6-38

175

Macroinvertebrate Monitoring for the Bagley Valley Watershed Restoration Project on the Humboldt-Toiyabe National Forest: First Year Post-Project Assessment

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Introduction

Rehabilitation of degraded stream environments has involved a variety of management approaches but inconsistent monitoring of project objectives and success for the documentation of case histories (NRC 1992). The purpose of this study was to establish a biological baseline and reference conditions for a channel reconstruction stream restoration project on lower Bagley Valley Creek in Alpine County, California. The channel of this small perennial stream has become progressively eroded and incised owing to overgrazing, flood events, and slope failure. A restoration project to reconfigure the geomorphic structure of a section of the lower channel was accomplished in the summer of 2001. The data presented in this report consists of 2 years of baseline conditions (1999 and 2000) and the first year of post-project monitoring (2002) in the existing reach of the restoration project area (this channel to be abandoned) and in a reach below the project area that will serve both as a control and as a downstream monitoring station of project effects. In addition, two external reference streams were selected for contrast with lower Bagley Valley Creek to assess what might be expected of successful ecological restoration. The external references were selected in the nearby drainages of Slinkard Creek and Silver King Creek as small stream matches to lower Bagley Valley Creek. Biological and physical survey data in 2002 from the re-located restored meadow reach provides the first assessment of project success.

The primary biological indicator evaluated in this study is the resident community of stream macroinvertebrates present in the survey reaches. The diversity, taxonomic composition, and environmental sensitivity of these organisms are used to interpret the relative ecological health of these habitats and serves as a benchmark for comparison to future conditions. Excess sediment transport and deposition degrade habitat quality and limit the survival of invertebrates (Waters 1995). Data from sites within the project area and in external reference streams will permit use of the statistical design known as BACI (before-after-control-impact) to test for differences resulting from the restoration project and erosion control. The design compares changes over time in treatment (restoration) sites(s) relative to control (reference) sites, before and after the project actions (outlined by Green 1979). Continued sampling for the after-project phase is planned for 2003 and possibly beyond to examine long-term changes in physical and biological conditions.

Methods

The physical location and habitat at each 150 meter length study reach were described according to standard stream channel survey methods. The location of each study reach was documented via global positioning system (GPS) coordinates and elevation. Physical habitat at each reach was characterized by conducting 15 channel transects at 10 meter intervals (5 points per transect). These surveys quantified current velocity, depth, width, substrate size, cobble embeddedness, bank stability, bank cover, riparian cover (using a densiometer mirror and visual ranks), discharge, bank angles, slope, sinuosity, riffle and pool lengths, and stream bed debris and vegetation cover. In addition, several water quality measures were taken including temperature, dissolved oxygen, alkalinity, turbidity, conductivity and pH.

Macroinvertebrates were collected in five replicate stream invertebrate samples from separate riffles within each reach (selected at random) were collected at each site. Each replicate sample consisted of a composite of 3 cross-channel collections made with a 250 micron mesh D-frame net (30-cm wide, 900 cm^2 area) at about one-quarter, one-half, and three-quarters the distance across a riffle transect. Samples were processed in the field to remove rock and leaf/wood debris, drained through a 100 micron aquarium net, and preserved in ethanol.

The benthic food resources of stream invertebrates were also quantified in sampling of organic matter and algae. Particulate organic matter was sampled using a 250 micron mesh D-frame net, sampling stream bottom riffles as above for invertebrates (3 replicate riffle samples). These samples were poured through a 1 mm screen, with the retained wood and leaf particle debris then weighed as a wet biomass measure of coarse particulate organic matter (CPOM). The fine fraction passing through the screen (particle range 250 microns to 1000 microns) was collected in a 100 micron mesh aquarium net, placed in a sample vial, preserved with formalin, and then dried and ashed in a muffle furnace at the laboratory to quantify ash-free dry mass of fine particulate organic matter (FPOM). Algal periphyton on three replicate cobble-size riffle rocks was quantified by scrubbing rock surfaces, homogenizing the algae removed using a large syringe, and subsampling the homogenate for (a) chlorophyll by filtration through 1 micron pore-size glass fiber filters, and (b) archived algae for cell counts and taxonomic identifications.

