

# Structure of Woody Riparian Vegetation in Great Basin National Park

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**Abstract**—The community composition and population structure of the woody riparian vegetation in Great Basin National Park are described. Community analyses were accomplished by sampling 229 plots along an elevational gradient of 8 major stream systems in the Park. TWINSPLAN analysis identified 4 primary species groups that were characterized by *Populus tremuloides* (aspen), *Abies concolor* (white fir), *Rosa woodsii* (Woods rose), and *Populus angustifolia* (narrowleaf cottonwood) as dominants, respectively. Detrended Correspondence Analysis (DECORANA) showed that the most important environmental factors associated with the distribution of species were elevation and slope, with flood-related physiographic factors having a secondary effect. Analysis of size-class distributions of the four major riparian tree species in the Park indicated that each dominant shows good recruitment on most watersheds. Overgrazing by domestic livestock and stream diversion are the two primary disturbance factors affecting riparian vegetation in Great Basin National Park.

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Riparian ecosystems are located at the functional interface between aquatic and upland terrestrial ecosystems. Although they occupy less than 1% of the total landscape in the western United States (Knopf et al. 1988), the biological and hydrological importance of riparian ecosystems in overall landscape function is substantial. In the arid/semiarid West, riparian areas typically exist as a narrow corridor of taxonomically distinct, dense plant populations relative to surrounding upland areas, with the resultant oasis effect leading to an enrichment of resident and migratory wildlife (Knopf et al. 1988, Szaro 1989). Riparian zones are also key management areas for water resources, as agricultural and recreational demands for water are placed on these systems due to the fact that water is limiting in most upland areas of the arid/semiarid West.

The central role played by arid land riparian areas in regional ecological processes, together with the unique attributes of riparian systems, has recently resulted in increased attention while at the same time underscoring the

need for appropriate vegetation classification and quantitative descriptions in riparian zones. Management of riparian forests depends on knowledge of recognizable community types and their environmental determinants, as well as knowledge of individual species interactions, population structures, and the interaction of those factors with stream channel stability and other disturbance factors (Miller and Johnson 1986). Recognition and classification of discrete vegetation units will allow information to be digitized into a Geographic Information System (GIS) framework that will aid in the production of spatial maps that can integrate riparian systems into the landscape as a whole (DeLong and Brusven 1991).

Quantitative descriptions of riparian communities in the arid land West are generally lacking. Szaro (1989) suggested that efforts to classify riparian vegetation are necessary in order to fully understand the distribution and dynamics of many bird, fish, and other vertebrate populations, and that much ecological work in this area has been plagued by oversimplification. Several studies have been conducted that have resulted in classification systems of riparian vegetation across broad geographic areas (Johnson et al. 1976, Szaro 1989, 1990). Although more localized studies have been conducted in a number of geographic areas of the arid land West and Intermountain Region, we presently know little of the structure and function of riparian ecosystems in the Great Basin.

In this study, we described the structure of woody riparian vegetation within the boundaries of Great Basin National Park in Nevada (hereafter referred to as the Park). We concentrated our analyses on woody riparian species due to the fact that true riparian meadows are not well represented in the Park, and many of those that do exist have a long history of grazing pressure that has converted them into more xeric meadows that are largely dominated by exotic species, such as *Bromus tectorum*. The primary objectives of this study were to (1) determine the relative cover values for all woody shrub and tree species in riparian corridors within the Park, (2) identify, through multivariate statistical techniques, the primary riparian community types (species groups) that occur predictably within the Park, (3) determine the relationship between the distribution of riparian plant species groups and environmental factors such as elevation, aspect, and stream physiography, and (4) quantify stand demographics, specifically population size structures, of the major tree dominants to determine population recruitment patterns in the Park.

Previous studies that have attempted to classify riparian plant communities and relate these communities to

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physical site characteristics (Minckley and Brown 1982, Szaro 1989) have considered geographically and physiographically diverse areas. In this study, we focused on a set of streams in exclusively mountainous terrain at relatively high altitudes, which has permitted a degree of resolution and detail that is not possible at much larger scales of inquiry. An applied goal of the study was that the detailed patterns provided herein would aid the National Park Service in future research and resource management efforts, such as vegetation mapping, GIS-based habitat classification, and long-term monitoring of the biodiversity and stability of riparian ecosystems in Great Basin National Park.

