Composition of Riparian Herb Communities on Streams with Regulated and Unregulated Streamflow, Eldorado National Forest, California

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Introduction

This study was carried out at the request of the USDA-Forest Service, Eldorado National Forest. The objective was to collect data about riparian herb communities associated with regulated and unregulated streams. The intended use of these data was to establish a baseline for analyzing effects of flow regulation.

There is a relatively extensive literature that describes the responses of meadow vegetation to changes in groundwater (Ponce and Lindquist 1990). Reduced groundwater levels can occur when streams incise to levels below their floodplains. When this occurs, vegetation composition may change from species adapted to high soil moisture to more drought tolerant species. These effects are thought to be common in the Sierra Nevada (Kattelmann 1996). Raising a water table through geomorphic restoration or use of instream structures can reverse these vegetation changes.

There have been few studies that have looked specifically at the effects of stream flow regulation on herb communities. When streams have been completely diverted in and regions there have been changes in species composition from mesic to xeric herb species (Ham's et. al. 1987). In cases such as Project No. 184 where hydrologic changes are relatively complex, responses of herb communities have not been studied. Soils, light and other environmental variability plus land use history confound attempts at such studies.

The information presented below does not provide a comprehensive assessment of the many regulated and unregulated streams in the Eldorado National Forest. It does provide a benchmark for considering whether or not herb monitoring might be warranted to determine future operational effects of Project No. 184.

Methods

We defined suitable study sites as having distinctive, relatively extensive (at least several hundred square feet) riparian meadows free from excessive forest or shrub cover. Study sites were selected on three stream reaches affected by Project No. 184: Caples Creek downstream from Caples Lake, South Fork American River downstream from the Echo Lake conduit, and South Fork American River in the vicinity of Phillips (Figure 1). Other regulated stream reaches on the South Fork, Caples Creek, and Silver Fork were evaluated for sampling but eliminated due to the absence of significant riparian herb communities. Study sites on unregulated streams were selected in consultation with Forest Service staff. These included Foster Meadow, Bryan Meadow, Benwood Meadow, Round Meadow and Kirkwood Meadow (Figure 1). All sites, including those affected by Project No. 184, are located at altitudes greater than 6000 feet. None are within active grazing allotments although they may receive limited grazing from horses passing through.

Sampling occurred in July-August, 2000 corresponding to the time when most species would be identifiable. At each site, experienced ecologists selected sampling locations. The objective was to select locations that typified the vegetation community. In some cases, more than one location was required.

The study design consisted of establishing transects that were generally 200 feet long, but that varied somewhat based on the diversity of vegetation and topography, width of meadow dominated sites, and accessibility. The transects were placed perpendicular to the channel, with a roll tape that was stretched across the creek where possible and secured with metal pegs at each end to hold it in place. The toe-point method was used to collect vegetation composition data (Anon. 1996). A pointed wooden dowel was used at one foot intervals along the transect to identify plant "hits" providing frequency data. Hits were recorded to the species level when possible, but grouped by the following categories: sedge, rush, graminoids, forbs, willow, barren, litter or water. Sedges and rushes are typical wet meadow plants. They have especially high value for streambank stabilization. Graminoids include all annual and perennial grasses. Forbs include all broad-leaved herbaceous plants, some of which are associated with wet or dry sites. Typical forbs include clovers, Indian paintbrush and lilies. Willows include any willow species. Data were recorded on a field data form along with relevant field notes and each site was photographed and described to facilitate finding the same location at a later date. Species that could not be identified in the field were later identified by a local botanist. Phenology prohibited developing complete lists of all species but the dominant species at each site were identified. Only inconspicuous or sparsely distributed species would have been missed.

Analysis included compiling tabulations of vegetation category frequency and percent frequency data for each site and for regulated and unregulated streams, combined. A species list was compiled for each site as well. Statistical analysis was performed to determine if there were significant differences between frequency of vegetation categories on regulated versus unregulated streams.

Results and Discussion

In all, data were collected on 14 transects at the eight study sites. This included five transects at Caples Creek, two at Kirkwood and Bryan Meadows and one each at the other sites. Appendix A contains lists of the plant species encountered at each site. Appendix B and C contain frequency distributions for vegetation units at regulated and unregulated sites, respectively. Appendix D is a chart of pooled data for regulated versus unregulated streams.

Species composition at regulated versus unregulated sites was not indicative of any specific effects of streamflow regulation. Because these sites have not been heavily grazed for many years, it was more indicative of natural meadow succession. All sites had essentially complete cover. Bare ground, litter and rock ranged from four to 16 percent cover on the transects.

Table I summarizes percentage frequency data for regulated and unregulated streams. Overall, the proportional distribution of vegetation categories on regulated versus unregulated streams was similar except for the sedge and water categories. Three transects on Caples Creek had relatively low proportions of sedge and relatively high proportions of graminoids. There was also more surface water present at Caples Creek than at other sites. This is an artifact of the flow regime which is augmented during normally low flow periods. When water was excluded from the transects i.e., only vegetation or bare ground hits were included, and proportions were recalculated, the difference in sedge cover between regulated and unregulated transects was reduced (average 35 percent on regulated versus average 42 percent on unregulated).

