

Water Table Dynamics and Soil Texture of Three Riparian Plant Communities

Abstract

Restoration of degraded riparian plant communities must consider relationships among water table dynamics, soil texture, and plant species. We compared water table dynamics, soil texture, and slope among riparian plant communities dominated by: 1) beaked sedge (*Carex rostrata* Stokes), 2) Geyer's willow (*Salix geyeriana* Anderss.), and 3) black cottonwood (*Populus trichocarpa* T. & G. ex Hook) occurring on recent alluvial bars. We examined six sites of each plant community in western Montana. Mean bimonthly fluctuation in water table depth did not differ among the three plant communities ($P = 0.67$), but mean depth to water table was greatest ($P = 0.004$) in the cottonwood community (62.8 cm), intermediate for the willow (32.0 cm) and least for sedge communities (20.7 cm). Soil texture differed among the three plant communities for sand ($P = 0.0004$), silt ($P = 0.0002$), and clay ($P = 0.003$). Cottonwood communities occurred on soils that averaged 78% sand, whereas sedge and willow sites averaged 47% sand and 35% sand, respectively. Silt content was 40% beneath willow, 35% beneath sedge and 15% beneath cottonwood communities. Soils of the willow sites averaged 25% clay compared with 18% and 7% for sedge and cottonwood communities, respectively. Soils beneath all three plant communities differed in coarse fragment percentage ($P = 0.01$), averaging 46% in cottonwood, 22% in willow, and 15% in sedge sites. We found no differences in slope among the three plant communities, either parallel to the stream ($P = 0.76$) or perpendicular to the stream ($P = 0.29$). Thus, these plant species exhibit a more narrow affinity for soil texture, coarse fragment content and water table depth than previously reported.

Introduction

Riparian ecosystems tend to be very dynamic changing dramatically through time and space (Padgett et al. 1989). Frequent and dramatic changes occur because of the constant reworking of stream substrates, the presence of side channels, topographic variability and regular flooding. In the wake of these abiotic interactions, managers need to know how changes in water flow (Fenner et al. 1985) influence riparian vegetation and how soil texture relates to both ripar-

ian vegetation (Hansen et al. 1995) and the water table (Friedman et al. 1997).

As a first attempt, to better understand riparian ecosystems several riparian vegetation classification systems have been developed to aid land managers in the western United States. These include classifications for eastern Idaho-western Wyoming (Youngblood et al. 1985), southern Oregon (Kovalchik 1987), Utah and southeastern Idaho (Padgett et al. 1989), Nevada and eastern California (Manning and Padgett 1995) and Montana (Hansen et al. 1995). All of these publications contain valuable information about successional pathways, soil pedon descriptions, and land management recommendations, but they typically contain only broad, casual observations of soil texture and water tables, even though these variables greatly influence the distribution of plant communities (Brady 1990). According to Hansen et al. (1995), soils are generally thought to influence riparian species composition, species coverage, and growth form. Groundwater may affect

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riparian vegetation more than soil characteristics (Hansen et al. 1995) and effects of water table declines are related to soil textures (Friedman et al. 1997). Therefore, increased understanding about the influence of soil texture and water table dynamics may improve efforts to identify the successional status of riparian communities and aid in the restoration of degraded riparian areas. The purpose of our study was to further define the ecological range of three riparian communities that are ubiquitous throughout the northern Rocky Mountains (Hansen et al. 1988).

Study Areas

We compared water table dynamics, soil texture, and slope among riparian plant communities dominated by: 1) beaked sedge (*Carex rostrata* Stokes), 2) Geyer's willow (*Salix geyeriana* Anderss.), and 3) black cottonwood (*Populus trichocarpa* T. & G. ex Hook) occurring on recent alluvial bars. Sites were classified according to Hansen et al. (1995). For each of the three plant communities, we examined six representative sites in western Montana. Study sites were located across a broad range of mountain valley landscapes at elevations

from 1000 to 1460 m (Figure 1). Average annual precipitation across all sites ranged from 584.2 – 711.2 mm with most of the precipitation occurring in May and June. Average annual air temperature across all sites was 3°C.

