RIPARIAN VEGETATION OF THE MONTANA YELLOWSTONE AND CATTLE GRAZING IMPACTS THEREON

By

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ABSTRACT

The objects of my research were two. To describe ungrazed vegetion of thirty sites well dispersed along the 500 mile length of the Yellowstone River. And to measure the effects of gazing on this vegetation by describing/comparing vegetation of these ungrazed 'control' sites with the vegetation of nearby grazed sites.

Vegetation of the Yellowstone consists of three lateral bands on open shore (gravel or sandbar), willow thicket, and cottonwood forest. Their appearance on successively older deposits suggests control both by decreasing water availability (greater depth to water on inland sites with 'over deposits') and increasing age (overtopping, first by willow and then by cottonwood, and accumulation of shrubs). The primary longitudinal (downstream) change between foothill and plains sites, probably driven by decreasing rainfall, was the change of forest dominant from P. angustifolia to P. deltoides. The apparent failure of *P. deltoides* reproduction could eventually eliminate the forest zone.

Grazing affects all of the five communities identified. With grazing, overall cover decreased in every vegetation type, with the greatest losses in sandbars, willow thickets and *P angustifolia* forests. Cottonwood seedlings were grazed on bars and in willow thickets. Cover of hydric (*Salix spp., Cornus, Ribes spp.)* and mesic *(Symphoricarpos)* native shrubs was significantly reduced. *Rosa spp.* lost cover with trampling. Invasive shrubs Russian olive and tamarisk, downstream, are apparently unaffected by grazing, except indirectly as grazing reduces their competition. Forb cover was most affected in *Populus* forests, with natives declining and non-natives increasing with grazing. Non-native grasses, the dominant herbs in cottonwoods, become more dominant with grazing.

Observation of the exotics present emphasized the equal or greater impact of their invasion. Cover of exotics rises laterally from shore (50% with equal grass/forb composition) through willow thicket (70%, mostly exotic grass) to cottonwood forest (76-78%). The diversity of exotic herbs increases (laterally and downstream.). In the shrub layer Russian olive and tamarisk, pests in the American Southwest, increased greatly in the Plains in the 1980-2000 period and have a potential to dominate the forest and willow zones respectively. The ecosystem impacts of exotic increase will likely modify aesthetics, wildlife, and ranching drastically.

INTRODUCTION

The primary object of our project is to identify and evaluate the effects of grazing management on riparian vegetation within riverine corridors of the northern foothills and plains. The work is stimulated by the knowledge that riparian vegetation of high plains rivers serves our aesthetic, recreational, economic and water quality needs and provides critical fish and wildlife habitat (Mosley et. al. 1997).

Our review of relevant literature (see below) examines our knowledge of the effects of grazing - - the major industry of the region- - on riparian community composition and structure. The impacts on trees, shrubs, forbs and graminoids are discussed, as well as the impacts of grazing on species diversity and native vs. non-native dominance in the communities.

To examine the effects of grazing, we need to find contrasting treatments and, in doing so, to control for other variables, especially geographic variation in water and temperature conditions. There are three primary dimensions in riparian ecosystems: lateral – perpendicular to the river, longitudinal - along the length of the river, and vertical (above to below ground) (Vannote et. al. 1980). The lateral gradient (sandbar and/or gravelbar, willow, and cottonwood) extends from plentiful to scarce water and from recent to long ago community establishment (Boggs and Weaver 1992). Vegetation simultaneously varies down river as the climate warms and dries from conifer through foothill to plains

ecosystems (Zelt 1999). Simultaneously vegetation in any environmental type varies among grazing treatments due, at least, to amount of forage removal, season of removal and selection in that removal.

Our specific objectives are thus to 1) identify and describe riparian vegetation/ecosystem types of ungrazed or little grazed riparian plant communities of northern foothills and plains to provide a well-controlled basis for comparing grazing treatments in each type; 2) describe the physical environments of these communities to verify environmental homogeneity of the types and identify environmental differences among them; 3) compare ungrazed and grazed examples of each type to determine/document effects of grazing; and 4) conduct our study over a large scale (500 miles of river) to encompass the inherent variability of riparian sites.

Hypotheses

Our description of ungrazed riparian vegetation revolves around five hypotheses. We use three base hypotheses in our test for grazing effects. And we examine several factors as potential controls of vegetation distribution.

Our baseline description of ungrazed riparian vegetation is centered on five hypotheses. 1. Overall species richness/site will fall laterally from bar through willow to cottonwood vegetation. 2. Non-native richness will fall with increasing lateral distance from the river as introductions decline and disturbance

increases. It will rise longitudinally downriver due to a larger seed bank and ameliorating conditions. 3. The percent low constancy species will fall with increasing lateral distance form the river due to reduced introductions and disturbance. 4. Native and non-natives will be equally likely to be low constancy species. 5. Community composition is constant though time, i.e. similar between Boggs 1980 and Eggers 2001.

Our hypotheses with respect to grazing effects on riparian vegetation are three: 1. Species richness/site will not differ between ungrazed and grazed in any vegetation type. 2. Vegetation cover will generally decrease with grazing: a) Total vegetation cover will decrease with grazing in every vegetation type; b) Tree seedling cover will decrease with grazing, in bar and willow communities; c) Shrub cover will decrease with grazing, in every vegetation type; d) Forb cover will not vary between grazed and ungrazed sites, in any vegetation type; and e) Graminoid cover will decrease with grazing, in every vegetation type. 3. Grazing will reduce the cover of natives and increase the cover of non-natives. a) Native shrubs, forbs and graminoid cover will decrease with in every vegetation type; and b) Non-native forb and graminoid cover will increase with grazing, in every vegetation type.

Our hypotheses regarding environmental control of vegetation distribution are three: 1. Water availability- - as indexed by height above water and depth to gravel - - will decrease laterally from bar to willow to cottonwood. 2. Organic matter - - as indexed by soil organic carbon and nitrogen - - will increase with

stand age from bar to willow to cottonwood, due to stand aging. 3. Other factors, i. e. $CaCO_3$, pH, and soil texture, will not show lateral or longitudinal patterns.

LITERATURE REVIEW

Values

Riparian areas contain some of our country's most valuable ecosystems. Though small in area, they have high productivity and biodiversity - due in part to their high physical variability, surface and subsurface water, and rich soils (Green and Kauffman 1995; Fleischner 1994; Ohmart 1996). Riparian zones and their streams comprise less than 1% of the 11 arid Western states (US-GAO 1988), yet they are a critical source of water for riparian plants, wildlife, livestock and humans (Armour et. al. 1994). Riparian ecosystems provide critical functions of recharging groundwater, maintaining streamflow and stream temperatures, protecting water quality by filtering sediments and excess nutrients, stabilizing streambanks, attenuating floods, and providing habitat for wildlife and fish (Kauffman and Krueger 1984).

Riparian Vegetation of the Northern Plains

The diversity of riparian plant communities is maintained by the erosion and deposition of sediments by rivers. The faster the rate of meandering, the higher the proportion of pioneer and early seral stages in relation to later seral and climax communities (Hansen et. al. 1988). In Montana, deposits of fresh

alluvial materials are colonized by *Populus* spp. and *Salix exigua* (sandbar willow). These species have delicate seeds, and require a constantly moist surface for seedling establishment (Wilson 1970). As these seedlings grow, a dense thicket of *Salix exigua* develops. *Populus deltoides* seedlings in these thickets overtop the willow, and eventually form young cottonwood stands. In eastern Montana, as the trees mature, an understory of smaller trees and shrubs develops. This can include *Fraxinus pennsylvanica, Juniperus scopulorum, Symphoricarpos occidentalis, Rosa woodsii* and other species (Boggs 1984; Boggs and Weaver 1994). Although the research on this successional sequence has been carried out in *Populus deltoides* communities (Wilson 1970; Boggs 1984), it has been assumed that the same sequence applies to *Populus angustifolia* communities (Hansen et. al. 1988).

Our study examined the riparian vegetation of the Yellowstone River from Emigrant, Montana, where *Populus angustifolia* replaces conifers of the montane zone - to Sidney, Montana where the river crosses into North Dakota and shortly thereafter empties into the Missouri. The riparian forests for the first 100 miles of this stretch are dominated by *Populus angustifolia* (narrowleaf cottonwood). The remaining 400 miles of the lower Yellowstone are bordered by *Populus deltoides* (Plains cottonwood) communities, in the Northern Great Plains. *Salix exigua, Populus angustifolia, Populus deltoides* are all recognized as Montana riparian dominance types, and have been briefly described (Hansen et. al. 1988). A more thorough description of the riparian vegetation of the lower Yellowstone,

1980-1981, was made by Boggs (1984). Our work characterizes the present communities, contrasts ungrazed and grazed sites, and compares the lower Yellowstone today with its status in the early 1980s as described by Boggs (1984).

Disappearing Resource

In the western United States, riparian ecosystems have been modified by livestock grazing, agriculture, logging, mining, road construction, flood control measures and other activities (National Research Council 1995). Nationwide, approximately 70 – 90% of all riparian areas has been altered significantly (Hirsch and Segelquist 1978). In the arid West, livestock grazing is an important factor in this degradation, having affected 80% of riparian ecosystems and streams (USDI 1994a). The known impacts of grazing on riparian vegetation, soil properties, streambank stability, fish and wildlife species, hydrology and stream water quality are summarized in numerous review articles (Kauffman and Krueger 1984; Chaney et al. 1990; Fleischner 1994; USDI 1994a; Mosely et. al. 1997, among others). The degradation of riparian areas continues, with less than 20% of the West's potential riparian habitat still in existence (USDI 1994a). Trimble and Mendel (1995) attribute this continued decline, in part, to a doubling of the cattle population on Western rangelands in the past half century: from 25.5 million in 1940 to 54.4 million in 1990. Federal land management agencies in the

11 western states still permit grazing on 91% of all federal lands (Armour et. al. 1991.)

Grazing Effects

There has been substantial research on effects of grazing on riparian vegetation. Most of it is focused on the Southwest, the Great Basin and the Pacific Northwest (Belsky 1999). Studies in the northern Great Plains are rare; some work has been done in northern Colorado (e.g. Popolizio et. al. 1994; Sedgwick and Knopf 1991), and in Montana (Marlow et. al. 1989; Ehrhart and Hansen 1998).

The susceptibility of vegetation to grazing varies greatly among regions due to adaptation, arising from long association with grazing animals and the resultant coevolution. Communities of the arid west (the Southwest, Colorado Plateau and Great Basin) lack such a long history of large, native grazers and are therefore more susceptible to grazing (Mack and Thompson 1981, Kay 1994, Berger and Cunningham 1994; Belnap 1997). On the Colorado Plateau, livestock grazing has had widespread impacts on ecosystem functions (Belnap 1997). On a worldwide basis, the most important factor determining grazing impacts on plant productivity is the evolutionary history of grazing animals in that local environment (Milchunas and Lauenroth 1993). In contrast, riparian herbaceous species of the northern plains (including the Yellowstone) that have

been bison grazed are hypothesized to be more grazing resistant. To restate, studies conducted in southwest, Great Basin and other arid regions of the West may have little application to riverside vegetation of the Northern Great Plains.

Grazing Effects on Woody Species

As *Populus, Salix* and *Carex* species found along the Yellowstone are common in riparian areas throughout the West, I review the literature describing grazing and browsing impacts on riparian vegetation. Many riparian studies have focused on wetter zones, with particular attention to grazing impacts on willows, sedges and grasses. A few researchers have included cottonwood, aspen and conifer dominated communities in their work (Powell et. al. 2000).

Biomass and cover of woody riparian species generally decline with cattle grazing (Kauffman and Krueger 1984). Where grazing is less than five years, one sees negative impacts on *Salix exigua* but not necessarily on other woody species. In a four year study of willows in the eastern Oregon sagebrush-steppe zone, *season long* grazing decreased the density of mature *Salix exigua*, but not of taller *Salix lasiandra.* Seedling densities of neither species was reduced by light to moderate grazing treatments in either the spring or fall (Shaw 1992). On sites that had not been grazed for thirty years (Sedgwick et. al. 1991, northeastern Colorado) the biomass of *Salix spp.* decreased significantly ($P<0.01$) with three years of late autumn grazing. Although there was no significant grazing effect for shrub species combined, the authors noted that a

major forage supplement of fallen cottonwood leaves minimized the grazing treatment originally prescribed. A third study of *Populus angustifolia* communities compared the effects of grazing intensity (moderate, light and none) and season of use (cool, warm and dormant) on cottonwoods in New Mexico. After two seasons of cattle grazing on cottonwood twigs, browsed trees (not seedlings) did not differ significantly in either density or height from unbrowsed trees (Lucas 2004).

In contrast, with thirty years of exclosure in north central Colorado, not only willow, but all the riparian shrub species increased cover. Willow cover was 8.5 times greater in the pastures rested for 30 years, than in pastures grazed season long since 1900, and total shrub cover was 5.5 times greater in the exclosures than the grazed sites. Furthermore, total density of all woody species was significantly higher in the ungrazed areas ($P \leq 0.02$) (Schulz and Leininger 1990). And in Nevada, vegetation of 30 year exclosures was compared to vegetation of adjacent riparian areas grazed during the summers. Protected areas had more woody vegetation ($P<0.01$) and more willow ($P<0.03$), than the grazed sites (Ammon and Stacy 1997).

Both long and short-term effects in eastern Oregon, were consistent with effects of shorter term vs. longer term grazing described above. After three years of late season grazing, the vegetation of grazed gravel bars had lesser heights and densities of cottonwood saplings and of willows (*Populus trichocarpa* and *Salix spp.),* than ungrazed gravelbars. The authors observed that the late

season grazing was likely retarding succession in these woody-dominated communities (Kauffman, Krueger and Vavra 1983a). After 11 years at the same site, with continued late season grazing, the height and density of *all* woody species (not just willows and cottonwoods) on gravelbars was reduced by grazing (Green and Kauffman 1995).

Grazing impacts on woody riparian species other than willow and cottonwood have been less studied (Powell et. al. 2000). In eastern Oregon, cattle grazed *Ribes spp.* hard, often taking more than 100% of current year's growth. They also browsed snowberry to a limited extent (Kauffman, Krueger and Vavra 1983a). In north central Colorado, the woody species that increased most after cattle grazing exclusion were willow *(Salix spp.),* shrubby cinquefoil *(Potentilla fructicosa),* and aspen *(Populus tremuloides),* however levels of increase were insignificant for these species considered individually.

The impact of grazing on woody riparian species varies with season of use. A survey of the impacts of eleven common cattle grazing systems on willow communities in central Oregon, concluded that season of use is a critical factor (Kovalchik and Elmore 1992)**.** *Fall grazing* was found to be "incompatible with willow management because of… the switch [from grazing] to browsing" after herbaceous plants dry out. Light fall grazing didn't eliminate the impacts on willow, it just "prolonged the outcome." Subsequent studies concurred that late season riparian grazing negatively impacts riparian shrubs (Lamman 1994, Winward 1994, and Myers and Swanson 1995). With *late spring grazing* of

willow dominated mountain meadows in Idaho, ten years of protection was imposed to compare the effects of this exclosure with light and moderate grazing. While willows increased most in the ungrazed exclosures, they also increased in the late spring light and moderate grazing treatments. There was no heavy grazing treatment in this study for comparison (Clary 1999).

In Montana all well managed traditional grazing systems – except season long – could be successfully applied to riparian grazing if the operator monitored impacts closely, managed their cattle to avoid overgrazing, and encouraged cattle not to loiter in the riparian areas. It also helped to provide off stream water for cattle (Ehrhart and Hansen 1998). Note that this study was conducted in the Northern Great Plains, and may not apply to riparian grazing in arid ecosystems on the west side of the Rockies.

Mechanisms of Shrub Damage. Cattle grazing damage to willows and cottonwoods is usually attributed to browsing on younger shrubs and saplings, rather than from rubbing and bedding on older shrubs (Clary 1989). Skovlin's (1984) review concluded that the negative impacts of grazing on riparian trees and shrubs were "from damage to the regenerative stage of woody plants." Similarly, Belsky (1999) concluded that the decline in tree and shrub biomass and cover is due to "browsing by livestock on shrubs and tree saplings when they are most vulnerable." In contrast, while Severson and Boldt (1977) agree that

browsing is important, they also see rubbing and trampling as important factors in the Dakotas.

Grazing Effects on Herb Cover/Production

Like shrub cover, graminoid cover and total vegetation cover typically decrease with long term or heavy grazing. Comparison of constantly grazed sites in Colorado with areas protected from grazing for 7 – 25 years, demonstrated that grazing reduced grass, forb and shrub cover, and reduced shrub height (Crouch 1978). Herbaceous cover was decreased by 42% on heavily grazed (75% removal) Missouri River sites (Hoffman and Stanley 1978). In north central Colorado long term grazing reduced total vascular cover, shrub cover, and graminoid cover, but total forb cover was not significantly affected (Schulz and Leininger 1990). In riparian mountain meadows in Idaho, ten years of grazing exclusion significantly decreased forb cover, while there was little change in the meadows' total graminoid cover. There was, however, a shift in species composition as sedges and other late seral species increased significantly, and exotic (*Poa pratensis)* cover decreased (Clary 1999). In contrast, a three year exclosure in north central Colorado showed no change in relative cover of life forms (forbs, rushes and sedges) but did not test the possibility that species composition within a life-form may have shifted (Popolizio et. al. 1994). Belsky's review (1999), citing 14 studies, concluded that the cover, biomass and productivity of herbaceous species declines with grazing.

The impact of grazing on forb cover is less clear and is undoubtedly affected by the chemical and physical properties of the plants concerned (Larcher 2003). Two of papers discussed in the preceding paragraph showed less forb cover in grazed than ungrazed riparian grassland, one showed no change and a fourth showed forbs decreased with *exclosure*.

Grazing Effects on Composition: Natives vs. Exotics

While grazing may not affect the life-form composition of a stand (e.g. grass vs forb cover), it might modify the species composition within a life-form. Species composition is likely to shift as grazing sensitive (decreaser) species are eliminated, increaser species expand their percent cover, and invader species move in. While species specific responses to grazing are commonly used in the evaluation of range condition on upland sites (Holechek et. al. 1989), the phenomenon is poorly documented in riparian sites of the northern plains.

Few riparian studies have examined the effects of grazing on invasion by non-native species. Significant responses to grazing have only been shown for a handful of species. In north central Colorado, sites with more than 70 years of grazing were exclosed and allowed to rest for thirty years. *Poa palustris* increased with this release from grazing, having six times the cover in ungrazed plots as grazed plots. *Poa pratensis,* on the other hand, decreased 75% with exclosure. *Trifolium repens* also decreased significantly with exclosure, to 11% of its former cover. *Carex nebraskensis* cover was not significantly different

between grazed and exclosed sites, leading the authors to conclude it was grazing resistant. The possibility that *Carex nebraskensis* simply couldn't recover substantially in the exclosures was not discussed (Schulz and Leininger 1990).

In a three year study in north central Colorado, *Taraxacum officianalis, Trifolium repens* and total legumes cover were higher ($p < 0.05$) on grazed than ungrazed sites, and *Poa pratensis* increased with grazing, though not significantly. Some native species, such as *Agropyron trachycaulum* and *Potentilla fructicosa*, were only found in exclosures; the old exclosures had a greater proportion of native species than the grazed sites, but none of the differences in cover were statistically significant (Popolizio et. al. 1994).

In Oregon after 11 years of treatment, there was no significant difference in percent exotic cover between grazed and exclosed sites on either gravel bar or cottonwood habitat. However, in the wet meadow exclosures frequencies of the exotics *Phleum pratense* and *Ranunculus acris* declined significantly. In contrast, *Poa pratensis,* a widespread exotic, declined significantly in the cottonwood community with grazing, but also declined significantly with exclosure in the Ponderosa Pine community (Green and Kauffman 1995).

Of the few studies that have examined species level grazing effects, none of them found more than four species with significant differences in cover between treatments within any one riparian plant community (Green and Kauffman 1995, Popolizio et. al. 1994, Clary 1995, Sedgwick et. al. 1991,

Schulz et. al. 1990). Unfortunately, because many grazing studies did not report species specific vegetation data, they are unable to address this question (Jones 2000). A number of researchers have observed and commented on species composition changes: either that grazing facilitates the invasion of weedy species, and/or that late seral, native species increase with exclosure (e.g. Kauffmann et. al. 1983a; Schultz and Leininger 1990; Clary and Medin 1990; Green and Kauffmann 1995; Clary 1999).

Grazing Effects on Species Diversity

Grazing can apparently increase or decrease species diversity. The variance is likely due to differences in initial condition and/or in the treatment level, with increased diversity due to opening of the stand (reduced competition, higher soil temperatures) and decreased diversity due to actual consumption of the plant considered. Thus some papers report increased species diversity in grazed riparian communities under certain grazing treatments (Dobson 1973; Green & Kauffmann 1995; Clary 1999; Lucas et. al. 2004). Other papers report no modification of diversity by grazing in riparian community types (Hoffmann and Stanley 1978; Kauffmann et. al. 1983b; Green & Kauffmann 1995). One review concludes that there is a decline in native species diversity with grazing, but doesn't address non-native species diversity (Belsky 1999).

Both for the sake of recording species diversity and to completely characterize community composition, one should record cover estimates for each

species present at sites sampled. First, with respect to measuring diversity, a review of grazing studies conducted in arid *upland* ecosystems, which found no statistically significant decrease in vegetation species diversity with grazing in thirteen studies (P = 0.086), notes, "Although…vegetation diversity [was] statistically similar between grazed and ungrazed areas, much of this apparent lack of response to grazing may simply be an artifact of lumping plant species into broad vegetation categories… The vegetation diversity category [in this review] would have had more useful implications for range scientists and managers if it had been possible to include grazing studies that reported vegetation diversity in terms of numbers of native and non-native species. I urge future investigators of grazing effects to collect and present vegetation data on a species-specific basis." (Jones 2000).

Second, with respect to fully characterizing community composition, gathering species specific data can also reveal information about rare species, which is missed by studies that collect and report data by plant life forms only. For instance, an Australian study that looked at the composition of plant communities along grazing gradients in upland rangelands, found that many species were "singletons," i.e. found only at one site, and that lightly grazed sites had more uncommon species (Landsberg et. al. 2003). The authors note that little "is known of the impact of livestock grazing on the less common species that comprise the bulk of plant diversity."

From these studies, it is apparent that change in species richness is a limited indicator of grazing effect on community integrity. Species richness, along, doesn't indicate changes in community composition or relative abundance of species (cf. Landsberg et. al. 2003). Diversity may increase with grazing, as the community is opened to exotic species (Dobson 1973), or decline as rare "decreaser" species disappear with grazing (Landsberg et. al. 2003). Diversity may remain unchanged if the community is unstressed or if the number of invading species matches the number of susceptible natives lost (e.g. Kauffman et. al. 1983a).

Effects on Litter and Bare Ground

As vegetation cover decreases with grazing, litter also declines, probably from lack of inflow (Belsky 1999, citing five sources). The percent bare ground increases correspondingly (Clary and Medin 1990; Schulz and Leininger 1990; Popolizio et. al. 1994; Lucas et. al. 2004 and others).

DESCRIPTION OF STUDY AREA

The Yellowstone River is the largest tributary of the Missouri River. Beginning in the Absaroka Range of northwestern Wyoming, it flows 670 miles north and then east through Montana, to join the Missouri near Williston, ND. At its confluence, the Yellowstone's mean annual discharge is 361 m^3/s, about 55 percent of the two rivers' combined discharge. The longest free-flowing river in the continental United States, it drains an area of 182,000 km^2, of which 48 percent is in Wyoming, 51 percent in Montana and 1 percent in North Dakota (Figure 1).

The major tributaries of the Yellowstone, from west to east, are the Clark's Fork of the Yellowstone, the Bighorn, the Tongue and the Powder Rivers. All flow north from Wyoming and empty into the Yellowstone in Montana. The upper Yellowstone, Clark's Fork and the Bighorn Rivers contribute 86% of the mean annual flow of the Yellowstone at its mouth. The headwaters for most of the perennial flow are in the Beartooth, Wind River, Bighorn and Absaroka Mountains. The reservoir behind Yellowtail Dam on the Big Horn River is the only major reservoir in the Yellowstone River Basin (Zelt 1999). Streamflow characteristics of the Yellowstone River are summarized in Table 1, in the Appendix.

We studied the vegetation along five hundred miles of the Yellowstone River, beginning 30 river miles north of the Yellowstone's entrance into Montana,

above Emigrant (elevation 1480 m) and ending at the river's exit into North Dakota just north of Sidney, Montana (elevation of 575 m.). The riparian gallery forest of the first 100 miles flows through the "foothills prairie" zone (Kuchler 1964) - and is dominated by *Populus angustifolia* (narrowleaf cottonwood). For the next 350 miles the Yellowstone flows predominantly through blue grama, needlegrass and wheatgrass grassland, changing to wheatgrass-needlegrass grassland for the final 50 or so miles before it reaches the Missouri River (Kuchler 1964). The riparian forest (northern floodplain deciduous forest, Kuchler 1964) is dominated by *Populus deltoides* (Plains cottonwood) for this 400 mile stretch (Figure 2).

For the basin as a whole, 44% of the potential natural vegetation is steppe, including the foothills prairie, and the grama-needlegrass-wheatgrass and wheatgrass-needlegrass grasslands. Invasive exotic species, such as Russian thistle, are common in some locations. Sagebrush steppe or semidesert shrub dominates 21% of the basin (out of a potential coverage of 25%); besides sagebrush, this vegetation commonly includes short grasses and rabbitbrush (Marston and Anderson 1991). Various types of coniferous forests cover about 19% of the basin, although their potential extent is estimated at 28% (Kuchler 1964). Alpine meadows (3%) are found at high elevations and northern floodplain deciduous forests (1%) occur in the lowlands, primarily along the Yellowstone (Zelt 1999). These riparian forests are typically dominated by Plains

cottonwood, with willows, boxelder, ash and the non-native Russian Olive being locally common (Knight 1994; Zelt 1999).

A transition from the Northern Rocky Mountains province into the Great Plains occurs between the communities of Mission and Springdale, Montana, at about mile 55 of this study (Fenneman and Johnson 1946). About 45 miles after this transition, the higher elevation *Populus angustifolia* (narrowleaf cottonwood) gives way to the lower elevation *Populus deltoides* (Plains cottonwood) (Figure 3).

The Rocky Mountain province gets more precipitation than the lower elevation Great Plains (Table 2). Average annual precipitation is 200-400 mm in the plains, 400-600 mm above Livingston, and still higher in the mountainous unstudied conifer forest zone (Figure 4) (Zelt 1999). In the Great Plains, average annual precipitation at five weather bureau stations along the river between Billings and Savage, MT, ranges from 343 mm to 360 mm, averaging 354 mm. Sidney, MT, at the very downriver end of this study, receives an average of 391 mm (National Climatic Data Center, at http://www5.ncdc.noaa.gov/pubs/publications.html#CD).

In most of the Yellowstone basin, 40-45% of the annual precipitation falls during the April – June period. In the upriver Rocky Mountains Province (Livingston), the highest mean daily precipitation falls in May and June, with a lesser peak in September. The winter period (December – March) is very dry. Downriver in the Great Plains Province (Glendive), the maximum mean daily

precipitation comes in June, with a lesser peak in late August – early September, followed by a dry winter period from November through March (Figure 5). Potential evaporation in the Great Plains province greatly exceeds precipitation, generally surpassing 900 mm/year and exceeding 1100 mm annually in drier parts of the Yellowstone River valley (Ostresh et. al. 1990; Marstone and Anderson 1991, cited in Zelt 1999).

Summer temperatures are slightly cooler and the growing season slightly shorter in the Rocky Mountain province, compared to the Great Plains. The maximum daily temperatures occur in late July for both provinces: in Livingston they average about 29°C, whereas in Glendive they are about 32°C (Figure 5, Western Regional Climate Center, digital data, 1997, in Zelt 1999). The number of frost free days at Pine Creek, upriver of Livingston, is 102, based on a 10 year average while on the lower Yellowstone the ten year average for 11 river communities is 121 days (Table 2) (http://www5.ncdc.noaa.gov/pubs/publications.html#CD). The lowest average minimum temperatures come in early January, with Livingston being milder than Glendive (-9 °C vs. -15 °C minimums).

Dominant human activities of the Yellowstone River Basin are primarily livestock production and secondarily irrigated and dryland crop production. In area, the principal land uses are range (65% of the area) and agriculture (11%). Forests (20%), mostly at higher elevations, support some timber production on

National Forest Service and Reservation lands. Urban or built up areas occupy only 0.3% of the land base (U.S. Geological Survey 1986, modified in Zelt 1999).

The geology of the Yellowstone River Basin is complex and is well described by Zelt (1999) (Figure 6). The upriver 75 miles of this study, in which the Yellowstone flows through the Foothills prairie, is underlain primarily by Tertiary and Cretaceous instrusive and volcanic rocks, with Quaternary unconsolidated deposits along some part of the River channel. From Big Timber (mile 75) downriver, Cretaceous and Tertiary sedimentary rocks underlie the grasslands of the Great Plains province, with deposits of Quaternary unconsolidated materials along most of the length of the Yellowstone.

METHODS

Overall Sampling Design

To test for grazing effects we sought sites in vegetation/ecosystem types along the main stem of the Yellowstone, with and without cattle grazing. Most of our "ungrazed" sites were located at fishing access areas where a low recreation impact segment represented the ungrazed condition. Matched sites on private land represented the grazed condition (Figure 7). We then examined vegetation composition in each of the vegetation types (sandbar, gravelbar, *S. exigua*, *P. angustifolia, P. deltoides*) present at each site. There were cases where we found a type (e.g. willow thicket) in one but not both treatments. If, in other cases, we wished to represent two distinct phases of a type (eg cottonwood forest) we took two samples and treated them as separate samples in t-tests comparing the grazed and ungrazed treatments. To ensure that the pools of ungrazed and grazed sites of each vegetation type did not differ from one another due to average river location, the environmental variables characterizing each pool were compared.

Vegetation of one zone (eg cottonwood) might contain two (or more) communities. To minimize this source of variation we ordinated the vegetation of each zone (Kruskal 1978, see below), and found that willow consisted of one community while cottonwood (P angustifolia and P deltoides) consisted of two

communities (Figures 32 & 35). Heterogeneity of community samples was further reduced by segregating juvenile vs mature cottonwoods. Thus we described sandbar, gravelbar, *S. exigua, P. angustifolia* and *P. deltoides* communities separately and tested for grazing effects in each.

Sampling

To characterize ungrazed riparian ecosystems of the Yellowstone River, I selected 27 locations from Emigrant to Sidney, MT. Twenty of these were at Montana Fish, Wildlife and Parks fishing access sites (FAS) and the remaining locations were on similarly protected state or federal lands (Table 3; Figure 7). The locations chosen were well distributed on the river, free from any significant cattle grazing (on average for > 20 years) or other human disturbance (e.g. agriculture, fire, logging, or heavy recreational use). Every Montana FAS on the Yellowstone River, from Emigrant to Sidney, which met these criteria was included in the study. Sites above Emigrant were omitted because they contain conifers and so represent the montane zone, rather than the grassland zone.

To compare grazed and ungrazed conditions I located a similar grazed stand near each protected site. Eighteen of the grazed locations were on private ranches, operated by the landowner, one was on a ranch managed for an absentee owner, and five were on state lands leased for grazing. Only one of the ranchers who was approached to participate, declined. Ranch selection was

based solely on location (close proximity to the fishing access site) and the presence of cattle grazing, and not on size of operation, management expertise or the intensity or system of grazing.

Plots were located at representative points in major riparian zones at each location, for a total of 119. Thirty-two riverside sites included twenty "gravelbar" and 12 "sandbar" sites. Thirty-two Salix exigua (sandbar willow) sites appeared slightly inland. And, further inland, I sampled cottonwood forest including 21 foothill zone Populus angustifolia (narrowleaf cottonwood) stands and 34 plains Populus deltoides sites. The *Salix exigua, Populus angustifolia* and *Populus deltoides* communities are recognized as Montana riparian dominance types (Hansen et. al. 1988).

Nine additional stands were sampled but not included in the analysis because they lacked design requirements. Six of these plots dominated by *Populus acuminata* (the hybrid of *P. angustifolia* and *P. deltoides*) lacked grazed site pairs. One site dominated by *Salix amygdaloides*, and two sites dominated by *Salix rigida* were inadequately replicated. The data from these sites are not reported here. An additional four stands of young cottonwood were sampled and found to be substantially different from mature cottonwood. The data from the three ungrazed cottonwood sapling stands (two *P acuminata* and one *P deltoides*) are reported here, but were not averaged with either the vegetation or the environmental data from the mature cottonwood communities.

Community Composition

The vegetation of each stand was characterized by sampling a 2 x 25 meter plot placed in a representative segment. Due to the relatively small size of sandbars, gravel bars, willow thickets, and ungrazed cottonwood forests there was usually little room for discretion in plot selection, and when the plot was located it covered much of the available area. Areas of cottonwood forest were larger on grazed public and private lands. Where there was evident variability, two or even three plots were selected to represent the range of variability in age or understory vegetation. Each 2 x 25 m plot was sampled for species present, their cover, and their frequency.

Species were identified following Dorn (1984), verified against the Montana State University herbarium in Bozeman, Montana, and voucher specimens placed with the MSU Bozeman herbarium. The determination of which species were non-native was made by consulting the U.S. Department of Agriculture on-line database (http://plants.usda.gov). For the few species for which there are both native and non-native varieties in the United States we assign origin by the sub-species or variety appearing in our area.

To measure frequency (=ubiquity, Daubenmire 1968), presence was recorded separately for each of the five 5 x 2 meter segments of the plot. Species occurring outside of the plot, but nearby and in the same vegetation type, were recorded as present, but “outside”.

Cover was estimated for each species. Understory cover was recorded, by cover class, for herb and low shrub species in a 2 x 2 meter plot at the beginning of each of five plot segments, i.e. for the 0-2 m., 5-7 m., 10-12 m., 15-17 m., and 20-22 m. segments. For taller shrubs, primarily juniper and Russian olive, cover was measured as the percent of a 25 meter line running through the center of the transect that intersected each species. Presence or absence of cottonwood canopy was recorded at twenty-five points, (i.e. at each meter of the 25 meter center-line). Canopy cover was measured with a vertical 'overhead periscope' that viewed a small disc of canopy or sky above the point selected (Weaver and Dale 1974). Cover was calculated as the percent of points where "presence" was recorded and, to the extent that both cover and sky appeared in the field, it is an overestimate.

Ranchers provided information on numbers of cattle in their riparian pasture, seasons of use and length of use. Detailed records that would have allowed calculation of stocking rates over the past twenty (or even five) years were generally not kept. Even when numbers of cattle and season of use could be described, exact dates cattle were moved and especially pasture sizes (in acres or hectares) were typically not known. To estimate grazing intensity (over recent years), cow pat density was recorded for all plots.

This research design: (1) can tell us how riparian vegetation responds to release from grazing, but not how grazing affects pristine vegetation; (2) can examine twenty year responses - for instance, shrub responses to grazing vs.

exclosure – but may not elucidate long term responses, such as impacts on the cottonwood life cycle; (3) encompasses the range of variability in riparian sites along 500 miles of the Yellowstone, as well as a variety of grazing systems, stocking rates and cattle management approaches. Therefore, any patterns revealed in vegetation responses to cattle grazing or to recreation site management will have broad applicability; 5) can quantitatively examine the responses of individual species to release from grazing, and examine questions related to plant origin (native vs. exotic); and 6) allows us to make longitudinal comparisons of riparian vegetation and environmental variables, between foothills and prairie, and between gravelbar and sandbar substrates as the river changes from transitional to depositional.

Environmental Sampling

The environment of each site was characterized with indices of climate, water availability (height above water and depth of soil to gravel), soil texture, soil salinity (conductivity), $CaCO_3$ and pH, organic matter and nitrogen. Methods are detailed below.

Climatological Data

Temperature, precipitation and number of frost free days/year data were all obtained from the National Climatic Data Center, National Oceanic and

Atmospheric Administration, U.S. Department of Commerce (http://www5.ncdc.noaa.gov/pubs/publications.html#CD). We used data for 13 locations along the Yellowstone River (from upstream to downstream): Livingston south (close to Pine Creek), Livingston, Big Timber, Columbus, Billings, Huntley, Hysham, Forsyth, Miles City, Terry, Glendive, Savage and Sidney. These sites reasonably represent all but the first 20 upriver miles of our study area.

Height Above Water

Height above the river, an index of water availability, was measured once with a stadia rod and a hand held level in each 2 x 25 m plot. As the water level in the Yellowstone River gradually dropped over the course of the summer, in some locations by as much as four feet, and as sites were sampled throughout the summer months, the “height above water” numbers recorded are only approximations of the average elevation difference between the soil surface and the river water surface.

Depth to Gravel

Depth to gravel is used as a second index of water availability; this assumes that the top of a mature gravel bar has a constant height above stream water and that when the bar is buried by deposition, that reference height is preserved. It was measured at the center of each transect by measuring down

from the surface through a bore hole, to the underlying gravel layer. The measurement was straight forward for the sandbar, willow and upriver cottonwood sites. For some downriver cottonwood sites, however, the depth to gravel exceeded the 152 cm length of our corer. In these cases, where the transect was bordered by an exposed, steep river bank, the distance from the soil surface down to the gravel layer was measured on the river bank instead. Depths to gravel measured in this way ranged from nearly 2 to 4.5 meters. Where depth to gravel couldn't be measured by either method, we assigned the minimal bank measurement, two meters.

Soil Sampling

Soils of cottonwood, willow and sandbar communities were sampled for three possible controlling features (soil texture, electrical conductivity, pH) and two measures of soil development (total nitrogen and organic carbon). Samples were drawn with an auger from the 0 – 10 cm layer at 20 points, a meter apart, along the center length of the transect. The samples were mixed, sieved of roots and stones, air dried (within 12 hours), and then oven dried and analyzed by the Montana State University soils lab. Soil texture was measured as an index of water holding capacity, using a modified Bouyoucous Mechanical Analysis (Klute 1986). Both EC and pH measurements were made on a 1:1 slurry (one part soil to one part water) with standard EC and pH meters (Sparks 1996).

Soil samples were also tested for organic carbon and total nitrogen as indices of soil development. Total carbon and total nitrogen were measured by combustion analysis, using a LECO Carbon-Nitrogen-Sulfur (CNS) 2000, per the instrument manufacturer's instructions. Percent $CaCO_3$ equivalency was measured by ignition, and was subtracted from total carbon to obtain total organic carbon (Sparks 1996). That is: Total percent organic carbon = (total % C) – (% $CaCO_3$ equivalency)(0.12).

Gravel Measurements

As one travels downriver, the river bed composition changes systematically from coarser to progressively finer sediments (i.e. due to such 'downstream fining,' particle sizes decline from boulders at the headwaters, replaced successively by cobble, gravel, sands, silts and clays, Thorne et. al. 1997). We documented fining on the Yellowstone, by measuring particle sizes at every gravel beach or sand bar sampled. To characterize particles on gravel bars we measured rocks at 100 equally spaced points along the center of the transect. The width of the stone hit by each point, was measured in millimeters. (Of the three dimensions - depth, width and length – width is the middle measurement and is therefore the minimum sieve size through which the stone will pass.) When the point fell on sand, its diameter was recorded as "1 mm." Percent sand substrate was calculated as the number of points out of 100 that fell on sand. This measurement specifies the surface area (%) of substrate

available for species that establish in sand, but not on gravel. All 100 measurements were sequenced from lowest to highest value, and the 10^{th}, 25^{th}, median, 75^{th} and 90^{th} values were recorded as a summary description of that gravelbar's substrate/ energy of deposition.

Statistics

Systat (SPSS, Inc 2000) was used to make our statistical analyses, which included multiple regressions and T- tests. T-tests were run with separate variance and again with pooled variance; both numbers are given if the values are not identical (as "sv" and "pv"). Means and standard deviations were calculated in Excel. Any results significant at $p \leq 0.10$ are reported.

To identify communites (sandbar, gravel bar, willow thicket, *P angustifolia*, and *P deltoides*) and assign stands to the correct community type, we used Non-Metric Multidimensional Scaling (NMDS) to create ordinations (Kruskal 1978). PCoA scores were used as initial starting points (Roberts 2005). Sørenson's dissimilarity was used to create the dissimilarity matrix (Sørenson 1948). A tolerance of $1*10^{-7}$ was used with 200 iterations to create the final configuration (e.g. McCune and Grace 2002). No additional dimensions were used if final stress for the solution was less than 20. Stress is the departure from monotonicity in the plot of distance in the original n-dimensional space versus distance in the NMS ordination space (McCune and Grace 2002). Strength of

association between environmental variables and NMDS scatter was quanitified with vector fitting techniques (Oksanen 2005). Vectors were scaled by their correlation coefficient in NMDS scatterplots.

RESULTS

Vegetation and Environment of Ungrazed Communities: Gravel Bars

Distribution

Gravel bars were located at fifteen of the forty-nine study blocks. Because river deposits become less gravelly downstream (Thorne et. al. 1997), ten of the fifteen gravelbar sites found were in the upper *P angustifolia* region (first 100 miles), four were found in the *P deltoides* (plains region) and one with a high percentage of sand was found deep in the plains region (mile 492) (Figure 8).

Community Composition

Species presence and cover are reported in Appendix Tables 5 & 6; these data support calculation of richness and constancy. On average, gravelbars had 17.6 $\pm$ 12 species, with 46% $\pm$ 13% of these (7.9) being non-native. Overall, 90 species were found on ungrazed gravelbars, 50% of which (45 spp) were non-native.

Every ungrazed gravelbar site had seedlings of a native cottonwood, either *P. angustifolia* (upstream) or *P. deltoides* (downstream) (figure 8).

Sites averaged 1.5 shrub species/plot, with six species of shrubs overall – four natives and two non-natives. Of the shrubs, *Salix exigua* had by far the highest constancy (79%), with *Salix amygdaloides* a distant second (29%). The

non-natives *Tamarisk chinensis* and *Elaeagnus angustifolia* (Russian olive) both occurred at low constancies (21% and 7% respectively).

Forb diversity was highest, averaging 9.8 species/plot, with 57% of these (5.1 species) being non-native. Altogether 57 forb species occurred in the fourteen ungrazed gravelbars sampled, including 30 native and 27 non-native species. Only five forbs occurred with more than 40% constancy: the natives *Rumex salicifolius* (64%) and *Plantago major* (43%), and the non-natives *Taraxacum officinale* (57%), *Melilotus officinalis* (57%), and *Melilotus alba* (43%). Forty of these 57 species (20 natives and 20 non-natives) were uncommon, occurring with less than 20% constancy. Twenty six out of these 40 species were "singletons," found only at one site out of 14.

Graminoid diversity was intermediate, at 5.4 species per plot on average, with 36% of these (2.5 species/plot) being non-natives. Overall, 25 species of graminoids were found, including 16 natives and 9 non-natives. Only the non-native *Poa pratensis (50%),* and the natives *Poa palustris (43%),* and *Carex spp. (43%)* had constancies over 40%. Nine of the 16 natives and only two of the nine non-native species were uncommon, with constancies less than 20%.

Vegetation Cover

Vegetation on gravelbars was sparse, averaging 16% $\pm$ 9% cover (Table 6). Tree and shrub seedlings comprised most of this cover. In the P angustifolia (foothill) region, *Populus angustifolia* (narrowleaf cottonwood) forms the

cottonwood forest so its seedlings were found on every site and provided an average of 5.0% cover. Principal shrubs were *Salix exigua* (3.4% cover) and *Salix amygdaloides* (peachleaf willow), averaging 1.3% cover. In the P deltoides (plains) region *Populus deltoides* forms the riparian forest so its seedlings appeared on every site and provided an average of 0.8% cover. *Salix exigua* was the dominant shrub, averaging 7.0% cover. *Salix amygdaloides* and the invasive *Tamarix chinensis* (tamarisk) are less common and sparser, averaging 0.6% and 1.8% cover, respectively.

Total forb cover averaged 3.0% (Table 6). Only the native *Rumex salicifolius* (willow dock, 0.4% cover) and two exotic sweetclovers (*Melilotus alba,* 1.1% cover, and *Melilotus officinalis,* 0.3% cover) averaged more than 0.1% cover. However, 42 other forb species occurred with $\leq$ 0.1% cover; 17 of these forbs were non-natives.

Total graminoid cover averaged 3.0% (Table 6). The few species averaging > 0.1% cover/site included the native *Deschampsia cespitosa* (0.6%) and non-natives *Agropyron repens* (0.8%), *Phalaris arundinacea* (0.5% cover) and *Alopecurus arundinaceus* (0.5%). Twelve other native, and five other non-native graminoid species occurred on gravel bar sites, averaging $\leq$ 0.1% cover/site.

To summarize, on ungrazed gravel bars, a very few species of cottonwood and willow seedlings dominate in terms of cover (9.3% cover, out of 15.8% cover present). On the other hand, forbs followed by graminoids have the highest

species diversity and the lowest constancy. Of the 82 species of forbs and graminoids found on ungrazed gravelbars, only eight had constancies of more than 40%. Non-natives comprise 34% of the cover, 46% of the species richness per site, and 50% of the richness overall.

Environment

Ecosystems are differentiated by age and environment. Water availability (e.g. height above water, soil fines, soil organic matter) and the force of flowing water (e.g. particle size) are important environmental factors.

Gravelbar surfaces averaged 1.4 m (4.7 ft) above water. Thus, established plants occupying these sites are probably rooted in the water table.

The gravelbar substrate indicates at least seasonally high water flows. It is a mixture of cobbles, gravel and sand (Table 7). Gravel bar sites averaged 17% (1-35%) sandy area. The percent sand is noteworthy, because species that don't establish directly in cobble may still grow in sandy microsites (personal observation). *Populus angustifolia* appeared to prefer cobble or gravel while *Salix exigua* (sandbar willow), appears to favor sand as a substrate. In figures 8 and 9, photos of a gravel bar at Emigrant West Fishing Access Site, *Populus angustifolia* (right) dominates the cobbles deposited on the level top of the gravelbar while *Salix exigua* occupies the small sandy bank (left).

The decline in particle size downstream (downstream fining principle) is illustrated (Table 7, figure 10) with measurements of cobble and gravel size for

the gravelbar sites. Of the twelve sites, the five sites with the largest cobbles occurred within the first 100 miles of the river studied. The ungrazed gravelbar sites from mile 100 to mile 308 generally had smaller cobbles, and the sites at mile 308 had the smallest cobbles. The decline in size with distance downriver was significant for both the 90% and the 75% cobble sizes ($p = 0.015$ and $p = 0.050$ respectively). Below mile 308, the newly deposited sediments almost always formed sandbars (Table 3).

Vegetation & Environment of Ungrazed Communities: Sandbars

Distribution

Sandbars were sampled wherever they occurred in the fishing access sites or other ungrazed sites. Three sandbar sites were in the Rocky Mountain province, and five were further downriver in the Great Plains province. Thus even where the Yellowstone River's substrate was primarily cobble and gravel, there were occasional sites where the river flow was slow enough to deposit sand (figure 11).

Community Composition

Sandbar community composition is described in Table 9. Three properties, constancy, richness and origin are emphasized below. First, because so few species occur repeatedly, we note that only 13 native and 13 exotic

species are present in more than 30% of the stands: two native trees, one native and two exotic shrubs, seven native/ten exotic forbs, and three native/one exotic grass.

Richness is a count of the species in the stand (average richness) or in all the stands in the type (total richness), without regard for how often they occur or how much ground they cover. Average species richness for sandbar sites was 25.2 ± 8.3 species; primarily in forb and graminoid species (17.1 and 5.5 species/site, respectively, Table 9). Total richness was 105 species. This included two tree, four shrub, 71 forb and 28 graminoid species.

Sandbars had few species of tree and shrub seedlings. In the upriver *P. angustifolia* region (three sites), one site had *P. angustifolia* seedlings, all had *Salix exigua* seedlings, and none had the exotic shrubs. Downstream, in the *P. deltoides* (great plains) region, *P. deltoides* seedlings were present at all five sites sampled, *Tamarisk* (exotic) occurred at four sites, *Salix exigua* at three sites, and *Eleagnus angustifolia* (exotic) at only one. *Salix amygdaloides* (native) seedlings were present at one upstream and two downstream sites (out of eight total).

Of the 71 forb species found on sandbars, the maximum constancy was 50%, with ten species in this category. Natives in this group included *Gnaphalium palustre, Rorippa palustris, Amaranthus albus* and *Xanthium strumarium;* non-natives included *Taraxacum officinale* (dandelion), *Medicago lupulina* (black medic), *Thlaspi arvense*, and three Chenopods. More than 75%

of the forb species (55 out of 71) were found at only one or two of the eight sites; 32 of these species were singletons, found at only one site.

Of the graminoids, *Eleocharis palustris* had the highest constancy (88%), with the non-native grasses *Phalaris arundinacea, Elymus repens* and *Bromus tectorum* distant seconds at 38% constancy. Of the 29 graminoid species found, 22 were singletons.

In terms of sandbar plants' origin, 44% (46 spp) of all species found were non-native. None of the trees was exotic. Two of the four shrub species were non-native. Non-natives made up 48% (34 spp.) of the sandbar forbs, and 36% (10 spp.) of the graminoids. Calculated on a per site basis, non-natives comprised 43% of the species present (11.3 out of 25.2, on average), including 45% of the forbs (8.6 out of 17.1 species/site) and 44% of the graminoids (2.1 out of 5.5 species/site).

Vegetation cover

Plant cover on sandbars averaged 39% ± 25%. Principal components were cover of trees (0.3%), shrubs (10%), forbs (16%) and graminoids (12%). Non-native plants averaged 31% of total plant cover. Exotics (31% ± 28%) varied among sites from 1% - 70% of existing cover (Tables 9 & 10).

Tree seedlings contributed little (0.3%) cover. In the P angustifolia (foothills) province P angustifolia cover averaged 0.3%, whereas in the plains region P deltoides seedling cover averaged 0.2%.

Shrub cover averaged 10%. *Salix exigua* was the dominant shrub, averaging 9% cover. *Salix amygdaloides* (native) *and Tamarix chinensis* (exotic) were also present in small amounts (0.2% and 0.8% cover, respectively).

Forb cover averaged 16%. *Polygonum lapathifolium* (native, 3% cover) and *Chenopodium glaucum* (non-native, 4% cover) were the most prevalent. Fifteen other forb species averaged between 0.9% and 0.2% cover, with *Polygonum lapathifolium* and *Equisetum arvense* at the top of this list (0.9% and 0.8% cover, respectively).

Graminoid cover averaged 12%. Of the graminoid cover, *Eleocharis palustris* (spike rush) averaged 3.0% cover, and *Echinochloa crus-galli* (exotic, barnyard grass) – less common but occurring in large patches where it was found – averaged 3.9% cover.

In sum, sandbars were dominated by herbaceous plants. Forbs and graminoids together provide 28.3% cover, trees and shrubs only 10.3% cover. Of the 25.1 species/site (average richness), 22.6 are non-woody. In terms of species diversity, forbs and graminoids were 99 out of 105 species occurring on sandbars. The great majority of these herbaceous species occurred with low constancy.

Non-natives are a substantial component of this plant community: comprising 31% of the plant cover, 43% of the average species richness and 44% of the species richness across all sites (Tables 9 & 10).

Environment

The environmental variables for all eight ungrazed sandbar sites were averaged and are presented in Appendix Table 8. Surfaces of ungrazed sandbar sites averaged 1.4 meters (4.6 feet) above water.

The sandiness of soils - 72% sand, 21% silt and 7% clay - is consistent with deposit at moderate flow rates, slower than gravel, but higher than silt. $CaCO_3$ increased with distance downriver. The quantity was negligible or too small to measure for the *Populus angustifolia* (upriver) zone, but averaged 3.0 percent equivalency for the downriver sites in the *Populus deltoides* zone. Organic carbon was 0.37%, and total nitrogen was 0.023%, consistent with the short time since deposit available for their accumulation (cf, Boggs 1984). Conductivity averaged 0.37 mmhos/cm, with no upriver vs. downriver difference.

Vegetation and Environment of Ungrazed Communities: *Salix exigua* (Sandbar Willow)

Distribution

Willow communities (figure 12) usually occupy a zone between sandbar/gravelbar and cottonwood forest. Despite environments ranging from cool/mesic to warm/dry on soils ranging from gravelly to fine textured, our ordinations did not segregate willow communities in the P angustifolia (foothill) region from those in the P deltoides (plains) region (figure 30). They included 22

ungrazed sandbar willow stands, 11 from the *Populus angustifolia* (foothills) zone and 11 from the *Populus deltoides* (plains) zone.

Community Composition

Species richness for this community was 22.0 ± 7.3 species per site, with averages of 0.6 tree species, 4.7 shrub, 11.5 forb and 5.1 graminoid species (Table 11). Non-natives comprised 46% ± 13% (9.6 ± 2.9 spp) of the average species richness. The range in both numbers of species (13 – 40) and in percent non-native species per site (21% - 73%) was substantial.

Total richness for this vegetation type was 132 species, including 3 trees, 21 shrubs, 75 forbs and 33 graminoids. 33% of the species found overall (43 out of 132) were non-natives. Percentages of forb and graminoid species (59%, 58%) that were non-natives, were higher than those of shrub species (10%).

Most of the woody plant diversity of the Salix community was due to native shrubs. In the 22 *Salix exigua* sites sampled (11 upriver, 11 downriver), there were 3 native tree species, 19 native shrub species and only 3 non-native shrub species. While *P angustifolia* was essentially absent in willow thickets in its (foothill) zone, *Populus deltoides* seedlings were 82% constant in its (plains) range. *Salix exigua* had 100% constancy, as its presence defined this vegetation type. Four other native shrubs had high (>30%) constancy across both zones: *Salix amygdaloides* (50%), *Ribes aureum* (45%), *Cornus stolonifera* (45%) and *Rosa sayi/R. woodsii* (36%). Two non-natives were sometimes present, but only

in the prairie zone: *Tamarix chinensis* (55% constancy) and *Elaeagnus angustifolia* (36%).

Average forb richness, 11.5 species, was more than half non-native (6.4 spp). Across all *Salix exigua* sites, there were 75 forb species, of which 39% (29 species) were non-native. Five non-native forbs had high (> 40%) constancies: *Cirsium arvense* (Canada thistle, 91%), *Taraxacum officinale* (dandelion, 68%), *Sonchus sp*. (sow thistle, 55%), *Cynoglossum officinale* (houndstongue, 41%) and *Solanum dulcamara* (nightshade, 41%). Only one native forb was as common: *Solidago gigantea,* with 50% constancy.

Average graminoid richness (5.1 species) was also more than half non-native (2.7 species/site), while overall richness (33 species) was 33% non-native (11 species). Common exotics were *Phalaris arundinacea* (73% constancy), *Poa pratensis* (68%) and *Elymus repens* (59%). *Agrostis stolonifera* (36%) was the most constant native graminoid. (Note: *A. stolonifera* is considered native by USDA and by Flora of the Pacific Northwest, but non-native by University of Montana's invader database (Table 4).)

Note that the average per site richness of both non-native forbs and graminoids (>50% in both cases) is higher than their overall cross site richness (39% and 33%, respectively). For this to be true, non-natives must have higher average constancy than natives in willow thickets. This may be an indication of the competitive ability of exotics. Indeed, there were eight non-native herbs with > 40% constancy, but only one such native in willow thickets.

Vegetation Cover

Plant cover, summed across all strata, in ungrazed *Salix exigua* (sandbar willow) communities averaged 111.4% (Table 12). In the upriver zone willow thickets, *Populus angustifolia* seedlings were virtually absent from the community while in the downstream zone, *Populus deltoides* seedlings averaged 1.4% cover.

Salix exigua dominated this shrub community with an average cover of 51% in the P angustifolia (foothills) and 50% in the P deltoides (plains) zones. Companion shrub species provided another 14% cover. Native mesic species included *Salix amygdaloides* (peachleaf willow) with 6% cover throughout, *Ribes aureum* (golden current) with 1% cover throughout and *Cornus stolonifera* (red osier dogwood, 1.6%). Dogwood was common in foothills zone willow communities where it averaged 3.3% cover, but while it can be important in downriver stands and can appear in mature cottonwood communities, it was absent from all our plains zone willow stands. More xeric native shrubs included *Symphoricarpos occidentalis* (western snowberry) with 1.1% cover throughout and *Rosa sayi/Rosa woodsii* (wild rose) with < 1% cover. Two non-native shrubs absent from upriver willow sites, *Elaeagnus angustifolia* (Russian olive) and *Tamarix chinensis* (tamarisk), appeared in downriver willow stands with average covers of 2.4% and 0.5%, respectively.

Forb species collectively averaged 17% cover in the *Salix exigua* zone. Although there was great diversity of native forb species, collectively they provided < 4% cover, and no single species averaged > 1% cover. Most of the forb cover (>13% out of 17%) consisted of non-native species, primarily *Cirsium arvense* (Canada thistle), at 7% average cover. Other non-natives, with average cover >1%, were *Melilotus officinalis, Melilotus alba, Solanum dulcamara* (climbing nightshade) and *Cynoglossum officinale* (hound's tongue).

Graminoid cover averaged 31%. As with forb cover, most of the graminoid cover (25% out of 31%) was composed of non-native species. The most important exotic graminoid was *Phalaris arundinacea* (reed canary grass), which averaged 20% cover. *Poa pratensis* averaged 2.5% cover. While native graminoids included rushes *(Juncus spp),* sedges *(Carex spp)* and grasses, only *Agrostis stolonifera* (red top), *Poa palustris* (fowl bluegrass), and *Carex sp.,* had >1% cover.

Overall, the *Salix exigua* vegetation type is dominated by sandbar willow and other native shrub species (51% cover out of a total 114%). Although there is a great diversity of native forb and graminoid species in sandbar willow thickets, the less diverse non-native forbs and graminoids appear to be more successful: they provide 38% cover compared to natives' 10%, and include more species with high (>40%) constancy than natives do (8 non-natives vs. one native) (Tables 11 & 12).

Upriver (foothill) and downriver (plains) willow sites had similar species richness (20 ± 7 spp vs. 24 ± 7 spp). While cover of non-natives was higher in downriver sites, standard deviations associated with these figures were large (32% ± 24% vs. 47% ± 23%, Table 11). Thus the difference was not statistically significant (p = 0.152 s.v./p.v.). The two most notable differences between upriver and downriver sites are that plains willow sites included both cottonwood (*P. deltoides)* seedlings (82% constant) and the invasive shrubs Russian olive and tamarisk (55% and 36% constancy). At upriver sites, *P. angustifolia* seedlings were a negligible presence (18% constancy) and the invasive shrubs were absent.

Environment

The environmental data for the 22 ungrazed *Salix exigua* sites were summarized for the vegetation type (Table 8). To compare the environment of *Salix exigua* thickets between the foothills and the plains zones, averages were also calculated for each zone (Table 8, "upriver" and "downriver").

Seven differences between the upriver and the downriver *Salix exigua* sites are noted. Indices of river water availability vary downstream. As one moves downriver, the height of the river banks increases (Table 8). Soil surfaces in the willow ecosystem of the foothills (*P. angustifolia*) zone averaged 1.8 m (5.9 ft) above water, while those of the downriver prairie (*P. deltoides*) zone averaged 2.3 m (7.6 ft) above water. The height of flood waters (i.e. current deposition) is

suggested by depth to gravel and surface textures. Upriver willow zone soil surfaces are elevated with respect to the gravel layer (116 vs. 106 cm.), contain slightly less sand, and contain slightly more silt than their downriver counterparts.

Organic matter content (C and/or N) might rise with site productivity, length of the productive period (stand age), or organic matter deposition. The soils of foothill willow sites have more organic carbon (1.35% vs. 0.62%) and more total nitrogen (0.090% vs. 0.039%) than their downriver counterparts (Table 8), however these differences are not quite statistically significant (for C: $p = 0.12$; for N: $p = 0.13$).

Finally, soil $CaCO_3$ is very low at upriver willow study sites (0.4 percent equivalency average) and gradually increases downriver (3.2 average) (Table 8). Soil pH follows suit; it is slightly more acid at upriver than downriver sites (pH 7.9 vs 8.2) (Table 8). Soil electrical conductivity (a leaching/water rise indicator) was relatively high in this vegetation type (0.51 mmhos/cm, average) and while it was variable among sites (0.18 – 1.51 mmhos) we saw no longitudinal pattern downstream (Table 8).

Vegetation & Environment of Ungrazed Communities: *Populus angustifolia* (Narrowleaf Cottonwood)

Distribution

Narrowleaf cottonwood forms mature forests with shrub understories at some distance from the river (figures 13 & 16). *Populus angustifolia* forest is a

major riparian dominance type of the foothills zone, central Montana, predominantly east of the Continental Divide (Hansen 1988). Our stands were found on upriver sites, from above Emigrant MT to Reed Point, MT. Eight sites supported mature cottonwood trees (figure 13). The largest trees of these stands, characterized by averaging the largest three, had average diameters at breast height of 56 cm, with a range of 35 – 81 cm. Two additional sites (UCN2 and UEN3) were sampled to represent younger sapling forests. In both of these, average maximum diameters were 5 cm.

Near Reed Point, *Populus angustifolia* disappears, to give *Populus deltoides* full dominance of downriver riparian forests. A hybrid, *P. acuminata* (lanceleaf cottonwood), is formed where the ranges of the species meet, at least on the Yellowstone. Occasional sites dominated by *P. acuminata,* and with either *P. angustifolia* or *P. deltoides*, were found between Livingston (river mile 46) and Reed Point (river mile 103). We do not describe ungrazed *P acuminata* forest because *P acuminata* forests were only found on grazed lands.

Community Composition

Average species richness for the *Populus angustifolia* community was 19.8 $\pm$ 5.9 species per site, with averages of 1.1 trees, 5.3 shrubs, 8.9 forbs and 4.5 graminoids. Non-natives comprised 34% $\pm$ 8% of average species richness (Table 13).

The woody vegetation was comprised exclusively of *Populus angustifolia* and native shrubs. *Rosa sp.,* although not dominant, had the greatest constancy (88%), followed by *Symphoricarpos occidentalis* (75% constancy). *Ribes aureum, Juniperus scopulorum, Rhus trilobata, Ribes setosum* and *Cornus stolonifera* all had constancies of 50% or more. *Salix exigua* was found at only one out of eight sites.

Average forb richness, 9 species, was equally split between natives (5 spp) and non-natives (4 spp). Across all *Populus angustifolia* sites, 39 forb species were found, of which 46% (18 species) were non-native. The most common natives were *Smilacina stellata* (100% constancy), *Solidago gigantea* (75%), and *Glycyrriza lepidota* (38%). The non-natives with highest constancy were: *Cirsium arvense* (Canada thistle, 88%), *Taraxacum officinale* (dandelion, 75%), *Arctium minus* (common burdock, 38%) and *Tanacetum vulgare* (tansy, 38%).

Average graminoid richness was predominantly non-native, with 3.0 of 4.5 species exotic. Across all sites, 14 different graminoid species were found, of which half were non-native. The non-native graminoids with the most cover also had the highest constancies: *Poa pratensis* (100% constancy), *Phalaris arundinacea* (63%) and *Bromus inermis* (50%). The native graminoids were less common; only *Elymus trachycaulus* (slender wheatgrass, 38%) approached 40% constancy.

Both sapling *Populus angustifolia* stands had a monospecific tree layer. Though essentially absent in mature stands, *Salix exigua* was still present in both. Native shrubs had not yet entered. The herbaceous layer was primarily non-native grasses (24% cover, 3.5 spp/site), forb cover was less than 1%, and herbaceous diversity at 9.5 species/site was 66% of that in mature forests (13.4 spp).

Vegetation Cover

The mature *P. angustifolia* community had substantial tree, shrub and herbaceous canopy layers, with 168% ± 26% total cover (Table 14).

Tree cover averaged 88% in the eight mature stands. With the exception of one site with *Fraxinus pennsylvanica* (green ash, 12%), the tree cover was entirely *Populus angustifolia*.

The shrub layer was also entirely native and averaged 47% cover in mature forests. Components included *Symphoricarpos occidentalis* (snowberry, 15%), *Cornus stolonifera* (red osier dogwood, 10%), *Juniperus scopulorum* (Rocky Mountain juniper, 10%) and *Rosa sayi/R. woodsii* (5%). Seven other native shrub species occurred, each with less than 2% average cover. The non-natives, Russian olive and tamarisk did not occur in the foothills zone. Willows, remnant from earlier seral stages, were rare; *Salix exigua* was not found and *Salix amygdaloides* only occurred in one of eight stands.

Forb cover averaged 13% in narrowleaf cottonwood forests, with half (7%) native and half (6%) non-native. The most important exotic was the noxious and ubiquitous *Cirsium arvense* (Canada thistle, http://invader.dbs.umt.edu, 4% cover). The most constant natives also had the most cover: *Smilacina stellata* (starry false Solomon's seal, 2.3% cover), *Glycyrrhiza lepidota* (wild licorice, 2.2%) and *Solidago gigantea* (late goldenrod, 1.2%).

