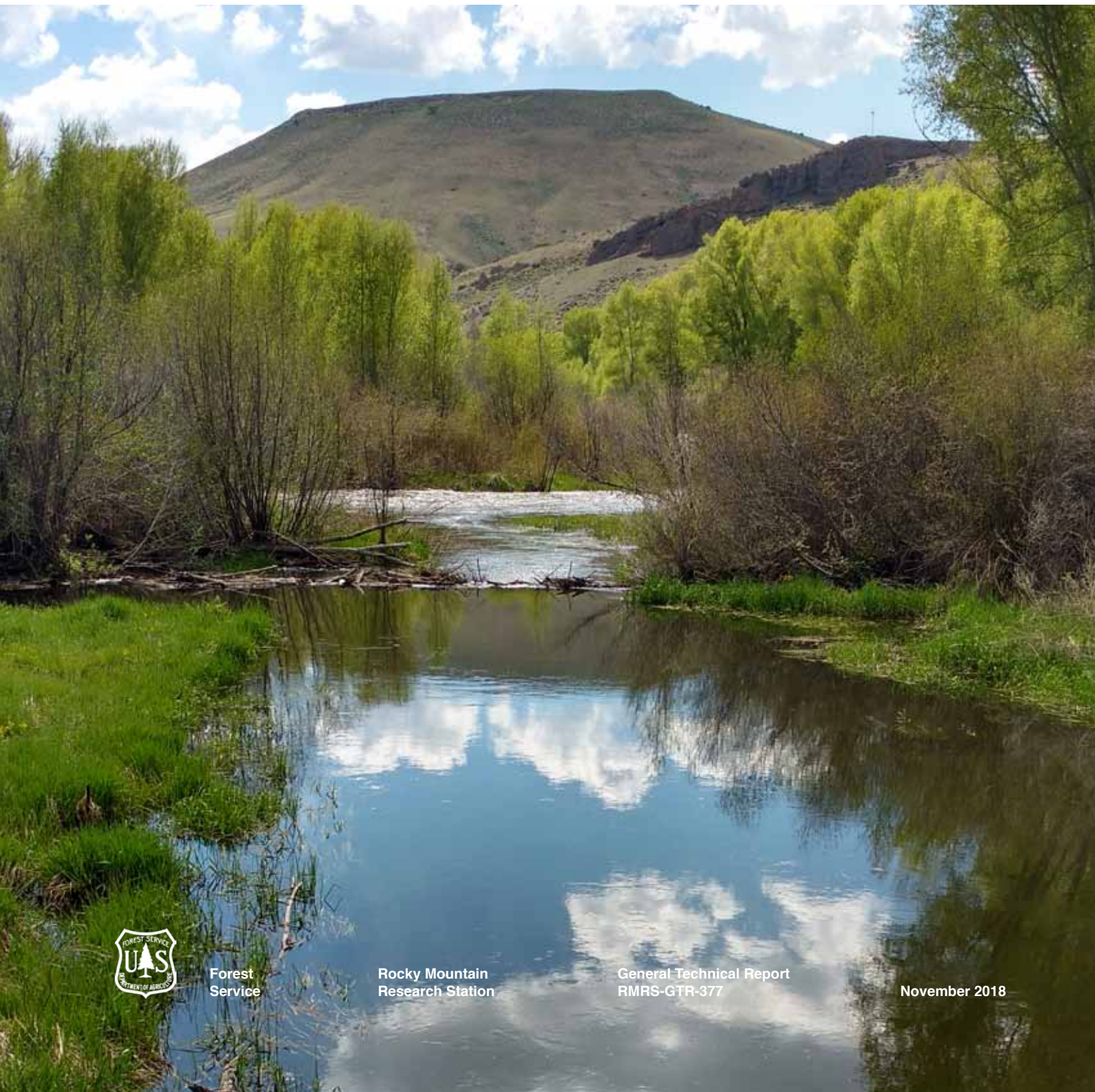




Riparian Research and Management: Past, Present, Future: Volume 1



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Abstract

Fifty years ago, riparian habitats were not recognized for their extensive and critical contributions to wildlife and the ecosystem function of watersheds. This changed as riparian values were identified and documented, and the science of riparian ecology developed steadily. Papers in this volume range from the more mesic northwestern United States to the arid Southwest and Mexico. More than two dozen authors—most with decades of experience—review the origins of riparian science in the western United States, document what is currently known about riparian ecosystems, and project future needs. Topics are widespread and include: interactions with fire, climate change, and declining water; impacts from exotic species; unintended consequences of biological control; the role of small mammals; watershed response to beavers; watershed and riparian changes; changes below large dams; water birds of the Colorado River Delta; and terrestrial vertebrates of mesquite bosques. Appendices and references chronicle the field's literature, authors, "riparian pioneers," and conferences.