Table 1: Proportions of Vegetation Units by Study Transect (values in percentages)

Site	Sedge	Grass	Shrub	Forb	Willow	Bare	Litter	Water	Rush
South Fork	34	7	1	37.5	0	1.5	11.5	0	7.5
South Fork	44.5	3.5	0	31.5	0	0	3.5	9	8
Caples	12	23	0	31	5.5	8.5	4	12.5	3.5
Caples	28	40.5	0	7.5	3.5	0	3	17.5	0
Caples	16	22.5	0	34	1.5	1.5	2	17.5	5
Caples	18	13	0	29.5	11.5	2.5	2	17.5	6
Caples	30.5	11.5	0	21.5	5	3.5	9.5	12.5	6
Average	26.1	17.3	0.1	27.5	3.9	2.5	5.1	12.4	5.1
Benwood	65	12	0	7	0	12	4	0	0
Bryan	31.5	17	0	25	7.5	7.5	1	2.5	8.5
Bryan	40	18	0	17	8	8	1	3	6
Foster	29	6	0	50	0	8	0	0	7
Kirkwood	36	17	0	32	5	1	9	0	0
Kirkwood	21	19	0	50	6	1	3	0	0
Round	48	14	0	24	5	3	1	2	0
Average	39	15	0	29	4.5	5.8	2.7	1.1	3.1

A chi-square analysis was performed to determine if samples from regulated versus unregulated streams differed in frequency distributions of vegetation categories, excluding water. Regulated streams had higher frequencies of barren, forb, and graminoid hits than unregulated streams, and lower frequencies of sedge and willow hits. Overall, the differences were highly significant ($p<0.001$). Riparian herb communities characterized by high proportions of sedges and rushes occurred on all sites to at least some degree. The somewhat higher proportions of graminoids on some Caples Creek transects may be indicative of a locally lowered groundwater table. Additional data on hydrology and channel morphology would be required to confirm this condition. Theoretically, reduced groundwater at Caples Creek could result from reduced frequency and magnitude of overbank flooding or it could be due to incision caused by the 1997 flood.

Conclusions

Because of the limited scope of this study it is not appropriate to draw any general conclusions. The conditions on the South Fork American River, where peak flows are not reduced and only low summertime flows are affected by Project No. 184, are suggestive of relatively rich riparian herb communities, comparable to those found on unregulated streams. Conditions at Caples Creek, where many factors have affected the stream, including recreational and livestock traffic, beaver dams and Project No. 184, suggest that monitoring meadow composition, in conjunction with additional hydrologic and geomorphic monitoring, might be useful for providing guidance on future management.

Literature Cited

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Appendix A: Species Lists for Study Sites (note that grasses are in Italics)

Project Affected Sites

Caples Creek: sampled July 17, 2000.

Achillea millefolium
Aconitum columbianum
Agrostis sp.
Aster occidentalis
Bromus inerinus
Calamagrostis canadensis
Carex utriculata (Old name C. rostrata)
Carex sp.
Castilleja sp.
Deschampsia cespitosa
Elvmus glaucus
Epilobium sp.
Heracleum lanatum
Hordeum brachvantherum
Ligusticum grayi
Pascopyrum smithii
Pen'den'dia sp.
Phleum pratense
Potentilla glandulos
Potentilla gracilis
Rumex sp.
Senecio triangularis
Sisyrichium bellum
Lupinus polyphyllus
Mimulus sp.
Polygonum bistortoldes
Potentilla gracilis
Salix lemmomi
.Salix lucida ssp. lasiandra

South Fork American River: sampled July 18, 2000.

Site #1
Sierra at Tahoe, Phillips Station meadow

Agrostis sp.
Aster apiginus var. andersonii

Carex nebrascensis
Carex sp.
Hordeum brachyantherum
Juncus balticus Juncus xipbioides Periden'dia sp.

Site #2
Above Sierra at Tahoe and Audrain Way

Aster alpinginus var. andersomi
Carex nebrasensis
Carex sp.
Lilium parvum
Muhlenbergia filiformis
Penstemon rydbergii
Phleum alpinum
Salix eastwoodiae
Trifolium longipes

Control Sites

Round Meadow: sampled July 25, 2000.

Agrostis idahoensis
Allium validum
Carex echinata ssp. echmata
Carex luzulma
Carex utriculata
Deschampsia caespitos
Muhlenbergi filifon-nis
Pamassia sp.
Periden'dia parisbii
Platanthera leucostacbys
Salix castwoodiae
Scirpus sp.
Senecio hydrophiloides

Foster Meadow: sampled July 25-26, 2000.

Achnatherum nelsonii ssp. dore
Agrostis capillaris
Agrostis stolonifera
Aster alpiginus var. andersonil
Aster integrifolius
Carex lemmomi
Carex sp.
Castilleja miniata ssp. miniata
Danthonia californica
Delphinium glaucum
Homalotheclum aeneum (moss)
Juncus xiphioides

Ligusticum grayi
Luzula comosa
Mimulus pnimuloides
Muhlenbergia richardsonis
Peridefidia so.
Poa pratensis
Polygonum bistortoldes
Senecio triangularis
Scirpus congdonii

Kirkwood Creek: sampled July 25, 2000.

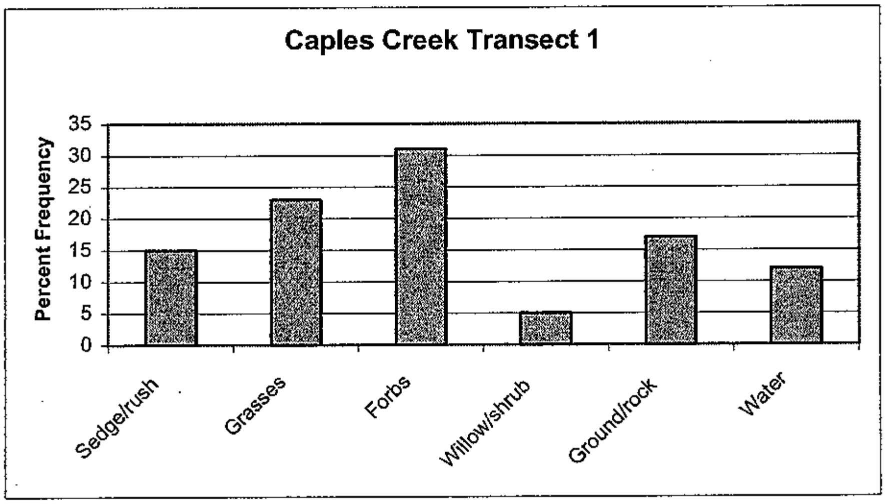
Achillea millefolium
Artemisia douglasian
Carex lemmomi
Carex nebrascensis
Castilleja miniata ssp. miniata
Deschampsia cespitosa
Hordeum brachyantherum
Poa pratensis
Trifolium longipes

Bryan's Meadow: sampled July 26, 2000.