Cottonwood Sites

The black cottonwood recent alluvial bar communities are early seral communities that require freshly deposited alluvium as a seedbed (Hansen et al. 1995). Two sites were on sandy to cobbly alluvium on glacial outwash along the Blackfoot River in a narrow mountain valley near Ovando, Montana. The remaining four sites were adjacent to the Gallatin River, which drains the wide Gallatin Valley, near Bozeman and Three Forks, Montana. Alluvial fill at these sites was a mixture of cobbles and boulders.

Sedge Sites

Two sites were adjacent to Railroad Creek (meandering meadow stream) near Norris, Montana. Railroad Creek occupies a broad valley floor and drains finely sorted gravel/cobble alluvium.

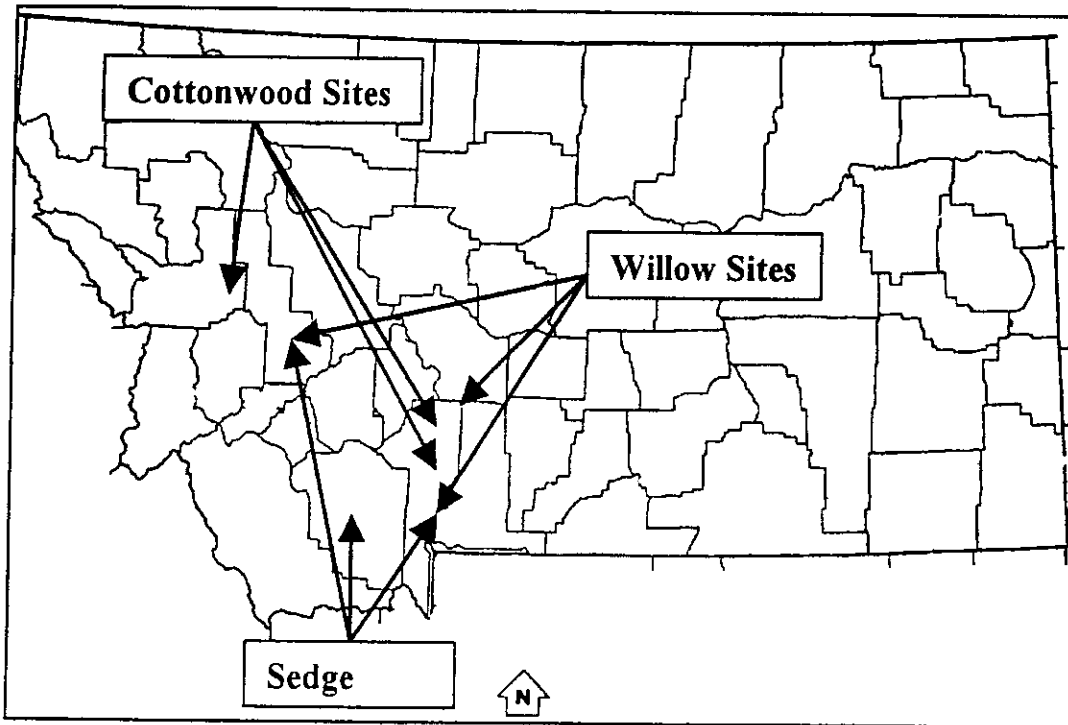


Figure 1. Map of Montana. Each arrow represents two sampling locations for each community type.

Archean granite is the primary parent material. Two other sedge sites were adjacent to Shanley and Lynn Creeks (meandering meadow streams) near Ovando, Montana. These two streams drain a rolling landform of glacial outwash and lateral moraines. Soils contain mixtures of sand, pebbles, gravel, cobbles, and boulders. The remaining two sedge sites were adjacent to Hyalite Creek (mountain stream) south of Bozeman, Montana. Tertiary volcanics and Madison limestone compose the alluvial parent material. Cobbles and gravel dominate the soil mix.

