, beaver actually create and maintain riparian areas. Many people, though, harbor negative attitudes toward beaver because they often interfere with human activities. For instance, beaver are held in low regard by many Western agricultural interests because they frequently dam irrigation ditches, highway culverts, and other facilities (Grasse and Putnam 1955). Land owners often consider beaver a nuisance because they fell streamside cottonwoods and aspen, which humans find aesthetically pleasing and which enhance property values (Hall 1960, Beier and Barrett 1987, Platts and Onishuk 1988). However, because beaver-felled aspen, cottonwoods, and willows usually resprout or reseed into an area (Hall 1960; Kindschy 1985, 1989; Masslich et al. 1988; Beier and Barrett 1989), it is not as if beaver eliminated those species.

Positive Impacts

During the 1930s, the Soil Conservation Service (SCS) enlisted beaver as an ally in its water-conservation program (Scheffer 1938). The SCS transplanted beaver to unoccupied areas because beaver dams "served . . . to stabilize the flow of the streams by reducing the force of the water and the crest of floods" (Scheffer 1938). The SCS even went so far as to parachute beaver into remote areas. The animals were housed in wooden cages and simply ate their way free after they landed.

Because their research demonstrated that beaver create and maintain riparian areas that are critical to other wildlife (Munther 1982, 1983; Smith 1980, 1983a, 1983b), both the BLM and the Forest Service have recently transplanted beaver to restore livestock-damaged riparian areas. The Forest Service used beaver to improve wetlands in Montana and Oregon (Johnson 1984, Bergstrom 1985, Kay 1988), while the BLM established two beaver-transplant demonstration projects on livestock-degraded streams in southwestern Wyoming. BLM's projects on Sage and Currant Creeks were extremely successful and have been widely reported in the popular press (Michelmore 1984, Skinner 1986, Kay 1988).

Other researchers have demonstrated that beaver is a keystone species that completely alters the hydrology, energy flow, and nutrient cycling of aquatic systems (Naiman and Melillo 1984; Parker et al. 1985; Naiman et al. 1986, 1988; Platts and Onishuk 1988; Johnston and Naiman 1990; Smith et al. 1991). Beaver dams impound water and trap sediments that raise the water table, increase the wetted perimeter, and allow the extension of riparian communities into former upland sites (Smith 1980, Apple 1983). In addition beaver dams regulate stream flow by storing water, reducing peak or flood flow, and augmenting low flows during summer (Smith 1983b). During dry periods, 30 to 60 percent of the water in a stream system can be held in beaver ponds (Smith 1983a). By trapping silt over thousands of years, beaver dams created many of the West's fertile valley bottoms (Ives 1942, Apple 1983). Munther (1982, 1983) reported that a typical creek without beaver furnishes only about two to four acres of riparian habitat per stream mile in the northern Rockies; but with beaver activity, that area can be expanded to twenty-four acres per mile.

Gebhardt et al. (1989:57) noted that frequent flood events appear to have little hydrological effect on beaver-dominated streams. They added that "larger, less frequent flood events may not cause more than some localized [stream] degradation." They concluded that "this lack of system degradation is probably attributable to the continuous presence of the beaver providing a consistent, rapid, and adaptable stream control." They also observed that "loss of beaver without adequate vegetation reestablishment prior to a flood occurrence can result in a very primitive, degraded [stream] channel."

In many Western cold-water streams, beaver ponds enhance fisheries production (Grasse and Putnam 1955). In those systems, low water temperatures usually inhibit fish growth; but because water temperatures are elevated in beaver ponds due to longer retention time and reduced shading, fisheries production is enhanced in these beaver-dominated aquatic systems (Gard 1961). Beaver ponds also produce an abundance of aquatic insects (Hodkinson 1975; Naiman et al. 1984, 1986), which are readily consumed by fish thereby increasing fisheries production. In warmer water systems, though, beaver ponds and beaver removal of streamside shade trees can increase water temperatures to such an extent that trout can be negatively affected or eliminated (Grasse and Putnam 1955, Churchill 1980).

Yellowstone's Beaver

Houston (1982:182–83) implied that beaver were not widespread in Yellowstone until around 1900 and suggested that "ephemeral colonies may be characteristic of most of the park." In 1835, 1836, and 1837, however, Osborne Russell (1965) found large numbers of beaver on Yellowstone's northern range. For instance, he and his companions trapped beaver on the upper Gardiner River from August 3 to August 20, 1835. That same year, Russell (1965:27) met some Shoshone Indians in Yellowstone's Lamar Valley who told him that "there had been a great many beaver on the branches of this stream [Lamar River] but they [Indians] had killed nearly all of them [for food]." Yet in 1836, Russell and his party spent several days trapping beaver on streams flowing into Lamar Valley, which would suggest the Shoshone had actually left a fair number of beaver. The next year, Russell and his associates spent nearly three weeks trapping beaver on Slough and Hellroaring Creeks.

Norris (1880:613) reported beaver to be common in the park during the 1870s and 1880s. He stated that trappers took "hundreds, if not thousands" of beaver skins from the park each year during his tenure as superintendent. Seton (1909) found beaver abundant near Tower Junction on the northern range in 1897. Skinner (1927:176) noted that "beaver have always been quite common in Yellowstone National Park, and although fluctuations are noticed at times, the actual number present remains about the same throughout a course of years." Skinner added that "beaver occur in practically every stream and pond [where there is suitable food] in the park." He estimated there were "about 10,000" beaver in the park during the early 1900s.

Bailey (1930:112–14) observed that "beavers are found along almost every stream in Yellowstone Park." He also noted that "the extensive herds of elk" on the northern range keep down the growth of the beavers' food supply, young aspen, and willows. Wright and Thompson (1935:72) concluded that in Yellowstone beaver were "endangered through the destruction of aspen and willow on the overbrowsed elk winter ranges." The available evidence indicates that beaver were common in the Yellowstone area and on the northern range from before park establishment in 1872 through the early 1900s. Warren (1926:183) suggested that beaver had increased during the early 1900s, but he attributed it to "the protection from molestation by trappers" and the "killing of predatory animals" by the Park Service.

In the early 1920s, Warren (1926) conducted a detailed beaver study on a small portion of the northern range near Tower Junction. He reported extensive beaver dams and estimated a population of 236 beaver. Jonas (1955) repeated Warren's study in the early 1950s and found no beaver nor any recent beaver activity. Jonas (1955, 1956, 1959) attributed the decline in beaver to three factors: (1) lack of preferred food plants, (2) poor water conditions, and (3) the rapid silting in of beaver ponds. He (1955) concluded that the beavers' "unfortunate food situation . . . was a result more from the overpopulation of elk than from any other single cause." He also noted that the poor water conditions and the siltation of beaver ponds were caused by "overgrazing." From 1986 to 1988, Kay (1990:166) repeated Warren's and Jonas' surveys and found no beaver nor any indication of major beaver activity that might have taken place since the 1950s. Although a few beaver still persist in parts of Yellowstone, for all practical purposes that species is ecologically absent from the northern range.

Beaver need tall willows or aspen as food and dam-building materials. Aspen and willows cut by beaver normally resprout (Warren 1926; Kindschy 1985, 1989) and in turn provide additional beaver food. Once the mature aspen trees or tall willows are cut, however, the new suckers are entirely within reach of browsing elk (McMillan 1950). By preventing aspen and willows from growing into sizeable plants, elk and moose eliminate beaver foods. Flook (1964) reported that high elk numbers negatively affected beaver through interspecific competition for willows and aspen in Banff and Jasper National Parks. Bergerud and Manuel (1968) and Collins (1976) noted that high moose densities had a similar negative effect on beaver in Newfoundland and in Jackson Hole. Heavy grazing by domestic livestock not only reduces woody vegetation but also negatively affects beaver populations (Platts et al. 1983, Smith and Flake 1983, Dieter 1987, Dieter and McCabe 1989a, 1989b).

According to the Park Service's "natural regulation" hypothesis, competitive exclusion of sympatric herbivores will not occur. Elk and moose, however, have acted to competitively exclude beaver from the northern range. Moreover, in the absence of beaver, several streams on the northern range have downcut 1-2 m (Chadde and Kay 1991), undoubtedly lowering the water table and reducing the wetted perimeter. The virtual elimination of beaver has probably had a greater long-term adverse effect on water resources available to willow communities than any drought or hypothesized climatic change. In all probability, many riparian communities on the northern range have become drier over the years due to the competitive exclusion of beaver by elk. This result would also be true throughout the Intermountain West where human settlement and trapping have eliminated or severely reduced the number of beaver that occupied those systems prior to European influence (Dobyns 1981).

Historical Abundance

While it is common knowledge that large numbers of beaver were trapped in the West during the 1800s (Chittenden 1986), ecologists have not used available historical source materials to obtain estimates of beaver abundance prior to European disturbance. Peter Skene Ogden's (1950, 1961, 1972) journals written in the 1820s provide a vivid firsthand account of how abundant beaver were throughout the Intermountain West before the fur trade.

Members of Ogden's (1950) party were the first whites to trap the streams in what has become known as Ogden Valley or Ogden's Hole. The Ogden River drains a relatively small area east of Utah's Wasatch Mountains and flows west into the Great Salt Lake. Ogden's fur brigade first entered the valley in May of 1825. On that day, they caught 244 beaver and added 109 more on the second day, 68 on the third, 67 on the fourth, and 23 on the fifth. A total of 511 beaver were trapped in five days. Today the Utah Division of Wildlife Resources estimates that there are probably only 300 to 600 beaver in the same area, though some of that system has been flooded by Pineview Reservoir (Don Paul, pers. comm. 1991).

Ogden (1972) and his fur brigade were also the first whites to trap Nevada's Humboldt River. Ogden's trappers first struck the Humboldt near present day Winnemucca on November 9, 1828, and traveled upstream until they left the Humboldt east of Elko on December 16. During that period, Ogden reported that his men took 627 beaver. On May 10, 1829, Ogden's party again struck the Humboldt east of Winnemucca and trapped its way downstream to Humboldt Sink before returning upriver to where on June 6 they left the Humboldt at its junction with the Little Humboldt River. During that time, Ogden reported that his men trapped 519 beaver. Earlier in that same year, April 8 to 15, 1829, Ogden and his fur brigade caught seventy-eight beaver on the upper reaches of the Humboldt between present day Carlin and Elko. Thus, by actual count of Ogden's daily journal entries, his party trapped 1,224 beaver on the Humboldt during 1828–1829.

The actual number of beaver they took, however, was probably somewhat greater because by comparing the brigade's total take with Ogden's daily entries, it can be determined that he apparently failed to record all the beaver his people caught each day. Also, along the entire Humboldt, Ogden encountered large numbers of Native Americans who constantly harassed his fur brigade. The Indians repeatedly stole the traps his men had set and presumably the beaver they held. Ogden (1972:194) finally abandoned the Humboldt in June of 1829 because he only had fifty traps left, and it was no longer profitable to continue the hunt.

Ogden (1972:144) also complained that the Indians, by using his stolen traps and other means, such as firing beaver lodges, destroyed many beaver before his men arrived at new sections of the river. At one point, Ogden (1972:149) wrote, "I have already observed the Indians in this river [Humboldt] destroy a great number of beaver, and I am correct in saying so for scarcely one have I seen but his shoes are made of beaver skin, and when I consider how numerous they [Indians] are the number [of beaver] destroyed must be great." Due to protection in the early 1900s, some transplanting, the Humboldt's relatively remote location, and today's low fur prices, the Nevada Department of Wildlife estimates that river still supports 80 percent of the beaver it held in Ogden's time (Walt Manderville, pers. comm., 1991).

From Ogden's journals, as well as from accounts left by other fur trappers, it is apparent that most hydrologic systems in the Intermountain West developed with large numbers of beaver. Equally clear, early fur trappers decimated or exterminated beaver populations over most of the West (Johnson and Chance 1974, Chittenden 1986). In his chronicle of the human-induced destruction of riparian zones in New Mexico and Arizona, Dobyns (1981) attributed those areas' initial decline to the extermination of beaver by the fur trade. Cox et al. (1982) reported that when beaver were trapped out of one Arizona stream, within five years the channel downcut from three to twenty feet, which, in turn, led to a reduction of streamside riparian vegetation. Since it is clear that systems with beaver behave differently than those without beaver, the historical reduction or elimination of beaver from many intermountain streams no doubt altered the ecology and hydrology of the associated riparian systems.

ECOSYSTEM EFFECTS

While this paper has focused primarily on the impact of ungulates and beaver on riparian vegetation, it should not be forgotten that many different species of insects, birds, and mammals are keyed to riparian habitats. Since the physical stature or structure of the vegetation is important in determining the composition of animal communities (Balda 1975), any alterations in those plant communities—such as the previously documented reduction or elimination of tall willows, cottonwoods, and aspen—would have serious consequences for other species. Based on other studies (Bergerud and Manuel 1968, Ross et al. 1970, Page et al. 1978, Crouch 1982, Mosconi and Hutto 1982, Casey and Hein 1983, Platts et al. 1983, Taylor 1986, Loft et al. 1987, Tucker 1987, Brooks and Healy 1988, Finch 1988, Knopf et al. 1988, Medin and Clary 1989, Putman et al. 1989), the decline or elimination of tall, woody riparian vegetation may have completely altered bird and small-mammal communities, as well as negatively affected larger animals such as grizzly bears (Kay 1989) and white-tailed deer (*Odocoileus virginianus*) (Kay 1990). In Rocky Mountain National Park, Braun et al. (1991) suggested that, by reducing the disturbance and abundance of willows, elk were having a negative effect on white-tailed ptarmigan (*Lagopus leucurus*) populations.

Ungulate-induced elimination of beaver and willow bank cover may also have caused decreases in the distribution and numbers of native trout species (Marcuson 1983, Hubert et al. 1985, Kay 1990:178). Entire plant and animal communities, not just riparian vegetation, have most likely been altered by ungulate use in Yellowstone National Park and other areas. The grazing-induced short-willow communities that presently exist in various national parks are not ecologically equivalent to the tall-willow communities that once occupied those same areas (Chadde and Kay 1991). Pastor et al. (1987, 1988) went so far as to conclude that by changing plant communities moose on Isle Royale altered soil microbes and even soil development.

CONCLUSIONS

1. Concentrations of native ungulates tend to eliminate woody riparian vegetation such as willows, cottonwoods, and aspen.

2. Willows protected from native ungulates exhibit significantly greater height growth and canopy cover than unprotected plants and in physical stature resemble the willows that existed during the late 1800s.

3. Browsing by native ungulates can reduce or eliminate willow seed production. This lack of seed production can prevent willows from colonizing new habitats that become available following flood or fire.

4. Grazing and trampling by native ungulates tend to reduce tall forb and shrub components of riparian systems while increasing the proportion of grasses and sedges in herbaceous communities.

5. Repeated use by native ungulates reduces the hiding or security-cover value of riparian habitats.

6. While alteration of riparian communities has been most frequently documented on wintering areas, native ungulates can also have severe negative effects on riparian habitats on higher-elevation summer ranges.

7. Browsing by native ungulates not only changes the stature and abundance of tall willows and other riparian vegetation but also affects animals commonly associated with riparian habitats.

8. Browsing by native ungulates acts to competitively exclude beaver from riparian habitats.

9. Prior to European influences, beaver were generally much more common and abundant throughout the Intermountain West than they are today.

10. Beaver is a keystone species that completely

alters the hydrology, energy flow, and nutrient cycling of aquatic and riparian systems. Systems with beaver are completely different from systems without beaver.

11. Beaver dams impound water and trap sediments that raise the water table, increase the wetted perimeter, and allow the extension of riparian communities into former upland sites.

12. Beaver create and maintain riparian areas that are critical to a host of other wildlife species. By trapping silt over thousands of years, beaver dams created many of the West's fertile valley floors.

13. Beaver can be used to restore riparian systems that have been damaged by native ungulate or livestock grazing, but it may be necessary to exclude ungulates from the area so that the woody plants can recover and provide food and dam-building materials for the beaver.

14. The elimination of beaver has a negative effect on the extent of willow and other riparian communities by lowering water tables and reducing stream flows.

ACKNOWLEDGMENTS

My Yellowstone research was funded by the Rob and Bessie Welder Wildlife Foundation, Sinton, Texas, and this paper is Contribution No. 373. Steve Chadde helped measure willow communities and willow seed production in Yellowstone Park. I thank Steve Chadde, Dr. Walter Mueggler, Dr. William Platts, and Dr. Phil Urness for reviewing this manuscript and for offering constructive suggestions.

REFERENCES

Aho, R. W., and P. A. Jordan. 1979. Production of aquatic macrophytes and its utilization by moose on Isle Royale National Park. Pages 341–48 *in* R. M. Linn, ed. Proceedings of the first conference on scientific research in the national parks. Vol. I. November 9–12, 1976. New Orleans, La. U.S. Department of the Interior, National Park Service Transactions and Proceedings Series No. 5.

Allison, T. D. 1987. The reproductive biology of Canada yew (*Taxus canadensis*) and its modification by herbivory: Implications for wind pollination. Ph.D. dissertation, University of Minnesota, Minneapolis.

Alverson, W. S., D. M. Waller, and S. L. Solheim. 1988. Forests to deer: Edge effects in northern Wisconsin. Conservation Biology 2:348–58.

Anderson, C. C. 1958. The elk of Jackson Hole: A review of Jackson Hole elk studies. Wyoming Game and Fish Commission Bulletin 10, Cheyenne.

Apple, L. L. 1983. The use of beavers in riparian/aquatic habitat restoration in a cold desert gully-cut stream system: A case history. American Fisheries Society 18:29–35.

Aune, K., and B. Brannon. 1987. East Front grizzly studies. Montana Department of Fish, Wildlife, and Parks, Helena.

Aune, K., M. Madel, and C. Hunt. 1986. Rocky Mountain Front grizzly bear monitoring and investigation. Montana Department of Fish, Wildlife, and Parks, Helena.

Aune, K., and W. Kasworm. 1989. Final report, East Front grizzly studies. Montana Department of Fish, Wildlife, and Parks, Helena.

Bailey, V. 1930. Animal life of Yellowstone National Park. Charles C. Thomas, Springfield, Ill; Baltimore, Md.

Baker, W. L. 1987. Recent changes in the riparian vegetation of the montane and subalpine zones of western Colorado, U.S.A. Ph.D. dissertation, University of Wisconsin, Madison.

Balda, R. P. 1975. Vegetation structure and breeding bird diversity. Pages 59–80 *in* D. R. Smith, tech. coord. Proceedings of the symposium on management of forest and range habitats for nongame birds. May 6–9, 1975. Tucson, Ariz. U.S. Department of Agriculture, Forest Service General Technical Report WO-1.

Barlow, J. W., and D. P. Heap. 1872. Report of a reconnaissance of the basin of the upper Yellowstone in 1871. U. S. 42d Congress, 2d Session, Senate Executive Document No. 66.

Barmore, W. J. 1981. Population characteristics, distribution, and habitat relationships of six ungulate species on winter range in Yellowstone National Park. Unpublished report on file, Research Office, Yellowstone National Park, Wyo.

Barnosky, C. W. 1988. The relationship of climate to sedimentation rates in lakes and ponds. Page 4 *in* F. Singer, ed. First annual meeting of research and monitoring on Yellowstone's northern range. U. S. Department of the Interior, National Park Service, Yellowstone National Park, Wyo.

Bassett, N. R. 1951. Winter browse utilization and activities of moose on the Snake and Buffalo River bottoms of Jackson Hole, Wyoming. M.S. Thesis, Utah State University, Logan.

Beetle, A. A. 1974. Letter to Charles T. Costen, Forest Supervisor, Bridger-Teton National Forest, Jackson, Wyo.

Beetle, A. A. 1979. Jackson Hole elk herd: A summary after 25 years of study. Pages 259–62 *in* M. S. Boyce and L. D. Hayden-Wing, eds. North American elk, ecology, behavior and management. University of Wyoming, Laramie.

Beier, P., and R. H. Barrett. 1987. Beaver habitat use and impact in Truckee River Basin, California. Journal of Wildlife Management 51(4): 794–99.

Beier, P., and R. H. Barrett. 1989. Beaver distribution in the Truckee River Basin, California. California Fish & Game 75(4): 233–38.

Bergerud, A. T., and F. Manuel. 1968. Moose damage to balsam fir-white birch forests in central Newfoundland. Journal of Wildlife Management 32(4): 729–46.

Bergstrom, D. 1985. Beavers: Biologists "rediscover" a natural resource. Forestry Research West (October): 1–5.

Bobek, B., K. Perzanowski, J. Siwanowicz, and J. Zielinski. 1979. Deer pressure on forage in a deciduous forest. Oikos 32:373–80.

Boyce, M. S. 1989. The Jackson elk herd: Intensive wildlife management in North America. Cambridge University Press, Cambridge; New York.

Bradley, W. P. 1982. History, ecology, and management of an introduced wapiti population in Mount Rainier National Park, Washington. Ph.D. dissertation, University of Washington, Seattle.

Brandner, T. A. 1986. Density dependent effects of moose herbivory on balsam fir in Isle Royale National Park, Michigan. M.S. Thesis, Michigan Technological University, Houghton.

Brandner, T. A., R. O. Peterson, and K. L. Risenhoover. 1990. Balsam fir on Isle Royale: Effects of moose herbivory and population density. Ecology 71(1): 155–64.

Braun, C. E., D. R. Stevens, K. M. Giesen, and C. P. Melcher. 1991. Elk, white-tailed ptarmigan and willow relationships: A management dilemma in Rocky Mountain National Park. Pages 74–85 *in* R. E. McCabe, ed. Transactions of the fifty-sixth North American wildlife and natural resources conference. March 17–22, 1991. Edmonton, Alberta. Wildlife Management Institute, Washington, D. C.

Brichta, P. H. 1987. Environmental relationships among wetland community types of the northern range, Yellowstone National Park. M.S. Thesis, University of Montana, Missoula.

Brinkman, K. A. 1974. *Salix l.*—willow. Pages 746–50 *in* Seeds of woody plants in the United States. U.S. Department of Agriculture, Forest Service Agriculture Handbook No. 450.

Brooks, R. T., and W. M. Healy. 1988. Response of small mammal communities to silvicultural treatments in eastern hardwood forests of West Virginia and Massachusetts. Pages 313–18 *in* R. C. Szaro, K. E. Severson, and D. R. Patton, tech. coords. Management of amphibians, reptiles, and small mammals in North America: Proceedings of the symposium. July 19–21, 1988. Flagstaff, Ariz. U.S. Department of Agriculture, Forest Service General Technical Report RM-166.