The area of each rock was estimated from measures of length, width, height and circumference, and the chlorophyll a per area determined by extraction of frozen filters in ethanol and reading of the extract in a fluorometer.

Invertebrate field samples were subsampled in the laboratory using a rotating drum splitter, sorted from subsamples under a magnifying visor and microscope, and identified to the lowest practical taxonomic level possible (usually genus; species when possible based on the availability of taxonomic keys). Data analysis yielded information on taxonomic composition by density and relative abundance. Metrics of community structure were calculated to express biological health in terms of diversity, composite community tolerance, number of sensitive taxa (mayfly-stonefly-caddisfly), dominance, and other measures of composition. All stages of sample processing and identification were checked using quality control procedures to assure uniformity, standardization and validation.

Physical Environment and Riparian Contrasts

Physical habitat contrasts between the four sample sites are summarized in Table 1 and Figures 1-4. Habitat surveys were conducted on Bagley Valley Creek (lower control reach and meadow restoration reach) in 1999 and 2002 (not in 2000) and on the Slinkard Creek (site name = restoration area, from a project completed in 1989-90) and Silver King tributary (first perennial tributary above confluence of Silver King with East Carson River) references in 2000 and 2002. Discharge was of similar magnitude in Bagley and Slinkard Creeks (varying from 0.3 to 2.4 cfs), and about one-tenth this volume in the tributary to Slinkard Creek (0.06 to 0.12 cfs). This small tributary channel also differed in having the most extensive riparian cover, steeper gradient but slower current velocity, and more organic matter than the other stream reaches. Though the Slinkard Creek restoration site had only herbaceous cover on the banks, the grasses overgrew the channel, providing extensive shading and stable, undercut banks. The Bagley reaches were wider with more shallow bank angles than reference reaches, more deposits of fine particle sizes, and greater density of algal periphyton (as chlorophyll a). These differences are consistent overall with an eroded, exposed channel with limited riparian cover in Bagley Valley, while the reference reaches had greater riparian vegetation bank cover in narrower channels with less fine particle deposition (Table 1, Figures 1-4). The most distinct change in physical habitat form was of course found in the re-located meadow restoration channel in Bagley Valley. The intent of the engineering was achieved in more riffle habitat and less fine and sand sediment cover than existed in the old meadow channel (Figures 1 and 2). Though willows have been planted and grass seeded, riparian establishment will follow more slowly, evident in the more open and exposed banks of the new channel (Figure 3).

Macroinvertebrate Community Comparisons

The diversity of aquatic invertebrates collected at the study sites indicate that little of no difference in the numbers of taxa was found between the references sites and the Bagley Valley sites, and that diversity was unchanged from 1999 to 2000 or to 2002 at the project or control Bagley Valley reaches (Figure 5). About 2/3 of the total taxa at a site were collected in a single average sample. Although overall diversity showed little difference, about twice as many sensitive taxa (EPT) were found at the reference sites than in Bagley sites (Figure 6). The restored meadow reach also doubled its pre-project diversity of EPT. This EPT index is the total diversity of ephemeroptera (E) or mayflies, plecoptera (P) or stoneflies, and trichoptera (T) or caddisflies, which in general are sensitive to poor water and habitat quality, preferring to live in clean, cold, shaded, well-oxygenated streams with varied substrate composition and food resources. In contrast with the reference sites, Bagley Valley reaches also had a higher proportion of tolerant invertebrates (Figure 7), resulting in a higher biotic index value (Figure 8) – an indicator of composite community tolerance to environmental degradation. Again the meadow reach showed response to restoration in reduced numbers of tolerant taxa and lower biotic index values. Examination of density (Figure 9) shows no pattern comparing Bagley sites between years or to reference sites. This variability in density is not uncommon and few bioassessment studies have found this measure to be a reliable indicator of water quality conditions.