Willow Sites

Two sites were near Ovando, Montana along Cottonwood Creek (meandering meadow stream). This stream drained a rolling landform of glacial outwash and lateral moraines. Soils contained mixtures of sand, pebbles, gravel, cobbles, and boulders. Two other willow sites were along Brackett Creek (mountain stream) northeast of Bozeman, Montana. The stream was formed over silt and mudstones from Jurassic-aged formations. The remaining two willow sites were adjacent to Hyalite Creek (mountain stream) south of Bozeman, Montana. Soils were derived from Tertiary volcanics and Madison limestone.

Methods

A 10 × 10 m macroplot was established at each of the 18 sites. Botanical composition was sampled to verify that site classification followed Hansen et al. (1995). Vegetative canopy cover, by species and by life form, was sampled via the Canopy Coverage Method along two 10 m transects located near the center of each macroplot (Daubenmire 1959). Estimates of herbaceous canopy cover were obtained from 25 × 50 cm quadrats placed along each transect at 1 m intervals.

Water And Soil Sampling

Water table depth was measured to the nearest centimeter in three shallow wells located near the center of each macroplot. Each well was constructed of 1.9 cm × 1.5 m schedule 40 perforated steel pipe placed into the soil to a depth of 1 m. Wells were spaced at 3 m intervals along an upslope gradient perpendicular from the stream. Depth to water table and water table fluctuation was measured bimonthly from June through Oc-

tober in 1997 and 1998. Water table fluctuation was calculated by subtracting each two-week measurement from the one previous.

Soil samples were collected from three 51 cm deep pits on each site. Pits were located 1 m away from the water wells. Due to the lack of horizonation in each pit, we chose to subsample each pit at four arbitrary depths (0-13, 14-25, 26-38 and 39-51 cm). The texture of each of the four strata was averaged to represent the whole soil pit. Prior to analyzing the samples for texture, coarse fragments were separated from each soil sample. A 2 mm sieve was used to separate larger fragments from the soil that were then weighed to determine their percentage of the total soil weight. Soil texture was analyzed using the hydrometer method (Bouyoucos 1936, Day 1965, Gee and Bauder 1979) on each of the four subsamples.

Slope of each macroplot was measured perpendicular to the stream and parallel to the stream. A stadia rod and abney level were used to measure slope over a distance of 6 m.

Statistical Analyses

Water table depth and fluctuation were compared among plant communities using a three-stage repeated measures ANOVA. Prior to the ANOVA, a square-root transformation was applied to the water table fluctuation data to achieve normality. A three-stage nested ANOVA was used to compare particle size (soil texture) and coarse fragment percentages among the three plant communities, and slope was compared using a nested ANOVA. A square-root transformation was also applied to the coarse fragment and slope data to achieve normality prior to ANOVA testing. All differences were declared significant at $P \leq 0.10$. Mean separation was accomplished with Bonferroni multiple comparison tests (Neter et al. 1996).

Results

Bimonthly mean water table fluctuation (Table 1, Figure 2) averaged 7.0 cm and did not differ among the three plant communities ($P = 0.67$). Mean depth to water table (Table 1, Figure 3) significantly differed between the three communities and was greatest ($P = 0.004$) for the cottonwood communities (63 cm). The willow depth (32 cm) to the water table was intermediate and

TABLE 1. Mean (\pm SE) two-year growing season values for several site variables of black cottonwood recent alluvial bar, Geyer's willow and beaked sedge riparian plant communities in western Montana.

Site Variable	Plant Community Type ¹		
	Cottonwood	Willow	Sedge
Water Table			
Water Table Depth (cm)	63 \pm 2.7 ^a	32 \pm 2.3 ^b	21 \pm 1.1 ^c
Water Table Fluctuation (cm)	11 \pm 0.4 ^a	5 \pm 0.2 ^c	5 \pm 0.1 ^a
Soil Texture			
%Sand	78 \pm 2.3 ^a	35 \pm 2.2 ^b	47 \pm 2.7 ^c
%Silt	15 \pm 1.8 ^a	40 \pm 1.2 ^b	35 \pm 1.8 ^c
%Clay	7 \pm 0.6 ^a	25 \pm 1.5 ^b	18 \pm 1.2 ^c
%Coarse Fragments	46 \pm 1.1 ^a	22 \pm 0.5 ^b	15 \pm 0.3 ^c
Slope			
Parallel Slope ($^{\circ}$)	0.6 \pm 0.02 ^a	1.0 \pm 0.1 ^a	1.0 \pm 0.2 ^a
Perpendicular Slope ($^{\circ}$)	0.6 \pm 0.1 ^a	1.6 \pm 0.2 ^a	0.8 \pm 0.02 ^a