Cannon, R. W., and F. L. Knopf. 1984. Species composition of a willow community relative to seasonal grazing histories in Colorado. Southwestern Naturalist 29(2): 234–37.

Casey, D., and D. Hein. 1983. Effects of heavy browsing on a bird community in deciduous forest. Journal of Wildlife Management 47(3): 829–36.

Chadde, S. 1989. Willows and wildlife of the northern range, Yellowstone National Park. Pages 168–69 *in* R. E. Gresswell, B. A. Barton, and J. L. Kershner, eds. Practical approaches to riparian resource management: An educational workshop. May 8–11, 1989. Billings, Mont. U. S. Department of the Interior, Bureau of Land Management BLM-MT-PT-89-001-4351.

Chadde, S. W., and C. E. Kay. 1988. Willows and moose: A study of grazing pressure, Slough Creek exclosure, Montana, 1961–1986. Montana Forest and Conservation Experiment Station Research Note 24, University of Montana, Missoula.

Chadde, S. W., and C. E. Kay. 1991. Tall-willow communities on Yellowstone's northern range: A test of the "natural regulation" paradigm. Pages 231–62 *in* R. B. Keiter and M. S. Boyce, eds. The greater Yellowstone ecosystem: Redefining America's wilderness heritage. Yale University Press, New Haven, Conn.

Chadde, S. W., P. L. Hansen, and R. D. Pfister. 1988. Wetland plant communities of the northern range, Yellowstone National Park. School of Forestry, University of Montana, Missoula.

Chase, A. 1986. Playing God in Yellowstone: The destruction of America's first national park. Atlantic Monthly Press, Boston, Mass.

Chittenden, H. M. [1935] 1986. The American fur trade of the far West. Reprint. University of Nebraska Press, Lincoln. 2 vols.

Churchill, J. E. 1980. Beaver are killing our trout streams! Trout 21(4): 22–25.

Clary, W. P., and D. E. Medin. 1990. Differences in vegetation biomass and structure due to cattle grazing in a northern Nevada riparian ecosystem. U.S. Department of Agriculture, Forest Service Research Paper INT-427.

Cole, G. F. 1969. The elk of Grand Teton and southern Yellowstone National Parks. U. S. Department of the Interior, National Park Service Research Report GRTE-N-1. Reissued (1978) by Office of Natural Science Studies, National Park Service.

Cole, K. 1985. Past rates of change, species richness, and a model of vegetational inertia in the Grand Canyon, Arizona. American Naturalist 125(2): 289–303.

Collins, T. C. 1976. Population characteristics and habitat relationships of beavers, *Castor canadensis,* in northwest Wyoming. Ph.D. dissertation, University of Wyoming, Laramie.

Cox, J. R., H. L. Morton, T. N. Johnsen, Jr., G. L. Jordan, S. C. Martin, and L. C. Fierro. 1982. Vegetation restoration in the Chihuahuan and Sonoran deserts of North America. U. S. Department of Agriculture, Agricultural Research Service, Agricultural Reviews and Manuals ARM-W-28.

Croft, A. R. 1974. A critique of "An ecological evaluation of Big Game Ridge." Unpublished report.

Croft, A. R., and L. Ellison. 1960. Watershed and range conditions on Big Game Ridge and vicinity, Teton National Forest, Wyoming. U.S. Department of Agriculture, Forest Service, Ogden, Utah.

Crouch, G. L. 1979. Long-term changes in cottonwoods on a grazed and an ungrazed plains bottomland in northeastern Colorado. U.S. Department of Agriculture, Forest Service Research Note RM-370.

Crouch, G. L. 1982. Wildlife on ungrazed and grazed bottomlands on the South Platte River, northeastern Colorado. Pages 186–97 *in* J. M. Peek and P. D. Dalke, eds. Wildlife-livestock relationships symposium: Proceedings 10. April 20–22, 1981. Coeur d'Alene, Idaho. University of Idaho, Forest, Wildlife and Range Experiment Station, Moscow.

Davis, K. M., and R. W. Mutch. 1989. The fires of the Greater Yellowstone Area: The saga of a long hot summer. Western Wildlands 15(2): 2–9.

Davis, M. B. 1986. Climatic instability, time lags, and community disequilibrium. Pages 269–84 *in* J. M. Diamond and T. J. Case, eds. Community ecology. Harper & Row, New York.

Davis, M. B., and D. B. Botkin. 1985. Sensitivity of cool-temperate forests and their fossil pollen record to rapid temperature change. Quaternary Research 23:327–40.

Despain, D. G. 1989. Interpretation of exclosures in riparian vegetation. Page 188 *in* R. E. Gresswell, B. A. Barton, and J. L. Kershner, eds. Practical approaches to riparian resource management: An educational workshop. May 8–11, 1989. Billings, Mont. U.S. Department of the Interior, Bureau of Land Management BLM-MT-PT-89-001-4351.

Despain, D. G., D. Houston, M. Meagher, and P. Schullery. 1986. Wildlife in transition: Man and nature on Yellowstone's northern range. Roberts Rinehart, Boulder, Colo.

Dieter, C. D. 1987. Habitat use by beaver along the Big Sioux River. M. S. Thesis, South Dakota State University, Brookings.

Dieter, C. D., and T. R. McCabe. 1989a. Notes and discussion: Factors influencing beaver lodge-site selection on a prairie river. American Midland Naturalist 122(2): 408–11

Dieter, C. D., and T. R. McCabe. 1989b. Habitat use by beaver along the Big Sioux River in eastern South Dakota. Pages 135–40 *in* R. E. Gresswell, B. A. Barton, and J. L. Kershner, eds. Practical approaches to riparian resource management: An educational workshop. May 8–11, 1989. Billings, Mont. Department of the Interior, Bureau of Land Management BLM-MT-PT-89-001-4351.

Dobyns, H. F. 1981. From fire to flood: Historic human destruction of Sonoran desert riverine oases. Ballena Press, Socorro, N. Mex.

Edge, W. D., C. L. Marcum, S. L. Olson-Edge. 1987. Summer habitat selection by elk in western Montana: A multivariate approach. Journal of Wildlife Management 51(4): 844–51.

Edge, W. D., C. L. Marcum, S. L. Olson-Edge. 1988. Summer forage and feeding site selection by elk. Journal of Wildlife Management 52(4): 573–77.

Edgerton, P. J. 1987. Influence of ungulates on the development of the shrub understory of an upper slope mixed conifer forest. Pages 162–67 *in* F. D. Provenza, J. T. Flinders, and E. D. McArthur, ed. Proceedings: Symposium on plant-herbivore interactions. August 7–9, 1985. Snowbird, Utah. U.S. Department of Agriculture, Forest Service General Technical Report INT-222.

Finch, D. M. 1988. Bird-habitat relationships in subalpine riparian shrublands of the central Rocky Mountains. Pages 162–72 *in* C. A. Troendle, ed. Management of subalpine forests: Building on 50 years of research: Proceedings of a technical conference. July 6–9, 1987.

Silver Creek, Colo. U. S. Department of Agriculture, Forest Service General Technical Report RM-149.

Flook, D. R. 1964. Range relationships of some ungulates native to Banff and Jasper National Parks, Alberta. Pages 119–28 *in* D. J. Crisp, ed. Grazing in terrestrial and marine environments: A symposium of the British Ecological Society, Bangor, 11–14 April 1962. Blackwell Scientific Publications, Oxford.

Fraser, D., and H. Hristienko. 1983. Effects of moose, *Alces alces,* on aquatic vegetation in Sibley Provincial Park, Ontario. Canadian Field-Naturalist 97:57–61.

Gard, R. 1961. Effects of beaver on trout in Sagehen Creek, California. Journal of Wildlife Management 25(3): 221–42.

Gebhardt, K. A., C. Bohn, S. Jensen, and W. S. Platts. 1989. Use of hydrology in riparian classification. Pages 53–59 *in* R. E. Gresswell, B. A. Barton, J. L. Kershner, eds. Practical approaches to riparian resource management: An educational workshop. May 8–11, 1989. Billings, Mont. U. S. Department of the Interior, Bureau of Land Management BLM-MT-PT-89-001-4351.

General Accounting Office. 1988. Public rangelands: Some riparian areas restored but widespread improvement will be slow. GAO RCED-88-105, Washington, D. C.

Grasse, J. E., and E. F. Putnam. 1955. Beaver management and ecology in Wyoming. 2d ed. Wyoming Game and Fish Commission Bulletin No. 6, Cheyenne.

Gruell, G. E. 1973. An ecological evaluation of Big Game Ridge. U.S. Department of Agriculture, Forest Service Intermountain Region.

Gysel, L. W. 1960. An ecological study of the winter range of elk and mule deer in the Rocky Mountain National Park. Journal of Forestry 58(9): 696–703.

Hall, J. G. 1960. Willow and aspen in the ecology of beaver on Sagehen Creek, California. Ecology 41(3): 484–94.

Hanley, T. A., and R. D. Taber. 1980. Selective plant species inhibition by elk and deer in three conifer communities in western Washington. Forest Science 26(1): 97–107.

Hansen, H. L., L. W. Krefting, and V. Kurmis. 1973. The forest of Isle Royale in relation to fire history and wildlife. University of Minnesota, Agricultural Experiment Station Technical Bulletin 294, St. Paul, Minn.

Hansen, P. L., S. W. Chadde, and R. P. Pfister. 1988. Riparian dominance types of Montana. Montana Forest and Conservation Experiment Station Miscellaneous Publication 49.

Harry, G. B. 1957. Winter food habits of moose in Jackson Hole, Wyoming. Journal of Wildlife Management 21:53–57.

Hodkinson, I. D. 1975. A community analysis of the benthic insect fauna of an abandoned beaver pond. Journal of Animal Ecology 44(2): 533–52.

Houston, D. B. 1968. The Shiras moose in Jackson Hole, Wyoming. Grand Teton Natural History Association Technical Bulletin 1, Wyo.

Houston, D. B. 1973. Wildfires in northern Yellowstone National Park. Ecology 54(5): 1111–17.

Houston, D. B. 1976. Research on ungulates in northern Yellowstone National Park. Pages 11–27 *in* Research in the parks: Transactions of the national park centennial symposium. December 28–29, 1971. U. S. Department of the Interior, National Park Service Symposium Series No. 1.

Houston, D. B. 1982. The northern Yellowstone elk: Ecology and management. Macmillan, New York.

Houston, D. B., E. G. Schreiner, B. B. Moorhead, and K. A. Krueger. 1990. Elk in Olympic National Park: Will they persist over time? Natural Areas Journal 10(1): 6–11.

Hubert, W. A., R. P. Lanka, T. A. Wesche, and F. Stabler. 1985. Grazing management influences on two brook trout streams in Wyoming. Pages 290–94 *in* R. R. Johnson, C. D. Ziebell, D. R. Patton, P. F. Ffolliott, and R. H. Hamre, eds. Riparian ecosystems and their management: Reconciling conflicting uses. U.S. Department of Agriculture, Forest Service General Technical Report RM-120.

Ives, R. L. 1942. The beaver-meadow complex. Journal of Geomorphology 5:191-203.

Janke, R. A. 1976. Moose-boreal forest ecology in Isle Royale National Park. Pages 70–90 *in* J. A. Hancock and W. E. Mercer, eds. Proceedings of the 12th North American moose conference and workshop. March 23–26, 1976. St. John's, Newfoundland. North American Moose Conference and Workshop.

Johnson, D. R., and D. H. Chance. 1974. Presettlement overharvest of upper Columbia River beaver populations. Canadian Journal of Zoology 52:1519-21.

Johnson, P. 1984. The dam builder is at it again! National Wildlife (June–July): 9–15.

Johnston, C. A., and R. J. Naiman. 1990. The use of a geographic information system to analyze long-term landscape alteration by beaver. Landscape Ecology 4(1): 5–19.

Jonas, R. J. 1955. A population and ecological study of the beaver (*Castor canadensis*) of Yellowstone National Park. M. S. Thesis, University of Idaho, Moscow.

Jonas, R. J. 1956. Northern Yellowstone's changing water conditions and their effect upon beaver. Yellowstone Nature Notes 30(1): 6–9.

Jonas, R. J. 1959. Beaver. Naturalist 10(2): 60–61.

Jordan, P. A. 1987. Aquatic foraging and the sodium ecology of moose: A review. Swedish Wildlife Research Supplement 1(1): 119–37.

Kay, C. E. 1985. Aspen reproduction in the Yellowstone Park-Jackson Hole area and its relationship to the natural regulation of ungulates. Pages 131–60 *in* G. W. Workman, ed. Western elk management: A symposium. Utah State University, Logan.

Kay, C. E. 1988. Leave it to beaver-stream rehab specialists. Montana Magazine No. 89:15–16.

Kay, C. E. 1989. Why Yellowstone's grizzly bears are declining: An alternative hypothesis. Paper presented at Examining the Greater Yellowstone ecosystem: A symposium on land and resource management. April 13–15, 1989. University of Wyoming, Laramie.

Kay, C. E. 1990. Yellowstone's northern elk herd: A critical evaluation of the "natural regulation" paradigm. Ph.D. dissertation, Utah State University, Logan.

Kay, C. E., and S. W. Chadde. 1992. Reduction of willow seed production by ungulate browsing in Yellowstone National Park. Pages 92–99 *in* W. P. Clary, E. D. McArthur, D. Bedunah, and C. L. Wambolt, eds. Proceedings—symposium on ecology and management of riparian shrub communities. May 29–31, 1991. Sun Valley, Idaho. U. S. Department of Agriculture, Forest Service General Technical Report INT-289, Ogden, Utah.

Kindschy, R. R. 1985. Response of red willow to beaver use in southeastern Oregon. Journal of Wildlife Management 49(1): 26–28.

Kindschy, R. R. 1989. Regrowth of willow following simulated beaver cutting. Wildlife Society Bulletin 17(3): 290–94.

Kittams, W. H. 1959. Future of the Yellowstone wapiti. Naturalist 10(2): 30–39.

Knight, D. H., and L. L. Wallace. 1989. The Yellowstone fires: Issues in landscape ecology. BioScience 39:700–706.

Knopf, F. L., and R. W. Cannon. 1982. Structural resilience of a willow riparian community to changes in grazing practices. Pages 198–207 *in* J. M. Peek and P. D. Dalke, eds. Wildlife-livestock relationships symposium: Proceedings 10. April 20–22, 1981. Coeur d'Alene, Idaho. University of Idaho, Forest, Wildlife and Range Experiment Station, Moscow.

Knopf, F. L., J. A. Sedgwick, and R. W. Cannon. 1988. Guild structure of a riparian avifauna relative to seasonal cattle grazing. Journal of Wildlife Management 52(2): 280–90.

Kovalchik, B. L. 1987. Riparian zone associations: Deschutes, Ochoco, Fremont, and Winema National Forests. U. S. Department of Agriculture, Forest Service R6-Ecol-TP-279-87.

Krefting, L. W. 1974. The ecology of the Isle Royale moose: With special reference to the habitat. University of Minnesota, Agricultural Experiment Station Technical Bulletin 297, St. Paul, Minn.

Loft, E. R., J. W. Menke, J. G. Kie, and R. C. Bertram. 1987. Influence of cattle stocking rate on the structural profile of deer hiding cover. Journal of Wildlife Management 51(3): 655–64.

Lovaas, A. L. 1970. People and the Gallatin elk herd. Montana Fish and Game Department, Helena.

McMillan, J. F. 1950. Summer food habits of moose (*Alces americana shirasi Nelson*) and effects of various factors on food supply in Yellowstone Park. Ph.D. dissertation, University of Michigan, Ann Arbor.

McMillan, J. F. 1953. Some feeding habits of moose in Yellowstone National Park. Ecology 34:102–10.

Marcuson, P. E. 1983. Overgrazed streambanks depress fishery production in Rock Creek, Montana. Pages 143–57 *in* J. W. Menke, ed. Proceedings of the workshop on livestock and wildlife-fisheries relationships in the Great Basin. May 3–5, 1977. Sparks, Nev. University of California, Berkeley, Special Publication 3301.

Masslich, W. J., J. D. Brotherson, and R. G. Cates. 1988. Relationship of aspen (*Populus tremuloides*) to foraging patterns of beaver (*Castor canadensis*) in the Strawberry Valley of central Utah. Great Basin Naturalist 48(2): 250–62.

Medin, D. E., and W. P. Clary. 1989. Small mammal populations in a grazed and ungrazed riparian habitat in Nevada. U. S. Department of Agriculture, Forest Service Research Paper INT-413.

Meehan, W. R., and W. S. Platts. 1978. Livestock grazing and the aquatic environment. Journal of Soil and Water Conservation 33(6): 274–78.

Michelmore, P. 1984. The amazing beavers of Currant Creek. Readers Digest (April): 109–13.

Moen, R. A., J. Pastor, and Y. Cohen. 1990. Seasonal patterns of browsing by moose (*Alces alces*) in Isle

Royale National Park, Michigan, USA. Ecological Society of America Bulletin 71(2): 259.

Morgantini, L. E., and R. J. Hudson. 1989. Nutritional significance of wapiti (*Cervus elaphus*) migrations to alpine ranges in western Alberta, Canada. Arctic and Alpine Research 21(3): 288–95.

Mosconi, S. L., and R. L. Hutto. 1982. The effects of grazing on land birds of a western Montana riparian habitat. Pages 221–33 *in* J. M. Peek and P. D. Dalke, eds. Wildlife-livestock relationships symposium: Proceedings 10. April 20–22, 1981. Coeur d'Alene, Idaho. University of Idaho, Forest, Wildlife and Range Experiment Station, Moscow.

Mueggler, W. F. 1988. Aspen community types of the intermountain region. U. S. Department of Agriculture, Forest Service General Technical Report INT-250.

Munther, G. L. 1982. Beaver management in grazed riparian ecosystems. Pages 234–41 *in* J. M. Peek and P. D. Dalke, eds. Wildlife-livestock relationships symposium: Proceedings 10. April 20–22, 1981. Coeur d'Alene, Idaho. University of Idaho, Forest, Wildlife and Range Experiment Station, University of Idaho, Moscow.

Munther, G. L. 1983. Integration of beaver into forest management. Paper presented at Colorado/Wyoming Chapter of American Fisheries Society, Laramie, Wyo.

Myers, L. H. 1981. Grazing on stream riparian habitats in southwestern Montana. Paper presented at Society for Range Management meeting, Tulsa, Okla. Paper on file, BLM office, Dillon, Mont.

Naiman, R. J., C. A. Johnston, and J. C. Kelley. 1988. Alteration of North American streams by beaver. BioScience 38(11): 753–62.

Naiman, R. J., D. M. McDowell, and B. S. Farr. 1984. The influence of beaver (*Castor canadensis*) on the production dynamics of aquatic insects. Verhandlungen Internationale Vereinigung Limnologie 22:1801–10.

Naiman, R. J., and J. M. Melillo. 1984. Nitrogen budget of a subarctic stream altered by beaver (*Castor canadensis*). Oecologia 62:150–55.

Naiman, R. J., J. M. Melillo, and J. E. Hobbie. 1986. Ecosystem alteration of boreal forest streams by beaver (*Castor canadensis*). Ecology 67(5): 1254–69.

Neilson, R. P. 1986. High-resolution climatic analysis and southwest biogeography. Science 232:27–34.

Nelson, J. R., and T. A. Leege. 1982. Nutritional requirements and food habits. Pages 323–67 *in* J. W. Thomas and D. E. Toweill, eds. Elk of North America: Ecology and management. Stackpole Books, Harrisburg, Pa.

Norris, P. W. 1880. Annual report of the superintendent of the Yellowstone National Park. Pages 573–631 *in* Annual report of the Secretary of the Interior for the year ended June 30, 1880.

Ogden, P. S. 1950. Peter Skene Ogden's Snake country journals, 1824–25 and 1825–26. E. E. Rich and A. M. Johnson, eds. Hudson's Bay Record Society Publication 13, London.

Ogden, P. S. 1961. Peter Skene Ogden's Snake country journal, 1826–27. K. G. Davies and A. M. Johnson, eds. Hudson's Bay Record Society Publication 23, London.

Ogden, P. S. 1971. Peter Skene Ogden's Snake country journals, 1827–28 and 1828–29. G. Williams, ed. Hudson's Bay Record Society Publication 28, London.

Packer, P. E. 1963. Soil stability requirements for the Gallatin elk winter range. Journal of Wildlife Management 27(3): 401–10.

Padgett, W. G., A. P. Youngblood, and A. H. Winward. 1989. Riparian community type classification of Utah and southeastern Idaho. U. S. Department of Agriculture Forest Service R4-Ecol-89-01.

Page, J. L., N. Dodd, T. O. Osborne, and J. A. Carson. 1978. The influence of livestock grazing on non-game wildlife. Cal-Neva Wildlife 1978:159–73.

Parker, M., F. J. Wood, Jr., B. H. Smith, and R. G. Elder. 1985. Erosional downcutting in lower order riparian ecosystems: Have historical changes been caused by removal of beaver? Pages 35–38 *in* R. R. Johnson, C. D. Ziebell, D. R. Patton, P. F. Ffolliott, and R. H. Hamre, eds. Riparian ecosystems and their management: Reconciling conflicting uses. U. S. Department of Agriculture, Forest Service General Technical Report RM-120.

Pastor, J., R. J. Naiman, and B. Dewey. 1987. A hypothesis of the effects of moose and beaver foraging on soil carbon and nitrogen cycles, Isle Royale. *Alces* 23:107–24.

Pastor, J., R. J. Naiman, B. Dewey, and P. McInnes. 1988. Moose, microbes, and the boreal forest. BioScience 38(11): 770–77.

Patten, D. T. 1963. Vegetational pattern in relation to environments in the Madison Range, Montana. Ecological Monographs 33(4): 375–406.

Patten, D. T. 1968. Dynamics of the shrub continuum along the Gallatin River in Yellowstone National Park. Ecology 49(6): 1107–12.

Patten, D. T. 1969. Succession from sagebrush to mixed conifer forest in the northern Rocky Mountains. American Midland Naturalist 82(1): 229–40.

