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Restoring O'Brien Creek

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O'Brien Creek, near Missoula, Montana, has been altered by tree harvest, road building, grazing and dewatering. These actions led to loss of streamside vegetation, increased streambank erosion and scouring, and decreased native fish and wildlife recruitment. The US Forest Service has recontoured roads in the upper watershed while Montana Fish, Wildlife and Parks has regraded and revegetated the lower creek to return it to a more natural state. I monitored the efficacy of a revegetation project on the newly restructured streambanks within the first year and a half of planting. The survival rate of the plantings after the first year was only 25% due, most probably, to the small size of the plants, competition with exotic weeds, and the placement of the plants well above the mid-summer water table. I recommend larger plants placed with their roots in the mid-summer water table or the use of drought hardy species and an effort to control weeds near the plantings. The restoration of O'Brien Creek was done in patchwork fashion, with 2 agencies working on separate projects in different areas of the watershed. Greater coordination and cooperation between agencies will likely result in more efficient and successful restoration efforts. However, the agencies are to be commended for their efforts, which may already be producing increases in fish population densities in O'Brien Creek.

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The days spent working along side O'Brien Creek would not have been nearly as entertaining had it not been for the company of Meg. Her patience, understanding, and support give me the courage to trudge that happy road.

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Introduction

The management of stream and river corridors cannot be isolated from the management of adjacent upland communities (USDA 1998). Individuals, organizations and agencies must work together to make the restoration and management of our streams and rivers more effective. The management of all landscapes within a watershed, by a group or groups, is the holistic watershed approach. The holistic watershed approach attempts to mitigate what are referred to as "cumulative watershed effects" or the effects of all activities within a watershed (Brooks et al. 1997). Holistic watershed management recognizes that what occurs upstream has a direct effect on resources downstream. Without the holistic management of the entire watershed, restoration effects in one area might be decreased by improper management elsewhere, or objectives narrowly focused on site specific problems might just transfer problems to other portions of the watershed.

O'Brien Creek near Missoula, Montana is an example of an accidental holistic approach to the management of the watershed. The United States Forest Service (USFS) and Montana Fish, Wildlife and Parks (MFWP) are working to restore O'Brien Creek, and each had some knowledge of the other agency's efforts but began their respective projects independently, without setting common goals for the watershed. The level of cooperation between USFS and MFWP will be explored and then briefly contrasted with a much more intense level of cooperation in another watershed restoration and protection project.

O'Brien Creek Watershed History

The O'Brien Creek Watershed has been heavily impacted by human uses since the turn of the century (Sandoval and Hegman 1998; Zyskind 1997; Silte 2000). Only in the last 10 years have local agencies and citizens made restoring the health of O'Brien Creek a priority. The USFS and MFWP began restoration efforts in the upper and lower watershed, respectively, and by chance at about the same time. The goals of USFS and MFWP were not identical, but, since both were ecologically guided, they were similar enough to complement one another's work.

At the turn of the century the McClay ranch began operations in the lower portions of O'Brien Creek. The ranch stretched from Big Flat Road to one mile upstream of Big Flat Road. The ranch owners installed a culvert and created a ditch as an irrigation channel about one mile up from the intersection of Big Flat Road and O'Brien Creek Road. From this point they diverted all of O'Brien Creek's water for the irrigation of hay fields. The only time water actually flowed in the stream channel was during high water events, particularly in the spring. The creek was dry for roughly 11 months of the year. Although ranching operations ceased in the 1950's, and the area was subdivided in the early 1970's, the irrigation diversion remained until the early 1990's (Zyskind pers comm. 1997; Stephens pers comm. 2000).

Portions of the McClay Ranch were bought by John Dydel in 1991. Dydel redirected the creek from the irrigation ditches and diversion, returning flow to the channel. The residents of lower O'Brien Creek now obtain water from wells.

The headwaters of O'Brien Creek were also modified by human use. The upper watershed was used as pasture from the turn of the century until 1992. From 1992 until 1995, logging in the headwaters was extensive, leaving very little cover on most slopes. The roads built and used by Owens & Hurst, (a Montana-based logging company) were built to very low standards (Sandoval and Hegman pers comm. 2000). These roads, as well as the large areas of deforested slopes, created a sediment problem within the watershed, degrading the water quality within O'Brien Creek (Sandoval and Hegman 1998; Silte pers comm. 2000).

Historically O'Brien Creek was an important spawning tributary to the Bitterroot River and the nearby Clark Fork River as well. Land use practices in the O'Brien Creek watershed degraded O'Brien Creek and it's spawning habitat (Sandoval and Hegman pers comm. 2000). Cumulative effects within the O'Brien Creek Watershed were substantial. In the headwaters and upland areas, increased sediment inputs to the stream from historic logging practices, road building, and grazing practices resulted in a stream that was well below its potential for both fisheries and habitat quality (Sandoval and Hegman 1998). Wildlife recruitment in the upper O'Brien Creek Watershed had decreased due to loss of cover from clearcutting, and increased traffic on logging roads. In the lower sections of O'Brien Creek, there were instances of structures blocking fish passage, degraded riparian habitat, bank sloughing, mass sediment movement and the loss of in-stream large woody debris which provides fish habitat (Schmetterling and Pierce 1996).

Upper O'Brien Creek restoration work (USFS Lolo National Forest)

In 1995, roughly 2900 acres of land in the upper O'Brien Creek Watershed (barring a small parcel owned by a private landowner in the valley bottom) were acquired by the Lolo National Forest from Owens & Hurst in a land trade. The restoration efforts of the Forest Service focused on the decommissioning of logging roads within the watershed. This would restrict vehicles from entering portions of the watershed, decrease the cost and impact of the maintenance of poorly designed roads, restrict vehicles from entering sensitive areas, and ultimately decrease the amount of sediment inputs to the stream (Sandoval and Hegman pers comm. 2000).