¹Means within rows followed by the same lowercase letter are not different ($p > 0.10$) using Bonferroni multiple comparison tests (Neter et al. 1996).

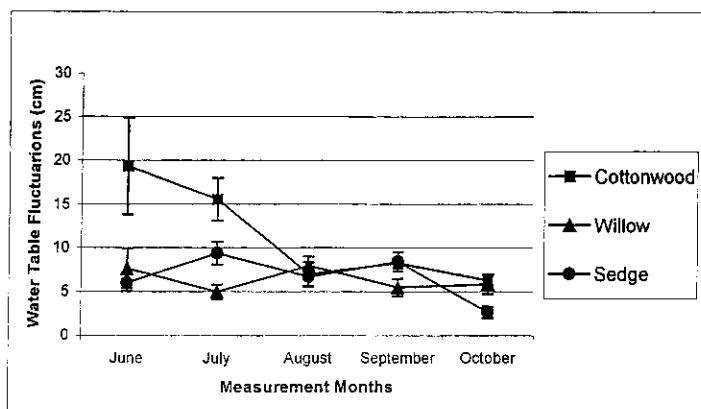


Figure 2. Mean 1997-1998 monthly water table fluctuations for each community type; error bars represent the standard error (σ/\sqrt{n}) of the sampling distribution (Ott and Mendenhall 1994).

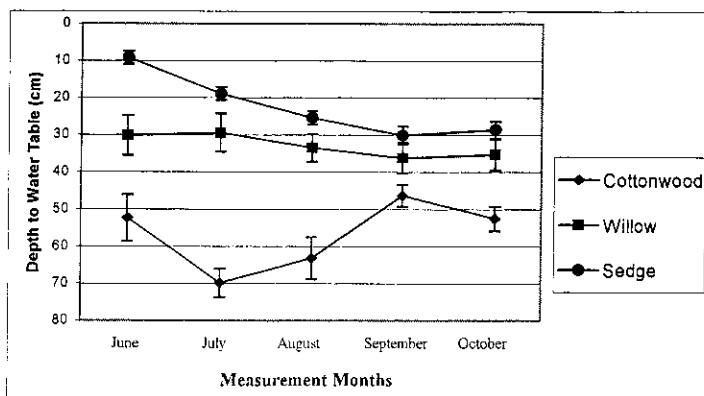


Figure 3. Mean 1997-1998 monthly depth to water table values for each community type; error bars represent the standard error (σ/\sqrt{n}) of the sampling distribution (Ott and Mendenhall 1994).

the sedge depth (21 cm) to water table was the shallowest.

Soil texture differed among the three plant communities (Table 1) for sand ($P = 0.0004$), silt ($P = 0.0002$), and clay ($P = 0.003$). Cottonwood soils were sandier (78% sand) than sedge soils, which were sandier (47% sand) than willow (35% sand) soils. Cottonwood soils also contained less clay (7% clay) and silt (15% silt) than sedge soils, which contained less clay (18% clay) and silt (35% silt) than willow soils which contained 25% clay and 40% silt. Sampled coarse fragments measured 2.1 mm to 11 cm and mean coarse fragment percentages differed among the three community types ($P = 0.01$). Cottonwood soils contained the most coarse fragment percentages (46%), willow soils were intermediate (22%) and sedge soils contained the least (15%).

We found no differences in slope among the three plant communities (Table 1), either parallel to the stream ($P = 0.76$) or perpendicular to the stream ($P = 0.29$). Across all sites, parallel slopes averaged 0.9° (1%) and perpendicular slopes averaged 1.0° (1%).