## Methods

Studies were conducted in Great Basin National Park during the summers of 1991 to 1993. The 31,081 ha Park is located in the South Snake Range of eastern Nevada, a north-south trending fault-scarp mountain system exhibiting a steep, dry west face, with a moister eastern slope. Eleven major drainage systems are found within Park boundaries (Figure 1), offering in excess of 155 km of riparian habitat that extend through a 1,350 m elevational

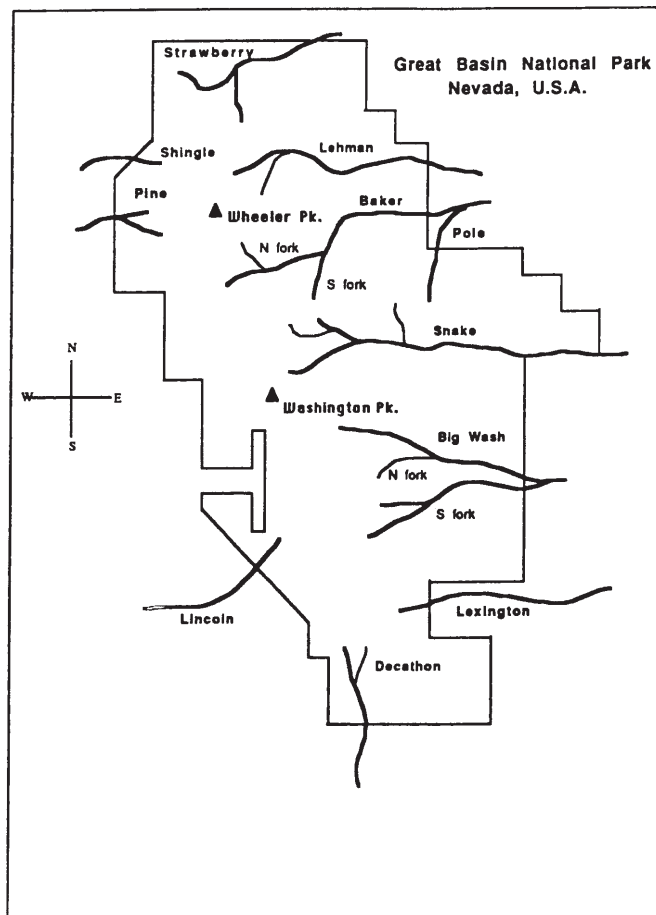
gradient from altitudes of 1,900 to 3,170 m (summits reach almost 4,000 m). The longest and best developed riparian corridors are located along perennial streams (e.g., Lehman and Baker Creeks) on the east flank of the Snake Range, where visitor use is most concentrated. Less well developed riparian corridors, often with shrubby vegetation, can be found along more ephemeral streams that are found on the western and southern flanks of the mountain range.

Eight major riparian systems (Baker, Big Wash, Lehman, Pine, Pole, Shingle, Snake, and Strawberry Creeks) were selected for quantitative analyses of vegetation structure (Fig. 1). They were selected because they offered a range of environmental conditions that typify the Park, given their variation in elevation, aspect, gradient, and valley form. For example, two of the streams (Pine and Shingle Creeks, both of western aspect) are Type 1 streams (Frissel and Liss 1993), streams draining steep canyons that lack glaciation signature and wide valley floors; two of the streams (Baker and Lehman Creeks) are Type 2 streams, which drain glacial landforms underlain by granitic rocks that yield boulder-sized and cobble-sized clasts with weathering; and four of the streams (Big Wash, Pole, Snake, and Strawberry Creeks) are Type 3 streams, which drain alluvial landforms with wide valley floors that lack glacial signature, and are underlain by limestones and shales that weather rapidly into gravel- and sand-size particles that are easily transported by fluvial processes.

All vegetation sampling efforts were based on a functional definition of riparian ecosystems as three-dimensional zones of direct interaction between aquatic and terrestrial ecosystems, which extend outward from the stream edge to the limits of flooding and upward into the canopy of streamside vegetation (Gregory et al. 1991). A total of 229 sample plots were placed at a minimum of 250 m intervals along each of the study streams. Each 50 m<sup>2</sup> plot was a 10 x 5 m rectangular quadrat placed perpendicular to the stream flow direction, with two 5 x 5 m subplots placed on opposite stream banks. The large number of plots from multiple stream systems were sampled in order to adequately represent the diversity of watersheds found in the Park, and to ensure a statistically valid sample given the high species richness and patch structure that typify riparian vegetation (Szaro and King 1990).