The road decommissioning, begun in 1997 and concluding in 2000, includes recontouring 15 miles of road to the land's original slope. The decommissioned road will then be seeded with a native seed mix and formed into a single-track trail, adequate for the use of mountain bikes. The concentration of roads within the upper watershed will decrease from 5.8 km/km^2 to just over 1.6 km/km^2. The goals of the Forest Service for the land in upper O'Brien Creek include: increased security for wildlife, the improvement of water quality within O'Brien Creek, and the elimination of "maintenance problems" (Sandoval & Hegman 1998; Sandoval & Hegman pers comm. 2000). The cost for the upper O'Brien Creek restoration by the USFS through the year 2000 will total $115,000 (Sandoval & Hegman 1998).

Beyond the immediate benefit of having fewer roads and vehicles in the upper watershed, there is only preliminary data confirming the positive effects of the road decommissioning. The study compares the sediment yield from existing Forest Service roads, newly recontoured roads, roads one year after recontour and revegetation, and undisturbed sites (Hickenbottom 2000). The preliminary results indicate that undisturbed sites have lower sediment yields than existing roads, and that after one year, recontoured roads generated only slightly more sediment than undisturbed sites (Hickenbottom 2000).

Lower O'Brien Creek restoration work (Montana Fish, Wildlife and Parks)

During the field season of 1998, Montana Fish, Wildlife and Parks began restoration work in the lower portions of O'Brien Creek. Restoration work included the complete restructuring of the streambed and banks (from Blue Mountain road downstream to the confluence with the Bitterroot River) to resemble less impacted streams in the area. The restoration also included the removal of an irrigation diversion, the replacement of a culvert with a bridge (to allow more natural flow and to eliminate a fish passage barrier), and revegetation of streambanks with native vegetation. All restoration work on the lower creek through 2000 totaled $45,600 and included monitoring costs. The goals of the restoration work done by MFWP were the improvement of spawning habitat for trout populations, increased trout recruitment, and the return of O'Brien Creek to a more natural state.

Amazingly, MFWP has already seen positive effects from the restoration work on Lower O'Brien Creek. Fish density in the treatment reaches of O'Brien Creek has increased in restored reaches compared to control reaches (Schmetterling pers comm. 2000).

Evaluation of Restoration Efforts on O'Brien Creek

What level of cooperation among stakeholders is needed to achieve the successful restoration of watersheds? The level of coordination between USFS and MFWP in the O'Brien Creek Watershed was not as great as in some other watershed restoration efforts, such as those in Big Spring Creek, MT (USDA 1998). At Big Spring Creek, drinking water was threatened by the actions of many private landowners, so a very high level of coordination and planning was needed. In the Big Spring Creek Watershed, the individuals and organizations involved formulated common goals for the watershed. With common goals, resources can be focused, conflicts minimized, and chances of success maximized.

The O'Brien Creek Watershed is an example of a patchwork of restoration efforts. Such efforts sometimes have serious conflicts (one group is building bank stabilization structures while another is pulling them out). However, because both agencies were guided by ecological principles, their goals and approaches were similar enough to be complementary but could have been done more efficiently. With better coordination and savings in time and dollars, it would have been possible to do more with less, an opinion expressed by a number of individuals both in and outside of the agencies.

Both USFS efforts and MFWP efforts involved cooperation from multiple agencies, individuals and landowners. However, there was not much communication between the agencies at the top and bottom of the watersheds. There were areas in which both agencies could have been more cooperative. The single largest of these would be having common goals for their restoration work. In O'Brien Creek, both the USFS and MFWP knew of the others' actions, and donated materials (USFS donated 100 mature trees to MFWP for in-bank stabilization) and financial help (MFWP donated $7,000 to the USFS project in the form of a Sikes grant) to one another.

Extensive coordination efforts like those on the Big Spring Creek Watershed cost time and money but may be essential where there is potential conflict. Because O'Brien Creek had much less potential conflict (fewer individuals and agencies involved), it did not need as much coordination and cooperation. The O'Brien Creek Watershed and the work done by USFS and MFWP throughout its drainage could benefit from a greater level of coordination and improved communication. The coordination would not have to be of the same intensity as that found on Big Spring Creek, but O'Brien Creek would still have benefited from more verbal communication.

Coordination time is like money, there is a limited amount and it must be used where it is most needed. Given the lack of conflicts in the restoration of O'Brien Creek, perhaps the Forest Service and Montana Fish, Wildlife and Parks coordinated about as much as they needed to. However, we cannot rely upon serendipity to restore our watersheds. The organizations involved in the restoration of our streams and rivers must begin to work together to restore our broken landscape. With greater coordination and cooperation in the future, the O'Brien Creek Watershed restoration can serve as an example to other urban and developing watersheds in Montana, just as the Big Spring Creek Watershed restoration has.

Chapter Two:
Survival Study of Shrubs Planted in Fall 1998 on O'Brien Creek, MT

Introduction

Riparian restoration is a relatively new science; constantly developing more effective techniques to repair damaged riparian areas (Goodwin et al. 1997). When in healthy functioning condition, riparian areas perform a number of important functions including, sediment filtering, streambank stabilization, floodwater absorption, groundwater recharge, stream energy dissipation, and fish and wildlife habitat (Hansen et al. 1995; Clayton 1996). Riparian health is defined as the ability of a given riparian area to perform the above functions (Hansen et al. 1995). Historically, riparian areas were not viewed as important to stream ecosystems; they were seen as separate entities, which could be altered without detrimental effects to adjacent water bodies (Brooks et al. 1997). Intact riparian areas are now seen as essential to the health of stream ecosystems (Hansen et al. 1995; Brooks et al. 1997). Timber harvesting, mining, urban development, and season-long grazing in riparian areas have left them in need of restoration (Hoag 1994).