While the three riparian communities covered in this study experienced similar water table fluctuations of 0–0.11 m and occupied gradients of 0.67–1.0%, there were significant differences in soil texture, percent of coarse fragments and depth to water table. These differences indicate that black cottonwood recent alluvial bar, Geyer's willow and beaked sedge communities occupy specific sites within the riparian zone.

Black cottonwoods occurring on recent alluvial bars occupy gravelly loamy sand soils (46% coarse fragments). Groundwater within these communities has a mean depth of 0.6 m. Mean depth to water table is 0.3 m in Geyer's willow communities and they occur on sites with gravelly loam soils (22% coarse fragments). Beaked sedge communities grow on sites with loam soils (15% coarse fragments) and a mean depth to water of 0.2 m.

Discussion

While there are a number of publications describing the physical characteristics of certain riparian communities, few of the descriptions provide enough detail to be of use to a resource manager when evaluating revegetation potential on a degraded riparian site. Not only are the descriptions

too general but they offer contradictory information. For example, Kauffman et al. (1985) found cottonwood soils, along Catherine Creek in north-eastern Oregon, to be well-drained loamy soils with sand, gravel and cobbles while a similar community type in Montana was described as occurring on silt loam soils (Hansen et al. 1995). Manning and Padgett (1995) reported that beaked sedge communities occurred on clayey sites while Hansen (1995) described soils under beaked sedge communities as loamy clay to sandy loam. The only area of general agreement appears to be the soil textural class for Geyer's willow communities.

Youngblood et al. (1985), Manning and Padgett (1995) and Hansen et al. (1995) reported that Geyer's willow communities occupied fine textured soils (clayey and fine-loamy textures). However, this description suggests substantial overlap with the beaked sedge community type (clayey to sandy loam). Based on the successional models for Rocky Mountain montane and subalpine wetlands described by Windell et al. (1986) changes in soil textural classes should be reflected by differences in riparian community composition. Thus, the presence of a particular soil texture should dictate the occurrence of a particular riparian community, e.g., Geyer's willow or beaked sedge. However, Manning and Padgett (1995) and Hansen et al. (1995) report the same soil textural class for both beaked sedge communities and Geyer's willow communities. This poses a question for the resource manager trying to rehabilitate a degraded riparian area; revegetate with sedge or willow? Judgements about which species to use becomes even more complex if the Hansen et al. (1995) description of cottonwood soils is included in the decision making process; sedges, willows and cottonwoods all appear to occur on fine-loamy textured soils. The question then arises as to whether or not the depth to water table is equally variable.

Stream loss, snowmelt, and precipitation infiltration recharge groundwater lost through wells, springs, and evapotranspiration. The interaction between drawdown and recharge rates can cause considerable daily and seasonal water table fluctuation (Hackett et al. 1960). One might assume that, given different soil textures, coarse fragment percentages, and depth to water table that water table fluctuation would also be significantly different among the community types, yet they were

not. Although there is some temporal variability (Figure 2), especially in the cottonwood communities, this parameter, alone, does not separate the three community types. This may be due to the fact that spring runoff and precipitation events are very similar across the sites. Also, the water table at some cottonwood sites began to drop below 1 m from the soil surface in late July. Fluctuations below 1 m were not taken into account. Thus, the temporal variability in water table fluctuations of the cottonwood sites could not be included in the analysis when this occurred (Table 2).

TABLE 2. High and low water table depths and fluctuations during the growing season across the cottonwood recent alluvial bar, Geyer's willow and beaked sedge riparian plant communities in western Montana.

Site Variable	Plant Community Type			
		Cottonwood	Willow	Sedge
Water Table				
Water Table	High	>100.0	>100.0	48.0
Depth (cm)	Low	4.0	0.0	0.0
Water Table				
Fluctuation (cm) ¹	High	49.0	59.0	30.0
	Low	1.0	0.0	0.0

¹Some cottonwood sites and one willow site's water table fluctuations occurred below 1 m at the later part of the growing seasons and were not included.

