EARLY RECOVERY OF AN EASTERN SIERRA NEVADA RIPARIAN SYSTEM AFTER 40 YEARS OF STREAM DIVERSION[1]

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Abstract: Rush Creek, which feeds Mono Lake, has been diverted below Grant Lake, totally or in part, for over 40 years. In the early 1980's, because of above normal snow packs, runoff was released into the creek. Minimum flow releases have also been established. The riparian vegetation has responded to these releases. In a few areas, riparian trees and shrubs (e.g., black cottonwood and willow) survived the diversion period but with high stem mortality. These plants are resprouting in response to the 1980's floods. In other areas, new plants are establishing within the floodplain; however, on areas away from the floodplain most riparian plants died and are not regenerating. The patterns of riparian regeneration and environmental requirements of each riparian species have been preliminarily determined.

Rush Creek, located in the eastern Sierra Nevada of California, is one of several streams that feed Mono Lake (fig. 1). Rush Creek, as is true of many eastern Sierra Nevada streams, has a long history of water management. Around 1915, a dam was constructed below Grant Lake depression forming Grant Lake, and the impounded waste was used to convert sagebrush desert to irrigated fields (Stine and others 1984). More intensive water management began in 1941 with completion by the Los Angeles Department of Water and Power (LADWP) of an extension of the Los Angeles Aqueduct to the Mono Basin.

Since 1941, LADWP has annually diverted varying amounts of water from Rush Creek (Grant Lake) for use by the city of Los Angeles (fig. 2). The diversion pattern is characterized by periods of relatively abundant release into Rush Creek interspersed by periods of almost total diversion into the aqueduct, such as occurred in the 1970's. The result has been mortality of riparian vegetation and invasion by upland shrubs along stretches of Rush Creek during the 1970's (Jones and Stokes 1985, Stine and others 1984, Taylor 1982).

In the early 1980's, above-average snowpack resulted in releases of large amounts of water into Rush Creek. These flows, coupled with recent litigation-required minimum flow releases, have stimulated regeneration of some riparian vegetation. In 1987, we began studying the riparian vegetation of lower Rush Creek, with two objectives:

1. Inventorying the riparian vegetation for composition, structure, and size classes.
2. Evaluating the amount of regeneration of each riparian species and the relationship between this reestablishment and the stream environment, especially substrate, channel morphology, and proximity of the species to the channel.

Methods

The methods used in this study included general reconnaissance, inventorying vegetation along transects, data analysis, and interpretation of aerial photographs. Rush Creek from Grant Lake (elevation of 2170 m) to Mono Lake was surveyed in fall 1987 to determine general types of stream morphology, vegetational communities, and to identify species. Species names follow Munz and Keck (1968).

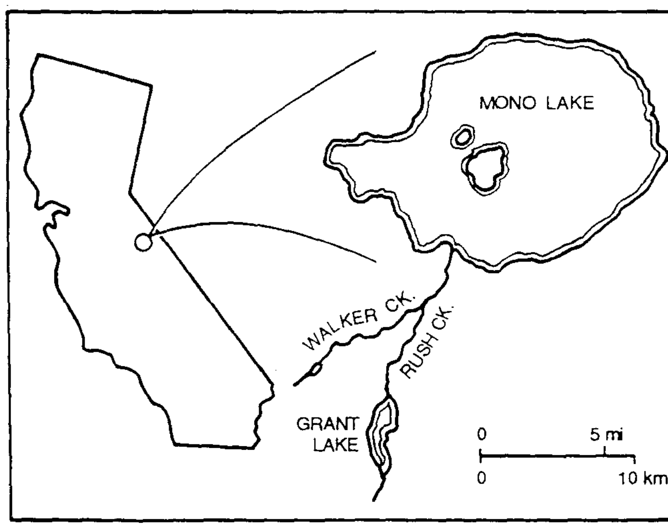

Figure 1– The study area includes Rush Creek from Grant Lake to Mono Lake.