Stream restoration goals often include returning riparian areas to healthy functioning condition. However, once restoration efforts have been completed, often there is little or no follow-up monitoring of the area (Bentrup and Hoag 1998; Kondolf 1995; Kondolf and Micheli 1995). Follow-up monitoring is vital to achieving restoration goals. To allocate funding effectively for future restoration projects, it is imperative that we learn what is working and what is not (Kershner 1997; McGurrin and Forsgren 1997). The science of riparian restoration will move forward only by monitoring riparian restoration projects, assessing the shortcomings of each project, and utilizing that data to inform future projects.

I evaluated the survival of native woody plants used to revegetate a reconstructed stream channel in a suburban area in a valley of the Northern Rockies. Also evaluated was the relationship of survival to four factors: plant diameter, plant height, and horizontal and vertical distance of plant base from the stream's wetted edge at base flow.

In the fall of 1996, Montana Fish, Wildlife and Parks (MFWP) began the restoration of sections of lower O'Brien Creek in Missoula, Montana. This restoration included the complete regrading and restructuring of the stream bed and banks in 1998 to restore the step, plunge and lateral scour pools characteristic of a Rosgen B-4 type stream channel (Rosgen 1996; Schmetterling pers comm. 1998). The restoration also included the removal of an irrigation diversion and the replacement of a culvert with a bridge.

To restore fish habitat, MFWP placed large organic debris and boulders on the stream bed and inside the banks so that the restructured stream would maintain its near bare banks until freshly planted riparian vegetation could begin to build deep, binding root masses (Water Consulting and West Water Consultants 1995). Thus far, the restructuring of the creek bed and banks has been judged successful with 80% of the structures in place and creating desired effects (Schmetterling pers comm. 2000).

The final phase of the restoration was the planting of seedlings and poles of native riparian species in the areas along lower O'Brien Creek. The re-establishment of woody riparian species is one of the most critical aspects of the restoration of degraded streams and rivers (Brooks et al. 1997).

Over the course of a year and a half, I monitored the survival of the riparian plantings made in the fall of 1998. To evaluate long-term success, monitoring must continue for several growing seasons (Bentrup and Hoag 1998; Kondolf and Micheli 1995). This report focuses on factors affecting short-term survival and provides some analysis of the design and early implementation of the project (Kershner 1997).

Methods

Study Area

O'Brien Creek is in Western Montana at 46.50 N latitude 114.10 W longitude.

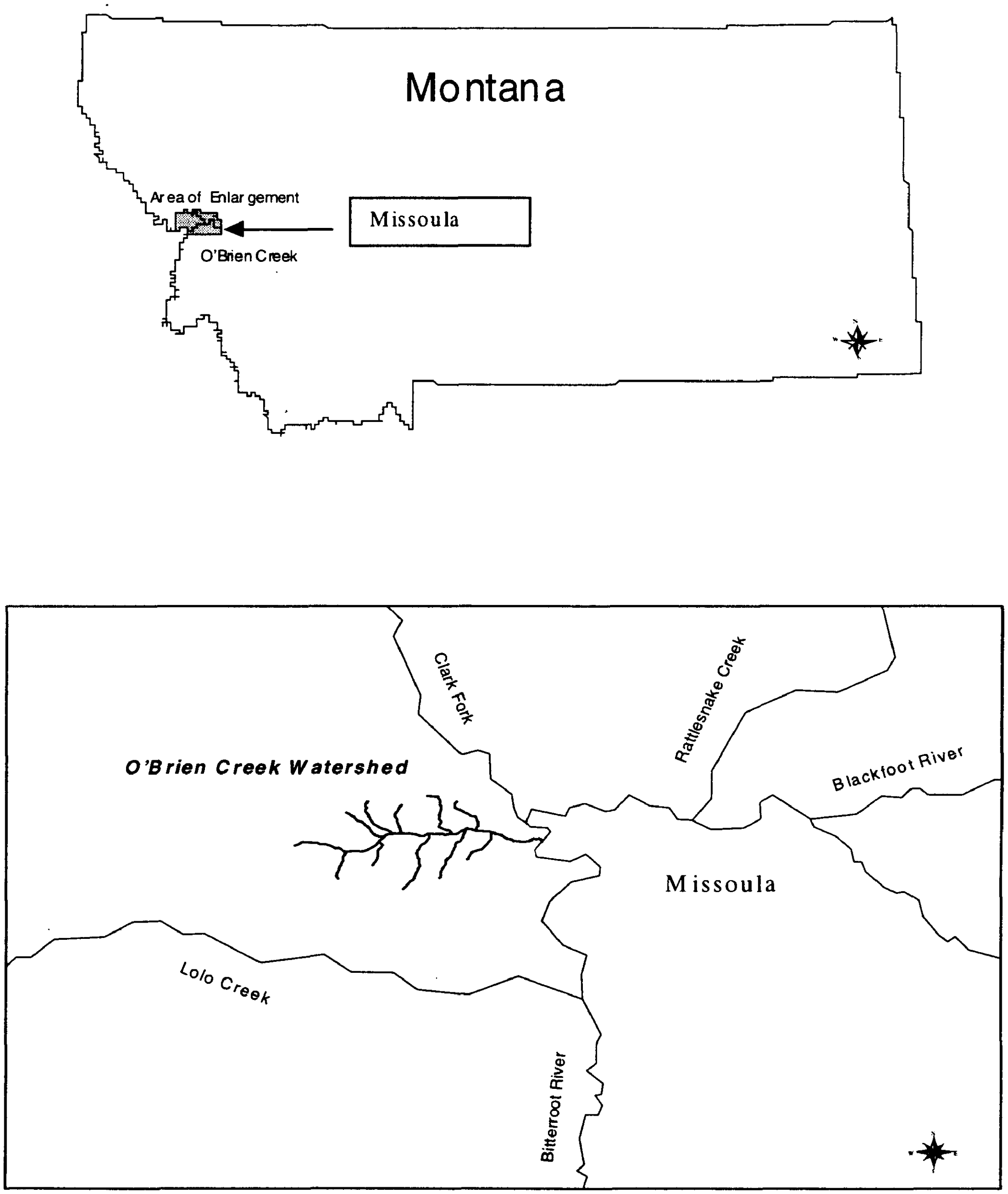

Figure 1 Map of the O'Brien Creek Watershed, the Missoula Valley and their location within the State of Montana.