Peek, J. M., A. L. Lovaas, and R. A. Rouse. 1967. Population changes within the Gallatin elk herd, 1932–65. Journal of Wildlife Management 31(2): 304–16.

Pengelly, W. L. 1963. Thunder on the Yellowstone. Naturalist 14(2): 18–25.

Pimlott, D. H. 1965. Influence of deer and moose on boreal forest vegetation in two areas of eastern Canada. International Congress of Game Biologists 6:105–16.

Platts, W. S., and M. Onishuk. 1988. "Good" beavers, "bad" beavers. Idaho Wildlife 41(2): 23–27.

Platts, W. S., R. L. Nelson, O. Casey, and V. Crispin. 1983. Riparian-stream habitat conditions on Tabor Creek, Nevada, under grazed and ungrazed conditions. Pages 162–74 *in* Proceedings of the Western association of fish and wildlife agencies. July 10–14, 1983. Teton Village, Wyo. Western Association of Fish and Wildlife Agencies.

Putman, R. J., P. J. Edwards, J. C. E. Mann, R. C. How, and S. D. Hill. 1989. Vegetational and faunal changes in an area of heavily grazed woodland following relief of grazing. Biological Conservation 47:13–32

Risenhoover, K. L., and S. A. Maass. 1987. The influence of moose on the composition and structure of Isle Royale forests. Canadian Journal of Forest Research 17(5): 357–64.

Romme, W. H., and D. G. Despain. 1989a. Historical perspective on the Yellowstone fires of 1988. BioScience 39:695–99.

Romme, W. H., and D. G. Despain. 1989b. The Yellowstone fires. Scientific American 261(5)(November): 37–46.

Romme, W. H., and D. H. Knight. 1981. Fire frequency and subalpine forest succession along a topographic gradient in Wyoming. Ecology 62(2): 319–26.

Ross, B. A., J. R. Bray, and W. H. Marshall. 1970. Effects of long-term deer exclusion on *Pinus resinosa* forest in north-central Minnesota. Ecology 51(6): 1088–93.

Rudersdorf, W. J. 1952. The coaction of beaver and moose on a joint food supply in the Buffalo River Meadows and surrounding area in Jackson Hole, Wyoming. M.S. Thesis, Utah State University, Logan.

Rush, W. M. 1932. Northern Yellowstone elk study. Montana Fish and Game Commission, Helena.

Russell, O. 1965. Journal of a trapper. A. L. Haines, ed. University of Nebraska Press, Lincoln.

Scheffer, P. M. 1938. The beaver as an upstream engineer. Soil Conservation 3(7): 178–81.

Schullery, P. 1989a. Yellowstone fires: A preliminary report. Northwest Science 63(1): 44–54.

Schullery, P. 1989b. The fires and fire policy. BioScience 39:686–94.

Schulz, T. T., and W. C. Leininger. 1990. Differences in riparian vegetation structure between grazed areas and exclosures. Journal of Range Management 43(4): 295–99.

Seton, E. T. 1909. Life-histories of northern animals: An account of the mammals of Manitoba. Vol. I. Charles Schribner's Sons, New York.

Shute, D. A. 1981. Decline of riparian communities in a portion of southwestern Wyoming. Unpublished report on file, U. S. Department of the Interior, Bureau of Land Management, Rock Springs, Wyo.

Singer, F. J. 1987. Range impacts of the northern Yellowstone elk 20 years after cessation of controls. Unpublished report, Research Office, Yellowstone National Park, Wyo.

Skinner, M. P. 1927. The predatory and fur-bearing animals of the Yellowstone National Park. Roosevelt Wild Life Bulletin 4(2): 163–281.

Skinner, S. 1986. BLM beavers. Wyoming Wildlife 50(7)(July): 10–15.

Skovlin, J. M. 1982. Habitat requirements and evaluations. Pages 369–413 *in* J. W. Thomas and D. E. Toweill, eds. Elk of North America: Ecology and management. Stackpole Books, Harrisburg, Pa.

Smith, A. G. 1965. Problems of inertia and threshold related to postglacial habitat changes. Proceedings of the Royal Society of London, Series B, 161:331–42.

Smith, B. H. 1980. Not all beaver are bad; or, an ecosystem approach to stream habitat management, with possible software applications. Pages 32–36 *in* R. Whaley, ed. Proceedings of the 15th annual meeting: Colorado/Wyoming Chapter, American Fisheries Society. Wyoming Game and Fish, Casper.

Smith, B. H. 1983a. Riparian willow management: Its problems and potentials, within the scope of multiple use on public lands. Pages 15–20 *in* Ninth Wyoming Shrub Ecology Workshop. June 5–6, 1980. Lander, Wyo.

Smith, B. H. 1983b. Restoration of riparian habitats within the BLM-Rock Springs District. Paper presented at Wildlife habitat rehabilitation and reclamation symposium. January 10–11, 1983. Salt Lake City, Utah.

Smith, M. E., C. T. Driscoll, B. J. Wyskowski, C. M. Brooks, and C. C. Cosentini. 1991. Modification of stream ecosystem structure and function by beaver (*Castor canadensis*) in the Adirondack Mountains, New York. Canadian Journal of Zoology 69:55–61.

Smith, R. L., and L. D. Flake. 1983. The effects of grazing on forest regeneration along a prairie river. Prairie Naturalist 15:41–44.

Snyder, J. D., and R. A. Janke. 1976. Impact of moose browsing on boreal-type forests of Isle Royale National Park. American Midland Naturalist 95(1): 79–92.

Stein, S. J., and P. W. Price. 1990. The effect of fire on stimulating willow regrowth and subsequent herbivore attack. Ecological Society of America Bulletin 71(2): 336.

Stevens, D. R. 1980. The deer and elk of Rocky Mountain National Park: A 10-year study. Rocky Mountain National Park ROMO-N-13.

Stewart, G. H., J. A. Wardle, and L. E. Burrows. 1987. Forest understorey changes after reduction in deer numbers, northern Fiordland, New Zealand. New Zealand Journal of Ecology 10:35–42.

Stivers, T. S. 1988. Effects of livestock grazing on grizzly bear habitat along the east front of the Rocky Mountains, Montana. M. S. Thesis, Montana State University, Bozeman.

Streeter, R. G. 1965. Environmental factors affecting vegetational patterns in the Daly Basin of northwestern Yellowstone National Park, Montana. M. S. Thesis, Virginia Polytechnic Institute, Blackburg.

Strickland, D. 1987. Wapiti welfare: Elk feedgrounds. Wyoming Wildlife 51(2)(February): 28–31.

Suter, S. M. 1990. Chemical and morphological response of willow in Alaska to simulated moose browsing. Ecological Society of America Bulletin 71(2): 340.

Taylor, D. M. 1986. Effects of cattle grazing on passerine birds nesting in riparian habitat. Journal of Range Management 39(3): 254–58.

Tiedemann, A. R., and H. W. Berndt. 1972. Vegetation and soils of a 30-year deer and elk exclosure in central Washington. Northwest Science 46(1): 59–66.

Tilghman, N. G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. Journal of Wildlife Management 53(3): 524–32.

Trottier, G. C., and A. Fehr. 1982. Re-evaluation of four range exclosures in Banff National Park, 1981. Canadian Wildlife Service, Edmonton, Alberta.

Tucker, T. L. 1987. Cattle grazing affects nongame wildlife populations and fish habitat in a montane riparian area. M. S. Thesis, Colorado State University, Fort Collins.

Tyers, D. B. 1981. The condition of the northern winter range in Yellowstone National Park: A discussion of the controversy. M.S. Thesis, Montana State University, Bozeman.

Veblen, T. T., M. Mermoz, C. Martin, and E. Ramilo. 1989. Effects of exotic deer on forest regeneration and composition in northern Patagonia. Journal of Applied Ecology 26:711–24.

Warren, E. R. 1926. A study of the beaver in the Yancey region of Yellowstone National Park. Roosevelt Wild Life Annals 1:1–191.

Windell, J. T., B. E. Willard, D. J. Cooper, S. Q. Foster, C. F. Knud-Hansen, L. P. Rink, and G. N. Kiladis. 1986. An ecological characterization of Rocky Mountain montane and subalpine wetlands. U. S. Department of the Interior, Fish and Wildlife Service Biological Report 86(11).

Wright, G. A. 1984. People of the high country: Jackson Hole before the settlers. Peter Lang, New York.

Wright, G. M., and B. H. Thompson. 1935. Fauna of the national parks of the United States. U. S. Department of the Interior, National Park Service Fauna Series No. 2.

Youngblood, A. P., and W. F. Mueggler. 1981. Aspen community types on the Bridger-Teton National Forest in western Wyoming. U. S. Department of Agriculture, Forest Service Research Paper INT-272.

Youngblood, A. P., W. G. Padgett, and A. H. Winward. 1985. Riparian community type classification of eastern Idaho-western Wyoming. U. S. Department of Agriculture, Forest Service R4-Ecol-85-01.

Recreational Effects on Riparian Areas

G. Allen Rasmussen
Department of Range Science
Utah State University
Logan, UT 84322-5230

Wayne Padgett
Ecologist
Wasatch-Cache National Forest
8230 Federal Building
125 S. State Street
Salt Lake City, UT 84138

Abstract

Historically, riparian areas have been used by people as a source of food and water, as travel corridors, and as recreational areas. Only recently the recreational effects of people on riparian zones have been actively considered. The primary effects associated with recreation are soil compaction, vegetation change, erosion, and waste. Unmanaged recreational use has effects similar to those of other chronic disturbances associated with riparian areas. Generally, recreational-management strategies must include two approaches. The first is to direct people away from the most sensitive areas to those areas capable of withstanding recreational effects. The second approach is to provide educational opportunities to recreational users, allowing them to understand the effects of their activities and how they can be alleviated.

INTRODUCTION

Riparian areas benefit everything from vegetation to wildlife to people. People are attracted to riparian areas because of what is offered: water, food (primarily the wildlife and fish found in the riparian areas), shade, easy travel corridors, and aesthetics. Historically, riparian areas were used for encampments by pioneers as well as by Native Americans throughout the West. People still rely on the resources in riparian areas in the West for survival but have developed another use that many argue is also needed for survival—recreation. This paper will discuss various riparian ecosystems, historical recreational use, and alternatives for management to reduce recreational effects on riparian ecosystems.

RIPARIAN ECOSYSTEMS

The dominant feature of riparian systems is the presence of water. Increased water relative to surrounding uplands provides the habitat for the unique vegetation that occurs in riparian ecosystems. The water and unique vegetation, in turn, provide habitat and food for wildlife and fish. The presence of water and shading vegetation, along with the associated fish and wildlife, attracts people to riparian ecosystems for recreation. The sound of water flowing through the channel and of birds singing, as well as the typically cooler temperatures, makes these areas highly desirable recreational sites. There is, however, a tremendous effect on riparian areas throughout the West from recreational use.

Riparian areas vary greatly according to their geomorphic and associated biotic characteristics.[1] Riparian types range from dry desert riparian ecosystems that occur as narrow bands along stream channels to midelevation broad meadows that are frequently flooded to high-elevation gravelly sites with a few scattered willows (*Salix* spp.).

The effects of various users are different on each type of riparian area. Those portions of riparian zones formed on fine sediment deposits (those high in silt and clay) are more susceptible to soil compaction and vegetation loss than those reaches in gravelly and rocky material. The coarse-textured sediments (those high in sand) can often result in highly erosive stream banks.

HISTORICAL RECREATION

There are numerous recreational uses associated with riparian ecosystems, the most common being camping, fishing, boating, hunting, trail packing, mountain biking, and viewing birds and wildlife. Camping has a tremendous effect because of the time people (and often their recreational vehicles and horses) spend in the riparian areas. Recreational management has often perpetuated these problems. Some dramatic examples of the effects of recreation on riparian ecosystems can be seen in the Greater Yellowstone ecosystem. Recreational use in Yellowstone Park reaches approximately 9 million recreational visitor days (RVDs) per year. The developed recreational facilities can handle about 90,000 visitors per day; undeveloped areas handle about the same number. Many of these developed facilities on both the National Forest- and the National Park Service-managed lands are located in riparian areas. Heavy use results in soil compaction and vegetation trampling. Soil compaction reduces water infiltration and has altered plant communities in many areas. Recreational activities often result in erosion of stream banks caused by trails adjacent to and across channels. This erosion increases stream width and sedimentation while reducing water depth, shading, and habitat diversity.

Some recreational activities affect the riparian areas even though they occur on the uplands outside of the riparian zone. Activities that result in increased erosion that ends up in the riparian zone affect those systems. Unmanaged recreation is no different than other types of unmanaged chronic disturbances in the riparian zones.[2] Secondary effects include the issues of litter and human waste associated with recreational use, which is a growing problem.

[1]See Swanson, this volume.

MANAGEMENT ALTERNATIVES

Various opportunities are available to work with the recreationists to mitigate and reduce various types of recreational effects on riparian ecosystems. Projects in Mill Creek and in Big Cottonwood Canyons in the Salt Lake Ranger District of the Wasatch-Cache National Forest provide good examples of improving existing conditions and of efforts to mitigate existing effects. These efforts integrated watershed, fisheries, and recreational management.

The first step in these projects was the identification of how many riparian areas were affected by recreation and to what degree the effect was occurring. The second step was to evaluate the effectiveness of existing mitigation procedures and to determine what management techniques could be employed and what the cost would be to make changes. Finally, a schedule was developed to make sure the improvements were being accomplished and that monitoring was done to ensure that activities were actually improving the riparian ecosystems' conditions.

IDENTIFICATION

The first step (locating critical areas) can be done in the office. Field data are collected to provide an idea of existing conditions relative to the desired future condition. At Box Elder Picnic Area and at Redmond Campground in the Salt Lake Ranger District of the Wasatch-Cache National Forest, a loss of fish habitat and barriers to fish passage were found. Stream banks were laid back rather than vertical or overhanging, tree roots were exposed, and most of the stream reaches were less than 50 percent vegetated. Rock dams built in the channel by recreationists created barriers to fish. Outside the Redmond Campground, stream banks were 100 percent vegetated and considered stable.

EFFECTIVENESS AND COSTS

Several management techniques are available to improve conditions in riparian areas that have been negatively affected by human recreational use. The

[2]See Krueger ("Agriculture and Riparian Areas") and Kay, this volume.

effectiveness and cost of managing recreation in riparian areas varies depending on the site and associated objectives. The management techniques used in managing recreation in these areas often have high short-term costs, which may limit the implementation of a plan. The most drastic measure to improve conditions is to close sites to recreational use, but a major goal of the Wasatch-Cache National Forest and most national forests is to maintain viable recreational use and positive recreational experiences for the majority of people. Closing an area often has the lowest direct costs, but indirect costs associated with the conflicts created by the closing are often high. However, closing should be considered as an option, at least for a short period of time. If an educational program accompanies the closing, conflicts can be reduced.

Techniques using vegetation as a management tool to direct human traffic flows tend to have lower costs but often cannot withstand heavy recreational use, particularly in riparian areas dominated by fine-textured soils. Using structures to direct human flow has a high short-term cost but offers the greatest protection to riparian areas from recreational use and results in lower long-term expenditures. Structures placed in the stream to direct water flow also have high costs and a high failure rate because of flood events. Placing structures in the stream should be used with caution. Other techniques to be considered are (1) the building of structures both in the stream to direct water flow and on the bank to direct human traffic flow and (2) vegetation management. The technique selected is often determined by the money available and by the time frame.

Another technique is to build walkways that direct the movement of people in recreational areas and that reduce the effects on the system. Along the walkways, the placement of benches and interpretive signs also helps direct movement of people. The movement of people away from the more susceptible stream banks helps stabilize the banks, reducing erosion and providing cover to trap sediments during flood periods.

Another management technique is to get the public involved. When people are involved, they have an interest in the project and in its outcome; and with education, they understand what the goals are for the area and what can be done to provide a quality recreational experience while maintaining a quality environment. With an educational program that teaches individuals and groups about the effects of their activities on riparian systems and what they can do to reduce those effects, a positive change can be implemented. This technique can have greater impacts beyond the immediate impact zone if behavior is affected.

Schedule

Once the techniques have been selected to meet the management objectives, the final step of the plan is to develop a schedule. Cost restrictions often make scheduling critical. The schedule should outline the sequence in which each component of the plan will be completed and who will be responsible. This schedule should include a monitoring plan to ensure that the objectives are being met. In the example of the Box Elder Picnic Area and the Redmond Campground, structural improvements in the stream were added, while attempts were made to reduce trampling damage on stream banks. The movement of people was directed to selected areas through the placement of rocks and woody vegetation on the stream and through the "hardening" of those areas to reduce the disturbance caused by people. To accomplish this, tree root wads were placed in the stream to add structure to the stream channel, with the trunks imbedded in the bank. Willows and other shrubs and trees were then planted to help stabilize the sites and to buffer against high-flood periods. These techniques inhibited the movement of people to the streams and directed them to specific areas. On the stream bank, rock stair steps to the stream were installed. With the aid of a landscape architect and a fisheries biologist, these areas looked much more natural than the gully they replaced. In addition they reduced the erosion and sediment introduced into the stream.

SUMMARY

When doing any kind of rehabilitation in recreational management, it is helpful to restrict use on highly sensitive areas. Recreationists should be concentrated on areas that are more resistant to their disturbances. Areas that are most susceptible to compaction tend to be those with fine-textured soils because they hold moisture and are easily disturbed. Sites with sandy soils can also be affected, often through easy stream-bank sloughing. If possible, people should be moved to a site that is rockier. In developed areas, sites should be hardened by providing walkways and physical barriers. Protecting the soil resource also helps protect the water resource.

If the objective is to mimic natural systems, the changes made should be difficult for the untrained eye to see. Many of these suggestions are related to developed areas, but undeveloped areas can benefit from the same ideas. In undeveloped areas, the riparian area may be protected by restricting access, which can range from moving the road out of the riparian area to fencing the area. Signs requesting that people camp away from the riparian area can be effective to some extent but must be accompanied by enforcement.

Many people want to use riparian ecosystems. They like to fish, to watch wildlife, and to relax next to the sound of rushing water. There is an opportunity to aesthetically develop recreational sites and still to have viable, quality riparian areas through education and through the judicious use of people management.

For those interested in more information on managing recreationists in riparian areas, e.g., meeting human needs, developing trails to direct people, and developing educational programs, references are listed below.

REFERENCES

Lyle, J. T. 1985. Design for human ecosystems: Landscape, land use, and natural resources. Van Nostrand Reinhold, New York.

Lynch, K., and G. Hack. 1984. Site planning. 3d ed. MIT Press, Cambridge, Mass.

Kaplan, S., and R. Kaplan. 1982. Cognition and environment: Functioning in an uncertain world. Praeger, New York.

Rutledge, A. J. 1971. Anatomy of a park: The essentials of recreation area planning and design. McGraw-Hill, New York.

Management of Livestock in Riparian Areas

Alma H. Winward
Regional Ecologist
USDA Forest Service, Region IV
324 25th Street
Ogden, UT 84401

Abstract

In the past, livestock-grazing management practices have not addressed the needs of riparian areas. The knowledge of how these areas function has increased and has brought about an awareness of the importance of these areas to the entire ecosystem. Management strategies have now been developed that allow livestock to utilize these areas without degrading them. The strategy for a particular area depends on the characteristics of the specific riparian zone, on the management level and goals, and on the type of animal being grazed.

INTRODUCTION

Management of riparian ecosystems must address the three basic components of these systems, i.e., the soil, the water, and the vegetation. Anything that negatively influences one of these basic factors in turn affects the other two factors. If the influence is severe enough, it can set up a cycle of degradation that can spiral downward. For example, any influence that negatively affects the vegetation has potential to change species cover and composition. If the plant species that hold the banks together or the cover that traps sediment are lost, additional sediment is introduced into the system. Downcutting of the stream channel can occur, often leading to a lowering of the water table. As the water table is reduced, the site becomes drier, resulting in further changes in the plant community. Species adapted to the drier conditions become dominant. These species often have inadequate root systems to buffer the forces of water. Consequently, the stream channel is lowered even further with resulting negative influences on sedimentation, species composition, and water storage. These negative influences then have detrimental effects on wildlife and fisheries habitat, forage for native and wild herbivores, and the general health and aesthetics of the area. In severe situations, sites can be altered to the point that they can no longer be classified as riparian.

On the other hand, when appropriate riparian vegetation is present and maintained there is a balance between the negative and the building forces of water. Sediments are caught and stored in secure stream banks bound by litter and root masses. The filtered water runs more clearly; and sediments, instead of being destructive, are used to maintain and build bank structure. Water tables are maintained at more natural levels, resulting in greater stored water for slow release in the drier season and reduced destructive flows in the wetter season. Sites remain moister, are nutrient enriched, and grow a greater abundance of appropriate soil-binding plant species. Habitat for fish and wildlife is improved, forage for ungulates is increased several fold, and aesthetics and general riparian health are improved. As we have increased our knowledge of interactions among these three basic riparian components, we have been able to improve our abilities to design and implement management strategies that will allow riparian ecosystems to provide useful grazing values yet continue to function properly.

LIVESTOCK/RIPARIAN INTERACTIONS

Livestock grazing in the Intermountain West has been a significant factor in the health of riparian ecosystems. This factor has consisted of grazing by sheep, by cattle, and occasionally by horses. These livestock can have both direct and indirect effects on riparian areas. Direct effects involve trampling and soil compaction as well as the effect on the grazed plant species within the riparian area proper. Indirect influences come from effects on upland areas that result in movement of sediments or runoff into riparian settings.

Sheep, by their grazing nature, tend to prefer upland areas. They seldom are found grazing or resting in riparian settings unless they are purposely herded into these areas. If this type of herding occurs, it can best be corrected by training the herder to keep sheep out of the bottomland areas.

Generally, negative impacts from sheep on riparian areas are indirect. Overuse on historic bedgrounds and repeated trailing on upland sites can result in barren areas. Erosional processes are initiated on these barren areas, and the effects carry down to the riparian settings. Excessive sediment from upland sites can overwhelm the sediment trapping capabilities of the riparian vegetation (Hunter 1991). The riparian vegetation may be healthy; but the filtration component cannot keep up with the sediment load, affecting stream banks as well as water quality and fisheries habitat. Management can best correct these problems by teaching herders not to allow sheep to bed down in the same area each night. Sheep driveways that extend for miles and often have ten or more bands of sheep using them each spring and late summer may need to be eliminated and animals trucked to the grazing area. Although this may require additional costs to the owners, elimination of these traditional "sacrifice areas" associated with repeated, concentrated sheep use may be necessary in order to protect the riparian portion of the grazing allotment.