Within each sample plot, percent cover was estimated for all species of woody plants, and a combined cover estimate was made for grasses/sedges, forbs, plant litter, standing dead, and bare ground. Cover for each woody species or other category was estimated visually by two experienced observers and a cover estimate was recorded as one of the following transformed cover classes: 0 = absent; 1 = < 1% cover; 2 = 1-5% cover; 3 = 6-25% cover; 4 = 26-50% cover; 5 = 51-75% cover; 6 = 76-95% cover; and 7 = > 95% cover, a scheme based on the releve method of Daubenmire (1959). Species nomenclature follows that of Welsh et al. (1987).

Elevation, aspect, stream gradient, and stream bank height were measured in the field and verified with USGS 7.5 minute topographic maps. Other physiographic features collected at each sample plot (collected by C. Frissel and colleagues, Oregon State University) included flow state (from dry to gaining reaches), channel pattern (from



**Figure 1**—Map of Great Basin National Park, showing the primary stream systems that drain the South Snake Range.

straight to lake or pond), valley form (from narrow V-shaped valleys to wide valleys with distinct floodplains), floodplain and terrace width, and valley fill texture (Frissel and Liss 1993).

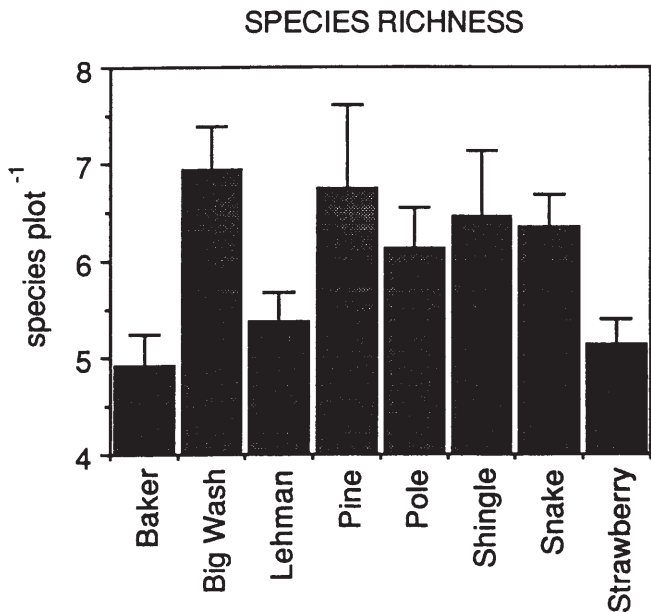
Two-way indicator analysis (TWINSPAN) was employed in the classification of community types. TWINSPAN is a polythetic, divisive program for arranging multivariate data into an ordered two-way table of classification of species and attributes (Hill 1979). The program organized sample stands into compositional groups based on species transformed cover values, and produced a set of species groups based on floristic similarities among the sampled stands. For more details of the TWINSPAN procedure, see Murray et al. (1995).

Detrended correspondence analysis (DECORANA; Hill and Gauch 1980) was used to arrange species and stand groups identified by the TWINSPAN procedure along ordination axes representing different environmental gradients. A rotational correlation analysis (Dargie 1984) was used to determine the vector direction of environmental and physiographic gradients that best correlated with DECORANA ordination axes. Parameters used to depict environmental and physiographic factors in the gradient analysis included: elevation, gradient, aspect, flow state, channel pattern, valley form, stream bank height, floodplain width, and terrace width, as described by Frissel and Liss (1993).

The population size structures of the four major riparian tree taxa in the Park (*Abies concolor*, *Picea engelmannii*, *Populus angustifolia*, *Populus tremuloides*) were surveyed at 21 sites, on six major watersheds, in the Park. Sites were selected subjectively in order to sample vegetation types that represented (1) homogeneous stands of the species or its characteristic species-group, (2) the diversity of community types with low, intermediate, and high elevations in the Park, and (3) riparian corridors that were not excessively disturbed by human activities. At each site, a 5 m wide plot was laid down adjacent and parallel to the stream through the riparian corridor. Within each plot, all individuals of the species were counted, and their diameters measured. For mature trees, diameters were measured at 1 m height above the ground surface (approximating diameter breast high); diameters of seedlings and saplings were measured just above the ground surface.