O'Brien Creek is located on the west side of Missoula, Montana, entering the Bitterroot River 3.2 kilometers upstream of its confluence with the Clark Fork River. O'Brien Creek is a small watershed, roughly 41 square kilometers, draining the Blue Mountain area of the Bitterroot Mountains. The annual precipitation ranges from 50.8 cm to over 127 cm, and the elevation in the watershed ranges from 951 meters to 1969 meters (Sandoval and Hegman 1998). The dominant vegetation in the lower reach is black cottonwood and the upper watershed is dominated by ponderosa pine (*Pinus ponderosa*) on south facing slopes and ponderosa pine/douglas fir (*Pseudotseuga menzisii*) on north facing slopes. The creek is a second order stream with a mean base flow of 3-5 cfs and the longest branch is roughly 4.8 kilometers in length (Schmetterling and Pierce 1996).

Historically, O'Brien Creek provided habitat for native westslope cutthroat trout (*Oncorynchus clarkii lewisis*). Since 1930, the riparian areas along the lower 4.8 kilometers of O'Brien Creek have been altered for domestic use as pasture and as streamside lawns. This alteration channelized the creek, reduced bank stability, increased the amount of sediment in the stream, and degraded habitat for fish and wildlife by reducing the amount of suitable cover, that is, instream organic debris and streamside vegetation (Schmetterling pers comm. 1998; Schmetterling and Pierce 1996). O'Brien Creek offers a unique opportunity to repair creek habitat and restore critical spawning sites for westslope cutthroat trout within an urban region.

As a result of land use, the 0.8-kilometer stretch of the creek from just above Blue Mountain Road Bridge down to the confluence with the Bitterroot River was left with only limited riparian vegetation. The stream reach had some stands of mature black cottonwood in the areas where streambanks had not been graded to a Rosgen type B channel. On the sections of stream which had their banks graded, there was little to no woody vegetation.

Due to the use of excavators in the reshaping of the stream channel, few upland grass species remained on the disturbed soil (Schmetterling pers comm. 2000). For the upland revegetation a mixture of native grass seed including, bluebunch wheatgrass (*Agropyron spicatum*), slender wheatgrass (*Elymus trachycaulus*), western wheatgrass (*Agropyron smithii*), Idaho fescue (*Festuca idahoensis*), and rough fescue (*Festuca scaberella*) was dispersed (Marler pers comm. 2000).

Revegetation project and Monitoring

Native riparian nursery stock was planted over a period of several weeks in the fall of 1998, after those plants had gone into dormancy. Four species of seedlings were used in the riparian plantings, black cottonwood (*Populus trichocarpa*), yellow willow (*Salix lutea*), common chokecherry (*Prunus virginiana*), and red-osier dogwood (*Cornus stolonifera*). Volunteers from around the Missoula valley planted the riparian vegetation, and the volunteers were trained on-site in planting techniques by the contractor (Marilyn Marler). The plants were placed by hand into holes roughly 40 centimeters deep and were placed no less than 14 centimeters into the ground. Many of the plants were placed in very coarse material (large gravel and cobbles). The soil under and around the transplant was wetted during planting to aid in soil compaction. The positions of the plantings had been determined beforehand by the contractor and MFWP, and were marked with flags. The total cost of the riparian transplant project, including materials was $600, with a cost of $.30 per riparian planting.

A total of 331 seedlings (<2 years old) and 10 poles were planted. Of the seedlings, 36 were yellow willow, 88 were red-osier dogwood, 165 were black cottonwood, and 42 were common chokecherry. Of the poles there were 7 black cottonwood, 2 yellow willow, and 1 red-osier dogwood. The poles were placed in the riprap located just downstream of the Blue Mountain Road Bridge and near the mouth of the creek.

I looked at survival of each individual plant in the first year and a half and related survival to four variables, including:

1. Plant height (cm) above ground
2. Stem diameter (cm) 2.5 centimeters above the ground surface
3. Horizontal distance (cm) of plant base from base flow wetted edge
4. Vertical distance (cm) of plant base above water level at base flow*

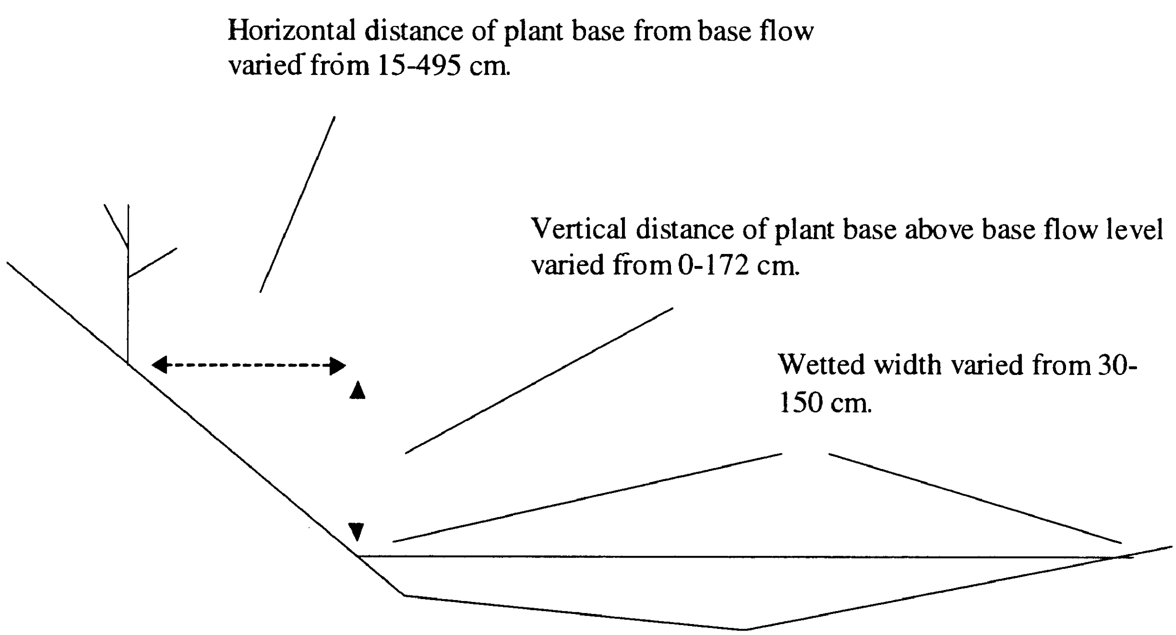

Figure 2
Schematic of creek cross section-showing two of the measurements taken on riparian plantings.
base flow refers to fall low flow levels (roughly 3-5 cfs).