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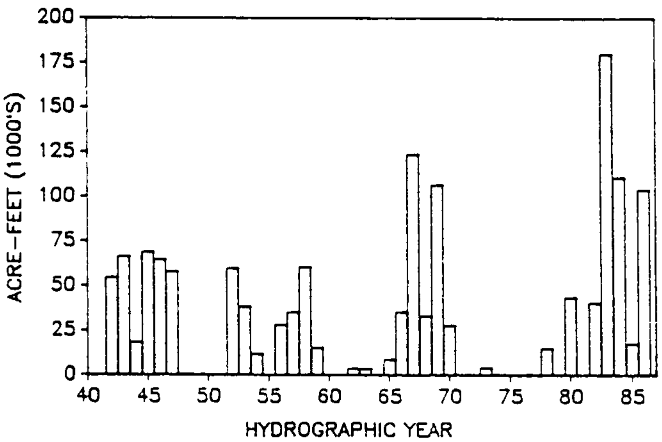

Figure 2– Water releases into Rush Creek through Mono Gate #1 and over Grant Lake spillway in thousands of acre-feet for hydrographic years (Oct. to Sept.) 1942-1986. About 3465 acre feet for 3 months equals a constant flow of 0.53 cubic meters per second.

An inventory characterizing the vegetation along Rush Creek was developed using 51 transects (20 of which were permanent). Locations of transects were based on reconnaissance and on analysis of August 1987 aerial photographs, and reflect the diversity of stream channel and floodplain morphologies and vegetation communities. Transects were sampled during September-October 1987. The transects were laid out perpendicular to the stream, running from the stream edge until riparian vegetation was no longer encountered. They ranged in length from 5 to 180 m. The transects were 2 m wide and divided into 5 m segments. For each segment, the following information was recorded: woody and herbaceous litter cover, total herbaceous cover, species cover and density for woody species (divided into height strata of <1 m, 1-3, and >3), and age of seedlings and saplings. Age was estimated from counts of internodes. Abiotic information recorded included substrate texture for the surface and at 1 to 10 cm, and height above the stream channel. Stream gradient at the transect site, and slope and aspect of the transect were also recorded.

Correlations between species and abiotic factors and in particular between regeneration and site characteristics were determined by developing correlation coefficients using SAS statistical packages (SAS Institute 1982). Correlations were based on a sample size of 651 transect subplots; P values less than 0.05 were considered significant. Additionally, means from each transect were used to determine commonality of transects using detrended correspondence analysis (DCA). DCA is a multivariate ordination technique that is useful in determining community relationships, since it reduces multivariate data into "low-dimensional space" such as a two-dimensional axis plot. Stands with similar vegetation structure occupy close positions on the plot. Information generated by DCA helped to determine relationships among species and to delineate stream reaches. Reaches were defined by homogeneity of the vegetation and stream morphology, and were numbered consecutively from Grant Lake to Mono Lake. Data from reaches 9 and 10 are not presented because these reaches are presently disturbed by gravel operations.

Results

Vegetation Structure

Total riparian zone vegetative cover at Rush Creek in 1987 averaged 48 percent, while woody cover in the zone averaged 35 percent (tables 1 and 2). This cover was located along riparian zones of variable widths, ranging from 5 to a maximum of 180 m per side of the stream). Most of the vegetation was less than 1 m in height, reflecting the dominance of small shrubs rather than trees. Tree density within the riparian zone averaged 3 per 100 m^2, and only 5 percent of all woody plants were taller than 3 m (table 2). Herbaceous cover, which contributed 30 percent of the total cover, grew as understory to the woody plants and, in certain reaches, as the dominant vegetation in wet meadows.

Two shrub species–one obligate to riparian habitats, coyote willow (*Salix exigua*), and the other facultative, mountain rose (*Rosa woodsii*)–contributed over one half of the total woody cover. The third most abundant species was big sagebrush (*Artemisia tridentata*), which dominates the surrounding uplands. The combined cover of all species that are considered to be obligate riparian (that is, grow only in wet, streamside habitats) was 14 percent, or 40 percent of the total cover, while upland and facultative riparian species comprised 60 percent of the total cover. Five obligate woody riparian species were present in the transects: black cottonwood (*Populus trichocarpa*), aspen (*P. tremuloides*), red willow (*Salix laevigata*), white willow *(S. lasiolepis),* and coyote willow. Facultative species included two trees: Jeffrey pine (*Pinus jeffreyi*) and silver buffaloberry (*Shepherdia argentea*), and a shrub (mountain rose). Three upland shrubs also were recorded: big sagebrush, rabbitbrush (*Chrysothamnus nauseosus*), and bitterbrush (*Purshia tridentata*).