Graminoid cover, averaging 20%, was mostly non-native (16%). Exotics *Phalaris arundinacea, Poa pratensis* (Kentucky bluegrass) and *Bromus inermis* (smooth brome) each averaged 5% cover. The most important native, *Agrostis stolonifera,* had 3% average cover; *Juncus* and *Carex* species so common in adjacent willow stands were uncommon and present only in small amounts (< 0.5%).

In sum, the cover of *Populus angustifolia* communities is composed primarily of native trees and shrubs (88% and 47% cover, respectively). Overall, the *Populus angustifolia* community was composed of monospecific stands of narrowleaf cottonwood trees, with a shrub layer characterized by a suite of eight commonly occurring native species. Of these, *Symphoricarpos occidentalis* is the most dominant, although *Juniperus scopulorum* and *Cornus stolonifera* are important where they occur. The herbaceous layer is dominated by the non-native grasses *Phalaris arundinacea, Poa pratensis* and *Bromus inermis,* and the invasive forb *Cirsium arvense.* The native forbs *Smilacina stellata* and *Solidago gigantea* are very common, but provide little cover. There are no common native

grasses. Non-native forbs and grasses (22% cover), provide more cover than native forbs and graminoids (11% cover).

The two sapling sites sampled were notably similar to one another. Tree canopy, exclusively *P. angustifolia,* was less than in mature forests (57% vs. 88% cover), there were no forest shrubs, and while forb cover averaged less than 1%, exotic grasses were well established in both (3% and 45% cover). One stand had remnant willow cover, linking it back to the precursor community.

Environment

Because narrowleaf cottonwood only grows at higher elevations (>1170 m. = 3835 ft.), it had relatively high rainfall (>400 mm/year), July temperatures with an average maximum daily temperature about 29°C, and a comparatively short frost-free season (102 days at Pine Creek) (Table 2). Throughout its range, the river substrate is primarily cobble and gravel.

Of the four upriver (foothill) communities, cottonwood forests are furthest above water. Surfaces average 2.4 m (7.7 ft) above the river (Table 8). Increases in fine material (36% sand, 49% silt, 15% clay), relative to that in adjacent willow (51%/38%/11%) and sandbar (72%, 21%, 7%) sites, also demonstrate the rising soil surface. Depth to gravel averaged 111 $\pm$ 45 cm, comparable to upriver *Salix exigua* sites, which averaged 116 $\pm$ 50 cm. This suggests that these two communities co-exist, rather than being in a seral relationship to one another.

Four other soil properties were examined. Soil organic carbon (2.80%) and total percent nitrogen (0.168%), indicators of duration of production (= stand age), and/or productivity, were higher than in adjacent younger communities and in communities downriver. Soil $CaCO_3$ was negligible (0.4 percent equivalency), and pH was correspondingly low (7.8). Soil electrical conductivity averaged 0.45 ±0.22 mmhos/cm.

Vegetation & Environment of Ungrazed *Populus deltoides* Communities (Plains Cottonwood)

Distribution

Populus deltoides occupies the driest riparian sites in the plains (downriver) region, i.e. from central through eastern regions (Hansen 1988). Our sites ranged from Reed Point (river mile 103) to Sidney (river mile 510) (Tables 15 & 16). Seventeen mature, ungrazed *Populus deltoides* stands were sampled (figure 13). Maximum diameters (DBH, largest three trees) averaged 60 cm, with a range from 38 to 112 cm. One younger stand, site U2P, was sampled to demonstrate a cottonwood sapling community.

Community Composition

Average species richness for Plains cottonwood forests was 19.4 ± 6.6 species per site, with averages of 1.5 trees, 5.8 shrubs, 7.9 forbs and 4.2

graminoids. Non-natives comprised 43% ± 11% (8.3 ± 3.4 spp) of the average richness (Table 15).

Populus deltoides, since it defined this community, had 100% constancy. Green ash, the only other tree species present, occurred as seedlings at 47% of the sites sampled, and at one site as a young tree.

Of the twenty shrub species present, eighteen were native. Natives included *Symphoricarpos occidentalis*, which had 59% constancy, followed by *Rosa spp.* (53%), *Vitis riparia* (wild grape, 47%), *Clematis ligusticifolia* (white virgin's bower, 41%) and *Toxicodendron rydbergii* (poison ivy, 41%). *Elaeagnus angustifolia*, was the most common exotic shrub, with 76% constancy (Table 15).

47 forb species occurred in mature Plains cottonwood stands, with 22 of these (47%) being non-native. Only four of these species had constancies greater than 40%. They were the natives *Apocynum sibiricum* (hemp dogbane, 59%) and *Smilacina stellata* (41%) and the non-natives *Taraxacum officinale* (65%) and *Medicago lupulina* (black medic, 59%) (Table 15).

Sixteen grass species were found overall, of which half (8 spp) were non-native. The exotics were common: *Poa pratensis* (76% constant), *Bromus inermis* (76%), *Elymus repens* (59%) and *Phalaris arundinacea* (53%). The natives were much less common, none having a constancy greater than 24% (Table 15).

Vegetation Cover

Summing across layers, ungrazed plains cottonwood communities averaged 156% cover, with trees contributing 81% cover, shrubs 41%, forbs 5% and grasses 29% (Table 16).

The tree canopy was exclusively *Populus deltoides*. Downriver, green ash seedlings became more common, averaging about 0.5% cover/site below mile 250 (Hysham, MT). Green ash saplings were found at only one site (U1P), where they provided 15% cover.

The shrub layer was well developed, averaging 41% cover. The primary shrub cover is provided by two species not found upriver, non-native *Elaeagnus angustifolia* (Russian olive, 15% cover) and native *Toxicodendron rydbergii* (poison ivy, 8% cover). The natives Symphoricarpos occidentalis (5% cover), Juniperus occidentalis (5%), Rosa sp. (1.5%), and Cornus stolonifera (1.1%) are present.

Forb cover was only 5% total, evenly divided between native and non-native species. Only the exotics *Arctium minus* and *Solanum dulcamara* averaged more than 0.5% cover.

Grass is more important with 29% cover, primarily non-native grasses (25%). Of the exotics, *Bromus inermis* is most extensive (15% cover) followed by *Poa pratensis* (4%), *Elymus repens* (4%) and *Phalaris arundinacea* (1.7%). The native *Elymus trachycaulus* provided 1.7% cover, on average.

In sum, in *Populus deltoides* stands the tree canopy layer is composed solely of Plains cottonwood. A great diversity of native shrub species (18 spp.) were found overall, collectively providing 26% cover per site, but the dominant shrub in terms of both cover (15%) and constancy (76%) was the exotic Russian olive. Forbs were the most diverse life form (47 spp overall), but the least important community component in terms of cover (5%). Grasses were less diverse than shrubs (16 spp. overall), with four non-natives dominating in terms of both cover and constancy: *Bromus inermis, Poa pratensis, Elymus repens* and *Phalaris arundinacea.* Non-natives account for 43% of the species richness per site, 38% of the overall richness for this vegetation type, and 28% of the cover (Tables 15 & 16).

The one sapling community sampled resembled the *P. angustifolia* sapling communities in lacking the native shrub layer. *Elaeagnus angustifolia* was already establishing, but with less than 1% cover. *Euphorbia esula* (leafy spurge) provided most of the 11% forb cover. While grass cover was only 1%, the four most common non-native grasses were already present (Table 16).

Environment

Precipitation in Plains cottonwood communities is low (averaging 354 mm precipitation/year) and summers are warm. July daily maximums in Glendive peak at about 32°C. The frost-free season averages 121 days, 2.5 weeks longer than at Pine Creek, in the *Populus angustifolia* zone (Table 2). Their range on

the Yellowstone reaches from the predominantly cobble substrate at Reed Point, to the sands and silts at the river's confluence with the Missouri.

Populus deltoides communities grow on alluvial terraces further above the river level (4.4 m, = 14.3 ft) on average, and with greater depth to gravel (157 cm average) than younger bar and willow stands (Table 8). This estimate is low because when the depth to gravel exceeded152 cm, the length of our auger (at 7 of 17 sites), we used a conservative estimate of depth (2 m.) This was based on depths to gravel measured on nearby river banks (see Methods).

Soil organic carbon (1.88% $\pm$ 0.93%) was significantly less (p= 0.069 s.v./p = 0.043 p.v.) and total nitrogen (0.125% $\pm$ 0.066%) was slightly less (p = 0.131 s.v./p = 0.132 p.v.) than the values for *Populus angustifolia* communities, but substantially higher than the sandbar and willow community soils (Table 8). Soil texture for both cottonwood communities was loamy (41% sand, 39% silt and 20% clay for *P. deltoides* soils), with less sand and more silt than the willow and sandbar soils.

Percent $CaCO_3$ equivalency increased significantly with distance downstream (squared multiple r = 0.75; p = 0.000). *P. deltoides* soils averaged 3.4% $CaCO_3$ equivalency, with a pH of 8.1 (Table 8), both higher than in *P angustifolia* stands. Electrical conductivity averaged 0.48 $\pm$0.23 mmhos/cm, comparable to *P. angustifolia* soils.

DISCUSSION

To determine how grazing management impacts plant communities of the Yellowstone we describe these communities and their functioning in absence of grazing. First, we describe the vegetation of the ungrazed sites, both in the lateral (seral) sequence from bar through willow to cottonwood forest and longitudinally from foothills downriver to the plains. Next we compare plant species richness, constancy and cover among the ungrazed types as further characterization. Finally lateral and longitudinal gradients in environmental factors will be described as possible causal agents. Our understanding of ungrazed vegetation will provide a basis for the following evaluation of grazing effects on riparian plant communities.

Ungrazed Vegetation

Composition

The botanical composition, both presence and quantity, of the five communities is recorded in tables 5 - 6 and 9 - 16.

Summary Description

We consistently saw three vegetation zones along the entire Yellowstone River's length: bar communities at the water's edge, a willow thicket immediately

inland, and a cottonwood forest further inland. Similar zones were recorded by Boggs (1984) and Hansen et al (1988).

Bar communities were either sand or cobble depending on source (gravel available in foothills) and energy of deposit (cobbles remaining in high energy areas). Upstream (foothill) bars were primarily cobble and supported a sparse (16±9%) cover dominated by cottonwood seedlings, with willow seedlings, forbs, and grass in lesser and roughly equal quantities. Downstream (plains) sites (and occasional upstream bars) were primarily sand and supported a dense cover (39 ± 25%) with few cottonwood seedlings (0.3% cover), more shrubs (10%), forbs (16%), and grasses (12%).

The thicket community was surprisingly consistent across foothill and plains zones. The canopy is willow (51% cover), with hydric shrubs (*Salix amygdaloides, Ribes spp, Cornus stolonifera*) (14%). The understory is dominated by forbs (17%) and grasses (31%). Cottonwood seedlings were almost nonexistent in the foothills zone (one site, with 0.001% cover) and common, but sparse in the plains (82% constancy, 1.4% cover). *Tamarix* and *Elaeagnus angustifolia* are invading the willows downstream.

The physiognomy of the cottonwood community was also surprisingly consistent. The canopy is dominated by cottonwood with 88% cover of *P angustifolia* in the foothills, and 81% of *P deltoides* in the plains. A layer of mesic shrubs covers 47% (foothills) - 41% (plains). Four species provide most of the shrub cover upstream (*Symphoricarpos* 15%, *Juniperus* 10%, *Cornus* 10%, and

Rosa 5% cover), but only a quarter of the downstream shrub cover. In the plains their dominance is shared by two heat loving shrubs: *Toxicodendron* (8%) that has always had a role, and exotic *Elaeagnus* (15%). Russian olive has recently invaded and appears to be adding cover to or replacing cover of its shrub associates, thereby modifying the composition of this community (Table 16; Boggs 1984).

An herbaceous ground layer provides an average cover of 33%. Grasses dominate the ground layer increasingly as one moves from the foothills (13% forbs/20% grasses) to the plains (5%/29%), perhaps because the plains climate is drier and grasses tend to be more drought tolerant than forbs.

Species Richness and Constancy Compared Across Vegetation Types

Diversity (Species Richness) in the Yellowstone River Riparian

The species present in a stand, its richness, include its dominant, more-or-less regular associates, and accidentals. We discuss diversity of the Yellowstone riparian zone as a means to characterize the system, to compare richness of component communities, and as a basis for comparing grazed and ungrazed examples of each type.

We consider three commonly used measures of diversity – total richness of the ecosystem, total richness of component community types and average

richness of sites in each community type. First, we found a total of 281 species in our 132 plots spread among five community types and distributed over 500 miles of the Yellowstone River (Tables 3 & 4). Since some vegetation types were not sampled, the actual value is certainly greater.

Second, richness of our five component plant communities, ranged from 68 to 132 species per community type (Table 17). At the river's edge, 105 species total occurred on sandbars, sampled with eight plots over 486 miles. On harsher riverside sites, gravelbars, 90 different species were found at 14 plots over 302 river miles. Just inland the *Salix exigua* type had both the highest species count, and also the greatest sampling effort: 132 species at 22 plots over 486 river miles (table 17). Furthest inland, the *Populus angustifolia* type of the foothills had 68 different species, found at eight plots distributed over 91 river miles. And in the plains the *Populus deltoides* community included 85 species, at 13 plots over 407 river miles. All plots were 25 m. x 2 m. Diversity differences among the types cannot be rigorously compared because they varied in sample size [species number increases with sample size (Keammerer 1975)], miles of river sampled (another aspect of sample size), and inherent community differences. *Populus angustifolia,* sampled at only eight sites over just 100 miles of river, had the lowest overall richness, and only a 3.4-fold difference between overall (68 species) and per site richness (19.8 spp). In contrast ungrazed *Salix exigua* communities, sampled with 22 sites distributed over 486 river miles had 132 species, six times the per site average of 22 species.

Third, because many species occurred with low frequencies, the average per site richness of each of our five communities was much lower than the overall richness for that community. However, because the sample was of a constant size (2 x 25 m) richness can be rigorously compared across our five community types (cf. Gregory et al 1991). Of the vegetation types surveyed riverside, sandbars (25.2 $\pm$ 8.3 species) and the harsher gravelbars (17.6 $\pm$ 12 species) (Table 17) had the highest and lowest average richness/site. *Salix exigua* thickets were second highest, with 22 $\pm$ 7.3 species per site. And *Populus angustifolia* and *P deltoides* forests had comparable richness, 19.8 $\pm$ 5.9 and 19.0 $\pm$ 6.6 species/site, respectively.

We compare our results with those of two parallel studies both because all describe riparian vegetation and because they illustrate the desirability, in making comparisons, of using the same methods. First, in a more humid (Oregon) location Green and Kauffman (1995) found 55 species/site on gravelbars (vs. our 18) and 40 species/site in the adjacent *Populus trichocarpa* community (vs. 19 - 20 for our cottonwoods). At each site, they sampled 2.4 m^2 total (thirteen 25 cm^2 plots in each of three stands) for herbs, and 10 m^2 (ten 1 m^2 plots) for shrubs, over three kilometers of river. How much of their 'greater richness' is due to the difference in their sampling strategy, one which covers less area/site, but samples a "site" that is more broadly distributed than our single 50 m^2 plots? Without common sampling strategies, the apparent differences are intriguing, but not conclusive.

Second, on the lower Yellowstone Boggs (1984), also sampling smaller plots distributed over a larger area, found fewer species (Table 29). The discrepancy is likely due in part to their sampling method being 60 step-points vs. ours being 2 x 25 m. transects. It is probably due also to the addition of non-native species to these communities since 1980. In 1980, the average percent non-native species across the three community types sampled was 20.0%; by 2001 it was 44.0% (Table 29).

Lateral Variation in Species Richness. We hypothesized that richness would fall from the river's edge through willow thicket to mature cottonwood forest due to decreasing seed rain (wash), diminishing site disturbance and water availability, and increasing competition from established plants (Cf. Green and Kauffman 1985; Kauffman et. al. 1985; Fleischner 1994; Ohmart 1996; Nilsson and Svedmark 2002). Richness did fall from sandbars (25.2 $\pm$ 8.3) through thicket (22.0 $\pm$ 7.3) to forest (19 $\pm$ 6). The exception was found on gravel bars (17.6 $\pm$ 12), where there is little suitable surface and that is unstable. However, these differences in richness are statistically insignificant, except that the most diverse vegetation type (sandbars) is marginally significantly richer than the least diverse (gravelbars) ($p = 0.10$ s.v./0.14 p.v.).

The base richness of sandbars (25 spp/site) is set by three qualities of the environment: their proximity to floodwaters, their openness, and their proximity to the water table. Proximity to flood waters, at an average 1.4 meters above

river level, facilitates delivery of seed. Fresh unoccupied deposits provide a non-competitive environment: with only an average 39% plant cover on sandbars, germinants are more likely to survive than those seeded into denser willow thicket or cottonwood forest. Proximity to the water table provides germinants with plentiful water that, because it retreats with falling river levels, must be pursued with vigorous rooting.

Gravelbars are similar to sandbars in their openness and proximity to floodwaters and the water table. However, gravelbars may have a lower richness than sandbars for four reasons. 1) They are on average further upstream, so collect seed from a smaller area of watershed (seed shed) than sandbars, which is likely to reduce seed diversity. 2) Seed outwash is higher, both because water flows are stronger and because there is less simultaneous deposit of silt. 3) Previously established plants are more likely to be removed by strong flow over gravel bars than by weaker flows over sandbars. 4) The rooting medium of sandbars supports better establishment than does the cobble of gravel bars. We regularly observed better establishment on patches of sand forming microsites in large gravelbars (Figure 15).

Willow thickets were second to sandbars in species richness (22 spp/site), and more diverse than cottonwood stands. We hypothesized that the following six factors are involved. 1) Flood deposited seed probably arrives in quantities similar to sand/gravel bar sites. 2) Flood exported seed is probably less in thickets than sand and gravel bars, due to more shrub and herb cover, and more

flotsam. 3) Due to their greater age, willow thickets have more years to have collected establishing species, either annual and/or perennial. 4) Willow communities are typically long, narrow thickets lying in the ecotone between the riverbanks and the cottonwood forests, and therefore share species with each. Most sites included along their edges a few species more characteristic of each of these neighboring communities. We hypothesize that of the vegetation types studied, willows have the greatest mix of obligate wetland, facultative wetland and upland species due to their ecotone location and high edge effect. 5) Compared to cottonwood stands, willow thickets have greater access to subsurface water. 6) Compared to sand/gravel bar sites, establishment of new species is reduced by existing plants; both shading and lateral root competition are more intense in willow thickets.

Cottonwood forests have lower richness (19 - 20 spp/site) than either sandbar or willow thickets/communities. We pose five conflicting mechanisms. 1) Since flooding is both less likely and less violent, seed input and seed and seedling export are relatively low. 2) Reduced flooding and a deeper water table remove the guarantee of an annual germination/establishment window. 3) Closed vegetation greatly inhibits the establishment of small seeded plants like *Populus* or *Salix*. 4) Presence of bird perches and mammal cover increases the input of 'berry' seeds and burs. These inputs are evidenced by the appearance of berry-bearing shrubs (e.g. *Symphoricarpos, Toxicodendron, Cornus, Juniperus, Rosa, Elaeagnus*) and burs (e.g. *Arctium, Glycyrrhiza, Cynoglossum*).

5) Older vegetation has had more time to accumulate plants adapted to the climate, soils, and the cottonwood canopy.

Longitudinal Variation in Species Richness. We expect species richness to increase downstream for three reasons. Increase in watershed (seed shed) areas will increase the diversity of seeds delivered from upstream sites. Increase in flood violence will increase the availability of establishment sites, but through recurrent floods, may reduce their longer term safety. The climate warms downriver (Table 2), thus providing suitable sites for warm-adapted species. While this may not affect the native plant richness, it will likely increase the diversity of exotics. For instance, non-native shrubs are absent in the foothills, but common in the plains (i.e. Russian olive and tamarisk).

Exotic diversity increases with warmth because our exotic flora is frequently from the Mediterranean and the Middle East, than from northern Europe. We cannot test this well in riverside sites because substrates differ between gravel bars of the foothills and sandbars of the plains. We can test for this by comparing non-native richness in willow thickets of foothills (8.8 $\pm$ 3.4 spp) and plains (10.4$\pm$ 2.2 spp), and in cottonwood forests of foothills (6.9 $\pm$ 2.9 spp) and plains (8.3 $\pm$ 3.4 spp). The difference is less than imagined, and not significant.

Species Constancy Along the Yellowstone

The large differences between overall community richness and average site richness imply that many species occur with low constancy. This has also been found in other riparian ecosystems (Gregory et al 1991).

Some species, the defining ones (eg Salix and Populus), are always present (100% constant), some are usually present, and some are rarely present, i.e. 'accidentals'. One can test for patterns regarding the distribution of the low constancy (accidental) species on longitudinal (up- vs downriver) and age/lateral (perpendicular distance) river gradients. To do so we will define accidentals as those species with less than 20% constancy, i.e. occur only once or twice.

We hypothesized that the percent low constancy species will fall laterally among vegetation types from the river to the forest. In other words, we expected constancy to increase from river's edge through cottonwood forest for two reasons. First, the likelihood of accidental delivery and establishment of a poorly adapted flood-borne plant is more likely at a moist streamside than in the adjacent cottonwood forest. Second, while plants well adapted to an environment arrive as "accidentals", the probability of arrival rises with time, so communities of older, relatively stable sites (e.g. cottonwood) eventually collect all their members, i.e. have higher average constancy than communities of ephemeral sites (e.g. sandbars and gravelbars).

Contrary to our hypothesis, inconstants were similar in bar (gravel 59%, sand 53%) and cottonwood (narrowleaf 44%, Plains 62%), but high in willow

(78%). We asked whether the excess of low constancy species in *S. exigua* thickets was native or non-native (Table 18). Low constancy species were most likely to be non-native on gravelbars (43%, or 23/54) and on sandbars (41%, or 23/46), less likely to be exotic in *P. angustifolia* (37%, or 11/30) and in *P. deltoides* stands (38%, or 20/53), and least likely to be exotic in willow thickets (27%, or 28/102). The difference for willow thickets was thus primarily due to large numbers of low constancy *native* shrubs, forbs, and to a lesser extent graminoids (table 18). Something about willow thickets favors incidental, low constancy species. One possibility is the ecotone location of willow thickets, between forests and river edge communities. Another might be the "intermediate disturbance hypothesis" applies: willows, with intermediate flood frequencies, could be more species rich than rarely or frequently flooded sites. This has been shown for riparian ecosystems in southeast Alaska (Pollock et. al. 1998). Note that in this study, sandbars had higher richness/site than willow thickets, but the difference was not significant.

We had originally hypothesized that natives and non-natives would be equally likely to occur at low constancies. This analysis showed that in all five vegetation types surveyed, the percent of non-native low constancy species was equal to or less than the percent of all species in that vegetation type that were non-native. In other words, natives are more likely to be accidental than non-natives (Table 18). And accidentals (native or non-native) are more likely to be

forbs than grasses, shrubs or trees, which may be due to the greater proportion of forbs in the flora.

Native/Exotic Comparison Across Vegetation Types

The factors contributing to high species richness in riparian ecosystems may also make them more invasible by non-native species (Pysek and Prach 1994; Hood and Naiman 2000). The high level of disturbance continually creates open sites for pioneer or invasive species, and the river corridor acts as a distribution network for propagules (Fox and Fox 1986; Crawley 1987; Planty Tabacchi et. al. 1996). For the Yellowstone (and many other rivers), the long history of human habitation, agriculture, ranching, industry and recreation along the river likely adds both to disturbance levels and to production/distribution of non-native propagules.

The percent exotic plant species present has been studied in riparian ecosystems, on country wide, river and drainage scales. In all of Great Britain, the percent of non-natives is 13 – 39% for riparian habitats. Invasive species came primarily from the Asteraceae, Poaceae and Fabaceae families. Non-natives represented 24% of the 1396 species found along the Adour River in southwest France, and 30% of 851 species for the MacKenzie River in the central Cascades, Oregon (Planty Tabacchi et. al. 1996). On a smaller scale, also in the Cascades, non-natives comprised 24% of the 148 species in the Hob

drainage, and 28% of the 200 species for the Dungeness drainage (Planty Tabacchi et. al. 1996). For four South African rivers, exotics accounted for 20% to 30% of the total species richness (Hood and Naiman 2000). In an extensive analysis of data from 184 sites (upland and riparian), Lonsdale (1999) found a positive relationship between native and non-native species diversity. High diversity riparian communities are thought to be more invasible than low diversity, resource poor communities, because their relatively rich resources are made available to invading species via disturbance (Stohlgren et. al. 1998, 1999, in Masters and Sheley 2001).

In my study, of the total 207 species found in ungrazed sites across the five major vegetation types, 33% were non-native (Table 17). Despite my examination of little disturbed sites, this exotic percentage is "high" relative to American, French or South African river studies mentioned above. The Yellowstone's non-native species came primarily from five plant families: Poaceae (18 spp.), Asteraceae (11), Brassicaceae (11), Chenopodiaceae (7) and Fabaceae (7) (Table 19).

Analyzing the data simply in terms of percent non-native species for the entire riparian ecosystem probably does not sharply represent what is happening on the ground. To more completely depict the situation, some researchers have subdivided riparian ecosystems into specific vegetation types (gravelbars, shrubs, forests), and have found that the more frequently flooded, earlier seral stages in riparian ecosystems have higher percentages (Planty-Tabacchi et al.

1996; Hood and Naiman 2000) or higher numbers (DeFerrari and Naiman 1994) of exotic plants. They suggest that flooding denudes lower lying areas, thereby increasing their invasibility (Hood and Naiman 2000). Although young communities had more alien species than older ones, even the mature communities appeared to be invasible (Planty-Tabacchi et al. 1996).

We had hypothesized that non-native richness would fall laterally among the vegetation types, with bar communities being the most invaded. In this study, breaking the data down by vegetation type reveals that while the percent non-native is still 33% for the willow community, it's higher for the other types. *Populus angustifolia* and *P. deltoides* contained 37% and 38% non-native species, respectively, whereas sandbars and gravelbars were higher yet, at 44% and 50% respectively. Using these figures, the earliest seral stages of the Yellowstone are apparently the most invasible, as has been found for other rivers.

If the non-native richness/site numbers are considered, non-native richness falls from sandbars (11.3 species/site) to willows (9.6 spp/site) and further to cottonwoods (6.9 spp/site for *P. angustifolia;* 8.3 spp/site for *P. deltoides.* Gravelbars, the least rich vegetation type overall, had 7.9 non-native species/site.

There is a discrepancy here between the "33% exotic species" for the Yellowstone's riparian vegetation as a whole, and the higher percentages of exotics in the individual vegetation types. This could only be happening if the

non-native species are occurring across a wider variety of vegetation types, on average, than the native species. The non-natives that are most widespread in riparian areas may have an adaptive edge over natives because they are better disperses, and/or perhaps have a greater tolerance for *resource variability*. Species that can survive in multiple riparian vegetation types, ranging from sunny to shady, frequently to rarely flooded, sand to loam - arguably have a great advantage in this very spatially and temporally heterogenous ecosystem. One study of five of the most widespread invasives of riparian ecosystems in North America found that all the species studied "show a high degree of morphological plasticity in response to hydrologic change" (Galatowitsch et. al. 1999). In other words, these successful invasives are particularly adapted to change in water availability, as is found from river edge to cottonwood forest, and from high to low river flows throughout the year.

To test this, I compared constancy of natives vs non-natives, across the five vegetation types surveyed (Table 20). Native shrubs were found across 2.3 plant communities on average, while non-native shrub species averaged 3.0. However, as there were only three non-native shrub species, this statistic isn't significant. For forbs and graminoids, natives had significantly more limited ranges. Native forb species occurred, on average, in 2.1 different plant communities, while non-native forbs averaged 2.6 communities ($p = 0.03$). Native graminoids occurred in 1.8 different vegetation types on average, while

non-native graminoids were more adaptable, occurring in 3.0 different communities on average ($p = 0.02$).

Non-native graminoids as a group *were* more successful in invading riparian ecosystems (as measured by percent cover) than non-native forbs (Table 17). While the two groups start out with equivalent percent cover in gravelbars (1.4% and 1.9%, respectively) and in sandbars (5.2% and 6.5% respectively), in willows non-native grasses contribute 24.6% cover, while non-native forbs only 13.3% on average. In *P angustifolia* stands, exotic grasses comprise 16.4% cover while exotic forbs only 6.3%. *Populus deltoides* stands have 25% cover of non-native grasses, but only 2.2% cover of non-native forbs.

Another test of this hypothesis that non-natives have either a greater ability to disperse and/or a greater tolerance of resource variability, is to compare numbers and characteristics of species that occur across all five vegetation types. The majority of these species are either woody or noxious. Seven native species were found in all five vegetation types. These included the woody species which germinate on fresh alluvial deposits and mature through succession (*Salix exigua* and *S amygdaloides*), a grass (*Agrostis stolonifera),* and four broadly occuring native forbs. Among forbs, *Glycyrrhiza lepidota* (wild licorice) is notable because it increases with grazing and is considered noxious by many of the ranchers who participated in this study. The *Populus* species might be included because they each occur across all seral stages from river edge to forest, but were only found in four of five vegetation types since they do

not co-occur (i.e. *P. angustifolia* isn't found in *P. deltoides* forests, nor vice versa, except for hybridization where their ranges meet).

The twelve non-natives that occurred in all five communities are ubiquitous or noxious. The forbs are *Cirsium arvense* (Canada thistle), *Euphorbia esula* (leafy spurge), *Melilotus officinalis* (yellow sweet clover), *Tanacetum vulgare* (tansy), *Taraxacum officinale* (dandelion), *Verbascum thapsus* (mullein), and *Sonchus asper* (marsh sow thistle). Grasses *Poa pratensis, Phalaris arundinacea, Elymus repens, Bromus inermis* and *Alopecurus arundinaceus* had equally broad ranges of tolerance.

This information is potentially useful in weed management, as it tells us which species are particularly in need of control on sandbars and gravelbars and/or in upland fields - before they invade the adjoining willow and cottonwood communities.

Evolution of Lower Yellowstone Riparian Communities 1980-2000

Boggs (1984) described riparian succession in Montana as beginning with the establishment of willow and cottonwood seedlings on sandbars and gravelbars, followed by willow-cottonwood thickets, which with willow die off are succeeded by young cottonwood forests, and eventually maturing cottonwood forests (at about 3, 7, 34 and 92 years, respectively). Shrubs appear under the cottonwoods, but when the cottonwoods die, the understory shrubland

community is replaced by grasslands (Boggs 1984) (Figure 16, showing progression from gravelbar to *P. angustifolia* forest).

We had hypothesized that there would be no significant changes in the plains riparian communities between 1980-1981 (Boggs 1984) and 2001 (our data). However, dynamics of the present (2001) suggest changes in early seral communities, leading to a dramatic change in future mature riparian forests. A graph of our foothills data (*Populus angustifolia* sere), Figure 17) is constructed paralleling Boggs' (1984) plot of his observations on the plains: gravelbar, willow and cottonwood replace each other serially. A graph of our plains data (Figure 18) shows similar dynamics. *Salix exigua* cover rishes and falls, and is replaced by other shrub species that increase as the cottonwood forests mature. Herbaceous cover peaks in the willow community, with graminoids retaining more cover in the *P. deltoides* community (29% cover) than in the *P. angustifolia* community (20%), and forbs more cover in the *P. angustifolia* community than in the plains (13% vs. 5%).

Populus deltoides cover, on the other hand, is low on sandbars and in willow thickets. This cottonwood's apparent failure to reproduce forbodes drastic change in the forest zone. The following paragraphs detail changes in the plains sere.

Gravelbars

On gravelbars in the plains, *Salix exigua* is the dominant woody species (7% cover), with *P. deltoides* seedlings contributing only 0.3% cover on average, and nowhere doing well. I don't know whether *P. deltoides* has declined on gravelbars, or has never established well on this substrate. The invasive *Tamarix chinensis* established well at all three gravelbar sites below river mile 250, averaging > 3% cover. This is notable because twenty years ago, no tamarisk was recorded in any of more than 50 transects of riparian sites along the lower Yellowstone (Boggs 1984).

Sandbars

Sandbar vegetation in the plains zone appears to have changed substantially in the past twenty years. In 1980-81 (Boggs 1984), *P. deltoides* seedlings dominated river edge sites along the lower Yellowstone, averaging 21% cover, with *Salix exigua* seedlings providing another 5% cover. Forbs (5% cover) and grasses (2% cover) were less important, with three *Polygonaceae* species and the exotic *Echinochloe crusgalli* (barnyard grass) providing most of the herbaceous cover. Neither tamarisk nor Russian olive was found at any of the nine river edge sites sampled. Non-native species accounted for 25% of the species richness across all sites, but only 10.9% of the total cover (Boggs 1984), i.e. 4.2% cover out of the total plant community cover of 38.4%.

In 2001 sandbars had essentially the same total cover (38.6%), but the composition changed dramatically. In the *Populus deltoides* zone, their seedlings have been reduced from dominance at 21% cover, to negligible at only 0.3% cover. Not one of the five plains sites, even the most remote, had cottonwood seedlings with 1% or more cover. *Salix exigua* had an increased presence at 8% cover, and the exotic tamarisk, absent in the early 1980s, is now present at 80% constancy and 1.5% average cover.

Herbaceous cover and percent non-native cover have increased at sandbar sites since the 1980s. Forbs have tripled to 16% cover and graminoids are up from 2% to 12% cover. The presence of non-natives has increased dramatically: from 25% to 44% of the total species richness, and from 11% to almost a third (31%) of the total cover (12.5% out of 38.6%) (Tables 9, 10 and 17). While it's possible the difference in sampling methods could account for some of this increase in absolute cover, the *ratios* of non-native/total species present shouldn't be affected by the use of different methods.

Both River Edge Communities

In sum, sandbar willow thrived on both ungrazed gravelbar and sandbar sites, in both 1980 and 2001. *Populus deltoides*' cover dropped from 21% (1980) to less than 1% cover (2001) over the past twenty years. Downriver in the *P. deltoides* zone, the exotic shrub tamarisk has gone from no recorded presence, to being widely established on both sand and gravelbars.

Is it possible that 1980 & 1981 were just good years for *P. deltoides,* when the earlier field work was done - while 2000-2001 just happened to be a poor year due to differences in river conditions and spring floods? This question can be addressed by looking at the next successional community, the thickets, which represent a longer time period.

Salix exigua Thickets

In the early 80s on the lower Yellowstone, *S. exigua* and *P. deltoides* saplings were co-dominants in thickets, each averaging 30% cover across the eight stands sampled (Boggs 1984). The cottonwood saplings were averaging two meters high, so they had not yet overtopped the willows. Herbaceous plants provided just 25% cover, and were predominantly native. There were two common non-natives: *Elymus repens* (quackgrass, 3% cover) and *Melilotus officinalis* (sweet clover, 1% cover). *Phalaris arundinacea* was found only at one site, at < 1% cover, and *Cirsium arvense* only averaged 0.5% cover and 38% constancy. Neither tamarisk nor Russian olive were present. Non-natives comprised 27% of the species richness/site, and approximately 9% of the total cover (Boggs 1984).

In 2001, *P. deltoides* is no longer a co-dominant in willow thickets; it now comprises only about 1% cover. Today, sandbar willow is dominant in thickets at ungrazed sites all along the Yellowstone, which average 50% *S. exigua* and 6% *S amygdaloides* cover (Tables 9 & 10). Sandbar willow is two to four meters

high, with peachleaf willow overtopping it where it occurs (figure 12). Shrub species that were absent twenty years ago are establishing in the willows, but all at less than 2% average cover apiece. The new shrubs include both exotics and natives. The exotics tamarisk and *Elaeagnus* (Russian olive) now occur in plains willow thickets with constancies of 55% and 36%, respectively. Native shrub species that form the understory in mature cottonwood forests also appear; these include *Cornus stolonifera* (Red osier dogwood), *Ribes aureum* (golden currant), and *Rosa sp.* (wild rose), with constancies of 45%, 45% and 36% respectively.

Consistent with the disappearance of our overstory dominant, this community has simultaneously developed an understory of exotic forbs and herbs, not present twenty years ago. *Phalaris arundinacea* (reed canary grass, 20% cover), *Cirsium arvense* (Canada thistle, 7% cover), and other less extensive non-natives have increased from 9% to 39% of the total cover, and from 27% to 46% of the overall species richness of this vegetation type (Table 17).

What has happened to the *P deltoides* saplings, once co-dominants with *Salix exigua*? We don't recollect ever seeing stands of 2-3 meter high *P deltoides,* and suspect that this tree has not reproduced well for at least ten years. The young *Populus deltoides* stand we did sample (site U2P, Tables 15 & 16) was composed of older, fairly tall trees, with a dominant tree cover, and minimal shrub understory (as they were some twenty years ago, Boggs 1984). A

survey of the age distribution of Plains cottonwood stands (adjusted for floodplain turnover rate), not undertaken in this study, would be valuable.

Mature *Populus deltoides* Community.

Twenty years ago, *P. deltoides* saplings in willow thickets grew to overtop the willows, to form mature cottonwood forests with a shrub understory dominated by natives *Rosa woodsii* (12% cover), *Toxicodendron rydbergii* (poison ivy, 13% cover) and *Symphoricarpos occidentalis* (snowberry, 6% cover). The native grasses *Elymus canadensis* (Canadian wild rye, 6% cover) and *Muhlenbergia racemosa* (muhly, 5% cover) were more extensive than the non-natives *Poa sp.* (bluegrass, 4%) and *Bromus inermis* (smooth brome, 2%). *Parthenocissus quinqefolia* (Virginia creeper, 1%), *Vitis riparia* (wild grape, 4%) and *Elymus smithii (= Agropyron smithii,* western wheatgrass, 1%) - all natives - were the only other species averaging more than 1% cover. Forbs were sparse and uncommon, with none averaging more than 0.5% cover in mature forests (Boggs 1984). Collectively, non-natives comprised 22% of the overall species richness, but only 3.9% of the total cover present.

It appears that the downriver willow thickets we sampled will not develop into cottonwood forests, for the simple reason that the cottonwood saplings are almost completely missing (Tables 11 & 12). Instead the willows are likely to be replaced by the largest shrub species now establishing in these thickets, Russian olive. This replacement may have been occurring in eastern Montana for

decades. In 1980-81, Russian olive was found in half of the mature cottonwood transects between Glendive to Sidney, but never with ≥ 1% cover (Boggs 1984). In 1988, Russian olive was described as a "minor, but locally abundant" riparian dominance type in eastern Montana, which had already "become a management concern" for both private and public land managers (Hansen 1988). Its "potential to displace native riparian vegetation" and interfere with both ranching and farming operations was recognized (Hansen 1988). In 2001, Russian olive occurred in 75% of cottonwood forest transects from Reed Point to Sidney - all 400 miles of the lower Yellowstone - and averaged 15% cover. This almost certainly underestimates the extent of its presence on the landscape scale, as transects were run only in *P. deltoides* communities. Russian olive dominated stands existed, but weren't sampled.

Russian olive is altering the composition of cottonwood communities, as it also establishes under mature *Populus deltoides* trees, as well as in willow thickets. In twenty years Russian olive has gone from minimal presence (never $\underline{\geq}$ 1%) (Boggs 1984) to being the dominant shrub, with 15% average cover and 75% constancy ($p = 0.003$ s.v./$p = 0.055$ p.v.). That it may outcompete the natives *Rosa sp.* and *Vitis riparia,* is suggested by their decline from 12% to 1.5%, and from 4% to 1% average cover, respectively ($p = 0.02$ s.v./0.00 p.v. and $p = 0.17$ s.v./0.01 p.v.). Natives *Toxicodendron rydbergii* (8% cover) and *Symphoricarpos occidentalis* (5% cover) are both still present, and forbs remain sparse (5% cover, collectively). Non-native grass cover has increased

substantially at the expense of native grasses. The exotic *Bromus inermis* has expanded from 2% to 15% average cover, and now dominates the herbaceous layer (p = 0.10 s.v./0.01 p.v.). Non-native *Poa pratensis* (Kentucky bluegrass) remains at 4% average cover, while exotic *Elymus repens* has gone from rare (one site out of six) to 59% constancy and 4% average cover (not significant, p = 0.400 s.v./0.122 p.v.) Native *Elymus canadensis* has been reduced from 6% to 1% average cover (p = 0.040 s.v./0.046 p.v.) and *Muhlenbergia racemosa* went from 5% average cover to almost none (p = 0.03 s.v./0.00 p.v.).

Collectively, non-natives have increased from 22% to 43% of the species richness, and have increased their percent of the total cover from 4% to 28%. It is important to note that this change in community composition over the past twenty years has happened while these sites have been exclosed from grazing.

Grazing Effects

We compare vegetation and physical environment on grazed and ungrazed sites in five vegetation/environmental types below. Grazing might affect vegetation either through selective consumption, through trampling sensitivity, or indirectly through soil compaction (Dale and Weaver 1974). Selective consumption might reduce a favored species or increase a dis-favored species by removing the competition of the favored species. Changes in vegetation might affect the physical environment (e.g. soil texture, soil moisture)

by reducing infiltration and increasing surface runoff, evaporation and erosion (Mosley et. al. 1997). We tested for other environmental correlates to reduce the likelihood of assignment of cause to non-causal correlates. Thus we measured grazing effects on cover (by stratum), richness, exotic presence, and environmental quality.

Gravelbar Communities

14 ungrazed gravelbar sites and 6 grazed gravelbars were sampled. Nine of the ungrazed and five of the grazed sites were in the foothills zone; the remaining gravelbars were in the plains (Table 3). The ordination (Figure 30) did not segregate foothills from plains gravelbars, so they are combined in the analysis. On three of six grazed sites, cover of cow pats averaged 0.2% cover, and woody seedlings were grazed. On the other three "grazed" sites cattle were present in pastures abutting the gravelly river edge and clearly had free access to the gravelbars, but the bars showed no signs of cattle use (no pats, no grazed seedlings). On "ungrazed" sites, cattle had no access and there were no cow pats on them.

Dominance. The most noticeable effects of grazing are visible cattle browsing of both cottonwood and willow seedlings, a reduction in average shrub cover (from 6.4% to 2.5%) and significant increases in three forbs, non-natives

Euphorbia esula and *Chenopodium botrys*, and the native *Equisetum variegatum* (Table 21, and Tables 17 vs. 26).

P angustifolia seedlings thrived in some locations, but did poorly in others, making it difficult to assess the impacts of grazing. On unrecreated, ungrazed sites, five transects averaged 8.8% cover. At the grazed sites, two locations with sign (GIA and GKA) had browsed *P angustifolia* seedlings with an average cover of 6.2%, while two transects at a fourth location had neither cottonwood seedling cover nor evidence of grazing. The single "grazed" site where *P angustifolia* seedlings were ungrazed, had no evidence of cattle presence (no cow pats, no other grazing, no hoof prints). The sixth site (G2B), in the plains, had cow pats and the *P deltoides* seedlings were grazed. In short, wherever there were both cattle and cottonwood seedlings, the seedlings were browsed.

Shrub cover may be reduced at grazed gravelbar sites. *Salix exigua* declined from 4.7 to 2.2% cover, *Salix amygdaloides* declined from 1.1 to 0.2% cover, and *Tamarisk chinensis* declined from 0.7 to 0.0% cover. We observed substantial grazing on willow seedlings at all three sites with cow pats. Although the declines in cover were not statistically significant ($p = 0.13$, separate variance/$p = 0.29$ pooled variance), it seems likely that the very visible decline in biomass (not measured) would be significant. (On sandbars, where *S exigua* has 9.0% cover on ungrazed sites, the decline in cover with grazing *is* significant.)

The overall forb cover increased slightly with grazing from 3% to 4%. Three forb species increased significantly: two non-natives *Euphorbia esula* (leafy spurge, p = 0.08), *Chenopodium botrys* (Jerusalem oak goosefoot, p = 0.05) and the native horsetail, *Equisetum variegatum* (p = 0.028). Graminoid cover was 3% on both ungrazed and grazed sites. *Phalaris arundinacea* was eliminated with grazing on gravelbars.

Richness. Overall species richness/site was similar: 17.6 ± 12 for ungrazed and 23.7 ± 11.5 for grazed gravelbars (p = 0.31). Nor did grazed and ungrazed gravelbars differ significantly for any specific life form. Although richness across all sites was slightly higher for ungrazed (90 spp vs. 74 spp), this is likely due to the fact that we sampled twice as many ungrazed (14) as grazed (6) gravelbars (Table 21, and Tables 17 vs. 26).

Exotic Presence. The percent of non-native species/site was also similar: 46% ± 13% for ungrazed sites, and 39% ± 8% for grazed sites. Percent of cover contributed by non-natives was 34% ± 35% for ungrazed sites, and 37% ± 27% for grazed sites. The variation in cover values, i.e. the contribution of other factors, prevents detection of any hypothesized difference. To restate, cover of non-natives was very variable, ranging from 1% - 100% of total cover on the 14 ungrazed sites, and from 12% - 76% of total cover on six grazed sites (Table 21, and Tables 17 vs. 26).

Environment. There were no statistically significant differences in the environment of the ungrazed sites vs. the grazed sites (Table 27).

Sandbar Communities

Eight ungrazed sandbars were sampled, but only four samples on grazed lands were found. Cow pats averaged 0.3% cover on grazed sites, but were absent from ungrazed sites.

Dominance. Grazed sandbars had substantially less cover (18.6% ± 14.1%) than ungrazed sandbars (38.6% ± 25.0%) (p = 0.105 s.v./0.17 p.v.) (Table 22, and Tables 17 vs. 26).

Forebodingly, cottonwood reproduction was slight on all sandbars for both species, never reaching 2% cover for any location. Cottonwood seedlings were heavily cattle grazed at the three ranch sites where they occurred (*P angustifolia* at GGB, *P deltoides* at G2B and G2B2). The decline in total vegetation cover with grazing is due primarily to loss of shrub cover, down from 10.0% cover to only 0.3% cover (p = 0.06 s.v./p = 0.15 p.v.). *Salix exigua* was most affected, declining from 9.0% to 0.3% cover (p = 0.08 s.v./p = 0.20 p.v.). This willow was moderately to severely grazed at all grazed sites, as was *Salix amygdaloides* at the one site it occurred. *Tamarisk* cover was reduced from 0.8% average cover on ungrazed sites to 0% cover at the single grazed site in its range (G2B/G2B2).

This site was heavily trampled by cattle. We never saw evidence of tamarisk being grazed by cattle or beaver.

Although both forb and graminoid cover decreased with grazing (16% to 11%, and 12% to 6%, respectively), neither reduction was significant. On both ungrazed and grazed sites, the exotic *Chenopodium glaucum* was the most prevalent herb.

Richness. Ungrazed sites had insignificantly higher richness than grazed sites (25 ± 8 vs. 20 ± 14), with most of this difference being due to ungrazed sites having higher forb richness/site (17.1 vs. 11.5).

Exotics. The importance of exotic species varied greatly among sandbar sites, as it did among gravelbar sites, i.e. the percent of total cover contributed by non-natives on sandbars varied from 1% to 70%. Exotics comprised 37% ± 31% of the cover on ungrazed sites compared with 26% ± 24% on grazed sites (P=0.55 s.v./0.57 p.v.) Whether this is random variation, or whether there is a correlation with recreational, grazing and/or other human impacts, is undetermined (Table 22, and Tables 17 vs. 26).

Environment. We attribute the differences between grazed/ungrazed sites to cattle treatment, because grazing and trampling were seen at all four grazed sandbar sites, and because alternate factors varied little. Cowpie cover

averaged 0.3% on grazed sites, and was absent from ungrazed sites. Ungrazed and grazed sandbar sites were not statistically different from one another with respect to most measured environmental variables that could contribute to differences in plant communities, i.e. mile on river, height above water, depth to gravel, pH, electrical conductivity and $CaCO_3$. Ungrazed and grazed sites differed significantly in soil clay content (7% vs. 11%; p = 0.068 p.v./0.165 s.v.), and organic carbon (0.38% vs 0.62%; p = 0.051 p.v./0.099 s.v.). While these differences are correlated with cattle use we doubt that they are caused by or influenced by cattle (Table 27).

Salix exigua (Sandbar willow) Thickets/Communities

Twenty-two ungrazed sites and ten grazed *Salix exigua* thickets were located. Of the grazed sites, seven were in the *P angustifolia* (foothills) zone, and three in the *P deltoides* (plains) zone.

Dominance. Grazed willow vegetation had significantly less cover (89%) than ungrazed transects (111%, p = 0.056 s.v./p = 0.041 p.v.) (Table 23, and Tables 17 vs. 26).

Cottonwoods were a minor component of *Salix exigua* communities. *Populus angustifolia* is rare in willow thickets, and was only found in two of 18 willow stands (one grazed, one ungrazed) in its range. At the grazed site, mature narrowleaf cottonwoods overhung the transect, and the seedlings below were

grazed with the willows. *P deltoides* reproduction was similar throughout its zone, with 1.5% cover on ungrazed sites and 1.0% cover on grazed sites.

Grazing reduced *Salix exigua* cover from 51% to 31% (p = 0.0005 s.v./p = 0.0016 p.v.) (Table 23). Constant grazing also prevented *Salix exigua* height from reaching its potential; heights were 2 - 4 meters on ungrazed sites, and less than one meter for some willows on six out of ten grazed sites (Figures 12 & 29). These six heavily grazed sites averaged 1.1% cow pat cover. At two other lightly grazed sites (cow pat cover 0.03%), willows were less reduced in height (from 3 to 2 m.). At one location, the willows were so tall the cattle could only hedge them. At the tenth location, there was no indication of recent grazing of any plants, and no cow pats in the transect.

Loss of *S exigua* is understated if grazing has eliminated willow thickets from some grazed lands. Willows were sampled wherever they occurred in our 24 ungrazed locations, and 21 grazed ranches. The facts that 75% of the ungrazed sites, but only 48% of the grazed sites had willows, and that the protected sites were much smaller (averaging 42 acres) than the grazed sites suggests that willow may have been grazed out at some sites (Table 3).

Grazing also reduced the quantity of *S. amygdaloides* (peachleaf willow, 6% - 1% cover, p = 0.083 s.v./0.188 p.v.) and *Cornus stolonifera* (red osier dogwood, 1.6 - 1.0% cover, p = 0.063 s.v./0.198 p.v) (Table 23). These species were grazed wherever they co-occurred with willows.

The loss of willows may increase erosion and increase beaver harvest of mature cottonwood. First, *S exigua* colonization of sandbars stabilizes streambanks. So, if willows are degraded, streambanks erode rapidly (Hansen 1988). And second, because beaver prefer willow and cottonwood saplings to mature cottonwoods, willow presence diverts them from harvest of mature trees (McGinley and Witham 1985). On several ranches where all that remained of the riparian vegetation were large cottonwoods and herbaceous plants, the trees were being felled by beaver. This causes loss of shade for cattle, and of tree roots to stabilize banks.

Grazing did not affect total forb cover (17% ungrazed and 21% grazed), but did affect graminoid cover (Table 23, and Tables 17 vs. 26). Grazing significantly reduced only one grass: the non-native *Phalaris arundinacea* (reed canary grass) declined from 20% to 0.3% cover with grazing ($p = 0.0004$ s.v./0.009 p.v.)(Table 23). The presence of *Phalaris* in this vegetation type may affect willow use by cattle, either as an attractant or a diversion. Loss of *Phalaris* may favor the two native associates which increased with grazing: *Eleocharis palustris* (spike rush, 0.01% to 0.1% average cover, $p = 0.079$ p.v./0.239 s.v.) and *Hordeum jubatum* (foxtail barley 0.01% to 0.1% cover, $p = 0.036$ p.v./0.161 s.v.). *Agrostis stolonifera* also increased with grazing (2% to 4%), but the change was not significant.

Richness & Exotics. There were no significant differences between ungrazed and grazed *Salix exigua* thickets in either richness/site (22.0 vs. 23.1 spp), or in richness in any life form/site category. The percent of species/site which were exotic was also comparable: 46% ± 13% for ungrazed, and 41% ± 9% for grazed. Grazed sites showed substantial loss of non-native cover (from 39% to 20%), primarily resulting from the loss of *Phalaris.*

Environment. Soil textures of grazed and ungrazed stands differed significantly. Grazed sites averaged 67% sand and 23% silt, while ungrazed sites had less sand (53%, p = 0.021 s.v./0.035 p.v.) and more silt (35%, p = 0.008 s.v./0.016 p.v.) (Tables 27 & 8). This is unlikely to be attributable to difference in river location, since the average location of ungrazed sites (river mile 162 ± 147) isn't that different from grazed sites (mile 97 ± 107). It seems more likely that the taller, denser willows on ungrazed sites slow river flows sufficiently to capture more transported silts or to prevent export of silts. Conversely, heavily grazed willow stands commonly had more bare ground susceptible to wind and water erosion. Ungrazed and grazed *S. exigua* sites were insignificantly different from one another with respect to other environmental variables tested (Table 27).

Populus angustifolia Communities

Eight ungrazed and thirteen grazed *P. angustifolia* stands were sampled. All were between miles 0 and 100 of the study region, i.e. between Emigrant and

Reed Point, MT. Cow pats were absent from the ungrazed sites, and averaged 3.5% cover on the grazed sites.

Dominance. Grazed *Populus angustifolia* stands (148% ±23%) had significantly less cover than ungrazed stands (168% ± 26%) (p = 0.098 s.v./0.082 p.v.) (Table 24, and Tables 17 & 26). The cottonwood canopy, out of reach of grazers, was apparently unaffected.

Native shrubs are greatly reduced by grazing (Table 24). Native shrub cover declined from 46.7% to 7.8% average cover (p = 0.005 s.v./p = 0.0001 p.v.). The nine most prevalent native shrubs all declined with grazing, four of them significantly. *Cornus stolonifera* (red osier dogwood) virtually disappeared, decreasing from 10.2% to 0.0% cover (p = 0.058 s.v./0.008 p.v.). *Symphoricarpos occidentalis* declined dramatically, from 15.1% to 2.5% cover (p = 0.200 s.v./0.086 p.v.). *Rosa sayi/R. woodsii* (4.9% to 0.9% cover, p = 0.173 s.v./0.074 p.v.) and *Ribes setosum* (redshoot gooseberry) (0.5% to 0.0%, p = 0.143 s.v./0.046 p.v.) also declined. Five other shrubs which provided (insignificantly) less cover in grazed than ungrazed stands were *Juniperus scopulorum* (Rocky Mountain juniper), *Rhus trilobata* (skunkbush sumac), *Shepherdia argentea* (buffaloberry), *Salix amygdaloides* and *Ribes aureum* (golden currant).

Cornus stolonifera (sites GMX and GJX) and *Salix amygdaloides* (sites GKX, G2B2) were seen browsed in other vegetation types; *Ribes sp.* and to a

lesser extent *Symphoricarpos* are known to be browsed by cattle (Kauffman et. al. 1983b). *Rosa sp.* appeared to decline from trampling, rather than from browsing, because it persisted immediately adjacent to large trees and between fallen logs – places where it was protected from trampling, but could have been browsed. No other shrubs showed this pattern.

While grazing did not reduce overall forb cover, three individual species showed significant declines (Table 24). The native *Smilacina stellata* (starry false Solomon's seal) dropped from 2.3% to 0.3% average cover (p = 0.279 s.v./0.007 p.v.), and from 100% to 23% constancy. *Solidago gigantea* (late goldenrod) declined from 1.2% to 0.0% average cover (p = 0.084 s.v./0.017 p.v.) and from 75% to 8% constancy. The exotic weed *Cirsium arvense* (Canadian thistle), prevalent in willow thickets, also lost cover with grazing (4.0% to 0.4% cover, p = 0.025 s.v./p = 0.003 p.v.).

The cover of non-native forbs as a group seemed to increase with grazing, from 6% to 10% average cover, though insignificantly (Table 24). *Centaurea maculosa* (knapweed), absent from ungrazed sites, averaged 0.6% cover and 38% constancy on grazed sites. *Cynoglossum officinale* (houndstongue) increased from 0.0% to 1.4% average cover, and from 13% to 62% constancy with grazing. The native *Glycyrrhiza lepidota* (wild licorice), which many ranchers considered a problem weed, doubled its average cover with grazing (2.2% to 4.8%).

Grass cover increased significantly with grazing, from 20% to 39% on average (p = 0.010 s.v./0.029 p.v.) (Table 24), perhaps due to reduction of shrub competition. The cover increase was mostly due to the near doubling of non-native grasses (16% to 32% cover, p = 0.071 s.v./0.115 p.v.). Exotic *Elymus repens* (quackgrass) increased from 1% to 14% cover (p = 0.044 s.v./0.094 p.v.). Other grasses which increased with grazing, albeit not significantly, were the exotics *Poa pratensis, Bromus inermis* and *Dactylis glomerata*, and native *Agrostis stolonifera. Phalaris arundinacea,* which disappeared from willow thickets with grazing, was likewise consumed in *P angustifolia* stands; it averaged 5.3% cover in ungrazed locations, but zero cover in grazed sites (p = 0.109 s.v./0.028 p.v.).

Richness. The species richness of the narrowleaf cottonwood community declines with grazing, from 19.8 to 16.0 species per site, due to a significant loss of native forbs (Tables 17 & 26). Tree diversity was unchanged. Native shrub diversity was reduced insignificantly, from 5.3 to 3.5 species/site (p = 0.153 s.v./0.111 p.v.). Native forb richness dropped significantly, from 5.0 to 2.3 species/site (p = 0.013 s.v./0.004 p.v.). Native grass richness declined slightly, from 1.5 to 1.0 species/site. Overall native species richness declined from 12.9 to 7.9 species/site (p = 0.005 s.v./0.003 p.v.). Non-native species richness increased insignificantly (6.9 to 8.1 spp, p = 0.379 s.v./0.382 p.v.).

Exotics. Grazing increased the dominance of exotic plants. The percent of total cover comprised of non-native species increased significantly with grazing, from 14% ± 10% to 27% ± 14% (p = 0.026 s.v./0.039 p.v.). Considering the ground layer only, the cover of non-native forbs and grasses increased from 23% ± 17% to 42% ± 25% cover (p = 0.054 s.v./p = 0.076 p.v.) (Table 24, and Tables 17 & 26).

Vegetation Overview. The change in *P. angustifolia* stands with grazing is visually striking: while the overstory is unchanged, the exclusively native shrub cover declines from 47% to less than 8%, and weedy grasses and forbs (primarily exotic) increase to fill the gaps. Less visually obvious is the loss of native species richness, including the shrubs *Cornus stolonifera, Ribes setosum, Ribes aureum* and *Rosa spp*, and forbs such as *Smilacina stellata* and *Solidago gigantea*. What are the ecological consequences of this shift in plant community composition?

Environment. The environments and soil properties of ungrazed *P. angustifolia* stands differed from those of grazed sites in two ways, both resulting from grazing effects on soil capture during the flood stage and/or on rates of erosion.

Depth to gravel was greater in ungrazed (111 cm ± 48 cm) than in grazed (74 cm ± 38 cm) stands (p = 0.084 s.v./0.077p.v.) (Table 27). This may be due

to higher deposition in ungrazed stands, higher export (erosion) from grazed stands, or geomorphologic changes downriver. With regard to geomorphic changes, depth to gravel (Figure 20) and soil surface height (above river water, Figure 19) both increase substantially with distance downriver in the foothills/P angustifolia zone (mile 0 to mile 100). Both phenomena are presumably due to greater deposition of fine sediments with distance downriver. The fact that the ungrazed stands were slightly offset downriver (average: mile 48) relative to grazed stands (average: mile 31) ($p = 0.36$ s.v./0.34 p.v.) raises the third possibility.

The second difference was that silt content of soils at ungrazed sites (49%) was higher than silt content at grazed sites (32%) ($p = 0.112$ s.v./0.075 p.v.) (Table 27). Sand contents were complementary, with ungrazed site soils (36% sand) less than those at grazed sites (56%) ($p = 0.18$ s.v./$p = 0.13$ p.v.). Again, the ungrazed sites may capture more silt, the grazed sites may lose more silt, or the process may be geomorphic (independent of vegetation/ grazing). Because grazed *P angustifolia* sites are sandier and less silty than their ungrazed counterparts at the same river mile (miles 0 – 100, figures 25 & 26), we reject the geomorphic hypothesis.

As we hypothesized for willow thickets, we suggest that the soil texture difference is due to greater erosion at grazed sites carrying off more silt than sand. The decrease in total plant cover, the shift from predominantly native shrub cover to predominantly non-native herbaceous cover, and the exposure of

bare ground at heavily grazed locations could all be factors. It's also possible that ungrazed sites trap more silt from surface runoff, and from the occasional floods high enough to reach these cottonwood forests (2.4 m above river level).

Populus deltoides Communities

Seventeen grazed and 17 ungrazed Plains cottonwood stands were sampled between Reed Point and Sidney, MT, a stretch of 400 river miles. Cow pat cover was absent from the ungrazed sites, and averaged 0.8% cover on the grazed sites.

Dominance. The impacts of grazing on *P deltoides* stands are more subtle, and not as visually striking, as in *P angustifolia* forests. As the percent cover cow pats in *P deltoides* (0.8%) was significantly less than that in *P angustifolia* (3.5%, p = 0.03 s.v./0.02 p.v.), it's possible that Plains cottonwood forests in this study were not as heavily grazed as the narrowleaf cottonwood stands. Tree cover, established long ago, is unaffected, because cows can't reach it (Tables 24 & 25).

Across all ages of stands, shrub cover declined insignificantly from 41.2% to 27.2% (p = 0.231 s.v./0.230 p.v.) (Table 25). The decrease in native shrub cover is greatest in mature stands, as younger stands have little developed shrub covers (Table 28). If only those stands with average DBH of 50 cm or more are considered, native shrub cover declined from 37.4% to 24.4% (p = 0.182

s.v./0.164 p.v.). Native shrub cover in mature, ungrazed *P deltoides* stands (37.8%) on the lower Yellowstone (Boggs 1984) was almost identical to our measurement. If his six sites are added to our sample the loss of native shrub cover at grazed, mature sites is significant (p = 0.095 s.v./0.091 p.v.).

One native shrub, *Toxicodendron rydbergii* (poison ivy) declined significantly with grazing in our sites, from 8% to 1% on average (p = 0.108 s.v./p = 0.101 p.v.). *Juniperus scopulorum, Vitis riparia, Cornus stolonifera, Salix amygdaloides, Ribes aureum* and other natives decreased, although not significantly. A few natives, such as *Rosa sp., Symphoricarpos occidentalis* and *Artemisia cana,* increased insignificantly with grazing.

The non-native Russian olive *(Elaeagnus angustifolia)*, the dominant shrub under cottonwoods with both the highest cover (15% ungrazed/9% grazed) and the highest constancy (76% ungrazed/65% grazed), was insignificantly reduced on grazed sites (p = 0.365 s.v./0.365 p.v.) (Table 25). Russian olive's dominance of the shrub understory is striking for two reasons. First, it did not have $\geq$ 1% cover in *any* of the cottonwood (or thicket) transects completed in the 1980-1981 survey of the lower Yellowstone (Boggs 1984). Second, a review of ungrazed *P deltoides* sites ordered by tree size (DBH) and therefore age of stand establishment, shows that Russian olive is establishing earlier in succession than any of the other shrubs of comparable size (Table 28). (*P deltoides* diameter at breast height [DBH] has been shown to be closely correlated with age, for the lower Yellowstone (Boggs 1984)).

Grazing is expected to increase Russian olive cover, both because cattle do not remove Russian olive and because their removal of other shrubs reduces competition with Russian olive. The statistically insignificant reduction observed on grazed land likely results from management of ranch vs fishing access land. Ranchers remove the shrub, while fishing access managers cannot address it, because it is not on the noxious weed list. We hypothesize that seedling establishment increases with grazing, at least in mature stands, due to reduction of native shrub cover.

Overall forb cover increased significantly on grazed sites, from 4.6% to 11.4% ($p = 0.07$ s.v./0.07 p.v.) (Table 25). This gain was primarily in non-native forbs (2.2% to 8.3% cover, $p = 0.04$ s.v./0.03 p.v.). Forbs increasing the most were *Taraxacum officinale,* from 0.1% to 1.9%, *Euphorbia esula* from 0.4% to 1.8%, *Cirsium arvense* from 0.3 to 1.2%, and *Medicago lupulina* from 0.04% to 0.5%. The increase was significant for *Taraxacum* ($p = 0.11$ s.v./0.10 p.v.) and *Medicago* ($p = 0.09$ s.v./0.08 p.v.). Overall, the forb pool shifted from natives comprising 68% of its cover, to non-natives dominating at 70% of forb cover.

Five of the seven native forbs with the greatest cover on ungrazed sites, virtually disappeared (to < 0.05% cover) with grazing (Table 25). These included *Solidago mollis, Apocynum sibiricum, Asclepias speciosa* and the two forbs which declined significantly with grazing in *P angustifolia* stands: *Smilacina stellata* and *Solidago gigantea.* One native forb, *Ambrosia psilostachya,* significantly increased with grazing, from 0.2% to 1.1% cover ($p = 0.09$ s.v./p =

0.08 p.v.). Native *Glycyrrhiza lepidota* also increased insignificantly, from 0.2% to 1.2% (p = 0.19 s.v./0.18 p.v.). Detection of grazing induced changes in quantities of inconstant species is a common problem (Popolizio et al 1994).