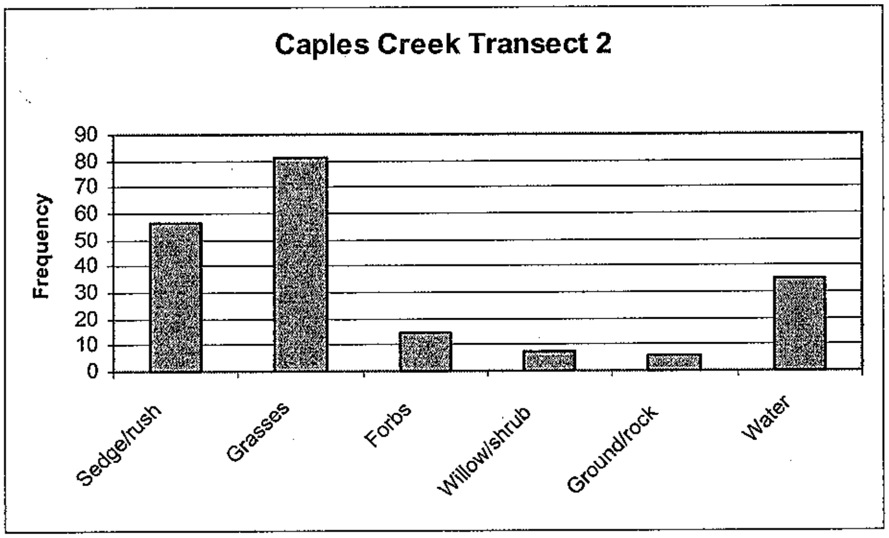
Agrostis sp.
Aster alpinginus var. andersonii
Carex angustata
Carex echinata ssp. echinata
Carex illota
Carex sp. (2)
Deschampsia cespitosa
Dodecatheon alpinum
Epilobium sp.
Muhlenbergia filiformis
Pamassia sp.
Polygonum bistortoides
Ranunculus sp.
Salix eastwoodiae
Salix orestera
Sambucus raccmosa var. microbotrys
Senecio triangulari
Trifolium longipes
Benwood Meadow: sampled July 27, 2000.

Atlium validum
Aster alpiginus var. andersonii
Carex nebrascensis
Deschampsia cespitosa
Deschampsia elongata

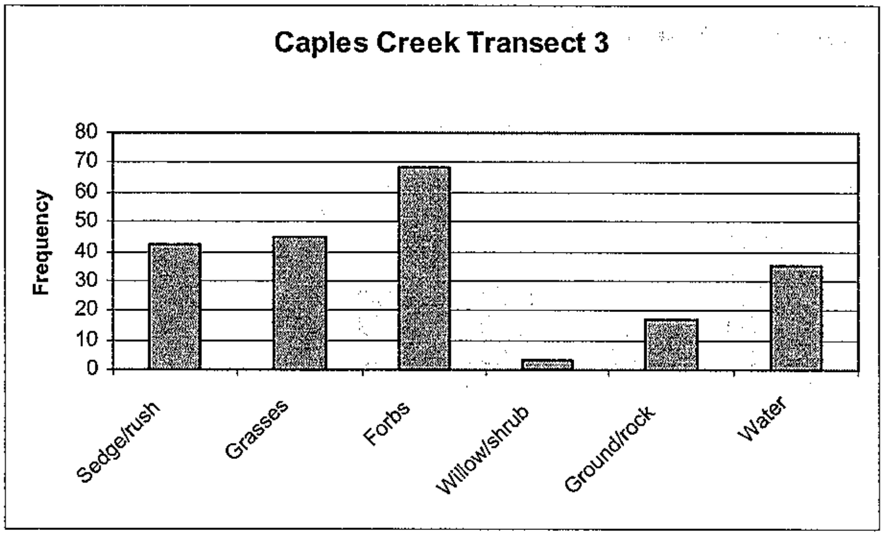
Penstemon rydbergii
Peridcn*dia sp.
Polygonum bistortoides
Sphenosciadium capitellatum