Table 1-Reach length, mean length of transects, plant cover (total and by strata- >3 m tall, 1-3 in tall, and <1 m tall), woody plant density (total and by strata), and species richness (number of woody species in transects), of lower Rush Creek as of 1987. Values are means for 1 to 7 transects per reach type.

Reach No.	Reach Length	Transect Length	Plant cover Total	>3	1-3	<1	Woody plant density Total	>3	1-3	<1	Species Richness
	km	m	percent				sterns/10m²				
1	NA	35	12	6	3	3	5	0	1	4	4.0
2	NA	5	25	0	2	23	13	0	4	9	2.0
3	0.15	15	60	1	29	30	91	0	46	45	4.0
4	0.49	28	71	28	19	43	35	3	16	16	5.7
5	0.85	51	76	8	25	47	69	6	34	31	4.5
6	0.55	74	11	0	3	8	11	0	4	7	3.0
7	0.61	27	60	7	16	37	49	5	21	24	4.4
8	0.73	40	23	2	8	14	29	0	11	18	5.5
11	0.28	60	18	6	5	7	7	0	3	4	5.3
12	0.58	148	54	3	12	39	23	0	12	12	5.0
13	0.21	130	93	39	18	42	23	6	14	4	6.0
14	0.82	115	36	5	11	21	30	4	14	12	5.0
15	0.24	53	28	6	0	22	43	0	1	43	4.0
16	0.64	68	51	3	17	32	20	2	11	8	5.7
17	0.76	130	49	12	11	26	27	3	14	11	4.5
18	0.37	35	27	1	7	20	41	0	9	32	3.0
Entire creek			48	8	13	29	36	2	16	18	4.5

Table 2-Cover by species] for woody plants within reach types at Rush Creek. Values are means for 1 to 7 transects per reach type.

Reach no.	Obligate riparian SX	PC	SV	SL	Facultative or upland RW	AT	CN	SA	PU	PJ	PM
	percent										
1	0	0	0	3	1	0	0	0	1	0	6
2	3	0	0	0	0	13	0	0	8	0	0
3	18	0	0	0	28	8	2	0	0	0	2
4	1	16	9	0	22	6	1	2	0	0	4
5	13	2	0	3	27	5	3	3	1	0	0
6	5	0	0	0	0	3	1	0	0	0	0
7	8	4	0	0	21	4	2	1	0	0	0
8	8	4	2	0	3	0	3	0	1	0	0
11	3	9	0	0	0	0	1	0	2	0	0
12	5	1	0	1	11	7	4	3	1	0	0
13	9	1	31	8	9	3	0	1	0	0	0
14	7	1	0	3	7	3	1	2	0	0	0
15	0	0	4	2	0	2	0	3	0	0	0
16	6	0	0	9	5	8	1	2	0	0	0
17	1	1	1	0	15	5	0	2	0	0	0
18	14	0	1	0	0	0	0	0	0	0	0
Entire creek	7	3	3	2	12	4	2	2	1	<1	<1

SX= *Salix exiqua*, PC= *Populus trichocarpa*, SV= *S. laevigata*, SL= *S. lasiolepis*, 1LW= *Rosa woodsii*, AT= *Artemisia tridentata*, CN= *Chrysothamnus nauseosus*, SA= *Shepherdia argentea*, PU = *Purshia tridentata*, PJ= *Pinus jeffreyi*, PM= *P. tremuloides*.

Vegetation cover, height, and species composition varied considerably within the 11 km stretch of lower Rush Creek. The nature of the stream differs above and below a natural quartzite gorge located about 3 km below State Highway 395. Below the gorge, riparian zones are generally wider, and in some areas, extensive wet meadows occur adjacent to the riparian zone. Vegetation characteristics varied even within these two broad zones, and 18 reach types were recognized. Two notably distinct reaches were 4 and 13, which formed an endpoint of one axis of the DCA analysis. These reaches were unusual in having high cover of tall, riparian trees, including mature red willow (table 2). Reach 4 is a steep-walled canyon area probably underlain by shallow bedrock, while reach 13 is a broad wet area. Both reaches receive water from stream flow and from supplemental sources, including run-off from irrigated fields. Other distinct reaches included 2, the sparsely vegetated transition area between the diversion point (Mono Gate #1 Canal) and the river channel, and 6 and 11, sparsely vegetated alluvial floodplains.