Keywords: riparian, ecosystem, ecology, riparian processes, restoration, aquatic, arid, semi-arid, upland, freshwater, groundwater, hydrology

Front cover: A backwater with beaver dam along the Gunnison River at Neversink, Curecanti National Recreation Area, Gunnison County, Colorado (photo by Kenneth J. Kingsley).

Chapter 2. Development of Riparian Perspectives in the Wet Pacific Northwest Since the 1970s

Frederick J. Swanson and Stanley V. Gregory

Introduction

Streams and riparian zones have been fertile ground for ecosystem science and a battleground for forest policy and management in the wet Pacific Northwest west of the crest of the Cascade Range for many decades. Competing, high-value resources of salmon and big Douglas-fir timber and their iconic places in cultures of the region sharpened the clash of values. Landslides from forestry operations and roads and elevated water temperature in streams where forest cover had been removed were points of physical connection between steep slope forestry and cold-water fishes. Logging slash from harvest operations had dammed streams and depleted dissolved oxygen, leading fisheries agencies and advocates to call for removal of wood from streams in the 1950s and 1960s.

In the decades since, science has played important roles in characterizing ecosystem components and dynamics and in identifying issues and management options. Social conflicts have propelled the science forward. In this essay, we offer a brief historical overview of steps in the development of concepts about riparian zones in this region and societal context from the perspective of the large, interdisciplinary science team—the Stream Team—based on the Oregon State University campus in Corvallis and at the H.J. Andrews Experimental Forest in the Willamette National Forest east of Eugene. Team members come from the University, Forest Service research and land management branches, and other institutions; and the participants have roots in stream ecology, fisheries and forest science, geomorphology, and other fields. The nucleus of the Stream Team has been large research programs—the International Biological Program in the 1970s and the Long-Term Ecological Research program since 1980, both supported by the National Science Foundation and the Forest Service, and based in Oregon State University. Important work occurred elsewhere in the region, most notably based in Seattle in fisheries and forestry research, and outreach programs based at the University of Washington (e.g., Naiman et al. 2005), but we do not attempt to cover that work in this chapter.

An apparent contrast in the perceptions of riparian zones between the dry interior west and the wet Pacific Northwest west of the crest of the Cascades may stem in part from the contrasts in the stature of vegetation. Riparian zones in many arid lands can be conspicuous as lush stands of shrubs and scattered trees in a sea of knee-high sagebrush. Westside conifer forests, on the other hand, can be 70+ m tall, dwarfing streamside willow (*Salix* spp.) and red alder (*Alnus rubra*) stands and creating continuous forest canopy from stream banks to ridge. Westside forest ecologists naturally focused their science on the interactions among forests, streams, and riparian zones. In the case of the

Andrews Forest team, stream ecologists pressured the forest scientists to extend their work down into the riparian zone.