One or only a few taxa often dominate disturbed communities, indicating an unbalanced distribution of habitat or food resources that favor generalists and opportunistic colonizers ("weeds"). The dominant taxa of Bagley and Slinkard reaches comprise 25-40% of the total number of invertebrates (Figure 10) but increases on the restored meadow to near 50%, suggesting that despite other improving patterns of biotic integrity, this *de novo* stream is in an instable state. Many Bagley taxa were also common to the Slinkard reference site, indicating that although the dominant species may be the same, the restored reach on Slinkard Creek harbors many of the more sensitive taxa than cannot currently be sustained in Bagley (Table 2). These additional taxa could be those that come to inhabit a restored channel in this watershed. The stonefly *Zapada* may be the first example of this shift. The Silver King tributary, though differing with respect to size and slope, also indicates the potential diversity and taxonomic composition for a small undisturbed stream with an intact riparian zone in the East Carson River watershed. One of the most distinctive taxonomic shifts on this small stream is the dominance of the small stonefly Yoraperla sp., an organism that feeds on decomposing coarse particulate organic matter. This is a clear biological response to the abundance of riparian vegetation and in-stream CPOM (Table 1). The more even distribution of relative abundance among taxa at this sites, evident in the lower percentage contributed by the three dominant groups here (Table 2), is also indicative of a greater variety of food and habitat resources available to the community inhabiting this site. Habitat disturbance or degradation often eliminates or marginalizes certain habitat types or food sources.

Conclusions

Though in the early phase of ecosystem establishment, the reconstructed stream channel in Bagley Valley shows consistent signs of improved biological integrity in the diversity and types of aquatic invertebrates present relative to the pre-project stream reach. In addition, the downstream control reach, where sediment or hydrologic disturbance from the construction project would have been received, showed no sign of impairment relative to the pre-project baseline. In-stream ecological restoration without detrimental side effect appears to be in progress.

The Slinkard restoration site, used here as a reference, may provide an important insight to the potential for improved biological integrity on the Bagley Valley restoration project. Stable banks with extensive undercuts and dense grass cover represent the desired condition in Bagley Valley, with eventual establishment of more complex willow and aspen riparian overstory. Along with these features, larger substrate size classes with more sorting in riffles and less deposition of fines will provide the type of habitat that may be expected to produce benthic macroinvertebrate communities with greater diversity of sensitive EPT taxa and less dominance by the tolerant fauna that now inhabitat these reaches. Recovery of biological integrity may still be an ongoing process at the Slinkard restoration site (established 10 years prior to these 1999-2000 surveys), so this reference location may not represent the best conditions attainable (dominance remains high), but it does indicate what is possible in a similar setting and the biological changes that may be anticipated in benthic invertebrate communities. The early phases of ecological restoration may be most related to substrate and macrohabitat changes (more rock and riffle), while secondary phases may involve riparian establishment (shade, bank stability, leaf/wood litter inputs) and stabilization of food resources conditions in the form of algal colonization and organic matter retention (leaves, detritus). This sequence should lead to reduced dominance in the community and further colonization by sensitive taxa. Continued monitoring of the Bagley Valley restoration will permit assessment of the extent of ecological recovery over time.

References:

Green, R.H. 1979. *Sampling Design and Statistical Methods for Environmental Biologists*. John Wiley and Sons, New York.

NRC (National Research Council). 1992. *Restoration of Aquatic Ecosystems*. National Academy Press, Washington, D.C.

Waters, T. F. 1995. *Sediment in Streams: Sources Biological Effects and Control.* Mongraph 7. American Fisheries Society, Bethesda, Maryland.