Due to its close proximity to stream ecosystems, riparian vegetation is subject to unique stresses (Carlson et al. 1995; Dennis-Perez et al. 1996; Goodwin et al. 1997; Brooks et al. 1997). The timing and duration of high water inundation and scouring, low-water desiccation, and browse potential are all factors that influence the success of vegetative restoration projects (Hosner 1958; Bradley and Smith 1985). Cottonwood (*Populus* spp.) and willow (*Salix* spp.) seedlings are shade-intolerant and require a bare, moist substrate for successful propagation, hence they are susceptible to competition from other vegetation and from natural stream dynamics like scour (Dennis-Perez et al. 1996; Clayton 1996; Bradley and Smith 1985; Friedman and Lewis 1995). Hoag (1993) found that as long as the saplings or poles are planted with their roots below the mid-summer water table, they could be placed fairly high on the streambank. He also found that if the transplanted individual extends above the competing vegetation, survival rates are high.

Bradley and Smith (1985) found that plains cottonwood (*Populus deltoides*) seedlings suffer high mortality rates from inundation, scouring and also from desiccation. Cottonwood seedlings and saplings can survive short-term inundation (no more than 16 days of continuous inundation) without serious effects as long as their anchoring substrate is not washed away (Clayton 1996; Hosner 1958).

Studies have shown that the long-term survival of transplanted cottonwood and willow saplings is a function of placement, plant length, and plant diameter (Clayton 1996; Bradley and Smith 1985; Hoag 1993; Hosner 1985). These studies suggest the best strategy for successful riparian plantings places plants high enough to reduce risk from inundation and scouring yet low enough to insure adequate water sources during the mid-summer months. In addition, individuals used must be long enough to compete with surrounding vegetation for light and water, and have adequate stem diameter to give sufficient reserves for establishment.

Selection of stem diameter and plant height as key variables was based on two studies done by Hoag (1992; 1993). Both of these studies found that stem diameters of willow and cottonwood cuttings directly affected the sprouting success of the cuttings. When cuttings are greater than 0.5 inches in diameter, sprouting success is significantly increased (Hoag 1992). Even greater sprouting success was found with cuttings greater than 1 inch (Hoag 1992; Hoag 1994; Hoag et al. 1992). Larger diameter cuttings have more energy reserves (Hoag 1993; Carlson et al. 1995) and are better able to withstand scouring flows (Hoag 1992).

Cutting length has also been found to influence sprouting success and survival of plants used in restoration work (Hoag 1992; 1993; Carlson et al. 1995). Chances for survival are decreased if the length of the cutting or sapling does not allow the individual to reach groundwater, compete for light with surrounding vegetation, or, in cases where inundation might occur, extend above the high water line (Hoag 1993; Carlson et al. 1995). I hypothesize similar effects of stem diameter and plant height on survival in cuttings and seedlings of black cottonwood, red osier dogwood, common chokecherry, and yellow willow.

Horizontal and vertical distances from the stream's "wetted edge" at base flow were used as indicators of the potential for death due to desiccation, scouring, or inundation. These variables did not take into account fluctuations in the groundwater table or disjunction between groundwater and surface water.

I measured each individual transplant, noted its species, marked it with an identification collar and assigned each a unique number. In spring after the winter dormancy period ended, I counted the number of living plants and assessed the cause of death in each individual. I used the scratch test (Hansen pers comm. 1999) to assess whether or not the individuals were alive or dead. The scratch test involves scraping a bit of the bark off of the sapling with a fingernail. If the underlying tissue is green, it is alive; if not, it is probably dead.

Cause of death was guessed from a visual inspection. Mortality by browsing was assumed if chew marks were observed or if the individual plant had been pulled out of the ground. Scouring mortality was estimated by counting the total number of missing individuals, and by searching downstream debris jams. Inundation mortality was evaluated by tallying individuals not lost to scour, but found submerged in the creek. Dead individuals that were not browsed, inundated, or lost to scour were assumed to have died from desiccation/competition (although the nursery stock could have been dead before planting).

Western Montana's snowpack for the winter of 1998-99 was slightly above average, and O'Brien Creek experienced spring flows that were average to above average (Western Regional Climate Center 2000). The first spring survey was timed so that it would take place after O'Brien Creek's flow had peaked, allowing for the observation of individuals taken by high water scour. The fall survey was done in October of 1999 after a drier than average summer (Western Regional Climate Center 2000). The second spring survey was done in April of 2000 after a winter of slightly lower than average snowpack conditions.

Results

Survival rates and causes of death after the fall 1999 census are summarized in Table 1. Chokecherry had the highest survival rate at 64%, while black cottonwood had the lowest at 16%.

Fall 1999

Species	% Survival	Cause of Death %				
		Browse	Scour	Inundation	Desiccation	Other
Cornus	26%	1%	11%	0%	61%	0%
Populus	16%	5%	16%	2%	47%	13%
Prunus	64%	0%	14%	0%	21%	0%
Salix	20%	6%	40%	0%	26%	9%
Pole	20%	0%	0%	0%	80%	0%

Table 1. Survival percentages by species and the suspected cause of death after the fall 1999 census ("Other" indicates that cause of death could not be determined by process of elimination from the four categories).