Water table depth and soil texture partially regulate soil Eh (aeration) and water availability, and both influence the potential of a site to support a given plant community (Brady 1990). Because oxygen is essential for root growth in all plant species (Yamasaki 1952), woody species are particularly dependent on well-watered and well-drained substrates (Pezeshki et al. 1998). It follows that Pezeshki et al. (1998) found net carbon fixation of black willow (*Salix nigra*) to be highest in well-watered and well-drained conditions. Also, total black willow root biomass, at a variety of soil depths, decreased significantly under low soil aeration. Black willow posts (cuttings) exposed to continuously flooded conditions next to creeks experienced 80% mortality, and 79% of live root biomass was within 15 cm of the soil surface in continuously flooded conditions. Baldcypress (*Taxodium distichum*) and oaks (*Quercus* spp.) also exhibit this trend (Pezeshki 1991). Ewing (1996) showed that 2-year-old saplings of Oregon ash (*Fraxinus latifolia*) and red

alder (*Alnus rubra*) died in static flooding to or above the soil surface and experienced decreased photosynthesis and growth in cycles of flooding and drying.

Anaerobic microbial respiration (Mitsch and Gosselink 1993) and chemical reactions such as the production of soluble iron, manganese, ethanol, acetaldehyde, and cyanogenic compounds and pH changes (Kozlowski, 1984) in continuously flooded soils may cause nutrients to become unavailable or toxic to plants. Root respiration also is constrained under reduced conditions, which limits the supply of energy to the roots and reduces their ability to absorb nutrients (Brady 1990). These relationships may explain why both cottonwoods and willows occupy sandy and gravelly sites where water tables remain relatively low.

Unlike woody species, beaked sedge apparently tolerates root zone saturation (Ewing 1996). High water tables influence beaked sedge distribution more than soil substrate properties (Youngblood et al. 1985). In support of this observation, Manning and Padgett (1995) stated that beaked sedge colonizes permanently flooded sites. Kauffman et al. (1985) described sedge soils, in northeastern Oregon, as having fine-textured A-horizons above coarse-textured horizons that discouraged percolation. Even though the sedge and willow communities covered by this study occurred on loam soils, there were more coarse fragments in the willow communities (22%) than in the sedge-dominated communities (15%). The higher percentage of coarse fragments in the willow sites may allow the soil to drain quickly thereby quickly restoring soil oxygen levels following flooding. Differences in water table depth, 32 cm for willows and 21 cm for sedges, may explain why sedge communities convert to willow communities when a drop in the water table occurs (Hansen et al. 1988).

Conclusions

Results from our study can be used to reduce the apparent confusion over ecological site differences between these commonly occurring riparian communities and, thereby, improve the likelihood of riparian revegetation efforts. First, Geyer's willow communities occupy more coarse textured soils than beaked sedge communities (gravelly loams vs. loams) and contain more coarse fragments than the herbaceous type (22% vs. 15%).

Sites occupied by young cottonwoods will have the coarsest textured soils of the group (gravelly loamy sands) and have the highest percentage of coarse fragments (46%). Second, our results also indicate that further differentiation can be made between the three communities by measuring depth to the water table.

In the study beaked sedge communities occupied fine textured soils with 15% or less coarse fragments and a relatively shallow water table (0.2 m). This water table depth/plant community relationship is in agreement with the findings of Manning and Padgett (1995) and Youngblood et al. (1985). If depth to water table is 0.4 m or deeper and the soil is coarser (gravelly loam) and has a coarse fragment volume of at least 22%, Geyer's willows should dominate the site. Again, an earlier description of the Geyer's willow commu-

nity (Hansen et al. 1995) reported the same depth to water table as we found in this study. Sites with gravelly loamy sandy soils and a mean water table depth of 0.6 m will most likely be occupied by young cottonwoods.

Based on these results we recommend that depth to water table, soil texture and percent of coarse fragments be included in riparian site inventories. As this information is gathered for other community types resource managers should be better able to identify potential natural communities that are realistic and to select plant communities that meet their management goals (Smith 1987).

Acknowledgements

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