

# Great Basin Research and Management Project: Restoring and Maintaining Riparian Ecosystem Integrity

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**Abstract**—The Great Basin Research and Management Project was initiated in 1994 by the USDA Forest Service, Rocky Mountain Research Station's Ecology, Paleocology, and Restoration of Great Basin Watersheds Project to address the problems of stream incision and riparian ecosystem degradation in central Nevada. It is a highly interdisciplinary project that is being conducted in cooperation with the Humboldt-Toiyabe National Forest. The project's focus is unique in that it is examining the linkages between the watershed, riparian corridor, and riparian ecosystem scales, and is focusing on both the mid to late Holocene (last 5,000 years) and the Recent Period (last 100 years). Major objectives include examining the effects of climate change and natural and anthropogenic disturbance on the structure and functioning of watersheds and ecosystems, evaluating methods and criteria for determining the effects of both disturbance and management activities, and developing methods for restoring or maintaining watershed and riparian ecosystem integrity.

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Riparian ecosystems constitute a vital resource in the arid Great Basin. Highly valued for livestock forage, recreation sites, and water for agricultural uses, they also provide critical habitat for animals and support most of the region's biodiversity. Because of their many uses, riparian areas in the Great Basin have been extensively exploited—over 50 percent are in poor ecological condition (Chambers 1995). Much of the degradation in these systems can be attributed to human-caused disturbance, including livestock grazing, road construction in the valley bottoms, mining activities, recreation, and alteration of upland ecosystems. However, it is becoming increasingly clear that both past and present climate change processes are influencing the response of watersheds and riparian ecosystems to natural and human disturbances (Chambers and others 1998). Restoring and maintaining the integrity of riparian areas and of the watersheds that support them requires understanding the effects of natural and human-caused disturbance and the potential for recovery. It also requires understanding the linkages between climate change processes and the effects of disturbance.

In the Great Basin, many of the riparian areas have exhibited major episodes of stream incision during the past 150 to 200 years. Changes in stream patterns and dimensions have occurred and, where incised, streams have been

isolated from their floodplains. The size of stream-associated riparian ecosystems has decreased, and significant changes in the species composition of riparian areas have occurred due to the effects of both stream incision and livestock grazing. To address these problems, the Great Basin Interdisciplinary Research and Management Project was initiated in 1994 (Chambers 1995). The overall objective of the project is to achieve a better understanding of the structure and functioning of riparian ecosystems and watersheds within central Nevada, and to develop guidelines for maintaining or restoring their integrity. It is an interdisciplinary project that is being conducted by the Rocky Mountain Research Station's Ecology, Paleocology, and Restoration of Great Basin Watersheds Project in close collaboration with the Humboldt-Toiyabe National Forest. Partners include the University of Nevada, Reno; the Nevada Biodiversity Initiative; Utah State University; Indiana University, Purdue University at Indianapolis; Lafayette University, Environmental Protection Agency, U.S. Geological Survey, Agriculture Research Service, and Fish and Wildlife Service.

The study area includes the Toiyabe, Toquima, and Monitor Mountain Ranges of central Nevada. Watershed elevations range from 1,850 to 3,200 m. This is an arid area and precipitation ranges from about 20 cm at the base of the watersheds to 50 cm at upper elevations. The wide, central valleys are characterized by salt desert vegetation. At low-mid elevations within the watersheds, Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) communities are interspersed with Utah juniper (*Juniperus osteosperma*) and singleleaf pinyon pine (*Pinus monophylla*). At higher elevations, mountain big sagebrush (*Artemisia tridentata vaseyana*) and limber pine (*Pinus flexilis*) dominate. The stream systems are typically high gradient, narrow, and highly incised. While low flows in these stream systems are typically less than 0.02 m<sup>3</sup>/s high flows can exceed 0.8 m<sup>3</sup>/s. Peak runoff and most flood events occur during snowmelt in late May or June. Riparian vegetation consists of quaking aspen (*Populus tremuloides*), narrowleaf cottonwood (*Populus angustifolia*), river birch (*Betula nigra*), willows (*Salix* spp.), and meadow communities.

## Objectives and Progress to Date \_\_\_\_\_

The project's approach is unique in that it is focusing on both the mid to late Holocene (last 5,000 years) and the Historic Period (last 150 years). Also, it is examining the linkages between the watershed, riparian corridor, and stream reach or riparian ecosystem scales. The studies address both basic questions that will increase our understanding of these ecosystems and applied questions that will allow us to effectively manage them.

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## Effects of Climate Change and Natural and Anthropogenic Disturbance

The effects of climate change and disturbance on our watersheds are being reconstructed by examining the vegetation and geomorphic histories of the Holocene (last 11,500 years) and period of record (last 50 to 100 years) (Chambers and others 1998). A highly interdisciplinary approach is being used that combines paleoecology, geomorphology, and vegetation ecology.