Cattle, unlike sheep, tend to concentrate in riparian areas for the most part. They prefer level terrain where they can feed, rest in the shade, and have drinking water without travelling very far. As a result, cattle grazing has brought about significant degradation of many Western riparian ecosystems.

Cattle especially show a preference for riparian settings when upland forage begins to dry or to become scarce. Past cattle-grazing prescriptions were primarily centered around improving upland vegetation. As a result, some of the riparian areas received inadequate management. Now, with an increased emphasis on better management of all wildland ecosystems, especially riparian areas, management strategies that will do a better job of livestock management overall must be designed.

Within riparian areas, cattle also show a preference for particular plant species. As the cattle select these plant species, composition changes toward plants that are utilized less intensively. Also, some plant species are more tolerant to livestock grazing than other species. A good example throughout the intermountain area is the effect of cattle on Nebraska sedge (*Carex nebrascensis*). Nebraska sedge is a species native to riparian areas. It has evolved to fit requirements for plant species occurring in these settings. It has a strong, rhizomatous root system that extends four to six feet into the soil profile. These strong roots buffer the effects of moving water and help hold stream banks in place.

If the species receives grazing pressure or trampling that is too heavy, it is replaced by Kentucky bluegrass (*Poa pratensis*). Kentucky bluegrass has a relatively weak, shallow root system. As such, it has a very reduced capability to buffer the effects of moving water. If it becomes a dominant streamside species, the entire riparian ecosystem begins to deteriorate.

Willows are another example of good riparian species that cattle can detrimentally affect if not managed correctly. Cattle prefer willows during the latter part of the grazing season as associated herbaceous species dry or become scarce. This detrimental effect is also true for many of the shrubs and trees (alder, birch, aspen, and cottonwoods) that are important in stabilizing riparian systems. If these species are browsed so severely that regeneration and long-term maintenance of the stands is not possible, the entire riparian ecosystem will begin to deteriorate.

Trampling effects from cattle are important particularly when the soil is wet. Trampling uproots plants and causes hummocky situations when the soil is saturated. When it is semiwet, trampling compacts the soil and breaks down stream banks. Management schemes must consider these potentially damaging effects if degradation of riparian areas is to be alleviated.

CATTLE MANAGEMENT

In the Western United States, with its uneven topography and relatively dry summer seasons, cattle tend to concentrate in riparian areas. Management strategies should be geared to make riparian areas less attractive and upland areas more attractive to livestock. Several potential management techniques designed to accomplish this include the following:

Placement of Water

More emphasis should be used in making water available for livestock outside of the riparian area. Improving the availability of water can be achieved with a variety of techniques including piping water, digging watering ponds, and developing troughs away from spring sources (Vallentine 1989). The objective is to provide animals an alternative watering source away from riparian settings.

Placement of Salt

Even though it has been the tradition in all range-management schools to teach the importance of using salt as a tool to move animals out of concentration areas, it is not uncommon to find most of the salting areas located near a watering source. This placement of the salt only serves to concentrate animals in riparian areas. Much more emphasis must be put on locating salt away from these areas that, by their nature, favor animal concentration.

Use of Herding

Although cattle are not generally herded in rangeland settings in the same way that sheep are herded, use of riders to daily move animals out of concentration areas can benefit riparian areas. Herding requires a consistent effort by the herders. Practical experience has shown herding to be most beneficial if used in conjunction with other techniques, such as water developments. Herding is also most effective when done during midday when cattle are most likely to seek shade. Time is also required to train cattle and the herders for this technique to be most effective (Roger Banner, pers. comm. 1991), and it requires the riparian area to be completely cleaned of animals on each drive. Even if just 2 to 5 percent of the animals are left in the riparian area, those animals can undo the work of the herder since riparian areas are normally very small and a few animals left to graze season long can easily abuse these small areas.

Use of Beaver

Beaver have been a part of many naturally functioning riparian areas in the intermountain area. In fact, it is difficult to understand their natural role since most were trapped or removed from Western lands before the first settlers arrived with their animals.[1] Dam-building activities of the beaver have the capacity to raise water tables, making riparian areas less attractive to livestock. This forces animals to spend more time foraging on adjacent upland areas. Beaver, however, can only be used in areas that have adequate habitat (woody vegetation).

Improve Adjacent Uplands

In the absence of natural historic fires throughout the Western United States, many of the dominant shrub and tree species have increased their densities above historic levels (Gruell 1983). This increase has led to a decline in the herbaceous vegetation in many areas. A better balance between understory/overstory species would make good ecological sense. In the 1950s and 1960s, there was an effort to increase the herbaceous component for livestock forage. Management has currently turned away from many of these practices for a variety of economic, ecologic, and aesthetic reasons.

Most of the negative attitudes associated with these earlier efforts centered around how the techniques were applied and how the exotic herbaceous species were used to revegetate these areas. Research has improved potential application of some of these techniques as well as species available for seeding. Current options available to improve the herbaceous/woody species balance in our wildland settings need to be reevaluated. This improved balance would have the potential to provide a greater foraging resource outside riparian settings and could improve the hydrologic regime by reducing evapotranspiration from upland settings and allowing more ground water to feed into riparian areas.

Fencing

Fences in wildland settings generally are expensive to install and difficult to maintain. Consequently, managers shy away from using them to help improve management of the relatively small riparian portions of their allotments. However, specialized fencing equipment, strategically located, can often be used to improve management of some riparian areas. For small-problem stream sections, short electric fences can be efficiently used in some settings, though conflicts with other riparian values such as recreation must be addressed. Pole-barrier fences can be used to keep animals off sections of banks, and these are often more aesthetic than barbed wire or electric fences. Fencing can also be designed to develop riparian pastures, i.e., sections within an overall allotment in which length of grazing and season of use can be strictly controlled. All fencing should be designed with other riparian values in mind.

Grazing Systems

Specialized grazing systems are often the most difficult to implement but potentially can provide the greatest influence for meeting land-management objectives. Season-long grazing generally has not been effective in providing adequate management on riparian areas in the Western United States, even when reduced animal numbers are used. This technique is ineffective because the reduced number of animals spends more time grazing the relatively small riparian portion of the allotment rather than utilizing upland forage.

[1]See Kay, this volume.

When various rotation grazing systems are used, care must be taken to remove all animals from the used pastures. If all of the animals are not removed, the few remaining often spend most of their time on the riparian areas, essentially resulting in season-long use on the riparian areas in that pasture. If this season-long use is not eliminated, most other riparian management techniques will not work. The grazing systems developed for riparian areas should be designed to eliminate the season-long grazing.

Riparian areas generally are least affected in the spring season by cattle because forage on the upland portion is lush and the riparian area is often soggy. These factors result in cattle spending more time grazing upland settings. If all grazing land could be used for a short time early in the season and animals then removed in time to allow regrowth, there likely would be few riparian grazing problems. However, cattle need feed throughout the growing season. Care must be used in developing a grazing system to alternate the period of use and not to remove more than the plant species are capable of tolerating or what is needed to provide adequate cover to protect the watershed values, i.e., trap sediments.

When grazing occurs late in the season, animals must be removed in time to leave 7-15 cm of stubble on the main plant species. This stubble serves as a filter for reducing sediment loss during thundershowers or during the following spring snow melt.

If grazing is done earlier in the growing season, animals must be removed early enough to allow 7-15 cm of regrowth on the major riparian species. This growth must remain on these species to serve as a sediment trap during high flow. Allowance of 7-15 cm of growth/regrowth also should provide adequate protection for plants to maintain their vigor.

SUMMARY

There are several management opportunities that can be used to reduce the effects of livestock in riparian areas. Nature provides a buffer for use because of increased availability of water for plant regrowth. This increase in water availability can provide opportunities for use of management techniques that will meet the needs both of riparian areas and of the livestock enterprise.

In the past, season-long grazing and misunderstandings of how riparian areas function have resulted in degradation of many Western riparian areas. Although application of many of the newer grazing strategies has proven valuable, these strategies often may result in increased costs. However, if livestock grazing is to remain a viable use of riparian resources, particularly on public land, these strategies will have to be implemented.

REFERENCES

Gruell, G. E. 1983. Fire and vegetative trends in the northern Rockies: Interpretations from 1871–1982 photographs. U. S. Department of Agriculture, Forest Service General Technical Report INT-158.

Hunter, C. J., E. D. Meloy, and T. Palmer. 1991. Better trout habitat: A guide to stream restoration and management. Island Press, Washington, D.C.

Vallentine, J. F. 1989. Range development and improvements. 3d ed. Academic Press, San Diego, Calif.

A Framework for Evaluating the Economic Benefits, Costs, and Trade-offs Associated with Riparian-Area Management Practices and Strategies

Frederick W. Obermiller
Department of Rangeland Resources
Oregon State University
Corvallis, OR 97331-6704

Abstract

The purpose of this paper is to provide an overview of the significant economic considerations in the analysis of the management, use, and enhancement of riparian zones in the interior West. Applied demonstration work has been done, including basic biological research relating to the functioning of riparian ecosystems and to the effects of domestic livestock grazing on the performance of the riparian system. The literature relating to that work is reviewed here, with an emphasis on implications for economic analysis. Attention is given to the subject of the costs and benefits of riparian-zone management, use, and enhancement strategies from the private and from the social perspectives. The final part of the paper deals with the types of values riparian zones provide, the social benefits resulting from the improvement of riparian zones, the private and social costs of riparian-zone degradation, and the possibilities for the provision of economic incentives to encourage voluntary private sector participation in riparian improvement projects on both private and public lands.

INTRODUCTION

Twenty years ago, riparian areas in the semiarid West were almost universally viewed as "sacrifice zones"—areas bordering streams that were habitually overgrazed by livestock. Given the traditional system of livestock grazing used nearly everywhere, the moderate to heavy season-long stocking levels with little active herding or cross-fencing, and the preferences of livestock for the forage and climate of riparian areas, sacrifice seemed natural. No one seemed to care, or to be very concerned, about the condition of these sacrifice zones.

Times have changed. Today the condition of Western riparian areas in relation to domestic livestock grazing is a major public concern (Holechek et al. 1989). The condition of Western riparian areas now constitutes a leading indicator of the environmental quality of the Western rangelands. Pressure is increasing to reduce or eliminate livestock grazing in riparian areas. What has happened?

CONFLICTING INTERESTS: THE HEART OF THE PROBLEM

Many users of riparian areas and their resources have come to believe, with some justification, that domestic livestock, and range cattle in particular, have done, and in the absence of intercession will continue to do, significant damage to riparian areas—and the charge has been led by fishery interests. That hypothesis guides the literature reviewed and evaluated in this paper.

This hypothesis is not tested; but it illuminates the way in which the body of knowledge on livestock grazing/riparian habitat condition/watershed relationships has developed over time. These interpretations are affected by the scientists' value and preference systems.

Social preferences and trade-offs in riparian-area management were suggested in a report dealing with the Oregon Range Evaluation Project (Megank and Gibbs 1979). All types of recreators favored more intensive livestock management, including additional fencing. Hunters favored practices to enhance forage for livestock in the belief that this would improve habitat for deer and elk. Fishermen opposed practices that would alter the native (meaning, essentially, ungrazed) riparian habitat. According to the American Fisheries Society (1982), "19,000 miles of sport fishing streams have declined in quality as a result of land management practices, including overgrazing." The key to this statement is the term *quality,* which, in this context, probably refers to stream and aquatic habitat supporting the sports fishery and negatively affected, in belief or fact, by livestock grazing in the adjacent riparian zone.

Scope and Diversity of Western Riparian Areas

Various definitions of *riparian areas* exist. The one used in the present discussion follows Skovlin (1984). Riparian areas are wetland fringes along rivers and streams. Wetlands are associated with swamps, marshes, and lakes. The narrow fringe of the riparian zone is critical to the functioning of the stream for aquatic habitat. Often, beyond this zone is the floodplain with a shallow water table providing meadow and sometimes shrub or forest vegetation. The herbaceous meadow layer may begin adjacent to the stream bank if an overstory of riparian shrubs or trees is not present (Ibid.: 1002).

This definition is important because when addressing interactions between livestock grazing and riparian zones and habitat conditions we must remember that the lines between aquatic zones and habitat, riparian zones and habitat, adjoining meadow or other wetland-zone habitats, and adjacent upland zones and habitat are not distinct. The interrelationships among these zones and habitats pose significant management challenges and hence have significant economic connotations. This point has been emphasized by Platts and Raleigh (1984), who state that at least three classes of riparian zones—forested, willow-shrub, and herbaceous—need to be distinguished from adjacent uplands (and from adjacent streams and meadows[1]) in the development and implementation of livestock grazing management plans (Behnke and Raleigh 1979, Platts 1979).

Extent and Ownership of Western Wetlands and Grazing Lands. The geographic scope of the riparian management challenge in the interior West is overwhelming. Various writers give different estimates of the extent of riparian and associated habitats; but whatever the actual numbers may be, they are quite large. In the eleven contiguous Western states, the federal government owns and manages 316 million acres of land, just under one-half of the total surface acres in the Western United States. Livestock grazing occurs on 500 million acres of land, of which 288 million acres (just under 60 percent) are public grazing land administered by either the Forest Service or the Bureau of Land Management (BLM) (Armour et al. 1991). Over 90 percent of all federal land holdings in the Western states are grazed by livestock.

Wetlands, including mountain meadows, arid and semiarid rangeland marshes, and riparian corridors, constitute a small but very significant portion of these grazed lands. Owen (1979) states that the Western public lands include 103,000 miles of fishing streams, of which only 19,000 miles (18 percent) are found on BLM rangelands while the remainder are on Forest Service lands. Of the 84,000 miles of Forest Service fishing streams, 12,400 miles are located in the Intermountain West range region. Skovlin (1984) estimates that there may be another 19,000 miles of fishing streams located on private lands in the interior West.

Lakes and reservoirs occupy 2,800,000 acres of federal property in the West, a similar percentage of which are on BLM lands. Another 2,800,000 acres of federal lands in the West are classified as riparian and wetland habitat, but this total may not include the additional 4,045,000 acres of mountain meadow reported by Skovlin (1984).

Extent and Nature of Grazing Management on Western Wetlands. With the possible exclusion of the strips of wetland vegetation surrounding man-made lakes and reservoirs, riparian and closely related habitats account for at least 2 percent of the total grazed surface area in the interior West—and this does not include the surface area of the perhaps 50,000 miles of fishing streams located on public and private lands in the region. These riparian areas provide a disproportionate amount of the total forage consumed by grazing livestock in the interior West (Skovlin 1984, General Accounting Office 1988, Chaney et al. 1990), and 93 percent of the riparian area on public lands is grazed. Kauffman et al. (1983b) stated that while riparian zones account for only 2 to 3 percent of the area in Western mountain rangelands, they provide 20 percent of the available forage in fenced pastures and 80 percent of the total amount of forage actually consumed by grazing livestock in the mountainous region.

The intensity of grazing management in the public-land portion of these riparian areas varies among regions. In the Western mountain rangelands, Skovlin (1984) estimated grazing management to be minimal on 25 percent of the public-land riparian area (averaging 0.6 animal unit months [AUMs] per acre),

[1]Author's remark. *Ed.*

extensive on 52 percent of the acreage (averaging 0.9 AUMs per acre), and intensive on only 4 percent of the acreage (averaging 2.5 AUMs per acre). He noted that on another 12 percent of the public-land riparian acreage grazing management is done to maximize forage production for livestock at a rate of 2.7 AUMs per acre, and it may be hypothesized that the same holds true for most of the privately owned riparian areas in the interior West.

LIVESTOCK GRAZING IN RIPARIAN AREAS: A CHRONOLOGY OF KNOWLEDGE BUILDING

Platts attributed the birth of interest in the interactions between livestock grazing and riparian condition to a speech given by a member of the Western conservation movement, A. S. Leopold:

> Leopold (1974), at the West Yellowstone Wild Trout Symposium, said that livestock grazing may have cumulative ecological ill effects on productivity of both lands and waters. Leopold admitted this hypothesis was intuitive, with few clear facts to back up his statement, and pleaded for studies to clear up the issue (Platts 1981).

A public outcry resulted, even though at the same time the Council for Agricultural Science and Technology (CAST) stated that well-managed livestock grazing is consistent with the preservation of environmental quality on public lands (1974). Two years later, a panel of scientists appointed by CAST concluded that the existing body of theory and data did not support declarations that grazing negatively influences other resources, presumably including the resources of riparian areas (1977).

Role of the Federal Land Policy and Management Act

In the same year, Congress passed the Federal Land Policy and Management Act (FLPMA 1988) calling for the management of public lands for multiple uses and sustained yields:

> Congress declares that it is the policy of the United States that . . . the public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that, where appropriate, will preserve and protect certain public lands in their natural condition; that will provide *food and habitat for fish and wildlife and domestic animals*;[2] and that will provide for outdoor recreation and human occupancy and use [Section 102. (a) (8)].

Elsewhere in FLPMA (especially Section 103), considerable emphasis was placed on the need to recognize livestock grazing as an authorized use of federal lands but to manage the grazing use in such a way that long-term or irreversible environmental damage is avoided. FLPMA, together with Leopold's earlier challenge, resulted in a surge of basic and applied research (summarized by Busby 1979, Meehan and Platts 1978, and Platts 1979) dealing with the interactions between livestock grazing and the functions and productivities of riparian habitats.

Fact-Finding by the National Research Council

Another result of FLPMA was a request for assistance in implementing FLPMA requirements made by the BLM to the National Research Council. This request led to six organized workshops over a two-year period beginning in November 1980 (Platts and Raleigh 1984). Workshop III dealt with the impacts of grazing intensities and specialized grazing systems on the use and value of rangeland, including riparian areas (Skovlin 1984, Platts and Raleigh 1984). Skovlin's conclusions were similar to the earlier CAST statements, while Platts and Raleigh were somewhat more negative with respect to the environmental compatibility of livestock grazing and restoration of riparian ecosystems.

Controlled Grazing Can Enhance Riparian Zones. Skovlin's findings and recommendations were particularly well developed and set the stage for subsequent public-sector participation in grazing management/riparian area restoration research and demonstration programs. According to Skovlin, the literature clearly suggests that control over grazing intensity (light to moderate preferred to heavy) and season of use (emphasizing mid- to late-season grazing) is in net terms beneficial to riparian zones and meadows and to most of the nonlivestock uses these zones support. Controlled grazing of this sort is, in the interest of cost efficiency, preferred to no grazing. The key to effective control over livestock preferences for riparian zones and adjoining meadows is distributional control through herding, fencing, and water developments away from the riparian corridor.

Livestock Management Options in Riparian Zones. Skovlin outlined ten management options for riparian-zone management. (He recognized shifting from cattle to sheep as a viable riparian-management alternative, although an impractical one for extensive adoption.) These options were to

[2]Author's emphasis. *Ed.*

1. Do nothing.
2. Improve distribution, including using more upland area, moving the animals out of the area, and making appropriate changes in the age class of cattle.
3. Change the season of use.
4. Implement specialized grazing seasons.
5. Rest for five years or until target riparian-zone recovery levels are achieved.
6. Separate by fencing the meadow floodplain zone from the adjoining riparian corridor.
7. Provide livestock access to fenced streamside corridors for stock watering purposes where needed.
8. Combine two or more of the above.
9. Revegetate with woody cover and apply the principles of items 5, 6, and 7 above.
10. Eliminate grazing.

Prescribed Management Strategies for Priority Enhancement Efforts. For prioritization purposes, Skovlin stated that critical stream reaches for fish should be identified. Acceptable targets for riparian habitat improvement and the desired time schedule for achieving those targets should be specified. Fencing corridors with limited watering access points is technically effective but costly and should be considered only for critical stream reaches, although it may be more economically efficient than reducing stocking rates to below moderate levels. Cross-fencing the meadow and riparian corridor is economically more efficient and may be environmentally preferable to riparian enclosures. Spring deferment or light grazing is appropriate in riparian areas during the restoration stage. Heavy late-season grazing is economically more acceptable to ranchers than light grazing in the riparian corridor season long and may even be effective in achieving revegetation targets as well.

The General Accounting Office Investigation

The National Research Council's findings were constructive, but the public outcry about the negative effects of public-land livestock grazing persisted. In view of the mixed signals from the scientific and public-land management communities, Congress again decided to act. This time the action took the form of an October 1986 request from the chairman of the House Committee on Interior and Insular Affairs and the chairman of its Subcommittee on National Parks and Public Lands to the General Accounting Office (GAO). GAO was asked to (1) identify specific examples of successful efforts to restore degraded riparian areas on Western public rangelands, (2) determine why those efforts had been successful, and (3) ascertain the transferability of the successful restoration techniques.

The GAO report was issued in June 1988. Its conclusions can be summarized as follows. First, riparian restoration with continued livestock grazing will not work unless the permittee is willing to actively manage, using alternatives to unmanaged, heavy, season-long grazing. If the restoration program is mandated on an active grazing allotment, trespass is probable. Upland water development and possibly upland reseeding may be necessary (if existing upland water and range conditions warrant) if cross-fencing is used. Additional herding and fence maintenance are requirements for riparian restoration with continued livestock grazing. Riparian enclosures should be used only if the nonlivestock values of the riparian area are quite high. Major instream and other habitat improvement expenditures probably are not warranted except under extremely fragile soil circumstances or when native seed sources needed for restoration have been entirely eliminated from the site.

Education Commissioned by the Environmental Protection Agency

The need for information to use in public education and for efforts to encourage ranchers and others to adopt improved grazing management systems for Western riparian areas and adjacent uplands was subsequently recognized by the U.S. Environmental Protection Agency (EPA). EPA commissioned a two-part study, with the first part being aimed at the general public. The result was titled "Livestock Grazing on Western Riparian Areas" (Chaney et al. 1990).

The conclusions of this report were similar to, but more specific than, the GAO observations. The successful riparian-restoration projects evaluated by the Northwest Resource Information Center under a contract with EPA illustrated that while specifics vary from case to case it is possible to improve both riparian areas *and* livestock-carrying capacity and animal performance using managed livestock-grazing systems.