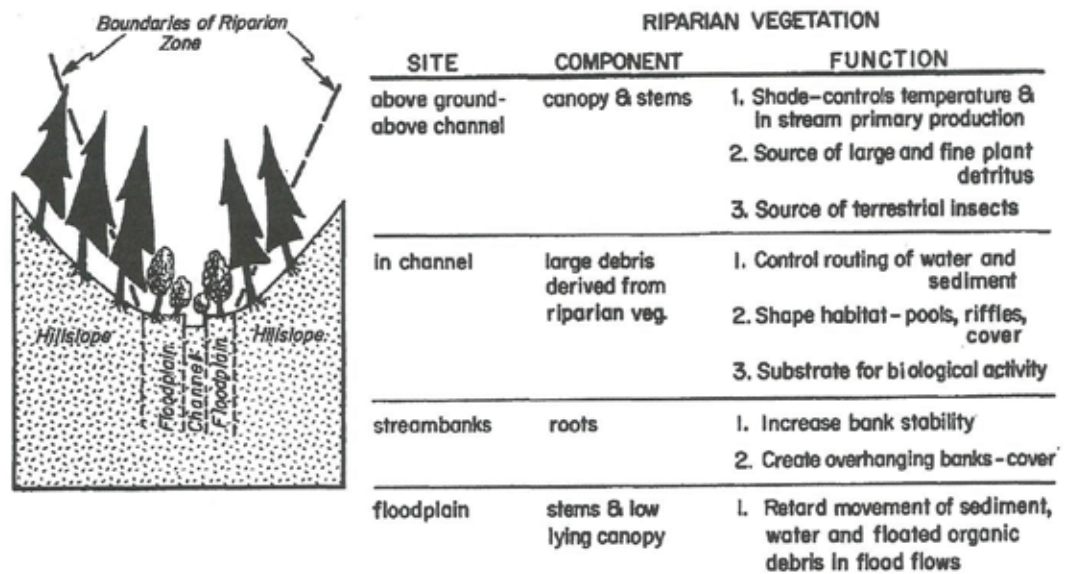
The evolution of thinking about riparian zones in the Andrews Forest team was the gradual awakening to the many interactions between forests and streams. Driven by both science and policy questions, big wood in streams became a pivotal issue in the mid-1970s. The policy question: Should loggers be required to remove wood from streams to provide for fish passage and limit biological oxygen demand? The science question: What does big wood contribute to the geomorphic structure, organic matter and nutrient budgets, and overall functioning of stream ecosystems? The history of logging slash and stream management often is characterized as, “First they told us to take wood out of streams and now they are telling us to put it back. When will those darn scientists change their minds again and tell us to take it out again?”

But, the management history was more nuanced; early rules called for leaving the pre-existing wood in streams and removing only logging debris. The pendulum swung from having too much wood in streams—especially readily mobilized logging slash—to removing too much wood from streams, especially wood of a natural size distribution, including big, stable pieces. The arguments about how much wood is appropriate continues, but the general thread of the story is that wood is a natural part of stream systems so policy now sustains that function through direct intervention in streams and management of riparian forests for future wood supply. The big wood connection between forest and stream turned out to be vital to the interdisciplinary spirit of the science team—the work required integrating the perspectives of stream and forest ecologists and geomorphologists.

By the latter half of the 1970s, the Andrews group had made substantial progress on their studies of nitrogen and organic matter budgeting (Triska et al. 1984), addressing both processes and standing stocks of materials all with attention to how forests affect streams. A succession of papers (in chronological order: Cummins 1975; Meehan et al. 1977; Swanson et al. 1982; Gregory et al. 1991) developed the thinking about forest-stream interactions in terms of regulation of light levels influencing primary productivity, water temperature, fish foraging efficiency, and other processes. Also summarized in figure 1, the roles of forests in supplying organic matter range from fine litter to whole old-growth trees that shape stream channels, provide cover, and provide substrates for biological activity. This evolution led to the notion of defining riparian zones in ecosystem terms as the zone of interaction rather than on the basis of hydrologic, botanical, or soil considerations (Gregory et al. 1991). Unlike lowland fluvial systems with well-defined floodplains, hydrologic criteria do not work well in steep mountain streams with their high levels of topographic complexity imposed by boulders, big wood, and narrow valley floors.

Botanical criteria have limitations in part because the great stature of vegetation means that trees distant from the stream can have important influences. Studies of riparian vegetation have been rather limited in these mountain environments. In the Andrews Forest, for example, in 1979 and 1990 forest ecologists established several large (2–2.4 ha) stem maps straddling streams of different size, but it took some years and a major flood to develop a record of sufficient length to reveal the disturbance dynamics of the riparian system (Acker et al. 2003). Hydric soils criteria for defining riparian

Figure 1—Forest-stream interactions as a basis for defining the riparian zone, as viewed in 1978 (source: Meehan et al. 1977, public domain).



systems in the forest setting are far too narrow and fail to encompass the terrestrial-aquatic interactions that strongly influence stream ecosystems.