Regeneration

Obligate Species

Most of the riparian species at Rush Creek, although having suffered high mortality from prior water diversion, are now regenerating in response to the high flows of the early 1980's and the subsequent controlled minimum flows which have not since dropped below 0.5 cubic meters per second (at Grant Lake release point). Individual species have responded in different fashions. Of the obligate riparian woody species, one (black cottonwood) is regenerating by asexual root sprouts, two (white and red willow) by seed, and one (coyote willow) by both sprouts and seed.

Black cottonwood, a dominant tree at Rush Creek, survived the prior diversion in low densities in most reaches of the stream. Although most of the survivors have crown dieback to the extent of death of the entire above-ground portion of the tree, all are vigorously re-sprouting and many are producing root sprouts. Sprouts were recorded in 14 percent of the transects (7 of 51). Many of the largest sprouts (up to 3 m tall) were esti-mated to have established in 1982 or 1983. Figures 3 and 4 show a cobble floodplain vegetated almost exclusively by cottonwood survivors or root sprouts.

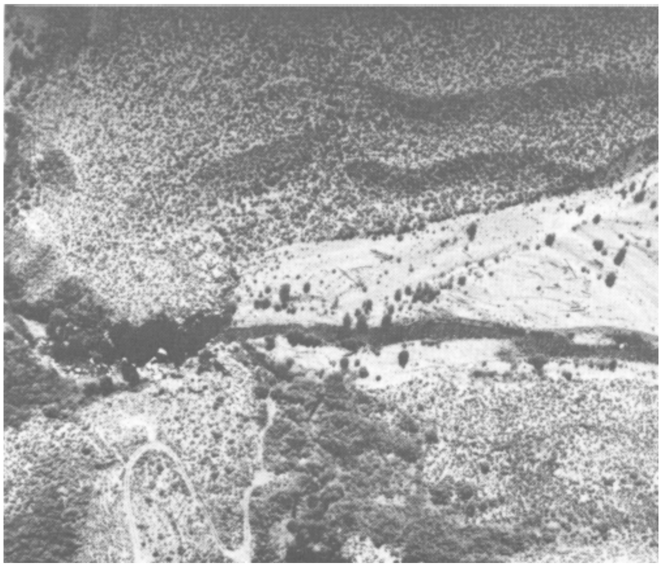

Figure 3– 1987 aerial photograph of a portion of Rush Creek. The cobble floodplain above the quartzite gorge is being revegetated in large part by sprouting roots from black cottonwood.

Figure 4– 1988 ground photograph of the floodplain shown in Figure 3, showing root sprouts and resprouted black cottonwoods.

Of the three willow species, coyote willow has shown the greatest amount of regeneration following increased flows. Asexually or sexually established plants were abundant in all but one of the sampled reaches, and stem density of plants less than 1 m tall averaged 3 per 10 m^2 for the study area as a whole. Young plants were most abundant along the stream edge (significant correlation coefficient of 0.27 between cover and proximity to stream, and -0.31 between cover and height above the channel). Along streamsides, plants occurred in mixed age classes, ranging from 1 to 5 years old. In certain reaches (e.g., no. 6), coyote willows grew throughout the broad, gravel/cobble floodplains in even-aged stands that established from seed in 1983.

Seedlings and saplings of white willow and red willow were also present, but in fewer reaches than coyote willow. Young plants were most abundant in the lower half of Rush Creek, below the quartzite gorge. Cover was significantly negatively associated with height above the channel (correlation coefficient of -0.28) and with stream gradient (-0.26). Young plants ranged in age from 1 to 5 years (established in 1983). Highest densities were on point bars where the subsurface soil was moist; combined seedling densities in such areas, such as reach 15, were 37 per 10 m^2. Many of the 5 year old plants were still very small, some under 0.1 m tall, due to heavy grazing by sheep.