## Results and Discussion

Riparian vegetation within Park boundaries consisted of 41 woody plant taxa, including a large number of species that primarily occur in upland habitats. Species richness (mean number of species per plot) varied between streams (Figure 2), ranging from 4.92 (Baker Creek) to 6.94 (Big Wash) woody species per 50 m<sup>2</sup> plot. These low richness values indicate that there is a finite number of woody species that have widespread distribution and reach dominant or co-dominant status at numerous sites. Species which have this status include three tree species, *Populus tremuloides* (aspen), *Abies concolor* (white fir), and *Picea engelmannii* (Engelmann spruce), and five shrub species or species complexes, *Rosa woodsii* (Woods rose), *Symphoricarpos oreophilus* (mountain snowberry), *Betula occidentalis*



**Figure 2**—Species richness (mean number of species per 50 m<sup>2</sup> sampled plot) for each study stream in Great Basin National Park. Vertical bars indicate standard error of the mean.

(water birch), *Salix* spp. (broadleaf willows; at least 3 species), and *Mahonia repens* (Oregon grape) (Table 1). Of interest is the fact that these dominants do not change across different stream types. Interesting localized distributions include well developed gallery forests of *Populus angustifolia* (narrowleaf cottonwood) at lower elevations along Big Wash and Snake Creek, and extensive stands of *Pinus ponderosa* (ponderosa pine) along Shingle Creek, *Equisetum hymenale* (common scouring rush) along Big Wash and *Equisetum arvense* (meadow horsetail, included here because of its structural contribution to the shrub canopy) along Strawberry Creek, and dense stands of *Cornus sericea* (Red-osier dogwood) along Big Wash and *Amelanchier alnifolia* (serviceberry) along Shingle Creek.

Four stable species groups were identified by TWINSPAN analysis of the releve data (Table 2). Species Group A was dominated by tree species such as aspen, Engelmann spruce, and limber pine, with an understory dominated by *Juniperus communis* (common juniper), and represented the highest elevation community type. Species Group B was characterized by a white fir tree canopy and a shrub layer dominated by snowberry, willow, and Oregon grape, and typified upper intermediate elevation stands. Species Group C lacked a well developed tree canopy, was characterized by an abundance of shrub species such as Woods rose, water birch, and chokecherry, and occupied lower intermediate elevations. Species Group D was distinct owing to the frequency of upland species such as big sagebrush, pinyon pine, and rabbitbrush, but also to the presence of obligate riparian taxa such as narrowleaf cottonwood and dogwood.

The TWINSPAN procedure was successful in producing a structural framework for classification of riparian community types in the Park. Although vegetation differed

**Table 1**—Dominant woody riparian species in Great Basin National Park (whole Park; pooled data from the eight study streams) and the three primary type streams in the Park. Species are listed in declining order of relative frequency in sampled stands (n = 229 for the whole Park). See text for a description of stream types; Pine and Shingle Creeks are Type 1 streams, Baker and Lehman Creeks are Type 2 streams, and Big Wash, Pole, Snake and Strawberry Creeks are Type 3 streams (see Figure 1).

Stream type	Tree species	Shrub species
Whole Park	<i>Populus tremuloides</i>	<i>Rosa woodsii</i>
	<i>Abies concolor</i>	<i>Symphoricarpos oreophilus</i>
	<i>Picea engelmannii</i>	<i>Betula occidentalis</i> <i>Salix</i> spp. <i>Mahonia repens</i>
Type 1 Streams	<i>Populus tremuloides</i>	<i>Betula occidentalis</i>
	<i>Abies concolor</i>	<i>Amelanchier alnifolia</i>
	<i>Picea engelmannii</i>	<i>Rosa woodsii</i>
Type 2 Streams	<i>Populus tremuloides</i>	<i>Rosa woodsii</i>
	<i>Picea engelmannii</i>	<i>Salix</i> spp.
	<i>Abies concolor</i>	<i>Mahonia repens</i>
Type 3 Streams	<i>Populus tremuloides</i>	<i>Rosa woodsii</i>
	<i>Abies concolor</i>	<i>Symphoricarpos oreophilus</i>
	<i>Picea engelmannii</i>	<i>Cornus sericea</i>

**Table 2**—Species groups determined by TWINSpan analysis using data from eight sampled streams in Great Basin National Park (N = 229 stands).