The significant increase in grass cover (from 20% to 39%) associated with shrub disappearance observed in foothills *P angustifolia* forests was not repeated. Ungrazed *P deltoides* stands already had 29% grass cover, which increased only slightly to 34% cover on grazed sites (Table 25). Grass cover in both *P angustifolia* and in *P deltoides* stands, ungrazed and grazed, was 80% or more exotic. The dominant grass in Plains cottonwood stands, non-native *Bromus inermis*, was unaffected by grazing (15% down to 13%); the non-native *Poa pratensis* doubled its cover (4.3% to 8.7%, p = 0.14 s.v./p.v.); neither difference was significance.

Richness. Richness of grazed and ungrazed stands was comparable, with ungrazed locations having 19 $\pm$ 6.6 species/site, and grazed locations 17.9 $\pm$ 6.9 species/site. The difference was in shrub diversity: 5.8 ungrazed, 4.2 grazed (insignificant, p = 0.17) (Tables 17 & 26).

Exotics. The percent of non-native species/site was higher on grazed (50% $\pm$ 10%) than on ungrazed sites (43% $\pm$ 11%), but the difference was not significant. By life form, native shrubs declined with grazing, at least in the more mature forests, and non-native forbs increased significantly with grazing. The

most important exotics in terms of cover, for all sites, were Russian olive, *Bromus inermis, Poa pratensis,* and a handful of invasive forbs, in order of declining dominance (Tables 17 & 26).

In sum, the dominant shrub is exotic and grazing appears to reduce its competition from native shrubs; exotic forbs increase from 32% to 70% of total forb cover with grazing, and exotic grasses are maintained at > 80% of total graminoid cover with grazing.

Environment. None of the environmental variables appeared to differ significantly between ungrazed and grazed sites (Table 27).

Summary of Grazing Effects

We hypothesized (GrHy 1) that species richness/site would be unaffected by grazing, and this is supported by our results. Species richness/site was not significantly changed in gravel (18 ± 12 to 24 ± 12), sand (25 ± 8 to 20 ± 14), willow (22 ± 7 to 23 ± 6), *P. angustifolia* (20 ± 6 to 16 ± 5), or *P deltoides* (19 ± 7 to 18 ± 7). (Tables 17 & 26).

We hypothesized (GrHy2) that overall cover would decrease in all vegetation types with grazing. Although cover did decrease in all types, this was only significant in *S. exigua* (111% to 89%)(p = 0.06 sv/0.04 pv) and in *P. angustifolia* (168% to 148%)(p = 0.098 sv/0.082 pv) vegetation types, and nearly significant for sandbars (39% to 19%)(p = 0.105 sv/0.167 pv).

Grazing effects on canopy (cottonwood) cover varies with stand age. *Populus* seedling cover was hypothesized to decline with grazing. Seedlings *were* consistently grazed on gravel, sand, and in willow thickets, wherever there was sign of cattle presence. However cover of seedlings on most sites – both ungrazed and grazed – was so low that there were no significant changes in cover with grazing. Grazing has no effect on older canopies, because they are above browsing height. Future tree canopy will be affected if grazing of seedlings reduces their survival rate.

Grazing significantly reduced native shrubs on bars, in willow thickets, in *P. angustifolia* forest and in mature *P. deltoides* forest. Physiognomy was most affected in willow thickets, where both cover and height of *Salix exigua* was reduced. There was less reduction in the shrub layer of *P. deltoides* stands, because ungrazed forests had less cover of palatable native shrubs to begin with (26% vs. 47% in *P angustifolia*), and the non-native Russian olive (15% cover) wasn't being browsed. As shrub cover increases with forest age, the impact on native shrubs was greater in older *P deltoides* stands.

Total forb cover was not affected by grazing in any community, as hypothesized, except in *Populus deltoides* forests where it increased significantly with grazing ($p = 0.07$ s.v.).

Graminoid cover was hypothesized to decrease with grazing, but we found no uniform response across vegetation types. Grass cover was essentially unchanged on gravelbars (3.0 to 3.5%) and declined insignificantly on sandbars

(12 to 6%). It also declined in willows (31 to 23%). Grass cover increased significantly in *P. angustifolia* stands (20 to 39%, p= 0.01 s.v.), and insignificantly in *P. deltoides* (29 to 34%).

Exotic presence might increase due to disturbance, seed introduction and reduction of competition from palatable natives. It might be especially strong if they were grazing (chemical or thorny) or trample resistant plants. The percent of site richness comprised of non-native species varied from 34% to 50% across all vegetation types (Tables 17 & 26), with no apparent significant changes from ungrazed to grazed for any one plant community.

We hypothesized that grazing would decrease cover of natives (shrubs, forbs and graminoids) and increase cover of non-natives (forbs and graminoids) in every vegetation type (GrHy3). This was true, with a few exceptions (Tables 21-25). On gravelbars, three non-native and one native forb increased significantly while on sandbars, the native shrub *S. exigua* declined significantly with grazing (9.0 to 0.3%). In willows the cover of four native shrubs and one exotic grass was reduced significantly by grazing, while the cover of two native grasses increased very slightly, but significantly (0% to 0.1% cover). Altogether, a total of eight native shrub species occurring in willow thickets and/or cottonwood stands declined significantly with grazing. In *P angustifolia* forests, while two native forbs were reduced by grazing, the non-native grass cover doubled significantly from 16% to 32% (p = 0.07 s.v.). In *P. deltoides* stands, non-native forbs also increased significantly, from 2% to 8% cover (p = 0.03 p.v.).

Among grasses, two exotics increased in willow. One exotic increased substantially in *P deltoides,* and four exotics increased in *P angustifolia* forests. One exotic grass, *Phalaris*, decreased with grazing in all zones and significantly so in willow thickets (Tables 23-25).

We expected no significant effects of grazing on environmental variables for any vegetation type. Surprisingly, comparison of bar, willow, and cottonwood communities suggested several possible impacts (Table 27). On sandbars clay increased (7% to 11%, p = 0.07 s.v./0.17 p.v.) and organic matter increased (0.38% to 0.62%, p = 0.05 s.v./0.10 p.v.) with grazing. Despite significant relationships, we doubt that grazing either caused or was affected by these soil qualities. On the other hand silt contents of soils were significantly higher in ungrazed than grazed vegetation in willow (35% vs 23%) and in *P angustifolia* (49% vs 32%) communities. Ungrazed stands may have had less bare ground than grazed, thus capturing more silt from surface flow. And reciprocally, grazed sites with less vegetation may have had more silt loss due to faster water flows and more wind erosion.

Comparison of Environmental Factors

Abiotic factors, including surface and subsurface water, climate change along the rivers, and rich soils are known to contribute to riparian species diversity (Green and Kauffman 1985; Kauffman et. al. 1985; Fleischner 1994;

Ohmart 1996). Variability in these factors both laterally (from bar to willow to cottonwood) and longitudinally along the river (foothills to prairie) is worth examining. We hypothesized that height above water, depth to gravel, percent organic carbon and percent nitrogen would increase laterally.

Height Above Water

Access to surface and subsurface water is indexed by the height of the soil surface above the river ("height above water"). Gravelbars and sandbars are similarly raised above the river surface, both site types averaged 1.4 meters height above water. In this study, we found that height above water increases from gravelbar to upriver willow sites (at 1.8 m) ($p = 0.01$) and from these willow to narrowleaf cottonwood stands (at 2.4 m) ($p = 0.004$). Similarly, height above water increases in the plains from sandbar (1.4 m) to downriver willow sites (2.3 m) to Plains cottonwood stands (4.4 m).

In addition, height above water increases *longitudinally* along the river for willow and for cottonwood. Ungrazed willow transects in the foothills (*P. angustifolia)* zone averaged 1.8 m above water; willows in the plains zone averaged 2.3 m above water. There is an even greater spread for cottonwood: ungrazed *Populus angustifolia* sites averaged 2.4 m above water, while *P. deltoides* stands averaged 4.4 m above water (Table 8 and figure 19). These longitudinal differences were significant at $p = 0.025$, and $p = 0.004$ when all the willow and cottonwood sites in this study were included.

This change in "height above water" can be readily observed as a substantial increase in bank height as one travels downriver from Emigrant to Sidney. In some upriver locations in Paradise Valley (Emigrant to Livingston), narrowleaf cottonwood stands are barely raised above the river edge gravel and flood readily (personal communication, local rancher); downriver towards Sidney, there are Plains cottonwood stands growing right up to the edge of eroded sandy banks, which drop off more than seven meters to the river below.

Depth to Gravel

Subsurface water may move readily through gravel layers below the soil surface, and so depth to gravel is another measure of potential water availability for plants (figure 20).

We hypothesized that depth to gravel would increase laterally. In the foothills zone, depth to gravel increases significantly from sandbar sites (28 cm average) to *Salix exigua* thickets (116 cm) ($p = 0.0002$), but foothills zone *S. exigua* and *P. angustifolia* stands had roughly equivalent depths to gravel (116 cm and 111 cm, respectively) (Table 8).

The equivalent depths to gravel can be explained by the deposition processes taking place in the foothills. In this zone, the original gravel bed surfaces are covered by overbank deposits of coarse to medium textured sands. The sedimentation curve increases steeply for the first fifty years after site establishment, and then within 100 years levels off (Merigliano and Polzin 2003).

Sandbar willow dominates lower elevation old channels that have filled in with sand, while cottonwoods establish on gravel bar crests. As cottonwood seedlings grow into saplings, and overbank deposits accumulate on the bar crests, sandbar willow will also establish with the cottonwoods (c. 25 years). By the time the cottonwoods have reached pole stage (c. 47 years), the willow understory is gone (Merigliano and Polzin 2003). However, our soil data indicate that sandbar willow thickets that established without cottonwoods, on lower elevation sandy surfaces overlaying old channels, may continue to persist.

The result is that both *P angustifolia* and *S exigua* communities can be found, the first at higher elevations on top of gravel bar crests, the latter at lower elevations in old channels. There is twice the variation in the depth of the original gravel deposit, than in the overbank deposit surface height (Merigliano and Polzin 2003), which explains why depth to gravel is comparable for the two communities even though cottonwoods are higher above water.

In the plains, depth to gravel increased from sandbars (28 cm) to *Salix exigua* thickets (106 cm) ($p = 0.00$), to *P. deltoides* stands, with a conservatively estimated 153 cm average depth (significant at $p = 0.00$). In some cases depth to gravel exceeded the reach of our 152 cm auger. Where possible depth to gravel was estimated from adjacent riverbanks; this was sometimes as much as four meters. In short, average depth to gravel was 106 - 116 cm for all *Salix exigua* and for narrowleaf cottonwood, and readily exceeded 150 cm for Plains cottonwood. The greater depth to gravel found in the plains corresponds to

greater heights above water found there, as the sedimentation curve continues to climb through time to as much as seven meters above the river at Sidney, MT (figure 19).

Calcium Carbonate and pH

Soil calcium carbonate and pH both increase significantly with distance downriver. The soil's calcium carbonate content was negligible in the foothills. It began to rise (to values > 1 percent equivalency) near Reedpoint, at the transition from *P. angustifolia* to *P. deltoides.* It continued to increase downstream to values as high as 5.7 (squared multiple r = 0.75; p = 0.000) (figure 21). $CaCO_3$ concentrations in river water generally increase with distance downstream (Kelly 2005). The increase in $CaCO_3$ downstream might be due to either increasing deposition (silts in river water), reduced leaching (with decreased precipitation), or both.

With the increasing $CaCO_3$, soil surface pH gradually becomes more basic (figure 22). Foothills sandbar soils had an average pH of 7.7, while their downriver counterparts were much more basic (8.4 pH, Tables 8 & 27 - ungrazed and grazed). The same range was found when soils of ungrazed upriver *Salix exigua* stands were compared with soils of downriver *Salix exigua* stands (pH 7.9 vs 8.2), and when soils of ungrazed *P. angustifolia* stands (pH 7.8) were compared with *P. deltoides* soils (pH 8.1, Table 8). An analysis of variance of soil pH against river mile gave a p value of 0.0000.

There is also a slight lateral increase in $CaCO_3$ from sandbar to later seral communities (Figure 21), perhaps due to the additional deposition of river silts. In the foothills, the increase is from 0.04 percent equivalency in sandbars, to 0.4 in both *S. exigua* and *P. angustifolia.* In the plains, sandbar soils have 3.0 percent equivalency $CaCO_3$, *S. exigua* 3.2 and *P. deltoides* 3.4. This could in turn affect soil pH in the respective plant communities. An analysis of variance of sandbar, willow, *P. angustifolia* and *P. deltoides* soils, with pH as the dependent variable, was marginally significant ($p = 0.10$).

The slightly higher pH downriver may help explain the presence of Russian olive in the plains, and its absence in the foothills zone, as it is believed to prefer slightly alkaline soils (Olson and Knopf 1986).

Soil Development Measures: Organic Carbon and Nitrogen

Percent organic carbon and percent total nitrogen were measured as indices of biological input, and were hypothesized to increase laterally (bar to willow to cottonwoods). Our data support this hypothesis. For the foothills zone, organic carbon increased from 0.37% for sandbar (all ungrazed sites) to 1.35% for upriver *Salix exigua* soils (significant at $p = 0.05$), and further to 2.80% for *P. angustifolia* soils (significantly greater than willow soils at $p = 0.0002$) (Figure 23, Table 8). There was a corresponding increase in total nitrogen from 0.023% (sandbars) to 0.090% (upriver willows) to 0.168% for *P. angustifolia* (Figure 24, Table 8).

In the plains, organic carbon increased from 0.37% in sandbar soils (all ungrazed sites) to 0.62% in plains *S. exigua,* and to 1.86% for *P. deltoides* soils (Table 8, Figure 23). Total nitrogen also increased, from 0.023% for sandbars (all ungrazed sites) to 0.039% for plains *S. exigua,* and to 0.123% for *P. deltoides* (Table 8, Figure 24). This pattern was also found by Boggs for the lower Yellowstone (1984).

A longitudinal comparison finds that foothills willow and cottonwood soils had higher levels of organic carbon and nitrogen than their downriver counterparts. The soil organic carbon content fell significantly from *P. angustifolia* soils (2.80%) to *P. deltoides* soils (1.86%) ($p = 0.07$ s.v./0.04 p.v.). The decline in soil organic carbon from upriver (1.35%) to downriver (0.62%) willow sites was not significant ($p = 0.12$). Total soil nitrogen shared the same pattern: it was higher for foothills soils than plains soils, in both the willow and the cottonwood communities (Figures 24 & 23, Table 8), but these differences were not (quite) significant ($p = 0.13$ for both).

A variety of factors might contribute to this difference. Greater annual precipitation (and less evaporation) in the foothills might lead to higher productivity. Cooler summer temperatures in the foothills might result in slower decomposition of soil humus. Stand ages might be greater up than downriver, if there is a longer flood plain turnover period for cobble substrates upriver than sandy substrates downriver. Foothills *Salix exigua* that establish without cottonwood on sandbars overlaying old channels, aren't age limited by being

overtopped by the growth of *P. angustifolia* - as willows in the Plains zone are (or were) by *P. deltoides* growth. Additionally, the sedimentation curve for the foothills zone levels off after 100 years (Merigliano and Polzin 2003), so height above water does not appear to rise too high for *S. exigua* to obtain moisture. (Even *P. angustifolia* stands – highest above water of the vegetation types in the foothills - averaged only 2.4 m above the river, while downriver *S. exigua* are averaging 2.3 m above water - thus demonstrating the willows' tolerance.) Perhaps foothills *S. exigua* thickets on the whole survive longer and are older than plains willow thickets?

Soil Texture

Variation in soil texture showed both lateral and longitudinal patterns, which we had not hypothesized. Laterally, sand drops from an average of 72% for sandbars to 53% for *Salix exigua* soils (significant at $p = 0.009$), and declines further to 36-42% sand in cottonwood soils ($p = 0.084$ s.v./0.092 p.v.). With the drop in sand (%) over time, silt (%) and clay (%) both increase reciprocally. The soils change from sands and sandy loams to loams. Longitudinally, the foothills soils in both willow and cottonwood communities had less sand (%) and more silt (%) on average than their plains counterparts - but the differences were not significant (Figures 25-27; Table 8).

Electrical Conductivity

The electrical conductivity of the soils from each transect was measured, but no patterns were found with relation to plant community, lateral position or longitudinal position (Table 8, Figure 28). Averages for vegetation types ranged from 0.37 ± 0.09 mmhos/cm for sandbars, to 0.57 ± 0.44 mmhos/cm for downriver *Salix exigua.* High standard deviations for these values were characteristic.

Vegetation/Environment Relations

Vegetation of the three zones may be determined by differences in age (through succession) or by differences in the environment (laterally or longitudinally along the river). The successional and the lateral gradient correspond, and here the changes in vegetation and environment interact.

The established view (Boggs 1984, Hansen 1988) is that in general the bar, willow and cottonwood communities replace one another serally, as *Salix* and *Populus* establish together on bars, grow into co-dominants in thickets and then the willows die and the cottonwoods mature into forests. While this appears to have been accurate for the plains zone of the Yellowstone 20 years ago, it does not appear to be happening today due to very poor *Populus deltoides* reproduction. In the foothills, *Populus angustifolia* and *S exigua* seedlings both establish on gravel bar crests, where they will grow into co-dominant thickets,

and then develop into cottonwood forests (Merigliano and Polzin 2003). However, willows also establish without cottonwoods on lower lying sandbars in the foothills (Merigliano and Polzin 2003).

The series might be externally (allogenically) or internally (autogenically) driven or both. The allogenic hypothesis states that the environment is dried as flood deposits of sand and silt, trapped by vegetation, increasingly distance the vegetated surface from the water below. Early seral plants are eliminated by drought. We have shown (above) that height above water increases in both foothills and plains as the community ages from bar to willow thicket to cottonwood forest. Depth to gravel shows the same pattern in the plains. In mature forests, hydric shrubs (*e.g. Salix*) are replaced by mesic shrubs (e.g. *Symphoricarpos*).

Two time-determined mechanisms might drive an autogenic transition in species composition. First, if ground layer plants are excluded by shade, the exclusion occurs only after taller plants accumulate wood and overtop plants they eventually dominate. Willows dominate the forbs of bars, and cottonwoods eventually dominate willows. Second, while hydric plants (eg *Salix, Carex, Juncus, Cornus, Ribes hudsonianum*) may vanish in the drying environment, it takes time to accumulate seed for succeeding xeric plants. While cottonwood and willow seeds are delivered to bars in or on the water or via the wind, riparian hydric and mesic shrubs more likely arrive by a biotic mechanism. Specifically, the fact that almost all riparian mesic shrubs have berries (*Juniperus, Rhus,*

Shepherdia, Symphoricarpos, Elaeagnus, Toxicodendron, Vitis, Rosa) suggests that seed delivery by birds increases in the maturing (aging) cottonwood community when the trees are large enough to provide nesting sites. Wide ranging mammals probably also deliver borages and burs adapted either to hydric streamside sites (e.g. Xanthium) or to dry forest (e.g. *Arctium, Glycyrrhiza*, *Cynoglossum*). Similarly, small mammals may cache and thereby distribute Russian olive berries (Currier 1982 in Olson and Knopf 1986). This is the autogenic hypothesis. Both allo- and autogenic processes apparently act in concert.

Plains Cottonwood Reproduction on the Yellowstone

Populus deltoides reproduction may be threatened, as seedlings and saplings are nearly absent from ungrazed sandbars and willow thickets in the plains, compared to the 21% cover on bars and 30% cover in thickets found 20 years ago (Boggs 1984). Although we found that cattle grazed cottonwood seedlings wherever they had access to them, it is critical to note that cottonwoods are not reproducing well *even when protected from grazing*. The existing literature, our data and rancher observations suggest several potential contributing factors that deserve further research attention.

Climate Change?

A study on long term *Populus angustifolia* reproduction along the upper Yellowstone (Gardiner to Springdale) found that there was a high level of flood plain creation from 100 – 150 years ago, and concurrently, a surge in cottonwood establishment (Merigliano and Polzin 2003). Cottonwoods did less well in the past century, and still less well in the past fifty years as the river system became less dynamic. The proportion of young cottonwood trees declined from 1948 to 1976, and dropped further to 1999 (Merigliano and Polzin 2003). Although cottonwood seedlings *did* establish on new deposits created by the 1996-1997 floods, flood plain creation in those two years was not as extensive as it had been in previous floods of comparable magnitude. On deposits older than 1996-97, seedlings are rare to absent (Merigliano and Polzin 2003).

They hypothesize that in addition to bank stabilization (which appears to have been a minor factor upriver of Livingston until very recently), there have been alterations in stream flow and sediment load, driven by climate change. The near absence of low terraces of modern origin along the upper Yellowstone River supports this (Merigliano and Polzin 2003). The Little Ice Age, which occurred in North America (and Europe) from the 1400s to the mid to late 1800s, was associated with more frequent large floods and greater sedimentation rates, resulting in more fluvial activity (Merigliano and Polzin 2003, citing eight different sources). They hypothesize that the warming of the climate since, with a

concomitant drop in river activity, could account for reduced flood plain and cottonwood establishment along the upper Yellowstone over the past century.

It would be worth replicating their study – of cottonwood age distribution and floodplain age, extent and distribution – on the lower Yellowstone, to see whether the same patterns hold true. It would be a further test of their hypothesis, and could shed some light on the status of *P deltoides* reproduction.

Hydrologic Change

Although the Yellowstone itself is not controlled, its major tributaries the Big Horn, Tongue and Powder River are dammed. These rivers all join the Yellowstone below Billings. In addition, there are irrigation outtakes from the Yellowstone itself (Marlow 2005). The historical records of spring flood levels for the Yellowstone should be examined, to determine if the flooding pattern has changed significantly in the past twenty years, as this could affect *P. deltoides* establishment.

Sediment Pollution

In addition to longer term climate change, another more recent factor may be at work. Sediment loads in the river increased following the 1988 Yellowstone fires (Ewing 1996), with 42 – 156% increases in sediment load at Corwin Springs, upriver of Emigrant (Merigliano and Polzin 2003). Perhaps this

additional sediment accounts for the healthy *P angustifolia* establishment with the 1996-1997 floods, in contrast to near lack of establishment during prior floods?

Higher sediment loads since the fires are having negative effects on the lower Yellowstone, according to at least four ranchers who participated in this study. They report that since the fire, more bars are forming in the river, which in turn become nurseries for weeds. Without any weed control on these mid river islands, they become continual suppliers of weed seeds to riverbank riparian pastures. Second, flooding on their pastures now deposits much coarser sediments than in the past – so coarse that the pastures are ruined and will grow nothing but a sparse cover of weeds. A couple ranchers have addressed this by plowing off the coarse deposits and replanting. One has resorted to building berms between the river and his riparian pastures to prevent future flooding. A fourth had to abandon the ruined pasture.

We hypothesize that this increase in coarse sediment could be contributing to either or both of the changes seen along the lower Yellowstone since the early 1980s: a dramatic increase in the percent cover of non-native (often weedy) species, and a decline in Plains cottonwood reproduction. Possibly the coarseness of recent deposits is detrimental to the establishment of *P deltoides,* but favors non-native weeds*?*

How could the river be carrying coarser sediment further downriver than it used to do? Perhaps flood flow rates have increased due to either streambank stabilization projects and/or a reduction in the riparian vegetation cover that

slows floodwaters. There could be a self-sustaining feedback loop: if coarser deposits mean less vegetation cover, leading to greater erosion, this would perpetuate the higher sediment pollution levels.

We are reminded that the biotic (e.g. vegetation) and abiotic (e.g. river flow rates, sediment pollution, deposition processes) aspects of riparian ecosystems continually interact and affect the other. Although cyclic change is an inherent characteristic of these ecosystems, directional change is another matter. Defined as “a general shift in the environment due to a widespread change in a driver such as flood frequency or sediment supply” (Merigliano and Polzin 2003), directional change could destabilize the Yellowstone’s riparian ecosystems.

Recreation

Heavy recreational use may impact cottonwood reproduction, as well as riverside vegetation in general. In the upstream P angustifolia zone, cover of cottonwood seedlings was much higher on four little recreated ungrazed sites (8.8% cover, sites UCA, UDA, UEA and UIA, Table 5) than on two heavily recreated ungrazed sites (0.2% cover, sites UJA/UJA2, UMA/UMA2, Table 5) ($p = 0.06$ s.v./p.v.). At the sites with healthy cottonwood establishment, forbs provided 0.4% cover, almost exclusively native grasses contributed just 0.5% cover, and only 4.4% of the total cover was comprised of non-natives. At the heavily recreated sites, grasses dominated with 8% cover (4% native, 4% exotic),

forbs added another 3% cover, and 51.6% of total cover consisted of non-natives ($p = 0.07$ s.v./0.02 p.v., for percent non-native cover). Possibly recreation is impacting not just cottonwood seedlings, but the gravelbar plant community as a whole.

While there could be unidentified factors making some gravelbars suitable for seedlings, and others not, the impacts of recreation on narrowleaf cottonwood seedling establishment deserves further investigation.

CONCLUSIONS [1]

Ungrazed Riparian Vegetation

Species richness/site (VgHy 1) varied among vegetation types, generally falling with distance from the river's edge. The coarse substrate of gravelbars, however, supported the lowest richness/site of any type. The differences in richness were not significant, except that the most diverse vegetation type (sandbars) was marginally significantly richer than the least diverse, gravelbars ($p = 0.10$ s.v.).

Non-native richness (VgHy 2) was highest for sandbars and gravelbars when averaged across all plots of each vegetation type, or when measured as percent of richness in all sites of that vegetation type. Non-native richness calculated per individual site was highest for sandbars. Non-native richness increased longitudinally downstream in willows and cottonwoods, but not significantly.

While the percent low constancy species (VgHy 3) fell from shore to cottonwood it was highest in *Salix exigua* thickets. The high richness was due primarily to higher levels of native forbs. Non-natives on average are more

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[1] Conclusions follow the hypotheses posed in the introduction. Parenthetic numbers correlate them.

constant (VgHy 4) in a vegetation type and range across a wider variety of communities than natives do.

The cottonwood canopy (VgHy 5) is short-term stable, but its future depends on its reproduction. Upriver, *P angustifolia's* seedlings are numerous on ungrazed gravelbars without heavy recreational use. Downriver, *Populus deltoides* is reproducing poorly on sandbars, and its minimal presence in willow thickets suggests that it has not established well for eight - ten years.

Shrubs are important in all stages. On bars *Salix exigua* established successfully, especially on sandbars, and it grows into thickets on ungrazed locations. Downriver *Tamarix chinensis*, is present with low cover but high constancy on both sand and gravelbars; thus, it may expand as it has in the southwest. Inland hydric and mesic native shrubs are thriving in ungrazed *P. angustifolia* and *P. deltoides* forests. Plains forests species composition is challanged by a vigorously increasing exotic shrub, *Elaeagnus angustifolia* (Russian olive).

In the herbaceous layer, non-native dominance increases inward from the river with community age. The herbaceous layer on sandbars and gravelbars is about equally split between forbs and graminoids, with non-natives providing almost half of the cover and species richness of each life form. In willows, exotic grasses and forbs dominate the understory ($\geq$ 70% of herbaceous cover). In cottonwoods, different exotic grass species (*Elymus repens, Bromus inermis* and *Poa pratensis)* dominate the herbaceous layer and forbs are secondary. Non-

native herbs comprise 76% of herbaceous cover in *Populus angustifolia* forests and 79% in *P. deltoides* stands.

Exotics are strongly invading (VgHy 6) the Yellowstone River's riparian communities, both grazed and ungrazed. Over the past 20 years in the plains, Russian olive has increased from < 1% average cover to 15% average cover. Tamarisk has increased from non-existent to common on sand and gravelbars. And non-native richness has doubled across all vegetation types. Meanwhile the percent of total cover comprised by non-native species has tripled in sandbars, quadrupled in *S. exigua* thickets and multiplied nine-fold in *P. deltoides* forests (cf. Boggs 1984).

Physical factors determine community siting in space and time (VgHy7). Decreasing water availability, as indicated by increasing height above water from shore though willow to cottonwood communities, may eliminate the first two communities (allogenic succession). Stand age probably contributes to this change as cottonwoods over-top willows and attract birds introducing berry seeds (autogenic succession).

Grazed Riparian Vegetation

We hypothesized (GrHy 1) that species richness/site would be unaffected by grazing, and this is supported by our results. Species richness/site was not significantly changed in any of the vegetation types studied (Tables 17 & 26).

Overall cover (GrHy 2) decreased with grazing in all vegetation types, especially in *P. angustifolia* forests, willow thickets and on sandbars. Cottonwood trees are most impacted as seedlings on bars and in willow thickets.

Native shrubs were reduced by grazing in all vegetation types, with *Salix exigua, Salix amygdaloides, Cornus canadensis, Ribes aureum, Ribes setosum,* and *Symphoricarpos* most affected. *Rosa spp.* lost cover with trampling. By reducing competition for the exotic shrubs (*Elaeagnus angustifolia* and *Tamarix)* grazing may favor them at the expense of native shrubs and trees of the future.

Total forb and total graminoid cover was not significantly affected by grazing, except in *Populus angustifolia* stands where grass cover increased significantly and in *Populus deltoides* forests, where forbs increased significantly. In both cases, the increases were due to increases in non-native species cover.

As expected native shrub and graminoid cover declined with grazing, while non-native forb and grass cover increased with grazing. Total native forb cover did not change significantly in any vegetation type, as some species decreased while others increased with grazing.

Grazers did not affect their environments significantly (GrHy3). Soils of grazed sandbars contained significantly more clay than grazed sandbars. Soils of grazed willows and *P. angustifolia* stands contained significantly less silt and more sand than their ungrazed counterparts.

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APPENDICES

APPENDIX A

TABLES

TABLE 1. Basin characteristics and annual streamflow statistics at selected sites, Yellowstone River Basin
(Number of years in analyses refers to complete years used in computation of annual streamflow statistics.)

				Annual streamflow			
Gauging Station number	Streamflow gauging station	Elevation (m above sea level)	Drainage area ($km^{2)}$	Mean annual (m^3/sec)	Mean annual (ft^3/sec)	Coefficient of variation	Number of years in analyses
6186500	Yellowstone River at Yellowstone Lake Outlet, YNP	2356	2606	37.6	1328	0.23	67
6191500	Yellowstone River at Corwin Springs, MT	1548	6794	87.9	3104	0.21	90
6192500	Yellowstone River near Livingston, MT	1385	9197	105	3731	0.19	71
6214500	Yellowstone River at Billings, MT	939	30,549	198	6988	0.23	68
6309000	Yellowstone River at Miles City, MT	711	124,980	324	11,440	0.23	69
6329500	Yellowstone River near Sidney, MT	573	178,980	361	12,750	0.27	84

Modified from Zelt 1999

Table 2. Montana precipitation and temperature data for the Yellowstone River valley.

Location	Lat	Long	Elevation feet	Elevation m.	River Mile*	Average Annual Precipitation inches	Average Annual Precipitation mm	Years of Record, Precip	Average Annual Temp	Yrs of Record, Temp	Jan. '01 Average Min Temp	July '01 Average Max Temp	# of frost free days, 10 yr avg
Livingston 12S	45 29	110 34W	4870	1485	23	16.95	430.5	50	43.6	22	15.7	81.9	102
Livingston AP	45 42	110 27W	4653	1419	36	15.73	399.5	63	45.4	32	--	85.2	106
Big Timber	45 50	109 57W	4100	1250	75	--		93	--	90	18.4	86.0	129
Columbus	45 38	109 16W	3585	1093	121	M 10.82	M 274.83	71	45.8	69	13.7	88.9	127
Billings WP	45 46	108 29W	3097	944	173	13.96	354.6	95	48.8	95	M 19.0	89.9	144
Huntley	45 55	108 15W	3000	915	185	14.17	359.9	89	46.2	88	15.6	89.7	128
Hysham	46 18	107 14W	2660	811	258	M 10.91	M 277.11	55	47.4	54	18.4	88.9	139
Forsyth	46 16	106 41W	2515	767	295	14.08	357.6	27	47.4	27	12.2	90.5	139
Miles City	46 26	105 53W	2628	801	349	13.49	342.6	64	46.3	64	--	87.9	141
Terry	46 48	105 18W	2248	685	391	--		52	41.6	52	11.1	88.7	127
Glendive	47 6	104 43W	2076	633	441	M 10.51	M 266.95	109	45.0	101.0	M 13.3	88.1	145
Savage	47 27	104 20W	1985	605	478	13.96	354.6	96	44.8	94	M 13.5	86.6	122
Sidney	47 44	104 9W	1920	585	499	15.40	391.2	59.00	44.6	59	15.8	85.3	124

All termperatures in degrees Fahrenheit.
"Average annual precipitation" and "Average annual temperature" have been adjusted for departures from "Normal."
The "Normal" is the average value of the meteorological element over a time period, in this case 1961-1990.
M = Insufficient or partial data. M is appended to average and/or total values computed with 1-9 daily values missing.
"--" = No record. Data not recorded, determined unreliable by quality control checks, or not received in time for publication.
* River miles are approximate river distances from Big Creek, MT, the upriver end of this study.
Based on river miles for the MT Fishing Access Sites; MT Fish, Wildlife & Parks website

Source: National Climatic Data Center, National Oceanic and Atmospheric Administration,
U.S. Department of Commerce (http://www5.ncdc.noaa.gov/pubs/publications.html#CD)

Table 3. List of research sites and their locations, elevation and river mile

Ungrazed Sites/transect number	Location	County	Year FAS acquired	Elevation (meters)	River Mile	Site Code
Emigrant FAS T1	E edge of Emigrant	Park	1962	1713	6	UBX
Emigrant FAS area: Island downriver T1	N edge of Emigrant	Park			6.1	UCN
Emigrant FAS area: Island downriver T2	N edge of Emigrant	Park			6.1	UCX
Emigrant FAS area: Island downriver T3	N edge of Emigrant	Park			6.1	UCA
Emigrant FAS area: Island downriver T4	N edge of Emigrant	Park			6.1	UCN2
Emigrant West FAS T1	I mi N of Emigrant	Park			6.4	UDA
Emigrant West FAS T2	I mi N of Emigrant	Park			6.4	UDA2
Emigrant West FAS T3	I mi N of Emigrant	Park			6.4	UDB
Emigrant West FAS T4	I mi N of Emigrant	Park	1979	1696	6.4	UDX
Grey Owl FAS, T1	3 mi N of Emigrant, Rt 89	Park			8.8	UEN
Grey Owl FAS, T2	3 mi N of Emigrant, Rt 89	Park			8.8	UEA
Grey Owl FAS, T3	3 mi N of Emigrant, Rt 89	Park			8.8	UEN3
Grey Owl FAS, T4	3 mi N of Emigrant, Rt 89	Park			8.8	UEB
Grey Owl FAS, T5	3 mi N of Emigrant, Rt 89	Park	1983	1694	8.8	UEN2
Pine Creek KOA, T1	10 mi S of Livingston	Park			22.9	UHX
Pine Creek area: Ranch T2 ungrazed	near Pine Creek KOA	Park			22	UIA
Sheep Mountain FAS T1	9 mi. NE of Livingston	Park			45.4	UJA
Sheep Mountain FAS T2	9 mi. NE of Livingston	Park			45.4	UJA2
Sheep Mountain FAS T3	9 mi. NE of Livingston	Park			45.4	UJX
Sheep Mountain FAS T4	9 mi. NE of Livingston	Park	1963	1523	45.4	UJN
Springdale Bridge FAS T1	1/2 mi. N. of Springdale	Park			57.5	UKN
Springdale Bridge FAS T2	1/2 mi. N. of Springdale	Park	1979	1473	57.5	UKX
Springdale FAS area: Ranch T5 ungrazed	Just west of Springdale FAS	Park			57.5	UKX2
Grey Bear FAS, west side, T1	10 km SW of Big Timber	Sweetgrass			67	UMX
Grey Bear FAS, east side, T2	10 km SW of Big Timber	Sweetgrass			67	UMX2
Grey Bear FAS, east side, T3	10 km SW of Big Timber	Sweetgrass			67	UMA
Grey Bear FAS, east side, T4	10 km SW of Big Timber	Sweetgrass			67	UMA2
Grey Bear FAS, east side, T5	10 km SW of Big Timber	Sweetgrass			67	UMB
Grey Bear FAS, west side, T7	10 km SW of Big Timber	Sweetgrass	1966	1434	67	UMN2
Site Code Key. 1st letter: U = ungrazed G = grazed	2nd letter: from A to Z to 4, upstream to downstream	3rd letter: A = gravelbar; B = sandbar; X = *S exigua* P = *P deltoides*; N = *P angustifolia*				

Table 3. List of research sites and their locations, elevation and river mile, cont'd.

Ungrazed Sites/transect number	Location	County	Year FAS acquired	Elevation (meters)	River Mile	Site Code
Bratten FAS, T1 (18 mi E of Big Timber)	4.5 mi W of Reed Pt	Sweetgrass			96.8	UNN
Bratten FAS, T2	4.5 mi W of Reed Pt	Sweetgrass			96.8	UNN2
Bratten FAS, T3	4.5 mi W of Reed Pt	Sweetgrass			96.8	UNX
Bratten FAS, T4	4.5 mi W of Reed Pt	Sweetgrass	1970	1182	96.8	UNX2
Bratten FAS area: Ranch T3 ungrazed	2 mi E of Reed Pt	Stillwater			103	UOX
Bratten FAS area: Ranch T4 ungrazed	2 mi E of Reed Pt	Stillwater			103	UOP
Buffalo Mirage FAS T1	6 mi SE of Park City	Yellowstone	1982	1156	144	UPP
Duck Creek FAS, T1	SW end of Billings	Yellowstone	1999	1115	156.4	UQX
Gritty Stone FAS, T1	3 mi N of Worden, CO Rd 19	Yellowstone			193.7	URP
Gritty Stone FAS, T2	3 mi N of Worden, CO Rd 19	Yellowstone			193.7	URP2
Gritty Stone FAS, T3	3 mi N of Worden, CO Rd 19	Yellowstone			193.7	URX
Gritty Stone FAS, T4	3 mi N of Worden, CO Rd 19	Yellowstone			193.7	URB
Gritty Stone FAS, T5	3 mi N of Worden, CO Rd 19	Yellowstone	1989	1020	193.7	URA
Pompey's Pillar T1	at the Park itself	Yellowstone			203	USX
Pompey's Pillar T2	at the Park itself	Yellowstone			203	USA
Pompey's Pillar T3	at the Park itself	Yellowstone			203	USP
Pompey's Pillar T4	at the Park itself	Yellowstone			203	USP2
Captain Clark FAS East Island T1	8 mi W of Custer	Yellowstone	1980	974	220.4	UTX
Amelia Is. area, Myers Br/Howrey Is., T2	5.5 mi W. of Hysham	Treasure	1986	927	248.4	UUX
Amelia Is. area, Isaac Homestead, T1	~3.5 mi W. of Hysham	Treasure	1969		251.5	UVP
Amelia Island, Wildlife Mngmt Area, T1	3 mi N. of Hysham	Treasure			258.5	UWP
Amelia Island, Wildlife Mngmt Area, T2	3 mi N. of Hysham	Treasure			258.5	UWX
Amelia Island, Wildlife Mngmt Area, T3	3 mi N. of Hysham	Treasure			258.5	UWA
Amelia Island, Wildlife Mngmt Area, T4	3 mi N. of Hysham	Treasure			258.5	UWB
Amelia Island, 2nd Island, T1	3 mi N. of Hysham	Treasure	1980	916	258.5	UWP2
Farwest FAS T1	10 mi. E. of Forsyth	Rosebud			308.3	UXX
Farwest FAS T2	10 mi. E. of Forsyth	Rosebud	1977	865	308.3	UXP
Farwest FAS area: Moon Island T1	10 mi. E. of Forsyth	Rosebud			308.3	UXA
Farwest FAS area: Moon Island T2	10 mi. E. of Forsyth	Rosebud			308.3	UXA2
Farwest FAS area: Moon Island T3	10 mi. E. of Forsyth	Rosebud			308.3	UXB
Farwest FAS area: Moon Island T4	10 mi. E. of Forsyth	Rosebud			308.3	UXB2

Table 3. List of research sites and their locations, elevation and river mile, cont'd.

Ungrazed Sites/transect number	Location	County	Year FAS acquired	Elevation (meters)	River Mile	Site Code
Kinsey Bridge FAS T1	15 km NE of Miles City	Custer			361.2	UYP
Kinsey Bridge FAS T2	15 km NE of Miles City	Custer	1986	804	361.2	UYX
Bonfield FAS, T1	7 mi NE of Kinsey	Custer			372.2	UZP
Bonfield FAS, T2	7 mi NE of Kinsey	Custer	1989	783	372.2	UZP2
Elk Island Wildlife Managemt Area, T1	1.5 mi NNE of Savage	Richland			479.3	U1X
Elk Island Wildlife Managemt Area, T2	1.5 mi NNE of Savage	Richland			479.3	U1Z
Elk Island Wildlife Managemt Area, T3	1.5 mi NNE of Savage	Richland			479.3	U1P
Elk Island Wildlife Managemt Area, T4	1.5 mi NNE of Savage	Richland	1975	594	479.3	U1P2
Seven Sisters Wildlife Managemt Area T1	1 mi E of Crane	Richland			491.5	U2B
Seven Sisters Wildlife Managemt Area T2	1 mi E of Crane	Richland			491.5	U2X
Seven Sisters Wildlife Managemt Area T3	1 mi E of Crane	Richland			491.5	U2P
Seven Sisters Wildlife Managemt Area T4	1 mi E of Crane	Richland	1981	582	491.5	U2P2
Diamond Willow FAS, T1	5.5 mi NE of Sydney	Richland			509.8	U4Z
Diamond Willow FAS, T2	5.5 mi NE of Sydney	Richland	1986	575	509.8	U4P

Table 3. List of research sites and their locations, elevation and river mile, cont'd.

Grazed Sites/transect number	Location	County	Elevation (approx)	River Mile	Site Code
Emigrant: Big Creek area ranch, T1	S of Emigrant	Park		0	GAX
Emigrant: Big Creek area ranch, T2	S of Emigrant	Park		0	GAX2
Emigrant FAS area ranch T1	S edge of Emigrant	Park		5.9	GBN
Emigrant FAS area ranch T2	S edge of Emigrant	Park		5.9	GBN2
Emigrant FAS area ranch T3	S edge of Emigrant	Park	1713	5.9	GBN3
Grey Owl area ranch upriver Mill Crk Rd T1	6 km NE of Grey Owl	Park		12.5	GFY
Grey Owl area ranch upriver Mill Crk Rd T2	6 km NE of Grey Owl	Park		12.5	GFN
Grey Owl area ranch upriver Mill Crk Rd T3	6 km NE of Grey Owl	Park		12.5	GFO
Grey Owl area ranch downrvr Mill Crk Rd T1	6 km NE of Grey Owl	Park		12.6	GGX
Grey Owl area ranch downrvr Mill Crk Rd T2	6 km NE of Grey Owl	Park		12.6	GGN
Grey Owl area ranch downrvr Mill Crk Rd T3	6 km NE of Grey Owl	Park		12.6	GGN2
Grey Owl area ranch downrvr Mill Crk Rd T4	6 km NE of Grey Owl	Park	1694	12.6	GGB
Pine Creek Area ranch, T1	next to Pine Creek KOA	Park		23	GHN
Pine Creek Area ranch, T2	next to Pine Creek KOA	Park	1427	23	GHN2
Pine Creek area ranch #2, T1	near Pine Creek KOA	Park		22	GIN
Pine Creek area ranch #2, T3	near Pine Creek KOA	Park		22	GIN2
Pine Creek area ranch #2, T4	near Pine Creek KOA	Park	1427	22	GIA
Sheep Mountain FAS area ranch T1	across river from Sheep Mtn	Park		45.4	GJO
Sheep Mountain FAS area ranch T2	across river from Sheep Mtn	Park		45.4	GJX
Sheep Mountain FAS area ranch T3	across river from Sheep Mtn	Park	1523	45.4	GJN
Springdale FAS area ranch T1	Just west of Springdale FAS	Park		57.3	GKX
Springdale FAS area ranch T2	Just west of Springdale FAS	Park		57.3	GKN
Springdale FAS area ranch T3	Just west of Springdale FAS	Park		57.3	GKA
Springdale FAS area ranch T4	Just west of Springdale FAS	Park	1473	57.3	GKB
Springdale FAS area ranch T1	Just east of Springdale FAS	Park		57.6	GLX
Springdale FAS area ranch T2	Just east of Springdale FAS	Park		57.6	GLA
Springdale FAS area ranch T3	Just east of Springdale FAS	Park	1473	57.6	GLA2
Grey Bear FAS, east side, T6	6 mi SW of Big Timber	Sweetgrass		67	GMN
Grey Bear FAS area ranch T1	6 mi SW of Big Timber	Sweetgrass		67	GMO
Grey Bear FAS area ranch T2	6 mi SW of Big Timber	Sweetgrass		67	GMX
Grey Bear FAS area ranch T3	6 mi SW of Big Timber	Sweetgrass	1434	67	GMO

Table 3. List of research sites and their locations, elevation and river mile, cont'd.

Grazed Sites/transect number	Location	County	Elevation (approx.)	River Mile	Site Code
Bratten FAS area: ranch c. 6 mi. west, T1	c. 18 mi. SE of Big Timber	Sweetgrass		94	GNN
Bratten FAS area: ranch c. 6 mi. west, T2	c. 18 mi. SE of Big Timber	Sweetgrass	1189	94	GNA
Bratten FAS area: ranch c. 9 mi. east, T1	2 mi E of Reed Pt	Stillwater		103	GOO
Bratten FAS area: ranch c. 9 mi. east, T2	2 mi E of Reed Pt	Stillwater	1170	103	GOO2
Buffalo Mirage FAS: adjoining ranch T1	6 mi SE of Park City	Yellowstone	1156	143.9	GPP
Buffalo Mirage FAS area: DNRC T1	6 mi SE of Park City	Yellowstone	1156	144.1	GPP2
Gritty Stone area ranch, T1	c. 3 mi. N. of Worden	Yellowstone		193.7	GRP
Gritty Stone area ranch, T2	c. 3 mi. N. of Worden	Yellowstone	1020	193.7	GRP2
Pompey's Pillar area ranch T1	across river from Park	Yellowstone		203	GSX
Pompey's Pillar area ranch T2	across river from Park	Yellowstone		203	GSP
Captain Clark FAS T1	8 mi W of Custer	Yellowstone		220.4	GTP
Captain Clark FAS T2	8 mi W of Custer	Yellowstone		220.4	GTX
Captain Clark FAS: ranch lease T1	8 mi W of Custer	Yellowstone	974	220.4	GTP2
Amelia Is. area, Myers Br/Howrey Is., T1	5.5 mi W. of Hysham	Treasure	927	248.4	GUP
Farwest FAS ranch lease T3	10 mi. E. of Forsyth	Rosebud		308.3	GXX
Farwest FAS ranch lease T5	10 mi. E. of Forsyth	Rosebud		308.3	GXP
Farwest FAS ranch lease T6	10 mi. E. of Forsyth	Rosebud	865	308.3	GXP2
Bonfield FAS area: adjoining ranch T1	7 mi NE of Kinsey, adjoins FAS	Custer		372.2	GZP
Bonfield FAS area: adjoining ranch T2	7 mi NE of Kinsey, adjoins FAS	Custer	783	372.2	GZP2
Elk Island area ranch T1	c. 2 mi. NE of Savage	Richland		479.3	G1P
Elk Island area ranch T2	c. 2 mi. NE of Savage	Richland	594	479.3	G1P2
Seven Sisters FAS area ranch T1	across river from 7 Sisters	Richland		491.5	G2P
Seven Sisters FAS area ranch T2	across river from 7 Sisters	Richland		491.5	G2A
Seven Sisters FAS area ranch T3	across river from 7 Sisters	Richland		491.5	G2B
Seven Sisters FAS area ranch T4	across river from 7 Sisters	Richland		491.5	G2B2
Seven Sisters FAS area ranch T5	across river from 7 Sisters	Richland	582	491.5	G2P2
Seven Sisters FAS area ranch #2, T1	near 7 Sisters	Richland	582	491.5	G3P

Table 4. Vascular plant species of Yellowstone River riparian communities

Family and Scientific name source: Vascular Plants of Montana (Dorn 1984)	Common name	Origin*		
		USDA	FPNW	UM
Alismataceae Sagittaria cuneata Sheldon	Arrowhead	N	N	N
Amaranthaceae Amaranthus albus L.	White Pigweed, Tumbleweed	N	N	N
Amaranthaceae Amaranthus blitoides S. Wats.	Prostrate Pigweed	X	N	N
Amaranthaceae Amaranthus retroflexus L.	Pigweed amaranth; rough pigweed	X	N	N
Anacardiaceae Rhus trilobata Nutt.	Skunkbush Sumac	N	N	N
Anacardiaceae Toxicodendron rydbergii (Small ex Rydb.) Greene	Poison Ivy	N	N	N
Apiaceae Cicuta douglasii (DC.) Coult. & Rose	Douglas' Water-Hemlock	N	N	N
Apiaceae Conium maculatum L.	Poison Hemlock	X	X	X
Apiaceae Heracleum sphondylium L.	Cow Parsnip	X	0	N
Apocynaceae Apocynum sibiricum Jacq.	Hemp Dogbane	N	N	N
Asclepiadaceae Asclepias speciosa Torr.	Showy Milkweed	N	N	N
Asclepiadaceae Asclepias verticillata L.	Milkweed	N	0	N
Asteraceae Achillea millefolium L.	Yarrow	N	N	N
Asteraceae Ambrosia psilostachya DC.	Western Ragweed	N	N	N
Asteraceae Ambrosia trifida L.	Giant Ragweed	N	N	N
Asteraceae Antennaria microphylla Rydb.	Rosy Pussy-toes	N	N	N
Asteraceae Arctium minus Bernh.	Common Burdock	X	X	X
Asteraceae Artemisia absinthium L.	Sageweed; Absinthium	X	X	X
Asteraceae Artemisia biennis Willd.	Biennial Wormweed	X	N	N
Asteraceae Artemisia campestris L.	Prairie Sagewort	N	N	N
Asteraceae Artemisia cana Pursh	Silver Sage	N	N	N
Asteraceae Artemisia dracunculus L.	Tarragon	N		N
Asteraceae Artemisia frigida Willd.	Fringed Sage	N	N	N
Asteraceae Artemisia ludoviciana Nutt.	Sweet Sage	N	N	N

This list is for species found in gravelbar, sandbar, *Salix exigua, S. amygdaloides, S. bebbiana, Populus angustifolia, P. acuminata and P. deltoides* communities, only.

* "N" is native, "X" is non-native, "0" means no data given, "both" means both native and exotic subspecies/varieties occur.

"USDA" is the U.S. Department of Agriculture's plant database, at http://plants.usda.gov.

"FPNW" is the Flora of the Pacific Northwest (Hitchcock and Cronquist 1973).

UM is University of Montana's Invader database, at http://invader.dbs.umt.edu.

Table 4, cont'd.

Asteraceae Aster ascendens Lindl.	Long-leaved Aster	N	N	N
Asteraceae Aster hesperius Gray	Western Willow Aster	N	N	N
Asteraceae Aster subspicatus Nees	Douglas' Aster	N	N	N
Asteraceae Centaurea maculosa auct. non Lam.	Spotted Knapweed	X	X	X
Asteraceae Chrysothamnus nauseosus (Palaas ex Pursh) Britt.	Rubber Rabbit-brush, Gray Rabbit-brush	N	N	N
Asteraceae Cirsium arvense (L.) Scop.	Canada Thistle	X	X	X
Asteraceae Cirsium undulatum (Nutt.) Spreng	Wavy-Leaf Thistle	N	0	N
Asteraceae Cirsium vulgare (Savi) Ten.	Bull Thistle	X	X	X
Asteraceae Conyza canadensis (L.) Cronq.	Canadian Fleabane	N	N	N
Asteraceae Filago arvensis L.	Fluffweed	X	X	X
Asteraceae Gnaphalium palustre Nutt.	Lowland Cudweed	N	N	N
Asteraceae Grindelia squarrosa (Push) Dunal	Curly cup gumweed	N	N	N
Asteraceae Helianthus annuus L.	Common sunflower	N		N
Asteraceae Heterotheca villosa (Pursh) Shinners	Hairy False Goldenaster	N		N
Asteraceae Lactuca oblongifolia (L. pulchella) Nutt.	Blue lettuce	N		N
Asteraceae Lactuca serriola L.	Prickly Lettuce	X	X	X
Asteraceae Rudbeckia laciniata L.	Tall Coneflower	N	N	N
Asteraceae Solidago gigantea Ait.	Late Goldenrod	N	N	N
Asteraceae Solidago missouriensis Nutt.	Missouri Goldenrod	N	N	N
Asteraceae Solidago mollis Bartl.	Velvety goldenrod	N	N	N
Asteraceae Solidago occidentalis (Nutt.) Torr. & Gray	Western Goldenrod	N	N	N
Asteraceae Solidago spathulata DC.	Dune goldenrod	N	N	N
Asteraceae Sonchus uliginosus (Bieb.)/S. asper (L.) Hill	Marsh Sow Thistle	X/X	X/X	N/X
Asteraceae Tanacetum vulgare L.	Common Tansy	X	X	X
Asteraceae Taraxacum officinale G. H. Weber ex Wiggers	Common Dandelion	X	X	X
Asteraceae Tragopogon dubius Scop.	Goatsbeard	X	X	X
Asteraceae Xanthium strumarium L.	Common Cocklebur	N	N	N
Betulaceae Alnus incana (L.) Moench	Alder	N	N	N
Betulaceae Betula occidentalis Hook.	River Birch (Water Birch)	N	N	N
Boraginaceae Asperugo procumbens L.	Catchweed	X	X	X
Boraginaceae Cynoglossum officinale L.	European Hound's Tongue	X	X	X
Brassicaceae Alyssum alyssoides (L.) L.	Alyssum	X	X	X
Brassicaceae Arabis holboellii Hornem.	Holboell's Rockcress	N	N	N

Table 4, cont'd.

Brassicaceae Brassica rapa (=B. campestris) L.	Field Mustard	X	X	X
Brassicaceae Camelina microcarpa DC.	Hairy False Flax	X	X	X
Brassicaceae Capsella bursa - pastoris (L.) Medik.	Shepherd's Purse	X	X	X
Brassicaceae Descurainia sophia(L.) Webb ex Prantl	Flixweed	X	X	X
Brassicaceae Erysimum asperum (Nutt.) DC.	Plains Wallflower	N	N	N
Brassicaceae Erysimum repandum L.	Bushy wallflower	X		X
Brassicaceae Lepidium campestre (L.) R. Br.	Field Pepper Grass	X	X	X
Brassicaceae Lepidium densiflorum Schrad.	Common Pepper Grass	N	N	N
Brassicaceae Lepidium perfoliatum L.	Clasping Pepper Grass	X	X	X
Brassicaceae Rorippa palustris (L.) Besser	Marsh Yellow Cress	N	N	N
Brassicaceae Sisymbrium altisssimum L.	Tall tumblemustard	X		X
Brassicaceae Sisymbrium loeselii L.	Tumble Mustard	X	X	X
Brassicaceae Thelypodium integrifolium (Nutt.) Endl. ex Walp.	Entire leaved thelypodium	N	N	N
Brassicaceae Thlaspi arvense L.	Pennycress	X	X	X
Cannabanaceae Humulus lupulus L.	European Hopvine	N	X	N
Caprifoliaceae Lonicera sp.	Honeysuckle	both	N	N
Caprifoliaceae Symphoricarpos occidentalis Hook.	Western Snowberry	N	N	N
Caryophyllaceae Lychnis alba P. Mill.	White Campion	X	X	N
Caryophyllaceae Silene noctiflora L.	Bladder Flower Plant	X	N	X
Caryophyllaceae Stellaria media (L.) Vill.	Chickweed	X	X	X
Chenopodiaceae Atriplex heterosperma Bunge	Saltbush	X	X	X
Chenopodiaceae Atriplex patula L.	Orache	N	N	N
Chenopodiaceae Chenopodium album L. var. album	Lamb's Quarter; White goosefoot	X	N	X
Chenopodiaceae Chenopodium botrys L.	Jerusalem-Oak Goosefoot	X	X	X
Chenopodiaceae Chenopodium fremontii S. Wats.	Fremont's Goosefoot	N	N	N
Chenopodiaceae Chenopodium glaucum L.	Oakleaf Goosefoot	X	N	X
Chenopodiaceae Chenopodium leptophyllum (Moq.)	Slim-leaf Goosefoot	N	N	N
Chenopodiaceae Chenopodium pratericola Rydb.	Slender-leaved Goosefoot	N	N	N
Chenopodiaceae Kochia scoparia (L.) Schrad.	Kochia; Summer Cypress	X	X	X
Chenopodiaceae Salsola kali L.	Russian Thistle	X	X	X
Convolvulaceae Convolvulus arvensis L.	Field Bindweed	X	X	X
Cornaceae Cornus stolonifera Michx.	Red Ozier Dogwood	N	N	N
Cupressaceae Juniperus scopulorum Sarg.	Rocky Mountain Juniper	N	N	N

Table 4, cont'd.

Cyperaceae Carex aquatilis Wahlenb.	Water Sedge	N	N	N
Cyperaceae Carex athrostachya Olney	Slender beaked sedge	N	N	N
Cyperaceae Carex brevior (Dew3ey) Mackenzie	Short beaked sedge	N	N	N
Cyperaceae Carex lanuginosa Michx.	Woolly Sedge	N	N	N
Cyperaceae Carex lenticularis Michx.	Kellog's Sedge	N	N	N
Cyperaceae Carex microptera Mackenzie	Small-winged Sedge	N	N	N
Cyperaceae Carex multicostata Mackenzie	Many ribbed sedge	N	N	N
Cyperaceae Carex nebrascensis Dewey	Nebraska Sedge	N	N	N
Cyperaceae Carex sp.	Sedge	N	N	N
Cyperaceae Cyperus aristatus Rottb.	Awned Flatsedge	N	N	N
Cyperaceae Eleocharis palustris (L.) Roemer & J.A. Schultes	Spike Rush	N	N	N
Cyperaceae Scirpus maritimus L.	Seacoast bulrush	N	N	N
Cyperaceae Scirpus pungens Vahl	Three Square Bulrush	N	0	N
Cyperaceae Scirpus validus Vahl	Softstem Bulrush	N	N	N
Elaeagnaceae Elaeagnus angustifolia L.	Russian Olive	X	X	X
Elaeagnaceae Shepherdia argentea (Pursh) Nutt.	Thorn Buffaloberry	N	N	N
Equisetaceae Equisetum arvense L.	Common Horsetail	N	N	N
Equisetaceae Equisetum hyemale L.	Common Scouring Rush	N	N	N
Equisetaceae Equisetum laevigatum A. Braun	Smooth Scouring Rush	N	N	N
Equisetaceae Equisetum pratense Ehrh.	Horsetail	N	N	N
Equisetaceae Equisetum sylvaticum L.	Wood Horsetail	N	N	N
Equisetaceae Equisetum variegatum Scheich. Ex F. Weber & D.M.H. Mohr	Variegated Horsetail	N	N	N
Equisetaceae Equisetum sp.	Horsetail	N	N	N
Euphorbiaceae Euphorbia esula L.	Leafy Spurge	X	X	X
Euphorbiaceae Euphorbia glyptosperma Engelm.	Ribseed sandmat; ridgeseed spurge	N		N
Fabaceae Glycyrrhiza lepidota Pursh	Wild Licorice	N	N	N
Fabaceae Hedasarum sp. L.	Sweetwetch; Hedysarum	N	N	N
Fabaceae Lupinus argenteus Pursh	Silvery lupine	N	N	N
Fabaceae Medicago lupulina L.	Black Medic; Hop Clover	X	X	X
Fabaceae Melilotus alba Medikus	White Sweet Clover	X	X	X
Fabaceae Melilotus officinalis (L.) Lam.	Yellow Sweet Clover	X	X	X
Fabaceae Melilotus sp. (alba/officinalis)	White or Yellow Sweet Clover	X	X	X
Fabaceae Melilotus sum (all Melilotus)	White, Yellow and sp. Sweet Clover	X	X	X

Table 4, cont'd.

Fabaceae Oxytropis deflexa (Pallas) DC.	Pendent Pod Crazyweed	N	N	N
Fabaceae Psoralea lanceolata Pursh	Lance leaf scurf pea	N	N	N
Fabaceae Trifolium fragiferum L.	Strawberry Clover	X	X	X
Fabaceae Trifolium hybridum L.	Alsike Clover (pink)	X	X	X
Fabaceae Trifolium pratense L.	Red Clover (deep red)	X	X	X
Fabaceae Trifolium repens L.	White Clover	X	X	X
Fabaceae Vicia americana Muhl. ex Willd	American Vetch	N	N	N
Fumariaceae Fumaria officianalis L.	Fumitory	X	X	X
Grossulariaceae Ribes aureum Pursh	Golden Currant	N	N	N
Grossulariaceae Ribes hudsonianum Richards.	Western or Northern Black Currant	N	N	N
Grossulariaceae Ribes setosum Lindl.	Redshoot Gooseberry	N	N	N
Grossulariaceae Ribes sp.	Gooseberry or currant	N	N	N
Hydrophyllaceae Phacelia hastata Dougl. Ex Lehm.	Silverleaf Phacelia	N	N	N
Iridaceae Iris missouriensis Nutt.	Wild Iris	N	N	N
Juncaceae Juncus articulatus L.	Jointed Rush	N	N	N
Juncaceae Juncus balticus Willd.	Baltic Rush, Wire Rush	N	N	N
Juncaceae Juncus bufonius L.	Toad Rush	N	N	N
Juncaceae Juncus compressus Jacq.	Roundfruit Rush	X	N	N
Juncaceae Juncus ensifolius Wikstr.	Dagger-Leaf Rush, Rocky Mountain Rush	N	N	N
Juncaceae Juncus interior Wieg.	Inland Rush	N	N	N
Juncaceae Juncus longistylis Torr.	Long-Syled Rush	N	N	N
Juncaceae Juncus nodosus L.	Tuberous Rush	N	N	N
Juncaceae Juncus tenuis Willd.	Slender Rush, Trail Rush	N	N	N
Juncaceae Juncus torreyi Coville	Torrey's Rush	N	N	N
Juncaceae Juncus sp.	Rush	N	N	N
Lamiaceae Galeopsis tetrahit L.	Hemp Nettle	X	X	X
Lamiaceae Glechoma hederocea (?) L.	Ground Ivy	X	X	X
Lamiaceae Lycopus americanus Muhl. ex W. Bart.	Cut Leaved Ragweed	N	N	N
Lamiaceae Mentha arvensis L.	Wild Mint (shusshua); Fieldmint	N	N	N
Lamiaceae Nepeta cataria L.	Catnip	X	X	X
Lamiaceae Stachys palustris L.	Hedge Nettle	N	N	N
Liliaceae Allium cernuum Roth	Nodding Onion	N	0	N
Liliaceae Asparagus officinalis L.	Wild Asparagus	X	X	X

Table 4, cont'd.

Liliaceae Smilacina stellata (L.) Dest.	Starry False Solomon's Seal	N	N	N
Marsileaceae Marsilea vestita Hook. & Grev.	Common Pepperwort; Clover fern	N	N	N
Oleaceae Fraxinus pennsylvanica Marsh	Green Ash	N	N	N
Onagraceae Epilobium minutum is E. paniculatum	(was mis-identified)			
Onagraceae Epilobium paniculatum Nutt. ex Torr. & Gray	Tall Annual Willow-herb	N	N	N
Onagraceae Oenothera villosa Thunb.	Common Evening Primrose	N	0	N
Plantaginaceae Plantago eriopoda Torr.	Alkali plantain	N	N	N
Plantaginaceae Plantago major L.	Broadleaved Plantain	N	X	N
Poaceae Agropyron cristatum (L.) Gaertn.	Crested Wheatgrass	X	X	X
Poaceae Agrostis scabra Willd	Rough bentgrass	N	N	N
Poaceae Agrostis stolonifera L.	Redtop, Creeping Bentgrass	N	N	X
Poaceae Alopecurus aequalis Sobol.	Stream Foxtail	N	N	N
Poaceae Alopecurus arundinaceus Poir.	Garrison Creeping Foxtail	X	0	X
Poaceae Beckmannia syzigachne (Steud.) Fern.	American Sloughgrass	N	N	N
Poaceae Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths	Blue grama	N	N	N
Poaceae Bromus inermis Leyss. ssp. inermis	Smooth Bromegrass	X	both	X
Poaceae Bromus inermis Leyss. ssp. pumpellianus	Smooth Bromegrass	N		N
Poaceae Bromus japonicus Thunb. ex Murr.	Japanese Bromegrass	X	X	X
Poaceae Bromus mollis aunct. non L.	Soft brome	X	X	X
Poaceae Bromus tectorum L.	Cheatgrass	X	X	X
Poaceae Calamagrostis stricta (Timm) Koel.	Northern Reedgrass	N	0	N
Poaceae Calamovilfa longifolia (Hook.) Schribn.	Prairie Sandreed	N	N	N
Poaceae Crypsis alopecuroides (Piller & Mitterp.) Schrad	Lovegrass	X	0	X
Poaceae Dactylis glomerata L.	Orchard Grass	X	X	X
Poaceae Deschampsia cespitosa (L.) Beauv.	Tufted Hairgrass	N	N	N
Poaceae Echinochloa crus-galli (L.) Beauv.	Barnyard Grass	X	N	X
Poaceae Elymus canadensis L.	Canada Wild Rye	N	N	N
Poaceae Elymus cinereus Schribn. & Merr.	Great Basin WildRye, Giant WildRye	N	N	N
Poaceae Elymus elymoides (Raf.) Swezey	Bottle Brush, Squirrel Tail	N	N	N
Poaceae Elymus hispidus (Opiz) Melderis	Intermediate Wheatgrass	X	X	X
Poaceae Elymus lanceolatus(Scribn. & Sm.) Gould	Thickspike Wheatgrass	N	N	N
Poaceae Elymus repens (L.) Gould	Quackgrass	X	X	X
Poaceae Elymus smithii (Rydb.) Gould	Western Wheatgrass	N	N	N

Table 4, cont'd.