Facultative Species

The facultative riparian species have also responded in distinct ways. Mountain rose appears to have increased in abundance as a result of past periodic dewatering of Rush Creek, and is now the dominant woody plant. Abundance of rose was significantly correlated with abundance of woody litter (correlation coefficient of 0.42), indicating invasion by rose in areas where obligate woody riparian species had died. Ability to reproduce sexually and vegetatively has contributed to its current abundance. Rose is continuing to regenerate by seed and root sprouts at the perimeter of large clonal populations. Current research is documenting the continued expansion or decline of these clones.

Aspen survived the water diversion in a few scattered reaches, including the silty-soiled canyon slopes of reach 4 and upper terraces of reach 5. Most of the survivors are regenerating by asexual root sprouts. However, grazing by sheep in the riparian zone is inhibiting growth of many of these sprouts. Scattered mature Jeffrey pines grow within the Rush Creek riparian zone, primarily in the upper canyon area (reaches 4 and 5). These pines are regenerating at very low rates; only one seedling, and no saplings or small diameter trees were observed within the riparian zone.

Small clusters of silver buffaloberry (a small tree) occur on silty-soiled, raised terraces along Rush Creek. Although buffaloberry trees have suffered much crown dieback as a result of prior diversion, many are now regenerating by sprouts and seed. All of the young plants recorded in transects were adjacent to adults.

Upland Species

The abundance of the three upland shrubs (big sage, bitterbrush, rabbit brush) is a result, in part, of their past invasion into previously dewatered areas. These shrubs are dying and declining in certain streamside floodplains, perhaps because of the recent high flows. These upland shrubs have become well established on some terraces; however, there was no evidence of continued regeneration of these shrubs anywhere along the stream.

Discussion

The riparian vegetation along Rush Creek has shown some resistance to decades of periodic water diversion. Although prior years of sporadic diversion of streamflow resulted in heavy mortality of obligate riparian species and increase in abundance of facultative and upland species in some areas, the riparian vegetation has not been totally eliminated as suggested by some researchers (Stine and others 1984). The riparian vegetation has also demonstrated potential high resilience, that is, ability to return to predisturbance state, as demonstrated by the recovery of key riparian species in response to recent high flows. The scattered surviving riparian plants are serving as seed sources and clonal parents, allowing regeneration of the riparian community in response to the above-average flows of the early 1980's, and to the controlled minimum instrearn flows that followed this period of flooding.

Regeneration response has not been uniform among species or among reaches of the stream. The causes of these variations include differences in stream geomorphology and hydrology as well as differences in species biology.

The influence of stream geomorphology and hydrology is evidenced by the markedly higher survival of riparian individuals in areas with shallow bedrock versus deep alluvium, and in areas that are fed by water sources supplemental to surface streamflow. Other examples include the abundance of willow seedlings and saplings on perennially wet point bars, and the absence of young willows (or presence only of plants that established in years with large spring floods) on floodplains with greater height above the stream channel. There is a need for detailed quantification and documentation of hydrology and geomorphology to more thoroughly understand their influence on riparian communities (Kondolf and others 1987).

Ability to reproduce sexually and vegetatively has contributed to the abundance of the two species which currently dominate lower Rush Creek. Answers to why certain key riparian species (e.g., the two *Populus* species) are not regenerating by seed in response to current flow conditions may lie in their particular autecological requirements. Aspen, for instance, is known to have exacting, and thus infrequently met, requirements for seed establishment (McDonough 1985). As for black cottonwood, available information on related species suggests a requirement for spring flooding that coincides with the short period of spring seed dispersal (Bradley and Smith 1985, Fenner and others 1985), followed by a period of low water stress (Strahan 1984, McBride and Strahan 1984). The potential requirements of this species' sexual regeneration for high spring flow pulses is being researched.

Although the riparian community along Rush Creek is regenerating following periodic flooding in the early 1980's and subsequent controlled flows, definitive answers to questions about the probability and timing of recovery to prediversion conditions await further monitoring and research. Whether current levels and patterns of controlled flows will allow complete recovery remains to be determined. Our first-year study of this recovery has answered some questions, and raised more, pertaining to the reasons for differences in recovery of the various components of the riparian community.

Acknowledgments

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