Species group	Tree dominants	Shrub dominants
Group A	<i>Populus tremuloides</i> (quaking aspen)	<i>Juniperus communis</i> (common juniper)
	<i>Picea engelmannii</i> (Engelmann spruce)	<i>Sambucus cerulea</i> (elderberry)
	<i>Pinus flexilis</i> (limber pine)	<i>Arctostaphylos patula</i> (greenleaf manzanita)
Group B	<i>Abies concolor</i> (white fir)	<i>Salix</i> spp. (broadleaf willows)
	<i>Pseudotsuga menziesii</i> (Douglas-fir)	<i>Symphoricarpos oreophilus</i> (mountain snowberry)
	<i>Pinus ponderosa</i> (ponderosa pine)	<i>Mahonia repens</i> (Oregon grape)
Group C	<i>Juniperus osteosperma</i> (Utah juniper)	<i>Rosa woodsii</i> (woods rose)
		<i>Betula occidentalis</i> (water birch)
		<i>Prunus virginiana</i> (chokecherry)
Group D	<i>Populus angustifolia</i> (narrowleaf cottonwood)	<i>Artemisia tridentata</i> (big sagebrush)
	<i>Pinus monophylla</i> (single-leaf pinyon)	<i>Cornus sericea</i> (red-osier dogwood)
		<i>Salix exigua</i> (narrowleaf willow)
		<i>Chrysothamnus nauseosus</i> (rabbitbrush)

across watersheds, the fundamental species groups consistently emerged when TWINSpan analysis was conducted on the riparian vegetation of individual watersheds (Murray et al. 1995). As a result, we view these species groups as community types that show excellent fidelity across riparian ecosystems in the Park. Riparian systems can be extremely diverse and vegetation structure is usually patchy (Hanson et al. 1990), but we found that the classification presented here has good field-truth and would be highly useful in efforts to map riparian communities in the Park as a whole.

Ordination of the 229 sampled stands by DECORANA resulted in significant stand group segregation along two orthogonal axes (Murray et al. 1995). DECORANA Axis 1, the axis which explained the highest amount of variation in the data set, was significantly correlated with elevation and slope (Table 3). Elevation and slope covary in a predictable fashion, with slope generally increasing with elevation. Zonation of riparian communities with respect to elevation is well recognized (Minckley and Brown 1982, Medina 1986), and we conclude that elevation is undoubtedly the most important environmental factor determining the distribution of species groups in the Park. From a functional perspective, the upper elevational distribution limits of species along the elevational gradient is primarily a temperature response, whereas the lower elevational limits are probably related to seasonal water stress (or episodic droughts) and/or competition. Stream bearing and stream gradient have also been shown to influence riparian community types (Szaro 1989). However, we found no significant relationship between the ordination of stands and stream aspect, probably because a majority of streams in the Park occur on the east-facing escarpment of the Snake Range, and individual streams are generally uniform in flow direction (i.e., they exhibit low sinuosity). However, riparian vegetation is clearly more reduced and assumes more of a shrub-like physiognomy on the west-facing side of the escarpment.

DECORANA Axis 2, which was orthogonal to Axis 1 and explained less total variation in the data set, was significantly, but weakly correlated with channel pattern, terrace width, stream bank height, flow state, and valley form (Table 3). However, when the individual factors are taken together, we interpret Axis 2 to represent a flood frequency/stream flow volume gradient. Channel pattern and terrace width are related to flow volume since terrace development is controlled by the frequency, seasonality, and magnitude of stream discharge events sufficient to cause overflow of the primary stream channel. Other investigators have shown that the distribution of riparian plant species is closely related to terrace development (Minckley and Clark 1984). Flooding is a common, naturally occurring form of disturbance in riparian systems which can strongly influence vegetation patterns (Johnson et al. 1976, Hupp and Osterkamp 1985). The ordination results from this study are similar to those found in other riparian studies in the region. In an analysis of 153 sites in the southwestern U.S., Szaro (1990) found elevation, stream direction, stream gradient, and valley cross-sectional area (in that order) to be the primary determinants in the ordering of 28 riparian community types.

**Table 3**—Coefficients of determination ( $r^2$  values) of component loadings of the first and second axes obtained from DECORANA ordination of riparian vegetation in Great Basin National Park with environmental/physiographic factors. Coefficients of determination are based on the analysis of 229 stands located on eight major watersheds in the Park. Only statistically significant  $r^2$  values are reported.