Why Have Some Riparian-Enhancement Projects Succeeded? Keys to success are as follows:

1. Defined objectives for the riparian area
2. Accurate knowledge of current and potential conditions in the riparian area
3. Grazing strategies based on encouraging specific plant composition and balancing needs of both upland and riparian vegetation through either inclusion of riparian areas in smaller pastures, close herding, or riparian exclosures throughout the recovery period
4. Avoiding simple reductions in stocking levels
5. Controlling the timing of livestock use to avoid

soil compaction and stream bank damage and to coincide with the physiological needs of target plant species
6. Adding longer or more rests to the grazing cycle
7. Increasing herding
8. Limiting grazing intensity
9. Minimizing the length of the riparian recovery interval

Also important are flexibility, commitment, monitoring and evaluation, progressiveness, education, and cost-sharing consistent with public benefits, as well as an expanded federal small watershed program, dedication of a portion of grazing-fee receipts to riparian-enhancement projects, fish and wildlife foundation grants, and expanded state and federal challenge cost-share programs. Further contributing to the success of riparian-enhancement projects are technology transfer by demonstration, applicable governmental incentives and disincentives, and withdrawal of permits and allotments as they become vacant or are transferred, including holding recovered riparian-area permits in reserve for use during droughts or as safety valves for degraded riparian areas elsewhere.

Policy and Management Implications. The EPA study suggests that site-specific goals and technical information are necessary if riparian-enhancement projects are to be successful. The by-the-book approach will not succeed. Rapport must be established among all interested or affected private and public parties. Livestock owners have the most to lose, particularly in the short run, but their cooperation is essential if riparian-enhancement efforts are to succeed. Incentives, either in the form of more or better livestock forage allocations and/or monetary transfers, are warranted in public-land riparian-enhancement projects.

GRAZING SYSTEMS AND PRACTICES FOR RIPARIAN-ZONE SUSTAINABILITY AND ENHANCEMENT

Prior studies have been done of the relationships among grazing intensities, grazing systems, and distribution-control practices. In a major literature review, Van Poollen and Lacey (1979) concluded that enhancement of herbage production adjustments in livestock numbers (intensities) had more influence than adjustments in systems. They recommended moderate (maximum *sustainable* level of forage removal by livestock) versus light (taking little forage with the aim of improving range condition and soil stability) or heavy (in excess of range carrying capacity and advocated only under controlled short-duration grazing systems) stocking rates but noted that most prior studies used some combination of intensities and systems.

Grazing Intensities

Moderate intensity of use does not necessarily imply uniformity of use in a given pasture or range tract. Riparian zones typically receive heavy grazing pressure. Methods to encourage better distribution of grazing livestock have been suggested. One of the reasons for greater grazing pressure is the higher palatability and gentler topography of meadows and related habitats in riparian zones. Overgrazing tends to be most extreme in the early summer and, topography permitting, may be reduced by salting away from the riparian zone (Roath 1979). Salting is not effective on dryer and steeper rangelands. Livestock-use preferences in riparian zones seem to be independent of changes in rainfall patterns over time (Roath 1979).

Distribution Control Practices

Factors contributing to livestock preferences for riparian zones include (1) forage density and palatability in the riparian zone opposed to the adjacent uplands, (2) distance to water, (3) distance upslope (slope length), and (4) microclimatic features (Skovlin 1984). More of the herbage is forage; and the forage stays green and is more nutritious for a longer period of time, including the interval of regrowth, in the riparian zones, leading to both livestock and big-game preferences for riparian zones.

Relative to use of upland forages, grazing animals expend less energy per unit of forage consumed in the riparian zone. Hence, given an adequate forage supply, it can be expected that the performance of ungulates (both domestic and wild) may be better if most of the grazing occurs in the riparian zone.

The riparian stream is often the sole source of water in a fenced pasture or range tract in the interior West, and level and pattern of forage utilization is directly related to distance from water. The same direct utilization relationship exists with regard to steepness and length of slope. Under hot weather and semiarid rangeland grazing conditions, the cool microclimate of the riparian zone created by a combination of evaporation, shade, and wind movement along with drinking water makes the riparian zone attractive to all mammals, including livestock. Following fall rains, cattle customarily will vacate riparian zones in favor of uplands.

For these reasons, researchers have found that water developments on uplands, salting, and herding on moderately stocked ranges that include riparian zones can reduce pressure on riparian areas in an economically efficient manner (Skovlin 1965; Workman and Hooper 1968). Riparian enclosure fencing has not been found to be economically efficient on either private or public rangelands, although there is some indication that at least temporary (two- to five-year) riparian enclosure fencing is a preferred control technique in many riparian and watershed enhancement projects on public (especially Forest Service) lands (Callaham 1990, Chaney et al. 1990, GAO 1988). On either private or public lands, livestock performance possibly could be efficiently enhanced through enclosure fencing on riparian areas with little vegetation, assuming ample forage and water is available on adjacent uplands, since forage intake diminishes with lower levels of forage availability (Hodgson and Wilkenson 1968).

Grazing Systems

The traditional livestock grazing system on Western rangelands is season long or, in parts of the Southwest, year long. Specialized alternatives include deferred, rotation, rest rotation, and deferred rotation. Other than simple deferred grazing, each specialized system requires pasture or range-tract subdivision.

Do Grazing Systems Make Economic Sense on Private Rangelands? Available evidence suggests that livestock performance is poorer under all specialized systems, possibly due to the level of management intensity and site-specific flexibility needs in each case. Skovlin (1984) stated that, "No grazing system has been devised for insuring proper use of small riparian meadows within extensive upland range." A better alternative may be fenced trailing lanes to riparian watering points (Seneva et al. 1971) or fencing off larger (thirty- to forty-acre) riparian meadows from adjoining upland ranges with corresponding control over season of use (Busby 1979).

Do Grazing Systems Make Economic Sense on Public Rangelands? From the public-land managers point of view, grazing systems on public lands may be a more cost-effective way to achieve environmental goals for riparian areas since the minimum requirement may only be to maintain animal production while enhancing other riparian resource values. From this public or social perspective, even temporary overuse of riparian zones has to be avoided. Following overuse of the riparian zone in any one year, it may take several years for the riparian zone to return to its previous ecologic condition. For this reason, many fish and wildlife biologists argue for complete exclusion of livestock from public riparian zones currently in degraded condition.

Busby (1979) and Kimball and Savage (1977) maintain that exclusion is not necessary. One popular recommendation is temporary exclusion for two to four or five years with concurrent reseeding and other artificial improvements, followed by subsequent grazing but with destocking to moderate intensity levels and a three or more unit rest-rotation system. The grazed units in any year would be alternatively deferred early and late in the grazing season. An added wrinkle could be rotation of winter use, particularly in the Southwest and in the Northern Great Plains states (Severson and Boldt 1978).

Which Approach to Grazing Management Is Best?

Methods to rehabilitate riparian zones include complete livestock exclusion, rotation grazing systems, changes in the type or class of livestock, and improved livestock distribution methods. The exclusion method is preferred by many professional land managers but is most heavily resisted by livestock operators. Skovlin (1984) has shown that riparian-zone improvement is possible without complete livestock exclusion. Rest rotation in conjunction with moderate stocking rates (Pieper and Heitschmidt 1988) seems to be the most effective way of improving riparian-zone vegetation and physical characteristics (Davis 1982, Platts 1982, Bohn and Buckhouse 1985).

It often is recommended that cattle be replaced with sheep due to ease of herding of the latter (Platts 1982), although Skovlin (1984) and others question the practicality of that option. Another possibility in changing type of livestock is to selectively cull for animals with preference for upland vegetation (Roath 1979, Roath and Krueger 1982).

Additional fencing and delayed grazing of riparian zones until late summer can benefit vegetation, stream banks, wildlife, and livestock performance (Holechek et al. 1982, Kauffman et al. 1983a, 1983b). This strategy has the dual advantage of reducing livestock gathering and removal costs at the end of the grazing season, although fencing costs do increase. Under other conditions, early spring grazing of riparian areas may be beneficial (Elmore and Beschta 1987).

Increased control over the distribution of domestic livestock, with or without reduced grazing intensity, appears superior to management-intensive grazing systems as a means of improving riparian habitats. Unless distribution is controlled, even reduced numbers of livestock will still show a preference for meadows and riparian areas vis-a-vis uplands. No grazing-management strategies other than riparian enclosure have been shown to be completely effective in riparian-enhancement projects, and even enclosures will be ineffective if upstream grazing is unmanaged and/or trespass cannot be eliminated.

The most appropriate strategies for effective and efficient riparian-zone enhancement are (1) site-prescriptive improvements in livestock distribution, (2) controlled periods of grazing deferment, rest, and rotation through pastures and tracts with a mix of riparian and upland habitats, and (3) combinations of fencing (with or without upland water developments).

Summarizing the Present State of Knowledge

In summary it would seem that both major and more specific research and demonstration efforts have tended to confirm the CAST statements made in 1974 and 1976. Domestic livestock grazing and restoration of riparian areas are compatible uses of public rangelands. The key it would seem is scientific and managerial knowledge coupled with appropriate incentives and the dedication to succeed. However, the knowledge base remains incomplete (Armour et al. 1991). A good portion of the knowledge void relates to the economic benefits, costs, and trade-offs associated with alternative livestock-grazing strategies for riparian areas and adjacent uplands.

CONCEPTUAL UNDERPINNINGS FOR RIPARIAN ECONOMICS

One often hears the phrase, "Just do the right thing." A common response from a hardened economist might be, "Right for whom, for what, where, and when?" The answer: "For everyone, everywhere, in every way, always!"

This not-so-contrived dialogue illustrates the way in which resource economists think about natural resource management and policy issues. Ask a simple question, get a complex response. What is "right" in the management and use of a fragile riparian zone in the semiarid vastness of the semiarid West is a matter of perspective.

Private and Public Perspectives on Riparian-Zone-Enhancement Issues

The perspectives offered here are those of the rancher (and other private users of the commodities and amenities provided by riparian areas) and those of society deriving enduring pleasure and satisfaction from the environmental services and economic resources riparian zones can provide. In a mixed-enterprise economy such as ours, both perspectives are relevant. The private rancher (or recreationist) has private interests in his or her use of private property—some of which are riparian. The American public has social interests in its use of public property—some of which also are riparian.

To complicate the situation, when private use of public property is allowed, as in our system of permitted livestock grazing on public lands, the private party (permittee) has legitimate private interests in public property (the permit or allotment); and further, when public interests are affected by private actions, the American public has legitimate social interests in private management actions and practices. That is the reason why nonpoint-source pollution and other regulatory concerns of the Environmental Protection Agency and other governmental organizations figure in the management of privately owned riparian areas.

There are four perspectives in the analysis of Western riparian areas: Private interest in private property; private interest in public property; public interest in private property; and public interest in public property. The benefits and costs germane to each perspective will differ, as will the solution to the basic question: What can be done to sustain and enhance the productive potential of our Western riparian zones for all uses, users, and times? In other words, not only does successful riparian enhancement require site-specific prescriptions but for each such prescription there may be as many as four relevant economic accounts. Ask a simple question, get a complex answer.

Economic Standards for Riparian-Zone Management and Policy Analysis

There are three economic standards or criteria for sound resource (including riparian-resource) management and use policy. Those standards are *efficiency* (from both the private and the social perspectives); *equity* (in the sense of the distributions of the benefits and costs associated with riparian-zone management and use allocations among individual people, regions, economic sectors, and over time); and *sustainability* (in both the productive capability of the riparian resource and its continuing contribution to the livelihood and welfare of its users). Efficient, fair, and sustainable approaches to the management and use of riparian zones must be sought if, from both private and public perspectives, enhancement projects are to succeed.

The problem in management and policy analysis is that different people and different groups attach different weights at different times to each of these three standards. The relative importance of the consequences of riparian-zone management, use, and enhancement strategies is a matter of individual and collective interpretation.

Relevant Standards from Different Perspectives

Profit-driven hedonists place great importance on maximizing private efficiency. Generating the largest amount of gross personal revenue at the least personal cost as quickly as possible is of primary concern. Short-term profit maximization is the primary motivating factor in private landowners' decisions about riparian-zone management, use, and enhancement.

While they may seek profit (or its conceptual equivalent, net satisfaction) in the management, use, and enhancement of riparian zones, those private parties who are permitted the right to use public riparian areas do so at the discretion of their landlord, i.e., the American public acting through its government and the various land- and resource-management (and regulatory) agencies. To retain that private right in public property over the long term, the permittee cannot afford to intentionally overgraze the riparian area any more than the camper can afford to litter it. Hence, the standards for those with private interest in public riparian property are profit maximization subject to sustaining the long-term productivity of the riparian zone.

The U. S. government and its management and regulatory agencies infringe on private management and use decisions when it serves the public interest to do so. This infringement occurs if a management or use practice on privately owned riparian areas generates off-site effects that are viewed, by society, as public costs. Intervention is driven by the dual standards of equity and social efficiency.

Finally, public-land riparian zones are managed and used for the public good. They are managed for multiple commodity and amenity uses, striving to maximize social efficiency by generating the greatest good for the largest number of people (as directed by FLPMA). Public-land riparian zones are managed with balance so that in the interest of equity no one is excluded from enjoying them. They are managed with foresight so that fragile riparian zones and their many uses and resources are conserved and sustained for all uses and users over time. In the case of public interest in public property, the standards for riparian management, use, and enhancement reach full fruition.

RIPARIAN ECONOMICS: THE SOCIAL AND PRIVATE PERSPECTIVES

In his systematic literature review of the effects of range-livestock grazing on vegetation, watershed, and fish and wildlife, Skovlin (1984) placed special emphasis on trees, shrubs, and herbaceous plants; on water quality, stream bank stability, and features of upland erosion; and on large and small mammals, birds, and invertebrate organisms. He also proposed grazing strategies to improve habitats. Adding economics to Skovlin's biological approach to problem analysis is a convenient way to place riparian-zone management, use, and enhancement issues in a social context.

Riparian zones are critical for aquatic (primarily fish) habitat, providing buffering shade and cover for water-temperature regulation, cover for fish shelter or protection, and habitat for a terrestrial food supply. In the interior West, most livestock forage actually comes from surrounding mountain meadows and uplands, while the riparian streams provide drinking water for livestock. The riparian zones filter overland water flow that carries sediment and other pollutants into streams. Streamside vegetation stabilizes channel banks against cutting action, reduces further sedimentation, and provides improved water quality for downstream communities. For the recreationist, these areas are aesthetically pleasing. These functions and products of riparian zones are their sources of social and private value.

Types of Values Associated with Riparian Zones

Noneconomists should understand that when economists talk about resource values they are referring to "net" concepts—for example, gross benefits minus gross costs. In order to obtain and use any resource, something must be given up or foregone, even if it is nothing more than time. Time is not free nor is any other scarce thing. The values of riparian-zone resources are the benefits derived from them less the monetary and nonmonetary costs incurred in order to use the riparian resources.

Riparian zones yield, primarily as inputs in production processes, products that have market-based commodity values. Commodity values associated with riparian zones include wood, livestock forage, and water for mining, industrial, agricultural, and domestic uses. Most of the commodity uses of riparian zones are consumptive. Commodity values are fairly easy to measure but not as easy as many people may believe.

As final outputs, riparian zones also yield services valued directly by consumers. Most of these outputs have nonmarket amenity values. The amenity values of riparian zones are derived, in large part, from the recreational value of fish and wildlife for which the riparian zone serves as a life-support system. Amenity values usually are measurable, but there is much debate in economic circles over the relative appropriateness of the various measurement techniques.

In addition riparian zones consist of biota and physical components that people, to varying degrees and for various reasons, find pleasing. These attributes of the riparian zone thus have intrinsic value. Unfortunately, intrinsic values are almost impossible to measure.

The Social Benefits of Riparian Zones and Their Enhancement

Lant and Tobin (1989) note that while riparian corridors have economic value in the social sense these values may not be reflected in market prices. The result is that while the corridors are farmed (in the Western United States, they are grazed) for the value of the agricultural products (domestic livestock) produced in part from their use in some cases the agricultural (grazing) use can be socially inefficient.

Nonmarket Riparian Benefits. The nonmarket benefits of riparian corridors include such environmental services (public goods) as improved water quality (resulting in part from the lower temperature of shaded streams and less stream-bank erosion) and enhanced recreational activities associated with improvement of sports fishery habitat and the aesthetic attributes of a stream and associated stream-bank vegetation in good condition. These benefits can be quantified using willingness-to-pay techniques. The multiple benefits then can be aggregated and expressed as an average total riparian value per acre, where it is understood that this value is a composite of all use values other than the grazing use. This nonlivestock-use riparian value can be called the "gross social benefit" resulting from enhancement of the riparian zone, including both the stream or waterway and the surrounding riparian vegetation.

The social benefits of riparian-zone enhancement accrue as follows. First, water quality and aquatic (as well as riparian) ecosystems improve. There may be concurrent direct benefits in the forms of flood control, salmonid and other fishery enhancement, terrestrial wildlife-habitat enhancement, and stream and associated riparian-zone aesthetics. Second, these improvements in environmental conditions increase the flow of available recreational opportunities and enhance the intrinsic attributes and values of the waterway. Third, these improvements lead to measurable increases in socioeconomic values.

From an economic perspective, riparian values vary in the spatial sense. Spatial factors affecting riparian values are both longitudinal and cross-sectional. The net effects of these spatial factors are to cause riparian areas to have greater economic value when (1) small acreages—generally those areas nearest to the stream bank containing predominately natural vegetation and/or composed of poorly drained soils—play critical roles for hydrologic reasons in regulating water quality; (2) local recreational users of riparian areas place high value on the environmental services furnished by streams and riparian corridors; and (3) large urban areas are directly affected by water quality. Consequently, the benefits to riparian enhancement will vary from site to site and with the size of a given site or a given enhancement project.

Implications for Locating Riparian Improvement Projects. Since riparian areas are found on both private and public lands, there are corresponding opportunities for improvement projects on both private properties and public-grazing allotments. The underlying economic logic is similar in both instances, however; and on both private and public grazing lands, the question, given limited time and money as well as knowledge, is *where* should the riparian enhancement occur.

If the aggregate nonlivestock riparian value exceeds the corresponding grazing value per acre, society would be better off to rent the properties at their riparian values from the property owners if the riparian zone were on private lands. The privately owned riparian areas contributing least to livestock revenues on private grazing lands or possessing the highest nonlivestock grazing riparian values thus would be converted from grazing to nongrazing uses. This conversion likely would result in a patchwork of privately owned and nongrazed riparian acreages which, at present, provide the least livestock forage and/or provide the most critical sports fishery habitats.

If the riparian area were in a grazing allotment, it would follow that the grazing use should be reduced until the value of the grazing use is equal to the average total nongrazing riparian value on the permit. Note, however, that this logic would justify total exclusion of livestock from the riparian area only if the livestock use had no positive value or if nonlivestock riparian values could be realized only in the absence of any livestock grazing. Again, the probable result would be a patchwork of riparian enclosures on public grazing lands that, at present, contribute least to permittee seasonal forage requirements or have the highest fishery habitat potential.

The Private and Social Costs of Riparian Degradation

According to Skovlin (1984), only 10 percent of the original riparian habitat of the United States remains intact today; and of this, 6 percent is lost annually. These losses have been due largely to the conversion of natural riparian areas to modified agricultural uses. Other causes of riparian-area loss include channelization for flood control, flooding for storage to produce hydroelectric power supplies, irrigation, recreation, and industrial and municipal encroachment.

In the riparian areas that still exist, alterations are taking place due to grazing, timber harvesting, mining, road construction, and other factors. In the interior West, public concern centers on riparian degradation resulting, or thought to result, from domestic livestock grazing.

The social costs of degradation of riparian zones are reflected in decreasing natural infiltration and corresponding increases in sediment yield (Braden and Uchtmann 1985, Clark et al. 1985, Cooper et al. 1987, Maas et al. 1985, Schlosser and Karr 1981); decreasing flood-control potential (Novitski 1979, Peterjohn and Correll 1984, Tobin 1986); and deteriorating fish and wildlife habitat and aesthetic quality of the riverine environment (where the latter are intrinsic attributes sometimes referred to as "river or stream quality"). These intrinsic riparian-zone attributes vary in direct relation to the ecological health of the riparian, adjoining meadow or wetland, and adjacent upland ecosystems. The private costs of riparian-zone degradation in the interior West are primarily the value of reduced livestock forage availability.

From a social perspective, the riparian-area degradation costs are reflected in reductions in the consumptive and nonconsumptive recreational usefulness of the riparian zone. The willingness to pay on the part of these various recreational users generates the measure of social benefit (average total nonlivestock value) for incremental improvements in the condition of riparian zones (Cerda 1991, Lant 1987). Foregone recreational benefits (opportunity costs) are the measure of the value of degradation.

From a private perspective, the costs of riparian degradation are reflected in either reduced aggregate carrying capacity for the overall ranch operation or in the cost of buying or renting alternative sources of feed and forage to replace the reduced forage available on the degraded riparian zone. These costs are best estimated using a "whole-ranch" approach to estimating the effects of either positive or negative changes in riparian-zone conditions on the economic performance and financial risk of the ranching operation, since the riparian zone is only a seasonal forage source. However, the literature is devoid of any such applications with respect to riparian-zone management, use, and enhancement.

Economic Incentives for Riparian-Zone Enhancement

Much of the biological and popular literature has focused on the enhancement of public-land riparian areas. Successes have been observed; but as GAO and others have observed, the pace of restoration has been slow. Restoration may or may not be achieved if livestock are removed from riparian zones; and in any case, the removal of livestock is both controversial and to a degree inconsistent with the body of underlying public-land law. For the sake of both private interests in public property and public interests in public property, incentives for enhancement of public-land riparian zones need to use livestock, under relatively more intense management, as a prescriptive tool.

Prescriptive grazing for riparian-zone enhancement is possible if either the permittee is awarded a larger overall forage allocation, a higher quality forage allocation, or both or if monetary incentives for better and more intensive livestock management on the allotment are provided. The points to remember are that more management means higher costs and carrots work better than sticks.

Voluntary private-land riparian enhancement is more problematic. No more is known about the technical and economic feasibility of riparian improvement strategies on private lands than on public lands. Further, private-land owners cannot capture the social values associated with improved riparian zones on private property. Streams and other waterways normally are openly accessible and nonexcludable (with the recreational users being "free riders").