Poaceae Elymus spicatus (Pursh) Gould	Bluebunch Wheatgrass	N	N	N
Poaceae Elymus trachycaulus/sp. (Link) Gould ex Shinners	Slender Wheatgrass	N	0	N
Poaceae Eragrostic hypnoides (Lam.) B.S.P.	Lovegrass	N	N	N
Poaceae Festuca arundinacea Schreb.	Tall Fescue	X	X	X
Poaceae Festuca pratensis Huds.	Meadow Fescue	X	X	X
Poaceae Hordeum jubatum L.	Foxtail Barley	N	N	N
Poaceae Hordeum pusillum Nutt.	Little Barley	N	N	N
Poaceae Muhlenbergia racemosa (Michx.) B.S.P.	Muhly	N	N	N
Poaceae Panicum capillare L.	Western Grass	N	N	N
Poaceae Phalaris arundinacea L.	Reed Canary Grass	N	X	N
Poaceae Phleum pratense L.	Timothy	X	X	X
Poaceae Poa compressa L	Canada Bluegrass	X	N	X
Poaceae Poa juncifolia (?) Scribn.	Alkali Bluegrass	N	N	N
Poaceae Poa palustris L.	Fowl Bluegrass	N	X	N
Poaceae Poa pratensis L.	Kentucky Bluegrass	N	X	N
Poaceae Poa sp.	Bluegrass (probably P. pratensis)	(X)	X	N
Poaceae Setaria glauca (L.) Beauv.	Yellow Bristlegrass or Foxtail	X	X	X
Poaceae Setaria viridis (L.) Beauv.	Green Bristlegrass or Foxtail	X	X	X
Poaceae Spartina gracilis Trin.	Alkali Cordgrass	N	N	N
Poaceae Spartina pectinata Bose ex Link.	Cordgrass	N	N	N
Poaceae Sporobolus cryptandrus (Torr.) Gray	Dropseed	N	N	N
Poaceae Stipa comata Trin. & Rupr.	Needle and Thread Grass	N	N	N
Poaceae Stipa viridula Trin.	Green Needlegrass	N	N	N
Polemoniaceae Polemonium sp.	Polemonium	N	N	N
Polygonaceae Polygonum achoreum Blake	Smartweed	N	N	N
Polygonaceae Polygonum amphibium L.	Water Smart Weed, Water Ladys Thumb	N	N	N
Polygonaceae Polygonum aviculare L.	Prostrate knotweed	X	N	N
Polygonaceae Polygonum convulvulus L.	Black Bindweed	X	X	X
Polygonaceae Polygonum douglasii Greene	Douglas' Knotweed, Mountain Knotweed	N	N	N
Polygonaceae Polygonum lapathifolium L.	Willow Weed, Curlytop Ladysthumb	N	X	X
Polygonaceae Polygonum sp.	Knotweed; Smartweed			
Polygonaceae Rumex crispus L.	Curly Dock	X	X	X
Polygonaceae Rumex maritimus L.	Golden Dock	N	N	N

Table 4, cont'd.

Polygonaceae Rumex patientia L.	Patience Dock	X		X
Polygonaceae Rumex stenophyllus Ledeb.	Narrowleaf Dock	X	0	N
Polygonaceae Rumex salicifolius Weinm.	Narrow-leaved or Willow Dock	N	N	N
Polygonaceae Rumex sp. (salicifolius or crispus)	Dock; Sorrel			
Portulaceae Portulaca oleracea L.	Common purslane	N	X	X
Primulaceae Lysimachia ciliata L.	Fringed Loosestrife	N	N	N
Ranunculaceae Anemone sp.	Wind Flower	N	N	N
Ranunculaceae Clematis ligusticifolia Nutt.	White Virgin's Bower	N	N	N
Ranunculaceae Ranunculus cymbalaria Pursh	Shore buttercup	N	N	N
Ranunculaceae Ranunculus macounii Britt.	Macoun's Buttercup	N	N	N
Ranunculaceae Ranunculus sceleratus L.	Blister Buttercup, Celery-leaved Buttercup	N	N	N
Ranunculaceae Thalictrum dasycarpum Fisch. & Ave-Lall.	Tall Meadowrue	N	N	N
Rosaceae Agrimonia striata Michx.	Agrimony	N	N	N
Rosaceae Amelanchier alnifolia (Nutt.) Nutt. ex M. Roemer	Juneberry; Serviceberry	N	N	N
Rosaceae Fragaria vesca L.	Wild Strawberry	N	N	N
Rosaceae Geum macrophyllum Willd.	Large-Leaved Avens	N	N	N
Rosaceae Potentilla anserina (L.) Rydb.	Common Silverweed	N	N	N
Rosaceae Potentilla gracilis Dougl. ex Hook.	Soft Cinquefoil	N	N	N
Rosaceae Potentilla norvegica L.	Norway Cinquefoil	N	N	N
Rosaceae Potentilla paradoxa Nutt.	Bushy cinquefoil	N	N	N
Rosaceae Prunus virginiana L.	Chokecherry	N	N	N
Rosaceae Rosa sayi Schwein.	Wild Rose	N	N	N
Rosaceae Rosa woodsii Lindl.	Wood's Rose	N	N	N
Rosaceae Rosa sp.	Wild Rose	N	N	N
Rubiaceae Galium aparine L.	Cleavers, Goose-grass	N	N	N
Rubiaceae Galium bifolium S. Wats.	Thinleaf bedstraw	N	N	N
Salicaceae Populus acuminata Rydb.	Lanceleaf or Rydberg's Cottonwood	N	N	N
Salicaceae Populus angustifolia James	Narrowleaf Cottonwood	N	N	N
Salicaceae Populus balsamifera L.	Black Cottonwood, Balsam Poplar	N	N	N
Salicaceae Populus deltoides Bartr. ex Marsh.	Plains Cottonwood	N	N	N
Salicaceae Populus tremuloides Michx.	Quaking Aspen; Trembling Aspen	N	N	N
Salicaceae Salix amygdaloides Anderss.	Peachleaf Willow	N	N	N
Salicaceae Salix bebbiana Sarg.	Bebb Willow	N	N	N

Table 4, cont'd.

Salicaceae Salix exigua Nutt.	Sandbar Willow	N	N	N
Salicaceae Salix lutea Nutt.	Diamond Willow, Yellow Willow	N		N
Salicaceae Salix sp. (small leaved willow)	(possibly Bebb's?)			
Scrophulariaceae Limosella aquatica L.	Mudwort	N	N	N
Scrophulariaceae Linaria dalmatica (L.) P. Mill.	Dalmation Toad Flax	X	X	X
Scrophulariaceae Mimulus guttatus DC.	Yellow Monkey Flower	N	N	N
Scrophulariaceae Verbascum thapsus L.	Mullein	X	X	X
Scrophulariaceae Veronica americana Schwein. ex Benth.	American Speedwell	N	N	N
Scrophulariaceae Veronica anagallis-aquatica L.	Water Speedwell, Water Pimpernel	N	N	X
Scrophulariaceae Veronica peregrina L.	Purslane Speedwell	N	N	N
Scrophulariaceae Veronica scutellata L.	Marsh speedwell	N	N	N
Solanaceae Hyoscyamus niger L.	Henbane	X	X	X
Solanaceae Solanum dulcamara L.	Climbing Nightshade	X	X	X
Solanaceae Solanum rostratum Dunal	Buffalo Bur	N	N	N
Solanaceae Solanum sarrachoides auct. non Sendtner	Hairy Nightshade	N	X	X
Soanaceae Solanum triflorum Nutt.	Cutleaved nightshade	N	N	N
Tamaricaceae Tamarix chinensis Lour.	Salt Cedar; Tamarisk	X	X	X
Typhaceae Typha latifolia L.	Broad-Leaved Cattail	N	N	N
Ulmaceae Ulmus pumila L.	Siberian Elm	X	X	X
Urticaceae Parietaria pensylvanica Muhl. ex Willd.	Pennsylvania pellitory	N		N
Urticaceae Urtica dioica L.	Stinging nettle	N	N	N
Verbenaceae Verbena bracteata Lag. & Rodr.	Bracted Vervain	N	N	N
Verbenaceae Verbena hastata L.	Blue Vervain	N	N	N
Violaceae Viola sp.	Violet		Most sp are N	
Vitaceae Parthenocissus inserta (Kerner) Fritsch	Virginia Creeper	N	0	N
Vitaceae Vitis riparia Michx.	Wild Grape	N	N	N

Table 5: Vegetation of ungrazed gravelbar sites: releve and frequency data. Species grouped by life form.

Ungrazed Study Sites					UCA	UDA	UDA2	UEA	UIA	UJA	UJA2	UMA	UMA2	URA	USA	UWA	UXA	UXA2
Mile on river from Big Creek, MT					6.2	6.4	6.4	8.8	22	45.4	45.4	67	67	194	203	259	308	308
		Avrg	Stnd															
Species Richness		#/site	Dev		Number of Species at each site													
# of non-native species/site		7.9	5.6		7	4	3	3	3	14	22	7	6	5	12	14	5	5
# of species/site		17.6	12.0		13	11	11	11	5	31	49	14	12	19	26	28	10	7
% non native species/site		46%	13%		54%	36%	27%	27%	60%	45%	45%	50%	50%	26%	46%	50%	50%	71%
Species Constancy & Frequency																		
Native/Non-native		Avrg	Con-	Sum	Presence/Absence of species per site													
TREES	N/X	#/site	stancy	Freq														
Avrg # of non-native tree spp		0			0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus angustifolia	N		1.0*	9	1	1	1	1	1	1	1	1	1					
Populus deltoides	N		1.0*	5										1	1	1	1	1
Avrg # of native tree species		1.0			1	1	1	1	1	1	1	1	1	1	1	1	1	1
Avrg # of tree species		1.0			1	1	1	1	1	1	1	1	1	1	1	1	1	1
SHRUBS																		
Percent non-native shrub spp		15%			0	0	0	0	0	0.33	0	0	0	0	0	0.33	0.5	1
Avrg # of non-native shrub spp		0.3			0	0	0	0	0	1	0	0	0	0	0	1	1	1
Tamarix chinensis	X		0.21	3												1	1	1
Elaeagnus angustifolia	X		0.07	1						1								
Salix exigua	N		0.79	11	1	1	1	1	1	1		1		1	1	1	1	0
Salix amygdaloides	N		0.29	4						1	1			1		1		
Amelanchier alnifolia	N		0.07	1	1													
Vitis riparia	N		0.07	1											1			
Avrg # of native shrub spp		1.2			2	1	1	1	1	2	1	1	0	2	2	2	1	0
Avrg # of shrub species		1.5			2	1	1	1	1	3	1	1	0	2	2	3	2	1

* Constancies calculated based on number of sites within the range of the species.

Table 5. Ungrazed gravelbar sites - releve & frequency data, cont'd.

FORBS				Site	UCA	UDA	UDA2	UEA	UIA	UJA	UJA2	UMA	UMA2	URA	USA	UWA	UXA	UXA2
Percent non-native forb spp		57%			0.80	0.50	0.40	0.75	1.00	0.50	0.47	0.50	0.40	0.20	0.57	0.53	0.57	0.80
Avrg # of non-native forb spp		5.1			4	2	2	3	3	9	16	3	2	2	8	9	4	4
Taraxacum officinale	X		0.57	8		1	1		1	1	1		1		1	1		
Melilotus officinalis	X		0.57	8	1		1			1	1		1		1		1	1
Melilotus alba	X		0.43	6					1	1	1				1		1	1
Chenopodium album	X		0.36	5								1			1	1	1	1
Medicago lupulina	X		0.36	5						1	1	1				1		1
Cirsium arvense	X		0.36	5	1					1	1	1				1		
Centaurea maculosa	X		0.21	3	1					1	1							
Sonchus uliginosus/S. asper	X		0.21	3						1	1					1		
Polygonum aviculare	X		0.14	2							1				1			
Sisymbrium loeselii	X		0.14	2							1					1		
Rumex stenophyllus	X		0.14	2										1	1			
Euphorbia esula	X		0.14	2							1				1			
Chenopodium botrys	X		0.14	2					1	1								
Verbascum thapsus	X		0.14	2							1						1	
Tanacetum vulgare	X		0.14	2						1	1							
Solanum dulcamara	X		0.14	2										1		1		
Conium maculatum	X		0.07	1							1							
Arctium minus	X		0.07	1							1							
Filago arvensis	X		0.07	1											1			
Cynoglossum officinale	X		0.07	1				1										
Lepidium campestre	X		0.07	1		1												
Thlaspi arvense	X		0.07	1	1													
Silene noctiflora	X		0.07	1							1							
Melilotus sp.	X		0.07	1				1										
Trifolium repens	X		0.07	1							1							
Artemisia biennis	X		0.07	1												1		
Convolvulus arvensis	X		0.07	1												1		
Rumex crispus	X		0.07	1				1										

Table 5. Ungrazed gravelbar sites - releve & frequency data, cont'd.

FORBS, cont'd.				Site	UCA	UDA	UDA2	UEA	UIA	UJA	UJA2	UMA	UMA2	URA	USA	UWA	UXA	UXA2
Rumex salicifolius	N		0.64	9			1	1		1	1	1	1	1	1	1		
Plantago major	N		0.43	6						1	1	1	1		1	1		
Verbena bracteata	N		0.36	5						1	1					1	1	1
Aster ascendens	N		0.21	3	1		1							1				
Aster hesperius	N		0.21	3						1	1				1			
Ranunculus sceleratus	N		0.21	3						1	1					1		
Solidago gigantea	N		0.21	3			1				1					1		
Oenethera villosa (=O.strigos	N		0.21	3						1	1						1	
Equisetum variegatum	N		0.21	3							1		1	1				
Polygonum lapathifolium	N		0.21	3							1			1	1			
Amaranthus albus	N		0.14	2							1			1				
Potentilla norvegica	N		0.14	2						1	1							
Rorippa palustris v. hispida	N		0.14	2						1	1							
Ranunculus cymbalaria	N		0.14	2							1					1		
Potentilla paradoxa	N		0.14	2											1	1		
Sagittaria cuneata	N		0.07	1										1				
Apocynum sibiricum	N		0.07	1											1			
Cirsium undulatum	N		0.07	1							1							
Arabis holboellii	N		0.07	1		1												
Equisetum laevigatum	N		0.07	1								1						
Glycyrrhiza lepidota	N		0.07	1							1							
Polygonum douglasii	N		0.07	1													1	
Polygonum sp.	N		0.07	1		1												
Portulaca oleracea	N		0.07	1										1				
Galium bifolium	N		0.07	1										1				
Veronica americana	N		0.07	1							1							
Gnaphalium palustre	N		0.07	1						1								
Epilobium paniculatum	N		0.07	1							1							
Mentha arvensis	N		0.07	1							1							
Veronica anagallis-aquatica	N		0.07	1												1		
Avrg # of native forb species		4.7			1	2	3	1	0	9	18	3	3	8	6	8	3	1
Avrg # of forb species		9.8			5	4	5	4	3	18	34	6	5	10	14	17	7	5

Table 5. Ungrazed gravelbar sites - releve & frequency data, cont'd.

GRAMINOIDS				Site	UCA	UDA	UDA2	UEA	UIA	UJA	UJA2	UMA	UMA2	URA	USA	UWA	UXA	UXA2
Percent non-ntv grmnd spp		36%			0.60	0.40	0.25	0.00	0.00	0.44	0.46	0.67	0.67	0.50	0.44	0.57	0.00	0.00
Avrg # of non-ntv grmnd spp		2.5			3	2	1	0	0	4	6	4	4	3	4	4	0	0
Poa pratensis	X		0.50	7	1	1	1			1		1	1			1		
Phalaris arundinacea	X		0.36	5						1	1			1	1	1		
Bromus tectorum	X		0.36	5	1		0			0	1	1			1	1		
Alopecurus arundinaceus	X		0.29	4						1	1	1	1					
Bromus inermis	X		0.29	4	1	1					1					1		
Poa compressa	X		0.29	4						1	1		1	1				
Elymus repens	X		0.29	4							1	1	1		1			
Crypsis alopecuroides	X		0.07	1										1				
Phleum pratense	X		0.07	1											1			
Poa palustris	N		0.43	6	1	1	1	1				1				1		
Carex sp.	N		0.43	6	1			1		1				1	1	1		
Elymus trachycaulus/E. sp.	N		0.29	4		1		1		1	1							
Agrostis stolonifera	N		0.29	4						1	1	1			1			
Deschampsia cespitosa	N		0.21	3				1			1		1					
Hordeum jubatum	N		0.21	3						1	1				1			
Eleocharis palustris	N		0.21	3							1		1	1				
Elymus elymoides	N		0.14	2			1	1										
Alopecurus aequalis	N		0.14	2						1	1							
Juncus sp.	N		0.07	1		1												
Elymus smithii	N		0.07	1												1		
Elymus cinereus	N		0.07	1			1											
Eragrostis hypnoides	N		0.07	1										1				
Hordeum pusillum	N		0.07	1											1			
Juncus interior	N		0.07	1							1							
Panicum capillare	N		0.07	1											1			
Avrg # of ntv graminoid spp		2.9			2	3	3	5	0	5	7	2	2	3	5	3	0	0
Avrg # of graminoid species		5.4			5	5	4	5	0	9	13	6	6	6	9	7	0	0

Table 6. Vegetation of ungrazed gravelbar sites: releve and cover data. Species in order by life form, then by average cover.

Ungrazed Study Sites		Avrg	UCA	UDA	UDA2	UEA	UIA	UJA	UJA2	UMA	UMA2	URA	USA	UWA	UXA	UXA2
Mile on river from Big Creek, MT		Cover	6.2	6.4	6.4	8.8	22	45.4	45.4	67	67	193.7	203	258.5	308.2	308.2
	St Dev	ALL	Cover/Individual Site													
Avrg cover of non-native spp	0.0474	0.046	0.008	0.001	0.004	0.007	0.003	0.026	0.080	0.079	0.067	0.024	0.039	0.026	0.139	0.135
Average cover of species	0.087	0.158	0.311	0.067	0.089	0.057	0.225	0.190	0.247	0.098	0.084	0.310	0.141	0.082	0.179	0.135
% non native species	35%	34%	2.6%	1.5%	4.5%	12.3%	1.3%	13.7%	32.4%	80.6%	79.8%	7.7%	27.7%	31.7%	77.7%	100%
Native/Non-native		AvCvr														
TREES	N/X	ALL														
Avrg cover of non-native tree spp		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus angustifolia (0.050, 9 sites)	N	0.032	0.073	0.032	0.070	0.046	0.220	0.001	0.001	0.003	0.002					
Populus deltoides (0.008, 5 sites)	N	0.003										0.001	0.008	0.001	0.030	
Avrgcover of native tree species		0.035	0.073	0.032	0.070	0.046	0.220	0.001	0.001	0.003	0.002	0.001	0.008	0.001	0.030	0.000
Average cover of tree species		0.035	0.073	0.032	0.070	0.046	0.220	0.001	0.001	0.003	0.002	0.001	0.008	0.001	0.030	0.000
SHRUBS																
% cover of non-native shrub spp		0.146	0	0	0	0	0	0	0	0	0	0	0	0.045	1.000	1.000
Avrg cover of non-native shrub spp		0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.044	0.046
Tamarix chinensis	X	0.007												0.002	0.044	0.046
Salix exigua	N	0.047	0.226	0.027	0.009	0.001	0.002	0.025		0.013		0.260	0.080	0.011		
Salix amygdaloides	N	0.011						0.115	0.004			0.001		0.031		
Avrg cover of native shrub spp		0.058	0.226	0.027	0.009	0.001	0.002	0.140	0.004	0.013	0.000	0.261	0.080	0.042	0.000	0.000
Average cover of shrub species		0.064	0.226	0.027	0.009	0.001	0.002	0.140	0.004	0.013	0.000	0.261	0.080	0.044	0.044	0.046
FORBS																
% cover of non-native forb spp		0.559	1.000	0.000	0.500	0.875	1.000	0.524	0.234	0.500	0.000	0.333	0.724	0.231	0.905	1.000
Avrg cover of non-native forb spp		0.019	0.004	0.000	0.003	0.007	0.003	0.011	0.022	0.002	0.000	0.011	0.021	0.003	0.095	0.089
Melilotus alba	X	0.011					0.003		0.001				0.004		0.090	0.057
Melilotus officinalis	X	0.003	0.002		0.002			0.001					0.006		0.004	0.030
Rumex stenophyllus	X	0.001										0.011	0.006			
Cirsium arvense	X	0.001	0.001					0.004	0.002							
Centaurea maculosa	X	0.000	0.001					0.004	0.001							
Euphorbia esula	X	0.000							0.004				0.002			

Table 6. Vegetation of ungrazed gravelbar sites: releve and cover data, cont'd.

FORBS, cont'd.			UCA	UDA	UDA2	UEA	UIA	UJA	UJA2	UMA	UMA2	URA	USA	UWA	UXA	UXA2
Melilotus sp.	X	0.000				0.006										
Taraxacum officinale	X	0.000			0.001			0.001	0.002				0.001			
Chenopodium album	X	0.000								0.001			0.001		0.001	0.001
Tanacetum vulgare	X	0.000							0.003							
Medicago lupulina	X	0.000								0.001				0.001		0.001
Polygonum aviculare	X	0.000							0.002							
Sonchus uliginosus/S. asper	X	0.000							0.001					0.001		
Verbascum thapsus	X	0.000							0.002							
Silene noctiflora	X	0.000							0.002							
Rumex crispus	X	0.000				0.001										
Chenopodium botrys	X	0.000						0.001								
Conium maculatum	X	0.000							0.001							
Sisymbrium loeselii	X	0.000							0.001							
Filago arvensis	X	0.000											0.001			
Solanum dulcamara	X	0.000												0.001		
Rumex salicifolius	N	0.004			0.001	0.001		0.003	0.034		0.001	0.007	0.004	0.001		
Plantago major	N	0.001						0.004	0.005	0.001	0.001			0.001		
Rorippa palustris v. hispida	N	0.001						0.001	0.011							
Mentha arvensis	N	0.001							0.009							
Oenethera villosa	N	0.001							0.001						0.006	
Polygonum lapathifolium	N	0.001							0.001			0.003	0.003			
Solidago gigantea	N	0.000			0.001				0.003					0.001		
Verbena bracteata	N	0.000												0.001	0.004	
Amaranthus albus	N	0.000										0.004				
Galium bifolium	N	0.000										0.003				
Veronica americana	N	0.000							0.003							
Portulaca oleracea	X	0.000										0.003				
Potentilla norvegica	N	0.000						0.001	0.001							
Aster ascendens	N	0.000			0.001							0.001				
Potentilla paradoxa	N	0.000												0.002		
Ranunculus cymbalaria	N	0.000												0.002		

Table 6. Vegetation of ungrazed gravelbar sites: releve and cover data, cont'd.

FORBS, cont'd.			UCA	UDA	UDA2	UEA	UIA	UJA	UJA2	UMA	UMA2	URA	USA	UWA	UXA	UXA2
Ranunculus sceleratus	N	0.000							0.001					0.001		
Equisetum variegatum	N	0.000									0.001					
Veronica anagallis-aquatica	N	0.000												0.001		
Sagittaria cuneata	N	0.000										0.001				
Apocynum sibiricum	N	0.000											0.001			
Aster hesperius	N	0.000						0.001								
Cirsium undulatum	N	0.000							0.001							
Equisetum laevigatum	N	0.000								0.001						
Glycyrrhiza lepidota	N	0.000							0.001							
Epilobium paniculatum	N	0.000							0.001							
Polygonum sp.	N	0.000		0.001												
Avrg cover of native forb species		0.010	0.000	0.001	0.003	0.001	0.000	0.010	0.072	0.002	0.003	0.022	0.008	0.010	0.010	0.000
Avrg cover of forb species		0.03	0.004	0.001	0.006	0.008	0.003	0.021	0.094	0.004	0.003	0.033	0.029	0.013	0.105	0.089
GRAMINOIDS																
% cover of non-native grmnd spp		0.439	0.500	0.143	0.250	0.000	0.000	0.536	0.392	0.987	0.848	0.867	0.750	0.875	0.000	0.000
Avrg cover of non-ntv grmnd spp		0.020	0.004	0.001	0.001	0.000	0.000	0.015	0.058	0.077	0.067	0.013	0.018	0.021	0.000	0.000
Agropyron repens	X	0.008							0.012	0.029	0.061		0.011			
Alopecurus arundinaceus	X	0.005						0.004	0.019	0.044						
Phalaris arundinacea	X	0.005						0.004	0.024			0.012	0.005	0.018		
Poa pratensis	X	0.001	0.003		0.001			0.005		0.004	0.003			0.001		
Poa compressa	X	0.001						0.002	0.002		0.003					
Bromus inermis	X	0.000	0.001	0.001										0.001		
Bromus tectorum	X	0.000							0.001					0.001		
Phleum pratense	X	0.000											0.002			
Crypsis alopecuroides	X	0.000										0.001				
Deschampsia cespitosa	N	0.006							0.076		0.011					
Agrostis stolonifera	N	0.001						0.007	0.007							
Poa palustris	N	0.001	0.004	0.004	0.002	0.001				0.001				0.001		
Hordeum jubatum	N	0.001						0.003	0.004				0.002			
Carex sp.	N	0.001						0.001				0.001	0.004	0.001		

Table 6. Vegetation of ungrazed gravelbar sites: releve and cover data, cont'd.

GRAMINOIDS, cont'd.			UCA	UDA	UDA2	UEA	UIA	UJA	UJA2	UMA	UMA2	URA	USA	UWA	UXA	UXA2
Eleocharis palustris	N	0.000							0.001		0.001	0.001				
Agropyron trachycaulum/A. sp.	N	0.000		0.001				0.001								
Alopecurus aequalis	N	0.000						0.001	0.001							
Elymus elymoides	N	0.000			0.001	0.001										
Juncus interior	N	0.000							0.001							
Juncus sp.	N	0.000		0.001												
Agropyron smithii	N	0.000												0.001		
Avrg cvr of native graminoid spp		0.010	0.004	0.006	0.003	0.002	0.000	0.013	0.090	0.001	0.012	0.002	0.006	0.003	0.000	0.000
Avrg cover of graminoid species		0.030	0.008	0.007	0.004	0.002	0.000	0.028	0.148	0.078	0.079	0.015	0.024	0.024	0.000	0.000

Table 7: Gravel Measurements for Ungrazed Gravelbar Sites

SITE		All sites	UCA	UDA	UEA	UIA	UJA	UMA	UMA2	URA	USA	UWA	UXA	UXA2
River Mile			6.2	6.4	8.8	22.0	45.4	67.0	67.0	193.7	203	258.5	308.2	308.2
% Sand		***17%***	35%	11%	23%	5%	1%	23%	20%	4%	9%	1%	23%	35%
Gravel	10%	5.3	1	1	1	5	17	1	1	21	5	9	1	1
Size	25%	13.5	1	26	7	17	25	2	11	28	19	16	9	1
(width	median	38.1	49.5	72.5	33	42.5	46.5	18	54.5	42.5	38.5	25	21.5	13.5
in mm)	75%	61.5	90	100	50	75	60	38	99	59	66	40	32	29
	90%	81.9	112	125	66	113	79	78	131	67	83	51	43	35
	largest	127.3	180	145	87	189	128	155	221	104	123	74	57	65

Notes: A "1 mm" reading for gravel size means the substrate was sand.
"Percent sand" is the number of readings/100 which were sand instead of gravel.
River miles were measured beginning at upstream end of the study, just south of Emigrant, MT.
No data for UDA2 or UJA2; they were islands which became inaccessible when water level rose.

Table 8. Environmental Variables at Ungrazed Sites

Environmental variables	Gravelbar All Sites		Sandbar All Sites		*Salix exigua* All Sites		*Salix exigua* Upriver sites*		*Salix exigua* Downriver*		*Populus angustifolia*		*Populus deltoides*	
	avrg	st dev	avrg	st dev	avrg	st dev	avrg	st dev	avrg	st dev	avrg	st dev	avrg	st dev
River mile (from Big Creek)	110.4	*106.6*	205.3	*162.4*	161.5	*146.5*	48.1	*34.0*	274.9	*125.1*	48.4	37.9	304.9	129.7
Gage height (ft)	7.1	*2.0*	6.9	*2.3*	9.7	*2.0*	9.5	*1.2*	9.8	*2.6*	11.2	2.3	16.7	5.5
Height above water (ft)	4.7	*2.1*	4.6	*2.4*	6.8	*2.4*	5.9	*2.0*	7.6	*2.5*	7.7	2.7	14.3	5.6
Height above water (m)	1.4	0.6	1.4	0.7	2.1	0.7	1.8	0.6	2.3	0.8	2.4	0.8	4.4	1.7
Depth to gravel (cm)			28	*24*	111	*40*	116	*50*	106	*28*	111	48	153	38
CaCO3% Equiv			1.5	*1.7*	1.8	*1.8*	0.4	*0.5*	3.2	*1.6*	0.4	0.5	3.4	1.6
pH (1 to 1)			8.1	*0.5*	8.1	*0.4*	7.9	*0.4*	8.2	*0.3*	7.8	0.2	8.1	0.3
Total C%			0.56	*0.23*	1.20	*1.09*	1.40	*1.51*	1.00	*0.39*	2.85	1.15	2.26	1.04
% Organic C			0.37	*0.06*	0.99	*1.13*	1.35	*1.49*	0.62	*0.36*	2.80	1.15	1.86	0.96
Total N%			0.023	*0.005*	0.065	*0.078*	0.090	*0.105*	0.039	*0.023*	0.168	0.065	0.123	0.069
Sand %			72	*11*	53	*17*	51	*21*	56	*13*	36	14	42	20
Silt %			21	*8*	35	*13*	38	*16*	32	*10*	49	12	38	12
Clay %			7	*3*	12	*5*	11	*6*	12	*4*	15	4	20	10
EC mmhos/cm, 1 to 1			0.37	*0.09*	0.51	*0.36*	0.44	*0.26*	0.57	*0.44*	0.45	0.22	0.47	0.24

* "Upriver" sites are those in the *Populus angustifolia* zone.
"Downriver" sites are in the *Populus deltoides* zone.

Table 9. Vegetation of ungrazed sandbar sites: releve & frequency data. Species grouped by life form.

Ungrazed Study Sites					UDB	UEB	UMB	URB	UWB	UXB	UXB2	U2B
Mile on river from Big Creek, MT					6.4	8.8	67.0	194	259	308	308	492
		Avrg	Stnd									
Species Richness		#/site	Dev		Number of species at each site							
Average # of non-native species		11.4	6.9		4.0	22.0	3.0	7.0	20.0	13.0	12.0	10.0
Average # of species		25.1	8.3		25.0	35.0	10.0	23.0	34.0	31.0	24.0	19.0
% of species which are non native		43%	16%		16%	63%	30%	30%	59%	42%	50%	53%
Species Constancy & Frequency												
Native/Non-native		Avrg	Con-	Sum	Presence/absence of species per site							
TREES	N/X	#/site	stancy	Freq								
Avrg number of non-native tree species		0			0	0	0	0	0	0	0	0
Populus angustifolia	N		0.33*	1			1					
Populus deltoides	N		1.00*	5				1	1	1	1	1
Average number of native tree species		0.8			0	0	1	1	1	1	1	1
Average number of tree species		0.8			0	0	1	1	1	1	1	1
SHRUBS												
Percent non-native shrub species		35%			0	0	0	0.33	0.50	1.00	1.00	0
Avrg number of non-native shrub species		0.6			0	0	0	1	2	1	1	0
Tamarix chinensis	X		0.50	4				1	1	1	1	
Elaeagnus angustifolia	X		0.13	1					1			
Salix exigua	N		0.75	6	1	1	1	1	1			1
Salix amygdaloides	N		0.38	3	1			1	1			
Average number of native shrub spp.		1.125			2	1	1	2	2	0	0	1
Average number of shrub species		1.8			2	1	1	3	4	1	1	1
FORBS												
Percent non-native forb species		45%			0.31	0.67	0.25	0.27	0.67	0.42	0.50	0.50
Avrg number of non-native forb species		8.6			4	20	1	3	14	11	10	6
Taraxacum officinale	X		0.50	4	1				1	1	1	
Chenopodium glaucum	X		0.50	4		1		1		1		1

*Constancies calculated as a percentage of only those sites within their respective zones.

Table 9. Vegetation of ungrazed sandbar sites: releve & frequency data, cont'd.

FORBS, cont'd.					UDB	UEB	UMB	URB	UWB	UXB	UXB2	U2B
Thlaspi arvense	X		0.50	4		1			1	1	1	
Kochia scoparia	X		0.50	4		1			1	1	1	
Chenopodium album	X		0.50	4		1			1	1		1
Medicago lupulina	X		0.50	4		1			1		1	1
Rumex crispus	X		0.50	4			1	1	1			1
Melilotus officinalis	X		0.38	3		1				1	1	
Sisymbrium loeselii	X		0.38	3		1				1	1	
Sonchus uliginosus/S. asper	X		0.38	3		1					1	1
Tanacetum vulgare	X		0.25	2	1	1						
Amaranthus retroflexus	X		0.25	2		1		1				
Chenopodium botrys	X		0.25	2		1			1			
Descurainia sophia	X		0.25	2		1			1			
Cirsium arvense	X		0.25	2		1			1			
Verbascum thapsus	X		0.25	2		1				1		
Filago arvensis	X		0.25	2					1	1		
Lactuca seriola	X		0.25	2					1	1		
Trifolium repens	X		0.13	1	1							
Glecoma hederocea (?)	X		0.13	1	1							
Cirsium vulgare	X		0.13	1		1						
Asperugo procumbens	X		0.13	1		1						
Cynoglossum officinale	X		0.13	1		1						
Brassica rapa (=B. campestris)	X		0.13	1		1						
Erysimum repandum	X		0.13	1		1						
Amaranthus blitoides	X		0.13	1		1						
Polygonum aviculare	X		0.13	1					1			
Artemisia biennis	X		0.13	1					1			
Lepidium perfoliatum	X		0.13	1					1			
Rumex stenophyllus	X		0.13	1						1		
Tragopogon dubius	X		0.13	1							1	
Melilotus alba	X		0.13	1							1	
Sisymbrium altissimum	X		0.13	1								1
Euphorbia esula	X		0.13	1							1	

Table 9. Vegetation of ungrazed sandbar sites: releve & frequency data, cont'd.

FORBS, cont'd.					UDB	UEB	UMB	URB	UWB	UXB	UXB2	U2B
Gnaphalium palustre	N		0.50	4	1	1		1		1		
Rorippa palustris v. hispida	N		0.50	4	1	1		1				1
Amaranthus albus	N		0.50	4		1				1	1	1
Xanthium strumarium	N		0.50	4				1		1	1	1
Ranunculus cymbalaria	N		0.38	3	1			1		1		
Polygonum lapathifolium	N		0.38	3				1		1	1	
Potentilla paradoxa	N		0.38	3					1	1		1
Epilobium paniculatum	N		0.25	2	1	1						
Equisetum variegatum	N		0.25	2	1				1			
Glycyrrhiza lepidota	N		0.25	2		1	1					
Polygonum achoreum	N		0.25	2		1		1				
Polygonum amphibium	N		0.25	2		1						1
Equisetum laevigatum	N		0.25	2			1		1			
Verbena bracteata	N		0.25	2					1	1		
Oenethera villosa	N		0.25	2					1		1	
Iva xanthifolia	N		0.25	2						1	1	
Aster hesperius	N		0.25	2						1	1	
Polygonum douglasii	N		0.25	2						1	1	
Galium bifolium	N		0.25	2						1	1	
Solanum rostratum	N		0.25	2						1	1	
Ranunculus sceleratus	N		0.13	1	1							
Mimulus guttatus	N		0.13	1	1							
Veronica americana	N		0.13	1	1							
Mentha arvensis	N		0.13	1	1							
Plantago major	N		0.13	1		1						
Potentilla norvegica	N		0.13	1		1						
Achillea millefolium	N		0.13	1		1						
Equisetum arvense	N		0.13	1			1					
Asclepias speciosa	N		0.13	1				1				
Ranunculus Macounii	N		0.13	1				1				
Helianthus annuus	N		0.13	1					1			

Table 9. Vegetation of ungrazed sandbar sites: releve & frequency data, cont'd.

FORBS, cont'd.					UDB	UEB	UMB	URB	UWB	UXB	UXB2	U2B
Apocynum sibiricum	N		0.13	1					1			
Verbena hastata	N		0.13	1						1		
Erysimum asperum	N		0.13	1						1		
Solidago occidentalis	N		0.13	1						1		
Ambrosia psilostachya	N		0.13	1							1	
Cicuta douglasii	N		0.13	1								1
Average number of native forb spp.		8.5			9	10	3	8	7	15	10	6
Average number of forb species		17.1			13	30	4	11	21	26	20	12
GRAMINOIDS												
Percent non-native graminoid species		44%			0	0.50	0.50	0.38	0.50	0.33	0.50	0.80
Avrg # of non-native graminoid species		2.1			0	2	2	3	4	1	1	4
Agropyron repens	X		0.38	3		1	1					1
Bromus tectorum	X		0.38	3		1			1	1		
Phalaris arundinacea	X		0.38	3				1	1			1
Echinochloa crus-galli	X		0.25	2				1				1
Alopecurus arundinaceus	X		0.13	1			1					
Crypsis alopecuroides	X		0.13	1				1				
Juncus compressus	X		0.13	1					1			
Poa pratensis	X		0.13	1					1			
Bromus japonicus	X		0.13	1							1	
Bromus inermis	X		0.13	1								1
Eleocharis palustris	N		0.88	7	1	1	1	1	1	1		1
Carex sp.	N		0.25	2	1			1				
Hordeum jubatum	N		0.25	2					1	1		
Juncus ensifolius	N		0.13	1	1							
Agrostis scabra	N		0.13	1	1							
Poa juncifolia (?)	N		0.13	1	1							
Juncus articulatus	N		0.13	1	1							
Alopecurus aequalis	N		0.13	1	1							
Juncus torreyi	N		0.13	1	1							
Juncus bufonius	N		0.13	1	1							
Juncus longistylis	N		0.13	1	1							

Table 9. Vegetation of ungrazed sandbar sites: releve & frequency data, cont'd.

GRAMINOIDS, cont'd.					UDB	UEB	UMB	URB	UWB	UXB	UXB2	U2B
Agrostis stolonifera	N		0.13	1		1						
Carex lanuginosa	N		0.13	1			1					
Scirpus maritimus	N		0.13	1				1				
Scirpus validus	N		0.13	1				1				
Eragrostis hypnoides	N		0.13	1				1				
Carex nebrascensis	N		0.13	1					1			
Juncus interior	N		0.13	1					1			
Sporobolus cryptandrus	N		0.13	1							1	
Average # of native graminoid species		3.4			10	2	2	5	4	2	1	1
Average number of graminoid species		5.5			10	4	4	8	8	3	2	5

Table 10. Vegetation of ungrazed sandbar sites: releve and cover data.
Species are in order by life form, and then by average cover.

Ungrazed Study Sites		Avrg	UDB	UEB	UMB	URB	UWB	UXB	UXB2	U2B
Mile on River (from Big Creek, MT)		Cover	6.4	8.8	67.0	193.7	258.5	308.2	308.2	491.5
	StDev	ALL	Cover/Individual Site							
Average cover of non-ntv spp	0.199	0.124	0.002	0.096	0.012	0.610	0.083	0.084	0.043	0.065
Average cover of species	0.245	0.386	0.399	0.141	0.269	0.872	0.374	0.458	0.079	0.494
% cover of non-native spp	28%	31%	1%	68%	4%	70%	22%	18%	54%	13%
Native/Non-native		AvCvr								
TREES	*N/X*	ALL								
Avrg cover of non-native tree spp		0	0	0	0	0	0	0	0	0
Populus deltoides (0.003, 5 sites)	N	0.002				0.007	0.005		0.003	0.002
Populus angustifolia (0.002, 3 sites)	N	0.001			0.005					
Avrg cover of native tree species		0.003	0.000	0.000	0.005	0.007	0.005	0.000	0.003	0.002
Average cover of tree species		0.003	0.000	0.000	0.005	0.007	0.005	0.000	0.003	0.002
SHRUBS										
% cover of non-native shrub spp		28%	0.000	0.000	0.000	0.143	0.062	1.000	1.000	0.000
Avrg cover of non-native shrub spp		0.008	0.000	0.000	0.000	0.012	0.005	0.027	0.017	0.000
Tamarix chinensis	X	0.008				0.012	0.005	0.027	0.017	
Salix exigua	N	0.090	0.320	0.004	0.010	0.072	0.074			0.240
Salix amygdaloides	N	0.002	0.014				0.002			
Avrg cover of native shrub species		0.092	0.334	0.004	0.010	0.072	0.076	0.000	0.000	0.240
Average cover of shrub species		0.100	0.334	0.004	0.010	0.084	0.081	0.027	0.017	0.240
FORBS										
% cover of non-native forb species		38%	0.091	0.794	0.018	0.695	0.898	0.129	0.333	0.100
Avrg cover of non-native forb spp		0.065	0.002	0.054	0.002	0.330	0.053	0.055	0.015	0.008
Chenopodium glaucum	X	0.043		0.008		0.330		0.001		0.003
Chenopodium album	X	0.006		0.032			0.011			0.003
Rumex stenophyllus	X	0.004						0.028		
Thlaspi arvense	X	0.002		0.003			0.001	0.015		
Rumex crispus (sp?)	X	0.001			0.002		0.007			0.001
Kochia scoparia	X	0.001		0.001			0.007	0.002		
Polygonum aviculare	X	0.001					0.009			
Taraxacum officinale	X	0.001	0.001				0.001	0.003	0.003	
Lepidium perfoliatum	X	0.001					0.007			
Melilotus officinalis	X	0.001		0.001					0.005	
Cirsium arvense	X	0.001		0.001			0.003			
Chenopodium botrys	X	0.001		0.001			0.003			
Medicago lupulina	X	0.001		0.001					0.003	0.000
Lactuca seriola	X	0.001					0.001	0.003		
Sonchus uliginosus/S. asper	X	0.000							0.003	0.000
Sisymbrium loeselii	X	0.000		0.001				0.001	0.001	
Amaranthus blitoides	X	0.000		0.002						
Filago arvensis	X	0.000					0.001	0.001		
Artemisia biennis	X	0.000					0.002			
Tanacetum vulgare	X	0.000	0.001	0.001						

Table 10. Vegetation of ungrazed sandbar sites: releve and cover data, cont'd.

FORBS, cont'd.			UDB	UEB	UMB	URB	UWB	UXB	UXB2	U2B
Asperugo procumbens	X	0.000		0.001						
Erysimum repandum	X	0.000		0.001						
Sisymbrium altissimum	X	0.000								0.001
Verbascum thapsus	X	0.000						0.001		
Polygonum lapathifolium	N	0.033				0.118		0.140	0.003	
Polygonum amphibium	N	0.009		0.001						0.067
Equisetum arvense	N	0.008			0.060					
Xanthium strumarium	N	0.006				0.015		0.034	0.001	0.001
Verbena bracteata	N	0.006					0.001	0.048		
Equisetum laevigatum	N	0.006			0.045					
Solidago occidentalis	N	0.005						0.040		
Aster hesperius	N	0.005						0.037	0.002	
Galium bifolium	N	0.004						0.033	0.001	
Iva xanthifolia	N	0.003						0.020	0.001	
Potentilla paradoxa	N	0.002					0.001	0.016		0.001
Polygonum douglasii	N	0.002						0.001	0.015	
Glycyrrhiza lepidota	N	0.002		0.006	0.006					
Rorippa palustris v. hispida	N	0.001	0.003	0.003		0.002				0.001
Ranunculus cymbalaria	N	0.001	0.002			0.004		0.001		
Gnaphalium palustre	N	0.001	0.004	0.001		0.002				
Solanum rostratum	N	0.001						0.001	0.005	
Polygonum achoreum	N	0.001		0.001		0.004				
Epilobium paniculatum	N	0.001	0.004	0.001						
Veronica americana	N	0.001	0.004							
Amaranthus albus	N	0.000						0.001	0.001	0.001
Equisetum variegatum	N	0.000	0.001				0.001			
Oenethera villosa	N	0.000					0.001		0.001	
Helianthus annuus	N	0.000					0.002			
Mentha arvensis	N	0.000	0.001							
Potentilla norvegica	N	0.000		0.001						
Cicuta douglasii	N	0.000								0.001
Ranunculus sceleratus	N	0.000	0.001							
Average cover of native forb species		0.096	0.020	0.014	0.111	0.145	0.006	0.372	0.030	0.072
Average cover of forb species		0.161	0.022	0.068	0.113	0.475	0.059	0.427	0.045	0.080

Table 10. Vegetation of ungrazed sandbar sites: releve and cover data, cont'd.

GRAMINOIDS			UDB	UEB	UMB	URB	UWB	UXB	UXB2	U2B
% cover non-native graminoid spp		41%	0.000	0.609	0.071	0.876	0.109	0.500	0.786	0.331
Avrg cover of non-native grmnd spp		0.052	0.000	0.042	0.010	0.268	0.025	0.002	0.011	0.057
Echinochloa crus-galli	X	0.039				0.260				0.050
Elymus repens	X	0.007		0.041	0.010					0.001
Bromus tectorum	X	0.003		0.001			0.020	0.002		
Bromus japonicus	X	0.001							0.011	
Phalaris arundinacea	N	0.001				0.006	0.004			0.001
Bromus inermis	X	0.001								0.005
Crypsis alopecuroides	X	0.000				0.002				
Juncus compressus	X	0.000					0.001			
Eleocharis palustris	N	0.030	0.013	0.021	0.087	0.002	0.001	0.002		0.115
Carex nebrascensis	N	0.025					0.200			
Carex lanuginosa	N	0.006			0.044					
Scirpus maritimus	N	0.003				0.024				
Eragrostis hypnoides	N	0.002				0.012				
Juncus longistylis	N	0.001	0.011							
Juncus ensifolius	N	0.001	0.007							
Agrostis stolonifera	N	0.001		0.006						
Alopecurus aequalis	N	0.001	0.005							
Hordeum jubatum	N	0.000					0.003			
Agrostis scabra	N	0.000	0.003							
Sporobolus cryptandrus	N	0.000							0.003	
Carex sp.	N	0.000	0.001							
Juncus bufonius	N	0.000	0.001							
Juncus articulatus	N	0.000	0.001							
Poa juncifolia (sp?)	N	0.000	0.001							
Avrg cover of native graminoid spp		0.070	0.043	0.027	0.131	0.038	0.204	0.002	0.003	0.115
Average cover of graminoid species		0.122	0.043	0.069	0.141	0.306	0.229	0.004	0.014	0.172

Table 11. Vegetation of ungrazed Salix exigua (sandbar willow) sites: releve & frequency data. Species grouped by life form.

Ungrazed Study Sites					UBX	UCX	UDX	UHX	UJX	UKX	UKX2	UMX	UMX2	UNX	UNX2	UOX	UQX	URX	USX	UTX	UUX	UWX	UXX	UYX	U1X	U2X
Mile on river from Big Creek, MT					6	6.2	6.4	23	45	58	57	67	67	97	97	103	156	194	203	220	248	259	308	361	479	492
		Avrg	Stnd																							
Species Richness		#/site	Dev.		Number of species at each site																					
# of non-native spp		9.6	2.9		8	11	6	7	7	3	7	9	11	14	14	13	11	9	11	10	11	6	11	12	7	13
# of species		22.0	7.3		11	22	11	28	14	14	17	24	20	31	28	21	18	22	29	25	21	13	24	40	31	21
% non-native spp		46%	13%		73%	50%	55%	25%	50%	21%	41%	38%	55%	45%	50%	62%	61%	41%	38%	40%	52%	46%	46%	30%	23%	62%
Species Constancy & Frequency																										
Native/Non-native		Avrg	Con-	Sum	Presence/absence of species per site																					
TREES	N/X	#/site	stancy	Freq																						
Avrg # of non-native tree spp		*0.0*			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus deltoides	N		0.82*	9												1	1	1	1	0	1	1		1	1	1
Fraxinus pennsylvanica	N		0.27*	3													1						1	1		
Populus angustifolia	N		0.18*	2				1					1													
Avrg # of native tree species		*0.6*			0	0	0	1	0	0	0	0	1	0	0	1	2	1	1	0	1	1	1	2	1	1
Avrg # of tree species		*0.6*			0	0	0	1	0	0	0	0	1	0	0	1	2	1	1	0	1	1	1	2	1	1
SHRUBS																										
% non-native shrub species		*10%*			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.33	0.14	0.40	0.33	0.00	0.13	0.20	0.17	0.33
Avrg # of non-native shrub spp		*0.5*			0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	2	1	0	1	1	1	1
Tamarix chinensis	X		0.55*	6													1	1		1	1		1			1
Elaeagnus angustifolia	X		0.36*	4															1	1				1	1	
Artemisia absinthium	X		0.05	1															1							
Salix exigua	N		1.00	22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Salix amygdaloides	N		0.50	11				1		1	1				1	1		1	1				1	1	1	1
Ribes aureum	N		0.45	10						1	1	1	1	1	1		1		1				1	1		
Cornus stolonifera	N		0.45	10		1				1	1	1	1	1	1				1				1		1	
Rosa sayi/Rosa woodsii	N		0.36	8		1						1		1	1		1		1	1			1			
Ribes setosum	N		0.23	5					1		1	1	1						1							
Symphoricarpos occidentalis	N		0.23	5								1							1	1	1			1		
Ribes hudsonianum	N		0.14	3						1		1		1												
Prunus virginiana	N		0.14	3							1	1							1							

* Constancies calculated as a percentage of only those sits within their respective zones.

Table 11. Vegetation of ungrazed Salix exigua sites: releve and frequency data, cont'd.

SHRUBS, cont'd.					UBX	UCX	UDX	UHX	UJX	UKX	UKX2	UMX	UMX2	UNX	UNX2	UOX	UQX	URX	USX	UTX	UUX	UWX	UXX	UYX	U1X	U2X
Vitis riparia	N		0.14	3															1				1		1	
Ribes sp.	N		0.09	2		1				1																
Rhus trilobata	N		0.09	2		1													1							
Juniperus scopulorum	N		0.09	2										1					1							
Clematis ligusticifolia	N		0.09	2															1				1			
Salix sp. (small leaved willow)	N		0.05	1				1																		
Humulus lupulus	N		0.05	1								1														
Amelanchier alnifolia	N		0.05	1								1														
Toxicodendron rydbergii	N		0.05	1													1									
Parthenocissus inserta	N		0.05	1																					1	
Avrg # of native shrub spp		*4.2*			1	5	1	3	2	6	6	10	4	6	5	2	4	2	12	3	2	1	7	4	5	2
Avrg # of shrub species		*4.7*			1	5	1	3	2	6	6	10	4	6	5	2	5	3	14	5	3	1	8	5	6	3
FORBS																										
Percent non-native forb specie		*59%*			0.80	0.57	0.67	0.38	0.75	0.20	0.63	0.67	0.70	0.58	0.65	0.78	1.00	0.40	0.67	0.36	0.54	0.57	0.60	0.33	0.22	0.82
Avrg # of non-native forb spp		*6.4*			4	8	4	5	6	1	5	8	7	11	11	7	7	6	8	5	7	4	6	7	4	9
Cirsium arvense	X		0.91	20	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Taraxacum officinale	X		0.68	15			1	1			1	1	1	1	1		1	1	1			1	1	1	1	1
Sonchus uliginosus/S. asper	X		0.55	12		1	1					1	1	1	1				1	1		1	1	1		1
Cynoglossum officinale	X		0.41	9	1	1		1			1	1	1				1				1			1		
Solanum dulcamara	X		0.41	9							1	1		1	1	1	1		1				1	1		
Verbascum thapsus	X		0.36	8	1	1			1				1	1	1					1					1	
Tanacetum vulgare	X		0.27	6		1			1					1	1	1		1								
Conium maculatum	X		0.27	6					1			1		1	1	1	1									
Tragopogon dubius	X		0.27	6										1							1	1	1	1		1
Cirsium vulgare	X		0.23	5		1								1	1	1	1									
Arctium minus	X		0.18	4		1						1			1	1										
Medicago lupulina	X		0.18	4				1					1						1							1
Silene noctiflora	X		0.18	4					1		1			1	1											
Euphorbia esula	X		0.18	4										1	1			1		1						
Melilotus officinalis	X		0.18	4														1	1					1		1
Sisymbrium loeselii	X		0.18	4															1		1				1	1
Nepeta cataria	X		0.14	3					1			1					1									
Lactuca seriola	X		0.14	3												1		1			1					

Table 11. Vegetation of ungrazed Salix exigua sites: releve and frequency data, cont'd.

FORBS, cont'd.					UBX	UCX	UDX	UHX	UJX	UKX	UKX2	UMX	UMX2	UNX	UNX2	UOX	UQX	URX	USX	UTX	UUX	UWX	UXX	UYX	U1X	U2X
Rumex crispus	X		0.09	2			1																			1
Linaria dalmatica	X		0.09	2									1										1			
Melilotus alba	X		0.09	2															1	1						
Lychnis alba	X		0.05	1	1																					
Centaurea maculosa	X		0.05	1		1																				
Trifolium hybridum	X		0.05	1				1																		
Trifolium pratense	X		0.05	1				1																		
Lepidium perfoliatum	X		0.05	1																1						
Artemisia biennis	X		0.05	1																1						
Descurainia sophia	X		0.05	1																						1
Chenopodium album	X		0.05	1																						1
Solidago gigantea	N		0.50	11		1		1	1	1	1			1	1				1				1	1	1	
Equisetum laevigatum	N		0.32	7				1		1										1			1	1	1	1
Glycyrrhiza lepidota	N		0.27	6		1	1				1		1							1				1		
Polygonum amphibium	N		0.27	6										1							1	1	1	1	1	
Plantago major	N		0.23	5				1										1	1		1				1	
Smilacina stellata	N		0.23	5						1	1	1	1	1												
Mentha arvensis	N		0.18	4				1										1		1				1		
Equisetum arvense	N		0.18	4						1			1			1									1	
Potentilla paradoxa	N		0.18	4														1						1	1	1
Galium aparine	N		0.14	3								1		1	1											
Potentilla gracilis	N		0.14	3										1	1			1								
Lysimachia ciliata	N		0.14	3										1	1								1			
Potentilla norvegica	N		0.14	3														1						1	1	
Apocynum sibiricum	N		0.14	3															1	1				1		
Ambrosia psilostachya	N		0.14	3																1				1	1	
Solidago occidentalis	N		0.14	3																1	1	1				
Verbena hastata	N		0.14	3																	1			1	1	
Verbena bracteata	N		0.14	3																	1			1	1	
Cicuta douglasii	N		0.09	2		1		1																		
Geum macrophyllum	N		0.09	2		1						1														
Urtica dioica	N		0.09	2					1						1											
Conyza canadensis	N		0.09	2														1			1					

Table 11. Vegetation of ungrazed Salix exigua sites: releve and frequency data, cont'd.

FORBS, cont'd.					UBX	UCX	UDX	UHX	UJX	UKX	UKX2	UMX	UMX2	UNX	UNX2	UOX	UQX	URX	USX	UTX	UUX	UWX	UXX	UYX	U1X	U2X
Aster hesperius	N		0.09	2															1						1	
Oenethera villosa	N		0.09	2																1		1				
Xanthium strumarium	N		0.09	2																1				1		
Cirsium undulatum	N		0.05	1	1																					
Thalictrum dasycarpum	N		0.05	1		1																				
Achillea millefolium	N		0.05	1		1																				
Iris missouriensis	N		0.05	1			1																			
Aster subspicatus	N		0.05	1				1																		
Vicia americana	N		0.05	1				1																		
Equisetum variegatum	N		0.05	1				1																		
Agrimonia striata	N		0.05	1								1														
Potentilla anserina	N		0.05	1										1												
Stachys palustris	N		0.05	1										1												
Asclepias speciosa	N		0.05	1											1											
Aster ascendens	N		0.05	1												1										
Polygonum sp.			0.05	1														1								
Parietaria pensylvanica	N		0.05	1														1								
Polygonum lapathifolium	N		0.05	1														1								
Equisetum hyemale	N		0.05	1																1						
Ranunculus cymbalaria	N		0.05	1																				1		
Ranunculus Macounii	N		0.05	1																				1		
Equisetum sylvaticum	N		0.05	1																					1	
Heterotheca villosa	N		0.05	1																					1	
Lycopus americanus	N		0.05	1																					1	
Avrg # of native forb species		*5.8*			2	7	3	10	2	4	3	4	4	8	6	2	0	9	5	10	8	3	5	14	14	5
Avrg # of forb species		*11.5*			5	14	6	13	8	5	8	12	10	19	17	9	7	15	12	14	13	7	10	21	18	11
GRAMINOIDS																										
% of non-ntv grmnd spp		*58%*			0.80	1.00	0.50	0.18	0.25	0.67	0.67	0.50	0.80	0.50	0.50	0.67	0.75	0.67	0.50	0.50	0.75	0.50	0.80	0.33	0.33	0.50
Avrg # of non-ntv grmnd spp		*2.7*			4	3	2	2	1	2	2	1	4	3	3	6	3	2	1	3	3	2	4	4	2	3
Phalaris arundinacea	X		0.73	16					1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1
Poa pratensis	X		0.68	15	1	1	1	1		1			1	1	1	1	1			1	1	1	1			1
Elymus repens	X		0.59	13	1	1	1	1			1	1	1			1		1		1	1		1			1

Table 11. Vegetation of ungrazed Salix exigua sites: releve and frequency data, cont'd.

GRAMINOIDS, cont'd.					UBX	UCX	UDX	UHX	UJX	UKX	UKX2	UMX	UMX2	UNX	UNX2	UOX	UQX	URX	USX	UTX	UUX	UWX	UXX	UYX	U1X	U2X
Bromus inermis	X		0.18	4	1								1			1								1		
Alopecurus arundinaceus	X		0.14	3										1	1		1									
Bromus tectorum	X		0.09	2	1																			1		
Phleum pratense	X		0.09	2		1										1										
Dactylis glomerata	X		0.09	2										1		1										
Bromus japonicus	X		0.05	1																			1			
Poa compressa	X		0.05	1																				1		
Juncus compressus	X		0.05	1																					1	
Agrostis stolonifera	N		0.36	8	1		1	1	1							1			1	1	1					
Carex sp.	N		0.36	8			1	1						1		1		1				1	1	1		
Poa palustris	N		0.32	7						1	1	1	1			1								1	1	
Carex aquatilis	N		0.14	3													1								1	1
Carex lanuginosa	N		0.09	2				1							1											
Deschampsia cespitosa	N		0.09	2				1																	1	
Juncus balticus	N		0.09	2				1																	1	
Carex microptera	N		0.09	2					1					1												
Elymus trachycaulus/A. sp.	N		0.09	2										1	1											
Spartina pectinata	N		0.09	2																1				1		
Elymus lanceolatus	N		0.09	2																		1		1		
Eleocharis palustris	N		0.09	2																				1		1
Hordeum jubatum	N		0.09	2																				1		1
Carex lenticularis	N		0.05	1				1																		
Juncus nodosus	N		0.05	1				1																		
Carex arthrostachya	N		0.05	1				1																		
Juncus longistylis	N		0.05	1				1																		
Elymus elynoides	N		0.05	1					1																	
uncus sp.	N		0.05	1											1											
Elymus cinereus	N		0.05	1																1						
Sporobolus cryptandrus	N		0.05	1																				1		
Scirpus pungens	N		0.05	1																				1		
Avrg # of ntv graminoid specie		*2.4*			1	0	2	9	3	1	1	1	1	3	3	3	1	1	1	3	1	2	1	8	4	3
Avrg # of graminoid species		*5.1*			5	3	4	11	4	3	3	2	5	6	6	9	4	3	2	6	4	4	5	12	6	6

Table 12. Vegetation of ungrazed Salix exigua (sandbar willow) sites, releve & cover data.
Species are in order by life form, then by average cover.

Ungrazed Study Sites		Avrg	UBX	UCX	UDX	UHX	UJX	UKX	UKX2	UMX	UMX2	UNX	UNX2	UOX	UQX	URX	USX	UTX	UUX	UWX	UXX	UYX	U1X	U2X
Mile on river from Big Creek, MT		Cover	6	6	6	23	45	58	57	67	67	97	97	103	156	194	203	220	248	259	308	361	479	492
St dev		ALL	Cover/Individual Site																					
Avrg cvr of non-ntv spp	0.243	0.394	0.17	0.17	0.61	0.09	0.70	0.33	0.71	0.27	0.05	0.19	0.22	0.38	0.65	0.73	0.54	0.18	0.75	0.62	0.13	0.15	0.60	0.43
Average cover of all spp	0.309	1.144	0.95	0.55	1.66	1.20	0.80	1.27	1.71	1.68	1.03	0.93	0.79	1.15	1.17	1.40	1.19	1.02	1.39	1.05	0.89	0.90	1.48	0.97
Non-ntv spp as % of ttl cvr	20%	34%	0.18	0.31	0.37	0.08	0.88	0.26	0.42	0.16	0.05	0.20	0.27	0.33	0.56	0.52	0.46	0.18	0.54	0.59	0.14	0.17	0.41	0.44
Native/Non-native		AvCvr																						
TREES	*N/X*	ALL																						
Avrg cvr of non-ntv tree spp		0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Populus angustifolia*	N	0.010				0.21					0.00													
Populus deltoides*	N	0.007													0.00	0.11	0.01		0.00			0.01	0.02	0.01
Fraxinus pennsylvanica	N	0.000																			0.00			
Avrg cvr of native tree spp		0.017	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01
Avrg cvr of all tree spp		0.017	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.01	0.00	0.00	0.00	0.00	0.01	0.02	0.01
SHRUBS																								
% cover non-ntv shrub spp		2%	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.01	0.00	0.07	0.00	0.20	0.00
Avrg cvr non-ntv shrub spp		0.015	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.05	0.00	0.17	0.00
Elaeagnus angustifolia	X	0.012															0.09						0.17	
Tamarix chinensis	X	0.003																0.00	0.00		0.05			
Artemisia absinthium	X	0.000															0.01							
Salix exigua	N	0.506	0.71	0.32	0.73	0.38	0.06	0.57	0.64	0.42	0.79	0.53	0.51	0.59	0.51	0.54	0.54	0.53	0.57	0.38	0.33	0.38	0.59	0.53
Salix amygdaloides	N	0.055				0.26		0.04	0.18				0.01	0.14		0.00	0.00				0.29	0.21	0.08	0.00
Cornus stolonifera	N	0.016		0.00				0.13	0.03	0.09	0.00	0.09	0.01				0.01							
Ribes hudsonianum	N	0.011						0.06		0.18														
Symphoricarpos occidentalis	N	0.011								0.23								0.00	0.01			0.00		
Ribes aureum	N	0.010						0.04	0.00	0.11	0.00	0.05	0.00		0.00		0.00				0.00			
Rosa woodsii/R. sayi	N	0.009		0.02						0.18			0.00		0.00		0.00				0.00			
Prunus virginiana	N	0.005							0.00	0.11							0.00							
Ribes sp.	N	0.003						0.06																

*Sites with "0.00" cover had 0.001-0.004, i.e. 0.1-0.4% cover. P. angustifolia cover in UHX was a neighboring mature tree, not seedlings.

Table 12. Vegetation of ungrazed Salix exigua sites, cover data - cont'd.