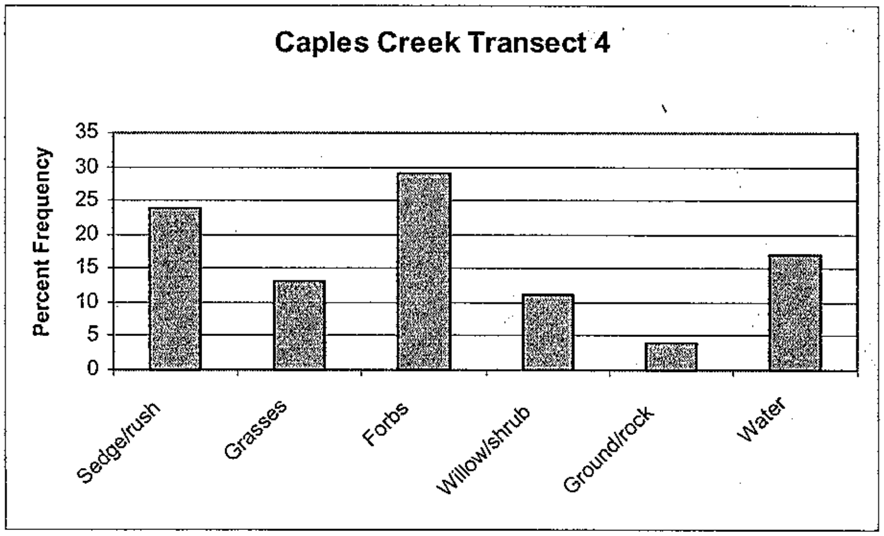


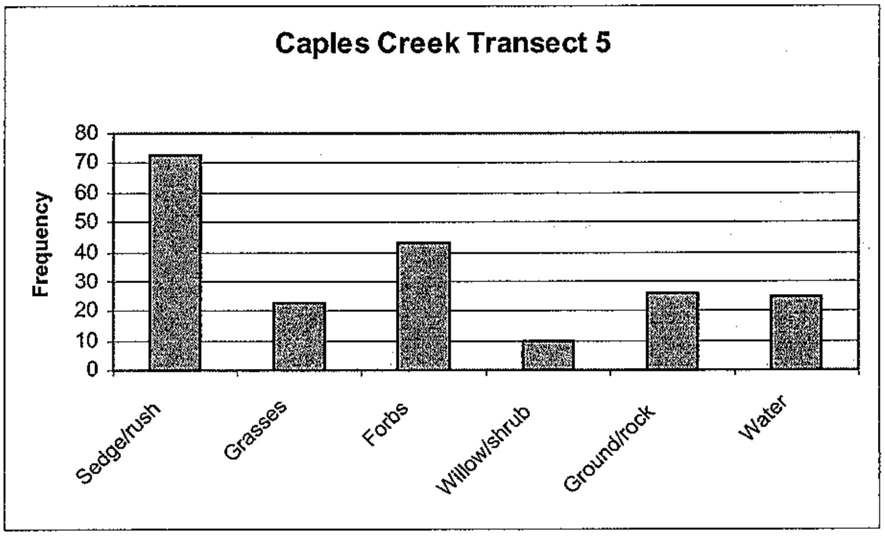
Caples Creek Transect 1
Percent Frequency
35
30
25
20
15
10
5
0
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water

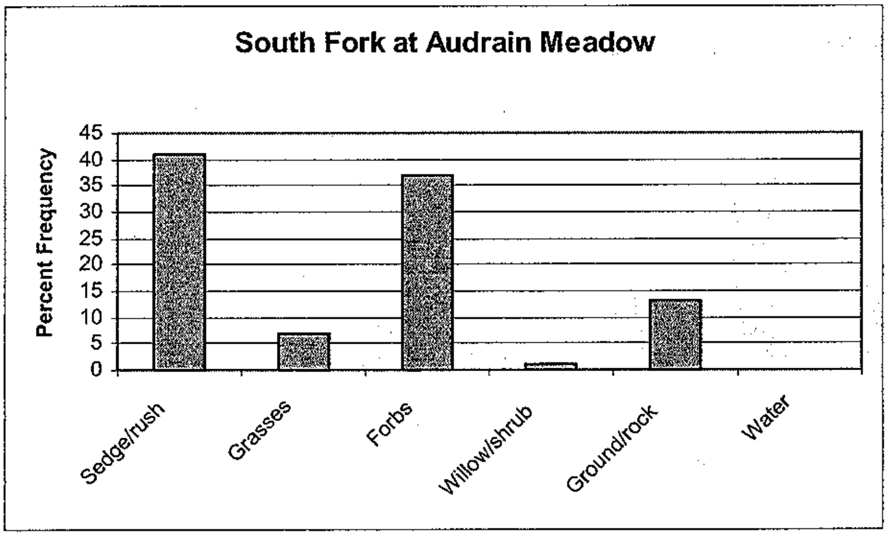


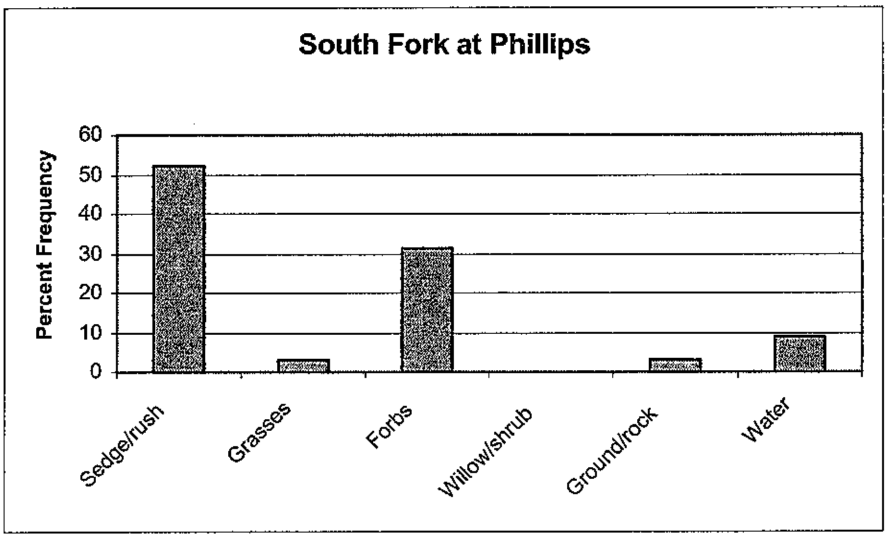
Caples Creek Transect 2
Frequency
90
80
70
60
50
40
30
20
10
0
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water