Factor	First axis	Second axis
Elevation	0.82	n.s.
Slope	0.40	n.s.
Aspect	n.s.	n.s.
Channel pattern	n.s.	0.25
Terrace width	n.s.	0.17
Streambank height	n.s.	0.14
Flow state	n.s.	0.12
Valley form	n.s.	0.11
Texture valley fill	n.s.	n.s.

In an analysis of riparian vegetation from Hells Canyon (Snake River Gorge, Idaho), Miller and Johnson (1986) found that their first ordination axis of riparian stands represented a temperature (i.e., elevation) gradient while the vertical axis represented a gradient of stream channel stability (i.e., disturbance). Therefore, the consistency of these results suggest that elevation exerts the strongest influence on the zonation of riparian vegetation within the montane West, but that flood-related disturbances are also important in the zonation of riparian vegetation along individual stream reaches.

The size class frequencies of four dominant tree species (aspen, white fir, Engelmann spruce, and narrowleaf cottonwood) all showed a majority of individuals to occur in the smaller size classes, with a very high percentage of seedlings and saplings and a gradually reduced frequency in each consecutive size class (Table 4). Engelmann spruce exhibited a distribution out to very large size classes, whereas white fir did not. There were, however, anomalous size frequency distributions for several of the species on individual watersheds. For example, there were no individuals of white fir between 20 and 55 cm trunk diameter on Pine Creek, and Engelmann spruce showed poor recruitment at higher elevations on both Lehman and Baker Creeks.

**Table 4**—Relative frequencies of individuals in different diameter size classes for the four dominant tree species in Great Basin National Park.

Species	D.b.h. (upper limit)							
	2	10	20	30	40	50	60	>60
	----- cm -----							
<i>Abies concolor</i>	.68	.20	.09	.02	.01	0	0	0
<i>Picea engelmannii</i>	.34	.28	.16	.09	.06	.03	.02	.02
<i>Populus angustifolia</i>	.58	.14	.10	.09	.06	.02	.01	0
<i>Populus tremuloides</i>	.55	.27	.13	.04	.01	0	0	0

Plant populations with a “normal” population structure exhibit a frequency distribution which is characterized by most individuals in the population occurring in the smaller size (age) classes, and a declining number of individuals in each successively larger size class. The dominant riparian trees of Great Basin National Park clearly exhibit such a population structure. The high frequency of seedlings and saplings encountered at many of the sampled stands indicates good recruitment of tree species within riparian systems of the Park. This was particularly evident at low elevation sites within the Park, whereas several high elevation sites exhibited low recruitment of several tree species. Although this is perhaps counter intuitive given the dry climate of Nevada, simulations of long-term cyclic dynamics of riparian forest stands indicate that warmer/drier conditions result in more diverse riparian forest with less distinct cyclic behavior than in cooler/wetter conditions, which tend to support one or two dominant species (Liu and Malanson 1992). Our demographic data tend to support these simulations, and suggest that recruitment processes and population turnover are perhaps more rapid events at lower elevation sites that are dominated by broad-leaf trees and shrubs, than in the cool, conifer-dominated forests at higher elevations.

Although many of the riparian ecosystems in the Park are in fair general condition, there is strong evidence that domestic livestock are stressing riparian systems and thus not allowing them to reach their ecological potential (relative to biodiversity, productivity, etc.). Invasive taxa that preferentially occupy disturbed sites, such as *Bromus tectorum* (cheatgrass) and *Chrysothamnus nauseosus* (rabbitbrush), are very common along many of the riparian corridors of the Park, particularly at lower elevations. Extensive coppicing of cottonwood saplings also indicates a potential negative impact of cattle browsing on tree regeneration.

A second anthropogenic disturbance in the Park is streamflow diversion, which only affects a lower, about 5 km, segment of Snake Creek. In comparison to most western watersheds, Great Basin National Park is relatively free of diversion effects. Nevertheless, the diverted stretch of Snake Creek shows typical diversion effects, with little or no recruitment of the dominant tree, narrowleaf cottonwood, and accelerated senescence of mature trees along that stretch of the stream. This dewatered segment of Snake Creek appears to be in imminent danger of decline, which can only be alleviated by the return of instream flows to the diverted stretch of the creek.

The continued practices of grazing and streamflow diversion in Great Basin National Park illustrate the inherent conflicts that are presented to the Park Service when attempting to manage riparian systems for both commodity (grazing, water) and non-commodity (recreation) uses in a National Park setting.

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