Desiccation and/or competition were the most common causes of mortality.

Total survival of all individuals from all censuses is shown in figure 3 below. The survival rates were very low, with a notable decrease between spring and fall of 1999.

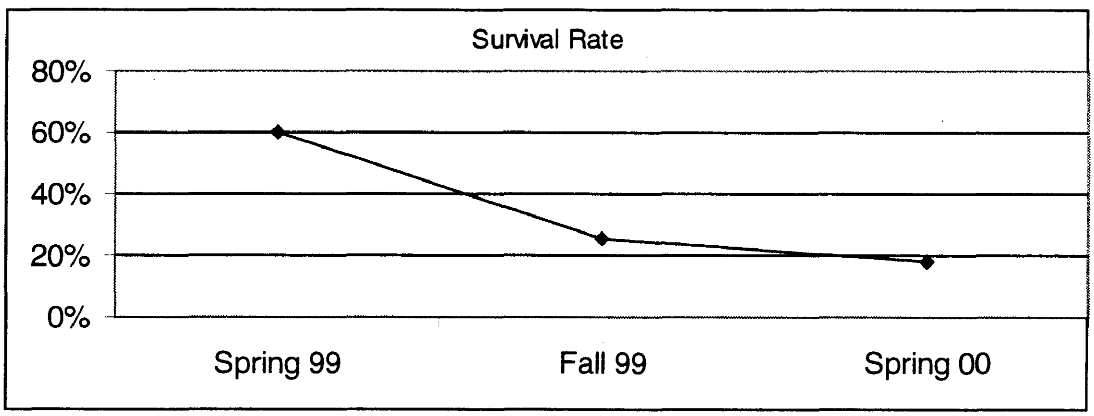

Figure 3. Graph showing total survival of all plantings at O'Brien Creek after a year and a half.

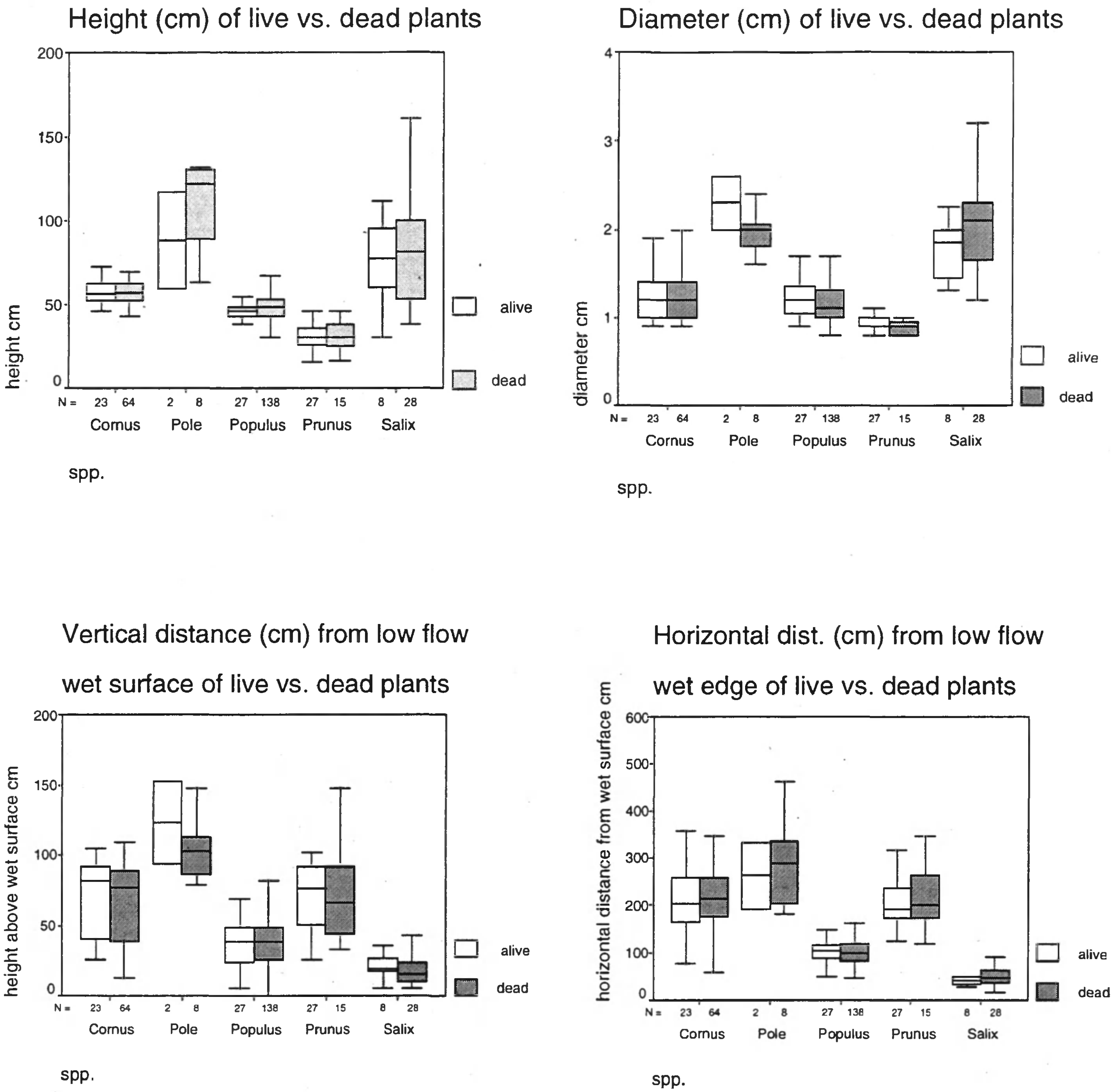

Figure 4. Box plots comparing surviving transplants to dead transplants one year after planting in terms of height, diameter, and distance (horizontal and vertical) from low flow wetted edge of stream (X axis gives species of seedlings-note pole refers to 10 individuals representing all species except common chokecherry).