Also, during the late 1970s, the highly influential River Continuum Concept (RCC) project was in full swing (Vannote et al. 1980, which had been cited more than 8,300 times as reported in Google Scholar as of 22 March 2017). A national program led by Robin Vannote of the Stroud Water Research Laboratory in southeastern Pennsylvania explored concepts of how forest influences on stream ecosystems varied from small headwater streams to large rivers. As the stream widened downstream, more light reaches the channel, so food resources for aquatic organisms shift from productivity driven dominantly by forest litter to in-stream primary production. A cascade of ecological consequences follows, including shifts in composition of the aquatic invertebrate community from one that processes organic inputs from the surrounding forest to grazers that process algae and diatoms produced in the channel itself. Many other aspects of the stream ecosystem, including big wood, were examined at four stream sizes from first- to seventh-order channels. The Andrews Forest was one of four study areas in the RCC project scattered across the country. This work helped place stream ecosystems in a landscape context by explaining variation along the longitudinal profile of the stream system. The RCC also argued for connectivity through the stream network via the influence of upstream areas as sources of nutritional resources for downstream rivers and floodplains.

A key feature of the Andrews Forest program has been its close partnership with land managers of the Willamette National Forest. Preparation of the forest management plan culminating in 1990 included a prime example of that partnering in the form of a 65-page supplement for stream and riparian management guide authored by two researchers working in collaboration with National Forest personnel (Gregory and Ashkenas 1990). This guide affirms the many important ecological functions of riparian zones, the policy direction to sustain them, and the necessary management standards and guidelines in the context of a full watershed perspective. The collaborative approach has been mutually beneficial; researchers bring the most up-to-date science and the land managers bring a great deal of real-world experience plus exposure to the competing

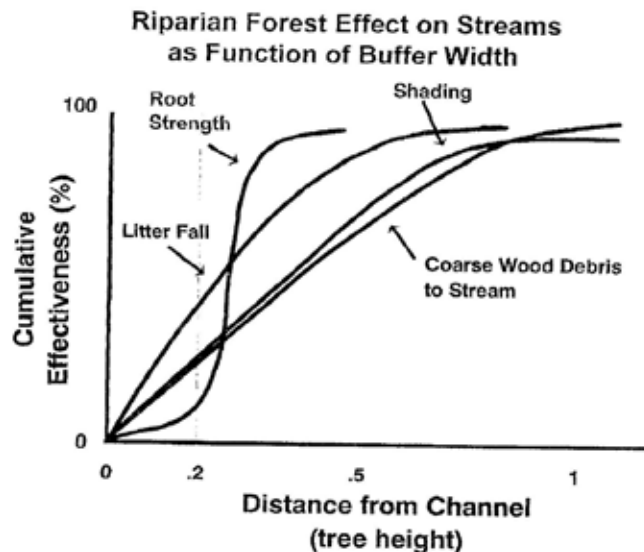
values within society. Therefore, the ultimate plan has the best chance to be credible on science, societal, and operational fronts.

This sense for integrating science and land management practices was valuable a few years later during the Forest Ecosystem Management Assessment Team (FEMAT) process convened by President Clinton in April 1993, to move beyond the injunction that Judge Dwyer had leveled on logging on Federal lands in the range of the northern spotted owl—10 million hectares along the Pacific Coast (FEMAT 1993). The FEMAT process set the path to the Northwest Forest Plan (NWFP) signed by the secretaries of Agriculture and Interior in 1994. A synthesis of some of the findings from Andrews Forest science and other sources was encapsulated in a figure that helped shape thinking about width of riparian reserves to maintain many functions of streamside forests within cutting units (fig. 2).

This conceptual framework was a dramatic departure from the policy debates about riparian buffer widths over the previous 20 years. One of the first questions that emerges in riparian zone management is: How wide should buffers be? Most discussions focused on uniform distances from the streams edge based on the operational willingness to forego some or all timber harvest within that distance. The Riparian Reserves of the NWFP designed riparian widths based on site-potential tree heights (the height of an average tree in late succession stage of stand development). As a result, riparian zone widths were conceived as varying among areas with different forest composition and site productivity. Riparian reserve widths could also be variable and shaped to local topography and potential interactions with the stream. As a result, riparian management areas were ecologically defined and based on the overall landscape rather than the tape measure.

The fixed-width riparian reserves prescribed in the Matrix land allocation of the NWFP, where some logging was to be permitted, were expected to be modified after “watershed analysis” provided a comprehensive, watershed-wide view of biotic and geomorphic conditions that might motivate widening or narrowing of the reserve widths. However, these modifications did not occur in most areas for a variety of reasons.