Shrubs, cont'd.			UBX	UCX	UDX	UHX	UJX	UKX	UKX2	UMX	UMX2	UNX	UNX2	UOX	UQX	URX	USX	UTX	UUX	UWX	UXX	UYX	U1X	U2X
Salix sp. (small lvd willow)	N	0.002				0.04																		
Clematis ligusticifolia	N	0.002															0.00				0.03			
Humulus lupulus	N	0.001								0.02														
Vitis riparia	N	0.000															0.00				0.00		0.00	
Ribes setosum	N	0.000					0.00		0.00	0.00							0.00							
Rhus trilobata	N	0.000		0.00																				
Amelanchier alnifolia	N	0.000								0.00														
Toxicodendron rydbergii	N	0.000													0.00									
Juniperus scopulorum	N	0.000															0.00							
Avrg cvr of all ntv shrub spp		0.632	0.71	0.34	0.73	0.68	0.06	0.90	0.85	1.34	0.79	0.67	0.53	0.73	0.51	0.54	0.57	0.53	0.58	0.38	0.66	0.60	0.68	0.53
Avrg cvr of all shrub spp		0.647	0.71	0.34	0.73	0.68	0.06	0.90	0.85	1.34	0.79	0.67	0.53	0.73	0.51	0.54	0.66	0.53	0.58	0.38	0.71	0.60	0.85	0.53
FORBS																								
% cover of non-ntv forb spp		70%	1.00	0.31	0.92	0.64	0.96	0.86	0.99	0.81	0.15	0.85	0.90	0.73	1.00	0.92	0.81	0.18	0.86	0.89	0.11	0.21	0.31	1.00
Avrg cvr of non-ntv forb spp		0.133	0.02	0.02	0.51	0.06	0.19	0.08	0.34	0.27	0.01	0.09	0.12	0.05	0.05	0.16	0.28	0.06	0.27	0.03	0.01	0.01	0.01	0.30
Cirsium arvense	X	0.073	0.02	0.01	0.51		0.19	0.08	0.33	0.00	0.01	0.05	0.07	0.03	0.04	0.15	0.00	0.03	0.06	0.02	0.00		0.00	
Melilotus officinalis	X	0.013															0.00							0.29
Melilotus alba	X	0.012															0.26	0.00						
Solanum dulcamara	X	0.012								0.22		0.00	0.02	0.00	0.00		0.00				0.01	0.01		
Cynoglossum officinale	X	0.010		0.00		0.00			0.00	0.00	0.00				0.00				0.20			0.00		
Trifolium hybridum	X	0.002				0.05																		
Tanacetum vulgare	X	0.002										0.03	0.01	0.00										
Sonchus uliginosus/asper	X	0.002			0.00					0.02			0.00				0.01				0.01	0.00		0.00
Taraxacum officinale	X	0.002			0.00	0.00			0.00	0.00	0.00	0.01	0.01		0.00	0.00	0.01				0.00	0.00		0.00
Verbascum thapsus	X	0.002	0.00	0.00			0.00					0.00	0.00					0.03						
Arctium minus	X	0.001								0.02				0.00										
Cirsium vulgare	X	0.001										0.00	0.01	0.01	0.00									
Euphorbia esula	X	0.000										0.00	0.00			0.01								
Sisymbrium loeselii	X	0.000															0.00		0.00				0.01	0.00
Conium maculatum	X	0.000								0.00		0.00	0.00	0.00										
Silene noctiflora	X	0.000							0.01															
Tragopogon dubius	X	0.000										0.00							0.00	0.00	0.00	0.00		
Nepeta cataria	X	0.000					0.00			0.00					0.00									

Table 12. Vegetation of ungrazed Salix exigua sites, cover data - cont'd.

Forbs, cont'd.			UBX	UCX	UDX	UHX	UJX	UKX	UKX2	UMX	UMX2	UNX	UNX2	UOX	UQX	URX	USX	UTX	UUX	UWX	UXX	UYX	U1X	U2X
Medicago lupulina	X	0.000				0.00					0.00						0.00							
Lactuca seriola	X	0.000																	0.00					
Lychnis alba	X	0.000	0.00																					
Centaurea maculosa	X	0.000		0.00																				
Lepidium perfoliatum	X	0.000																	0.00					
Descurainia sophia	X	0.000																						0.00
Rumex crispus	X	0.000																						0.00
Glycyrrhiza lepidota	N	0.007		0.02	0.04						0.04							0.06				0.00		
Solidago gigantea	N	0.006		0.02			0.01	0.01				0.00	0.00				0.00				0.08	0.00		
Solidago occidentalis	N	0.005																0.08	0.04	0.00				
Equisetum hyemale	N	0.004																0.09						
Smilacina stellata	N	0.003						0.00	0.00	0.06	0.00	0.00												
Apocynum sibiricum	N	0.003															0.06	0.01						
Lysimachia ciliata	N	0.002										0.01	0.00								0.03			
Polygonum amphibium	N	0.002										0.00							0.00		0.00	0.02	0.01	
Ambrosia psilostachya	N	0.001																0.01				0.00	0.01	
Mentha arvensis	N	0.001				0.00										0.01		0.00				0.00		
Aster ascendens	N	0.001												0.02										
Equisetum arvense	N	0.001									0.01			0.00									0.00	
Aster subspicatus	N	0.001				0.01																		
Plantago major	N	0.000				0.01										0.00	0.00							
Asclepias speciosa	N	0.000											0.01											
Verbena bracteata	N	0.000																				0.01		
Equisetum variegatum	N	0.000				0.01																		
Conyza canadensis	N	0.000														0.00			0.01					
Oenethera villosa	N	0.000																0.00		0.00				
Equisetum laevigatum	N	0.000				0.00		0.00										0.00			0.00	0.00		
Heterotheca villosa	N	0.000																					0.00	
Geum macrophyllum	N	0.000		0.00						0.00														
Verbena hastata	N	0.000																	0.00			0.00		
Galium aparine	N	0.000								0.00			0.00											
Potentilla gracilis	N	0.000										0.00	0.00											
Polygonum sp.		0.000														0.00								

Table 12. Vegetation of ungrazed Salix exigua sites, cover data - cont'd.

FORBS, cont'd.			UBX	UCX	UDX	UHX	UJX	UKX	UKX2	UMX	UMX2	UNX	UNX2	UOX	UQX	URX	USX	UTX	UUX	UWX	UXX	UYX	U1X	U2X
Xanthium strumarium	N	0.000																0.00				0.00		
Potentilla paradoxa	N	0.000																				0.00		
Equisetum sylvaticum	N	0.000																					0.00	
Circuta douglasii	N	0.000		0.00																				
Thalictrum dasycarpum	N	0.000		0.00																				
Iris missouriensis	N	0.000			0.00																			
Potentilla anserina	N	0.000										0.00												
Parietaria pensylvanica	N	0.000													0.00									
Polygonum lapathifolium	N	0.000													0.00									
Aster hesperius	N	0.000														0.00								
Avrg cvr of all native forb sp		0.039	0.00	0.04	0.05	0.03	0.01	0.01	0.00	0.07	0.05	0.02	0.01	0.02	0.00	0.01	0.07	0.25	0.04	0.00	0.11	0.05	0.02	0.00
Avrg cvr of all forb spp		0.172	0.02	0.06	0.56	0.09	0.20	0.09	0.34	0.34	0.06	0.11	0.13	0.07	0.05	0.17	0.35	0.31	0.31	0.03	0.12	0.06	0.03	0.30
GRAMINOIDS																								
% cvr non-ntv gramnd spp		73%	0.69	1.00	0.27	0.15	0.94	0.90	0.73	0.00	0.25	0.60	0.76	0.92	1.00	0.99	0.93	0.68	0.96	0.92	1.00	0.58	0.72	0.98
Avrg cvr non-ntv gramnd spp		0.246	0.15	0.15	0.10	0.03	0.51	0.25	0.38	0.00	0.04	0.09	0.10	0.33	0.60	0.57	0.16	0.12	0.47	0.59	0.06	0.14	0.42	0.13
Phalaris arundinacea	X	0.200					0.51	0.23	0.37		0.00		0.02	0.16	0.58	0.52	0.16	0.11	0.47	0.59	0.01	0.11	0.42	0.13
Poa pratensis	X	0.025	0.11	0.08	0.07	0.03		0.02			0.02	0.09	0.08	0.02	0.00			0.01			0.00			0.00
Elymus repens	X	0.017	0.04	0.06	0.03	0.00			0.01		0.02			0.10		0.05			0.00		0.05			0.00
Bromus inermis	X	0.003									0.00			0.03								0.02		
Alopecurus arundinaceus	X	0.001										0.00			0.02									
Phleum pratense	X	0.001		0.01										0.00										
Dactylis glomerata	X	0.000												0.01										
Bromus tectorum	X	0.000	0.01																			0.00		
Agrostis stolonifera	N	0.019	0.07		0.08	0.13	0.01							0.02			0.01	0.06	0.02					
Poa palustris	N	0.014						0.03	0.14	0.00	0.13			0.00										
Carex sp.	N	0.010			0.19	0.00						0.02		0.00		0.00				0.00		0.00		
Carex aquatilis	N	0.007																					0.16	
Spartina pectinata	N	0.004																				0.09		
Elymus lanceolatus	N	0.002																		0.05		0.00		
Elymus trachycaulus/E. sp.	N	0.002										0.04	0.01											
Deschampsia cespitosa	N	0.002				0.04																		
Carex lanuginosa	N	0.001				0.00							0.02											

Table 12. Vegetation of ungrazed Salix exigua sites, cover data - cont'd.

GRAMINOIDS, cont'd.			UBX	UCX	UDX	UHX	UJX	UKX	UKX2	UMX	UMX2	UNX	UNX2	UOX	UQX	URX	USX	UTX	UUX	UWX	UXX	UYX	U1X	U2X
Elymus elymoides	N	0.001					0.01																	
Carex microptera	N	0.000					0.01					0.00												
Juncus nodosus	N	0.000				0.00																		
Sporobolus cryptandrus	N	0.000																				0.00		
Eleocharis palustris	N	0.000																				0.00		0.00
Hordeum jubatum	N	0.000																				0.00		0.00
Carex lenticularis	N	0.000				0.00																		
Juncus longistylis	N	0.000				0.00																		
Juncus sp.	N	0.000											0.00											
Avrg cvr of ntv gramnd spp		0.063	0.07	0.00	0.27	0.18	0.03	0.03	0.14	0.00	0.13	0.06	0.03	0.03	0.00	0.00	0.01	0.06	0.02	0.05	0.00	0.10	0.16	0.00
Avrg cvr of graminoid spp		0.309	0.22	0.15	0.37	0.21	0.54	0.28	0.52	0.00	0.17	0.15	0.13	0.36	0.60	0.57	0.18	0.18	0.49	0.64	0.06	0.24	0.58	0.13

Table 13. Vegetation of ungrazed *Populus angustifolia* (narrowleaf cottonwood) sites: Releve & frequency data. Species are in order by life form, then by constancy.

Ungrazed Study Sites		Mature	UCN	UEN	UEN2	UJN	UKN	UMN2	UNN	UNN2	Young	UCN2	UEN3
Mile on river from Big Creek, MT			6	9	9	45	58	67	97	97		6	9
Percent cover of cow pies			0	0	0	0	0	0	0	0		0	0
Average DBH (cm), three largest trees			35	c 50	49	81	66	58	51	53		5	5
		Avrg	Stnd								Avrg	Stnd	
Species Richness		#/site	Dev		Number of species at each site						#/site	Dev	# spp/site	
Average # of non-native species		6.9	2.9		8	6	3	11	6	3	9	9	7	3	9	5
Average # of species		19.8	5.9		25	21	13	28	15	12	24	20	12	6	16	8
Percent non-native species		34%	8%		32%	29%	23%	39%	40%	25%	38%	45%	59%	4%	56%	63%
Species Constancy & Frequency																
Native/Non-native		Avrg	Con-	Sum	Presence/absence of species per site								Con-	Sum	Pres/abs	
TREES	N/X	#/site	stancy	Freq									stancy	Freq		
Average # of non-native tree spp		0			0	0	0	0	0	0	0	0			0	0
Populus angustifolia	N		1.00	8	1	1	1	1	1	1	1	1	0.50	1	1	1
Fraxinus pennsylvanica	N		0.13	1							1		0.00	0		
Average # of native tree species		1.1			1	1	1	1	1	1	2	1			1	1
Average # of tree species		1.1			1	1	1	1	1	1	2	1			1	1
SHRUBS																
Average # of non-natv shrub spp		0			0	0	0	0	0	0	0	0			0	0
Rosa sayi/R. woodsii	N		0.88	7	1	1		1	1	1	1	1	0.00	0		
Symphoricarpos occidentalis	N		0.75	6	1	1		1	1	1	1		0.00	0		
Ribes aureum	N		0.63	5		1		1	1		1	1	0.00	0		
Juniperus scopulorum	N		0.50	4	1	1	1	1					0.50	1	1	
Rhus trilobata	N		0.50	4	1	1	1	1					0.00	0		
Ribes setosum	N		0.50	4	1	1		1	1				0.00	0		
Cornus stolonifera	N		0.50	4				1	1		1	1	0.00	0		
Clematis ligusticifolia	N		0.25	2	1		1						0.00	0		
Prunus virginiana	N		0.25	2				1	1				0.00	0		
Salix exigua	N		0.13	1				1					1.00	2	1	1
Ribes hudsonianum	N		0.13	1	1								0.00	0		

Table 13. Vegetation of ungrazed P. angustifolia sites - releve and frequency data, cont'd.

SHRUBS, cont'd.					UCN	UEN	UEN2	UJN	UKN	UMN2	UNN	UNN2			UCN2	UEN3
Shepherdia argentea	N		0.13	1	1								0.00	0		
Salix amygdaloides	N		0.13	1				1					0.00	0		
Average # of native shrub spp		5.3			8	6	3	10	6	2	4	3			2	1
Average # of shrub species		5.3			8	6	3	10	6	2	4	3			2	1
FORBS																
Percent of non-native forb spp		44%			0.36	0.57	0.33	0.54	0.50	0.40	0.38	0.42			0.71	0.80
Average # of non-native forb spp		3.9			4	4	2	7	2	2	5	5			5	4
Cirsium arvense	X		0.88	7	1	1		1	1	1	1	1	0.50	1		1
Taraxacum officinale	X		0.75	6	1	1	1		1		1	1	0.50	1	1	
Arctium minus	X		0.38	3		1		1				1	0.00	0		
Tanacetum vulgare	X		0.38	3				1			1	1	0.00	0		
Conium maculatum	X		0.25	2				1			1		0.00	0		
Cynoglossum officinale	X		0.13	1	1								0.50	1	1	
Verbascum thapsus	X		0.13	1				1					0.50	1		1
Melilotus sp.	X		0.13	1						1			0.50	1		1
Trifolium hybridum	X		0.13	1	1								0.00	0		
Sonchus uliginosus/S. asper	X		0.13	1		1							0.00	0		
Melilotus officinalis	X		0.13	1			1						0.00	0		
Cirsium vulgare	X		0.13	1				1					0.00	0		
Tragopogon dubius	X		0.13	1				1					0.00	0		
Euphorbia esula	X		0.13	1							1		0.00	0		
Polygonum convulvulus	X		0.13	1								1	0.00	0		
Centaurea maculosa	X		0.00	0									1.00	2	1	1
Artemisia biennis	X		0.00	0									0.50	1	1	
Salsola kali	X		0.00	0									0.50	1	1	
Smilacina stellata	N		1.00	8	1	1	1	1	1	1	1	1	0.00	0		
Solidago gigantea	N		0.75	6	1		1	1		1	1	1	0.00	0		
Glycyrrhiza lepidota	N		0.38	3			1		1	1			0.00	0		

Table 13. Vegetation of ungrazed P. angustifolia sites - releve and frequency data, cont'd.

FORBS, cont'd.					UCN	UEN	UEN2	UJN	UKN	UMN2	UNN	UNN2			UCN2	UEN3
Equisetum laevigatum	N		0.25	2		1	1						0.00	0		
Mentha arvensis	N		0.25	2				1			1		0.00	0		
Geum macrophyllum	N		0.25	2				1			1		0.00	0		
Urtica dioica	N		0.25	2							1	1	0.00	0		
Apocynum sibiricum	N		0.25	2							1	1	0.00	0		
Equisetum pratense	N		0.25	2							1	1	0.00	0		
Fragaria vesca	N		0.13	1	1								0.50	1	1	
Polygonum sp.	N		0.13	1	1								0.50	1		1
Achillea millefolium	N		0.13	1	1								0.00	0		
Equisetum sp.	N		0.13	1	1								0.00	0		
Vicia americana	N		0.13	1	1								0.00	0		
Iris missouriensis	N		0.13	1		1							0.00	0		
Plantago major	N		0.13	1				1					0.00	0		
Potentilla norvegica	N		0.13	1				1					0.00	0		
Galium aparine	N		0.13	1							1		0.00	0		
Potentilla gracilis	N		0.13	1								1	0.00	0		
Rudbeckia laciniata	N		0.13	1								1	0.00	0		
Oxytropis deflexa	N		0.00	0									0.50	1	1	
Average # of native forb spp		5.0			7	3	4	6	2	3	8	7			2	1
Average # of forb species		8.9			11	7	6	13	4	5	13	12			7	5
GRAMINOIDS																
Percent of non-native grass spp		68%			0.80	0.29	0.33	1.00	1.00	0.25	0.80	1.00			0.67	1.00
Avrg # of non-native grass spp		3.0			4	2	1	4	4	1	4	4			4	1
Poa pratensis	X		1.00	8	1	1	1	1	1	1	1	1	0.50	1	1	
Phalaris arundinacea	X		0.63	5		1		1	1		1	1	0.00	0		
Bromus inermis	X		0.50	4	1			1	1		1		0.50	1	1	
Elymus repens	X		0.25	2	1							1	1.00	2	1	1
Alopecurus arundinaceus	X		0.25	2	1							1	0.50	1	1	
Dactylis glomerata	X		0.25	2				1	1				0.00	0		
Agropyron cristatum	X		0.13	1							1		0.00	0		

Table 13. Vegetation of ungrazed P. angustifolia sites - releve and frequency data, cont'd.

GRAMINOIDS, cont'd.					UCN	UEN	UEN2	UJN	UKN	UMN2	UNN	UNN2			UCN2	UEN3
Elymus trachycaulus/A. sp.	N		0.38	3		1				1	1		0.00	0		
Agrostis stolonifera	N		0.25	2		1	1						0.50	1	1	
Elymus smithii	N		0.25	2		1	1						0.00	0		
Carex sp.	N		0.25	2		1				1			0.00	0		
Elymus canadensis	N		0.13	1						1			0.50	1	1	
Carex microptera	N		0.13	1	1								0.00	0		
Juncus balticus	N		0.13	1		1							0.00	0		
Avrg # of native grass species		1.5			1	5	2	0	0	3	1	0			2	0
Average # of grass species		4.5			5	7	3	4	4	4	5	4			6	1

Table 14. Vegetation of ungrazed Populus angustifolia (narrowleaf cottonwood) sites, releve and cover data. Species are in order by life form, and then by average cover.

Ungrazed Study Sites		Mature	UCN	UEN	UEN2	UJN	UKN	UMN2	UNN	UNN2	Young	UCN2	UEN3
Mile on river from Big Creek, MT			6	9	9	45	58	67	97	97		6	9
Percent cover of cow pies			0	0	0	0	0	0	0	0		0	0
Avrg DBH (cm), three largest trees			35	c 50	49	81	66	58	51	53		5	5
		AvCvr									AvCvr		
	StDev	Mature	Cover/Individual Site								Young	Cover/Site	
Avrg cvr of non-ntv spp	0.170	0.228	0.217	0.029	0.027	0.476	0.210	0.116	0.432	0.313	0.244	0.035	0.453
Avrg cover of species	0.258	1.680	1.150	1.650	1.695	1.901	2.046	1.682	1.627	1.688	0.821	0.544	1.098
% cvr of non-native spp	10%	14%	19%	2%	2%	25%	10%	7%	27%	19%	0.238	6%	41%
Native/Non-native		AvCvr									AvCvr		
TREES	*N/X*	Mature									Young		
Avrg cvr of non-ntv tree spp		0	0	0	0	0	0	0	0	0	0	0	0
Populus angustifolia	N	0.865	0.600	0.960	0.840	1.000	0.800	0.920	0.840	0.960	0.573	0.506	0.640
Fraxinus pennsylvanica	N	0.015							0.120		0.000		
Avrg cover of native tree spp		0.880	0.600	0.960	0.840	1.000	0.800	0.920	0.960	0.960	0.573	0.506	0.640
Avrg cover of tree species		0.880	0.600	0.960	0.840	1.000	0.800	0.920	0.960	0.960	0.573	0.506	0.640
SHRUBS													
% cvr of non-native shrub spp		0%	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0	0.000	0.000
Avrg cvr of non-ntv shrub spp		0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Symphoricarpos occidentalis	N	0.151	0.002	0.070		0.022	0.610	0.500	0.004		0.000		
Cornus stolonifera	N	0.102				0.201	0.081		0.207	0.326	0.000		
Juniperus scopulorum	N	0.096	0.013	0.342	0.412						0.000		
Rosa sayi/R. woodsii	N	0.049	0.003	0.034		0.032	0.210	0.111	0.001	0.004	0.000		
Rhus trilobata	N	0.019	0.030	0.096	0.022						0.000		
Shepherdia argentea	N	0.017	0.133								0.000		
Salix amygdaloides	N	0.015				0.120					0.000		
Ribes aureum	N	0.014		0.002			0.104		0.002		0.000		
Ribes setosum	N	0.005		0.003		0.016	0.020				0.000		

Table 14. Vegetation of ungrazed Populus angustifolia sites: releve and cover data, cont'd.

SHRUBS, cont'd.		Mature	UCN	UEN	UEN2	UJN	UKN	UMN2	UNN	UNN2	Young	UCN2	UEN3
Ribes hudsonianum	N	1E-04	0.001								0.000		
Prunus virginiana	N	1E-04					0.001				0.000		
Salix exigua	N	0									0.001		0.001
Avrg cover of ntv shrub spp		0.467	0.182	0.547	0.434	0.391	1.026	0.611	0.214	0.330	0.001	0.000	0.001
Avrg cover of shrub species		0.467	0.182	0.547	0.434	0.391	1.026	0.611	0.214	0.330	0.001	0.000	0.001
FORBS													
% cover non-native forb spp		46%	0.057	0.037	0.010	0.871	0.901	0.508	0.857	0.462	71%	1.000	0.429
Avrg cover of non-ntv forb spp		0.063	0.009	0.001	0.002	0.230	0.091	0.033	0.066	0.073	0.005	0.006	0.003
Cirsium arvense	X	0.040	0.006			0.058	0.090	0.032	0.062	0.070	0.001		0.002
Arctium minus	X	0.013				0.100				0.002	0.000		
Tanacetum vulgare	X	0.009				0.070					0.000		
Taraxacum officinale	X	0.001	0.001	0.001	0.002		0.001		0.002	0.001	0.001	0.001	
Centaurea maculosa	X	0									0.003	0.005	
Conium maculatum	X	3E-04				0.001			0.001		0.000		
Melilotus sp.	X	1E-04						0.001			0.001		0.001
Trifolium hybridum	X	1E-04	0.001								0.000		
Tragopogon dubius	X	1E-04				0.001					0.000		
Euphorbia esula	X	1E-04							0.001		0.000		
Cynoglossum officinale	X	1E-04	0.001								0.000		
Smilacina stellata	N	0.023	0.142	0.025	0.003	0.003	0.006	0.003	0.001		0.000		
Glycyrrhiza lepidota	N	0.022			0.152		0.004	0.017			0.000		
Solidago gigantea	N	0.012	0.003		0.042	0.030		0.012	0.004	0.001	0.000		
Apocynum sibiricum	N	0.005								0.041	0.000		
Rudbeckia laciniata	N	0.005								0.036	0.000		
Equisetum pratense	N	9E-04							0.003	0.004	0.000		
Polygonum sp.	N	1E-04	0.001								0.002		0.004
Urtica dioica	N	4E-04								0.003	0.000		

Table 14. Vegetation of ungrazed Populus angustifolia sites: releve and cover data, cont'd.

FORBS, cont'd.		Mature	UCN	UEN	UEN2	UJN	UKN	UMN2	UNN	UNN2	Young	UCN2	UEN3
Equisetum laevigatum	N	3E-04		0.001	0.001						0.000		
Achillea millefolium	N	1E-04	0.001								0.000		
Equisetum sp.	N	1E-04	0.001								0.000		
Vicia americana	N	1E-04	0.001								0.000		
Mentha arvensis	N	1E-04							0.001		0.000		
Geum macrophyllum	N	1E-04							0.001		0.000		
Galium aparine	N	1E-04							0.001		0.000		
Plantago major	N	1E-04				0.001					0.000		
Avrg cover of ntv forb species		0.068	0.149	0.026	0.198	0.034	0.010	0.032	0.011	0.085	0.002	0.000	0.004
Avrg cover of forb species		0.131	0.158	0.027	0.200	0.264	0.101	0.065	0.077	0.158	0.007	0.006	0.007
GRMINOIDS													
% cvr of non-ntv grmnd spp		79%	0.990	0.241	0.113	1.000	1.000	0.965	0.973	1.000	95%	0.906	1.000
Avrg cvr of non-ntv gram. spp		0.164	0.208	0.028	0.025	0.246	0.119	0.083	0.366	0.240	0.240	0.029	0.450
Phalaris arundinacea	X	0.053				0.214	0.001		0.078	0.130	0.000		
Poa pratensis	X	0.049	0.114	0.028	0.025	0.018	0.001	0.083	0.112	0.014	0.006	0.011	
Bromus inermis	X	0.046	0.090			0.010	0.090		0.174		0.005	0.009	
Elymus repens	X	0.013	0.004							0.096	0.229	0.008	0.450
Dactylis glomerata	X	0.004				0.004	0.027				0.000		
Agropyron cristatum	X	3E-04							0.002		0.000		
Alopecurus arundinaceus	X	0									0.001	0.001	
Agrostis stolonifera	N	0.028		0.080	0.144						0.001	0.001	
Elymus smithii	N	0.007		0.004	0.052						0.000		
Elymus trachycaulus/E. sp.	N	0.002						0.002	0.010		0.000		
Juncus balticus	N	5E-04		0.004							0.000		
Carex microptera	N	3E-04	0.002								0.000		
Elymus canadensis	N	0									0.001	0.002	
Carex sp.	N	1E-04						0.001			0.000		
Avrg cvr of ntv graminoid spp.		0.037	0.002	0.088	0.196	0.000	0.000	0.003	0.010	0.000	0.002	0.003	0.000
Avrg cover of graminoid spp		0.202	0.210	0.116	0.221	0.246	0.119	0.086	0.376	0.240	0.241	0.032	0.450

Table 15. Vegetation of ungrazed *Populus deltoides (*Plains cottonwood) sites: releve and frequency data.
Species grouped by life form, then in order by constancy.

Ungrazed Study Sites				Mature	UOP	UPP	URP	URP2	USP	USP2	UVP	UWP	UWP2	UXP	UYP	UZP	UZP2	U1P	U1P2	U2P2	U4P	U2P
Mile on river from Big Creek, MT					103	144	194	194	203	203	252	259	259	308	361	372	372	479	479	492	510	492
Percent cover cow pies					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Diameter at breast height (cm), 3 largest trees					82	72	76	65	33	112	54	40	56	50	38	44	41	71	75	36	73	2
		Avrg	Stnd																			
Species Richness		#/site	Dev		Number of species at each site																	
Avrg # of non-native species		8.3	3.4		10	14	15	13	10	10	5	5	7	10	7	6	6	6	6	3	8	9
Avrg # of species		19.4	6.6		19	33	23	25	29	19	15	13	11	28	14	16	14	20	17	10	23	15
% non-native species		43%	11%		53%	42%	65%	52%	34%	53%	33%	38%	64%	36%	50%	38%	43%	30%	35%	30%	35%	60%
Species Constancy & Frequency																						
Native/Non-native		Avrg	Con-	Sum	Presence/absence of species per site																	
TREES	N/X	#/site	stancy	Freq																		
Avrg # of non-native tree spp		*0*			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Populus deltoides	N		1.00	17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fraxinus pennsylvanica	N		0.47	8							1			1	1	1	1	1		1	1	
Avrg # of native tree species		1.5			1	1	1	1	1	1	2	1	1	2	2	2	2	2	1	2	2	1
Avrg number of tree species		1.5			1	1	1	1	1	1	2	1	1	2	2	2	2	2	1	2	2	1
SHRUBS																						
Percent of non-ntv shrub spp		25%			0.00	0.13	0.33	0.22	0.18	0.13	0.00	0.25	1.00	0.13	0.50	0.50	0.50	0.10	0.00	0.20	0.11	0.5
Avrg # of non-native shrub spp		1.0			0	1	2	2	2	1	0	1	1	1	1	1	1	1	0	1	1	1
Elaeagnus angustifolia	X		0.76	13		1	1	1	1			1	1	1	1	1	1	1		1	1	1
Artemisia absinthium	X		0.24	4			1	1	1	1												
Symphoricarpos occidentalis	N		0.59	10		1	1	1		1	1			1		1		1	1		1	
Rosa sayi/R. woodsii	N		0.53	9	1			1		1		1		1	1		1	1			1	
Vitaceae Vitis riparia	N		0.47	8		1			1	1	1			1				1		1	1	1
Clematis ligusticifolia	N		0.41	7		1	1	1	1	1				1						1		
Toxicodendron rydbergii	N		0.41	7						1	1			1				1	1	1	1	
Cornus stolonifera	N		0.35	6					1	1	1	1						1			1	

Table 15. Vegetation of ungrazed *Populus deltoides* sites: releve and frequency data, cont'd.

SHRUBS, cont'd.					UOP	UPP	URP	URP2	USP	USP2	UVP	UWP	UWP2	UXP	UYP	UZP	UZP2	U1P	U1P2	U2P2	U4P	U2P
Shepherdia argentea	N		0.29	5		1		1	1									1			1	
Ribes aureum	N		0.29	5			1	1	1	1				1								
Salix amygdaloides	N		0.24	4	1	1			1			1										
Prunus virginiana	N		0.24	4		1			1									1	1			
Rhus trilobata	N		0.18	3		1		1											1			
Juniperus scopulorum	N		0.18	3			1	1						1								
Ribes setosum	N		0.18	3					1									1			1	
Parthenocissus inserta	N		0.18	3														1		1	1	
Salix exigua	N		0.06	1					1													1
Artemisia dracunculus	N		0.06	1															1			
Artemisia cana	N		0.06	1															1			
Artemisia frigida	N		0.06	1															1			
Avrg # of native shrub species		4.8			2	7	4	7	9	7	4	3	0	7	1	1	1	9	7	4	8	2
Avrg number of shrub species		5.8			2	8	6	9	11	8	4	4	1	8	2	2	2	10	7	5	9	3
FORBS, cont'd.																						
Percent of non-ntv forb spp		53%			0.64	0.50	0.75	0.73	0.36	0.86	0.33	0.20	0.67	0.47	0.50	0.40	0.67	0.50	0.50	0.50	0.50	0.57
Avrg # of non-native forb spp		4.3			7	9	9	8	4	6	1	1	2	7	4	2	2	3	2	1	5	4
Taraxacum officinale	X		0.65	11	1	1	1	1	1	1	1		1	1				1			1	
Medicago lupulina	X		0.59	10		1	1	1	1					1		1	1	1	1	1		1
Cirsium arvense	X		0.35	6	1	1			1	1					1						1	
Solanum dulcamara	X		0.29	5			1	1						1	1						1	
Arctium minus	X		0.24	4	1	1				1				1								
Melilotus officinalis	X		0.24	4		1				1								1			1	1
Melilotus alba	X		0.18	3	1	1			1													
Euphorbia esula	X		0.18	3	1	1													1			1
Nepeta cataria	X		0.18	3			1	1		1												
Sonchus uliginosus/S. asper	X		0.18	3			1	1													1	
Chenopodium album	X		0.18	3				1						1	1							1
Cynoglossum officinale	X		0.18	3						1				1	1							

Table 15. Vegetation of ungrazed *Populus deltoides* sites: releve and frequency data, cont'd.

FORBS, cont'd.					UOP	UPP	URP	URP2	USP	USP2	UVP	UWP	UWP2	UXP	UYP	UZP	UZP2	U1P	U1P2	U2P2	U4P	U2P
Tanacetum vulgare	X		0.12	2	1	1																
Verbascum thapsus	X		0.12	2		1	1															
Sisymbrium loeselii	X		0.12	2			1	1														
Asparagus officinalis	X		0.12	2								1	1									
Melilotus sp.	X		0.12	2												1	1					
Centaurea maculosa	X		0.06	1	1																	
Cirsium vulgare	X		0.06	1			1															
Salsola kali	X		0.06	1			1															
Conium maculatum	X		0.06	1				1														
Polygonum convulvulus	X		0.06	1										1								
Apocynum sibiricum	N		0.59	10	1					1	1	1		1	1	1		1		1	1	
Smilacina stellata	N		0.41	7	1	1					1	1		1				1			1	
Glycyrrhiza lepidota	N		0.29	5	1							1		1	1	1						1
Solidago gigantea	N		0.24	4	1	1			1						1							
Asclepias speciosa	N		0.24	4		1						1	1				1					
Galium aparine	N		0.24	4			1	1						1							1	
Parietaria pensylvanica	N		0.18	3			1	1						1								
Plantago major	N		0.12	2		1			1													
Solidago occidentalis	N		0.12	2		1			1													
Equisetum hyemale	N		0.12	2		1			1													
Aster ascendens	N		0.12	2		1										1						
Violaceae Viola sp.	N		0.12	2			1							1								
Ambrosia psilostachya	N		0.12	2					1										1			
Solidago mollis	N		0.06	1		1																
Equisetum variegatum	N		0.06	1		1																
Rumex salicifolius	N		0.06	1				1														
Equisetum laevigatum	N		0.06	1					1													
Mentha arvensis	N		0.06	1					1													
Lactuca pulchella	N		0.06	1										1								
Solanum sarrachoides	N		0.06	1										1								

Table 15. Vegetation of ungrazed *Populus deltoides* sites: releve and frequency data, cont'd.

FORBS, cont'd.					UOP	UPP	URP	URP2	USP	USP2	UVP	UWP	UWP2	UXP	UYP	UZP	UZP2	U1P	U1P2	U2P2	U4P	U2P
Polygonum sp.	N		0.06	1											1							
Lysimachia ciliata	N		0.06	1														1				
Asclepias verticillata	N		0.06	1															1			
Anemone sp.	N		0.06	1																	1	
Lonicera sp.	N		0.06	1																	1	
Polygonum lapathifolium	N		0.00	0																		1
Xanthium strumarium	N		0.00	0																		1
Avrg # of native forb species		3.6			4	9	3	3	7	1	2	4	1	8	4	3	1	3	2	1	5	3
Avrg number of forb species		7.9			11	18	12	11	11	7	3	5	3	15	8	5	3	6	4	2	10	7
GRAMINOIDS																						
% of non-ntv grass spp		78%			0.60	0.67	1.00	0.75	0.67	1.00	0.67	1.00	0.67	0.67	1.00	0.43	0.43	1.00	0.80	1.00	1.00	1
Avrg # of non-native grass spp		3.0			3	4	4	3	4	3	4	3	4	2	2	3	3	2	4	1	2	4
Poa pratensis	X		0.76	13	1	1	1	1		1	1		1	1		1	1	1	1		1	1
Bromus inermis	X		0.76	13	1	1			1		1	1	1		1	1	1	1	1	1	1	1
Agropyron repens	X		0.59	10		1	1		1	1	1	1	1			1	1		1			1
Phalaris arundinacea	X		0.53	9	1	1	1	1	1	1	1	1			1							1
Alopecurus arundinaceus	X		0.18	3			1		1					1								
Festuca arundinacea	X		0.06	1				1														
Dactylis glomerata	X		0.06	1									1									
Poa compressa	X		0.06	1															1			
Agrostis stolonifera	N		0.24	4	1			1	1					1								
Elymus canadensis	N		0.24	4							1		1			1	1					
Elymus trachycaulus/E. sp.	N		0.18	3	1											1	1					
Cyperaceae Carex sp.	N		0.18	3		1			1		1											
Calamovilfa longifolia	N		0.18	3												1	1		1			
Muhlenbergia racemosa	N		0.12	2		1											1					
Elymus lanceolatus	N		0.06	1									1									
Spartina pectinata	N		0.06	1												1						
Avrg # of native grass species		1.2			2	2	0	1	2	0	2	0	2	1	0	4	4	0	1	0	0	0
Avrg number of grass species		4.2			5	6	4	4	6	3	6	3	6	3	2	7	7	2	5	1	2	4

Table 16. Vegetation of ungrazed Populus deltoides (Plains cottonwood) sites; releve and cover data.
Species are in order by life form, then by average cover.

Ungrazed Study Sites			UOP	UPP	URP	URP2	USP	USP2	UVP	UWP	UWP2	UXP	UYP	UZP	UZP2	U1P	U1P2	U2P2	U4P	U2P
Mile on river from Big Creek, MT			103	144	194	194	203	203	252	259	259	308	361	372	372	479	479	492	510	492
Percent cover cow pies			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DBH (cm), 3 largest trees	Avrg:	60	82	72	76	65	33	112	54	40	56	50	38	44	41	71	75	36	73	2
	StDev	AvCvr	Cover/Individual Site																	
Average cover of non-ntv spp	0.207	0.423	0.34	0.42	0.80	0.67	0.24	0.18	0.44	0.54	0.65	0.28	0.47	0.68	0.13	0.12	0.32	0.60	0.32	0.12
Average cover of species	0.301	1.563	1.65	1.63	1.43	2.11	1.22	2.14	1.46	1.15	1.38	1.53	1.41	1.84	1.35	1.67	1.11	1.65	1.85	1.05
% cover non-native species	14%	28%	0.20	0.26	0.56	0.32	0.20	0.09	0.30	0.47	0.47	0.18	0.33	0.37	0.10	0.07	0.29	0.36	0.17	0.11
Native/Non-native		AvCvr																		
TREES	N/X	ALL																		
Avrg cover of non-ntv tree spp		0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Populus deltoides	N	0.802	1.00	0.96	0.12	0.84	0.80	1.00	0.96	0.51	0.72	0.96	0.92	1.00	1.00	0.52	0.44	0.92	0.96	0.93
Fraxinus pennsylvanica	N	0.012							0.01			0.01			0.00	0.15		0.00	0.02	
Average cover of ntv tree spp		0.813	1.00	0.96	0.12	0.84	0.80	1.00	0.97	0.51	0.72	0.97	0.92	1.00	1.00	0.67	0.44	0.92	0.98	0.93
Average cover of tree spp		0.813	1.00	0.96	0.12	0.84	0.80	1.00	0.97	0.51	0.72	0.97	0.92	1.00	1.00	0.67	0.44	0.92	0.98	0.93
SHRUBS																				
% cover of non-ntv shrub spp		42%	0.00	0.59	0.60	0.43	0.03	0.02	0.00	0.65	1.00	0.38	1.00	1.00	1.00	0.11	0.00	0.00	0.26	
Avrg cvr of non-ntv shrub spp		0.152	0.00	0.21	0.63	0.44	0.00	0.02	0.00	0.16	0.12	0.15	0.14	0.36	0.05	0.11	0.00	0.00	0.19	0.00
Elaeagnus angustifolia	X	0.1495		0.21	0.63	0.43	0.00			0.16	0.12	0.15	0.14	0.36	0.05	0.11			0.19	0.00
Artemisia absinthium	X	0.0022				0.02	0.00	0.02												
Toxicodendron rydbergii	N	0.0784						0.57	0.00			0.16				0.27	0.03	0.01	0.29	
Symphoricarpos occidentalis	N	0.0472			0.00	0.06		0.22	0.02			0.01		0.00		0.23	0.17		0.09	
Juniperus scopulorum	N	0.0392			0.41	0.26														
Rosa sayi/R. woodsii	N	0.0152	0.02			0.04		0.08		0.01						0.09			0.02	
Vitis riparia	N	0.0124					0.00	0.00	0.01			0.00				0.16		0.00	0.03	0.00
Cornus stolonifera	N	0.0108					0.00	0.02	0.00							0.08			0.08	
Rhus trilobata	N	0.0106		0.06		0.02											0.10			
Shepherdia argentea	N	0.0084		0.08		0.06	0.00												0.00	
Clematis ligusticifolia	N	0.0081			0.00	0.05	0.01	0.00				0.06						0.01		

Note: An entry of "0.00" for cover means there was cover present, but it was less than 0.005 (0.5%) for that site.

Table 16. Vegetation of ungrazed Populus deltoides sites: releve and cover data, cont'd.

SHRUBS, cont'd.			UOP	UPP	URP	URP2	USP	USP2	UVP	UWP	UWP2	UXP	UYP	UZP	UZP2	U1P	U1P2	U2P2	U4P	U2P
Salix amygdaloides	N	0.0077	0.03	0.00			0.02			0.08										
Parthenocissus inserta	N	0.0072														0.01		0.10	0.01	
Ribes aureum	N	0.0069			0.01	0.10	0.00	0.01												
Salix exigua	N	0.0038					0.06													0.00
Artemisia dracunculus	N	0.0024															0.04			
Ribes setosum	N	0.0012					0.00									0.01			0.01	
Prunus virginiana	N	0.0006		0.00												0.01	0.00			
Solanum sarrachoides	N	0.0005										0.01								
Artemisia frigida	N	6E-05															0.00			
Avrg cover of native shrub spp		0.261	0.04	0.14	0.42	0.59	0.10	0.90	0.04	0.09	0.00	0.24	0.00	0.00	0.00	0.86	0.34	0.13	0.53	0.00
Average cover of shrub spp		0.412	0.04	0.35	1.05	1.03	0.11	0.92	0.04	0.25	0.12	0.40	0.14	0.36	0.05	0.97	0.34	0.13	0.72	0.00
FORBS																				
% cover of non-ntv forb spp		32%	0.40	0.42	0.14	0.80	0.44	0.73	0.00	0.00	0.07	0.73	0.14	0.00	0.86	0.10	0.17	0.00	0.44	
Avrg cover of non-ntv forb spp		0.022	0.01	0.07	0.01	0.00	0.01	0.14	0.00	0.00	0.00	0.10	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.11
Euphorbia esula	X	0.004		0.06																0.11
Arctium minus	X	0.006	0.00					0.11				0.00								
Solanum dulcamara	X	0.006			0.00							0.09	0.00							
Cirsium arvense	X	0.003	0.01	0.00			0.00	0.03											0.01	
Taraxacum officinale	X	0.001		0.00	0.00	0.00	0.00				0.00	0.00							0.01	
Melilotus officinalis	X	0.000		0.00				0.00								0.00				0.00
Medicago lupulina	X	0.000		0.00								0.00			0.00	0.00	0.00			0.00
Melilotus alba	X	0.000	0.00				0.01													
Melilotus sp.	X	0.000													0.01					
Nepeta cataria	X	0.000			0.01															
Verbascum thapsus	X	0.000		0.00	0.00															
Chenopodium album	X	0.000				0.00						0.00	0.00							0.00
Sonchus uliginosus/asper	X	0.000			0.00	0.00													0.00	
Tanacetum vulgare	X	0.000	0.00	0.00																
Cirsium vulgare	X	0.000			0.00															
Sisymbrium loeselii	X	0.000			0.00	0.00														
Polygonum convulvulus	X	0.000										0.00								

Table 16. Vegetation of ungrazed Populus deltoides sites: releve and cover data, cont'd.

FORBS, cont'd.			UOP	UPP	URP	URP2	USP	USP2	UVP	UWP	UWP2	UXP	UYP	UZP	UZP2	U1P	U1P2	U2P2	U4P	U2P
Cynoglossum officinale	X	0.000											0.00							
Parietaria pensylvanica	N	0.005			0.08							0.00								
Solidago mollis	N	0.005		0.08																
Apocynum sibiricum	N	0.005	0.00					0.05	0.01	0.00		0.01		0.00		0.01		0.00		
Smilacina stellata	N	0.003	0.00	0.00						0.00		0.02				0.00			0.01	
Glycyrrhiza lepidota	N	0.002	0.02							0.01			0.01							0.00
Solidago gigantea	N	0.001		0.00			0.00						0.02							
Asclepias speciosa	N	0.001		0.00						0.00	0.01				0.00					
Anemone sp.	N	0.001																	0.01	
Galium aparine	N	0.000			0.00	0.00						0.00							0.00	
Aster ascendens	N	0.000		0.01										0.00						
Asclepias verticillata	N	0.000															0.00			
Solidago occidentalis	N	0.000		0.00			0.00													
Equisetum hyemale	N	0.000		0.00			0.00													
Violaceae Viola sp.	N	0.000			0.00							0.00								
Ambrosia psilostachya	N	0.000					0.00										0.00			
Lonicera sp.	N	0.000																	0.00	
Equisetum variegatum	N	0.000		0.00																
Mentha arvensis	N	0.000					0.00													
Polygonum lapathifolium	N	0.000																		0.00
Polygonum sp.	N	0.000											0.00							
Lysimachia ciliata	N	0.000														0.00				
Plantago major	N	0.000					0.00													
Xanthium strumarium	N	0.000																		0.00
Average cover of ntv forb spp		0.024	0.02	0.10	0.09	0.00	0.01	0.05	0.01	0.01	0.01	0.04	0.03	0.00	0.00	0.01	0.01	0.00	0.02	0.00
Average cover of forb spp		0.046	0.03	0.17	0.10	0.01	0.02	0.19	0.01	0.01	0.01	0.14	0.03	0.00	0.01	0.01	0.01	0.00	0.04	0.11

Table 16. Vegetation of ungrazed Populus deltoides sites: releve and cover data, cont'd.

GRAMINOIDS, cont'd.			UOP	UPP	URP	URP2	USP	USP2	UVP	UWP	UWP2	UXP	UYP	UZP	UZP2	U1P	U1P2	U2P2	U4P	U2P
% cover of non-ntv grass spp		89%	0.56	0.99	1.00	0.94	0.78	1.00	1.00	1.00	1.00	0.97	1.00	0.68	0.26	1.00	0.98	1.00	1.00	
Avrg cvr of non-ntv grass spp		0.250	0.33	0.14	0.16	0.23	0.23	0.03	0.44	0.38	0.53	0.03	0.32	0.33	0.08	0.02	0.32	0.60	0.11	0.01
Bromus inermis	X	0.147	0.31	0.00					0.26	0.26	0.10		0.32	0.32	0.06	0.01	0.15	0.60	0.11	0.00
Poa pratensis	X	0.043	0.01	0.11	0.02	0.22		0.00	0.00		0.18	0.03		0.00	0.01	0.01	0.13		0.00	0.01
Elymus repens	X	0.040		0.01	0.12		0.10	0.01	0.07	0.12	0.24				0.01					0.00
Phalaris arundinacea	X	0.017	0.01	0.01	0.01	0.00	0.14	0.01	0.10	0.00										0.00
Poa compressa	X	0.002															0.04			
Alopecurus arundinaceus	X	0.000			0.00															
Festuca arundinacea	X	0.000				0.00														
Elymus trachycaulus/E. sp.	N	0.018	0.25			0.00								0.03	0.02					
Elymus canadensis	N	0.013							0.00		0.00			0.03	0.19					
Calamovilfa longifolia	N	0.006												0.09	0.00		0.01			
Agrostis stolonifera	N	0.005	0.00			0.01	0.07					0.00								
Muhlenbergia racemosa	N	0.000													0.00					
Cyperaceae Carex sp.	N	0.000		0.00			0.00													
Spartina pectinata	N	0.000												0.00						
Average cover of ntv grass spp		0.042	0.25	0.00	0.00	0.01	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.22	0.00	0.01	0.00	0.00	0.00
Average cover of grass spp		0.292	0.58	0.14	0.16	0.24	0.30	0.03	0.44	0.38	0.53	0.03	0.32	0.48	0.29	0.02	0.32	0.60	0.11	0.01

Table 17. Comparison of cover, richness and percent non-native species across ungrazed riparian plant communities.

Vegetation Type	Tree		Shrub				Forb				Graminoid			
	X*	Total	% Non Ntv	# Non Ntv	# Ntv	Total #	% Non Ntv	# Non Ntv	# Ntv	Total #	% Non Ntv	# Non Ntv	# Ntv	Total #
Gravelbar (n = 14)														
Richness/all sites	0	2	33%	2	4	6	47%	27	30	57	64%	16	9	25
Richness/each site	0	1.0	15%	0.3	1.2	1.5	57%	5.1	4.7	9.8	36%	2.5	2.9	5.4
Cover	0	0.035	15%	0.007	0.058	0.064	56%	0.019	0.011	0.030	44%	0.020	0.010	0.030
Sandbar (n = 8)														
Richness/all sites	0	2	50%	2	2	4	48%	34	37	71	36%	10	18	28
Richness/each site	0	0.8	35%	0.6	1.2	1.8	45%	8.6	8.5	17.1	44%	2.1	3.4	5.5
Cover	0	0.003	28%	0.008	0.092	0.100	38%	0.065	0.096	0.161	41%	0.052	0.070	0.122
Salix exigua (n = 22)														
Richness/all sites	0	3	14%	3	18	21	39%	29	46	75	33%	11	22	33
Richness/each site	0	0.6	10%	0.5	4.2	4.7	59%	6.4	5.1	11.5	58%	2.7	2.4	5.1
Cover	0	0.017	2%	0.015	0.632	0.647	70%	0.133	0.039	0.172	73%	0.246	0.063	0.309
Populus angustifolia (n = 8)														
Richness/all sites	0	2	0%	0	13	13	46%	18	21	39	50%	7	7	14
Richness/each site	0	1.1	0%	0	5.3	5.3	44%	3.9	5	8.9	68%	3.0	1.5	4.5
Cover	0	0.88	0%	0	0.467	0.467	46%	0.063	0.068	0.131	79%	0.164	0.038	0.202
Populus deltoides (n = 17)														
Richness/all sites	0	2	10%	2	18	20	47%	22	25	47	50%	8	8	16
Richness/each site	0	1.5	25%	1.0	4.8	5.8	53%	4.3	3.6	7.9	78%	3.0	1.2	4.2
Cover	0	0.813	42%	0.152	0.261	0.412	32%	0.022	0.024	0.046	89%	0.250	0.042	0.292
All Communities														
Richness/all sites	0	3	11%	3	24	27	39%	49	78	127	27%	15	40	55

* No non-native tree species were found. *Elaeagnus angustifolia* was classified as a shrub, per the USDA on-line plants database.

Table 17. Comparison of cover, richness and percent non-native species across ungrazed riparian plant communities, cont'd.

Vegetation Type	SUMMARY						
	% Non Ntv	*St Dev*	# Non Ntv	*St Dev*	# Ntv	Total #	*St Dev*
Gravelbar (n = 14)							
Richness/all sites	50%	*N/A*	45	*N/A*	45	90	*N/A*
Richness/each site	46%	*13%*	7.9	*5.6*	9.7	17.6	*12*
Cover	34%	*35%*	0.046	*0.047*	0.113	0.159	*0.087*
Sandbar (n = 8)							
Richness/all sites	44%	*N/A*	46	*N/A*	59	105	*N/A*
Richness/each site	43%	*16%*	11.3	*6.9*	13.9	25.2	*8.3*
Cover	31%	*28%*	0.125	*0.199*	0.261	0.386	*0.245*
Salix exigua (n = 22)							
Richness/all sites	33%	*N/A*	43	*N/A*	89	132	*N/A*
Richness/each site	46%	*13%*	9.6	*2.9*	12.3	22	*7.3*
Cover	35%	*20%*	0.394	*0.243*	0.72	1.114	*0.309*
Populus angustifolia (n = 8)							
Richness/all sites	37%	*N/A*	25	*N/A*	43	68	*N/A*
Richness/each site	34%	*8%*	6.9	*2.9*	12.9	19.8	*5.9*
Cover	14%	*10%*	0.227	*0.17*	1.453	1.680	*0.258*
Populus deltoides (n = 17)							
Richness/all sites	38%	*N/A*	32	*N/A*	53	85	*N/A*
Richness/each site	43%	*11%*	8.3	*3.4*	11.1	19	*6.6*
Cover	28%	*14%*	0.424	*0.207*	1.139	1.563	*0.301*
All Communities							
Richness/all sites	33%	*N/A*	68	*N/A*	139	207	*N/A*

Table 18. Species occurring with 20% or less constancy, across ungrazed riparian plant communities.

Plant community	Number of low constancy species	Total # of species	% low constancy
Gravelbars	54	91	59%
Sandbars	56	105	53%
Salix exigua	102	130	78%
P. angustifolia	30	68	44%
P. deltoides	53	85	62%
Average, all plant communities:			59.5%

Plant community	Origin	Trees	Shrubs	Forbs	Gramnds	TOTALS	Percent low constancy which are non-native	% of spp in veg type which are non-native
	Native	0	2	20	9	31		
Gravelbars	Non-Native	0	1	20	2	23	43	50%
	Native	0	0	17	16	33		
Sandbars	Non-Native	0	1	16	6	23	41	44%
	Native	3	12	40	19	73		
Salix exigua	Non-Native	0	1	19	8	28	28	33%
	Native	1	4	11	3	19		
P. angustifolia	Non-Native	0	0	10	1	11	37	37%
	Native	0	8	19	6	33		
P. deltoides	Non-Native	0	0	16	4	20	38	38%

Table 19. Non-native species found in riparian plant communities, both ungrazed and grazed sites. Grouped by families.

Scientific name	Common name	UM*	FPNW	USDA
Asteraceae Sonchus uliginosus (Bieb.)/S. asper (L.) Hill	Marsh Sow Thistle	N/X**	X/X	X/X
Amaranthaceae Amaranthus blitoides S. Wats.	Prostrate Pigweed	N	N	X
Amaranthaceae Amaranthus retroflexus L.	Pigweed amaranth; rough pigweed	N	N	X
Apiaceae Conium maculatum L.	Poison Hemlock	X	X	X
Apiaceae Heracleum sphondylium L.	Cow Parsnip	N	0	X
Asteraceae Arctium minus Bernh.	Common Burdock	X	X	X
Asteraceae Artemisia absinthium L.	Sageweed; Absinthium	X	X	X
Asteraceae Artemisia biennis Willd.	Biennial Wormweed	N	N	X
Asteraceae Centaurea maculosa auct. non Lam.	Spotted Knapweed	X	X	X
Asteraceae Cirsium arvense (L.) Scop.	Canada Thistle	X	X	X
Asteraceae Cirsium vulgare (Savi) Ten.	Bull Thistle	X	X	X
Asteraceae Filago arvensis L.	Fluffweed	X	X	X
Asteraceae Lactuca serriola L.	Prickly Lettuce	X	X	X
Asteraceae Tanacetum vulgare L.	Common Tansy	X	X	X
Asteraceae Taraxacum officinale G. H. Weber ex Wiggers	Common Dandelion	X	X	X
Asteraceae Tragopogon dubius Scop.	Goatsbeard	X	X	X
Boraginaceae Asperugo procumbens L.	Catchweed	X	X	X
Boraginaceae Cynoglossum officinale L.	European Hound's Tongue	X	X	X
Brassicaceae Alyssum alyssoides (L.) L.	Alyssum	X	X	X
Brassicaceae Brassica rapa L.	Field Mustard	X	X	X
Brassicaceae Camelina microcarpa DC.	Hairy False Flax	X	X	X
Brassicaceae Capsella bursa-pastoris (L.) Medik.	Shepherd's Purse	X	X	X
Brassicaceae Descurainia sophia(L.) Webb ex Prantl	Flixweed	X	X	X
Brassicaceae Erysimum repandum L.	Bushy wallflower	X		X
Brassicaceae Lepidium campestre (L.) R. Br.	Field Pepper Grass	X	X	X
Brassicaceae Lepidium perfoliatum L.	Clasping Pepper Grass	X	X	X

* UM = http://invader.dbs.umt.edu (Univ. of Montana)
USDA = http://plants.usda.gov (US Dept of Agriculture)
FPNW = Flora of the Pacific Northwest (Hitchcock & Cronquist 1973)

** N = native, X = non-native (exotic), 0 = no data, both = depends on species or sub-species

Table 19. Non-native species found in riparian plant communities, both ungrazed and grazed sites, cont'd.

Brassicaceae Sisymbrium altisssimum L.	Tall tumblemustard	X		X
Brassicaceae Sisymbrium loeselii L.	Tumble Mustard	X	X	X
Brassicaceae Thlaspi arvense L.	Pennycress	X	X	X
Caryophyllaceae Lychnis alba P. Mill.	White Campion	N	X	X
Caryophyllaceae Silene noctiflora L.	Bladder Flower Plant	X	N	X
Caryophyllaceae Stellaria media (L.) Vill.	Chickweed	X	X	X
Chenopodiaceae Atriplex heterosperma Bunge	Saltbush	X	X	X
Chenopodiaceae Chenopodium album L. var. album	Lamb's Quarter; White goosefoot	X	N	X
Chenopodiaceae Chenopodium botrys L.	Jerusalem-Oak Goosefoot	X	X	X
Chenopodiaceae Chenopodium glaucum L.	Oakleaf Goosefoot	X	N	X
Chenopodiaceae Kochia scoparia (L.) Schrad.	Kochia; Summer Cypress	X	X	X
Chenopodiaceae Salsola kali L.	Russian Thistle	X	X	X
Chenopodiaceae Spinacia oleracea?? L.	Spinach			X
Convolvulaceae Convolvulus arvensis L.	Field Bindweed	X	X	X
Elaeagnaceae Elaeagnus angustifolia L.	Russian Olive	X	X	X
Euphorbiaceae Euphorbia esula L.	Leafy Spurge	X	X	X
Fabaceae Medicago lupulina L.	Black Medic; Hop Clover	X	X	X
Fabaceae Melilotus alba Medikus	White Sweet Clover	X	X	X
Fabaceae Melilotus officinalis (L.) Lam.	Yellow Sweet Clover	X	X	X
Fabaceae Trifolium fragiferum L.	Strawberry Clover	X	X	X
Fabaceae Trifolium hybridum L.	Alsike Clover	X	X	X
Fabaceae Trifolium pratense L.	Red Clover	X	X	X
Fabaceae Trifolium repens L.	White Clover	X	X	X
Fumariaceae Fumaria officianalis L.	Fumitory	X	X	X
Juncaceae Juncus compressus Jacq.	Roundfruit Rush	N	N	X
Lamiaceae Galeopsis tetrahit L.	Hemp Nettle	X	X	X
Lamiaceae Glechoma hederocea (?) L.	Ground Ivy	X	X	X
Lamiaceae Nepeta cataria L.	Catnip	X	X	X
Liliaceae Asparagus officinalis L.	Wild Asparagus	X	X	X
Poaceae Agropyron cristatum (L.) Gaertn.	Crested Wheatgrass	X	X	X
Poaceae Alopecurus arundinaceus Poir.	Garrison Creeping Foxtail	X	0	X
Poaceae Bromus inermis Leyss. ssp. inermis	Smooth Bromegrass	X	X	X
Poaceae Bromus japonicus Thunb. ex Murr.	Japanese Bromegrass	X	X	X

Table 19. Non-native species found in riparian plant communities, both ungrazed and grazed sites, cont'd.

Poaceae Bromus mollis aunct. non L.	Soft brome	X	X	X
Poaceae Bromus tectorum L.	Cheatgrass	X	X	X
Poaceae Crypsis alopecuroides (Piller & Mitterp.) Schrad.	Lovegrass	X	0	X
Poaceae Dactylis glomerata L.	Orchard Grass	X	X	X
Poaceae Echinochloa crus-galli (L.) Beauv.	Barnyard Grass	X	N	X
Poaceae Elymus hispidus (Opiz) Melderis	Intermediate Wheatgrass	X	X	X
Poaceae Elymus repens (L.) Gould	Quackgrass	X	X	X
Poaceae Festuca arundinacea Schreb.	Tall Fescue	X	X	X
Poaceae Festuca pratensis Huds.	Meadow Fescue	X	X	X
Poaceae Phalaris arundinacea L.	Reed Canary Grass	X	X	N
Poaceae Phleum pratense L.	Timothy	X	X	X
Poaceae Poa compressa L	Canada Bluegrass	X	N	X
Poaceae Poa pratensis L.	Kentucky Bluegrass	X	X	N
Poaceae Poa sp. (probably pratensis)	Bluegrass	X	X	X
Poaceae Setaria glauca (L.) Beauv.	Yellow Bristlegrass or Foxtail	X	X	X
Poaceae Setaria viridis (L.) Beauv.	Green Bristlegrass or Foxtail	X	X	X
Polygonaceae Polygonum aviculare L.	Prostrate knotweed	N	N	X
Polygonaceae Polygonum convulvulus L.	Black Bindweed	X	X	X
Polygonaceae Rumex crispus L.	Curly Dock	X	X	X
Polygonaceae Rumex patientia L.	Patience Dock	X		
Polygonaceae Rumex stenophyllus Ledeb.	Narrowleaf Dock	N	0	X
Scrophulariaceae Linaria dalmatica (L.) P. Mill.	Dalmation Toad Flax	X	X	X
Scrophulariaceae Verbascum thapsus L.	Mullein	X	X	X
Solanaceae Hyoscyamus niger L.	Henbane	X	X	X
Solanaceae Solanum dulcamara L.	Climbing Nightshade	X	X	X
Tamaricaceae Tamarix chinensis Lour.	Salt Cedar; Tamarisk	X	X	X
Ulmaceae Ulmus pumila L.	Siberian Elm	X	X	X
Caprifoliaceae Lonicera sp.	Honeysuckle	N	N	both

Table 20. Number of plant communities in which each species occurs, segregated by native/non-native. Ungrazed sites only.

Totals: 139 native, 68 non-native, 207 spp total. 33% non-native.

Plant Life Form	Native/Exotic	Gravel	Sandbar	Salix exigua	P angustifolia	P deltoides	Number of Plant Cmmts	Average
Native Trees	N/X							
Fraxinus pennsylvanica	N			1	1	1	3	3.7
Populus angustifolia	N	1	1	1	1		4	
Populus deltoides	N	1	1	1		1	4	
Native Shrubs								
Amelanchier alnifolia	N	1		1			2	2.4
Artemisia cana	N					1	1	
Artemisia dracunculus	N					1	1	
Artemisia frigida	N					1	1	
Clematis ligusticifolia	N			1	1	1	3	
Cornus stolonifera	N			1	1	1	3	
Humulus lupulus	N			1			1	
Juniperus scopulorum	N			1	1	1	3	
Parthenocissus inserta	N			1		1	2	
Prunus virginiana	N			1	1	1	3	
Rhus trilobata	N			1	1	1	3	
Ribes aureum	N			1	1	1	3	
Ribes hudsonianum	N			1	1		2	
Ribes setosum	N			1	1	1	3	
Ribes sp.	N			1			1	
Rosa sayi/R. woodsii	N			1	1	1	3	
Salix amygdaloides	N	1	1	1	1	1	5	
Salix exigua	N	1	1	1	1	1	5	
Salix sp. (small leaved willow)	N			1			1	
Shepherdia argentea	N				1	1	2	
Symphoricarpos occidentalis	N			1	1	1	3	
Toxicodendron rydbergii	N			1		1	2	
Vitis riparia	N	1		1		1	3	
Non-Native Shrubs								
Artemisia absinthium	X			1		1	2	3.0
Elaeagnus angustifolia	X	1	1	1		1	4	
Tamarix chinensis	X	1	1	1			3	

Table 20. Number of plant communities in which each species occurs, cont'd.

Native Forbs	Native/Exotic	Gravel	Sandbar	Salix exigua	P angustifolia	P deltoides	Number of	Plant Cmmts	Average
Achillea millefolium	N		1	1	1			3	2.1
Agrimonia striata	N			1				1	
Amaranthus albus	N	1	1					2	
Ambrosia psilostachya	N		1	1		1		3	
Anemone sp.	N					1		1	
Apocynum sibiricum	N	1	1	1	1	1		5	
Arabis holboellii	N	1						1	
Asclepias speciosa	N		1	1		1		3	
Asclepias verticillata	N					1		1	
Aster ascendens	N	1		1		1		3	
Aster hesperius	N	1	1	1				3	
Aster subspicatus	N			1				1	
Cicuta douglasii	N		1	1				2	
Cirsium undulatum	N	1		1				2	
Conyza canadensis	N			1				1	
Epilobium paniculatum	N	1	1					2	
Equisetum arvense	N		1	1				2	
Equisetum hyemale	N			1		1		2	
Equisetum laevigatum	N	1	1	1	1	1		5	
Equisetum pratense	N				1			1	
Equisetum sylvaticum	N			1				1	
Equisetum variegatum	N	1	1	1		1		4	
Equisetum sp.	N				1			1	
Erysimum asperum	N		1					1	
Fragaria vesca	N				1			1	
Galium aparine	N			1	1	1		3	
Galium bifolium	N	1	1					2	
Geum macrophyllum	N			1	1			2	
Glycyrrhiza lepidota	N	1	1	1	1	1		5	
Gnaphalium palustre	N	1	1					2	
Helianthus annuus	N		1					1	
Heterotheca villosa	N			1				1	
Iris missouriensis	N			1	1			2	
Iva xanthifolia	N		1					1	
Lactuca pulchella	N					1		1	
Lonicera sp.	?					1		1	
Lycopus americanus	N			1				1	
Lysimachia ciliata	N			1		1		2	
Mentha arvensis	N	1	1	1	1	1		5	
Mimulus guttatus	N		1					1	
Oenethera villosa	N	1	1	1				3	
Oxytropis deflexa	N				1			1	
Parietaria pensylvanica	N			1		1		2	
Plantago major	N	1	1	1	1	1		5	

Table 20. Number of plant communities in which each species occurs, cont'd.