I used a t-test to compare the means of surviving groups and dead groups (mean and standard deviation for each of these groups can be found in appendix A) for each species and each characteristic (height, stem diameter, height above and horizontal distance from base flow wet edge). No significant difference was found between live and dead individuals for any of the characteristics. This result was not surprising since the variation in sizes and distances to water was small.

Logistic regression showed that only height was statistically significant in predicting survival (Hosmer and Lemeshow 1989). Although statistically significant, height performed poorly in the model, predicting only 2/341 individuals to survive. The three other categories, stem diameter, height above base flow wet surface, and horizontal distance from base flow wet edge were not statistically significant in predicting survival.

Species	Distance in centimeters from Low Flow Wet Edge					Number surviving out of total planted and (%)
	0-99	100-199	200-299	300-399	400 +	
Cornus	1\3 (33%)	10\35 (29%)	9\40 (22%)	3\7 (43%)	0\1 (0%)	
Pole		1\3 (33%)	0\3 (0%)	1\3 (33%)	0\1 (0%)	
Populus	11\80 (14%)	16\81 (20%)	0\2 (0%)			
Prunus		15\22 (68%)	9\14 (64%)	3\6 (50%)		
Salix	8\32 (24%)	0\3 (0%)				

Table 2. Number of surviving individuals of each species (out of total planted) for various distances (cm) from the low flow wetted edge.

Species	Height in centimeters above Low Flow Wet Surface					Number surviving out of total planted and (%)
	0-24	25-49	50-74	75-99	100 +	
Cornus	0\7 (0%)	7\24 (28%)	3\8 (38%)	11\42 (42%)	2\4 (50%)	
Pole				1\5 (20%)	1\5 (20%)	
Populus	7\35 (19%)	14\90 (16%)	5\35 (14%)	0\2 (0%)		
Prunus		7\12 (58%)	6\10 (60%)	13\16 (81%)	1\4 (25%)	
Salix	5\26 (19%)	3\10 (30%)				

Table 3. Number of surviving individuals of each species (out of total planted) for various vertical distances (cm) above low flow wet surface

No pattern is apparent from these data. The numbers within each category are simply too low for any statistical power. Moreover, not all species were planted in every zone making it harder to evaluate the effect of these parameters on survival.

Discussion

The restoration plantings on O'Brien Creek experienced high levels of mortality in the first season of growth. Between fall (November 1998) planting and the spring (May 1999) census, 39% of the plants had died. Between the spring (May 1999) and fall (October 1999) 57% of the plants surviving to spring 1999 had died. This could be due to a variety of factors. Large portions of the creek, especially near the mouth, showed high levels of scouring, streambank loss, and sediment movement. Many of the scouring losses were in these areas of chronic physical disturbance. The spring of 1999 was unusually wet, but the summer was unusually dry (Western Regional Climate Center 2000). The drier than average summer might have led to the high number of deaths by desiccation.

It is likely that many individuals were lost to competition with exotic species such as, leafy spurge (*Euphorbia esula* L.), spotted knapweed (*Centaurea maculosa* Lam.), smooth brome (*Bromus inermus*), and common tansy (*Tanacetum vulgare* L.). The lower reaches of the restoration site were heavily infested by exotics; more over, non-browse and non-scour mortality rates were highest there. The riparian areas of O'Brien Creek that were disturbed by the regrading of the creek had lower densities of weeds and higher rates of survival by the riparian plantings, suggesting competition may have been important elsewhere.

Because the study area was not subject to grazing by domestic animals, browse damage was minimal. There was some browsing loss due to white tail deer populations (*Odocoileus virginianus*) in the area; however, very few plants were lost to browsing.

The results of the logistic regression and the t-test for live versus dead plants' size and distance to water suggest that these parameters had little effect on survival over the narrow range of sizes and distances studied here. However, larger sample sizes and wider variation in size and distance may show significant effects on survival.

Future plantings on O'Brien Creek would benefit by placing plantings of adequate size within a reasonable distance to the "wet-surface". The studies done by Hoag (1993), Bradley and Smith (1985) and Conroy and Svejcar (1991), and McBride and Strahan (1984) suggest guidelines for this "reasonable distance". They each state that the plantings' roots must be able to access the mid summer water table while at the same time be high enough to protect from scour. Hence small plants must be placed so close to the streams low flow surface that they are likely to be scoured out at high flow.

The majority (77%) of the plants at O'Brien Creek were not placed within a "reasonable distance". Because of the small size of the plants used at O'Brien Creek, they were unable to access the mid summer groundwater table.

In a restoration project on Trout Creek in Northeastern Nevada, the survival rates were much higher. After two seasons of growth, 82% of the willows had survived, and after the first season of growth 60% of the red-osier dogwoods had survived (Hoag et al. 1992). Although not identical, the two streams (O'Brien Creek and Trout Creek) are of similar size. The red-osier dogwoods used at Trout Creek were unrooted cuttings of less than 2.5 cm in diameter (red-osier dogwood rarely grows larger than 2.5 cm in diameter) rather than seedlings with a mean diameter of 1.2 cm as in this study. It was generally accepted in the Trout Creek study that larger diameter red-osier dogwood cuttings were more desirable. The willows used in the Trout Creek study (92-305 cm in length) were significantly larger than those used in the O'Brien Creek study (12-63 cm in length). Cuttings of this size were of adequate size to be placed in the mid-summer groundwater table.

Restoration projects similar to O'Brien Creek contracted to Bitterroot Restoration of Corvallis, Montana and the Riparian and Wetland Research Program at the University of Montana (RWRP) also have higher rates of survival. Bitterroot Restoration uses seedlings because they are the most cost effective for both transport and placement (Massey pers comm. 2000). The seed is collected from the site and is matched by elevation. With these conditions, a 40% survival rate with bare rooted seedlings is common (Massey pers comm. 2000). The RWRP used containerized seedlings in a study on the Upper Clark Fork River in Montana and had first year survival rates of 90% (DeFrancesco et al. 2000). In both these cases the substrate in which transplants were placed was smaller than the large gravel and cobbles found on O'Brien Creek.