TABLE 1. HABITAT FEATURES	PRE-PROJECT				POST-PROJECT			
	Bagley V. Crk lower control	Bagley V. Crk unrestored meadow	Slinkard V. Crk restoration area	Trib.1 -Silver King above Silver King	Bagley V. Crk lower control	Bagley V. Crk meadow restoration	Slinkard V. Crk restoration area	Trib.1 -Silver King above Silver King
	8 VII 99	8 VII 99	27 VII 00	23 VIII 00	24 VII 02	24 VII 02	23 VII 02	5 VIII 02
Mean Width (cm)	136	133	66	75	119	158	87	86
Mean Depth (cm)	18	13	21	9	20	5.7	22.5	5.4
Mean Velocity (cm/s)	25	51	41	8	9	12.4	18.7	2.1
Discharge (cfs) [non-zero mean]	1.517	2.364	1.693	0.123	0.260	0.354	1.000	0.058
Sinuosity	1.20	1.24	1.24	1.21	1.27	1.13	1.27	1.23
Elevation (ft)	6310	6360	6160	6640	same	6380	same	same
GPS northing UTM	4274750	4274920	4275540	4270150	same	4275250	same	same
GPS easting UTM	11268770	11269213	11276280	11272695	same	11269500	same	same
Slope (%)	1.8	2.4	1.3	9.3	1.78	2.42	1.2	8.19
Conductivity (uS)	242	283	216	179	244	195	218	178
D.O. (mg/L)	8.3	8.0	8.2	8.8	7.0	7.9	7.5	7.8
Turbidity (NTU)	1.2	0.79	0.05	1.42	2.35	2.46	2.23	2.43
Temperature (°C)	21.9	22.0	14.0	15.0	21.4	18.2	16.0	17.8
Alkalinity (mg/L)	180	166	136	115	151	124	123	112
Riparian Index herb cover (1-5)	5	5	5	5	5	1	5	5
Riparian Index woody cover (1-15)	1	1	0	9	1	3	0	8
%Riparian Cover (avg.)	27.4	18.1	63.3	75.0	46.6	12.6	77.5	74.9
%Eroded bank (avg.)	10	10	0	0	0	10	0	3
%Cobble Embeddedness (avg.)	32	23	13	30	37	23	14	26
% Free Cobble (avg.)	44	52	72	28	44	56	76	68
FPOM (g AFDM/m^2)	0.860	1.374	0.836	1.974	0.913	1.242	1.046	2.838
CPOM (wet g/m^2)	44.0	202.7	64.0	696.0	104.0	33.0	37.0	196.0
Periphyton Chl a (ug/cm^2)	4.374	4.042	0.323	0.358	9.867	0.643	0.681	2.253

Table 2. Dominant Taxa

listed as:

1st dominant taxon
2nd dominant taxon
3rd dominant taxon
Percent of Total

	Bagley Valley Creek		Bagley Valley Creek
1999	Lower control	1999	before meadow restoration
1	*Oligochaetes*	1	*Baetis sp.*
2	*Cricotopus-Orthocladius spp.*	2	*Simulium spp.*
3	*Hyalella azteca*	3	*Hyalella azteca*
	44.7		**59.3**
2000		2000	
1	*Cricotopus-Orthocladius spp.*	1	*Simulium spp.*
2	*Simulium spp.*	2	*Optioservus quadrimaculatus*
3	*Optioservus quadrimaculatus*	3	*Optioservus divergens*
	51.6		**48.1**
2002		2002	after restoration
1	Simulium spp.	1	Baetis sp.
2	Baetis sp.	2	Simulium spp.
3	Tvetenia bavarica grp.	3	Zapada sp.
	40.0		**73.9**

Reference sites:

	Slinkard Creek		Tributary 1 Silver King
2000	Restoration area	2000	Above SK Creek
1	*Optioservus quadrimaculatus*	1	*Baetis sp.*
2	*Baetis sp.*	2	*Yoraperla sp.*
3	*Zapada sp.*	3	*Ironodes sp.*
	74.7		**32.4**
2002		2002	
1	Optioservus quadrimaculatus	1	Simulium spp.
2	Optioservus divergens	2	Yoraperla sp.
3	Baetis sp.	3	Oligochaetes
	59.4		**31.6**