Caples Creek Transect 3
Frequency
80
70
60
50
40
30
20
10
0
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water


Caples Creek Transect 4
Percent Frequency
35
30
25
20
15
10
5
0
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water


Caples Creek Transect 5
Frequency
80
70
60
50
40
30
20
10
0
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water


South Fork at Audrain Meadow
Percent Frequency
45
40
35
30
25
20
15
10
5
0
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water


South Fork at Phillips
Percent Frequency
60
50
40
30
20
10
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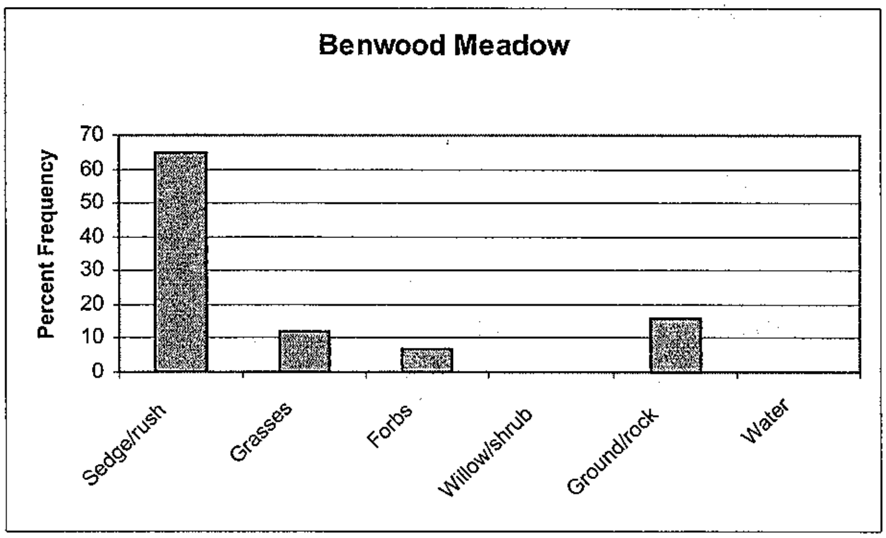
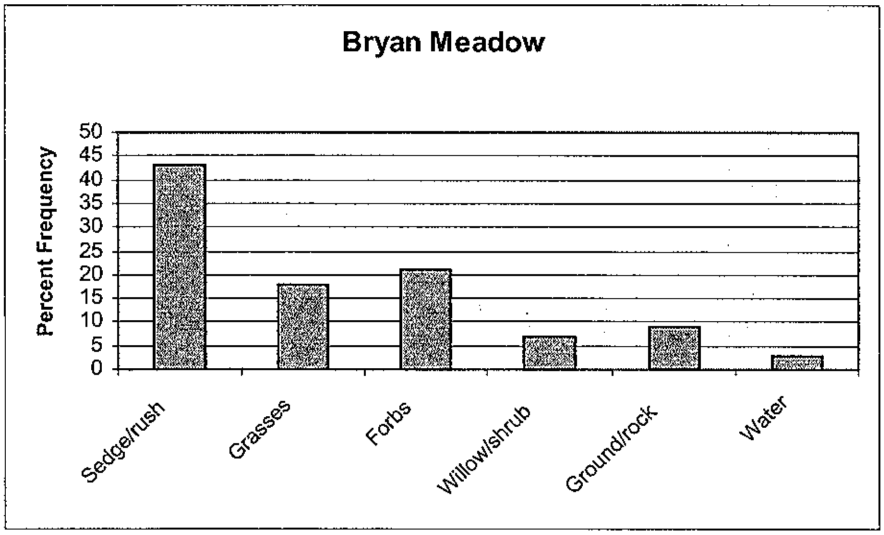
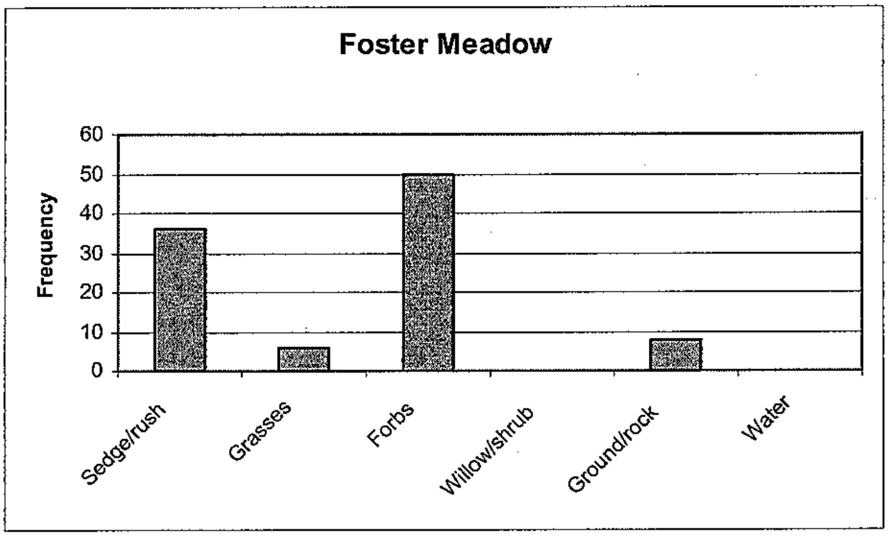
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water


Benwood Meadow
Percent Frequency
70
60
50
40
30
20
10
0
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water


Bryan Meadow
Percent Frequency
50
45
40
35
30
25
20
15
10
5
0
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water