Figure 2—Effectiveness of streamside forest in providing litter fall, root strength in streambanks, shading, and large wood to the channel as a function of distance from the channel as measured in proportion of tree height (source: FEMAT 1993, public domain).



The NWFP also charged the research-management partnership team based at the Andrews Forest with developing a landscape management plan based on the historic wildfire regime. This ecosystem-dynamics approach to landscape planning, developed as the Blue River Landscape Plan, contrasts with the species-specific conservation approach that dominates the NWFP (Cissel et al. 1999). A key part of the Blue River plan is to consider the frequency and severity of disturbance in the uplands as well as the streamside forest when managing for aquatic conservation objectives consistent with the historic disturbance regime. Several timber sales in native, mature-age-class (ca. 150 years) forests that are part of implementing and testing the plan are completed, but further implementation has been stopped with the region-wide cessation of logging accomplished by environmentalists over the past 20-plus years. Despite the management outcomes, the multi-discipline, multi-scale research carried out at the Andrews Forest in past decades proved to be an important part of the foundation for both the local plan and the regional conservation strategy of which stream and riparian networks are a vital part.

Even as input to policy and management proceeded, research efforts were gaining new insights to the complexity of riparian systems. Several decades of study have revealed secrets of the hyporheic system—the down-valley, subsurface flow of water beneath the streambed and within the valley-floor alluvium that experiences periodic exchange with surface waters (Wondzell and Swanson 1996). The hyporheic system facilitates interaction of surface water with root systems of riparian vegetation, which in the westside Pacific Northwest often includes red alder, a nitrogen-fixing species. An isotopic nitrogen tracer study revealed that some nitrogen in streamwater can actually flow upward into the terrestrial system via a pathway beginning as hyporheic flow is taken up by riparian plants, which incorporate the dissolved nitrogen in streamwater into foliage, which is then consumed by herbivorous invertebrates fed upon by birds that integrate with the terrestrial food web (Ashkenas et al. 2003).

Given the ever-changing perceptions of riparian systems prompted by new science, new tools, and biophysical and social disturbance events, we are confident that the next generation of students of riparian zones will make many interesting discoveries of forest-stream interactions at micro-site to large watershed scales. We often wonder: What is it that is right in front of us now that we cannot see—just like the fallen logs we tripped over in the early 1970s until recognizing their importance and building much of our science careers around them? Young scientists and land managers beginning their careers have exciting opportunities for discovery in riparian systems.

Acknowledgments

We write this as a shared, personal essay, with a sense of great gratitude to many wild, wonderful, and too-numerous-to-name colleagues of the Stream Team based on the Oregon State University campus over the decades. Decades of funding and other forms of institutional support of NSF, OSU, and USFS Pacific Northwest Research Station are deeply appreciated. We dedicate this essay to the memory of Jim Sedell, our inspiring friend and colleague whose ashes are now part of biogeochemical system associated with Mack Creek in the Andrews Forest; his ideas live on as well. Jim loved rivers and worked for their betterment in many capacities while working in academia, government research, corporate, and NGO sectors.

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Foreword

The availability of drinking water is the paramount environmental issue of the 21st century in the western United States and especially in the Southwest. Growing populations in Albuquerque, Phoenix, Tucson, Las Vegas, and Southern California are already testing water supply and delivery infrastructure in the face of just a moderate drought. Conservation in major cities and innovations in agriculture have greatly reduced per capita and per acre water use over the last 15 years, providing a margin of security to water supplies. But as populations continue to grow, it's important for the people of the Southwest to reflect upon and confront the stresses caused by modest drought. Now is the time to collaborate to develop responses and put in place coordinated systems that can handle deeper drought, reduced water availability, and greater variability in precipitation predicted in upcoming decades.

Water delivery in the arid Southwest relies on the connection of forests, particularly the National Forests, to water storage facilities and eventually the faucets in our homes. The National Forests are a small part of the watershed, but they are disproportionately where rain and snowfall can become the water supply the system relies upon. Forests, streams, and riparian areas are the green infrastructure that captures, stores, and releases water, which is then delivered to our cities through the dams, canals, and pipelines we've built in support of our daily lives. Without the water supply provided by the green infrastructure, the built infrastructure is useless.