From the results of other similar studies, plant size does have an effect on survival (Hoag 1992; Hoag 1993; Hoag et al. 1992). Because my study involved such a small number of poles (10) and all were about the same size, I cannot support nor refute these findings. However, because the mortality rates of the seedlings within the first year of planting were high as compared to other studies (Hoag et al. 1992), the small size of the individuals used may have played a role.

Vertical and horizontal distance from water did not show any significant effect on survival for any species. There are at least two possible explanations of which both could be true: 1) the zone (0-172 cm vertical, 15-495 cm horizontal distance from wet surface and wet edge respectively) within which these plants were located was narrow enough that differences in stress were not significant, or, 2) the uneven planting distribution of most of the species within this zone did not allow an adequate test of distribution effect.

Conclusions and Recommendations

Plant size and location used at O'Brien Creek were not effective. The use of larger plantings (> 2.5 cm in diameter) might ensure a higher survival rate within the first year, the most dangerous year for a transplant. The use of larger plantings would likely reduce numerous causes of death. The loss to scour would decrease due to deeper planting. The loss to inundation and desiccation would decrease because of the ability to plant larger individuals higher on the bank, while still in the low flow summer water table. Loss to competition should also decrease due to the ability of larger individuals to compete for light and water. Hence, the use of larger plants increases the area in which plants can be placed. Larger plants can be placed higher on the bank, protecting from scouring loss, and still be placed below mid summer water table levels.

Plantings on O'Brien Creek have the potential to be more successful with changes in design and implementation. The following are suggestions based on the observations of the species used for this study and the results of other more successful projects of a similar nature.

1. Seedlings should not be used (in this case). They are simply too small (in length and diameter) to be effective, and are much more vulnerable than cuttings or poles. Based on the literature, cuttings and poles of 4 to 7.5 cm in diameter should be used (Hoag 1993;1992; Hoag et al. 1992). If a species (red-osier dogwood) does not grow to the suggested diameter, use the largest possible size.

2. The below ground length of the cutting or pole should be adequate to be placed in or near the mid summer ground water table (especially when soils are very coarse as they are at O'Brien Creek). The above ground length should be twice the height of surrounding ground cover. This length will allow access to the mid summer water table, while at the same time give the plant the ability to be above the shade of competing vegetation (particularly non-natives) (Hoag et al. 1992).

3. If possible, the mid summer water table should be determined before planting begins. This will give some idea as to how deep the transplants must be placed.

4. As a rule, roughly 1/2 to 2/3 of the cutting should be in the ground (Hoag 1993). This will enable the cutting to have an appropriate anchor against scouring, and survive the competing vegetative root mass (aggressive non-native species).

5. Care should be taken to minimize the effect of aggressive non-native species on transplants for at least the first year of growth and perhaps longer. Site preparation plays an important role for control of noxious weeds, the area should be tilled, mulched, irrigated, and sprayed if necessary (Massey pers comm. 2000).

6. If seedlings must be placed due to cost constraints, I recommend that different species be used in the next transplant project. The survival rate of common chokecherry (64%) was far greater than any other species used for the restoration of lower O'Brien Creek. Chokecherry is a riparian species that thrives in a slightly drier environment than the other riparian species used at O'Brien Creek. Given the site conditions, including the cobble substrate and the terraced nature of stream banks on a Rosgen B-4 stream, chokecherry and other drought hardy species should be used in the future (water loving species such as black cottonwood should be avoided). Some examples of species more appropriate to the site conditions might include, ponderosa pine (*Pinus ponderosa*), woods rose (*Rosa woodsii*), western snowberry (*Symphoricarpos occidentalis*), or western serviceberry (*Amelanchier alnifolia*). These species will be able to withstand the drier nature of the site and will hopefully decrease the number of deaths by desiccation.

The plantings placed in the fall of 1998 on O'Brien Creek displayed only 18% survival. Hopefully, with the experience from the first O'Brien Creek revegetation and the information gathered here, a more successful vegetative transplant could be planned for O'Brien Creek.

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Appendix A -Table showing median, mean and standard deviation of surviving plants compared to dead plants one year after planting in terms of height, diameter, and distance (horizontal and vertical) from low flow wetted edge of stream.

	Height			Diameter			Height above Wet Surface			Distance from Wet Surface (Horizontal)		
	Median	**Mean**	**StdDev**	**Median**	**Mean**	**StdDev**	**Median**	**Mean**	**StdDev**	**Median**	**Mean**	**StdDev**
Cornus - A	55.88	59.14	11.75	1.20	1.30	0.39	78.74	67.37	27.49	193.04	206.62	68.98
Cornus - D	57.15	58.84	10.95	1.20	1.23	0.27	77.47	64.49	29.12	213.36	216.57	70.34
Pole - A	90.81	90.81	44.00	2.35	2.35	0.35	115.57	115.57	52.09	265.43	265.43	95.19
Pole - D	107.95	98.11	38.18	1.90	1.86	0.32	102.87	97.79	33.61	288.29	276.86	107.96
Populus - A	45.72	45.63	6.94	1.20	1.22	0.22	38.10	36.50	15.55	101.60	99.62	26.40
Populus - D	48.26	48.95	10.66	1.10	1.20	1.04	38.10	38.27	17.79	100.33	102.36	32.07
Prunus - A	29.21	29.54	8.41	0.90	0.94	0.15	73.66	69.80	23.38	195.58	211.29	57.73
Prunus - D	30.48	34.54	12.98	0.90	0.93	0.18	66.04	72.31	43.64	198.12	208.96	87.53
Salix - A	73.66	73.18	27.59	1.85	1.77	0.34	19.05	20.64	9.15	44.45	47.31	22.43
Salix - D	83.82	83.30	31.23	2.10	2.10	0.57	15.24	18.72	11.63	48.26	56.49	27.08