Foster Meadow
Frequency
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30
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10
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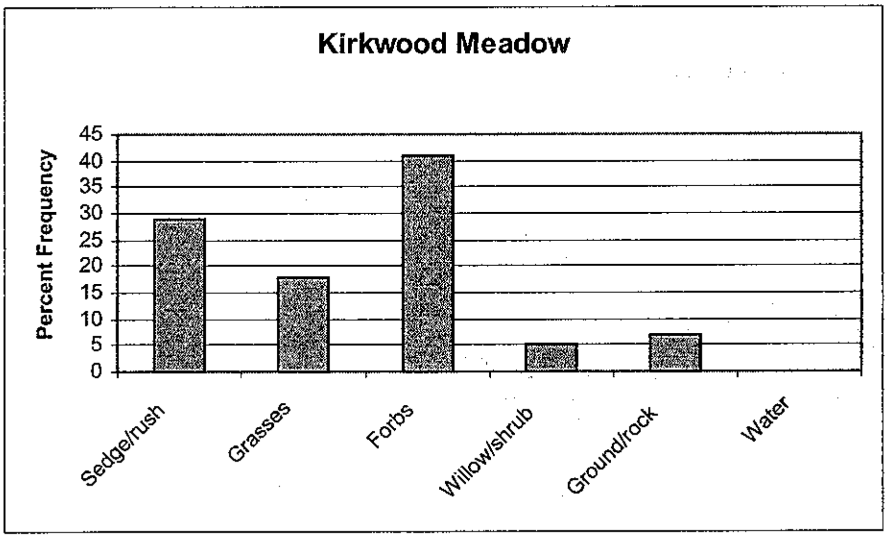
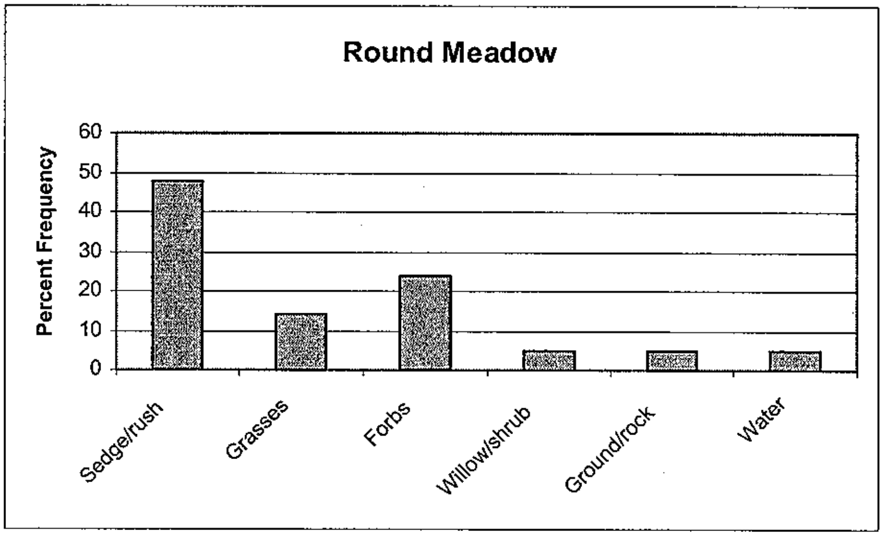
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water


Kirkwood Meadow
Percent Frequency
45
40
35
30
25
20
15
10
5
0
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water


Round Meadow
Percent Frequency
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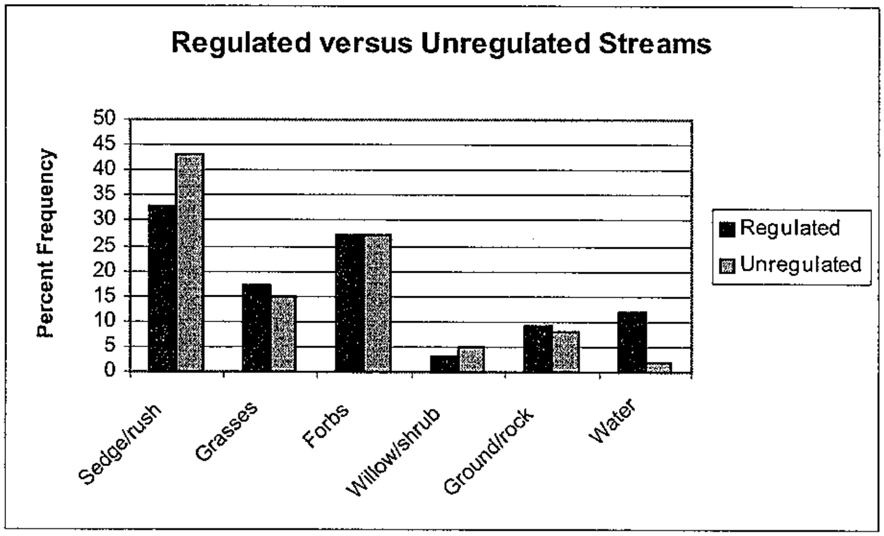
50
40
30
20
10
0
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water


Regulated versus Unregulated Streams
Percent Frequency
50
45
40
35
30
25
20
15
10
5
0
Sedge/rush
Grasses
Forbs
Willow/shrub
Ground/rock
Water
Regulated
Unregulated

RIPARIAN VEGETATION ESTABLISHMENT AND SURVIVAL ON CAPLES CREEK AND KIRKWOOD CREEK, SUMMER, 2000

Report of a study by Richard R. Harris and Donna Lindquist
October, 2000

Introduction

In the Project #184 application for new licensing the potential for regulated flows to impair recruitment of riparian vegetation below Caples Lake was discussed. To evaluate this potential effect, a monitoring project was conducted to determine patterns of willow reproduction and recruitment in Caples Meadow and effects of streamflow regulation on it.