Just as the built infrastructure has been recently tested by drought, the green infrastructure is now being tested by fire and land use practices. Can the green infrastructure reliably provide human communities drinking water, wildlife habitat, and other critical ecosystem services? Can riparian ecosystems in particular produce the expected level of services as populations increase, and the climate changes, with the Southwest becoming both warmer and drier? Healthy riparian systems are linchpins connecting land and water, and they are integral to future water availability. This compendium of research on riparian areas could not be timelier or address a more essential need in the West.

In the past couple of decades, researchers, land managers, and regulators have focused on the holistic management of ecosystems, watersheds, and meeting the needs of human communities, while still addressing individual species, habitat components, and services. Community leaders and land managers have also embraced collaborative planning and cooperative solutions across broader landscapes. They have worked in a more inclusive manner to look past previous polarized thinking to see shrinking streams and riparian systems and value them beyond managing for individual interests. This publication, guided by the inseparable nature of streams and riparian ecosystems, emphasizes the interrelationships and continuity of riparian areas along with dependent wildlife and human services.

The scientific papers in this General Technical Report continue the long, demanding, and now urgent task of conveying scientific information on riparian systems, organisms, and their human interactions to give the reader a better sense of the history, conditions, and working of these resources, along with potential solutions for today's challenges. This report represents the current state of knowledge and points to some essential steps for connecting science, management, and politics for the restoration and sustenance of riparian ecosystems in the West and the sustainability of the human communities that depend on them.

Calvin Joyner
Regional Forester
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Preface—The Western Riparian Project

“You can’t talk about streams without talking about riparian ecosystems.”

(David L. Rosgen, Leader in Stream Classification and Stream Restoration; Western Riparian Project Science Advisor)

“Most impacts are insidious and cumulative.”

(Christopher C. Estes, At-Large Director, Instream Flow Council; Western Riparian Project Science Advisor)

The Western Riparian Project (WRP) is a riverine project with emphasis on riparian ecosystems in western North America. Our objectives are:

- To review the historic needs for and beginnings of the science of riparian ecology;
- To assess the current state of riparian research and management; and
- To lay a foundation for the planning of conservation and research activities.

To attain these objectives, the WRP consists of two basic parts: (1) publishing a General Technical Report of selected papers that review the past 50 years of research and management activities to be distributed electronically and in print, and (2) convening a conference with invited speakers consisting of many of the report chapter authors. A conference is planned near the time of the release of this General Technical Report. Speakers will be selected by the Steering Committee. This General Technical Report is to be issued by the Rocky Mountain Research Station of the Forest Service, U.S. Department of Agriculture, in two volumes. More than 50 scientists from Mexico to Alaska contributed to this effort, which covers a broad spectrum of issues from “phreatophyte control” to current and future impacts of the newly introduced tamarisk beetles (*Diorhabda* spp.) on naturalized and native riparian ecosystems. The effort also covers implications of global climate change for riparian habitat restoration and conservation.

This discussion of riparian ecosystems uses a watershed approach that recognizes connectedness of the entire water-driven continuum, from atmospheric moisture to instream flows and groundwater. The term “riparian” is used to describe a range of conditions:

Wet riparian ecosystems (hydroriparian and mesoriparian) associated with lotic waters—on the banks of flowing and intermittent streams. These range from the Rio Grande, Colorado, Gila, and Sacramento rivers, some of the nation’s largest rivers, to the Salt, Bill Williams, and San Pedro rivers, southwestern streams that are perennial in the upper portions of their watersheds but become intermittent downstream.

- Ecosystems associated with lentic waters—on the shores of lakes.
- Xeroriparian ecosystems—along banks of usually dry ephemeral streams such as desert washes.

In short, we are concerned with biotic and abiotic factors related to biologically available water. Our watershed approach emphasizes both the instream flow model of connectivity as well as the connectedness of the hydrologic cycle. Our motto, “You can’t talk about streams without talking about riparian ecosystems,” acknowledges the importance of healthy riparian ecosystems to the health of a stream. This motto is also reversible, i.e., “You can’t talk about riparian ecosystems without talking about streams,” thereby acknowledging the interconnectedness of water and instream flows to riparian ecosystems. Thus, aquatic ecosystems and instream flow characteristics are considered an integral part of the riparian story. This approach emphasizes connectivity in time and space as proposed by the Instream Flow Council—longitudinal, lateral, and vertical space—and the natural hydrograph, addressing the temporal factors of seasonality.