**Vegetation History of the Study Basins**—Woodrat middens are being used to determine plant species distributions and, thus, climate change from the end of the Pleistocene to the present. As part of the Project, we have sampled a total of 29 different strata from three woodrat midden locations (Chambers and others 1998). Midden strata range in age from 100 to 8,900 years before present (YBP) and, together with the modern community, include a total of 236 taxa. During the early to mid Holocene (11,500 to 5,500 YBP), the total number of plant taxa identified in the middens remained stable. With the onset of the Neoglacial (4,500 to 2,500 YBP), there was a reduction in desert shrub vegetation, high numbers of plant taxa, and an increase in tree ranges at middle to low elevations throughout the Great Basin. A severe drought (2,500 to 1300 YBP) followed the Neoglacial and taxa numbers decreased by 50 percent or more, desert shrub vegetation increased, and there was a regional decline in woodlands. Taxa numbers increased again in the Medieval Warm Period (1,300 to 900 YBP), and reached a peak during the Little Ice Age (550 to 150 YBP) which was a cooler, wetter period characterized by range expansion of both pinyon and juniper. Since the Little Ice Age, taxa numbers have again been declining.

**Geomorphic History of the Study Basins**—Stratigraphic analysis and detailed geomorphic mapping have been used to reconstruct the geomorphic history of the study basins (Chambers and others 1998). The vegetation and climatic patterns observed in the woodrat middens closely parallels the recent (mid to late Holocene) geomorphic history of the basins. During the cool, wet Neoglacial, there was little hillslope erosion and both the valley bottoms and streams were relatively stable, exhibiting little aggradation or degradation. However, the severe drought that followed the Neoglacial resulted in a change from relatively mesic to xeric vegetation and in increased runoff and sediment removal from the hillslopes. There was significant deposition of sediment in the valley bottoms and large side valley fans formed. During the Medieval Warm Period, there was little hillslope erosion and the streams exhibited only minor adjustments with the shift to moister conditions.

The most recent period of channel incision began at the end of the Little Ice Age before the arrival of European settlers, about 200 to 300 years ago. A lack of hillslope sediment production and the generation of sediment free runoff have caused the most recent channel incision. Incision is not uniformly distributed along the channel, but varies as a function of distance from alluvial fans or other features that constrict the valley floor. Fans are controlling local rates of entrenchment, keeping the active channel from developing an “equilibrium” gradient during the most recent phase of entrenchment. Thus, some stream reaches may be

inherently unstable as a result of the depositional patterns within the valley bottoms that occurred approximately 2,000 years ago.

The side valley fans and other base level controls significantly affect stream gradient and depositional regimes and determine vegetation patterns within the riparian corridor. Stream reaches immediately above the alluvial fans or other base level controls are characterized by lower gradients, higher past or present deposition of fine materials, locally high water tables, and meadow ecosystem types. In contrast, higher gradients, coarser materials, confined water tables, and shrub or tree ecosystem types characterize reaches farther upstream of base level controls. When streams incise through the alluvial fans, the water tables in the meadows are often lowered, resulting in a decrease in the aerial extent of the riparian corridor.

**Recent Stream and Vegetation Dynamics**—Recent stream dynamics have been reconstructed by examining a series of permanently located stream transects and reconstructing flood/incision events using dendrochronology (Chambers and others 1998). Where recent stream incision has occurred, a series of gravel-dominated surfaces have been produced along the active channel that are inset below the valley floor. Willow stands of similar maximum ages occur on bars that are similar heights above the active channel bed. The maximum willow age within a stand is highly correlated with the timing of floods (1983, 1978, 1975, and 1973), indicating that the surfaces were colonized following incision by significant flood flows. These observations are consistent with data collected at permanently monitored cross-sections, which illustrate that during the past 6 years most of the entrenchment was associated with 1995 and 1998 flood events. Analysis of the cross-sectional data suggests that variations in channel incision and bank erosion are the product of the geomorphic setting with respect to valley constrictions, substrate characteristics, the biomass and life form of bank vegetation, and the size, age class and, thus, rooting density of the willows.

**Hierarchical Classification of Basin Sensitivity**—Our initial data indicate that the sensitivity of upland watersheds in central Nevada differs, and that the rates and magnitudes of geomorphic responses to natural and anthropogenic disturbances vary dramatically. We are currently examining the geologic, hydrologic and biotic factors that contribute to these. We are developing conceptual and applied models of how these factors influence basin response to natural and anthropogenic disturbance and, conversely, how they affect recovery potential. The product will be a hierarchical classification of basin sensitivity that can be used in managing the watersheds.

