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and storage of sediment. Preventing sediments from reaching aquatic environments both reduces erosion and water turbidity and preserves sustainable habitats for fish and other aquatic animals.

The second category of riparian activity is preventing contaminants, such as the fertilizer sometimes contained in runoff water, from entering and polluting the adjoining river or stream. Slowing the flow of runoff water allows for purification within riparian soils. This biological remediation reduces the need for more expensive remediation tactics.

The third critical category of riparian activity concerns the support of aquatic and terrestrial habitat diversity. Numerous bird and fish species are dependent on riparian habitats for entire or significant portions of their life cycles. In addition to animals, many species of amphibians, reptiles, and arthropods – the aquatic insects that birds and fish eat – require healthy riparian habitats to complete their life cycles.

Riparian habitats have a direct and significant effect on both the production and quality of our fresh water supplies. National Forest System (NFS) lands contribute nearly 20 percent of the nation's water supply. In the relatively arid western states, NFS lands produce over 50 percent of the region's water supply. The total economic value of high-quality fresh water flowing from NFS lands exceeds \$7.2 billion annually. The long-term sustainability of this important economic and recreational resource depends on attentive monitoring and ongoing restoration and conservation efforts.

Nearly 75 percent of our nation's outdoor recreation – including fishing, hiking, and viewing wildlife – takes place within one-quarter mile of streams or other bodies of water. Each year, more than 46 million people visit the National Forests to fish. Supporting fishing interests, while producing over \$2 billion in expenditures, also

provides 51,000 jobs and generates more than \$264 million in federal taxes. As Forest Service Chief Kimbell often mentions, establishing personal connections to our nation's forests helps us appreciate their biological and aesthetic importance and encourages conservancy.

The ultimate effects of climate variability on riparian habitats and their associated NFS watersheds are largely unknown at this time. In some parts of the United States, changes in regional weather patterns may influence the frequency, severity, and duration of drought and other extreme weather events such as hurricanes and tornadoes. In other parts of the nation, regional climate change may affect the timing, and the amount of rain or snow. Ultimately, modifications in precipitation patterns may cause a spectrum of damaging effects. This makes protecting riparian habitats and their associated watersheds currently at-risk for events such as fire and floods especially important. In the long term, climate change may reduce riparian water quality, diminish riparian plant, animal, and fish diversity, and lower the economic value and quality of life that riparian habitats provide. ■

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Social and Economic Value of Riparian Environments

Riparian areas commonly represent only a small percentage of a landscape, but typically are more structurally diverse and more productive in plant and animal biomass than adjacent upland areas. Yet, this small percentage of land area provides many benefits to society. These benefits, however, are not generally accounted for in market transactions. One exception to this appears to be private property values. Studies in both Arizona and Oregon found that proximity to a stream corridor increased the value of vacant land in residential areas by as much as 10 to 27 percent.

Economic valuation of riparian ecosystems is complicated by the fact that these areas are characterized by multiple and intertwined ecological roles that provide benefits to society known as ecosystem services. For example, riparian vegetation both provides habitat for fish and birds and helps capture sediments. A review of published research on the valuation of freshwater ecosystems from 1971 to 1997 (30 studies) found that most studies focused on a specific indicator of water quality such as water clarity. While these studies have demonstrated that these ecosystems have value, particularly non-use value, they only provide partial benefit estimates because they are based on an incomplete list of potentially important ecosystem services.

One group of riparian nonmarket ecosystem services is related to wildlife and fish habitat. Riparian areas supply food, cover, and water for a broad diversity of animals, and serve as migration routes and forest connectors between habitats for a variety of wildlife, particularly ungulates and birds. Riparian ecosystems generally are characterized by increased structural diversity of vegetation compared to surrounding plant communities. In addition, their linear shape gives riparian zones a lengthy edge with adjacent plant communities. Both structural diversity and edge are important wildlife habitat characteristics. In the arid Southwest, riparian habitats support higher species richness and densities of wildlife than any other desert habitat. Riparian areas of western rangelands provide food, water, shade, and cover for fish and wildlife. Recreation is only one aspect of the value of wildlife and fish, but it alone is substantial. More than half of all US adults hunt, fish, birdwatch, or photograph wildlife. US fishing-

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related expenditures alone totaled more than \$37 billion in 1996.

In addition to providing wildlife habitat, riparian areas provide other very valuable ecosystem services as well. Riparian (streamside) forests act as “living filters” that intercept and absorb sediments, and store and transform excess nutrients and pollutants carried in runoff from adjacent lands. These excess nutrients and pollutants include salts, sediments, organic wastes, pesticides, and other pollutants running into our streams and, ultimately, our drinking water. Riparian areas can reduce the nitrogen concentration in water runoff and floodwater by up to 90 percent and reduce the phosphorous concentration by as much as 50 percent. Excess nitrogen and phosphorous, both substances that compose animal wastes, manufactured fertilizers, and other commonly encountered compounds, promote the overgrowth of algae and undesirable weeds.

The economic worth of these living filters in improving water quality is difficult if not impossible to measure. The fact that the US spends more than \$2 billion annually for clean water initiatives is an indicator of the value of clean water.

Another major role of the riparian zone is to dissipate stream energies and decrease the extent of soil erosion associated with high flows. This, in turn, permits sediments to deposit and continue development of the alluvial valley floor. Alluvial riparian zones also function as shallow aquifers that recharge at high flows and drain at low flows. This interaction between surface flows and groundwater

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storage results in moderation of high flows and enhanced or prolonged base flows. These prolonged base flows are valuable for water use during low flows, such as irrigation, instream flows for fisheries, boating, and delivery to downstream users.

One of the challenges to realizing the values of riparian areas is the loss

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of functioning riparian areas that has occurred over time. As an illustration of the magnitude, the US Fish and Wildlife Service estimates that 70 percent of the natural riparian communities in the US had been lost by 1981, much of it on private land. On National Forest lands, the Forest

ments such as timber cutting and prescribed burning in riparian areas and adjacent buffers does protect these areas in the short run, ecologists are beginning to question the wisdom of this policy over the longer term. Studies of disturbance history of forested riparian areas are



A City of Albuquerque Waste Water Treatment Center technician testing outflow water to the Rio Grande. By permission Janet Yagoda Shagam, PhD, RhizoTech, Albuquerque, New Mexico.

Service is responsible for maintaining and enhancing riparian areas. Agency policies protect riparian habitat by restricting timber harvest and prescribed burning within riparian buffers, limiting grazing by domestic animals in riparian areas, improving road stream crossings, limiting construction of new roads adjacent to riparian zones, and removing existing roads that are in or adjacent to riparian areas. Roads and road crossings are often problematic sources of stream sediments.

While restricting vegetation treat-

providing evidence that fires visited riparian zones adjacent to upland, fire-adapted ecosystems. These fires rejuvenated riparian areas by reducing less diverse coniferous vegetation and promoting more ecologically diverse deciduous vegetation, such as willows and cottonwood. Periodic fire or disturbances that mimic fire may be needed to maintain the vitality of riparian habitats in the long run. ■ *Greg Jones, PhD, is a research forester with the RMRS Forestry Sciences Laboratory, Missoula, Montana.*

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