The connectedness of water is conceptualized as the hydrologic cycle, often referred to as “the water cycle,” detailing the movement of water from the earth’s surface into the atmosphere, through evaporation, and finally back to the earth’s surface as precipitation, much of it then percolating underground. In riverine systems, biotic and abiotic factors associated with aquatic and riparian ecosystems, and even interconnected upland ecosystems, are inseparably linked in a feedback loop related to water and instream flows. A thorough analysis of these systems requires information from ecology, hydrology, geomorphology, biochemistry, and a multitude of related disciplines.

We use the term “regeneration” to include both natural reestablishment and humanly assisted restoration of riparian habitats, while “restoration” is generally used only to indicate intentional human-induced changes. Our project includes

practical field applications for riparian ecosystem restoration and riparian zone management as well as observations of naturally occurring habitat reestablishment as evidenced by natural revegetation and wildlife repopulation of recovering riparian areas. We include these findings with the goal of encouraging integration of riparian ecology and wildlife conservation with the routine operations of land and water resource management agencies at all levels of government as well as non-governmental groups.

The geographic area to be covered in this phase of the project extends from California eastward to Trans-Pecos Texas and adjacent northwestern Mexico and from there, northward, to the Pacific Northwest but emphasizing the more arid and semi-arid regions of the West. Our reason for emphasis on this region is the suite of biophysical differences compared to regions of the eastern United States. We particularly emphasize the Rio Grande, Colorado, Gila, and Sacramento-San Joaquin watersheds because of the extensive change effected by anthropogenic activities in their riparian and aquatic ecosystems. In addition, a great deal of research, related to regeneration and restoration, has been and continues to be conducted along these rivers.

This General Technical Report is the book part of the Project and covers three primary topics:

- Review of the development of the science of riparian ecology, the history of riparian research, and the riparian movement in the region from their beginnings in the 1960s until the present;
- Determination of the current status of research and of riparian ecosystem conditions, in relation to ongoing management actions (e.g., biological control of *Tamarix*); and
- Evaluation of needed research studies and management actions in response to climate change and future water resource development.

Chapters in the book are designed for widespread applicability to particular riparian issues, examining each topic as it pertains especially to the region. A philosophical and practical approach to these issues is presented with examples of specific projects used to illustrate wider scale concepts. Chapter authors for the book have been selected because of first-hand field experience as well as a robust publication record and/or reports of successful accomplishments. Most of the participants have a long-time record of involvement in research and/or conservation of riparian ecosystems.

We consider this the most comprehensive publication yet produced on riparian ecosystems. Unlike most previous efforts, our focus is on examining watersheds as a whole to facilitate regeneration of sustainable riparian ecosystems now and into the future. Unlike most previous riparian literature that primarily presents a series of reports on specific projects, here we use project reports only as illustrations of larger scale riparian issues. We hope that this endeavor will serve to inspire and support continuing and future efforts in the study, protection, and restoration of our western riparian resources.

R. Roy Johnson
Steven W. Carothers
Co-Directors

Acknowledgments

This is the first of a two-volume technical report on riparian habitats in the western United States. The idea for this series of technical reports was an outgrowth of what is now recognized as The Western Riparian Project, a project initiated by a group of riparian ecologists and resources managers, all of whom have decades of experience in the biological aspects of riparian habitat productivity, management, and conservation. The Western Riparian Project is in its sixth year and has benefitted from participation by more than 50 scientists who have collectively spent thousands of uncompensated hours to ensure the success of the Project. Several of us have been involved with riparian ecology since the earliest days of its establishment as a science beginning in the late-1960s. The idea for the project originated Thanksgiving week, 2012, during a three-way conversation in Yuma, Arizona, between Karen Reichhardt, Bureau of Land Management, Elaine Johnson, U.S. Fish and Wildlife Service, and R. Roy Johnson. Reichhardt and E. Johnson had been involved in our Arizona Verde River riparian habitat avian field studies almost 50 years earlier (Carothers and Johnson 1970; Carothers et al. 1974; Johnson 1971). Now, they suggested it was time to examine the progress made in western aridland riparian ecology and conservation since those early studies.