## Methods and Criteria for Evaluating the Effects of Disturbance and Management Activities

**Instream Flows and Groundwater Dynamics**—Stream and groundwater flows are critical to maintaining riparian vegetation, but can be severely altered by water diversions and developments as well as by stream incision. We have examined the temporal and spatial relationships

between hydrologic gradients, vegetation, and soils in central Nevada meadows to increase our understanding of the hydrologic regimes required to support riparian vegetation (Chambers and others 1999; Castelli 1999). As described above, our meadows occur primarily above alluvial fans. They exhibit hydrologic gradients with water tables ranging from the soil surface at the lowest elevation upstream of the fan to depths of 400 cm or greater at the upper end of the meadow complexes. In general, vegetation types include, from wettest to driest, the Nebraska sedge (*Carex nebraskensis*) meadow, mesic meadow, dry meadow, and sagebrush meadow. Plant species composition of the Nebraska sedge and mesic meadow is determined by depth to water table during the growing season, the time the depth to water table is less than 30 or 70 cm, and the degree days of anaerobiosis, while composition of the dry and sagebrush meadows is related to the range in depth to water table, elevation, the presence of shrubs, and aerial cover of gravel and litter. Indicator species for each type include Nebraska sedge (water tables 1 to 30 cm deep), Kentucky blue grass (*Poa pratensis*) and Baltic sedge (*Juncus balticus*) for the mesic meadow (water tables 90 to 149 cm deep); clustered field sedge (*Carex praegracillis*) and intermediate wheatgrass (*Agropyron intermedium*) (water tables 133 to 172 cm deep) for the dry meadow; and Douglas' sedge (*Carex douglassii*), bottlebrush squirreltail (*Elymus elymoides*), and basin big sagebrush (*Artemisia tridentata tridentata*) for the sagebrush meadow (water tables 196 to 400 cm deep). Variables related to water table often respond more rapidly than vegetation following disturbances affecting water tables and should be measured along with indicator species.

**Water Quality**—We examined the dissolved sediments, turbidity, water chemistry, and water temperature of the major perennial stream systems in the Toiyabe range during both high and low flows for the past five years. The effects of roads crossings and cut banks on water quality were evaluated for four study drainages. The primary water quality problems within the drainages are suspended sediments and particulate matter. Several of the water quality variables, including suspended sediments, appear to be closely related to basin lithology, and this must be taken into account when monitoring water quality in these streams.

**High Resolution, Low-altitude Video Imagery**—As part of the project, we have evaluated the usefulness of low-altitude, high-resolution video imagery for rapidly assessing riparian corridors and ecosystems. Video imagery can be a useful tool for determining the major vegetation types within the riparian corridor and for obtaining certain stream geomorphic characteristics such as curvature and width ecosystems (Neale 1997). Vegetation types are most accurately classified when: (1) imagery is obtained in the fall and variations in vegetation coloration exist due to differences in leaf senescence and soil moisture availability; and (2) ground-truthing is used to verify the classification. Low altitude aerial photography compares favorably to resource scale aerial photography in terms of identification of major vegetation types. Video imagery does not allow quantification of understory vegetation or species composition and, thus, it cannot be used to assess ecological condition.

## Methods for Restoring or Maintaining Watershed and Riparian Ecosystem Integrity

**Mesic Meadow Restoration**—Mesic meadows are among the most productive within the riparian corridor and are highly valued for wildlife habitat and livestock forage and as recreation sites. Consequently, they are often degraded. We have examined the plant physiological and community responses of degraded mesic meadows to determine (1) the effects of livestock grazing and nitrogen addition and (2) the response to potential restoration treatments, including soil aeration and revegetation (Martin 1999). Gas exchange and water potential measurements of two important mesic meadow species, Nebraska sedge and Kentucky bluegrass, and community rooting response were measured. Herbage removal had little effect, possibly because of the heavy use in the past. Nitrogen addition reduced root growth and accelerated plant phenology and, thus, may impede meadow recovery processes. Aeration increased root growth and photosynthetic activity, indicating that it can ameliorate at least some of the negative effects of grazing. Revegetation was ineffective due to unfavorable growing conditions for seedling establishment.

**Dry Meadow Restoration**—In many cases, degradation of riparian corridors has led to the dominance of basin big sagebrush. We have used two environmentally similar ecosystem types, dry meadows and basin big sagebrush/basin wildrye (*Leymus cinereus*) trough drainageways as models for evaluating the restoration of sagebrush dominated sites to dry meadows using alternative stable state concepts (Blank and others 1998; Linnerooth and others 1998; Linnerooth 1999). We conducted a restoration experiment in which we burned the sagebrush and seeded with dry meadow species on sites that exhibited different water table levels. Burning resulted in higher soil temperatures, higher levels of extractable nutrients, and higher soil water availability at deeper depths. Emergence and survival of dry meadow species was highest on sites with high water tables, during high precipitation years, and for species adapted to drier conditions. Our results indicate that sagebrush dominated sites with high water tables represent an alternative state of the dry meadow type and that restoration is possible.

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