If the private benefits of riparian-enhancement projects are less than the associated private costs, improvement programs will not, in most cases, be adopted on private properties. This reality has led some resource economists to suggest the implementation of "riparian-enhancement markets" where development and use rights for specific acreages of riparian areas would be bought and sold. The underlying logic is that while the private owner might not be able to capture private revenues in excess of private costs there is nonetheless a marketable social value from improvement of privately owned riparian acreages.

This logic explains why subsidies (rents) obtained through riparian-market transactions might be required as incentives for riparian-zone improvements on private grazing lands. It also is why other types of subsidies or incentives (e.g., cost-sharing arrangements and other monetary incentives or increases in levels of permitted use elsewhere in the allotment or perhaps in a different allotment) could, from a social perspective, be rationalized to entice cooperation in riparian-enhancement programs on the part of permittees.

REFERENCES

American Fisheries Society. 1982. Management and protection of Western riparian stream ecosystems. American Fisheries Society, Western Division.

Armour, C. L., D. A. Duff, and W. Elmore. 1991. The effects of livestock grazing on riparian and stream ecosystems. Fisheries 16(1): 7–11.

Behnke, R. J., and R. F. Raleigh. 1979. Grazing and the riparian zone: Impacts and management perspectives. *In* R. R. Johnson and J. F. McCormick, eds. Strategies for protection and management of floodplain wetlands and other riparian ecosystems: Proceedings of the symposium, December 11–13, 1978, Callaway Gardens, Georgia. U. S. Department of Agriculture, Forest Service Technical Report WO-12.

Bohn, C. C., and J. Buckhouse. 1985. Some responses of riparian soils to grazing management in northeastern Oregon. Journal of Range Management 38(4): 378–82.

Braden, J. B., and D. L. Uchtmann. 1985. Agricultural nonpoint pollution control: An assessment. Journal of Soil and Water Conservation 40(1): 23–26.

Busby, F. E. 1979. Riparian and stream ecosystems, livestock grazing, and multiple-use management. Pages 6–12 *in* O. B. Cope, ed. Proceedings of the forum—grazing and riparian/stream ecosystems. November 3–4, 1978. Denver, Colo. Trout Unlimited, Denver, Colo.

Callaham, R. Z., tech. ed. 1990. Case studies and catalog of watershed projects in Western provinces and states. Wildland Resources Center, Division of Agriculture and Natural Resources, University of California, Berkeley.

Cerda, A. A. 1991. An economic analysis of alternative water allocations and habitat investments for anadromous fish production, John Day basin, Oregon. Ph.D. dissertation, Department of Agriculture and Resource Economics, Oregon State University, Corvallis.

Chaney, E., W. Elmore, and W. S. Platts. 1990. Livestock grazing on Western riparian areas. U.S. Environmental Protection Agency; Northwest Resource Information Center, Inc.

Clark, E. H., II, J. A. Haverkamp, and W. Chapman. 1985. Eroding soils: The off-farm impacts. Conservation Foundation, Washington, D.C.

Cooper, J. R., J. W. Gilliam, R. B. Daniels, and W. P. Robarge. 1987. Riparian areas as filters for agricultural sediment. Soil Science Society of America Journal 51(1): 416–20.

Council for Agricultural Science and Technology. 1974. Livestock grazing on federal lands in the 11 Western states. Journal of Range Management 27(3): 174–81.

Council for Agricultural Science and Technology. 1977. Proposed domestic livestock grazing program for the Challis Planning Unit. U.S. Department of the Interior, Bureau of Land Management Report 58.

Davis, J. W. 1982. Livestock vs. riparian habitat management—there are solutions. Pages 175–84 *in* J. M. Peek and P. D. Dalke, eds. Wildlife-livestock relationships symposium: Proceedings 10. April 20–22, 1981. Coeur d'Alene, Idaho. University of Idaho, Forest, Wildlife and Range Experiment Station, Moscow.

Elmore, W., and R. L. Beschta. 1987. Riparian areas: Perceptions in management. Rangelands 9(6): 260–65.

Federal Land Policy and Management Act. 1988. United States Code 43:1782.

General Accounting Office. 1988. Public rangelands: Some riparian areas restored but widespread improvement will be slow. GAO/RCED-88-105, Washington, D.C.

Hodgson, J., and J. W. Wilkinson. 1968. The influence of the quantity of herbage offered and its digestibility on the amount eaten by grazing cattle. Journal of the British Grassland Society 23(1): 75–80.

Holechek, J. L., R. D. Pieper, and C. H. Herbel. 1989. Range management: Principles and practices. Prentice Hall, Englewood Cliffs, N. J.

Holechek, J. L., M. Vavra, and J. Skovlin. 1982. Cattle diet and daily gains on a mountain riparian meadow in northeastern Oregon. Journal of Range Management 35(6): 652–55.

Kauffman, J. B., W. C. Krueger, and M. Vavra. 1983a. Effects of late-season cattle grazing on riparian plant communities. Journal of Range Management 36(6): 685–91.

Kauffman, J. B., W. C. Krueger, and M. Vavra. 1983b. Impacts of cattle grazing on streambanks in northeastern Oregon. Journal of Range Management 36(6): 683–85.

Kimball, J., and F. Savage. 1977. Diamond Fork aquatic and range habitat improvements. U.S. Department of Agriculture, Forest Service Intermountain Region, Uinta National Forest, Provo, Utah.

Lant, C. L. 1987. Greenbelts: An economic analysis of riparian corridors in the agricultural Midwest. Research in Contemporary and Applied Geography 11(1): 1–9.

Lant, C. L., and G. A. Tobin. 1989. The economic value of riparian corridors in Cornbelt floodplains: A research framework. Professional Geographer 41(3): 337–49.

Leopold, A. S. 1974. Ecosystem deterioration under multiple uses. Pages 96–98 *in* Wild trout management symposium. September 25–26, 1974. Yellowstone National Park. Trout Unlimited, Denver, Colo.

Maas, R. P., M. D. Smolen, and S. A. Dressing. 1985. Selecting critical areas for nonpoint-source pollution control. Journal of Soil and Water Conservation 40(1): 68–71.

Meehan, W. R., and W. S. Platts. 1978. Livestock grazing and the aquatic environment. Journal of Soil and Water Conservation 33(6): 274–78.

Meganck, R. A., and K. C. Gibbs. 1979. A methodology applied to the analysis of selected grazing management strategy and dispersed recreation: Final report. U.S. Department of Agriculture, Forest Service PNW-40, Supplement 57, Oregon State University, Corvallis.

Novitski, R. P. 1979. Hydrologic characteristics of Wisconsin's wetlands and their influence on floods, stream flow, and sediment. Pages 377–78 *in* P. E. Greeson, J. R. Clark, and J. E. Clark, eds. Wetland functions and values: The state of our understanding. American Water Resources Association, Minneapolis, Minn.

Owen, M. 1979. Keynote address. Pages 1–2 *in* O. B. Cope, ed. Proceedings of the forum—grazing and riparian/stream ecosystems. November 3–4, 1978. Denver, Colo. Trout Unlimited, Denver, Colo.

Peterjohn, W. T., and D. L. Correll. 1984. Nutrient dynamics in an agricultural watershed: Observations on the role of a riparian forest. Ecology 65(5): 1466–75.

Pieper, R. D., and R. K. Heitschmidt. 1988. Is short-duration grazing the answer? Journal of Soil and Water Conservation 43(2): 133–37.

Platts, W. S. 1979. Livestock grazing and riparian/stream ecosystems: An overview. Pages 39–45 *in* O. B. Cope, ed. Proceedings of the forum—grazing and riparian/stream ecosystems. November 3–4, 1978. Denver, Colo. Trout Unlimited, Denver, Colo.

Platts, W. S. 1981. Environmental concerns. Page 4 *in* W. R. Meehan, ed. Influence of forest and rangeland management on anadromous fish habitat in Western North America. U.S. Department of Agriculture, Forest Service General Technical Report PNW-124.

Platts, W. S. 1982. Sheep and cattle grazing strategies on riparian-stream environments. Pages 251–70 *in* J. M. Peek and P. D. Dalke, eds. Wildlife-livestock relationships symposium: Proceedings 10. April 20–22, 1981. Coeur d'Alene, Idaho. University of Idaho, Forest, Wildlife and Range Experiment Station, Moscow.

Platts, W. S., and R. F. Raleigh. 1984. Impacts of grazing on wetlands and riparian habitat. Pages 1105–17 *in* National Research Council/National Academy of Sciences, eds. Developing strategies for rangeland management. Westview Press, Boulder, Colo.

Roath, L. R. 1979. Cattle grazing habits and movements related to riparian habitats and forested ranges with inference to acute dietary bovine pulmonary emphysema (ADBPE). Ph.D. dissertation, Oregon State University, Corvallis.

Roath, L. R., and W. C. Krueger. 1982. Cattle grazing influence on a mountain riparian zone. Journal of Range Management 35(1): 100–103.

Schlosser, I. J., and J. R. Karr. 1981. Riparian vegetation and channel morphology impact on spatial patterns of water quality in agricultural watersheds. Environmental Management 5(3): 233–43.

Severson, K. E., and C. E. Boldt. 1978. Cattle, wildlife, and riparian habitats in the western Dakotas. *In* Management and use of Northern Plains rangeland: The proceedings of a symposium held February 27–28, 1978, at Bismarck, North Dakota. North Dakota State University Cooperative Extension Services, Bismarck.

Skovlin, J. M. 1965. Improving cattle distribution on Western mountain rangelands. U. S. Department of Agriculture Farmers' Bulletin No. 2212.

Skovlin, J. M. 1984. Impacts of grazing on wetlands and riparian habitat: A review of our knowledge. Pages 1001–1103 *in* National Research Council/National Academy of Sciences, eds. Developing strategies for rangeland management. Westview Press, Boulder, Colo.

Sneva, F. A., L. R. Rittenhouse, and L. Foster. 1973. Stockwater restriction and trailing effects on animal gain, water drunk, and mineral consumption. Pages 34–48 *in* H. F. Mayland, ed. Water-animal relations proceedings. June 1973. Twin Falls, Idaho. Water-Animal Relations Committee, Kimberly, Idaho.

Tobin, G. A. 1986. Modification of peak flood discharges by wetland environments. Geographical Perspectives 14(1): 6–18.

Van Poollen, H. W., and J. R. Lacey. 1979. Herbage response to grazing systems and stocking intensities. Journal of Range Management 32(4): 250–53.

Workman, J. P., and J. F. Hooper. 1968. Preliminary economic evaluation of cattle distribution practices on mountain rangelands. Journal of Range Management 21(5): 301–4.

Riparian Reform: Who Pays?

John A. Baden
Chairman, Foundation for Research on
Economics and the Environment
4900 25th, NE, Suite 201
Seattle, WA 98101

Abstract

The Constitution of the United States provides the understanding of who should pay for rangeland riparian reform in its discussion of private property rights. The economic theory used for Western rangeland management has used mechanistic models but should begin using an ecosystem model, where the assumptions do not isolate the model. The use of an ecosystem model would tie the right to act with the responsibility of the action's outcome. Management agencies use the mechanistic model to describe the economics behind current management and the current grazing-fee structure. If permits for all uses were issued in a market, the highest good for each area would be realized. Any use (consumptive or nonconsumptive) would have a protective covenant requiring the permit holder to maintain the riparian areas (and surrounding uplands) regardless of their use. This covenant would provide the incentive needed to maintain riparian areas and the associated uplands.

INTRODUCTION

This paper's approach to the topic of riparian management is a bit unusual; it blends anthropology, ecology, and economics with rural roots. Much of the research has involved studying the intersection of ecology and economics.

Just outside Preston, Idaho, a town nearly on the Utah border, there was a billboard with a single, straightforward, declarative sentence:

The American Constitution Is Divinely Inspired

A person could see that sign dozens of times and wonder each time, "How do I know this is true?" While most Americans have immense respect for our Constitution, there is no empirical test of its divine origin; but clearly its design is a great intellectual achievement. The Founding Fathers gave our nation the recipe for the world's most successful large-scale constitutional experiment.

An understanding of that recipe is needed to deal with riparian reform; and in the Intermountain West, this means rangeland reform. In the Intermountain West, the condition and management of the riparian areas are directly tied to the management of the rangelands. To deal with who should pay for riparian management, rangeland management must be addressed. For this reason, the remainder of this paper will focus on rangeland reform.

The Founding Fathers understood that nearly all polities are predatory; governments normally work as engines of plunder. Yet the predatory state is preferable to anarchy because it economizes on violence. This structure frees people to specialize in production rather than in looting or self-defense. As is seen so clearly throughout Latin America, Africa, and Eastern Europe, the predatory state describes most countries today.

People use politics to gain control of the coercive power of the state. Whatever the initial motives, the temptation to plunder follows and normally dominates political decision-making. Triangles of special interests, administrators, and elected politicians work to tax, regulate, and creatively take from some to give to others. This is especially evident in America's public-land management.

This pattern is highly persistent across time and geographic boundaries. The reason is compelling: even a predatory state provides some measure of regularity—and anarchy is nearly everyone's last choice. To the degree that order fosters wealth creation, this exchange is positive sum. Exploitation, however, is inherent in this system. The Founding Fathers' major intellectual problem was to design a constitution, a set of rules for making rules, that gave the state sufficient power to maintain order while constraining opportunities to use the coercive apparatus of the state to the advantage of special interests.

The Founding Fathers' understanding of political economy remains unsurpassed. The *Federalist Papers* stands as one of the greatest works of political philosophy. It adds analytical leverage to our tool kit and provides a true science of politics. It ranks with *The Wealth of Nations* as an invaluable political document.

BIONOMICS AND THE POLITICAL ECONOMY OF RANGE REFORM

A new approach to range reform is required, but a guidebook through the labyrinth of special-interest politics and the problems of transitional gains traps is needed. In sum we need a new model for viewing the world if we are to succeed in protecting environmental and social values of the Western range.

Bionomics (Rothschild 1990) is a book that might serve this function. It integrates important and disparate findings into a new perspective that enables us to better see economic patterns. Discovering this framework is like finding glasses for a 3-D movie. If it works, the lenses become, in effect, glued to our cornea; and the world never again looks the same.

Bionomics is an early nomination for the 1990s book that matters in political economy, for it advances the Founding Fathers' concern with plunder and predation with a paradigm shift from physics and celestial mechanics to ecology. Its discussion of parasitism would fit well into *The Federalist Papers*.

THE MECHANISTIC MODEL OF THE ECONOMY

The prime failure of economics, Rothschild (1990:44) argues, is that it "remains wedded to the classical Newtonian paradigm of a mechanistic model of the world. Sadly," he writes, "several generations of economists have spent the last century elaborating a system of thought that tries to explain the intricate relationships of economic life with concepts invented to describe the motion of planets."

In Rothschild's view, the cost of mathematical elegance is insulation from the real world of economic evolution. Science's mechanistic models are inappropriate for organic, creative systems of which economics is one. By simplifying assumptions, he argues, mathematical and econometric models, in effect, exclude precisely those features that make an economy vibrant.

For him, the ecosystem, not the machine, is the appropriate model for an economy. In an ecosystem, he explains, resources flow up the value-added chain like energy moving up though trophic levels of an ecological system. Instead of replicating their genes in progeny as frogs make tadpoles, firms convert resources into products. Hence, "products are like the sea shells abandoned by molting crabs—shaped by the genes, but not alive" (Rothschild 1990:215). The diversity parallels the ecological diversity of the rain forests; and governmental suppression of legitimate economic activities, through, for example, price controls, duplicates the destruction of the rain forests.

THE ALTERNATIVE: AN ECOLOGICAL MODEL OF POLITICAL ECONOMY

The problem with contemporary economic theory, Rothschild argues, is that it misses the essential evolutionary feature of capitalism. Natural selection is analogous to economic competition among firms. Only when the spontaneous coordination of the market is permitted expression, he argues, can prosperity and freedom replace command-and-control impoverishment. (Essentially he discovers for himself the theme of Hayek's 1945 classic *American Economic Review* article "The Use of Knowledge in Society.") Hence, progress is dependent upon how political and economic institutions utilize or ignore knowledge.

This process is the time-lapsed analogue to biological evolutions. When economic dynamics are misunderstood, momentous policy decisions hinge upon political mood swings and raw intuition, unaided by any deeper comprehension of how an economy works. This fundamental problem of democratic capitalism is especially clear when the current debate over rangeland reform is reduced to slogans such as "No More Moos in '92" and "Livestock Free by '93." Meanwhile, the traditional livestock interest groups consort with politicians attempting to buy those who can only be rented. The learning curve of the stockmen seems to resemble the topography of the plains on which they graze.

NEW ANALYTICAL LEVERAGE?

Rothschild's book helps us understand that our economy and our ecology share more than the Greek root *oikos* (eco). The economy is better understood as an ecosystem itself as opposed to a machine isolated and insulated from the environment. Economy and ecology are linked in a potentially positive-sum game where nature bats last, but only when our legal and economic arrangements tie the right to act with responsibility for the action's outcome can we expect a positive-sum game. This tie is precisely what is lacking in the institutions that currently dominant the range-policy arena.

In addition to the new perspective offered in *Bionomics*, there is a body of economics upon which to build. For example, public-choice theory emphasizes the importance of institutions and how the information and incentives they create affect opportunistic behavior (Buchanan and Tullock 1962). Austrian economics emphasizes spontaneous order and the impossibility of planning (Sowell 1980). Law and economics stress the importance of secure property rights to achieve progress. All of this work complements the bionomics approach. In the sections below, this analysis is applied to range reform.

THE HISTORICAL CONTEXT OF PROPOSED REFORMS

During the days of the Homestead Acts, much of the land now managed by the Bureau of Land Management (BLM) was not claimed. Though it was available at no charge, it was too dry and rocky and the climate was too unforgiving to grow crops. Although few people wanted to own these lands, many ranchers wanted to use them for grazing.

In 1873 the Desert Land Act increased to 640 acres the allotment of land to homesteaders. Even so, some ranchers merely fenced in public lands to graze their livestock, without obtaining a title. Without private property rights, ranchers had economic incentives to overgraze before their neighbors did, to turn out stock before young grasses had matured and seeded, and to run more stock than the land could sustain, thus paving the way for the Dust Bowl era. As a result, much of the Western lands became barren, devoid of topsoil, and unable to economically support livestock in commercial numbers.

By 1934, 25 million acres of Western rangeland had been plowed up and abandoned. In that year, an executive order called the Taylor Grazing Act withdrew all public land from further homesteading in ten Western states (Junkin 1986). To administer the rangeland and to help stabilize the livestock industry in the West, Congress established the Grazing Service in the Department of the Interior (Kemp 1981).

This act was a step forward because it created quasi-private-property rights on public lands. Under the act, ranchers could invest in the maintenance and improvement of public grazing lands they used and be reasonably secure that they would enjoy the benefits for which they paid. This act led to some substantial improvements (Baden 1986). The land leases held by the ranchers even had equity value at federally insured banks.

However, the new agency was not fully successful. Eastern representatives, unwilling to grant Westerners a free ride, were pushing the agency to raise grazing fees to market values. Western representatives, trying to satisfy the demands of ranchers, fought to keep the fees low. The resulting political tussle caught the agency in a political quagmire that remains today.

In 1946 Congress combined the Grazing Service and the General Land Office into the Bureau of Land Management. The BLM's first director was Marion Clawson, a Harvard-trained economist who had grown up on a Nevada ranch. Clawson spent the next seven years reducing the red tape and paperwork of the agency. He also raised grazing fees and hired more rangeland management. These efforts made him unpopular with the stockmen who had grazing rights on public lands and who were used to cheap fees. They did not appreciate an economist operating the BLM like a professional land-management agency. In 1952 he conducted a detailed study of grazing fees and concluded that they should be raised to an average of 28 cents per animal per month. This study led to some substantial improvements (Baden 1986), but Clawson's efforts to raise fees to that level failed due to heavy political pressure from the stockmen. Shortly thereafter he was fired (Culhane 1981).

The ranchers saw any attempt to impose market strategies on public lands as an infringement on their rights—and on their way of life. Once a group is nurtured and coddled at the public trough, it is virtually impossible to break the cycle without a major political battle. That battle is still being fought. Meanwhile, the taxpayer loses.

Many people believe that ranchers derive huge subsidies when grazing the public lands. The situation, however, is complex. Following are some facts:

Twenty-nine thousand ranchers have permits to use BLM and Forest Service lands on which they pay one-fifth to one-tenth the price charged for grazing rights on adjacent or proximate private land (Baden 1986). Bardow (1986:13) wrote that "grazing fees yielded only $23 million in 1984, while administration of the rangeland, according to Department of Interior economist Robert Nelson, costs the government between $100 million and $200 million annually." These numbers seem insignificant, perhaps smaller than rounding errors, when compared with many Department of Defense or Housing and Urban Development programs. Yet they provide ammunition for those who oppose grazing on the federal lands.

Several acts passed in the 1960s and 1970s culminated in the Land Policy and Management Act of 1976. They reversed the trend toward quasi-property rights set in the Taylor Grazing Act. The recent acts have given the BLM more control over grazing rights and private ranchers less incentive to invest in improving the quality of public land. Baden (1987:38) stated, "The BLM has no incentive to keep costs down, or even maximize revenues from grazing fees, which go into the overall U.S. Treasury rather than its own coffers. Instead the BLM builds its budget by winning political support from ranchers who then lobby for BLM expenditures."

Wildlife management, recreation, watershed maintenance, and energy development should receive the attention of the agency in accord with its multiple-use mandate. Proper attention would maximize the land's net value from an aesthetic as well as from an economic perspective, but recreational and aesthetic activities offer less effective methods of increasing budgets than does grazing. Therefore, the amenity values tend to lose out when vying for funds. As public-choice economists have shown, a bureaucracy is driven to emphasize those activities that promote a continually expanded budget. The BLM fits this pattern well. Furthermore, the BLM's traditional constituents are politically powerful ranchers.

The BLM's emphasis on grazing has led to environmentally destructive behavior. Perhaps no BLM practice appalls so many people as does "chaining." This dramatic land-management technique is considered an especially ugly way of removing trees that compete with grass for space. Chaining is accomplished by linking two D-8-class crawler-tractors together with a 600-foot anchor chain. The tractors are then moved along in tandem. The chain that is dragged between them uproots trees and large brush in its path. By removing the tree and shrub competition for nutrients and water, more forage is available for livestock; and more grazing land means a larger inventory of political favors for the BLM. Chaining is an expensive method for sweeping scrub trees from an area to "improve" rangeland.