As the idea for a book on the status of southwestern riparian habitat began to fully develop, and we began to focus on what we know, what we don't know, and what we still need to know about the remarkably productive riparian habitats in western North America, we naturally revisited the primary literature on the subject and began searching for potential chapter authors. Most of the authors of the chapters in this General Technical Report (GTR) have spent decades attempting to document the importance of conserving and managing riparian habitats due to their disproportionate value to wildlife and people compared to upland habitats.

The Project began in earnest in June of 2014 when 19 Project participants attended a 2-day workshop at the Museum of Northern Arizona, Flagstaff. Workshop attendees were from as far as Alaska—Christopher Estes, At-Large Director of the Instream Flow Council; New York—Jon Kusler, Associate Director, Association of State Wetland Managers; Oregon—Suzanne Fouty, USDA Forest Service; Colorado—Robert Hamre, retired, former Leader, Research Information Group, USDA Forest Service Rocky Mountain Research Station, Fort Collins, Colorado, who had previously issued proceedings of several riparian conferences; Utah—Dale A. Jones, co-editor of the nation's second riparian conference (Johnson and Jones 1977) and retired Director of Wildlife, Fisheries, and Endangered Species, USDA Forest Service, Washington DC; and California—F. Thomas Griggs, River Partners.

Travel to the workshop and additional funding was provided by SWCA Inc. Environmental Consultants, Phoenix, Arizona, and local arrangements were made by Larry Stevens and Jeri Ledbetter of the Museum of Northern Arizona. In addition to many of these participants being involved in ongoing riparian studies, a sense of the history of the development of riparian ecology prevailed at that meeting. Six of the 19 workshop attendees had been directly involved in the aforementioned Verde Valley riparian studies of the early 1970s: Steve Carothers, Christopher Estes, Elaine Johnson, Kenneth J. Kingsley, Larry Stevens, and R. Roy Johnson. Two of the workshop attendees had helped to provide funding for those early studies: Bud Bristow, then with Arizona Game and Fish Department, and Dale Jones of the USDA Forest Service. Besides those already recognized, we have been fortunate to have scientists and managers of many agencies, universities, and NGOs associated with riparian and related issues involved in the Project. Without their input, this work would not be complete. This includes Duncan T. Patten, founding President of The Arizona Riparian Council, the nation's first State riparian council; and three of the five founding board members of the Society for Ecological Restoration (SER): John Reiger, Founding President, John T. Stanley, and Anne Sands, SER Board Members. Anne also served as a co-director of our project during 2013 and 2014.

Critical assistance has been rendered on an assortment of issues throughout the project by members of our Science Advisory Board, including Exequiel Ezcurra, Director, Institute for Mexico and the United States, U.C. Riverside, CA; Stefan Lorenzato, Coordinator of the California Riparian Habitat Joint Venture, an association of 18 government and NGOs involved in protecting and enhancing riparian habitat; Daniel and Ellen Plunkett, founders of the 7,200 Acre Doris Wilderness sanctuary, Belize; Ann Riley, member of the California State Water Quality Control Board; David Rosgen, leading authority and practitioner in stream classification and restoration; Bo Shelby, leading researcher on issues related to recreation in riparian habitats; and Robert Webb, hydrologist, and one of the leading experts on the Colorado River in Grand Canyon.

In addition to appreciation for our co-editors (Deborah Finch, Kenneth Kingsley, and John Stanley), Bob Hamre deserves special mention for untold hours spent editing most of the GTR chapters, including several renditions of some chapters. Additional reviewers included Dale A. Jones, Duncan T. Patten, Harley G. Shaw, and Patricia M. Woodruff. Deborah Finch assisted throughout the project and with the review process by "loaning" us several USDA Forest Service employees working for the Forest Service Southwest Regional Office and Rocky Mountain Research Station, including Katelyn P. Driscoll, Roy Jemison, Ernest Taylor, and F. Jack Triepke. We also thank David L. Hawksworth, of the Rocky Mountain Research Station, for help in reviewing the overall manuscript for formatting errors. Space prohibits us from thanking all of the authors, individually, of the various chapters but their affiliations can be found in this GTR's front matter. Finally, we thank Cal Joyner for writing the insightful Foreword to the report.

R. Roy Johnson and Steven W. Carothers

Co-directors

The Western Riparian Project

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