Native Forbs, cont'd.	Native/Exotic	Gravel	Sandbar	Salix exigua	P angustifolia	P deltoides	Number of Plant Cmmts	Average
Polygonum achoreum	N		1				1	
Polygonum amphibium	N		1	1			2	
Polygonum douglasii	N	1	1				2	
Polygonum lapathifolium	N	1	1	1			3	
Polygonum sp.	N	1		1	1	1	4	
Portulaca oleracea	N	1					1	
Potentilla anserina	N			1			1	
Potentilla gracilis	N			1	1		2	
Potentilla norvegica	N	1	1	1	1		4	
Potentilla paradoxa	N	1	1	1			3	
Ranunculus cymbalaria	N	1	1	1			3	
Ranunculus Macounii	N		1	1			2	
Ranunculus sceleratus	N	1	1				2	
Rorippa palustris v. hispida	N	1	1				2	
Rudbeckia laciniata	N				1		1	
Rumex salicifolius	N	1				1	2	
Sagittaria cuneata	N	1					1	
Smilacina stellata	N			1	1	1	3	
Solanum rostratum	N		1				1	
Solanum sarrachoides	N					1	1	
Solidago gigantea	N	1		1	1	1	4	
Solidago mollis	N					1	1	
Solidago occidentalis	N		1	1		1	3	
Stachys palustris	N			1			1	
Thalictrum dasycarpum	N			1			1	
Urtica dioica	N			1	1		2	
Verbena bracteata	N	1	1	1			3	
Verbena hastata	N			1			1	
Veronica americana	N		1				1	
Veronica anagallis-aquatica	N	1					1	
Vicia americana	N	1		1	1		3	
Viola sp.	N					1	1	
Xanthium strumarium	N		1	1			2	

Table 20. Number of plant communities in which each species occurs, cont'd.

Non-native Forbs	N/X	G	S	SE	PA	PD	# Cmts	Avrg
Amaranthus blitoides	X		1				1	2.6
Amaranthus retroflexus	X		1				1	
Arctium minus	X	1		1	1	1	4	
Artemisia biennis	X	1	1	1	1		4	
Asparagus officinalis	X					1	1	
Asperugo procumbens	X		1				1	
Brassica rapa	X		1				1	
Centaurea maculosa	X	1		1	1	1	4	
Chenopodium album	X	1	1	1		1	4	
Chenopodium botrys	X	1	1				2	
Chenopodium glaucum	X		1				1	
Cirsium arvense	X	1	1	1	1	1	5	
Cirsium vulgare	X		1	1	1	1	4	
Conium maculatum	X	1		1	1	1	4	
Convolvulus arvensis	X	1					1	
Cynoglossum officinale	X	1	1	1	1	1	5	
Descurainia sophia	X		1	1			2	
Erysimum repandum	X		1				1	
Euphorbia esula	X	1	1	1	1	1	5	
Filago arvensis	X	1	1				2	
Glechoma hederocea (?)	X		1				1	
Kochia scoparia	X		1				1	
Lactuca seriola	X		1	1			2	
Lepidium campestre	X	1					1	
Lepidium perfoliatum	X		1	1			2	
Linaria dalmatica	X			1			1	
Lychnis alba	X			1			1	
Medicago lupulina	X	1	1	1		1	4	
Melilotus alba	X	1	1	1		1	4	
Melilotus officinalis	X	1	1	1	1	1	5	
Melilotus sp.	X				1	1	2	
Nepeta cataria	X			1		1	2	
Polygonum aviculare	X	1	1				2	
Polygonum convulvulus	X				1	1	2	
Rumex crispus	X	1	1	1			3	
Rumex stenophyllus	X	1	1				2	
Salsola kali	X				1	1	2	
Silene noctiflora	X	1		1			2	
Sisymbrium altissimum	X		1				1	
Sisymbrium loeselii	X	1	1	1		1	4	
Solanum dulcamara	X	1		1		1	3	
Sonchus uliginosus/S. asper	X	1	1	1	1	1	5	
Tanacetum vulgare	X	1	1	1	1	1	5	
Taraxacum officinale	X	1	1	1	1	1	5	
Thlaspi arvense	X	1	1				2	
Tragopogon dubius	X		1	1	1		3	
Trifolium hybridum	X			1	1		2	
Trifolium pratense	X			1			1	
Trifolium repens	X	1	1				2	
Verbascum thapsus	X	1	1	1	1	1	5	

Table 20. Number of plant communities in which each species occurs, cont'd.

Native Graminoids, cont'd.	Native/Exotic	Gravel	Sandbar	Salix exigua	P angustifolia	P deltoides	Number of Plant Cmmts	Average
Agrostis scabra	N		1				1	1.8
Agrostis stolonifera	N	1	1	1	1	1	5	
Alopecurus aequalis	N	1	1				2	
Calamovilfa longifolia	N					1	1	
Carex aquatilis	N			1			1	
Carex arthrostachya	N			1			1	
Carex lanuginosa	N		1	1			2	
Carex lenticularis	N			1			1	
Carex microptera	N			1	1		2	
Carex nebrascensis	N		1				1	
Carex sp.	N	1	1	1	1	1	5	
Deschampsia cespitosa	N	1		1			2	
Eleocharis palustris	N	1	1	1			3	
Elymus canadensis	N				1	1	2	
Elymus cinereus	N	1		1			2	
Elymus elymoides	N	1		1			2	
Elymus lanceolatus	N			1		1	2	
Elymus smithii	N	1			1		2	
Elymus trachycaulus/E. sp.	N	1		1	1	1	4	
Eragrostis hypnoides	N	1	1				2	
Hordeum jubatum	N	1	1	1			3	
Hordeum pusillum	N	1					1	
Juncus articulatus	N		1				1	
Juncus balticus	N			1	1		2	
Juncus bufonius	N		1				1	
Juncus ensifolius	N		1				1	
Juncus interior	N	1	1				2	
Juncus longistylis	N		1	1			2	
Juncus nodosus	N			1			1	
Juncus torreyi	N		1				1	
Juncus sp.	N	1		1			2	
Muhlenbergia racemosa	N					1	1	
Panicum capillare	N	1					1	
Poa juncifolia (?)	N		1				1	
Poa palustris	N	1		1			2	
Scirpus maritimus	N		1				1	
Scirpus pungens	N			1			1	
Scirpus validus	N		1				1	
Spartina pectinata	N			1		1	2	
Sporobolus cryptandrus	N		1	1			2	

Table 20. Number of plant communities in which each species occurs, cont'd.

Non-Narive Graminoids	Native/Exotic	Gravel	Sandbar	Salix exigua	P angustifolia	P deltoides	Number of	Plant Cmmts	Average
Agropyron cristatum	X				1			1	3.0
Alopecurus arundinaceus	X	1	1	1	1	1		5	
Bromus inermis	X	1	1	1	1	1		5	
Bromus japonicus	X		1	1				2	
Bromus tectorum	X	1	1	1				3	
Crypsis alopecuroides	X	1	1					2	
Dactylis glomerata	X			1	1	1		3	
Echinochloa crus-galli	X		1					1	
Elymus repens	X	1	1	1	1	1		5	
Festuca arundinacea	X					1		1	
Juncus compressus	X		1	1				2	
Phalaris arundinacea	X	1	1	1	1	1		5	
Phleum pratense	X	1		1				2	
Poa compressa	X	1		1		1		3	
Poa pratensis	X	1	1	1	1	1		5	

Table 21. Comparison of ungrazed and grazed gravelbar sites, cover data & t test results.
Species grouped by life form, then in order by cover.

UNGRAZED SITES (n = 14)	AvCvr	StDev		Separate variance	Pooled variance
Average cover of non-native species/ungr site	0.046	0.047			
Average cover of species/ungr site	0.158	0.087		0.470	0.540
Percent cover of non native species/ungr site	34%	35%		0.911	0.924

GRAZED SITES (n = 6)	AvCvr	StDev
Average cover of non-native species/grzdsite	0.048	0.040
Average cover of species/grzdsite	0.134	0.026
Percent cover of non native species/grzdsite	37%	27%

		UNGRAZED		GRAZED		T test, ungr vs grzd	
Native/Non-native		Avg	Sum	Avg	Sum	Separate	Pooled
TREES	N/X	Cvr	Cvr	Cvr	Cvr	variance	variance
Avrg cvr of non-ntv tree spp, ungr	0.000						
Avrg cvr of non-ntv tree spp, grzd	0.000						
Salicaceae Populus angustifolia	N	0.032	0.446	0.031	0.185	0.964	0.970
Salicaceae Populus deltoides	N	0.003	0.042	0.002	0.014	0.837	0.857
Avrg cover of tree species, ungr	0.035						
Avrg cover of tree species, grzd	0.033					0.939	0.950
SHRUBS							
% Avrg cvr of non-ntv shrubs, ungr	15%						
% Avrg cvr of non-ntv shrubs, grzd	2%						
Avrg cvr of non-ntv shrubs ungr	0.007						
Avrg cvr of non-ntv shrub spp, grzd	0.000					0.16	0.35
Tamaricaceae Tamarix chinensis	X	0.007	0.092	0.000	0.001	0.165	0.356
Salicaceae Salix exigua	N	0.047	0.654	0.022	0.132	0.338	0.504
Salicaceae Salix amygdaloides	N	0.011	0.151	0.002	0.014	0.333	0.521
Salicaceae Salix rigida	N	0.000	0	0.000	0.001	Insufficient Data	
Avrg cvr native shrub species, ungr	0.058						
Avrg cover of native shrub spp, grzd	0.025						
Avrg cover of shrub species, ungr	0.064						
Avrg cover of shrub species, grzd	0.025					0.130	0.286
Avrg % cvr of non-ntv forb spp, ungr	56%						
Avrg % cvr of non-ntv forb spp, grzd	49%						
Avrg cvr of non-ntv forb spp, ungr	0.020						
Avrg cvr of non-ntv forb spp, grzd	0.022					0.855	0.890
Fabaceae Melilotus alba	X	0.011	0.155	0.001	0.005	0.184	0.377
Fabaceae Melilotus officinalis	X	0.003	0.045	0.001	0.004	0.186	0.377
Polygonaceae Rumex stenophyllus	X	0.001	0.017	0.000	0	Insufficient Data	
Asteraceae Cirsium arvense	X	0.001	0.007	0.001	0.003	1.000	1.000
Polygonaceae Polygonum lapathifolium	X	0.001	0.007	0.000	0.002	0.713	0.742
Asteraceae Centaurea maculosa	X	0.000	0.006	0.000	0	I. D.	
Euphorbiaceae Euphorbia esula	X	0.000	0.006	0.006	0.037	0.295	0.083
Fabaceae Melilotus sp.	X	0.000	0.006	0.000	0		
Asteraceae Taraxacum officinale	X	0.000	0.005	0.001	0.006	0.366	0.195
Chenopodiaceae Chenopodium album	X	0.000	0.004	0.001	0.004	0.485	0.313

Table 21. Comparison of ungrazed and grazed gravelbar sites, cover data & t tests, cont'd.

		UNGRAZED		GRAZED		T test, ungr vs grzd	
FORBS		AvCvr	Ttl cvr	AvCvr	Ttl Cvr	separate	pooled
Asteraceae Tanasetum vulgare	X	0.000	0.003	0.002	0.014	0.140	0.020
Fabaceae Medicago lupulina	X	0.000	0.003	0.002	0.009	0.315	0.101
Portulaceae Portulaca oleracea	X	0.000	0.003	0.000	0	I. D.	
Asteraceae Sonchus uliginosus/S. asp	X	0.000	0.002	0.001	0.006	0.432	0.202
Scrophulariaceae Verbascum thapsus	X	0.000	0.002	0.001	0.005	0.346	0.157
Caryophyllaceae Silene noctiflora	X	0.000	0.002	0.000	0	I. D.	
Polygonaceae Rumex crispus	X	0.000	0.001	0.001	0.008	0.388	0.154
Chenopodiaceae Chenopodium botrys	X	0.000	0.001	0.001	0.007	0.226	0.046
Apiaceae Conium maculatum	X	0.000	0.001	0.000	0	I. D.	
Asteraceae Filago arvensis	X	0.000	0.001	0.000	0	I. D.	
Brassicaceae Sisymbrium loeselii	X	0.000	0.001	0.000	0	I. D.	
Polygonaceae Rumex sp.		0.000	0.001	0.000	0	I. D.	
Solanaceae Solanum dulcamara	X	0.000	0.001	0.000	0	Insufficient Data	
Chenopodiaceae Chenopodium glaucum	X	0.000	0	0.003	0.018	I. D.	
Asteraceae Cirsium vulgare	X	0.000	0	0.000	0.001	I. D.	
Asteraceae Tragopogon dubius	X	0.000	0	0.000	0.001	I. D.	
Chenopodiaceae Salsola kali	X	0.000	0	0.000	0.001	I. D.	
Polygonaceae Rumex salicifolius	N	0.004	0.051	0.005	0.027	0.814	0.836
Plantiginaceae Plantago major	N	0.001	0.012	0.002	0.01	0.45	0.372
Brassicaceae Rorippa palustris	N	0.001	0.012	0.001	0.003	0.705	0.779
Lamiaceae Mentha arvensis	N	0.001	0.009	0.001	0.008	0.515	0.545
Onagraceae Oenethera villosa	N	0.001	0.007	0.000	0.001		
Asteraceae Solidago gigantea	N	0.000	0.005	0.000	0	Insufficient Data	
Verbenaceae Verbena bracteata	N	0.000	0.005	0.000	0	I. D.	
Amaranthaceae Amaranthus albus	N	0.000	0.004	0.001	0.004	0.522	0.491
Rubiaceae Galium bifolium	N	0.000	0.003	0.000	0	I. D.	
Scrophulariaceae Veronica americana	N	0.000	0.003	0.000	0	I. D.	
Rosaceae Potentilla norvegica	N	0.000	0.002	0.002	0.009	0.348	0.123
Asteraceae Aster ascendens	N	0.000	0.002	0.000	0.001	0.905	0.898
Rosaceae Potentilla paradoxa	N	0.000	0.002	0.000	0.001	0.915	0.924
Polygonaceae Polygonum aviculare	N	0.000	0.002	0.000	0	I. D.	
Ranunculaceae Ranunculus cymbalar	N	0.000	0.002	0.000	0	I. D.	
Ranunculaceae Ranunculus sceleratus	N	0.000	0.002	0.000	0	I. D.	
Equisetaceae Equisetum variegatum	N	0.000	0.001	0.001	0.003	0.117	0.028
Scrophulariaceae Veronica anagallis-aquatica	N	0.000	0.001	0.001	0.003	I. D.	
Alismataceae Sagittaria cuneata	N	0.000	0.001	0.000	0	I. D.	
Apocynaceae Apocynum sibiricum	N	0.000	0.001	0.000	0	I. D.	
Asteraceae Aster hesperius	N	0.000	0.001	0.000	0	I. D.	
Asteraceae Cirsium undulatum	N	0.000	0.001	0.000	0	I. D.	
Equisetaceae Equisetum laevigatum	N	0.000	0.001	0.000	0	I. D.	
Fabaceae Glycyrrhiza lepidota	N	0.000	0.001	0.000	0	I. D.	
Onagraceae Epilobium paniculatum	N	0.000	0.001	0.000	0	I. D.	
Polygonaceae Polygonum sp.	N	0.000	0.001	0.000	0	I. D.	
Asteraceae Conyza canadensis	N	0.000	0	0.004	0.022	I. D.	
Asteraceae Gnaphalium palustre	N	0.000	0	0.003	0.017	I. D.	
Polygonaceae Polygonum amphibium	N	0.000	0	0.001	0.004	I. D.	
Euphorbiaceae Euphorbia glyptosperma	N	0.000	0	0.000	0.002	I. D.	

Table 21. Comparison of ungrazed and grazed gravelbar sites, cover data & t tests, cont'd.

		UNGRAZED		GRAZED		T test, ungr vs grzd	
FORBS, cont'd.		AvCvr	Ttl cvr	AvCvr	Ttl Cvr	separate	pooled
Asteraceae Achillea millefolium	N	0.000	0	0.000	0.001	I. D.	
Brassicaceae Thelopodium integrifolium	N	0.000	0	0.000	0.001	I. D.	
Polygonaceae Polygonum achoreum	N	0.000	0	0.000	0.001	I. D.	
Scrophulariaceae Veronica peregrina	N	0.000	0	0.000	0.001	I. D.	
Solanaceae Solanum triflorum	N	0.000	0	0.000	0.001	I. D.	
Avrg cvr of native forb species, ungr	0.010						
Avrg cvr of native forb species, grzd	0.020						
Avrg cover of forb species, ungr	0.029						
Avrg cover of forb species, grzd	0.042					0.450	0.485
GRAMINOIDS							
Avrg % cvr of non-ntv gramnd spp ungr	44%						
Avg % cvr of non-ntv gramnd spp, grzd	54%						
Avrg cvr of non-ntv graminoid spp, ungr	0.020						
Avrg cvr of non-ntv graminoid spp, grzd	0.025					0.792	0.733
Poaceae Elymus repens	X	0.008	0.113	0.022	0.131	0.538	0.363
Poaceae Alopecurus arundinaceus	X	0.005	0.067	0.000	0	*calculator*	*0.364*
Poaceae Phalaris arundinacea	X	0.005	0.063	0.000	0	*calculator*	*0.184*
Poaceae Poa pratensis	X	0.001	0.017	0.002	0.011	0.675	0.584
Poaceae Poa compressa	X	0.001	0.007	0.001	0.007	0.537	0.385
Poaceae Bromus inermis	X	0.000	0.003	0.000	0	I. D.	
Poaceae Bromus tectorum	X	0.000	0.002	0.000	0	I. D.	
Poaceae Phleum pratense	X	0.000	0.002	0.000	0	I. D.	
Poaceae Crypsis alopecuroides	X	0.000	0.001	0.000	0	I. D.	
Poaceae Echinochloa crus-galli	X	0.000	0	0.000	0.001	I. D.	
Poaceae Setaria viridis	X	0.000	0	0.000	0.001	I. D.	
Poaceae Deschampsia cespitosa	N	0.006	0.087	0.001	0.008	0.396	0.571
Poaceae Agrostis stolonifera	N	0.001	0.014	0.003	0.015	0.585	0.439
Poaceae Poa palustris	N	0.001	0.013	0.001	0.007	0.828	0.785
Poaceae Hordeum jubatum	N	0.001	0.009	0.000	0.002	0.465	0.594
Cyperaceae Carex sp.	N	0.001	0.007	0.000	0.001		
Cyperaceae Eleocharis palustris	N	0.000	0.003	0.001	0.004	0.245	0.117
Poaceae Elymus trachycaulus/A. sp.	N	0.000	0.002	0.001	0.006	0.344	0.127
Poaceae Alopecurus aequalis	N	0.000	0.002	0.001	0.003	0.512	0.320
Poaceae Elymus elynoides	N	0.000	0.002	0.000	0	I. D.	
Juncaceae Juncus interior	N	0.000	0.001	0.000	0.001	0.616	0.541
Juncaceae Juncus sp.	N	0.000	0.001	0.000	0	I. D.	
Poaceae Elymus smithii	N	0.000	0.001	0.000	0	I. D.	
Poaceae Panicum capillare	N	0.000	0	0.000	0.002	I. D.	
Cyperaceae Carex arthrostachya	N	0.000	0	0.000	0.001	I. D.	
Juncaceae Juncus longistylis	N	0.000	0	0.000	0.001	I. D.	
Juncaceae Juncus tenuis	N	0.000	0	0.000	0.001	I. D.	
Juncaceae Juncus torreyi	N	0.000	0	0.000	0.001	I. D.	
Poaceae Sporobolus cryptandrus	N	0.000	0	0.000	0.001	I. D.	
Avrg cover of native gramnd spp, ungr	0.010						
Avrg cover of native grmnd spp, grzd	0.009						
Avrg cover of graminoid species, ungr	0.030						
Avrg cover of graminoid species, grzd	0.035					0.855	0.844

Table 22. Comparison of ungrazed and grazed sandbar sites, cover data & t test results. Species grouped by life form, then in order by cover.

Ungrazed Sites (n = 8)		AvCvr	StDev	T tests,		Sep Var	Pool Var
Average cover of non-ntv spp/site		0.155	0.24	grazed vs.		0.21	0.361
Average cover of spp/site		0.386	0.25	ungrazed		0.105	0.167
% cover of non ntv spp/site		37%	31%			0.519	0.555
Grazed Sites (n = 4)				AvCvr	StDev		
Average cover of non-ntv spp/site				0.037	0.022		
Average cover of spp/site				0.186	0.141		
% cover of non ntv spp/site				26%	24%		
		UNGRAZED		GRAZED		T test, ungr v. grzd	
Native/Non-native		Avg Cover	Sum Cover	Avrg Cover	Sum Cover	Separate variance	Pooled variance
TREES	N/X						
Cover of non-ntv tree spp, Ungr	0						
Cover of non-ntv tree spp, Grzd	0						
Salicaceae Populus deltoides	N	0.002	0.017	0.007	0.029	0.323	0.141
Salicaceae Populus angustifolia	N	0.001	0.005	0.004	0.017	0.458	0.253
Total cover of tree spp, Ungr	0.003						
Total cover of tree spp, Grzd	0.012						
SHRUBS							
% cover of non-ntv shrub spp, Ungr	28%						
% cover of non-ntv shrub spp, Grzd	0%						
Cover of non-ntv shrub spp, Ungr	0.008						
Cover of non-ntv shrub spp, Grzd	0.000					Insufficient Data	
Tamaricaceae Tamarix chinensis	X	0.008	0.061	0.000	0.000	0.079	0.187
Salicaceae Salix exigua	N	0.090	0.720	0.003	0.010	0.084	0.195
Salicaceae Salix amygdaloides	N	0.002	0.016	0.001	0.002	0.429	0.567
Cover of ntv shrub spp, Ungr	0.092						
Cover of ntv shrub spp, Grzd	0.003						
Total cover of shrub spp, Ungr	0.100						
Total cover of shrub spp, Grzd	0.003					0.060	0.154
FORBS							
% cover of non-ntv forb spp, Ungr	38%						
% cover of non-ntv forb spp, Grzd	41%						
Cover of non-ntv forb spp, Ungr	0.065						
Cover of non-ntv forb spp, Grzd	0.025					0.244	0.395
Chenopodiaceae Chenopodium glaucum	X	0.043	0.342	0.007	0.028	0.416	0.562
Chenopodiaceae Chenopodium album	X	0.006	0.046	0.001	0.002	0.231	0.386
Polygonaceae Rumex stenophyllus	X	0.004	0.028	0.000	0.000	I. D.	
Brassicaceae Thlaspi arvense	X	0.002	0.019	0.000	0.000	I. D.	
Chenopodiaceae Kochia scoparia	X	0.001	0.010	0.000	0.001	0.297	0.445
Polygonaceae Rumex sp.		0.001	0.009	0.000	0.000	I. D.	
Polygonaceae Polygonum aviculare	X	0.001	0.009	0.000	0.000	I. D.	
Asteraceae Taraxacum officinale	X	0.001	0.008	0.001	0.002	0.381	0.49
Brassicaceae Lepidium perfoliatum	X	0.001	0.007	0.000	0.000	I. D.	
Fabaceae Melilotus officinalis	X	0.001	0.006	0.000	0.001	0.474	0.596
Asteraceae Cirsium arvense	X	0.001	0.004	0.000	0.000	I. D.	

Table 22. Comparison of ungrazed and grazed sandbar sites, cover data & t test results.

		UNGRAZED		GRAZED		T test, ungr v. grzd.	
		Avg	Sum	Avrg	Sum	Separate	Pooled
FORBS, cont'd.	N/X	Cover	Cover	Cover	Cover	variance	variance
Asteraceae Lactuca seriola	X	0.001	0.004	0.000	0.000	I. D.	
Chenopodiaceae Chenopodium botrys	X	0.001	0.004	0.000	0.000	I. D.	
Fabaceae Medicago lupulina	X	0.001	0.004	0.001	0.003	0.593	0.672
Asteraceae Sonchus uliginosus/S. asper	X	0.000	0.003	0.000	0.000	I. D.	
Brassicaceae Sisymbrium loeselii	X	0.000	0.003	0.000	0.000	I. D.	
Asteraceae Filago arvensis	X	0.000	0.002	0.000	0.000	I. D.	
Asteraceae Tanacetum vulgare	X	0.000	0.002	0.000	0.001	1.000	1.000
Boraginaceae Asperugo procumbens	X	0.000	0.001	0.000	0.000	I. D.	
Brassicaceae Erysimum repandum	X	0.000	0.001	0.000	0.000	I. D.	
Brassicaceae Sisymbrium altissimum	X	0.000	0.001	0.000	0.000	I. D.	
Amaranthaceae Amaranthus blitoides	X	0.000	0.002	0.000	0.000	I. D.	
Asteraceae Artemisia biennis	X	0.000	0.002	0.000	0.000	I. D.	
Polygonaceae Rumex crispus	X	0.000	0.001	0.000	0.000	I. D.	
Scrophulariaceae Verbascum thapsus	X	0.000	0.001	0.000	0.000	I. D.	
Euphorbiaceae Euphorbia esula	X	0.000	0.000	0.014	0.054	I. D.	
Polygonaceae Polygonum lapathifolium	N	0.033	0.261	0.002	0.006	0.185	0.334
Polygonaceae Polygonum amphibium	N	0.009	0.068	0.000	0.000	I. D.	
Equisetaceae Equisetum arvense	N	0.008	0.060	0.000	0.000	I. D.	
Asteraceae Xanthium strumarium	N	0.006	0.051	0.000	0.000	I. D.	
Verbenaceae Verbena bracteata	N	0.006	0.049	0.000	0.001	0.359	0.514
Equisetaceae Equisetum laevigatum	N	0.006	0.045	0.000	0.000	I. D.	
Asteraceae Solidago occidentalis	N	0.005	0.040	0.000	0.000	I. D.	
Asteraceae Aster hesperius	N	0.005	0.039	0.000	0.000	I. D.	
Rubiaceae Galium bifolium	N	0.004	0.034	0.000	0.000	I. D.	
Asteraceae Iva xanthifolia	N	0.003	0.021	0.000	0.000	I. D.	
Rosaceae Potentilla paradoxa	N	0.002	0.018	0.001	0.005	0.658	0.74
Polygonaceae Polygonum douglasii	N	0.002	0.016	0.000	0.000	I. D.	
Fabaceae Glycyrrhiza lepidota	N	0.002	0.012	0.000	0.000	I. D.	
Brassicaceae Rorippa palustris v. hispida	N	0.001	0.009	0.001	0.005	I. D.	
Ranunculaceae Ranunculus cymbalaria	N	0.001	0.007	0.005	0.020	I. D.	
Asteraceae Gnaphalium palustre	N	0.001	0.007	0.005	0.019	0.475	0.264
Solanaceae Solanum rostratum	N	0.001	0.006	0.000	0.000	I. D.	
Polygonaceae Polygonum achoreum	N	0.001	0.005	0.001	0.003	0.894	0.890
Onagraceae Epilobium paniculatum	N	0.001	0.005	0.000	0.000	I. D.	
Scrophulariaceae Veronica americana	N	0.001	0.004	0.000	0.000	I. D.	
Amaranthaceae Amaranthus albus	N	0.000	0.003	0.000	0.000	I. D.	
Equisetaceae Equisetum variegatum	N	0.000	0.002	0.051	0.203	0.388	0.164
Onagraceae Oenethera villosa	N	0.000	0.002	0.001	0.003	0.383	0.239
Asteraceae Helianthus annuus	N	0.000	0.002	0.000	0.000	I. D.	
Lamiaceae Mentha arvensis	N	0.000	0.001	0.002	0.008	0.347	0.132
Rosaceae Potentilla norvegica	N	0.000	0.001	0.000	0.001	0.675	0.624
Apiaceae Cicuta douglasii	N	0.000	0.001	0.000	0.000	I. D.	
Ranunculaceae Ranunculus sceleratus	N	0.000	0.001	0.000	0.000	0.471	0.258
Plantiginaceae Plantago major	N	0.000	0.000	0.017	0.066	I. D.	
Scrophulariaceae Veronica anagallis-aquatica	N	0.000	0.000	0.004	0.015	I. D.	
Iridaceae Iris missouriensis	N	0.000	0.000	0.000	0.001	I. D.	

Table 22. Comparison of ungrazed and grazed sandbar sites, cover data & t test results.

		UNGRAZED		GRAZED		T test, ungr v. grzd.	
FORBS, cont'd.		Avg Cover	Sum Cover	Avrg Cover	Sum Cover	Separate variance	Pooled variance
Scrophulariaceae Veronica peregrina	N	0.000	0.000	0.000	0.001	I. D.	
Scrophulariaceae Veronica scutellata	N	0.000	0.000	0.000	0.001	I. D.	
Cover of ntv forb spp, Ungr	0.096						
Cover of ntv forb spp, Grzd	0.090						
Total cover of forb spp, Ungr	0.161						
Total cover of forb spp, Grzd	0.113					0.551	0.630
GRAMINOIDS							
% cover non-ntv gramnd spp, Ungr	41%						
% cover non-ntv gramnd spp, Grzd	13%						
Cover of non-ntv gramnd spp, Ungr	0.052						
Cover of non-ntv gramnd spp, Grzd	0.012					0.273	0.416
Poaceae Echinochloa crus-galli	X	0.039	0.310	0.000	0.000	I. D.	
Poaceae Elymus repens	X	0.007	0.052	0.000	0.001	0.258	0.416
Poaceae Bromus tectorum	X	0.003	0.023	0.000	0.001	0.323	0.479
Poaceae Bromus japonicus	X	0.001	0.011	0.000	0.000	I. D.	
Poaceae Phalaris arundinacea	X	0.001	0.011	0.000	0.000	I. D.	
Poaceae Bromus inermis	X	0.001	0.005	0.000	0.000	I. D.	
Poaceae Crypsis alopecuroides	X	0.000	0.002	0.000	0.000	I. D.	
Poaceae Poa sp.	X	0.000	0.000	0.012	0.046	I. D.	
Juncaceae Juncus compressus	X	0.000	0.001	0.000	0.000	I. D.	
Poaceae Poa pratensis	X	0.000	0.000	0.000	0.001	I. D.	
Cyperaceae Eleocharis palustris	N	0.030	0.241	0.021	0.084	0.679	0.722
Cyperaceae Carex nebrascensis	N	0.025	0.200	0.000	0.000	I. D.	
Cyperaceae Carex lanuginosa	N	0.006	0.044	0.000	0.000	I. D.	
Cyperaceae Scirpus maritimus	N	0.003	0.024	0.000	0.000	I. D.	
Poaceae Eragrostis hypnoides	N	0.002	0.012	0.000	0.001	0.437	0.579
Juncaceae Juncus longistylis	N	0.001	0.011	0.000	0.001	0.446	0.586
Juncaceae Juncus ensifolius	N	0.001	0.007	0.000	0.000	I. D.	
Poaceae Agrostis stolonifera	N	0.001	0.006	0.006	0.023	0.450	0.241
Poaceae Alopecurus aequalis	N	0.001	0.005	0.001	0.004	0.762	0.746
Poaceae Hordeum jubatum	N	0.000	0.003	0.003	0.013	0.443	0.230
Poaceae Agrostis scabra	N	0.000	0.003	0.000	0.000	I. D.	
Poaceae Sporobolus cryptandrus	N	0.000	0.003	0.000	0.000	I. D.	
Cyperaceae Carex sp.	N	0.000	0.001	0.000	0.001	0.675	0.624
Juncaceae Juncus bufonius	N	0.000	0.001	0.000	0.001	0.675	0.624
Juncaceae Juncus articulatus	N	0.000	0.001	0.000	0.000	I. D.	
Poaceae Poa juncifolia (?)	N	0.000	0.001	0.000	0.000	I. D.	
Juncaceae Juncus tenuis	N	0.000	0.000	0.010	0.038	I. D.	
Poaceae Panicum capillare	N	0.000	0.000	0.004	0.016	I. D.	
Juncaceae Juncus torreyi	N	0.000	0.000	0.001	0.002	I. D.	
Cyperaceae Cyperus aristatus	N	0.000	0.000	0.000	0.001	I. D.	
Poaceae Elymus trachycaulus/A. sp.	N	0.000	0.000	0.000	0.001	I. D.	
Cover of ntv gramnd spp, Ungr	0.070						
Cover of ntv gramnd spp, Grzd	0.047						
Total cover of gramnd spp, Ungr	0.122						
Total cover of gramnd spp, Grzd	0.059					0.215	0.307

Table 23. Comparison of ungrazed vs. grazed *Salix exigua* sites, cover data & t test results
Species grouped by life form, then in order by cover.

UNGRAZED SITES (n = 22)		AvCvr	StDev			SepVar	PoolVar
Avrg cover of non-ntv spp/ungrazed site		0.394	0.243			0.013	0.026
Avrg cover of spp/ungrazed site		1.144	0.309			0.056	0.041
non-ntv spp cover/total cover, ungr sites		34%	20%			0.198	0.190
GRAZED SITES (n = 10)				AvCvr	StDev		
Avrg cover of non-ntv spp/grazed site				0.203	0.173		
Avrg cover of spp/grazed site				0.885	0.340		
non-ntv spp cover/total cover, grzd sites				25%	20%		
	Native/non-native	UNGRAZED Avrg	Total	GRAZED Avrg	Total	T test ungr v grzd separate variance	Pooled variance
TREES	N/X	Cover	Cover	Cover	Cover		
Avrg cover of non-ntv tree spp, ungr	0						
Avrg cover of non-ntv tree spp, grzd	0					N/A	N/A
Populus deltoides	N	0.007	0.153	0.003	0.031	0.495	0.62
Populus angustifolia	N	0.010	0.213	0.021	0.212	0.344	0.141
Fraxinus pennsylvanica	N	0.000	0.002	0.000	0.002	0.628	0.569
Avrg cover of all tree spp, ungr	0.017						
Avrg cover of all tree spp, grzd	0.024					0.749	0.718
SHRUBS							
Non-ntv shrub cvr/total shrub cvr, un	2%						
Non-ntv shrub cvr/total shrub cvr, gr	1%						
Avrg cover of non-ntv shrub spp, un	0.015						
Avrg cover of non-ntv shrub spp, gr	0.006					Insufficient Data	
Elaeagnus angustifolia	X	0.012	0.263	0.000	0.004	0.198	0.381
Tamarix chinensis	X	0.003	0.058	0.006	0.056	0.634	0.567
Artemisia absinthium	X	0.000	0.005	0.000	0.001	0.612	0.716
Salix exigua	N	0.506	11.141	0.311	3.113	0.0005	0.0016
Salix amygdaloides	N	0.055	1.217	0.013	0.131	0.083	0.188
Cornus stolonifera	N	0.016	0.359	0.001	0.012	0.063	0.198
Ribes hudsonianum	N	0.011	0.241	0.000	0.000	I. D.	
Symphoricarpos occidentalis	N	0.011	0.239	0.031	0.310	0.427	0.355
Ribes aureum	N	0.010	0.210	0.000	0.000	I. D.	
Rosa woodsii/R. sayi	N	0.009	0.203	0.064	0.638	0.356	0.169
Prunus virginiana	N	0.005	0.118	0.002	0.022	0.578	0.691
Ribes sp.	N	0.003	0.060	0.000	0.000	I. D.	
Salix sp. (small leaved willow)	N	0.002	0.042	0.000	0.000	I. D.	
Clematis ligusticifolia	N	0.002	0.033	0.000	0.000	I. D.	
Humulus lupulus	N	0.001	0.020	0.000	0.000	I. D.	
Ribes setosum	N	0.000	0.008	0.000	0.000	I. D.	
Vitis riparia	N	0.000	0.007	0.000	0.001	0.340	0.485
Rhus trilobata	N	0.000	0.001	0.000	0.000	I. D.	
Toxicodendron rydbergii	N	0.000	0.001	0.000	0.000	I. D.	
Juniperus scopulorum	N	0.000	0.001	0.000	0.000	I. D.	
Amelanchier alnifolia	N	0.000	0.001	0.000	0.000	I. D.	
Artemisia frigida	N	0.000	0.000	0.000	0.002	I. D.	

Table 23. Comparison of ungrazed vs grazed *Salix exigua* sites, cover & t tests, cont'd.

		UNGRAZED		GRAZED		T test ungr v grzd	
SHRUBS, cont'd.	N/X	Avrg Cover	Total Cover	Avrg Cover	Total Cover	separate variance	Pooled variance
Avrg cover af all native shrub spp, ungr	0.632						
Avrg cover of all native shrub spp, gr	0.423						
Avrg cover of all shrub spp, ungr	0.647						
Avrg cover of all shrub spp, grzd	0.429					0.041	0.030
FORBS							
Non-ntv forb cvr/total forb cvr, ungr	70%						
Non-ntv forb cvr/total forb cvr, grzd	56%						
Avrg cover of non-ntv forb spp, ungr	0.133						
Avrg cover of non-ntv forb spp, grzd	0.091					0.241	0.368
Cirsium arvense	X	0.073	1.600	0.043	0.425	0.357	0.474
Melilotus officinalis/M. alba	X	0.025	0.560	0.003	0.030	0.216	0.400
Solanum dulcamara	X	0.012	0.262	0.000	0.001	0.257	0.442
Cynoglossum officinale	X	0.010	0.212	0.009	0.086	0.92	0.942
Trifolium hybridum	X	0.002	0.054	0.000	0.000	I. D.	
Tanacetum vulgare	X	0.002	0.037	0.001	0.013	0.807	0.858
Sonchus uliginosus/S. asper	X	0.002	0.036	0.001	0.011	0.686	0.731
Taraxacum officinale	X	0.002	0.034	0.002	0.024	0.573	0.49
Verbascum thapsus	X	0.002	0.033	0.002	0.021	0.773	0.775
Arctium minus	X	0.001	0.026	0.001	0.010	0.889	0.91
Cirsium vulgare	X	0.001	0.019	0.000	0.001	0.123	0.285
Euphorbia esula	X	0.000	0.010	0.000	0.000	I. D.	
Sisymbrium loeselii	X	0.000	0.009	0.000	0.004	0.98	0.984
Conium maculatum	X	0.000	0.008	0.000	0.000	I. D.	
Tragopogon dubius	X	0.000	0.006	0.000	0.001	0.272	0.365
Silene noctiflora	X	0.000	0.006	0.000	0.001	0.557	0.679
Nepeta cataria	X	0.000	0.005	0.000	0.000	I. D.	
Medicago lupulina	X	0.000	0.003	0.011	0.106	0.33	0.13
Lactuca seriola	X	0.000	0.002	0.003	0.025	0.361	0.156
Descurainia sophia	X	0.000	0.001	0.000	0.000	I. D.	
Lepidium perfoliatum	X	0.000	0.001	0.000	0.000	I. D.	
Lychnis alba	X	0.000	0.001	0.000	0.000	I. D.	
Rumex crispus	X	0.000	0.001	0.000	0.000	I. D.	
Centaurea maculosa	X	0.000	0.001	0.000	0.001	0.628	0.569
Chenopodium album	X	0.000	0.000	0.000	0.001	I. D.	
Amaranthus retroflexus	X	0.000	0.000	0.000	0.001	I. D.	
Trifolium repens	X	0.000	0.000	0.015	0.150	I. D.	
Glycyrrhiza lepidota	N	0.007	0.162	0.017	0.166	0.27	0.215
Solidago gigantea	N	0.006	0.125	0.017	0.168	0.425	0.279
Solidago occidentalis	N	0.005	0.116	0.009	0.087	0.725	0.678
Equisetum hyemale var. affine	N	0.004	0.088	0.000	0.001	0.341	0.52
Smilacina stellata	N	0.003	0.068	0.000	0.000	I. D.	
Apocynum sibiricum	N	0.003	0.067	0.000	0.000	I. D.	
Lysimachia ciliata	N	0.002	0.036	0.000	0.000	I. D.	
Polygonum amphibium	N	0.002	0.036	0.002	0.022	0.821	0.794

Table 23. Comparison of ungrazed vs grazed Salix exigua sites, cover & t tests, cont'd.

		UNGRAZED		GRAZED		T test ungr v grzd	
FORBS, cont'd.	N/X	Avrg Cover	Total Cover	Avrg Cover	Total Cover	separate variance	Pooled variance
Ambrosia psilostachya	N	0.001	0.018	0.000	0.000	I. D.	
Mentha arvensis	N	0.001	0.016	0.001	0.009	0.803	0.811
Aster ascendens	N	0.001	0.016	0.003	0.027	0.413	0.286
Equisetum arvense	N	0.001	0.014	0.026	0.261	0.353	0.149
Aster subspicatus	N	0.001	0.013	0.000	0.000	I. D.	
Plantago major	N	0.000	0.010	0.005	0.053	0.305	0.115
Asclepias speciosa	N	0.000	0.010	0.000	0.001	0.454	0.608
Verbena bracteata	N	0.000	0.010	0.000	0.002	0.596	0.713
Equisetum variegatum	N	0.000	0.008	0.000	0.002	0.676	0.769
Oenethera villosa (=O.strigosa)	N	0.000	0.006	0.000	0.001	0.445	0.576
Conyza canadensis	N	0.000	0.006	0.029	0.291	0.346	0.143
Equisetum laevigatum	N	0.000	0.005	0.001	0.008	0.363	0.177
Heterotheca villosa	N	0.000	0.004	0.000	0.000	I. D.	
Geum macrophyllum	N	0.000	0.003	0.000	0.000	I. D.	
Verbena hastata	N	0.000	0.003	0.000	0.001	0.799	0.825
Equisetum sylvaticum	N	0.000	0.002	0.000	0.000	I. D.	
Polygonum sp.		0.000	0.002	0.000	0.000	I. D.	
Potentilla gracilis	N	0.000	0.002	0.000	0.000	I. D.	
Potentilla paradoxa	N	0.000	0.002	0.000	0.000	I. D.	
Galium aparine	N	0.000	0.002	0.000	0.000	I. D.	
Xanthium strumarium	N	0.000	0.002	0.002	0.023	0.362	0.157
Cicuta douglasii	N	0.000	0.001	0.000	0.000	I. D.	
Iris missouriensis	N	0.000	0.001	0.000	0.000	I. D.	
Thalictrum dasycarpum	N	0.000	0.001	0.000	0.000	I. D.	
Potentilla anserina	N	0.000	0.001	0.000	0.000	I. D.	
Parietaria pensylvanica	N	0.000	0.001	0.000	0.000	I. D.	
Polygonum lapathifolium	N	0.000	0.001	0.000	0.000	I. D.	
Aster hesperius	N	0.000	0.001	0.000	0.001	0.628	0.569
Achillea millefolium	N	0.000	0.000	0.000	0.001	I. D.	
Marsilea vestita	N	0.000	0.000	0.000	0.001	I. D.	
Rumex salicifolius	N	0.000	0.000	0.000	0.001	I. D.	
Typha latifolia	N	0.000	0.000	0.000	0.001	I. D.	
Chenopodium fremontii	N	0.000	0.000	0.000	0.002	I. D.	
Artemisia campestris	N	0.000	0.000	0.000	0.004	I. D.	
Rudbeckia laciniata	N	0.000	0.000	0.001	0.005	I. D.	
Avrg cover of all ntv forb spp, ungr	0.039						
Avrg cover of all native forb spp, grzd	0.114						
Avrg cover of all forb spp, ungr	0.172						
Avrg cover of all forb spp, grzd	0.205					0.609	0.578

Table 23. Comparison of ungrazed vs grazed Salix exigua sites, cover & t tests, cont'd.

GRAMINOIDS	N/X	UNGRAZED Avrg Cover	UNGRAZED Total Cover	GRAZED Avrg Cover	GRAZED Total Cover	T test ungr v grzd separate variance	T test ungr v grzd Pooled variance
Non-ntv grmnd cvr/total grmnd cvr, un	73%						
Non-ntv grmnd cvr/total grmnd cvr, gr	41%						
Avrg cover of non-ntv grmnd spp, un	0.246						
Avrg cover of non-ntv grmnd spp, gr	0.108					0.070	0.061
Poa pratensis	X	0.025	0.544	0.064	0.644	0.487	0.301
Phalaris arundinacea	X	0.200	4.395	0.003	0.034	0.000	0.009
Elymus repens	X	0.017	0.368	0.039	0.394	0.299	0.162
Bromus inermis	X	0.003	0.055	0.000	0.003	0.212	0.395
Alopecurus arundinaceus	X	0.001	0.022	0.000	0.000	I. D.	
Phleum pratense	X	0.001	0.011	0.000	0.002	0.551	0.668
Dactylis glomerata	X	0.000	0.010	0.000	0.000	I. D.	
Bromus tectorum	X	0.000	0.007	0.000	0.004	0.843	0.859
Bromus japonicus	X	0.000	0.000	0.000	0.001	I. D.	
Agrostis stolonifera	N	0.019	0.410	0.039	0.389	0.596	0.422
Poa palustris	N	0.014	0.299	0.006	0.059	0.404	0.552
Carex sp.	N	0.010	0.220	0.022	0.215	0.472	0.464
Carex aquatilis	N	0.007	0.162	0.000	0.000	I. D.	
Spartina pectinata	N	0.004	0.088	0.001	0.008	0.441	0.598
Elymus lanceolatus	N	0.002	0.054	0.000	0.000	I. D.	
Elymus trachycaulus/A. sp.	N	0.002	0.053	0.000	0.004	0.32	0.498
Deschampsia cespitosa	N	0.002	0.040	0.000	0.002	0.386	0.557
Carex lanuginosa	N	0.001	0.022	0.000	0.000	I. D.	
Elymus elymoides	N	0.001	0.013	0.000	0.000	I. D.	
Carex microptera	N	0.000	0.007	0.000	0.003	0.965	0.968
Juncus nodosus	N	0.000	0.002	0.000	0.000	I. D.	
Sporobolus cryptandrus	N	0.000	0.002	0.000	0.000	I. D.	
Eleocharis palustris	N	0.000	0.002	0.001	0.006	0.239	0.079
Hordeum jubatum	N	0.000	0.002	0.001	0.007	0.161	0.036
Carex lenticularis	N	0.000	0.001	0.000	0.002	I. D.	
Juncus sp.	N	0.000	0.001	0.000	0.000	I. D.	
Juncus longistylis	N	0.000	0.001	0.000	0.001	0.628	0.569
Calamagrostis stricta	N	0.000	0.000	0.000	0.001	I. D.	
Carex athrostachya	N	0.000	0.000	0.000	0.002	I. D.	
Carex brevior	N	0.000	0.000	0.000	0.002	I. D.	
Scirpus pungens	N	0.000	0.000	0.000	0.002	I. D.	
Panicum capilare	N	0.000	0.000	0.000	0.002	I. D.	
Carex nebrascensis	N	0.000	0.000	0.001	0.008	I. D.	
Juncus balticus	N	0.000	0.000	0.001	0.010	I. D.	
Elymus canadensis	N	0.000	0.000	0.006	0.058	I. D.	
Agrostis scabra	N	0.000	0.000	0.040	0.400	I. D.	
Avrg cover of native grmnd spp, ungr	0.063						
Avrg cover of native grmnd spp, grzd	0.118						
Avrg cover of graminoid spp, ungr	0.309						
Avrg cover of graminoid spp, grzd	0.226					0.341	0.307

Table 24. Comparison of ungrazed and grazed *Populus angustifolia* sites, cover data and t test results. Species grouped by life form, then in order by cover.

UNGRAZED SITES (n = 8) (0% cow pie)	AvCvr	StDev	T tests,	SepVar	PoolVar
Avrg cvr of non-ntv spp	0.228	0.170	grazed vs.	0.054	0.076
Avrg cvr of species	1.680	0.258	ungrazed	0.098	0.082
Cover non-natives/total cover	14%	10%		0.026	0.039

GRAZED SITES (n = 13) (3.5% cow pie)	AvCvr	StDev
Avrg cvr of non-ntv spp	0.416	0.249
Avrg cvr of species	1.483	0.226
Cover non-natives/total cover	27%	14%

Native/non-native		UNGRAZED		GRAZED		T test ungr v grzd	
		Avrg	Total	Avrg	Total	Separate	Pooled
TREES	N/X	Cover	Cover	Cover	Cover	variance	variance
Avrg cvr of non-ntv tree spp, ungr	*0*						
Avrg cvr of non-ntv tree spp, gr	*0*					N/A	N/A
Populus angustifolia	N	0.865	6.920	0.858	11.16	0.902	0.893
Fraxinus pennsylvanica	N	0.015	0.120	0.000	0.000	Insufficient Data	
Avrg cvr of tree species, ungr	0.880						
Avrg cvr of tree species, gr	0.858					0.693	0.663
SHRUBS							
Avrg cvr of non-ntv shrub spp, ung	0						
Avrg cvr of non-ntv shrub spp, gr	0					N/A	N/A
Symphoricarpos occidentalis	N	0.151	1.208	0.025	0.319	0.200	0.086
Cornus stolonifera	N	0.102	0.815	0.000	0.001	0.058	0.008
Juniperus scopulorum	N	0.096	0.767	0.025	0.326	0.299	0.186
Rosa sayi/R. woodsii	N	0.049	0.395	0.009	0.115	0.173	0.074
Rhus trilobata	N	0.019	0.148	0.004	0.052	0.277	0.181
Shepherdia argentea	N	0.017	0.133	0.006	0.075	0.545	0.445
Salix amygdaloides	N	0.015	0.120	0.000	0.000	Insufficient Data	
Ribes aureum	N	0.014	0.108	0.000	0.002	0.336	0.197
Ribes setosum	N	0.005	0.039	0.000	0.001	0.143	0.046
Ribes hudsonianum	N	0	0.001	0.000	0.000	I.D.	
Prunus virginiana	N	0	0.001	0.000	0.003	0.617	0.657
Salix exigua	N	0	0.000	0.000	0.004	Insufficient Data	
Artemisia frigida	N	0	0.000	0.000	0.001	I.D.	
Clematis ligusticifolia	N	0	0.000	0.000	0.001	I.D.	
Betula occidentalis	N	0	0.000	0.009	0.112	I.D.	
Avrg cvr of shrub species, ungr	0.467						
Avrg cvr of shrub species, grzd	0.078					0.0045	0.0001
FORBS							
Cvr non-ntv forbs/cover forbs, ungr	46%						
Cvr non-ntv forbs/cover forbs, grzd	55%						
Avrg cvr of non-ntv forb spp, ungr	0.063						
Avrg cvr of non-ntv forb spp, grzd	0.101					0.435	0.494
Cirsium arvense	X	0.040	0.318	0.004	0.058	0.025	0.003
Arctium minus	X	0.013	0.102	0.001	0.098	I.D.	
Tanacetum vulgare	X	0.009	0.070	0.000	0.001	0.355	0.214

Table 24. Comparison of ungrazed and grazed *Populus angustifolia* sites, cont'd.

FORBS, cont'd.		UNGRAZED		GRAZED		T test ungr v grzd	
		Avrg Cover	Total Cover	Avrg Cover	Total Cover	Separate variance	Pooled variance
Taraxacum officinale	X	0.001	0.008	0.006	0.077	0.819	0.813
Conium maculatum	X	3E-04	0.002	0.000	0.000	I.D.	
Trifolium hybridum	X	1E-04	0.001	0.000	0.000	I.D.	
Tragopogon dubius	X	1E-04	0.001	0.000	0.001	0.749	0.732
Melilotus sum	X	1E-04	0.001	0.000	0.002	0.750	0.796
Euphorbia esula	X	1E-04	0.001	0.004	0.057	0.351	0.460
Cynoglossum officinale	X	1E-04	0.001	0.014	0.176	0.239	0.348
Cirsium vulgare	X	0	0.000	0.000	0.002	I.D.	
Medicago lupulina	X	0	0.000	0.000	0.002	I.D.	
Rumex crispus	X	0	0.000	0.000	0.004	I.D.	
Lactuca serriola	X	0	0.000	0.001	0.008	I.D.	
Trifolium repens	X	0	0.000	0.001	0.010	I.D.	
Silene noctiflora	X	0	0.000	0.001	0.012	I.D.	
Kochia scoparia	X	0	0.000	0.001	0.014	I.D.	
Stellaria media	X	0	0.000	0.003	0.038	I.D.	
Chenopodium album	X	0	0.000	0.005	0.069	I.D.	
Centaurea maculosa	X	0.000	0.000	0.006	0.077	0.368	0.441
Galeopsis tetrahit	X	0	0.000	0.007	0.088	I.D.	
Atriplex heterosperma	X	0	0.000	0.039	0.512	I.D.	
Smilacina stellata	N	0.023	0.183	0.003	0.033	0.279	0.007
Glycyrrhiza lepidota	N	0.022	0.173	0.048	0.627	0.374	0.420
Solidago gigantea	N	0.012	0.092	0.000	0.002	0.084	0.017
Apocynum sibiricum	N	0.005	0.041	0.000	0.000	I.D.	
Rudbeckia laciniata	N	0.005	0.036	0.000	0.002	0.367	0.227
Equisetum pratense	N	9E-04	0.007	0.000	0.000	I.D.	
Urtica dioica	N	4E-04	0.003	0.000	0.000	I.D.	
Equisetum laevigatum	N	3E-04	0.002	0.000	0.002	0.674	0.687
Polygonum sp.	N	1E-04	0.001	0.001	0.008	0.449	0.546
Achillea millefolium	N	1E-04	0.001	0.000	0.000	I.D.	
Equisetum sp.	N	1E-04	0.001	0.000	0.000	I.D.	
Vicia americana	N	1E-04	0.001	0.000	0.000	I.D.	
Mentha arvensis	N	1E-04	0.001	0.000	0.000	I.D.	
Geum macrophyllum	N	1E-04	0.001	0.000	0.000	I.D.	
Galium aparine	N	1E-04	0.001	0.000	0.000	I.D.	
Plantago major	N	1E-04	0.001	0.000	0.002	0.862	0.863
Solidago missouriensis	N	0	0.000	0.000	0.001	I.D.	
Equisetum arvense	N	0	0.000	0.000	0.001	I.D.	
Equisetum variegatum	N	0	0.000	0.000	0.002	I.D.	
Fragaria vesca	N	0	0.000	0.000	0.004	I.D.	
Asclepias speciosa	N	0	0.000	0.001	0.010	I.D.	
Antennaria microphylla	N	0	0.000	0.001	0.010	I.D.	
Aster ascendens	N	0	0.000	0.007	0.085	I.D.	
Avrg cvr of native forb spp, ungr	0.068						
Avrg cvr of native forb spp, grzd	0.061						
Avrg cvr of forb species, ungr	0.131						
Avrg cvr of forb species, grzd	0.161					0.529	0.578

Table 24. Comparison of ungrazed and grazed *Populus angustifolia* sites, cont'd.

GRAMINOIDS		UNGRAZED		GRAZED		T test ungr v grzd	
		Avrg Cover	Total Cover	Avrg Cover	Total Cover	Separate variance	Pooled variance
Cvr non-ntv grass/cvr grass, ungr	79%						
Cvr non-ntv grass/cvr grass, grzd	75%						
Avrg cvr of non-ntv grass spp, ung	0.164						
Avrg cvr of non-ntv grass spp, gr	0.313					0.071	0.115
Elymus repens	X	0.013	0.100	0.139	1.808	0.044	0.094
Phalaris arundinacea	X	0.053	0.423	0.000	0.000	0.109	0.028
Poa pratensis	X	0.049	0.395	0.085	1.100	0.398	0.485
Bromus inermis	X	0.046	0.364	0.059	0.762	0.742	0.772
Dactylis glomerata	X	0.004	0.031	0.027	0.346	0.285	0.393
Agropyron cristatum	X	3E-04	0.002	0.000	0.000	I.D.	
Elymus hispidus	X	0	0.000	0.000	0.001	I.D.	
Poa compressa	X	0	0.000	0.000	0.002	I.D.	
Bromus tectorum	X	0	0.000	0.000	0.004	I.D.	
Phleum pratense	X	0	0.000	0.004	0.047	I.D.	
Agrostis stolonifera	N	0.028	0.224	0.054	0.708	0.454	0.515
Elymus smithii	N	0.007	0.056	0.001	0.012	0.381	0.249
Elymus trachycaulus/E. sp.	N	0.002	0.012	0.000	0.000	I.D.	
Juncus balticus	N	5E-04	0.004	0.000	0.000	I.D.	
Carex microptera	N	3E-04	0.002	0.000	0.000	I.D.	
Carex sp.	N	1E-04	0.001	0.001	0.007	0.468	0.562
Elymus cinereus	N	0	0.000	0.002	0.024	I.D.	
Poa palustris	N	0	0.000	0.002	0.030	I.D.	
Carex aquatilis	N	0	0.000	0.012	0.159	I.D.	
Avrg cvr of native grass spp, ungr	0.037						
Avrg cvr of native grass spp, grzd	0.072					0.412	0.456
Avrg cvr of grass species, ungr	0.202						
Avrg cvr of grass species, grzd	0.385					0.010	0.029

Table 25. Comparison of ungrazed vs. grazed *Populus deltoides* sites, cover data and t test results. Species grouped by life form, then in order by cover.

UNGRAZED SITES (n = 17) (0.0% cow pie)	AvCvr	StDev	T tests, grazed vs. ungrazed.	Sep Var.	Pool Var.
Cover of non-ntv spp/cover of all spp, ungr	0.423	0.207		0.576	0.575
Average cover of species/ungrazed site	1.563	0.301		0.996	0.996
Percent cover of non-native species/ungr	28%	14%		0.772	0.773

GRAZED SITES (n = 17) (0.8% cow pie)	AvCvr	StDev
Cover of non-native species/cover of all species, grzd	0.450	0.234
Average cover of all species/grazed site	1.535	0.252
Percent cover of non-native species/grazed site	28%	12%

Native/Non-native TREES	N/X	UNGRAZED Avrg Cover	UNGRAZED Sum Cover	GRAZED Avrg Cover	GRAZED Sum Cover	T test ungr v. grzd Separate variance	T test ungr v. grzd Pooled variance
Avrg cvr of non-native tree spp, ungr	0						
Avrg cvr of non-native tree spp, grzd	0						
Salicaceae Populus deltoides	N	0.745	13.630	0.792	13.480	0.585	0.583
Oleaceae Fraxinus pennsylvanica	N	0.012	0.198	0.001	0.011	0.234	0.226
Salicaceae Populus angustifolia	N	0.000	0.000	0.014	0.240	Insufficient Data	
Avrg cvr of tree spp, ungr	0.813						
Avrg cvr of tree spp, grzd	0.808					0.868	0.870
SHRUBS							
Cvr non-ntv shrubs/cvr all shrubs, ungr	42%						
Cvr non-ntv shrubs/cvr all shrubs, gr	25%						
Avrg cvr of non-native shrub spp, ungr	0.152						
Avrg cvr of non-ntv shrub spp, grzd	0.092					0.413	0.412
Elaeagnaceae Elaeagnus angustifolia	X	0.149	2.541	0.092	1.563	0.365	0.365
Asteraceae Artemisia absinthium	X	0.002	0.038	2E-04	0.004	0.192	0.184
Anacardiaceae Toxicodendron rydbergii	N	0.078	1.332	0.011	0.192	0.108	0.101
Caprifoliaceae Symphoricarpos occidentalis	N	0.047	0.803	0.071	1.210	0.584	0.583
Cupressaceae Juniperus scopulorum	N	0.039	0.666	8E-04	0.014	0.184	0.175
Rosaceae Rosa sayi/R. woodsii	N	0.016	0.263	0.018	0.300	0.904	0.905
Vitaceae Vitis riparia	N	0.012	0.211	0.003	0.053	0.367	0.362
Cornaceae Cornus stolonifera	N	0.011	0.184	0.000	0	I. D.	
Anacardiaceae Rhus trilobata	N	0.011	0.181	0.017	0.295	0.612	0.611
Elaeagnaceae Shepherdia argentea	N	0.008	0.143	0.021	0.364	0.565	0.561
Ranunculaceae Clematis ligusticifolia	N	0.008	0.138	0.016	0.266	0.518	0.515
Salicaceae Salix amygdaloides	N	0.008	0.131	0.000	0	I. D.	
Vitaceae Parthenocissus inserta	N	0.007	0.123	0.001	0.016	0.301	0.293
Grossulariaceae Ribes aureum	N	0.007	0.117	0.001	0.013	0.322	0.314
Salicaceae Salix exigua	N	0.004	0.064	0.000	0	I. D.	
Asteraceae Artemisia dracunculus	N	0.002	0.041	0.000	0	I. D.	
Grossulariaceae Ribes setosum	N	0.001	0.020	0.000	0.002	0.237	0.228
Rosaceae Prunus virginiana	N	6E-04	0.010	0.000	0.001	0.28	0.272
Asteraceae Artemisia frigida	N	6E-05	0.001	0.001	0.014	0.294	0.287
Asteraceae Artemisia cana	N	0.023	0.000	0.000	0.399	I. D.	
Salicaceae Salix rigida	N	1E-04	0.000	0.000	0.002	I. D.	
Avrg cvr of native shrub spp, ungr	0.261						
Avrg cvr of native shrub spp, grzd	0.185					0.416	0.415
Avrg cvr of shrub spp, ungr	0.412						
Avrg cvr of shrub spp, grzd	0.277					0.310	0.315

Table 25. Comparison of ungrazed vs. grazed *Populus deltoides* sites, cont'd.

FORBS		UNGRAZED		GRAZED		T test ungr v. grzd	
		Avrg Cover	Sum Cover	Avrg Cover	Sum Cover	Separate variance	Pooled variance
Cvr non-ntv forbs/cvr all forbs, ungr	32%						
Cvr non-ntv forbs/cvr all forbs, grzd	70%						
Avrg cvr of non-native forb spp, ungr	0.022						
Avrg cvr of non-native forb spp, grzd	0.083					0.036	0.032
Euphorbiaceae Euphorbia esula	X	0.004	0.060	0.018	0.308	0.343	0.337
Asteraceae Arctium minus	X	0.006	0.110	0.000	0.001	0.318	0.311
Solanaceae Solanum dulcamara	X	0.006	0.095	0.001	0.011	0.377	0.371
Asteraceae Cirsium arvense	X	0.003	0.048	0.012	0.197	0.294	0.288
Asteraceae Taraxacum officinale	X	7E-04	0.012	0.019	0.316	0.105	0.095
Fabaceae Melilotus alba/officinalis	X	0.001	0.017	0.002	0.033	0.39	0.387
Fabaceae Medicago lupulina	X	4E-04	0.006	0.005	0.082	0.089	0.080
Lamiaceae Nepeta cataria	X	3E-04	0.005	0.000	0.002	0.583	0.581
Scrophulariaceae Verbascum thapsus	X	3E-04	0.005	0.001	0.01	0.578	0.576
Chenopodiaceae Chenopodium album	X	2E-04	0.003	0.009	0.149	0.241	0.233
Asteraceae Sonchus uliginosus/asper	X	2E-04	0.003	0.000	0	I. D.	
Asteraceae Tanacetum vulgare	X	2E-04	0.003	0.000	0.001	0.413	0.41
Asteraceae Cirsium vulgare	X	1E-04	0.002	0.000	0	I. D.	
Brassicaceae Sisymbrium loeselii	X	1E-04	0.002	0.004	0.06	0.348	0.341
Polygonaceae Polygonum convulvulus	X	6E-05	0.001	0.000	0	I. D.	
Boraginaceae Cynoglossum officinale	X	6E-05	0.001	0.000	0.005	0.142	0.137
Apiaceae Conium maculatum	X	0	0.000	0.000	0.001	I. D.	
Brassicaceae Camelina microcarpa	X	0	0.000	0.000	0.001	I. D.	
Brassicaceae Capsella bursa - pastoris	X	0	0.000	0.000	0.001	I. D.	
Brassicaceae Descurainia sophia	X	0	0.000	0.000	0.001	I. D.	
Chenopodiaceae Kochia scoparia	X	0	0.000	0.000	0.002	I. D.	
Chenopodiaceae Salsola kali	X	0	0.000	0.000	0.002	I. D.	
Asteraceae Centaurea maculosa	X	0	0.000	0.000	0.003	I. D.	
Liliaceae Asparagus officinalis	X	0	0.000	0.000	0.003	I. D.	
Fabaceae Trifolium fragiferum	X	0	0.000	0.000	0.007	I. D.	
Asteraceae Tragopogon dubius	X	0	0.000	0.001	0.009	I. D.	
Asteraceae Lactuca serriola	X	0	0.000	0.001	0.012	I. D.	
Chenopodiaceae Atriplex heterosperma	X	0	0.000	0.001	0.014	I. D.	
Fumariaceae Fumaria officinalis	X	0	0.000	0.011	0.186	I. D.	
Urticaceae Parietaria pensylvanica	N	0.005	0.084	0.003	0.056	0.776	0.776
Asteraceae Solidago mollis	N	0.005	0.080	0.000	0	I. D.	
Apocynaceae Apocynum sibiricum	N	0.005	0.077	0.000	0.002	0.150	0.141
Liliaceae Smilacina stellata	N	0.003	0.043	0.000	0.005	0.152	0.143
Fabaceae Glycyrrhiza lepidota	N	0.002	0.033	0.012	0.2	0.181	0.172
Asteraceae Solidago gigantea	N	0.001	0.022	0.000	0.001	0.191	0.181
Asclepiadaceae Asclepias speciosa	N	0.001	0.019	0.000	0.002	0.22	0.212
Ranunculaceae Anemone sp.	N	6E-04	0.010	0.000	0	I. D.	
Solanaceae Solanum sarrachoides	N	5E-04	0.008	0.000	0	I. D.	
Rubiaceae Galium aparine	N	4E-04	0.007	0.000	0	I. D.	
Asteraceae Aster ascendens	N	4E-04	0.007	0.000	0.001	0.339	0.333
Asclepiadaceae Asclepias verticillata	N	2E-04	0.004	0.000	0	0.223	0.229
Asteraceae Solidago occidentalis	N	2E-04	0.004	0.000	0.001	0.316	0.311

Table 25. Comparison of ungrazed vs. grazed *Populus deltoides* sites, cont'd.