Environmentalists see chaining as having disastrous consequences (Lanner 1981). As with nuclear activities undertaken by the federal government, it is difficult to obtain accurate information regarding chaining. Between 1950 and 1964, nearly three million acres had been chained, with millions more planned.

The environmental impact is substantial. There are approximately 50 species of fish, 66 species of reptiles and amphibians, 75 species of mammals, and 140 species of birds in or around the pinion and juniper trees that are uprooted by chaining. Wild ungulates, such as mule deer, tend to avoid the chained areas due to their natural hesitancy to expose themselves in the middle of clearings that often exceed a section (one mile by one mile) in area.

Trout are threatened because overgrazing leads to soil erosion, which muddies streams and makes it difficult for the trout to reproduce. Trout taxonomist Robert J. Benke of Colorado State University has observed, "Livestock overgrazing is the greatest threat to the integrity of trout stream habitat in the Western United States" (Baden 1986:23); yet the Forest Service and the BLM actually maintain that chaining is beneficial to the environment. They either possess some scientific knowledge that enables them to improve Mother Nature's handiwork—knowledge that is superior to independent researchers who have found otherwise—or they are desperately attempting to protect an activity that increases their budget.

Edward Abbey probably enjoyed greater influence among environmentalists than all the range scientists combined. He argued that we do not need the "public lands beef industry" because it only supplies 2 percent of our beef. The great majority of our beef comes from private lands in the Midwest, East and Southeast "and for a very good reason: back East one can support a cow on maybe half an acre. [In the West] it takes anywhere from 25 to 50 acres. In the red rock country of Utah, the rule of thumb is one section—a square mile per cow" (Abbey 1986).

The Western livestock industry still agitates for heavy subsidies on public lands. While one can understand the economic motivation and empathize with many of the values underlying ranchers' arguments, one must also marvel at their political naiveté. Time unstuffs ballot boxes and exposes special interests: It is no wonder that professional and avocational environmentalists give tours of our rangelands and point out sacred cows at the public troughs. In politics as in all things people see it when they believe it. It may be asked in the privacy of the mind, "Who is the public predisposed to believe—the followers of Ed Abbey or of Bob Burford?"[1]

[1]Bob Burford is the former director of the BLM. *Ed.*

THE FOUNDERS' GUIDE TO RANGE REFORM

If the land's values, e.g., water rights, wildlife habitat, and recreational amenities, could all be in private hands, there would be incentive to prevent overgrazing in order to protect the productive base of the land. One of the most obvious methods to stop overgrazing is to charge market prices, something private interests naturally do in response to supply and demand conditions. Such a scheme would have two major benefits: the taxpayers would be free from the burden of paying the costs for ranchers who use public lands, and the environmental degradation that results from poor grazing management would be reduced.

A far more radical method of improving the conditions of BLM lands is divestiture via auction. Stroup and Baden (1979:37) wrote that "only in this way can all of the people of the nation capture the benefits into perpetuity produced by the 170 million acres of grazing land in the West now managed by the BLM." Private ownership of the BLM lands encourages a diversity of uses and generates a dynamic management system capable of adapting to changing needs and priorities. However, capital has an opportunity cost (interest or carrying charges), and managers have strong incentives to neglect those values that don't pass through the market; and increasingly some of the most important values, endangered species for example, are not marketed and cannot be under current institutional arrangements.

To safeguard the multiple values, grazing rights could be sold with protective covenants. For example, the rights to graze an area frequently used for recreation would be sold with the understanding that the holder of grazing rights must manage to protect recreational values. The ranchers now grazing on public lands need not be disadvantaged. Current lease holders could be offered secure and transferrable rights to the grazing they now claim. Secure property rights would increase the value of the land to the user, since long-term management practices, such as range improvement, would present the user with future benefits and the option of selling to wildlife organizations, such as the North American Elk Foundation (Stroup & Baden 1979). In many areas, such as Greater Yellowstone, wildlife clearly has higher value than domestic stock on the public lands.

Further, the wide array of benefits flowing from a divestiture plan should be considered: Current users of the land gain because of the opportunity to engage in better long-term management practices, and citizens gain from increased productivity and by not having to fund inefficient BLM management practices. The only interest not to gain is the BLM itself.

Costly lobbying and the constant struggle to placate both the ranchers and environmentalists would be eliminated through such a plan. A divestiture of grazing rights would encourage environmental groups to purchase environmentally sensitive forage areas and ranchers to purchase the most productive range. Both interests would be better served, and economic efficiency and environmental integrity would be fostered.

A free market, with institutional arrangements that recognize economic incentives and traditional American values, offers unique opportunities to many of the environmental problems our nation faces. However, progressive-era type institutions such as the BLM and the Forest Service circumvent the market and maintain that market forces cause problems. They have it exactly backward: The absence of property rights and markets causes problems.

Bureaucratic institutions have been part of the American political landscape for more than a hundred years. They are so entrenched that any alternative arrangements for management are usually considered ludicrous. However, there is nothing ludicrous about granting control of the BLM and Forest Service grazing to those who use and appreciate it most highly. This arrangement is the end our Founding Fathers originally intended, and it is consistent with our growing environmental sensitivity.

REFERENCES

Abbey, E. 1986. Even the bad guys wear white hats. Harpers(272)(January): 51–55.

Baden, J. 1986. Destroying the environment: Government mismanagement of our natural resources. National Center for Policy Analysis Report #124, Dallas, Tex.

Baden, J. 1987. Crimes against nature. Policy Review Number 39 (Winter).

Bardow, I. 1986. Critical issues—protecting the environment: A free market strategy. Heritage Foundation, Washington, D.C.

Buchanan, J. M., and G. Tullock. 1962. The calculus of consent, logical foundations of constitutional democracy. University of Michigan Press, Ann Arbor.

Culhane, P. J. 1981. Public lands politics: Interest group influence on the Forest Service and the Bureau of Land Management. Johns Hopkins University Press, Baltimore, Md.

Hamilton, A., J. Madison, and J. Jay. 1961. The federalist papers. New American Library, New York.

Hayek, F. A. 1945. The use of knowledge in society. American Economic Review 35(4): 519–30.

Junkin, E. D. 1986. Lands of brighter destiny: The public lands of the American West. Fulcrum, Golden, Colo.

Kremp, S. 1981. A perspective on BLM grazing policy. Pages 124–53 *in* J. Baden and R. L. Stroup, eds. Bureaucracy vs. environment: The environmental costs of bureaucratic governance. University of Michigan Press, Ann Arbor.

Lanner, R. M. 1981. Chained to the bottom. Pages 154–69 *in* J. Baden and R. L. Stroup, eds. Bureaucracy vs. environment: The environmental costs of bureaucratic governance. University of Michigan Press, Ann Arbor.

Rothschild, M. L. 1990. Bionomics: The inevitability of capitalism. Henry Holt, New York.

Smith, A. 1976. An inquiry into the nature and causes of the wealth of nations. R. H. Campbell and A. S. Skinner, eds. Clarendon Press, Oxford. 2 vols.

Sowell, T. 1980. Knowledge and decisions. Basic Books, New York.

Stroup, R., and J. Baden. 1979. Property rights and natural resource management. Literature of liberty: A review of contemporary liberal thought. Cato Institute 1979:37.

Striving for Unanimity and Consensus:

Finding the Common Ground in Conflict over Riparian Management

Mark L. Johnson
District Ranger
Caribou National Forest
Montpelier, Idaho 83254

Abstract

Dealing with natural resources conflicts creates an uncomfortable situation for many people. To successfully deal with the conflicts associated with riparian-area management, four points must be addressed: paradigms, strategic planning, decision-making, and implementation and monitoring. The paradigms of everyone involved in the resolution of the conflict must be understood. Strategic planning helps find the common ground of the people involved and reduces the misunderstandings. The decision-making method provides a mechanism to ensure that goals are addressed. Implementation of the decision is required but must be followed with monitoring. Monitoring ensures that the goals are met and that the plan is adjusted appropriately when the goals are not being met. These four areas help reduce the conflicts among people associated with riparian management by helping produce win/win agreements.

INTRODUCTION

Natural resources are managed by biological constraints and by society's objectives. As society changes, the uses and objectives for natural resources also change, which often leads to conflict. Conflict is a natural result of change. However, it is not pleasant to many people. This paper will provide a practical information base to help reduce the anxiety many people have about conflict. This information base has been gained by the practical experience of trying to implement management decisions on riparian zones and on many other natural resources situations. Understanding four key areas has helped me deal with managing conflicts. These four areas are paradigms,[1] strategic planning, decision-making, and implementation and monitoring.

The goal of resource or riparian managers is to make and then implement a decision, "a change." With public resources, this is done in a group or team setting. There are generally five approaches to making this decision (Suhr 1990a):

1. Make no decision.
2. Arrive at a 9-1 decision.
3. Hold a democratic vote.
4. Develop a consensus.
5. Arrive at a unanimous vote.

Unanimity and consensus are results of decisions that are win/win. Everyone involved in these types of decisions feels as if he or she won something. Decisions reached through 9-1 or voting result in winners and losers. These types of decisions are generally not well supported and are less likely to be implemented or to succeed. To get the best management decisions implemented and to succeed, it is important to strive for unanimity and, as the next best choice, consensus.

Implementing changes that improve the resource situation is the objective. These positive changes can only be achieved with the involvement of people

[1]In this paper, the author uses the word *paradigm* to mean a set of beliefs (Covey 1989). *Ed.*

affected by that improvement. The best resource decision in the world can be made; but if the people who are going to make the change don't support that decision, it will never be implemented. At the same time, a good resource decision, supported by those who will implement the change, can be stopped by people who are affected by the change if they do not support it. Those affected can stop it through appeals. In a third scenario, the correct resource decision can be made and the people who are affected by the decision may support it; but it will not be implemented because the time is not right for it. The decision is out of sequence. A good resource decision needs to do the following (Suhr 1990b):

1. Have proper biological impact
2. Have the support of those implementing it
3. Have the support of those affected by it
4. Be in sequence

PARADIGMS

Paradigms are maps of the world. They are how people view the world. They are the individual's reality. Different people's paradigms are different about the same subject. Paradigm differences are the primary source of all conflict. There are two phases to understanding and managing attitudes about paradigms. The first is to examine one's own paradigms. This examination will provide an understanding of those paradigms that are helping you and those that are not beneficial to you. The second phase is to determine the paradigms of the other people involved.

Determining Your Paradigms

To determine your paradigms you must determine how you feel about "things." Listen to yourself talk. The feelings expressed provide you with your paradigms. From my personal experience, the paradigms that provide the most unpleasant and unmanageable conflicts in my life are the following:

1. Change is bad.
2. Conflict is bad and needs to be avoided.
3. Subjects must be dealt with on a high level of abstraction.
4. Differences in opinion destroy teamwork.
5. There is only one correct answer.
6. There are right and wrong answers.
7. I have to find out what peoples' positions and issues are.

I have changed or am in the process of changing those paradigms to the following:

1. Change is good. Change is the only way humans progress. Without change we would still be riding a horse and using buggy whips. I have also found in myself that if I am either the instigator of change or a participant in deciding what the change is I feel much more comfortable with the change.
2. Conflict is good. Only conflict that is allowed to escalate to a point where the situation becomes completely destructive, as in a conflagration, is bad. Conflict, I realize, is a natural and logical part of change. If you change something, conflict will be a natural result. I look upon conflict as I look upon spring: it is a harbinger of progress and warmer and more productive days to come.
3. Thinking in low levels of abstraction is beneficial. Conflict and change are really neither good nor bad—they are both. When we think that conflict is either good or bad, it paints a picture of extremes. Therefore, thinking on a lower level of abstraction results in a conclusion that conflict is sometimes good and sometimes bad. This tactic helps calm things down in my own mind, and it helps me deal with things outside of myself.
4. Diversity of opinion—conflict—is essential to team building and effective teamwork. If you have a team of people that feels as you do, you are not as apt to build logical alternatives and to find the best solution. Team building and effective teamwork depend on honest, open discussions about important, sensitive points. Without that, teamwork never occurs.
5. There are always at least two answers—yours and the right one. If you think you hold the correct answer, you will not be open to someone else's alternative or to someone else's altering your idea. If you think there are always at least two answers—yours and the right one—you will be in a mode of discovery and in a better situation to find an answer.
6. There are no right or wrong answers. There are only effects, with some effects being more desir-

able than others. If you look upon potential answers as being right or wrong, every answer is wrong to someone. If you open up your mind to determining what the effects are, you will be choosing a course of action based on the most desirable effects. You will not be striving to find the nonexistent right answer. Your mind is freed from the destructive dichotomy of being right or wrong.

7. Finding out what peoples' interests are avoids a win/lose situation. I no longer ask people what their issues are. If you ask people their issues (their position), you are asking them to take a stand on an issue. Once a position is stated, any movement from this stand is likely to be thought of as a win or loss for the person holding the opinion. Once set up in the win/lose dichotomy, a person will do almost anything to win. Most are not likely to enjoy losing. On the other hand, an interest is just that—something a person is interested in. If you deal with someone's interest, you are more likely to avoid win/lose dichotomies.

Following is a summary of my progress producing paradigms:

1. Change is good, bad, and in between.
2. Conflict is good, bad, and in between.
3. Think in low levels of abstraction.
4. Diversity equals true teamwork and high productivity.
5. There are always at least two answers—yours and the right one.
6. Avoid dichotomous thinking.
7. Determine others' interests.

Two tenets to follow are: (1) there are only effects instead of right or wrong thinking; (2) there are only interests in place of win/lose position thinking.

With these paradigms in place, a person is put in a discovery mode when dealing with others. In a discovery mode, defensiveness is an unnecessary emotion. When someone says something that goes against your belief, there is no reason to be defensive if there is no vested interest. Remember, you are just trying to determine the other person's paradigms. In addition, there is less chance on your part to consciously or unconsciously avoid delicate, sensitive, or emotionally charged topics when you are in a discovery mode.

Human nature drives us to try to get along with other humans. This desire is good in most cases except when we avoid conflict with other people at all costs. If you know an issue is an emotional one for a particular person, you can deduce that it may be that person's tendency to avoid talking about that issue. In riparian-management decisions, these issues will come up sooner or later; and if brought up later, often they stop the project.

Another advantage to having these paradigms is their tactical value. If you have the paradigm that "differences of opinion mean a stronger team," when a person brings up something to you in an argumentative way that goes against your belief you may easily say, "Good, you have a different opinion than I do." This attitude has many benefits. It shows you are open to another opinion without giving up your interest. Often the other person is expecting a different reaction and is shocked that you are not upset by the comment. This open-mindedness helps develop a working relationship within a group.

STRATEGIC PLANNING

Strategic planning is used for two things. The first is to visualize where you are going so that you can take strategic, tactical action to arrive at a consensus or unanimity in your decision. The second is to visualize what the future is so that you can create a comfort zone to be used at those times in the future when your action will be required.

In order to bring this into focus, Lou Tice (1990), in "Investment in Excellence," made a point about a person's view of the world and how that view of the world can create the person's future. He used the metaphor of when a child is just learning to ride a bike and he sees a rock in his path on the sidewalk. Remember how *you* felt, how unsteady you were in the beginning? If you look at the rock in panic and focus on the rock, more than likely you will hit it. The point is: See the rock, but don't focus on it. See the rock; then quickly find a way around it; then focus on this new route. You will naturally steer around the rock.

With that as an example, the first step in strategic planning is to go through a "futuring" exercise to discover a way around the "rock." First, brainstorm the trends seen in your situation. In other words, if you are dealing with a riparian situation, ask the following questions:

1. What are the things that are happening regarding all parts of that riparian system?
2. What are the trends of the fish?

3. What are the trends of the livestock use?

4. What are the trends of the recreation use?

Everything affecting that riparian system must be addressed. In the second part of futuring, project each one of those trends into the future for some period of time, e.g., five or ten years. These trends and where you think they may go are called "the reference future." Examine the reference future. This is the "rock" to manage around. The next step is to formulate the "perfect future."

The perfect future is where you want to end up on the other side of the rock. The perfect future needs to be designed in relation to what you like and don't like in the reference future. It must be specific and written down. Now, with the perfect future, review the trends again. What needs to be changed in those trends to allow the perfect future to be reached? The changes become the route around the "rock." The specific actions, to change the trends, are the heart of the strategic plan.

Three things are needed to complete a strategic plan based on this type of futuring:

1. Contingency plans at decision points. If a decision is needed but you do not know what that decision is to be, develop contingency futures for all alternatives.

2. Documentation of decisions on who will do what.

3. Documentation of decisions on when and in what sequence things will be done.

From my experience, for strategic planning to be successful and beneficial time must be invested in team formation. Learn each team members' perspective and establish a personal relationship with him or her. Invest this time and it will pay off in the end. The second recommendation is to be extremely careful about who is invited to be on the team. This point is controversial because in public-resources management you may not have control over who will be on the team. It is easier to get people on a team than to get them off, particularly if things are falling apart. On my teams, I want people with a diversity of opinion (Again, because of the strength of diversity, I don't need four Mark Johnson's on my team), team workers, and people who are flexible but not limp.

Effective teams generally must work through four stages of teamwork (Blanchard 1990). These stages are: forming, storming, "norming," and performing. Some teams stop before they get to the performing stage because of unmanaged conflicts in the team setting.

During the forming stage, people are enthusiastic. They are excited about what they are doing, they are meeting new people, they are interested in what they are doing, and there is a lot of energy. During storming they realize their interests are different from others in the group. This stage is when destructive conflicts can occur. A team must work its way through this period, often with the team leader taking control. In "norming" a team starts establishing working relationships. Synergy, energy, and some cooperation begin to develop. In the fourth stage, performing, the group knows its job and little must be done. The group members know how to react with one another and how to "synergize."

DECISION-MAKING

The next important phase is decision-making. In my experience, conflicts become most apparent at this stage and caution must be used to keep them from escalating. I believe three things about decision-making:

1. Decisions matter because they are the starting points for actions that end in results. Results are based on a decision.

2. Decision methods matter. They range from those methods that depend on chance to the more sophisticated method developed by Ben Franklin (List the advantages and disadvantages) to more modern decision-making processes. Some of these are sound ways of making decisions, though many are unsound. Using an unsound decision process often leads to wrong answers and increased conflicts.

3. Different decisions require different methods. If you are making a decision between two of your favorite ice cream flavors, maybe a chance method is all right: it really doesn't matter because you will enjoy either flavor. If a decision is about a threatened or endangered species, a person's livelihood, or the future of a stream segment, a sound method will result in a good decision.

I am a profound advocate of a decision-making process known as "sound decision-making," which is also known as "choosing by advantages" (Suhr 1990a). This method is based on the foundation of alternatives being selected on the basis of the importance of the advantages. Methods that weigh both advantages and disadvantages can lead to double counting and selecting an improper alternative. Invariably, a disadvantage of one alternative is always an advantage of another alternative. Unsound methods can be a source of conflict rather than a tool to manage the conflict. The choosing-by-advantages process also manages interactions on an interest basis and does not set up adversarial positions. The focus is on the problem or situation—not on win/lose situations.

A good decision is categorized as one that (a) is a correct, long-term resource decision; (b) is a decision that the people who will effect the change support and will implement; (c) affected people will at least give grudging consent to but won't appeal; (d) is timely or properly sequenced (Suhr 1990b). A good decision that can be implemented has all of these characteristics.

IMPLEMENTATION AND MONITORING

The last phase of the riparian project is the implementation phase. This phase never ends, but conflicts are most likely to occur in the first five years after implementation. Major conflicts during this period are from words used and misunderstanding of those words, the lack of understanding about human planning and implementation, and obligating more time for implementation or monitoring than is available.

Be prepared to deal with misunderstandings about the consensus built around the riparian project. Just as people see the world differently, they also have different definitions for words, concepts, and theories. If you maintain the discovery attitude discussed earlier, you can manage the conflict and arrive at a resolution.

There are two types of planning and implementation:

1. God's way in which God plans it, sets it to work, and it runs perfectly. An example of this is a stream. If God sits up high and looks down and feels that there needs to be a stream somewhere, he plans it, creates it, and it runs perfectly.

2. The human way. Since humans are not God, we cannot plan perfectly for anything to run perfectly; so humans must design, test, and improve the plan over and over until it reaches acceptable nonperfection.

Any team member who does not know the human way of implementation is a potential source of conflict. Imagine thinking that a consensus has been reached but later finding it has been modified without your knowledge. Will there be a conflict? How to manage around this "rock" is obvious. Just know this "rock" exists and be prepared. Keep people informed of changes that must be made because the plan will have to be improved.

I have experienced another paradigm shift through increased understanding of the human way of planning and implementation. This shift has to do with failure. My previous paradigm was that all failure is bad; but failure is a natural, normal, and perfectly successful application of change. When you test something, part of it is going to fail—unless you are God. This failure is only bad if no improvement results from the next attempt. If the first effort is improved upon, a failure is a success. Here is my paradigm shift: Failure improved upon is a good failure. A failure that is ignored and not learned from is bad. The more you learn from a failure and improve upon the failure, the better the failure is.

The third and major area of conflict to plan for and to avoid is to set up monitoring for only the most important interests in the consensus. Then commit only to the amount of monitoring that can actually be accomplished. There is a tendency to think we will be able to monitor more than we will. Even though Congress requires us to monitor, it rarely dedicates the money to this important task. Congress believes we plan and implement "God's way." Do not commit to more than can be done. This premise leads to another "total quality management" saying, which is, "Under promise, over deliver" (3M Corp. 1990). Promise to monitor only what can be done with available resources. Plan it—then do it.

SUMMARY

I believe the lack of understanding of paradigms—both your own and others—is the basis of most destructive conflicts, which mimic conflagration: everything associated with it is damaged. To keep conflicts from escalating, we must deal with our own and others' paradigms. Strategic planning can be useful to help find common ground by avoiding unnecessary conflict and by assuring common understandings. The decision-making process can facilitate finding common ground. From my experience, the sound decision-making process (Suhr 1990a) is the easiest to use. Finally, the implementation phase has two major pitfalls that must be dealt with: misunderstandings during the planning period and a lack of understanding that there will be a need to refine a human decision. An understanding of these four key areas of conflict management—paradigms, strategic planning, decision-making, and implementation and monitoring—has helped me deal with the conflicts I have faced in riparian and other resource-management decisions. These tools should help you to be more comfortable in dealing with conflict and to approach a conflict as an ally not as an enemy.