Willows present in Caples Meadow include *Salix lemonii* and *Salix lucida ssp. lasiandra.* Both of these are widely distributed throughout the Sierra Nevada (Argus 1997) and are commonly associated with meandering streams. They provide important ecological functions including streambank stabilization and wildlife habitat. Their reproductive behavior has not been studied in detail. Both species flower in May-June, depending on altitude and latitude (Munz and Keck 1973; Weeden 1979). Pollination in willow may be by wind or insects (Sacchi and Price 1988; Douglas 1997). Seed production in willow is generally high (Sacchi and Price 1988; Johnson 1994) but interspecific hybridization, which is common, can produce nonflowering offspring (Mosseller 1990). The interaction between seed dispersal and stream water levels is the process dominating seedling establishment in the Salicaceae (Blom 1999). Seedling establishment depends on soil moisture availability, particularly the effects of spring floods and the rate of flood recession (Rood et al. 1999). Seedling establishment can be extremely variable from year to year (Roelle and Gladwin 1999). Seedlings commonly establish on open sites but some researchers have found greater densities of seedlings on gravel bars with some vegetation cover present (Douglas 1995). First year mortality of seedlings is commonly greater than 90 percent (Sacchi and Price 1992). Studies have shown that specific hydrologic conditions are required for seedling survival, including reduced flooding in the first few years after establishment (McBride and Strahan 1985). Survival rates improve with seedling age (Sacchi arid Price 1992). Local microsite characteristics such as topographic relief and sedimentation can affect survival (Merigliano 1998; Taylor et al. 1999).

Streamflow regulation by dams commonly causes increased recruitment of willows and other pioneer riparian species on alluvial streams (Williams and Wolman 1984; Harris et. al. 1987; Johnson 1994). This is caused by dampening of scouring peak flows and stabilization of low flows, both of which create conditions conducive to survival of seedlings. In the case of Caples Lake, low flows are not just stabilized but they are augmented in late summer and fall. Theoretically, flow augmentation could cause seedling inundation or scouring if at sufficient magnitudes.

Methods

The general hypothesis that we sought to test was whether or not regulated streamflows affect the recruitment and survival of willows on Caples Creek. To test this, data were collected at Caples Creek and a control (unregulated) stream. The data collection spanned the period when recruitment should have been occurring and when flows were both reduced (late spring and summer) and then augmented (early fall) below Caples Lake.

The area affected by regulated flows we studied was the reach of Caples Creek below the confluence of the Caples Lake spillway channel. This reach has experienced significant aggradation due to spillway channel erosion and other causes. The control area was Kirkwood Creek below Highway 88. This area was taken as a control because Kirkwood Creek does not have a major dam on it. Both study areas are grazed to a limited extent by horses passing through. Neither is currently used as a pasture. Both have similar composition of willow species, primarily *Salix lemonii.*

Twenty-four sites were chosen on the two study reaches (see map in accompanying photographic exhibit). These were chosen because they were on or near fluvial deposits where recruitment would be expected or most likely. Nearly all such sites on the two reaches were included.

Permanent photopoints were located at each site. Methods of Platts et. al. (1987) were generally followed. Each site was photographed across, downstream and upstream from the photopoints on three dates. The first date was June 28, 2000 corresponding to the time when seed production should have commenced; the second date was August 15, 2000 corresponding to the time when willow seedlings or sprouts should be present; and the third date was September 11-12, 2000 when Caples Lake was releasing and streamflow was augmented as compared to natural flows. The study areas were visited on June 21 and July 17 as well and general observations were made.

In addition to the photography at each site, observations were recorded on the following: 1) presence or absence of any form of plant regeneration on fluvial deposits; 2) flowering and fruiting of willows; 3) herbivory; and 4) land user impacts. These observations were recorded either photographically or in field notes.

Results

Streamflow conditions in Caples Creek for the three sample dates are summarized in Table 1. No streamflow data are available for Kirkwood Creek:

Table 1: Streamflow Data for Three Monitoring Dates, 2000

Date	Estimated Natural Flow Average and (Range) (1972-1997) (CFS)	Operational Releases from Caples Lake(2000) (CFS)	Actual Gaged Flows in Caples Creek Below Caples Lake(CFS)
6/28	92.3 (8.7-360.4)	8	75.3
8/15	14.2 (0.9-78.1)	33	32.6

9/12	5.1 (0.3-20.1)	55	56.1

It should be noted that these flow data included contributions from the Caples Lake spillway in June (no spills occurred in August or September) but they did not include the contributions of Kirkwood Creek or the small amount of flow from the spillway in August or September. These amounted to much less than 10 cfs on both dates. These data indicate that in June, Caples Lake was releasing very little water and flows were below estimated natural flows. In August and September, releases from Caples Lake caused flows to exceed average estimated natural flows by up to an order of magnitude. This regulated flow regime was comparable to how the project has operated over its history.

Below, a site by site tabulation is presented. In general, on both Caples Creek and Kirkwood Creek, flowering and seed production by willows was nearly absent this year. The implications of this are that the only potential sources of seed for both places were drift from upstream or wind dispersal from other streams. Neither of these sources was considered a significant source of seed. No willow seedlings were observed in either study area. It is unknown if this was typical or anomalous.

The only willow regeneration that was observed in either study area consisted of root layering from terraces onto terrace banks or into the interface with fluvial deposits. Over the course of this study, less than a dozen instances of layering were observed at both streams combined. The only significant plant recruitment was herbaceous, consisting of annual forbs and grasses, horsetail and sedges. Even this was generally sparse on open sites and tended to concentrate on a few bar littoral edges and in protected areas behind woody debris (see accompanying photographic exhibit).