FORBS, cont'd.		UNGRAZED		GRAZED		T test ungr v. grzd	
		Avrg Cover	Sum Cover	Avrg Cover	Sum Cover	Separate variance	Pooled variance
Equisetaceae Equisetum hyemale	N	1E-04	0.002	0.000	0	I. D.	
Violaceae Viola sp.	N	7E-04	0.002	0.000	0.011	0.341	0.335
Asteraceae Ambrosia psilostachya	N	1E-04	0.002	0.011	0.181	0.089	0.079
Caprifoliaceae Lonicera sp.	N	6E-05	0.001	0.000	0	I. D.	
Equisetaceae Equisetum variegatum	N	6E-05	0.001	0.000	0	I. D.	
Lamiaceae Mentha arvensis	N	6E-05	0.001	0.000	0	I. D.	
Polygonaceae Polygonum sp.	N	6E-05	0.001	0.000	0	I. D.	
Primulaceae Lysimachia ciliata	N	6E-05	0.001	0.000	0	I. D.	
Plantiginaceae Plantago major	N	6E-05	0.001	0.000	0.001	1.000	1.000
Asteraceae Conyza canadensis	N	0	0.000	0.000	0.001	I. D.	
Asteraceae Helianthus annuus	N	0	0.000	0.000	0.001	I. D.	
Asteraceae Solidago spathulata	N	0	0.000	0.000	0.001	I. D.	
Brassicaceae Rorippa palustris	N	0	0.000	0.000	0.001	I. D.	
Fabaceae Vicia americana	N	0	0.000	0.000	0.001	I. D.	
Ranunculaceae Thalictrum dasycarpum	N	0	0.000	0.000	0.001	I. D.	
Verbenaceae Verbena hastata	N	0	0.000	0.000	0.001	I. D.	
Brassicaceae Lepidium densiflorum	N	0	0.000	0.000	0.003	I. D.	
Fabaceae Psoralea lanceolata	N	0	0.000	0.000	0.005	I. D.	
Asteraceae Xanthium strumarium	N	0	0.000	0.000	0.006	I.D.	
Asteraceae Grindelia squarrosa	N	0	0.000	0.000	0.006	I. D.	
Polygonaceae Polygonum achoreum	N	0	0.000	0.001	0.010	I. D.	
Asteraceae Ambrosia trifida	N	0	0.000	0.001	0.024	I. D.	
Avrg cvr native forb spp, ungr	0.024						
Avrg cvr native forb spp, grzd	0.031						
Avrg cvr of forb spp, ungr	0.046						
Avrg cvr of forb spp, grzd	0.114					0.072	0.068
GRAMINOIDS							
Cvr non-ntv grmnd/cvr all grmnd, ung	89%						
Cvr non-ntv grmnd/cvr all grmnds, grz	81%						
Avrg cvr of non-ntv grmnd spp, ungr	0.250						
Avrg cvr of non-ntv grmnd spp, grzd	0.274					0.528	0.529
Poaceae Bromus inermis	X	0.147	2.504	0.125	2.120	0.732	0.732
Poaceae Poa pratensis	X	0.043	0.736	0.087	1.472	0.137	0.136
Poaceae Elymus repens	X	0.04	0.672	0.043	0.728	0.903	0.903
Poaceae Phalaris arundinacea	X	0.017	0.290	0.007	0.121	0.408	0.408
Poaceae Poa compressa	X	0.002	0.040	0.002	0.028	0.792	0.791
Poaceae Alopecurus arundinaceus	X	1E-04	0.002	0.000	0	I. D.	
Poaceae Festuca arundinacea	X	1E-04	0.002	0.000	0	I. D.	
Poaceae Setaria viridis	X	0	0.000	0.000	0.001	I. D.	
Poaceae Bromus mollis	X	0	0.000	0.001	0.014	I. D.	
Poaceae Bromus japonicus	X	0	0.000	0.002	0.031	I. D.	
Poaceae Bromus tectorum	X	0	0.000	0.009	0.149	0.160	0.150
Poaceae Elymus trachycaulus/A. sp.	N	0.018	0.300	0.008	0.131	0.541	0.539
Poaceae Elymus canadensis	N	0.013	0.223	0.000	0.004	0.269	0.261
Poaceae Calamovilfa longifolia	N	0.006	0.098	0.004	0.071	0.811	0.811

Table 25. Comparison of ungrazed vs. grazed *Populus deltoides* sites, cont'd.

GRAMINOIDS, cont'd.		UNGRAZED		GRAZED		T test ungr v. grzd	
		Avrg Cover	Sum Cover	Avrg Cover	Sum Cover	Separate variance	Pooled variance
Poaceae Agrostis stolonifera	N	0.005	0.082	0.003	0.058	0.775	0.775
Poaceae Muhlenbergia racemosa	N	2E-04	0.004	0.001	0.011	0.34	0.339
Cyperaceae Carex sp.	N	2E-04	0.003	0.000	0.001	0.413	0.41
Poaceae Spartina pectinata	N	6E-05	0.001		0	I. D.	
Poaceae Stipa viridula	N	0	0.000	0.000	0.001	I. D.	
Poaceae Sporobolus cryptandrus	N	0	0.000	0.001	0.012	I. D.	
Poaceae Spartina gracilis	N	0	0.000	0.001	0.014	I. D.	
Poaceae Stipa comata	N	0	0.000	0.002	0.03	I. D.	
Poaceae Hordeum jubatum	N	0	0.000	0.003	0.045	I. D.	
Poaceae Boutelua gracilis	N	0	0.000	0.003	0.047	I. D.	
Poaceae Elymus spicatus	N	0	0.000	0.015	0.260	I. D.	
Poaceae Elymus smithii	N	0	0.000	0.022	0.369	0.083	0.074
Avrg cvr of native grass spp, ungr	0.042						
Avrg cvr of grass spp, ungr	0.292						
Avrg cvr of native grass spp, grzd	0.062						
Avrg cvr of grass spp, grzd	0.336					0.367	0.368

Table 26. Comparison of cover, richness and percent non-native species across grazed riparian plant communities.

Vegetation Type	Tree		Shrub				Forb				Graminoid			
	X*	Total	% Non Ntv	# Non Ntv	# Ntv	Total #	% Non Ntv	# Non Ntv	# Ntv	Total #	% Non Ntv	# Non Ntv	# Ntv	Total #
Gravelbar (n = 6)														
Richness/all sites	0	2	40%	2	3	5	47%	22	25	47	25%	5	15	20
Richness/each site	0	0.7	11%	0.3	1.7	2	47%	7.5	7.7	15.2	31%	1.5	4.3	5.8
Cover	0	0.033	0%	0.000	0.025	0.025	50%	0.022	0.020	0.042	54%	0.025	0.009	0.035
Sandbar (n = 4)														
Richness/all sites	0	2	33%	1	2	3	34%	11	21	32	24%	5	16	21
Richness/each site	0	1.0	13%	0.25	1.0	1.25	43%	4.3	7.3	11.5	31%	1.3	5.0	6.3
Cover	0	0.012	0%	0	0.003	0.003	41%	0.025	0.090	0.113	11%	0.012	0.047	0.059
Salix exigua (n = 10)														
Richness/all sites	0	4	23%	3	10	13	42%	21	29	50	28%	8	21	29
Richness/each site	0	0.6	9%	0.5	3.1	3.6	52%	6.5	5.8	12.3	46%	2.7	3.9	6.6
Cover	0	0.024	1%	0.006	0.423	0.429	56%	0.091	0.114	0.205	41%	0.108	0.118	0.226
Populus angustifolia (n = 13)														
Richness/all sites	0	2	0%	0	16	16	59%	24	17	41	53%	9	8	17
Richness/each site	0	1.1	0%	0	3.5	3.5	69%	4.8	2.3	7.1	77%	3.3	1.0	4.3
Cover	0	0.858	0%	0.000	0.078	0.078	55%	0.101	0.061	0.161	75%	0.315	0.070	0.385
Populus deltoides (n = 17)														
Richness/all sites	0	3	20%	3	15	15	49%	30	31	61	39%	9	14	23
Richness/each site	0	1.2	24%	0.8	3.4	4.2	59%	4.7	3.2	7.9	63%	2.5	2.0	4.5
Cover	0	0.808	25%	0.092	0.185	0.277	71%	0.083	0.031	0.114	81%	0.274	0.062	0.336

* No non-native tree species were found. *Elaeagnus angustifolia* was classified as a shrub, per the USDA on-line plants database.

Table 26. Comparison of cover, richness and percent non-native species across grazed riparian plant communities, cont'd.

Vegetation Type	SUMMARY						
	% Non Ntv	*St Dev*	# Non Ntv	*St Dev*	# Ntv	Total #	*St Dev*
Gravelbar (n = 6)							
Richness/all sites	39%	*N/A*	*29*	*N/A*	45	74	*N/A*
Richness/each site	39%	*10%*	*9.3*	*4.5*	14.4	23.7	*11.5*
Cover	37%	*27%*	*0.048*	*0.040*	0.087	0.134	*0.026*
Sandbar (n = 4)							
Richness/all sites	29%	*N/A*	*17*	*N/A*	41	58	*N/A*
Richness/each site	34%	*16%*	*5.8*	*2.1*	14.3	20	*14*
Cover	26%	*24%*	*0.037*	*0.022*	0.152	0.186	*0.141*
Salix exigua (n = 10)							
Richness/all sites	33%	*N/A*	*32*	*N/A*	64	96	*N/A*
Richness/each site	41%	*9%*	*9.7*	*3.9*	13.4	23.1	*6.4*
Cover	25%	*20%*	*0.203*	*0.173*	0.679	0.885	*0.340*
Populus angustifolia (n = 13)							
Richness/all sites	43%	*N/A*	*33*	*N/A*	43	76	*N/A*
Richness/each site	50%	*10%*	*8.1*	*3*	7.9	16	*4.9*
Cover	27%	*14%*	*0.416*	*0.249*	1.067	1.483	*0.226*
Populus deltoides (n = 17)							
Richness/all sites	40%	*N/A*	*42*	*N/A*	63	105	*N/A*
Richness/each site	50%	*10%*	*8.1*	*3.8*	9.8	17.9	*6.9*
Cover	28%	*12%*	*0.450*	*0.234*	1.086	1.535	*0.252*

Table 27. Environmental variable averages at ungrazed vs. grazed sites, by riparian plant community.

Environmental variables	*Populus angustifolia*				*Populus deltoides*				*Salix exigua*				Sandbars			
	Ungrazed		Grazed		Ungrazed		Grazed		Ungrazed		Grazed		Ungrazed		Grazed	
	avrg	st dev	avrg	st dev	avrg	st dev	avrg	st dev	avrg	st dev	avrg	st dev	avrg	st dev	avrg	st dev
Mile on river*	48.4	37.87	31	26.98	304.9	129.7	315.4	131.5	161.5	146.5	97.2	107.4	205.3	162.4	263.2	264.2
Gage height (ft)	11.2	2.3	11.5	1.9	16.7	5.5	14.7	3.8	9.7	2.0	9.5	2.3	6.9	2.3	7.9	2.9
Height above water (ft)	7.7	2.7	8.6	2.5	14.3	5.6	12.3	3.5	6.8	2.4	6.8	2.4	4.6	2.4	5.1	3.0
Height above water (m)	2.4	0.8	2.6	0.8	4.4	1.7	3.7	1.1	2.1	0.7	2.1	0.7	1.4	0.7	1.5	0.9
Depth to gravel (cm)	111	48	74	38	153	38	176	93	111	40	125	54	28	24	32	34
CaCO3% Equiv	0.4	0.5	0.2	0.2	3.4	1.6	3.3	1.3	1.8	1.8	1.0	1.4	1.5	1.7	2.3	2.6
pH (1 to 1)	7.8	0.2	7.9	0.3	8.1	0.3	8.2	0.2	8.1	0.4	8.1	0.3	8.1	0.5	8.0	0.3
Total C%	2.85	1.152	3.78	4.409	2.26	1.04	2.3	1.3	1.20	1.09	0.77	0.46	0.56	0.23	0.89	0.47
% Organic C	2.80	1.149	3.75	4.404	1.86	0.96	1.9	1.3	0.99	1.13	0.65	0.40	0.37	0.06	0.62	0.21
Total N%	0.168	0.065	0.271	0.358	0.123	0.069	0.133	0.095	0.065	0.078	0.041	0.025	0.023	0.005	0.032	0.012
Sand %	36	14	56	10	42	20	45.5	18.4	53	17	67	13	72	11	59	15
Silt %	49	12	32	8	38	12	35.4	10.6	35	13	23	10	21	8	30	11
Clay %	15	4	12	3	20	10	19.1	9.5	12	5	10	6	7	3	11	5
EC mmhos/cm, 1 to 1	0.45	0.221	0.65	0.677	0.47	0.24	0.46	0.52	0.51	0.36	0.37	0.24	0.37	0.09	0.35	0.13

Environmental variables	Gravelbars			
	Ungrazed		Grazed	
	avrg	st dev	avrg	st dev
Mile on river*	110.4	106.6	130.0	178.6
Gage height (ft)	7.1	2.0	6.6	2.9
Height above water (ft)	4.7	2.1	2.8	2.7
Height above water (m)	1.4	0.6	0.9	0.8

*Measured from Big Creek, MT, going downriver

Table 28. Shrub cover of ungrazed vs. grazed *Populus deltoides* sites; releve and cover data.
Sites are segregated by ungrazed/grazed, then in order by DBH. Species are in order by life form, then by average cover.

UNGRAZED STUDY SITES			USP	U2P2	UYP	UWP	UZP2	UZP	UXP	UVP	UWP2	URP2	U1P	UPP	U4P	U1P2	URP	UOP	USP2
Percent cover cow pie			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DBH, three largest trees			33	36	38	40	41	44	50	54	56	65	71	72	73	75	76	82	112
Mile on river from Big Creek, MT			203.0	491.5	361.2	258.5	372.2	372.2	308.3	251.5	258.5	193.7	479.3	144.0	509.8	479.3	193.7	103.0	203.0
Populus deltoides	N	0.802	0.800	0.920	0.920	0.510	1.000	1.000	0.960	0.960	0.720	0.840	0.520	0.960	0.960	0.440	0.120	1.000	1.000
SHRUBS (UNGRAZED)		AvCvr																	
Avrg cover of non-native shrub spp		0.152	0.003	0.000	0.142	0.160	0.048	0.359	0.152	0.000	0.119	0.442	0.106	0.210	0.188	0.000	0.630	0.000	0.020
Elaeagnus angustifolia	X	0.149	0.001		0.142	0.160	0.048	0.359	0.152		0.119	0.426	0.106	0.210	0.188		0.630		
Artemisia absinthium	X	0.002	0.002									0.016							0.020
Toxicodendron rydbergii	N	0.078		0.010					0.158	0.004			0.270		0.290	0.030			0.570
Symphoricarpos occidentalis	N	0.047						0.001	0.014	0.021		0.055	0.230		0.088	0.170	0.004		0.220
Juniperus scopulorum	N	0.039										0.256					0.410		
Rosa sayi	N	0.014				0.005						0.044	0.094		0.016				0.084
Vitis riparia	N	0.012	0.001	0.004					0.001	0.009			0.164		0.028				0.004
Cornus stolonifera	N	0.011	0.004							0.001			0.078		0.083				0.018
Rhus trilobata	N	0.011										0.020		0.061		0.100			
Shepherdia argentea	N	0.008	0.001									0.060		0.080	0.002				
Clematis ligusticifolia	N	0.008	0.011	0.012					0.062			0.051					0.001		0.001
Salix amygdaloides	N	0.008	0.020			0.082								0.002				0.027	
Parthenocissus inserta	N	0.007		0.100									0.014		0.009				
Ribes aureum	N	0.007	0.002									0.102				0.000	0.006		0.007
Salix exigua	N	0.004	0.064																
Artemisia dracunculus	N	0.002														0.041			
Ribes setosum	N	0.001	0.001										0.005		0.014				
Rosa sp.	N	0.001																0.016	
Prunus virginiana	N	0.001											0.008	0.001		0.001			
Solanum sarrachoides	N	0.000							0.008										
Artemisia frigida	N	0.000														0.001			
Artemisia cana	N	0.000																	
Salix rigida	N	0																	
Avrg cvr of ntv shrub spp		0.261	0.104	0.126	0.000	0.087	0.000	0.001	0.243	0.035	0.000	0.588	0.863	0.144	0.530	0.343	0.421	0.043	0.904
Average cover of shrub spp		0.412	0.107	0.126	0.142	0.247	0.048	0.360	0.395	0.035	0.119	1.030	0.969	0.354	0.718	0.343	1.051	0.043	0.924

Table 28. Shrub cover of ungrazed vs. grazed *Populus deltoides* sites; releve and cover data, cont'd.
Sites are segregated by ungrazed/grazed, then in order by DBH. Species are in order by life form, then by average cover.

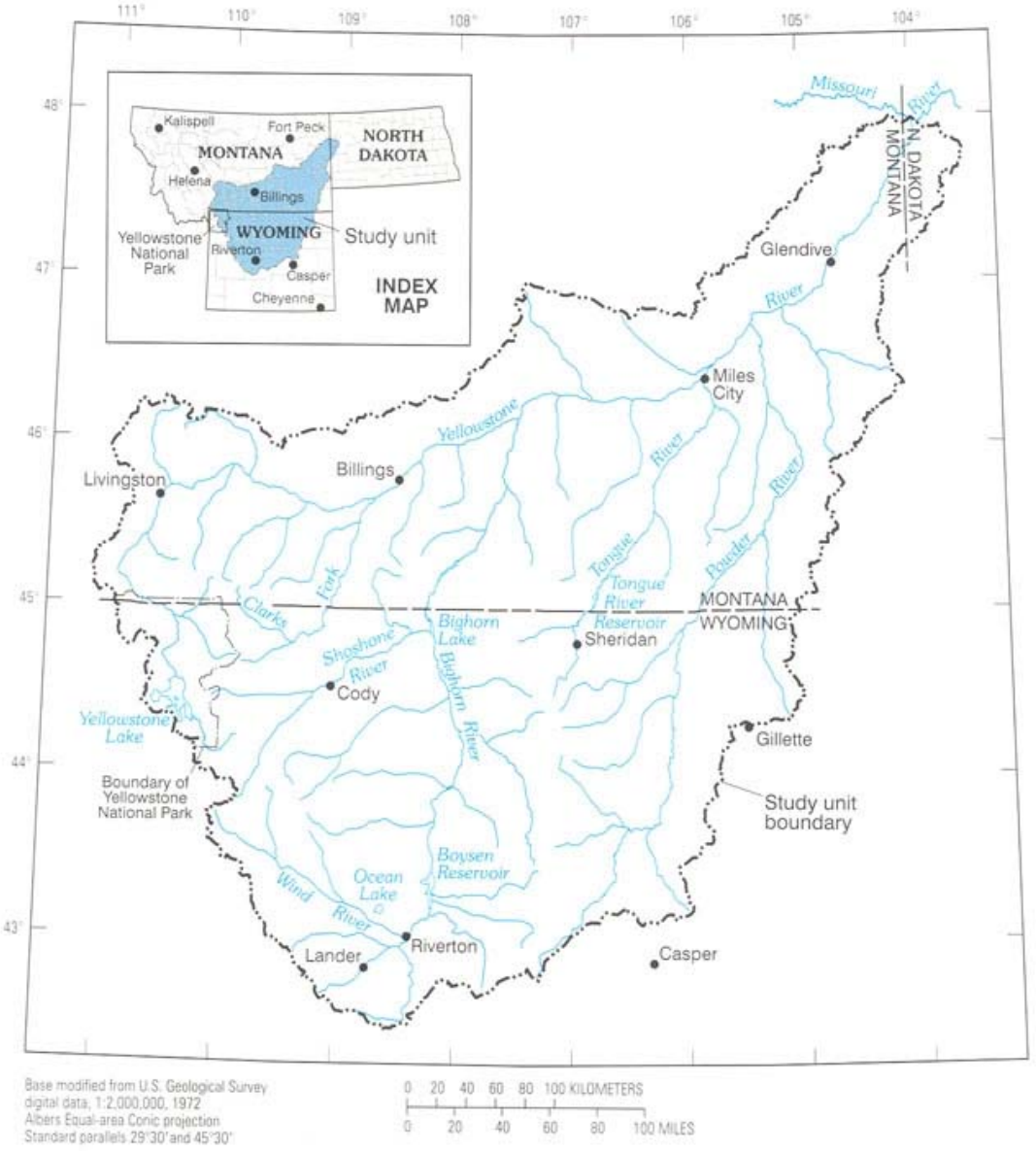
GRAZED STUDY SITES			G2P2	G2P	G3P	G1P	G1P2	GPP2	GUP	GXP	GXP2	GRP2	GPP	GRP	GSP	GZP	GZP2	GTP	GTP2
Percent cover cow pie			0.000	0.000	0.000	0.004	0.014	0.028	0.016	0.018	0.018	0.000	0.006	0.000	0.000	0.005	0.011	0.008	0.016
DBH, three largest trees			28	41	44	?	?	54	55	66	66	70	c. 72	80	84	88	88	96	103
Mile on river from Big Creek, MT			491.5	491.5	491.5	479.3	479.3	144.1	248.4	308.3	308.3	193.7	143.9	193.7	203.0	372.2	372.2	220.4	220.4
Populus deltoides	N	0.793	0.880	1.000	0.880	0.920	0.960	0.880	0.960	0.640	0.600	0.760	0.920	0.680	0.600	0.600	0.520	0.760	0.920
SHRUBS (GRAZED)		AvCvr											Shrubs PODE Cover						
Average cover of non-native shrub spp		0.092	0.003	0.001	0.117	0.000	0.078	0.000	0.582	0.000	0.048	0.038	0.001	0.578	0.000	0.000	0.000	0.000	0.121
Elaeagnus angustifolia	X	0.092	0.003	0.001	0.117	0.000	0.078	0.000	0.582		0.048	0.038	0.001	0.574					0.121
Artemisia absinthium	X	0.000										0.000		0.004					0.000
Toxicodendron rydbergii	N	0.011	0.002	0.002			0.020								0.162			0.006	
Symphoricarpos occidentalis	N	0.071	0.003	0.011		0.018		0.001				0.260	0.001		0.380			0.526	0.010
Juniperus scopulorum	N	0.001								0.014									
Rosa sayi	N	0.014	0.004	0.004														0.118	0.111
Vitis riparia	N	0.003	0.001	0.001	0.001										0.050			0.000	
Cornus stolonifera	N	0.000																	
Rhus trilobata	N	0.017						0.041			0.010	0.190	0.024		0.030				
Shepherdia argentea	N	0.021									0.364								
Clematis ligusticifolia	N	0.016	0.108	0.008										0.150					
Salix amygdaloides	N	0.000																	
Parthenocissus inserta	N	0.001	0.005	0.001	0.004	0.004	0.002												
Ribes aureum	N	0.001	0.004								0.002	0.001			0.006				
Salix exigua	N	0.000																	
Artemisia dracunculus	N	0.000																	
Ribes setosum	N	0.000		0.002															
Rosa sp.	N	0.004										0.021			0.042				
Prunus virginiana	N	0.000		0.001															
Solanum sarrachoides	N	0.000																	
Artemisia frigida	N	0.001	0.001							0.012							0.001		
Artemisia cana	N	0.023									0.001					0.070	0.328		
Salix rigida	N	0.000				0.002													
Avrg cvr of ntv shrub spp, grzd		0.185	0.128	0.030	0.005	0.024	0.022	0.042	0.000	0.026	0.377	0.472	0.025	0.150	0.670	0.070	0.329	0.650	0.121
Average cover of shrub spp		0.277	0.131	0.031	0.122	0.024	0.100	0.042	0.582	0.026	0.425	0.510	0.026	0.728	0.670	0.070	0.329	0.650	0.242

Table 29. Species richness found by sampling lower Yellowstone River sites by two methods.

Community	1980 (Boggs 1984)			2001 (our data)		
	Species/ site	# of non-natives/site	Percent non-native	Species/ site	# of non-natives/site	Percent non-native
Sandbar	9.8	2.2	22.40%	25.2	11.3	44.8%
Salix exigua	*15.9*	4.1	25.8%	22.0	9.6	43.6%
P. deltoides	*16.8*	2.0	11.9%	19.0	8.3	43.7%
Average			20.0%			44.0%

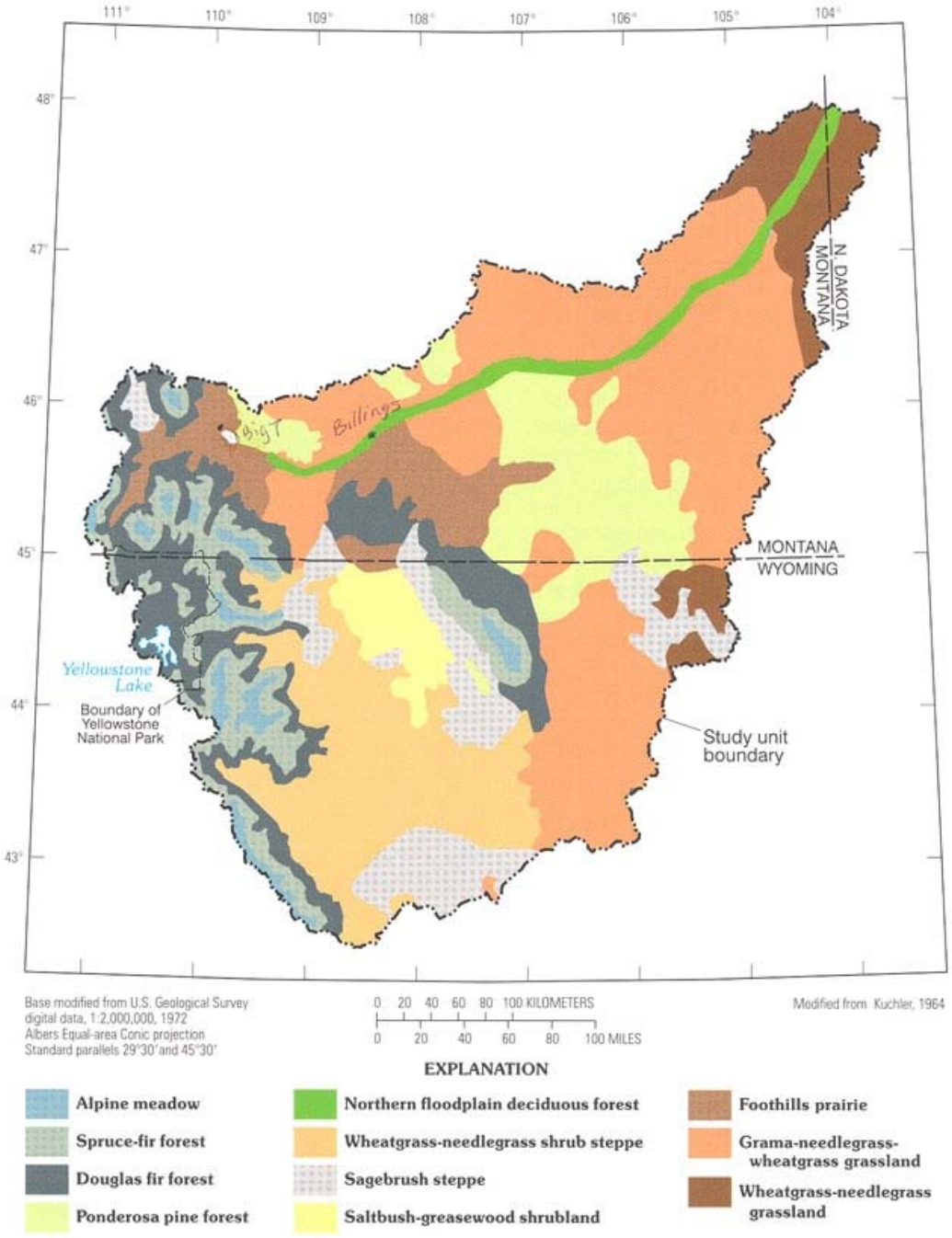
APPENDIX B

FIGURES



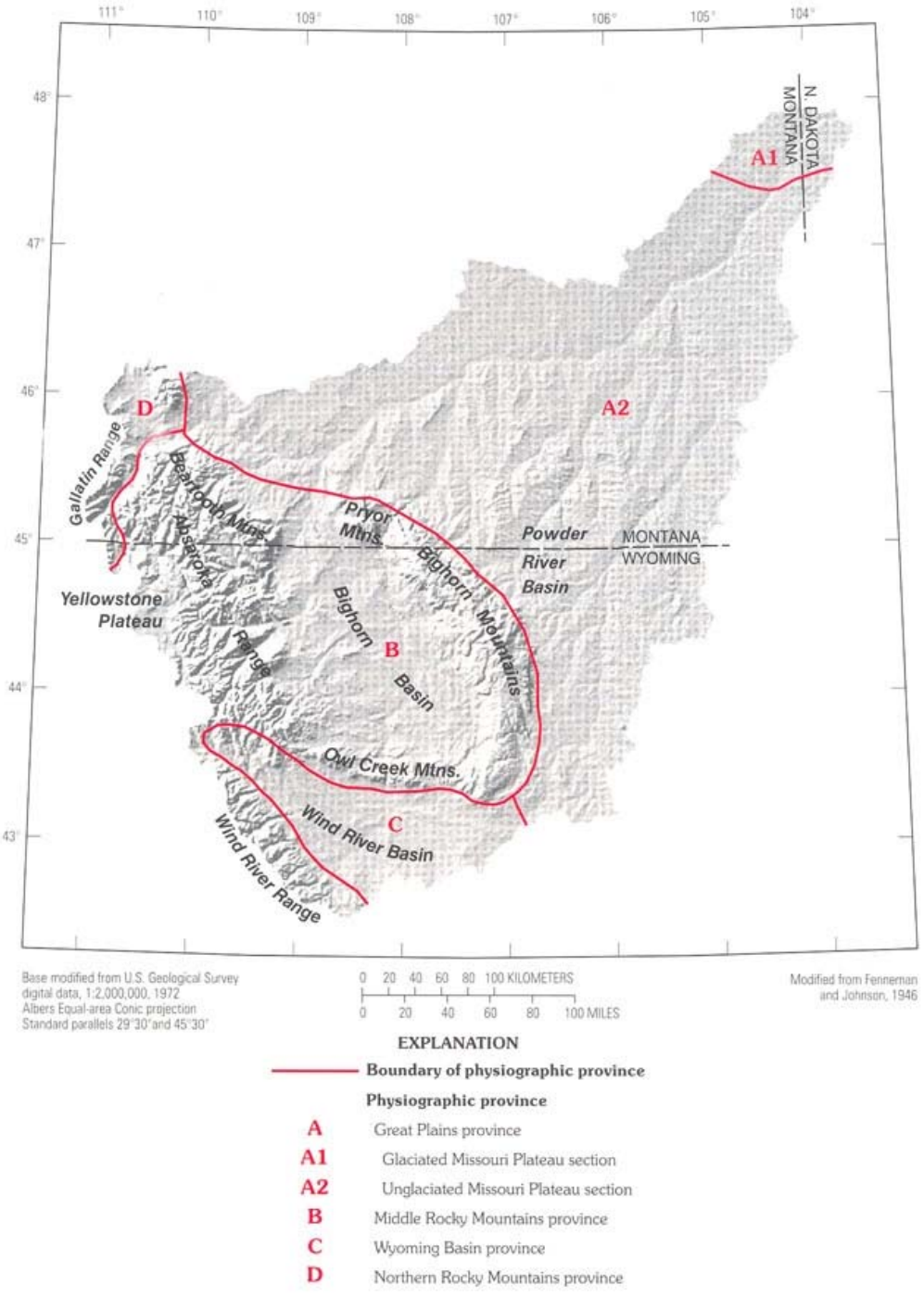
From Zelt, 1999

Figure 1 - The Yellowstone River Basin. The River flows out of Yellowstone Lake in Wyoming, north into Montana and turns east at Livingston. It passes through Billings, Miles City and Glendive before crossing in to North Dakota and emptying into the Missouri.



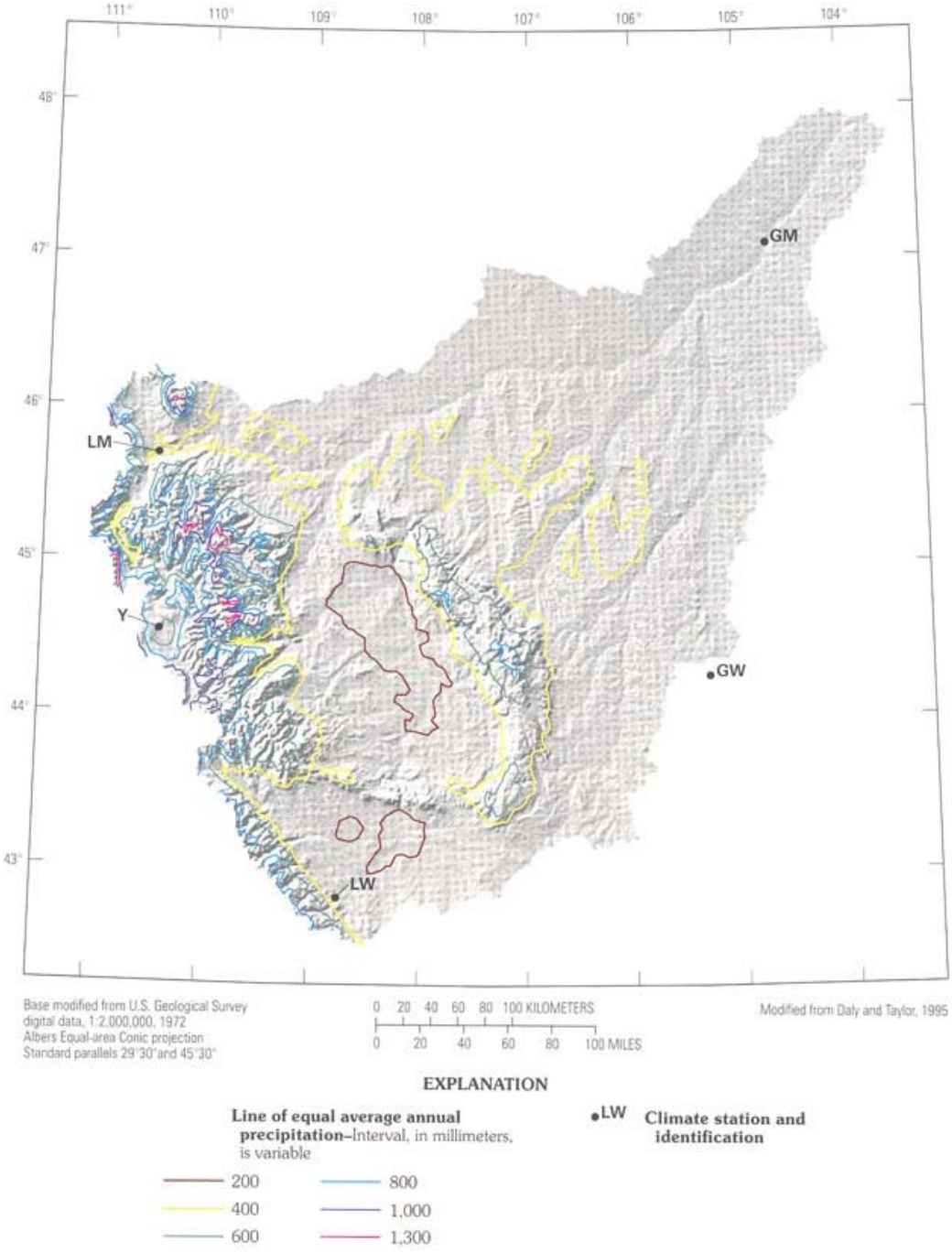
From Zelt, 1999

Figure 2. Potential natural vegetation of the Yellowstone River Basin.



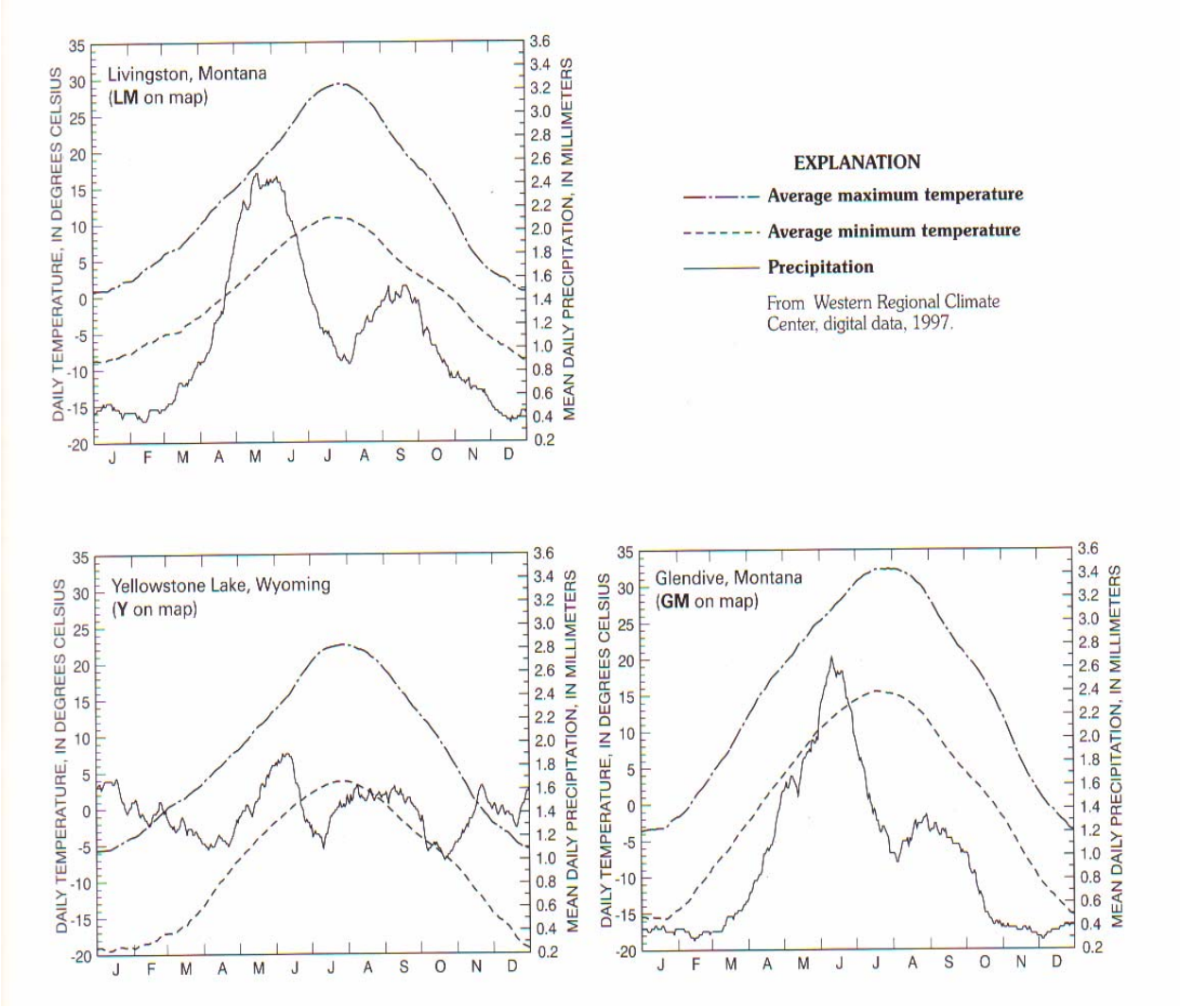
From Zelt, 1999

Figure 3. Physiographic provinces of the Yellowstone River Basin.



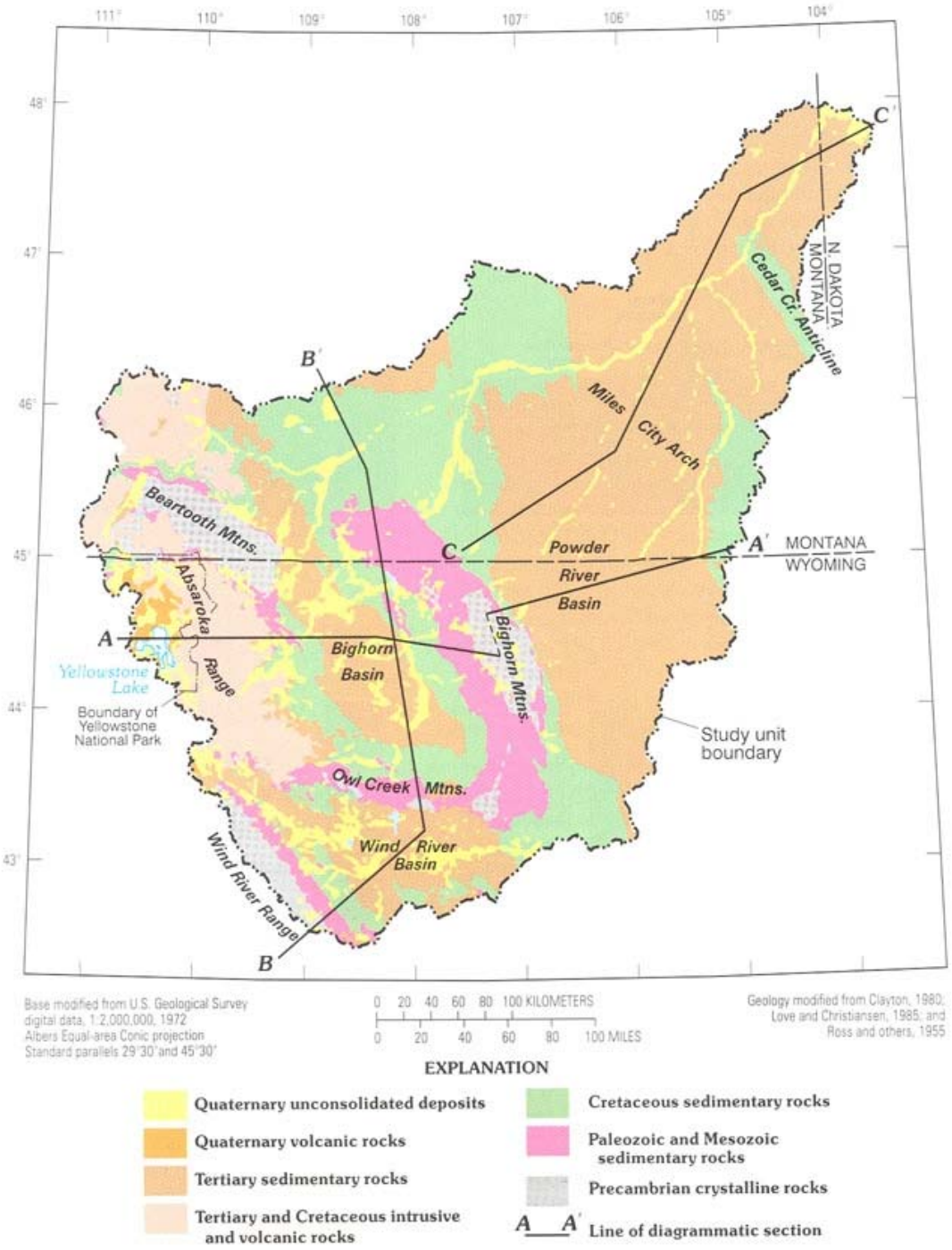
From Zelt, 1999

Figure 4. Average annual precipitation, Yellowstone River Basin.



Modified from Zelt 1999

Figure 5. Mean daily precipitation and temperature at selected stations along the Yellowstone River.



From Zelt, 1999

Figure 6. Generalized geology of the Yellowstone River Basin.

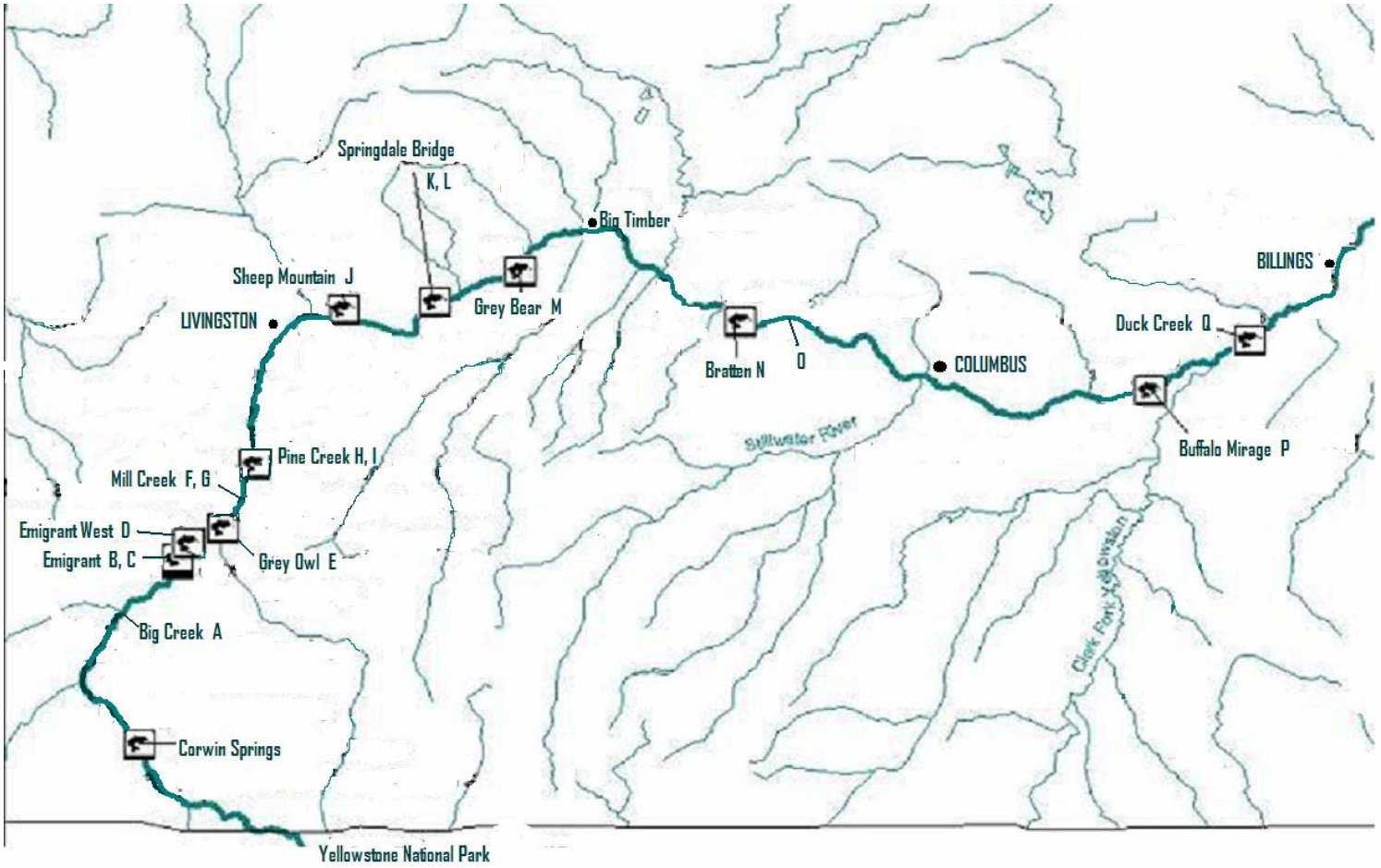


Figure 7. Sites along the upper Yellowstone River, from Big Creek and Emigrant through Springdale to Billings. Capital letters on the map are the middle digit of the site code, e.g. UJN and GJX are at or by Sheep Mountain FAS.

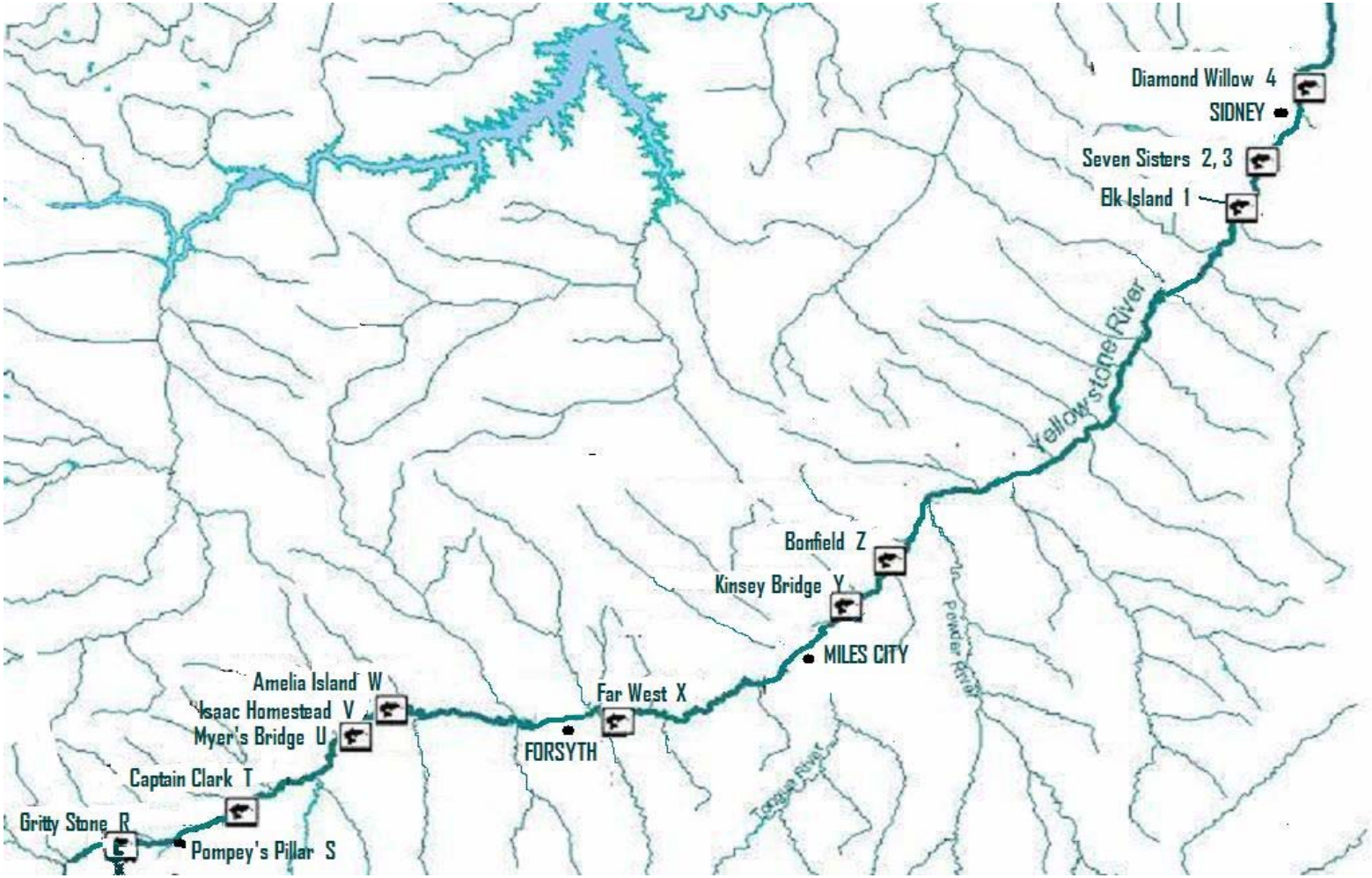


Figure 7. Sites along the lower Yellowstone River, from Worden (Gritty Stone Fishing Access Site) to Sidney. Letters & numbers on the map are the middle digit of the site code, e.g. GXX and UXP are at Far West FAS.

Figure 8. Gravelbar at Emigrant West Fishing Access Site. Seedlings of *Populus angustifolia* are the dominant cover.

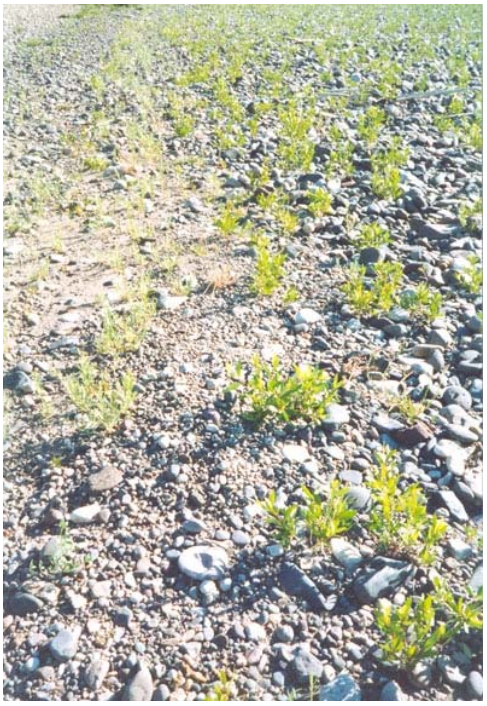


Figure 9. Gravelbar at Emigrant West Fishing Access Site. *P angustifolia* seedlings dominate the cobble deposited on the level top of the gravelbar (right), while *Salix exigua* seedlings are establishing on the small sandy bank (left).

Figure 10. Gravel size distribution on gravelbars

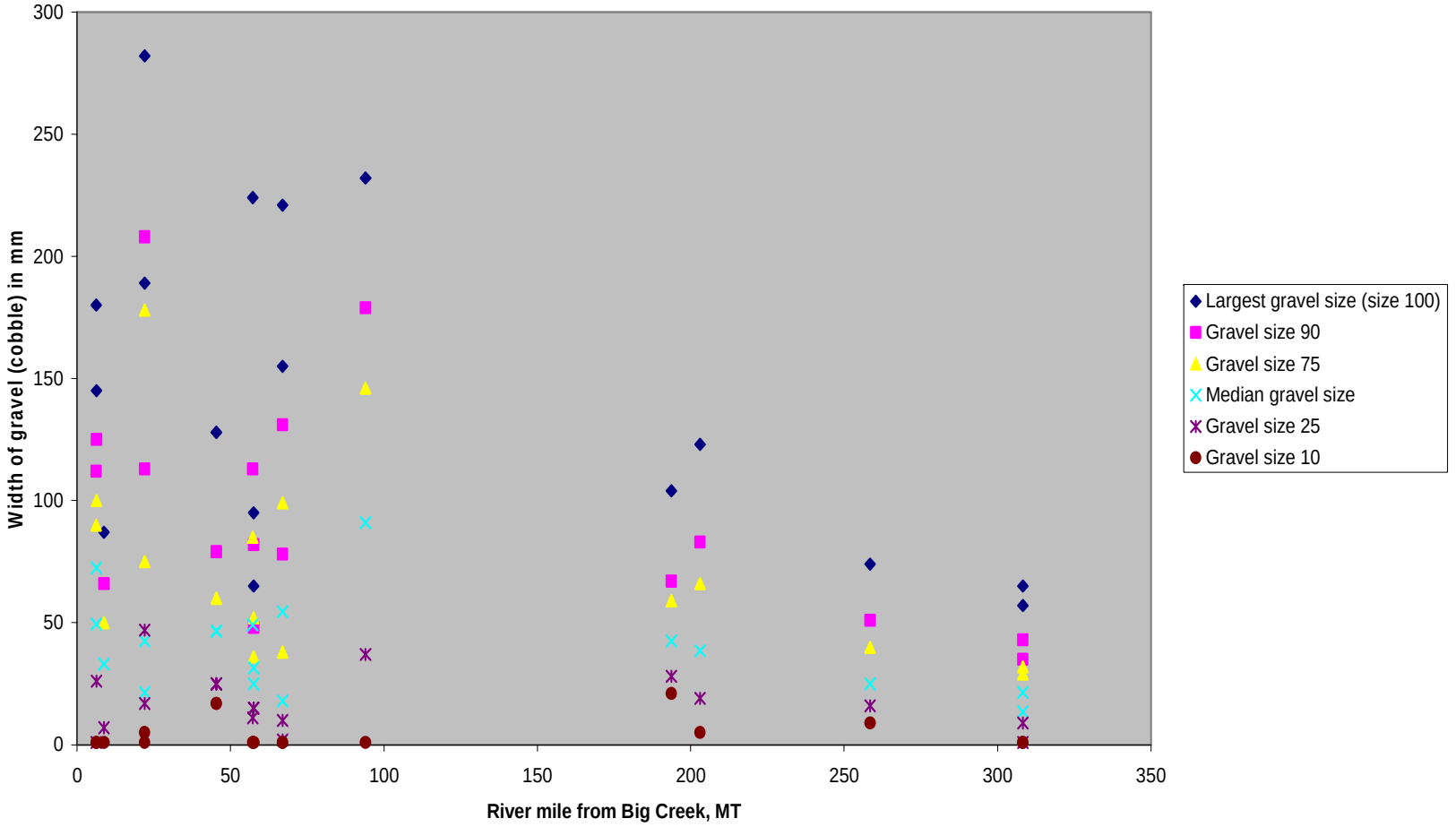


Figure 11. Sandbar at Seven Sisters Wildlife Management Area. Note *Salix exigua* seedlings establishing.

Figure 12. *Salix exigua* thicket with taller *Salix amygdaloides* behind it. Far West Fishing Access Site.

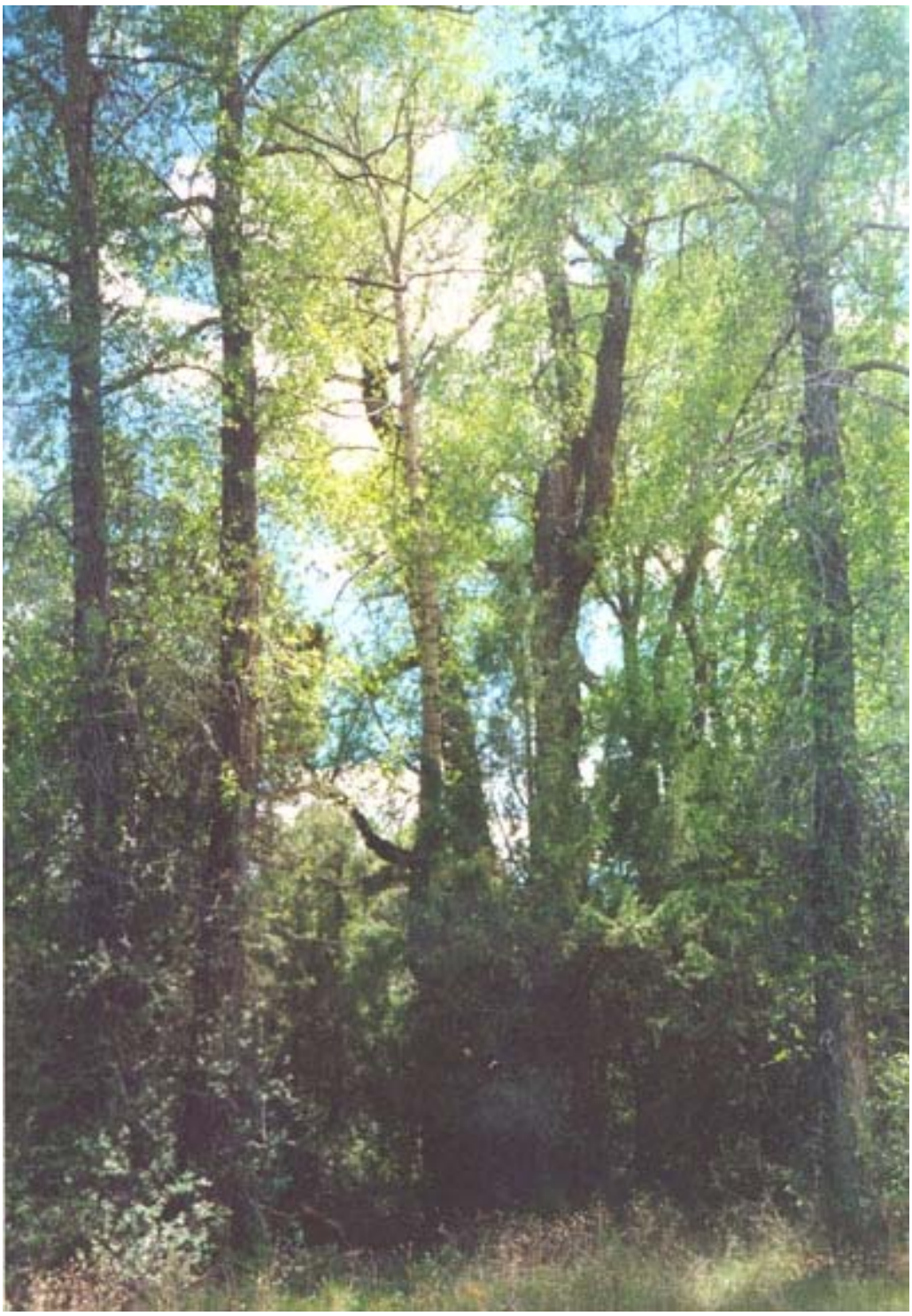


Figure 13. *Populus angustifolia* forest at Grey Owl Fishing Access Site.

Figure 14. *Populus deltoides* forest at Far West Fishing Access Site.

Figure 15. Grass growing in a sandy patch of a gravelbar, at Emigrant West fishing access site.

Figure 16. Succession on a gravel bar near Emigrant, Montana (site UCA). The upriver end of the island is in the foreground of the photo, where *Populus angustifolia* seedlings are establishing. Behind them, and higher in elevation, are young *P angustifolia* mixed with *S exigua*. Pole sized and then mature *P angustifolia* can be seen in the background. There were no signs of grazing on this island.