REFERENCES

Blanchard Training and Development. 1990. Training session: Building high performance teams. Escondito, Calif.

Covey, S. R. 1989. The seven habits of highly effective people: Restoring the character ethic. Simon and Schuster, New York.

3M Corporation. 1990. Training session: Managing total quality, St. Paul, Minn.

Suhr, L. D. 1990a. Training session: Sound decision-making. Decision Innovations, Ogden, Utah.

Suhr, L. D. 1990b. Training session: Congruent decision-making. Decision Innovations, Ogden, Utah.

Tice, L. 1990. Training session: Investment in excellence. The Pacific Institute, Inc., Seattle, Wash.

Building Consensus for Riparian Users:
Toward the Twenty-First Century

William C. Krueger
Department of Rangeland Resources
Oregon State University
Corvallis, OR 97331-6704

Abstract

Society's definition of the acceptable use of riparian areas changes over time. Land managers must accept these changes and find ways to help rangeland users work together to develop shared visions for all resources. One approach that has worked for the Oregon Watershed Improvement Coalition (OWIC) is the use of abundance theory and the coalition-building process. Abundance theory focuses attention on the needs of the people and on the importance of understanding one another. This method helps to allay the fear with which many resource users approach one another on resource issues. By using abundance theory and coalition building, OWIC has successfully improved the management and shared vision of Oregon's watersheds and associated riparian areas.

INTRODUCTION

The purpose of this paper is to describe certain issues that arise as industrial and amenity rangeland interests come together. Management of rangelands has successfully improved ecological conditions, and rangeland owners and managers are rightfully proud of their accomplishments. However, major environmental interests do not find the changes or rates of change adequate. Range managers' predictions of what society would accept as success were wrong. There is large-scale concern about livestock use and the condition of rangelands in the West.

The evolution of society has always been a result of an accumulation of information. Now technological developments have permitted individuals to acquire information at rates faster than can be assimilated, evaluated, and sorted to fully appreciate different points of view throughout society. Though change is a principle of societal development, it may be that change is occurring so rapidly in some segments of society that it cannot be accommodated by other segments. There is an information overload, and there is unequal access to information. Most societal groups are developing their views in isolation. Somehow natural resources professionals must come to grips with these issues and find a way to help people function together.

CURRENT STATUS

Belief Systems and Truth

The people of the "Wild West" are largely urbanized. People living in cities commonly have no close relatives who live or work on ranches or farms. The family bonds that historically tied rural and urban people together are gone, and with them a major communication link has been lost. Without the intense common understanding that characterizes close relationships of a family, fundamental beliefs and ways of evaluating natural resources issues among urban and rural groups have become increasingly different. Each group has lost information in this evolution of paradigms. Each group analyzes different, sometimes selected, information in a different logical framework and naturally defines the truth differently. This practice has prevented a common understanding of many issues. One result has been the generation of intense controversy concerning protection and use of natural resources.

The view of one group of environmentalists is reflected in the writings of Ferguson and Ferguson (1983): "Until now stockmen have brazenly challenged the rights and wishes of the American public—they have thrown the gauntlet. At this point, the American people have little choice other than to accept the challenge of a recalcitrant, uncompromising, and coddled minority—the public should boot every last one of them off the public lands. The nation no longer needs them." Godfrey and Pope (1990) explain this as a "negative externality" and cite the widespread dissatisfaction by critics of livestock grazing as one of five factors justifying elimination of public-land grazing.

The beef cattle industry sees the situation differently. In the 1989 "Strategic Plan on the Environment," the National Cattlemen's Association described the issue of the environment as follows: "Environmental issues now directly impact the cattle industry. Environmental activists have criticized the cattle industry for years and promoted legislation and regulation with adverse impact for cattlemen. The general public and key influences are receiving more and more misinformation about the cattle industry's impact on the environment. It is urgently clear that the cattle industry must actively communicate accurate information to the public on these issues. The industry must demonstrate the industry's contributions to environmental protection and must increase producers' awareness of how these issues impact on them."

Even now, the vision of the truth remains different on each of the issues.

PHILOSOPHY OF RESOURCE USE

Society has made little progress in bringing the visions of environmentalists and ranchers together to find consensus on resource issues of the Western states. This lack of consensus is not surprising when we consider the way we generally do business in the United States. Our laws and policies are based on allocation of scarce resources. Society must be sure everyone gets a fair share of the resources, especially public resources, so laws are passed and policy is made to allocate what we have according to certain priorities. A major assumption underpinning our laws and policies is that there are not enough resources for everyone, resulting in each getting a share that is less than he wants. Inevitably, allocation of a scarce resource leads to conflict and often to mistrust. This mistrust inevitably leads to fear. There is fear that the representatives of other interests will be more skilled at negotiating their position and that they will get the best allocation of the resources in the end. This perception leads to fear of losing the profitability of watershed-based businesses, fear of losing the sustainability and aesthetic values of a resource, and a multitude of other fears. One only has to observe the relationships of environmental groups opposed to public-land grazing and public-land graziers to illustrate the concept.

Leritz (1987) describes a procedure for successful negotiating. He indicated that negotiating from a basis of scarcity involves three assumptions: There is not enough of the resource, people are greedy, and the best approach is better strategizing. Negotiating from a basis of abundance involves a different set of assumptions: There is more than enough of the resource, people are basically needy not greedy, and understanding is the best strategy. The acceptance of one set of assumptions or the other has a major effect on relationships in negotiations. The former yields negotiations based on fear. The latter yields negotiations based on understanding.

If society can change the negotiation for resources from allocation of scarcity to sharing in abundance, a way can be found to move from limiting peoples' wants through allocation to meeting peoples' needs through abundance of resources. The potential is there. The professional judgment of many range managers is that about two-thirds of the rangelands in the United States are meeting less than half of their perceived potential (Society for Range Management 1989). Obviously, the potential productivity of the Western rangeland is manyfold greater than its current level. This potential for abundance can allow ranchers and environmentalists to find common ground and to reach consensus in improving Western watersheds.

This abundance can be achieved through progressive range management that will meet the needs for all rangeland values. Meeting these needs may well require major changes in current practices; but if a sound ecological and economical foundation is maintained, most problems can be resolved. The time and process involved is a function of the skills of the rancher, the land manager, environmental advisors, and others contributing to an objective-based resources-management program.

If society will move from a primary focus on the current philosophy of scarcity, which controls consumptive and nonconsumptive use and retards enhancement of rangelands, to one of abundance that rewards those uses rather than punishes them, it can increase the amount of land currently being improved.

ABUNDANCE THEORY IN ACTION

Oregon Watershed Improvement Coalition (OWIC)

When OWIC was established in 1986, the prevailing view of those who would become members focused on scarcity of resources. During the first meeting, fear for the future was expressed because everyone knew resources were scarce. At the same time, developers of OWIC realized that the resources about which they were concerned were really abundant—if they were managed so that they would develop to their potential. Together this core group of range professionals, the Riparian Task Force, set out to see if there was a possibility for ranching and environmental interests to communicate on riparian issues.

Formation. The first step in setting up the initial meeting of the group involved determination of criteria for participation and selection of participants. This selection was done by the Riparian Task Force appointed by the Pacific Northwest (PNW) section of the Society for Range Management. The criteria for participation were that participants be leaders on Oregon riparian issues and that they be willing to discuss these issues with an open mind. While representatives of natural resources professions were included, no representatives of government were invited. Achieving balance among the interests was attempted. This balance created a safe environment and thus maximized the opportunity for each participant to express concerns and ideas.

The Riparian Task Force decided to confine participants to Oregon's mainstream environmental interest groups with a national focus, environmental groups with a local focus, and livestock producers. Leaders of selected organizations were telephoned, and the program was explained. Each group was asked to participate in one meeting to identify any common ground and to help develop some communication about riparian issues. Every group contacted agreed to participate and espoused real interest. Initially the group consisted of representatives from the Oregon Cattlemen's Association (five), Oregon Trout (two), Oregon Environmental Council (one), Izaak Walton League-Public Lands Restoration Task Force (one), Oregon Natural Resources Council (one), and the PNW section of the Society for Range Management (four). Later, representatives from the Oregon Forest Industries Council (one) and Oregon Small Woodlands Association (one) were added since the upper portion of most Oregon watersheds is forested, and forest interests are important in dealing with an entire watershed.

During the first meeting, the participants began to recognize the sincerity of the interested parties. The fears and needs of each interest group were explained and recognized. It was decided that common ground existed, and the participants agreed to a second meeting.

Members perceptions were not the same when talking about issues, so the group was kept oriented to the field. Using a field orientation, OWIC members could discuss the issues from a common base of observation. Members agreed to keep the focus of the group on a constructive basis and to focus on the results of good management and how to improve current rangeland conditions. It was agreed not to seek problems but rather to seek solutions to problems. OWIC usually meets for two days, with the first day spent in the field. The purpose is to build understanding among OWIC members on an issue or idea and to provide a basis for future discussion. Every participant is encouraged to speak on some topic at the beginning of every meeting. This structure is important to maintain effective group dynamics. When someone speaks in a group for the first time, it is usually much easier to speak again and to become an active participant in the group. The second day is spent discussing ideas on how to solve problems identified during the previous day's tour and conducting the business of OWIC. This coalition has been actively working since 1986 with an average of five meetings each year.

Principles of Operation. Individuals with an interest in developing natural resources programs based on building consensus often ask, "What makes OWIC work?" Evolution of the group has produced several recognized or passively accepted principles of operation:

1. OWIC shares a common desire to achieve the potential of Oregon's watersheds. Products are secondary. If the potential of the watershed is achieved, the products will follow.

2. OWIC has agreed to seek a common understanding, and common goals are shared.

3. OWIC is a private organization. Those members of OWIC who work for a government agency represent the profession of range management on the coalition. This inclusion of range-management professionals is important to enhance the outreach programs of OWIC in dealing with private lands and private interests on public lands. It also permits each member to represent the interest of the resources independent of any governmental policy.

4. OWIC recognizes that most resource damage of the past and present was not intentional. The

conditions of today are, therefore, accepted without placing blame on anyone for resource destruction. What is important is to implement action to improve resources where needed.

5. OWIC focuses activities on developing programs or ideas for programs in which everyone's needs can be met. This tactic involves approaching rangeland use through a philosophy of abundance and consequently a focus on individual needs not wants.

6. OWIC operates from consensus. Every member of OWIC must agree on a course of action or no action is taken. No issue is discussed if the members do not agree to the discussion. By following this premise, the coalition members are able to maintain the actions of OWIC on a positive, constructive track. Members don't agree on all facets of resource use but do operate where agreement is reached.

7. OWIC is kept field oriented. This allows discussions to focus on real situations rather than on abstractions.

8. In dealing with riparian zones and watersheds, OWIC has focused its attention on inexpensive solutions. Members agree that most of the time improvement in management will bring desired improvement in conditions. Structures are expensive and often are not needed. In fact, when structures are constructed without the appropriate land management to sustain the system, they usually fail to do the intended job.

9. OWIC focuses programs on constructive activities that will improve Oregon's watersheds. When Oregon's watersheds have reached their ecological potential, OWIC will have been successful.

10. Role playing has allowed each of the participants to better understand the position of different interests. In the field, a cattleman might be asked to evaluate a situation observed from the viewpoint of a specific environmental group; or an environmentalist might be asked to evaluate from the view of a timber manager. Through this approach, members have been forced to attempt an understanding of the other person's point of view.

In the final analysis, solutions to Oregon's watershed problems will be found by the application of sound ecological knowledge. Implementation of an ecologically sound program will only be possible if it is practical and, therefore, economical. There is no magic, and there is no quick fix. The land will be improved only through hard work.

FORMAL STATEMENT OF OWIC

Goals and Objectives

OWIC recognizes the multitude of benefits that can be derived from proper management of watersheds that consist of riparian zones and their associated uplands. Benefits from watersheds include wildlife habitat, fish habitat, livestock forage, water storage, aesthetic and recreational values, aquifer recharge, and others. Also recognized is the absolute need to communicate among the varied interest groups to create solutions to Oregon's watershed problems.

Goal

The goal of this coalition is to ensure the long-term sustainability of Oregon's watersheds and to improve communication among the diverse interest groups that affect watershed management.

The approach used to attain OWIC's goal addresses the condition of the entire watershed. OWIC recognizes the ecological relationships among the riparian zone and its associated uplands.

Implicit in the goal is OWIC's desire to develop a healthy, productive environment within its potential, with yield as a secondary output. Yields of all values can be expected to increase if the resource is managed with this in mind. Gains should not be measured solely in a quantitative manner, e.g., kilograms of forage or logs per hectare or number of trout per stream kilometer.

OWIC members view themselves as facilitators not mediators. Compromise and trade-offs are not goals in and of themselves. The concept fostered is that of a healthy watershed, with the resulting effect that everyone benefits. OWIC, through its unique membership, can provide the impetus and support for seeking pathways to develop working programs for sound watershed management.

Objectives

The coalition has agreed on four basic objectives:

1. Provide a mechanism for landowners, land managers, and the public to determine achievable objectives for watershed management irrespective of ownership.

2. Promote recognition that watersheds vary in potential and that the quality of riparian zones is influenced by these differences so that solutions to problems and responses of watershed streams are site specific.

3. Help develop management programs that identify objectives that respond to and are consistent with riparian and upland ecological processes operating in a watershed.

4. Promote a greater understanding of watershed-management potentials and riparian processes by private and public interests through an educational program.

Tasks

During the course of the operation of OWIC, several tasks have been attempted. Currently OWIC is working on four specific tasks:

1. Sponsoring a demonstration showing that environmental, livestock, and timber interests are working toward a common end. OWIC is working with public and private landowners and managers in the Bridge Creek watershed of eastern Oregon to facilitate changing management to improve the total watershed.

2. Promoting advisory groups and helping local advisory groups solve local problems on a watershed basis. Through these efforts, the philosophy of OWIC will be extended throughout Oregon.

3. Supporting education and research. OWIC has developed educational programs and continues to implement additional projects. Members of the coalition maintain close contact with active research institutions.

4. Exploring incentives to promote watershed enhancement. OWIC has helped develop legislation to provide specific funds for watershed improvements. The major thrust is to clearly define the intrinsic ecological benefits of watershed enhancement, with the belief that these benefits are the basis for economic sustainability.

Accomplishments of OWIC

The accomplishments of OWIC are significant. During the past five years, a real change in attitudes among members of the coalition has occurred. To some extent, positions of member organizations have also changed. There is trust and respect among the members. Environmentalists, ranchers, and timber interests share some expressed common goals. Within the coalition, there is honest and true communication. Together members share the confidence that they can help change Oregon for the better.

Members of the coalition continue to teach one another about watershed management from their various perspectives. Together the membership has produced brochures, a common statement of organization, a slide show, and other information to use in teaching members of the parent organizations as well as the public.

In developing the coalition, OWIC avoided developing a bureaucracy. The coalition is private, so it is unencumbered by government policy and regulations. OWIC enjoys excellent cooperation and support from all of the natural resources agencies in Oregon. The coalition is widely accepted in the state and has generated great interest in cooperation to solve resource problems.

Through the efforts of OWIC and in cooperation with many legislators and interested parties, Oregon passed legislation to form the Governor's Watershed Enhancement Board (GWEB). This interagency organization provides incentive funds to encourage improvement of private and public watersheds in Oregon. During the 1989 to 1991 biennium, the state allocated $1 million for education and on-the-ground watershed enhancement.

The project at Bridge Creek is under way, though requiring considerable time and energy for planning, monitoring, and implementing. Without a paid staff, the coalition members often find themselves short of time to fully assist with the ongoing efforts of the project. The land owners and managers are continuing the project with regular communication from the project committee of the coalition. The OWIC contribution was to stimulate action and provide access to needed technical assistance.

OWIC has developed a good foundation upon which to build. The organization's members have been through difficult times and have attempted to solve difficult problems but have remained together. OWIC has learned that ranchers, environmentalists, and timber managers can work together in constructive ways. OWIC has helped neighboring states, such as California, Washington, Idaho, Utah, Wyoming, and Colorado, to understand, evaluate, and work toward developing similar organizations that reflect the special circumstances in each state.

The success of OWIC in demonstrating that communication and agreement between ranching and environmental interests are possible has prompted its members to address large-scale problems and opportunities in Oregon. Members of OWIC have joined with agency, ranching, and environmental interests in dealing with a difficult range-management problem in the Trout Creek Mountains of southeastern Oregon. The Trout Creek Mountains Working Group has moderated a conflict that was heading toward litigation (and no change on the land) and changed the result to one of agreed-upon resource use (and positive changes on the land). The moral is that land can improve only through thoughtful, ecologically sound management. Laws alone will not bring about a general improvement in land condition. People can enhance the land with the right incentives, but there is not enough time or money to sue everyone. The Trout Creek Mountains Working Group grew out of such a problem. The group has been effective in producing profound grazing-management changes on several hundred thousand hectares of a sensitive watershed. These management changes have all been voluntary. The Trout Creek Mountains Working Group is cautiously optimistic that the management changes will produce long-term ecological successes.

The Central Oregon Natural Resources Coalition (CONRC) is another example of a consensus group that brings several interests together to foster a community vision of responsible and proper land use. This group is confident that it will enjoy the abundance of the rangeland resources in central Oregon and will fully meet or exceed everyone's needs. CONRC is an action group—made up of private landowners, land-managing agencies, resources agencies, environmental leaders, and a few technical advisors—that is planning integrated use of an area of several hundred square kilometers. The broad vision is established and all participants are working toward common goals. These goals will mean intensifying commercial uses in some areas, setting other areas aside as preserves, focusing on wildlife as a primary product of some private and public land, and coordinating it all so that the needs of the various groups are met. The group has been operational for more than a year and has completed the first phase of a general-vision consensus. In this consensus document, the participants of CONRC have written their expectations of what the land should be like. The first coordinated resources management plan involving more than 250,000 hectares of public and private land was completed. This plan represents the first action step toward meeting the vision of CONRC for the total area. A massive coordinating effort has brought agreement between environmentalists and ranchers as they plan to achieve the potential of their resources and share the abundance from these resources. Each group will operate differently on private and public lands.

THE FUTURE

OWIC provides a model forum for building understanding and for networking among individuals with diverse needs and beliefs. Action-oriented consensus groups, such as the Trout Creek Mountains Working Group and the Central Oregon Natural Resources Coalition, are in part logical extensions of the OWIC philosophy.

By approaching natural resources negotiations with a philosophy of abundance and by opening communications among rural and urban citizens with common interests in the land, it is possible to come to a common understanding of site-specific land use. By sharing information and by working from common information, the possibility to work together to achieve the potential of the range increases. Everyone must come to recognize the truth as perceived by others, to understand that truth, and to work together to realize the potential abundance of the West. When this philosophy is followed, plans for the future—based on broad consensus—can indeed meet everyone's needs when founded on a healthy resource.

REFERENCES

Ferguson, D., and N. Ferguson. 1983. Sacred cows at the public trough. Maverick Publications, Bend, Ore.

Godfrey, E. B., and C. A. Pope III. 1990. The case for removing livestock from public lands. Pages 6–23 *in* F. W. Obermiller and D. Reesman, eds. Current issues in rangeland resource economics: A series of papers written by members and associates of Western Regional Coordinating Committee 55 "Rangeland Resource Economics." Oregon State University Extension Service Special Report 852, Corvallis.

Leritz, L. 1987. No-fault negotiating: A simple and innovative approach for solving problems, reaching agreements and resolving conflicts. Pacifica Press, Portland, Ore.

National Cattlemen's Association. 1989. Strategies plan on the environment. Mimeo. Denver, Colo.

Society for Range Management. 1989. Assessment of rangeland condition and trend of the United States. Society for Range Management, Denver, Colo.

Copies of *Natural Resources and Environmental Issues* are available from the S. J. and Jessie E. Quinney Natural Resources Research Library, College of Natural Resources, Utah State University, Logan, UT 84322-5260. Single issues are $20.00 in the United States and $25.00 elsewhere. Please make payment with a check, money order, or purchase order, payable in U.S. dollars to the Quinney Library. EIN: 87-6000528

Vol. I	Riparian Resources. Edited by G. Allen Rasmussen and James P. Dobrowolski. 1994.
Vol. II	Mapping Tomorrow's Resources. Edited by Allan Falconer. 1993.
Vol. III	Conflicts in Natural Resources Management. Edited by Joanna Endter-Wada and Robert J. Lilieholm. 1994.

Acknowledgments

Although the series *Natural Resources and Environmental Issues* (*NREI*) officially began publication in 1993, its intellectual and conceptual beginnings predate the physical publication by many years. The College of Natural Resources envisioned a publications center for its library when the library was only an idea. In 1992 the library was dedicated, and its new staff moved rapidly to create reality from vision. The process could not have been completed without the participation of many different individuals. At this time, I would like to acknowledge those who have helped in the establishment of the Library Publications Center and the new series borne of it, *Natural Resources and Environmental Issues.*

Because of the vision of the S. J. and Jessie E. Quinney Foundation of Salt Lake City, the idea of a library within the College of Natural Resources at Utah State University (USU) became a reality; and because of the vision of Joseph A. Chapman, dean of the College of Natural Resources, the concept of a publications center was included in the development of that library.

The technical information and assistance needed to begin and to continue this publication have come from many sources. First, there are the planners of the College of Natural Resources Week Symposiums, who provided the intellectual content by bringing together people to share information disseminated first in presentations at the annual symposiums and then between the covers of this publication series. Also, I want to acknowledge Dale Smith, Office of Publication Design and Production at USU, who explained patiently the ins and outs of paper and printing requirements; Linda Keith, University Editor at USU, who proofread this volume; and Amy Lyn De Zwart, staff editor for the Library Publications Center, who brought continuity to this volume and will continue to do so for this series. Many thanks to each of you for your individual contributions, which have made this project a reality.

As a novice in the publishing field, I found many ideas and questions continually posing themselves. Special thanks go to Humanities & Sciences Associates and their director, Robert A. Heister, for numerous consultations and expert advice throughout this long and arduous process.

Carla G. Heister
Director, S. J. and Jessie E. Quinney Natural Resources Research Library

UTAH STATE UNIVERSITY