In August, during the lowest flows, bars were the most exposed on Caples Creek. On Kirkwood Creek, bars gradually exposed as flows receded over the course of the summer. On both streams it is evident that these bars were deposited at much higher flows during the 1997 flood, and at the present time, would only be inundated during bankful or higher discharges. This probably has implications both for accessibility to seed or willow sprouts and moisture availability for establishment.

Field observations indicated that Caples meadow has been subjected to extensive alterations by beaver for many years. At the present time, beaver are active both above and in the study reach. Browsing reduces both the cover and height of willows adjacent to the stream (see accompanying photographic exhibit). There have been no studies of the effects of beaver on the ability of willows to produce flowers and seed. Since seed production is also limited on Kirkwood Creek where beaver are absent, other factors may be at play, including hybridization, inbreeding depression, or absence of pollinators (Sacchi and Price 1988; Mosseller 1990; Douglas 1997).

Finally, both sites are subjected to horse traffic and grazing. Trampling on bars and barren trails are evident (see accompanying photographic exhibit). It did not appear that horses have a significant impact overall on willow recruitment.

<u>Site Comparisons Over Time.</u> The accompanying photographic exhibit shows conditions at each sample site for the three measurement periods. Table 2 summarizes observed conditions.

Table 2: Conditions Observed at Monitoring Sites, Caples Creek and Kirkwood Creek

Sample Site	Landform and Substrate	Willow Seedlings or Sprouts Present?	Herbaceous Vegetation Present/Cover	Comments
Caples I	Gravel bar	No	Yes <10 %	None.
Caples 2	Debris bar, sand/silt	No	Yes >50 %	Willow layering on banks above bar.
Caples 3	Gravel-sand bar	No	No	Horse trampling.
Caples 4	Mid-channel bar, sand/silt	No	Yes>80 %	None.
Caples 5	Point bar, gravel	Yes, layering (<10 sprouts)	Yes on back of bar >50 %	Layering at back of bar.
Caples 6	Gravel-sand bar	No	Yes >50 %, less towards water's edge	None
Caples 7	Floodplain, sand/silt	No	Yes >80 %	Adjacent bar had herbaceous recruitment in littoral zone and layering of willows at terrace bank.
Caples 8	Point bar, gravel	No	Negligible	Horsetail recruitment at terrace bank.

Caples 9	Point bar, gravel	Yes, layering (<5 sprouts)	No	Layering at back of bar.
Caples 10	Gravel bar with silt drape	Yes, layering (<5 sprouts)	Yes >20 %	None
Caples 11	Point bar, gravel	No	Yes <10 %	None
Caples 12	Gravel-sand bar	No	Yes <10 %	None
Caples 13	Debris bar, gravel	No	Yes <20 %	Vegetation present in protected area behind debris.
Caples 14	Sand-silt bar	No	Yes >20 %	Adjacent mid-channel bar had limited recruitment of sedges.
Kirkwood 15/16	Gravel bar/floodplain	No, but dense mature willow and sedge	Yes >80 %	Adjacent bars barren.
Kirkwood 17	Gravel bar	No, but dense mature willow and sedge	Yes >80 %	Adjacent bar barren.
Kirkwood 17A	Gravel bar	No	Yes on back of bar >80%	Horsetail dominant.
Kirkwood 18	Floodplain	No, but dense mature willow and sedge	Yes on back of adjacent bar>50 %	Horsetail dominant.
Kirkwood 19	Gravel bar/floodplain	No, but dense willow and sedge	Yes >80 %	Adjacent sand bar barren
Kirkwood 20	Floodplain	No, but dense sedge	Yes >80 %	Adjacent gravel bar barren
Kirkwood 21	Gravel bar	No	No	None
Kirkwood 22	Gravel bar/floodplain	No, but dense mature willow and sedge	Yes >80 %	Adjacent to Site21.
Kirkwood 23/24	Gravel bar/floodplain	No	Yes on floodplain >50 %	None

As may be seen in the accompanying photographic exhibit, exposed fluvial surfaces experienced very little change over the period of study.

Conclusions

This year, willow flowering and seed production were minimal on both the regulated and the control stream. Although we did not put out seed traps to quantify seed rain, we were present on the sites when seed production should have been peaking. Virtually no seed was observed. Willow seed transport by wind or water from upstream or other streams did not appear to be a major factor at these sites. In the absence of natural regeneration, attempts to increase willow recruitment at Caples Creek would have to depend on artificial propagation.

The only willow regeneration observed in either study area was vegetative layering from established plants or plant parts. This amounted to fewer than 20 sprouts. Over time, this regeneration could have some positive effects on channel form recovery at Caples Creek. More rapid recovery could be achieved through artificial propagation.

Exposed bar surfaces generally had little or no recruitment of any kind, probably because of deficiencies in soil moisture. Protected areas behind woody debris, backs of bars, and portions of bars with finer substrate were more likely to have herbaceous recruitment.

At no time did regulated flows inundate higher bars or floodplains on Caples Creek during the period of observation. No mobilization of sediment due to flow augmentation was observed. However, we did not observe the full range of potentially augmented flows. Nevertheless, most instream bars were apparently created during the extreme flow of January 1997 and would only be inundated or mobilized by flows of similar magnitude.

Beaver, especially, and to a much lesser extent, horses, are reducing the cover and extent of existing willows on Caples Creek. Insect herbivory studies have shown significant effects on willow reproduction. There is some evidence that herbivores may selectively feed on male or female plants, thereby changing population sex ratios and seed production. Herbivory also affects susceptibility of willows to drought stress (Bach 1994). If restoration efforts were to implemented at Caples Creek consideration must be given to controlling herbivory.

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