Figure 17. Growth of *Populus angustifolia* community from gravelbars

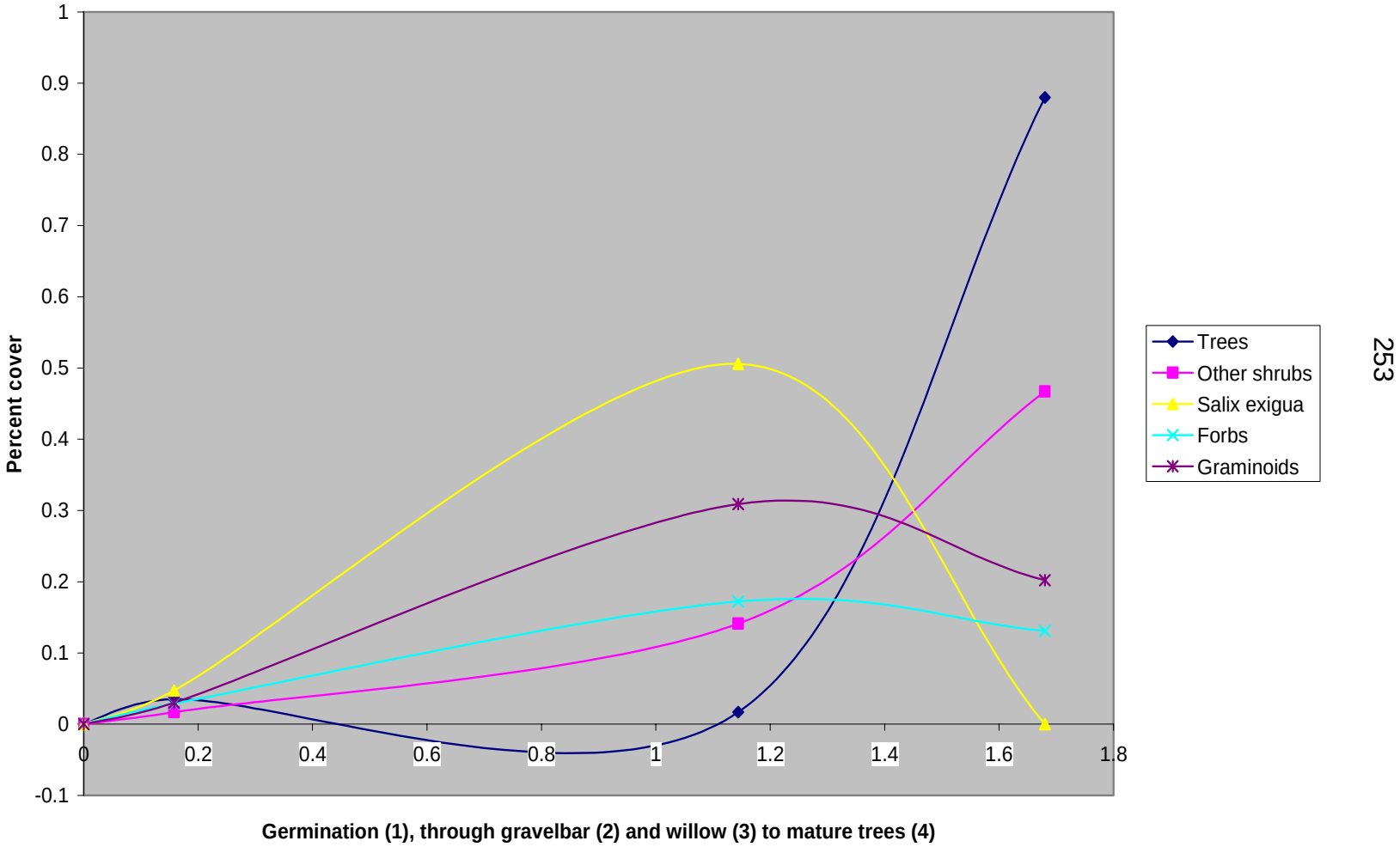


Figure 18. Growth of *Populus deltoides* community from sandbars

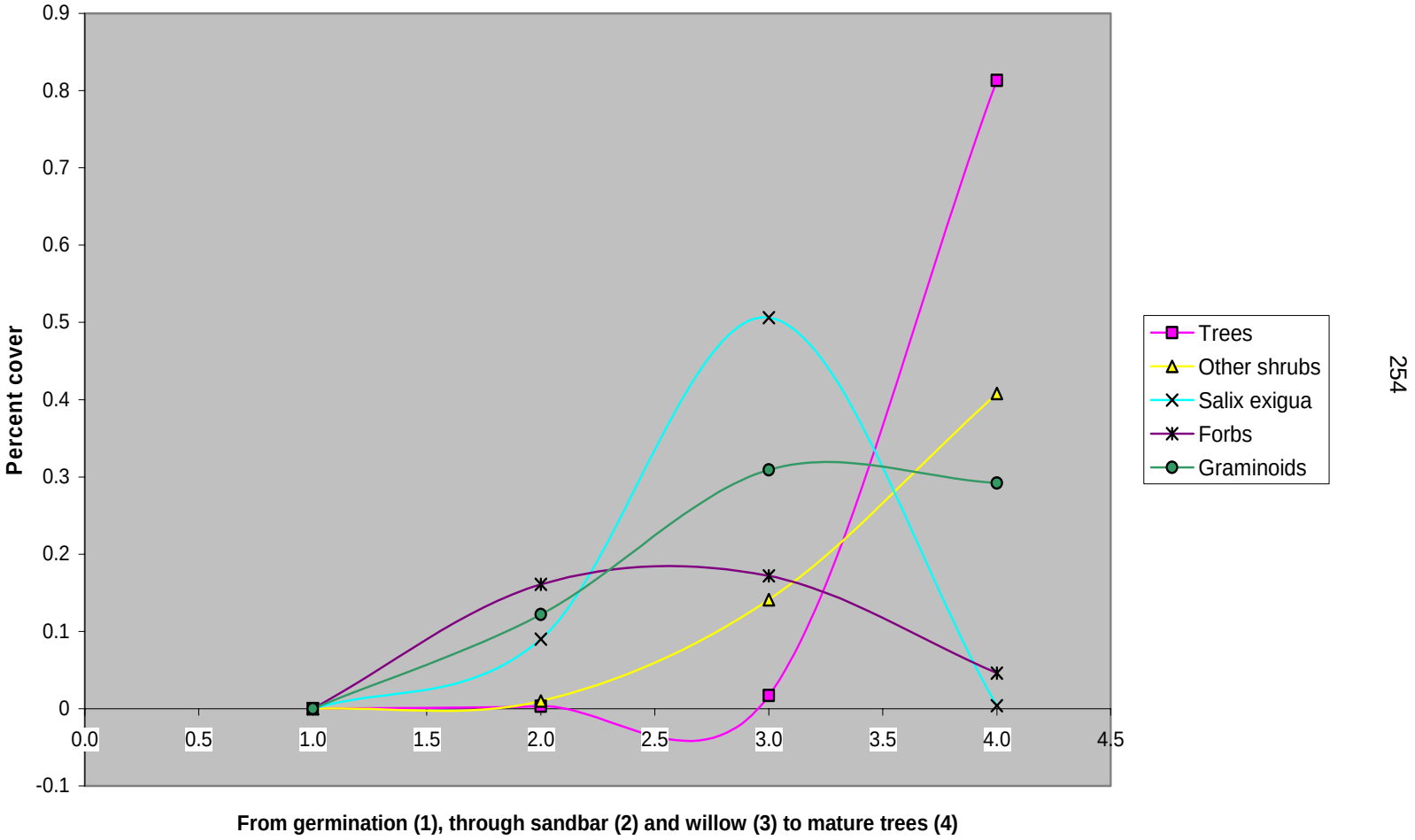


Figure 19. Height above water of research sites

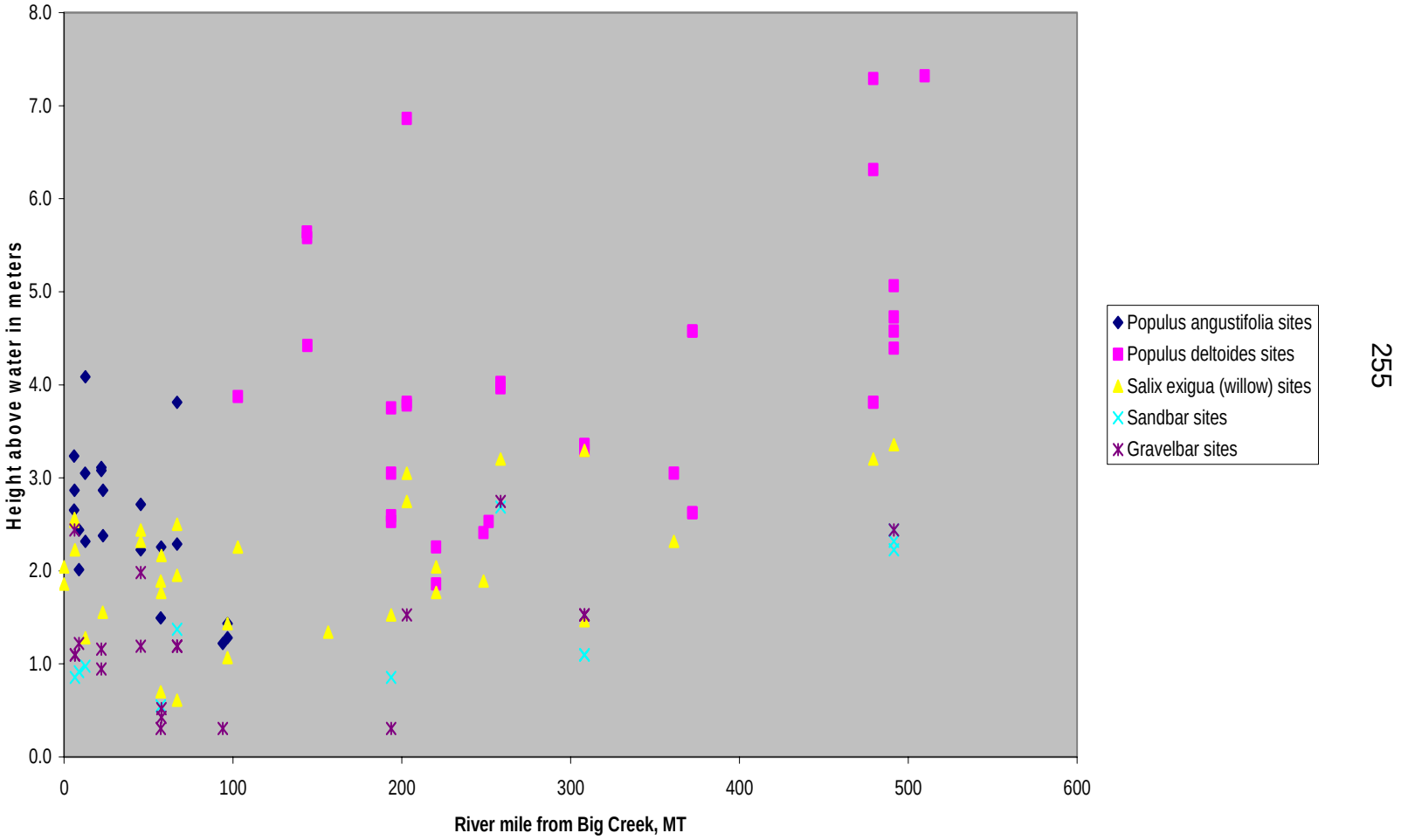


Figure 20. Depth to gravel at research sites

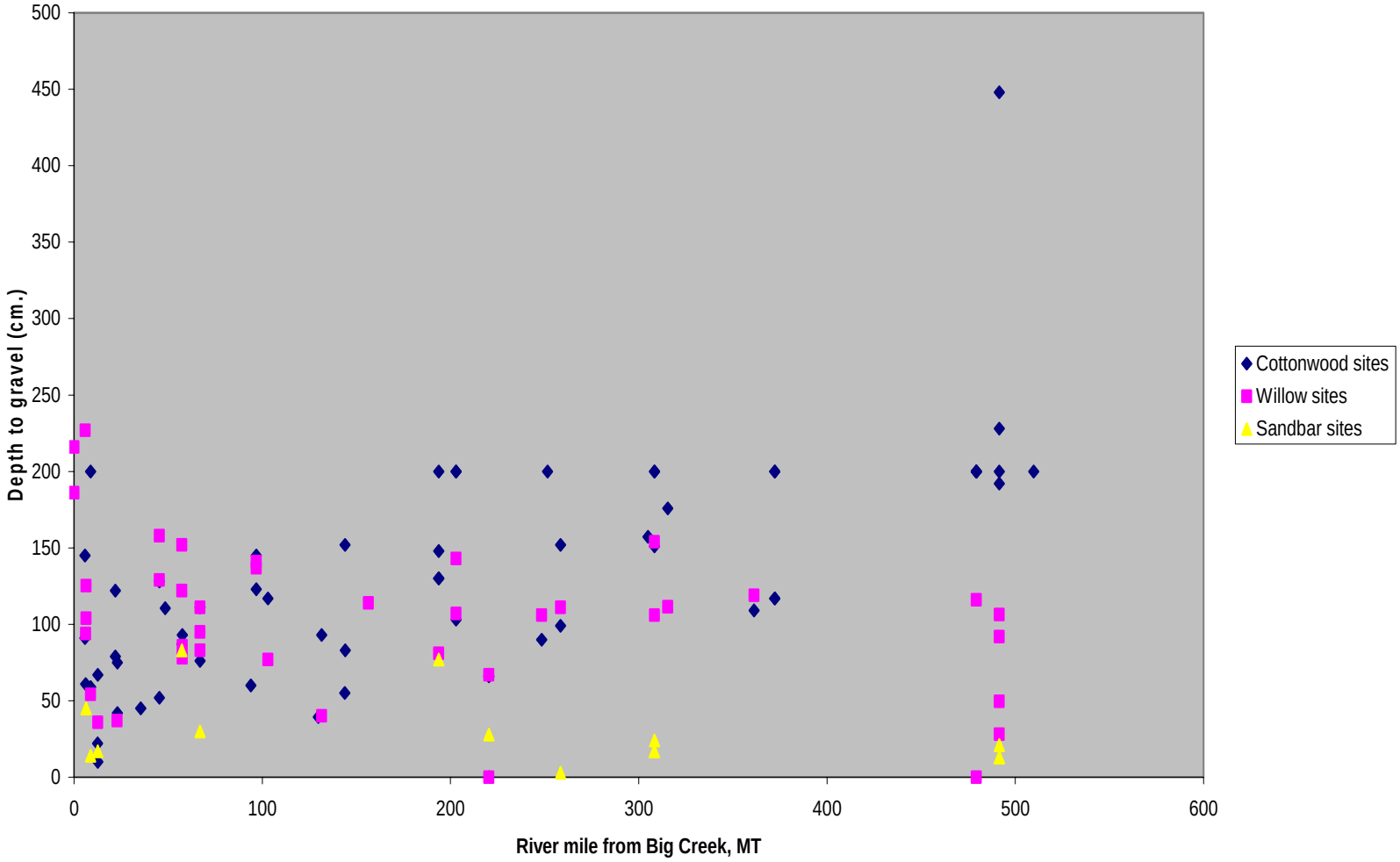


Figure 21. Soil CaCO3 percent equivalency at research sites

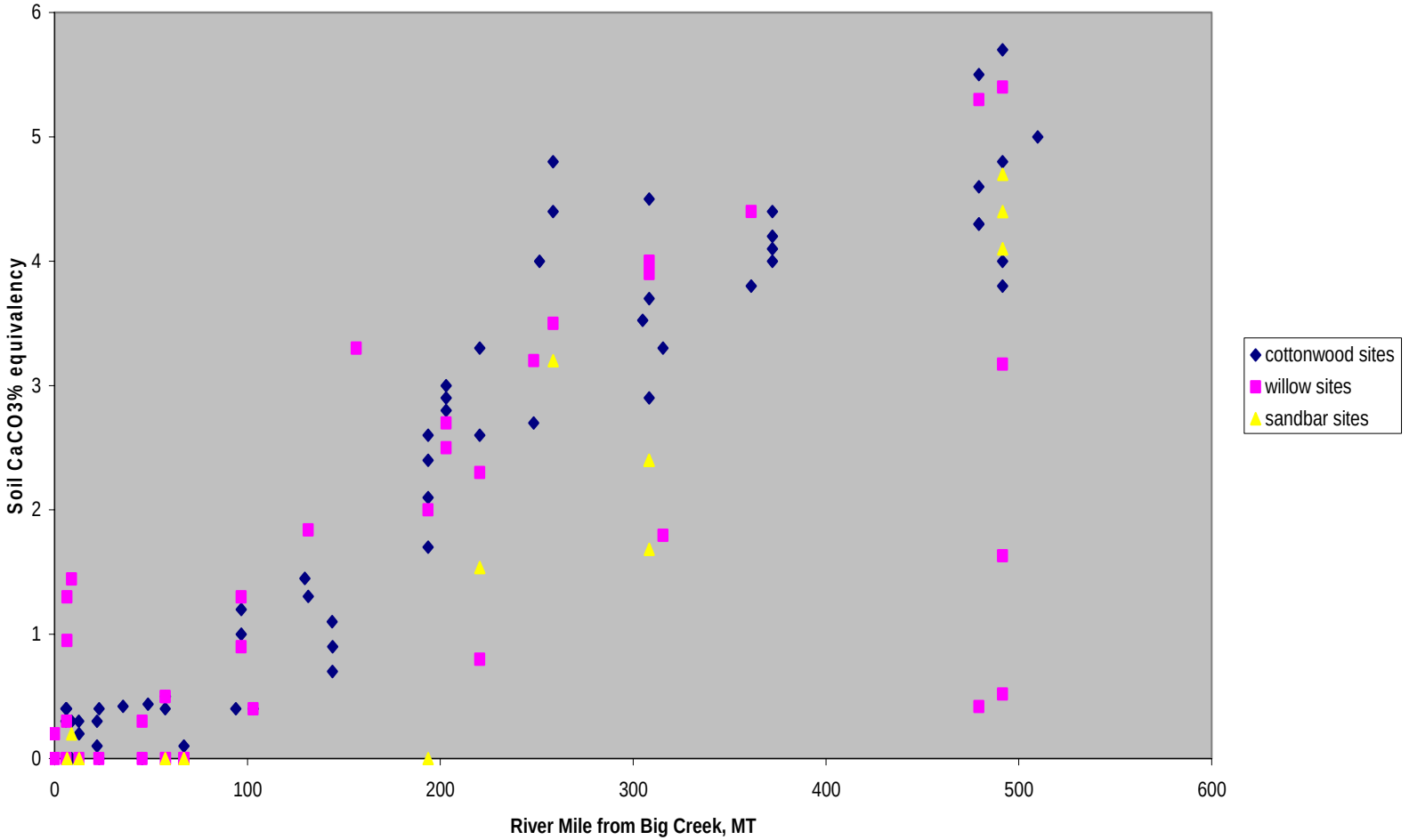


Figure 22. Soil pH at research sites

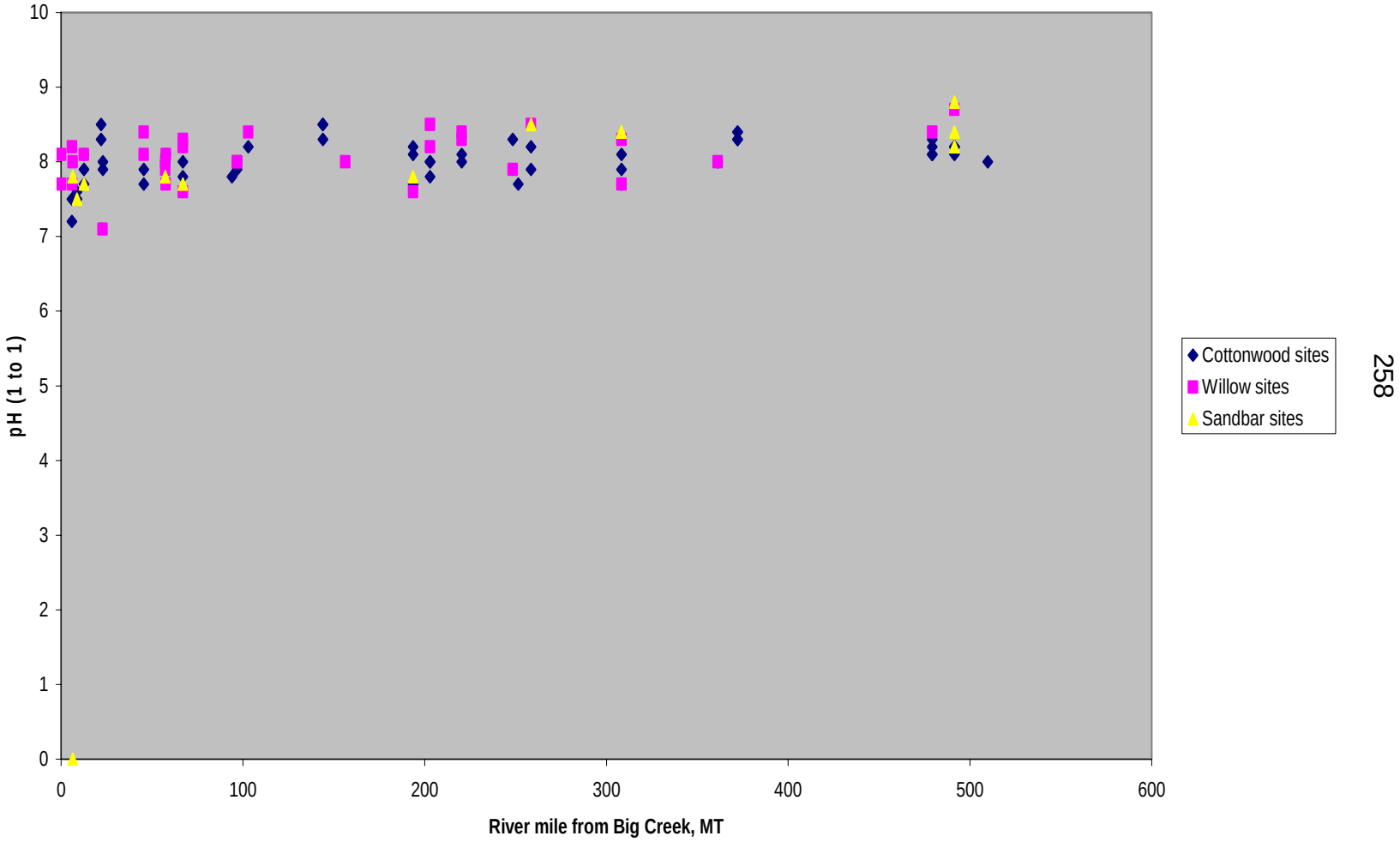


Figure 23. Soil percent organic carbon at ungrazed sites

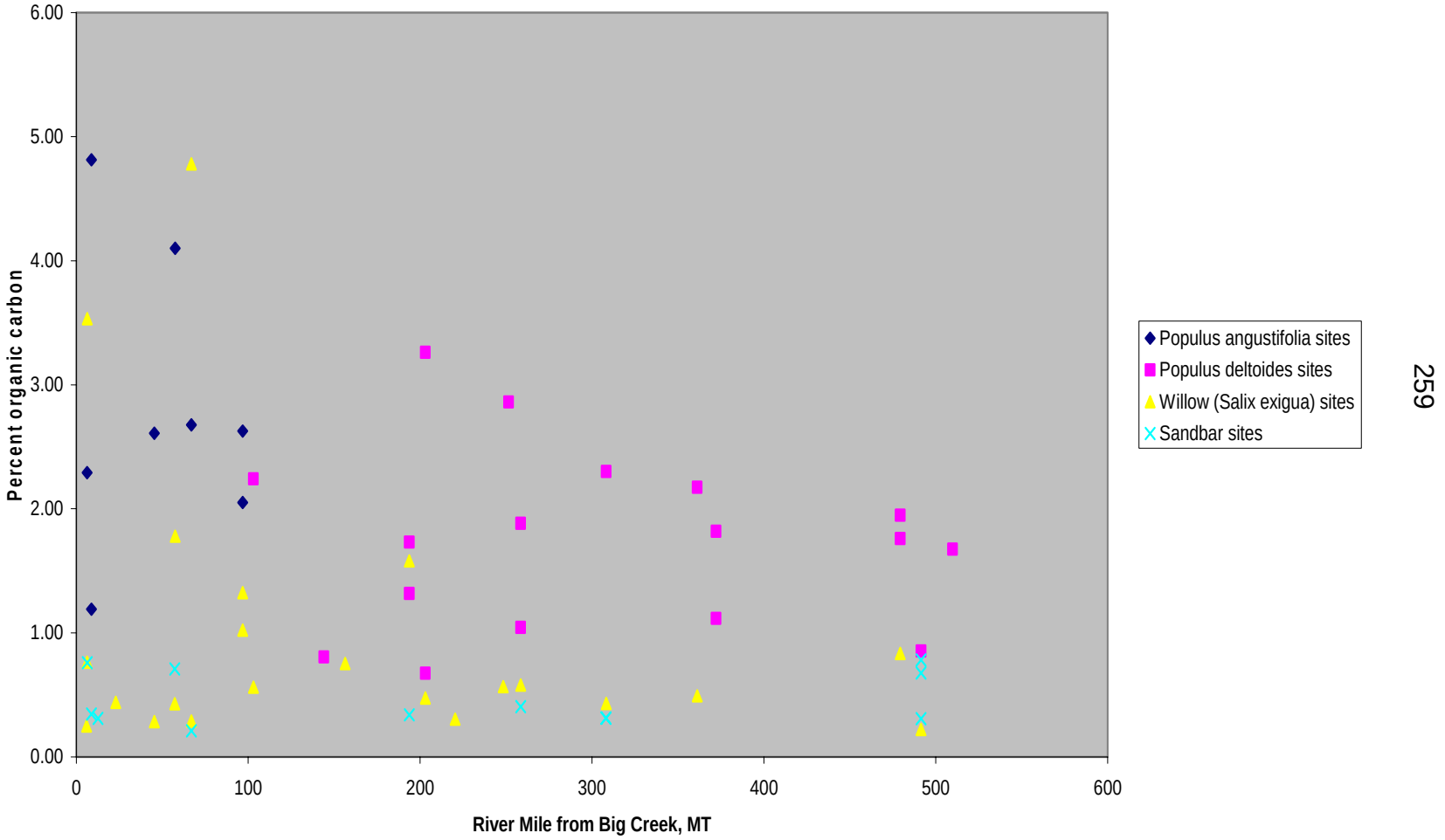


Figure 24. Soil percent nitrogen at ungrazed sites

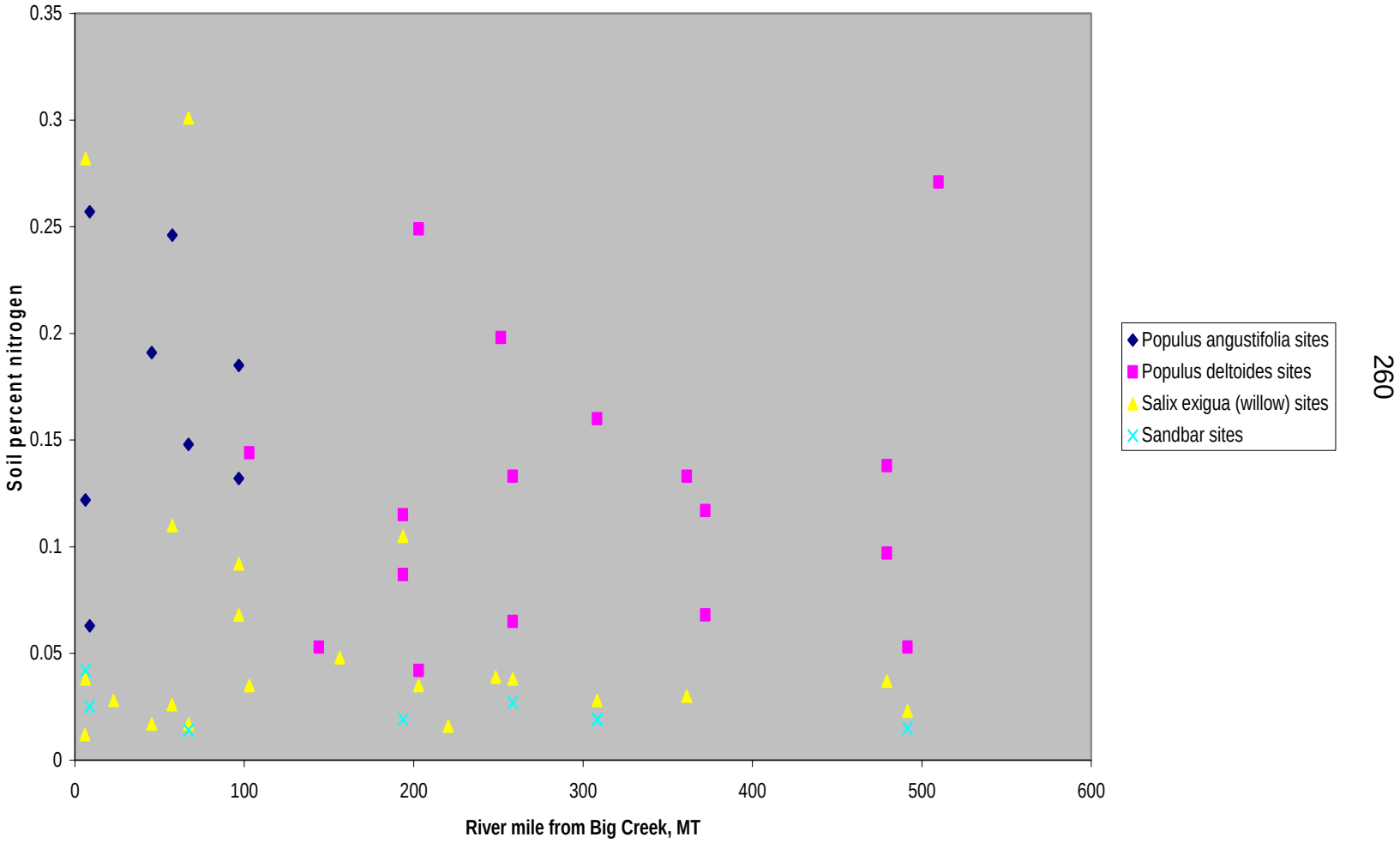


Figure 25. Soil texture: percent sand at ungrazed sites

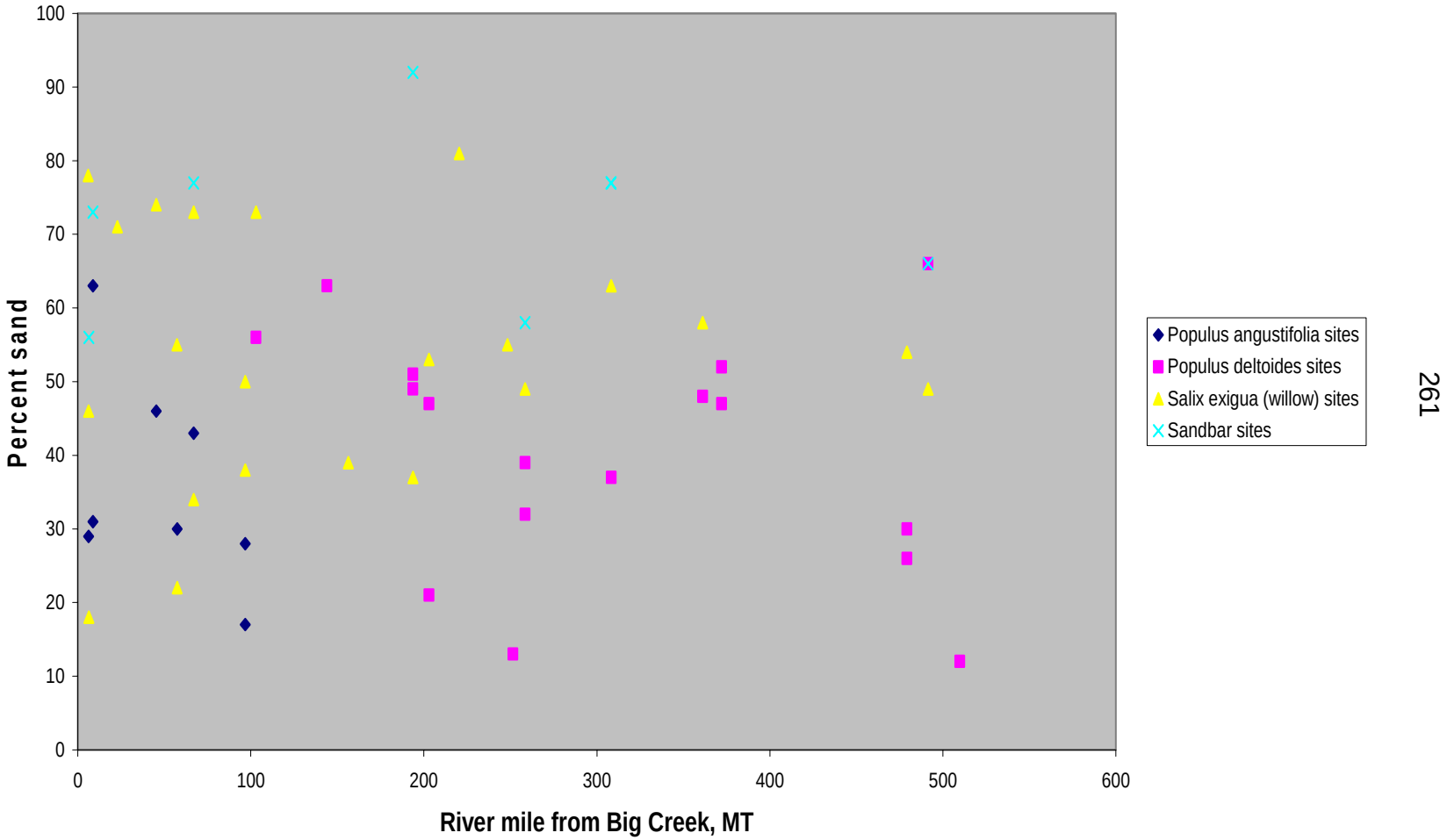


Figure 26. Soil Texture: percent silt at ungrazed sites

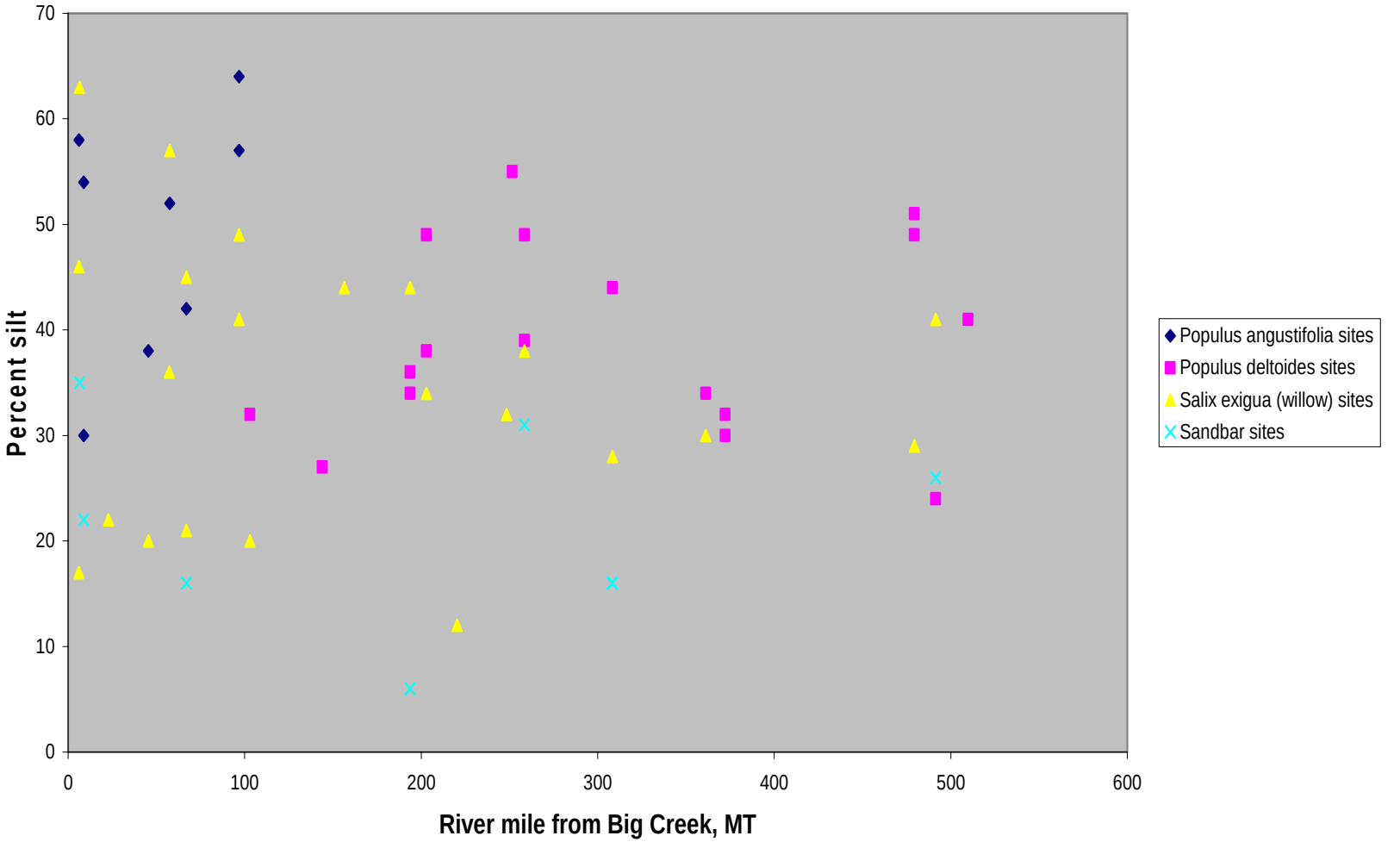


Figure 27. Soil texture: Percent clay at ungrazed sites

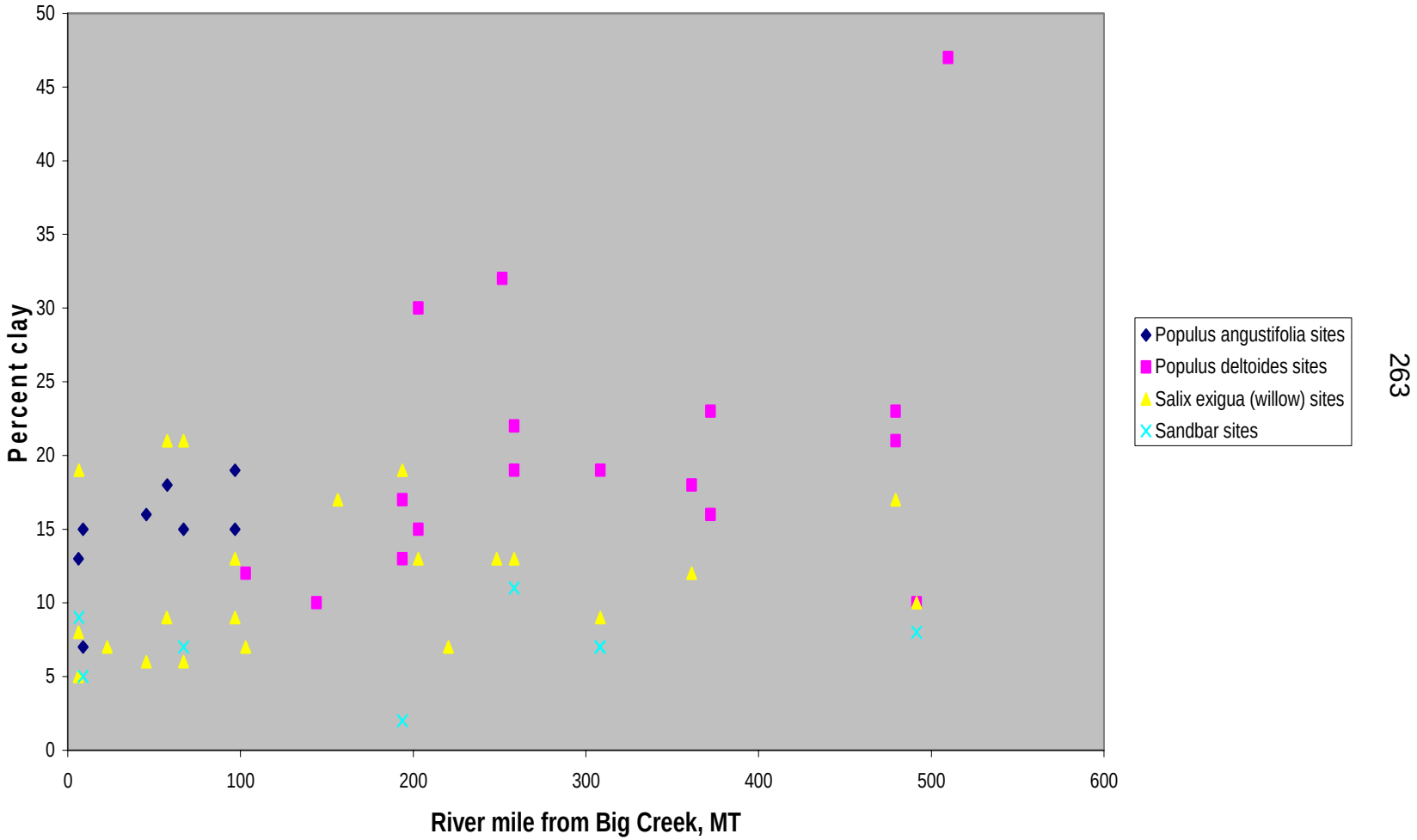


Figure 28. Soil electrical conductivity at research sites

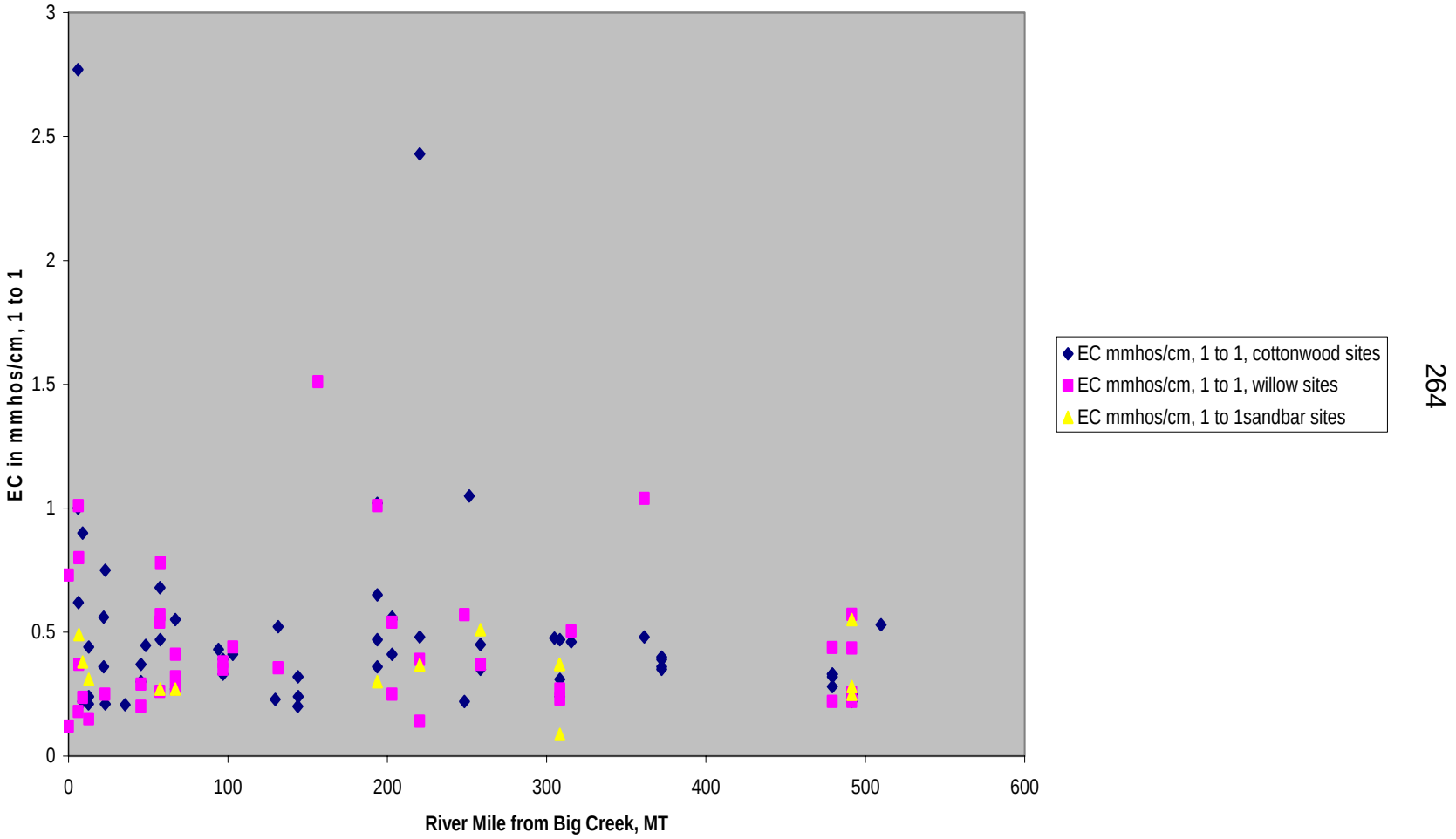
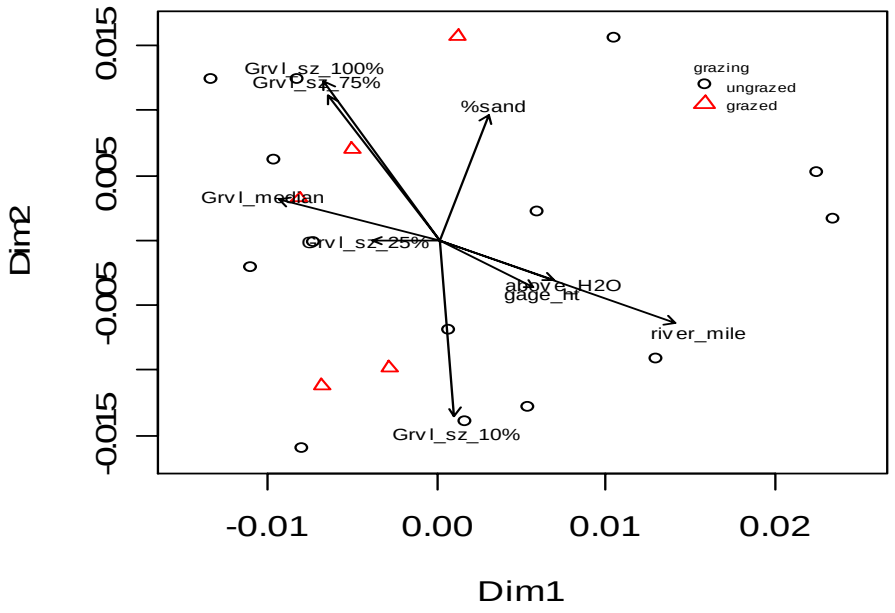


Figure 29. Heavily grazed sandbar willows, foothills zone.
The dowel is one meter high.

Figure 30. Ordination of ungrazed vs. grazed gravelbars. The top diagram shows environmental variables, the lower diagram gives sites codes.



gravel 2D NMS stress = 20.7, mult = .022. Transect G2A deleted, no (gravel size 90%) among environmental vectors

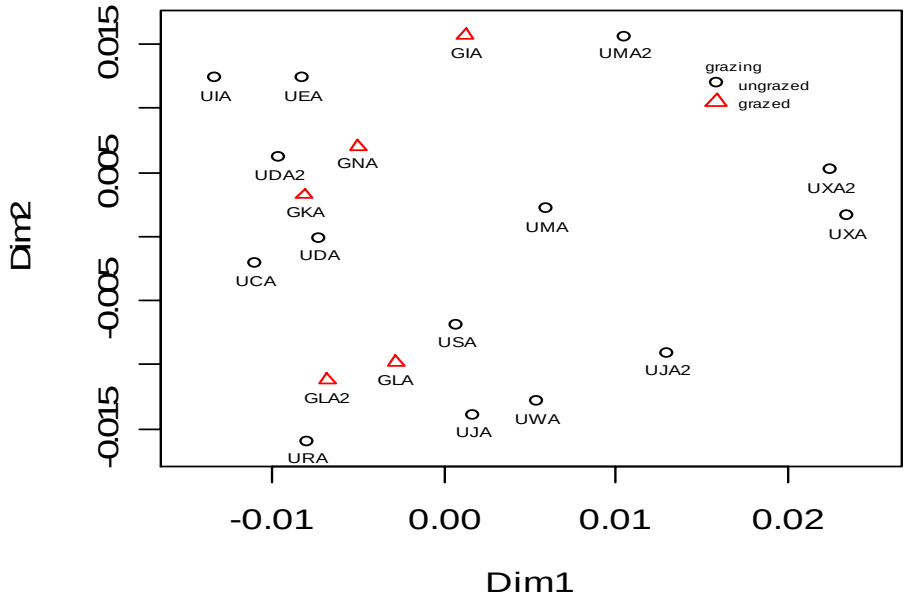
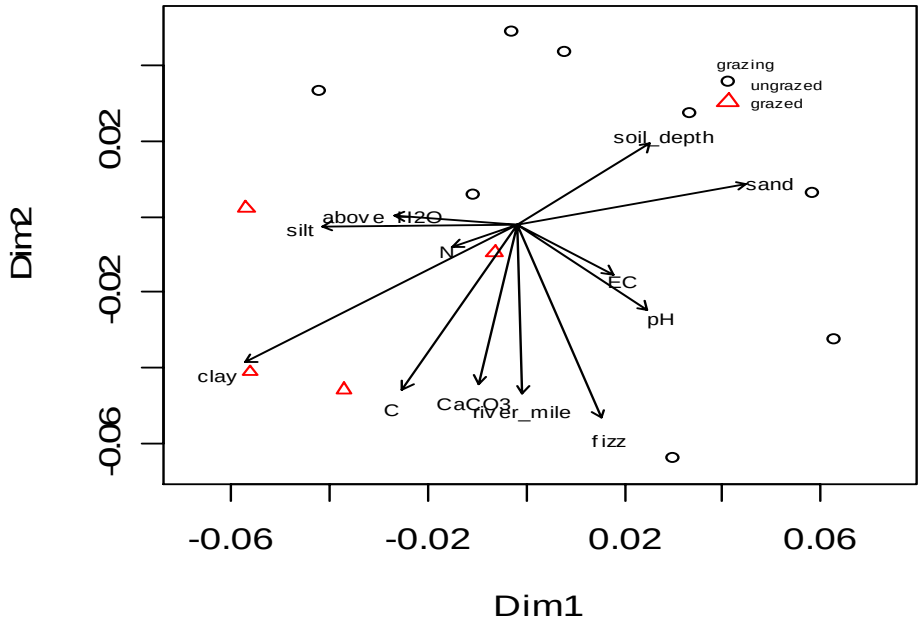


Figure 31. Ordination of ungrazed vs. grazed sandbar sites. The top diagram shows environmental variables, the lower diagram gives site codes.



sandbar 2D NMS stress = 13.09, mult=.1

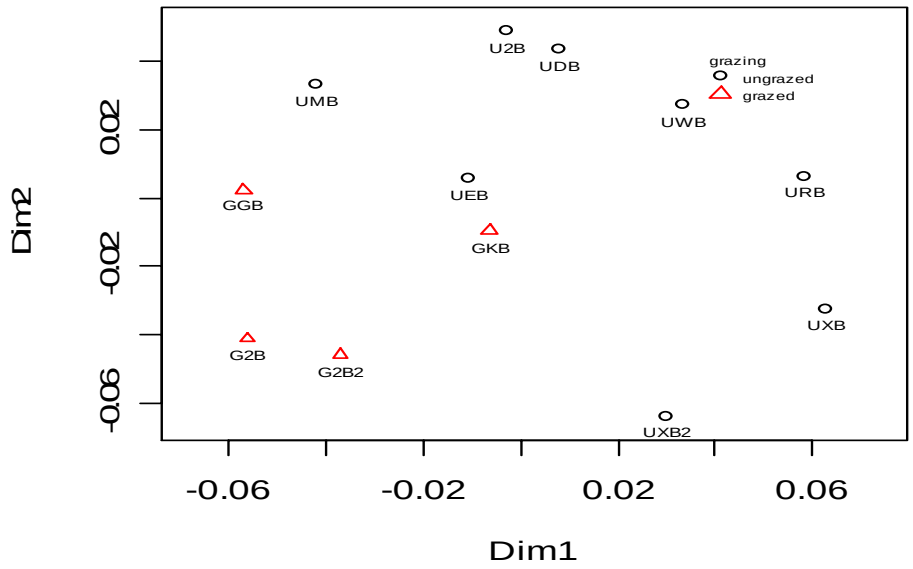
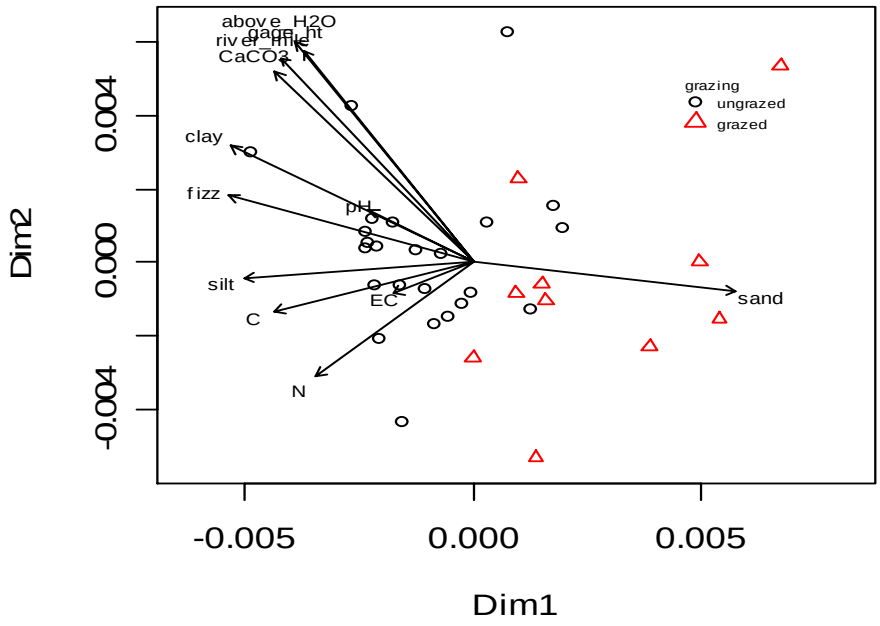


Figure 32. Ordination of ungrazed vs. grazed *Salix exigua* communities. The top diagram shows environmental variables, the lower diagram gives site codes.



Willow 2D solution stress = 19.45, mult=.015.

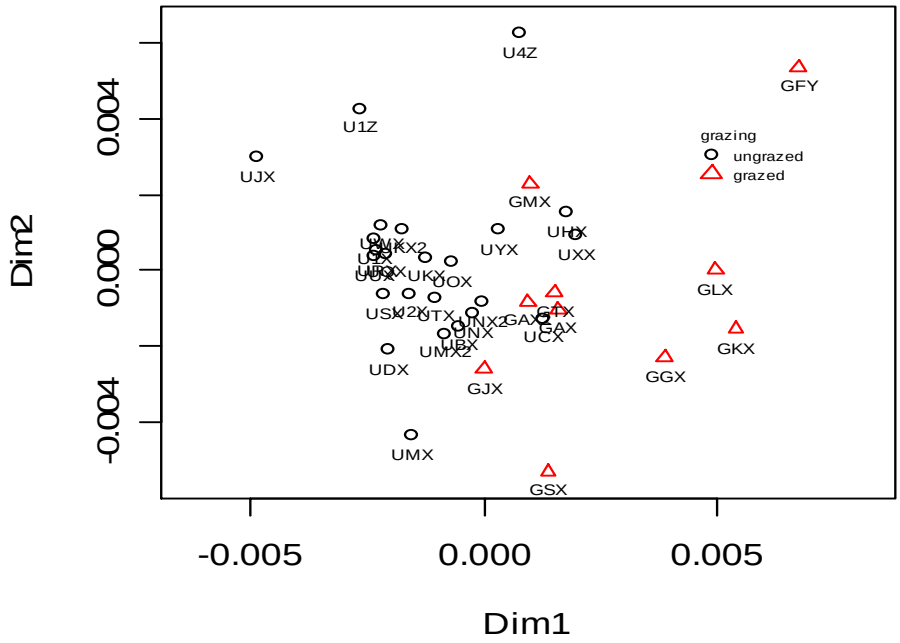
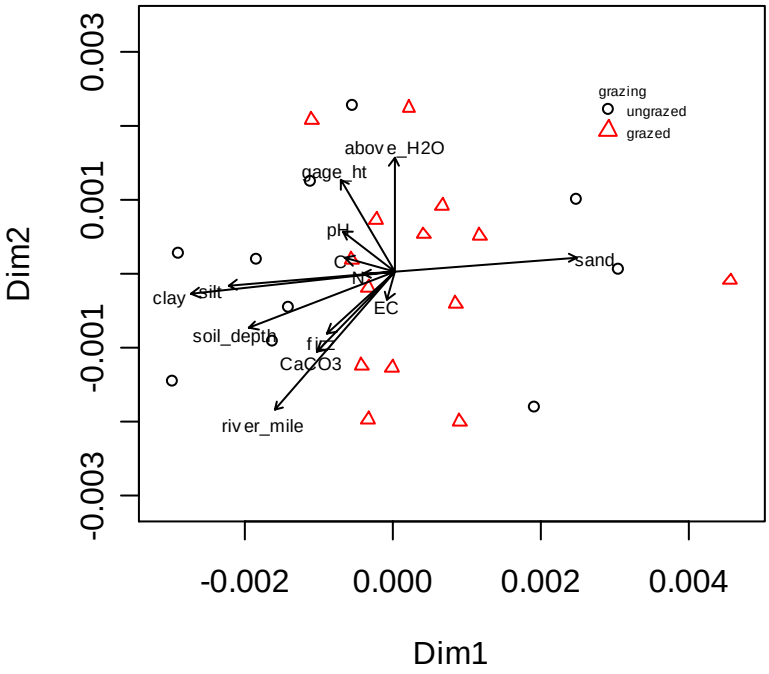


Figure 33. Ordination of ungrazed vs. grazed *Populus angustifolia* stands. The top diagram shows environmental variables, the lower diagram gives site codes.



2D solution Populus angustifolia, stress = 19.4, mult. = .004.

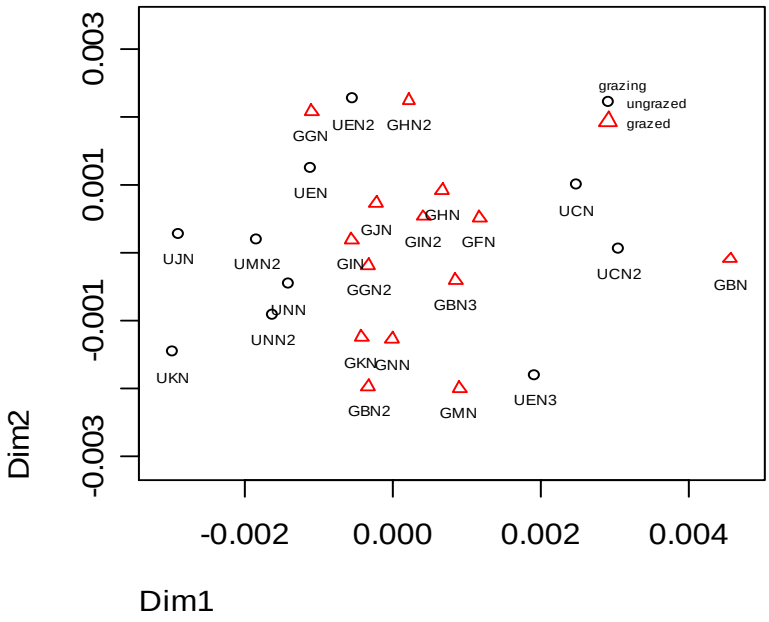
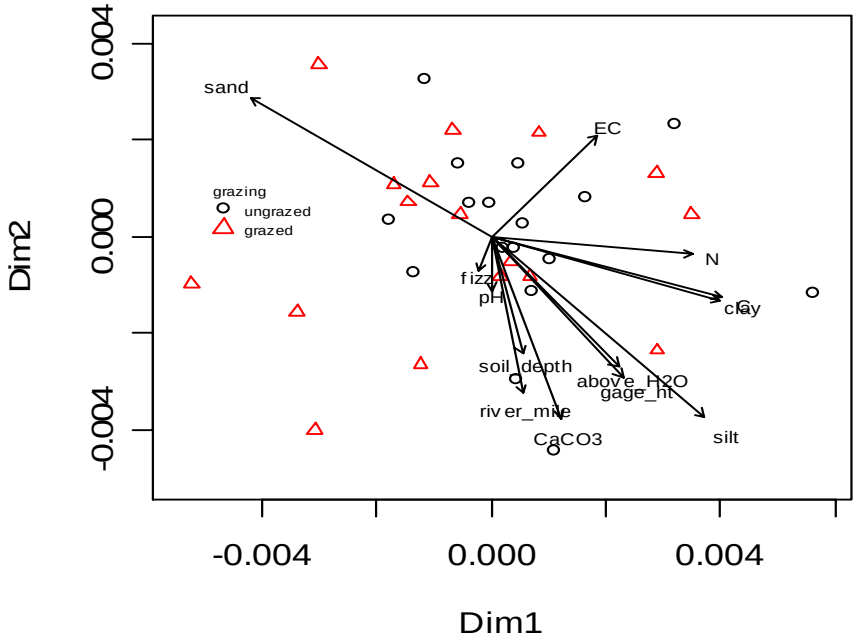


Figure 34. Ordination of ungrazed vs. grazed *Populus deltoides* stands. The top diagram shows environmental variables, the lower diagram gives the site codes.



stress = 20.7 P. deltoides 2D NMS, URP dropped, mult = .01

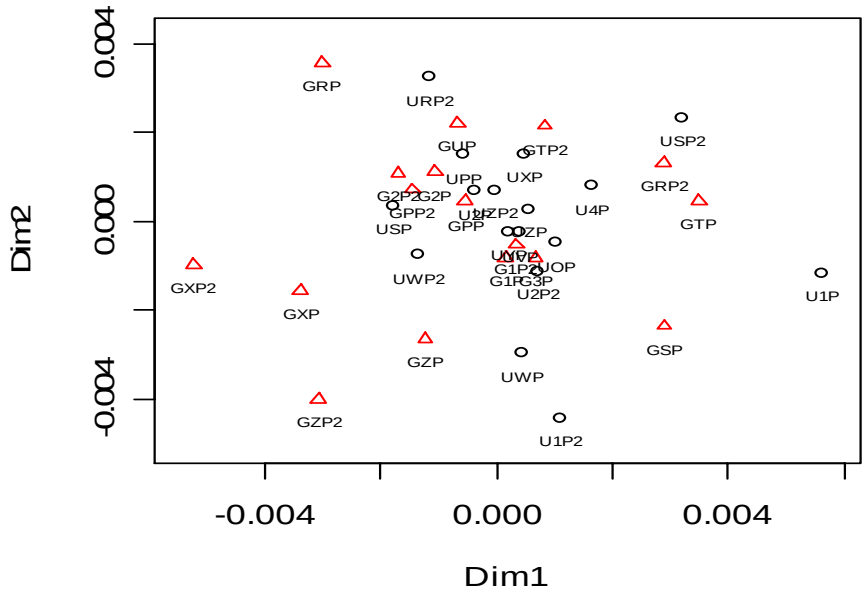
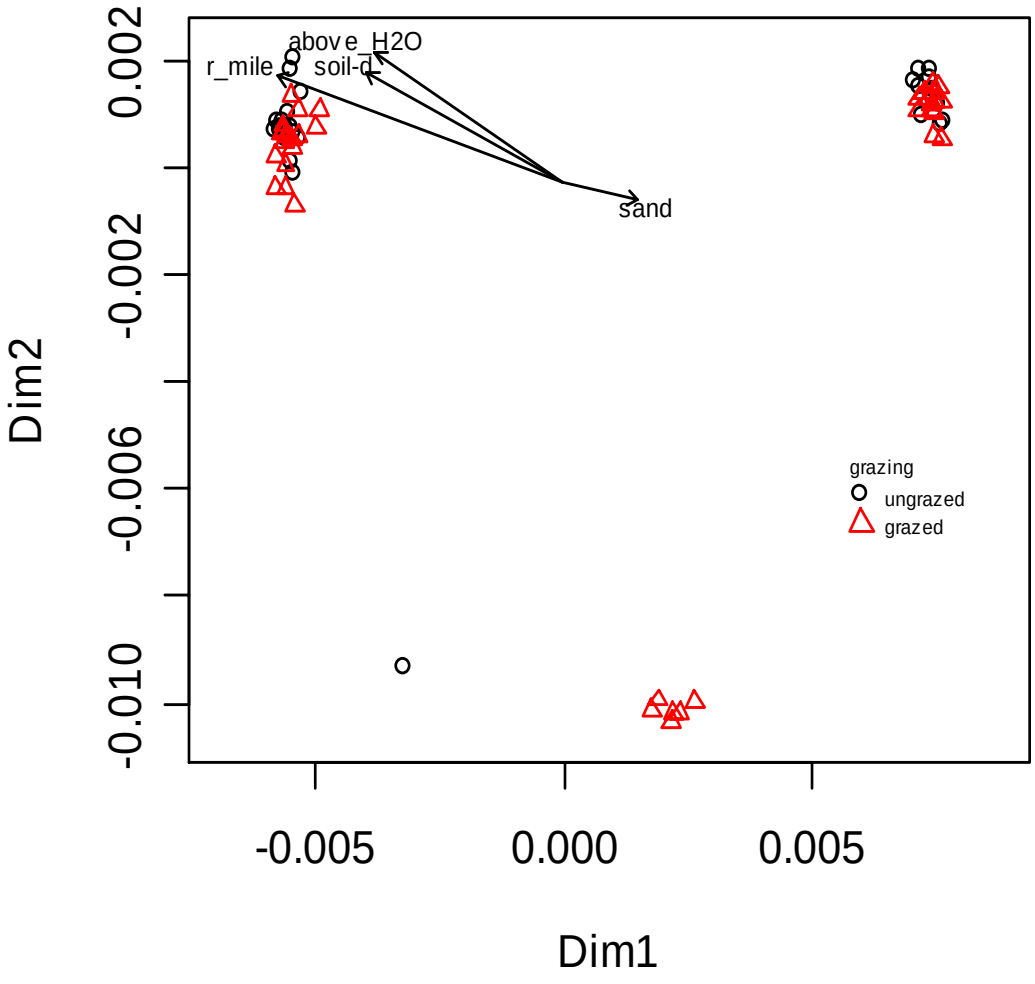


Figure 35. Ordination of *Populus angustifolia, P. deltoides* and *P. acuminata* communities. The cluster in the upper left are grazed and ungrazed *P deltoides* stands, the cluster in the upper right are grazed and ungrazed *P angustifolia* stands. The six grazed sites in the lower center are *P acuminata* stands, the hybrid between the other two *Populus* species. The lone grazed site in the lower left is a location with low cover of *P deltoides,* and high cover of *Elaeagnus angustifolia.*



2D NMS cottonwood, sor. dist, stress = 8.3, env mult. = .004