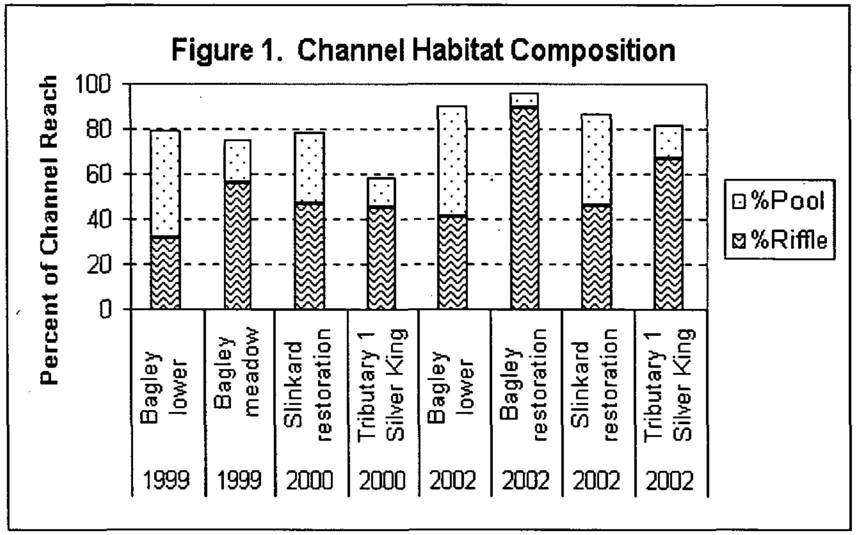


Figure 1. Channel Habitat Composition

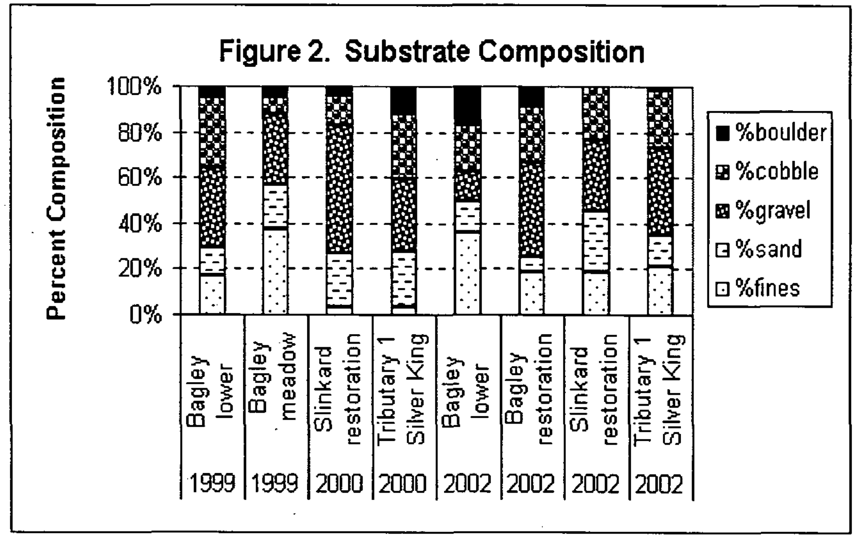


Figure 2. Substrate Composition

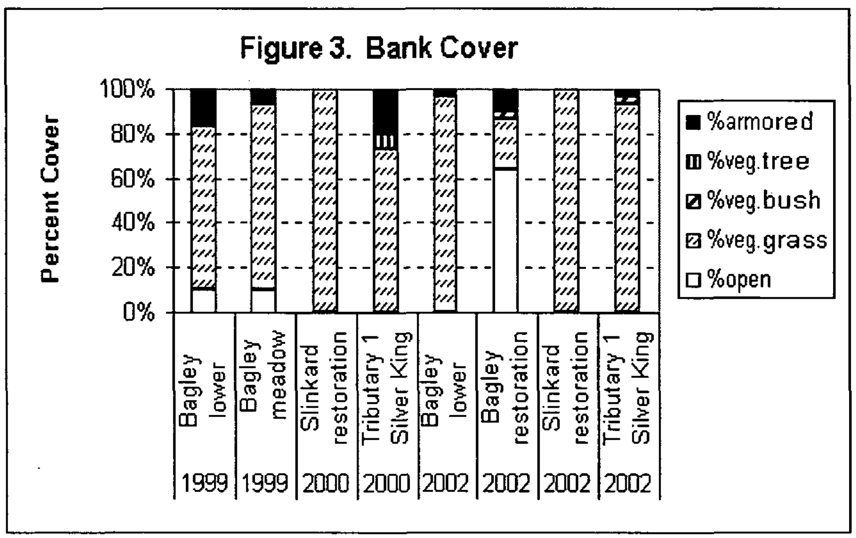


Figure 3. Bank Cover

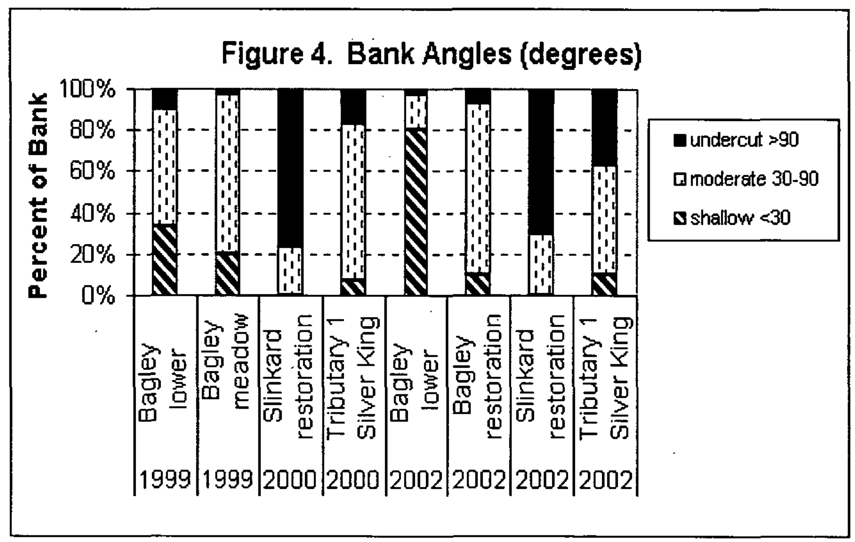


Figure 4. Bank Angles (degrees)

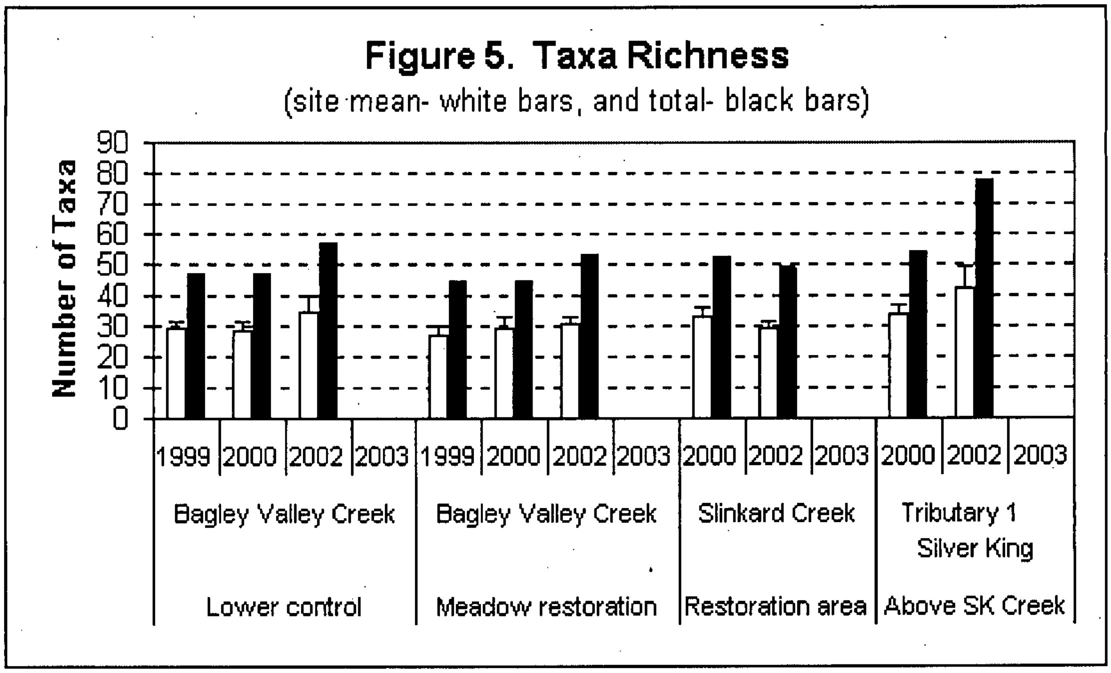


Figure 5. Taxa Richness
(site mean- white bars, and total- black bars)
Number of Taxa
0
10
20
30
40
50
60
70
80
90
1999
2000
2002
2003
1999
2000
2002
2003
2000
2002
2003
2000
2002
2003
Bagley Valley Creek
Lower control
Bagley Valley Creek
Meadow restoration
Slinkard Creek
Restoration area
Tributary 1
Silver King
Above SK Creek

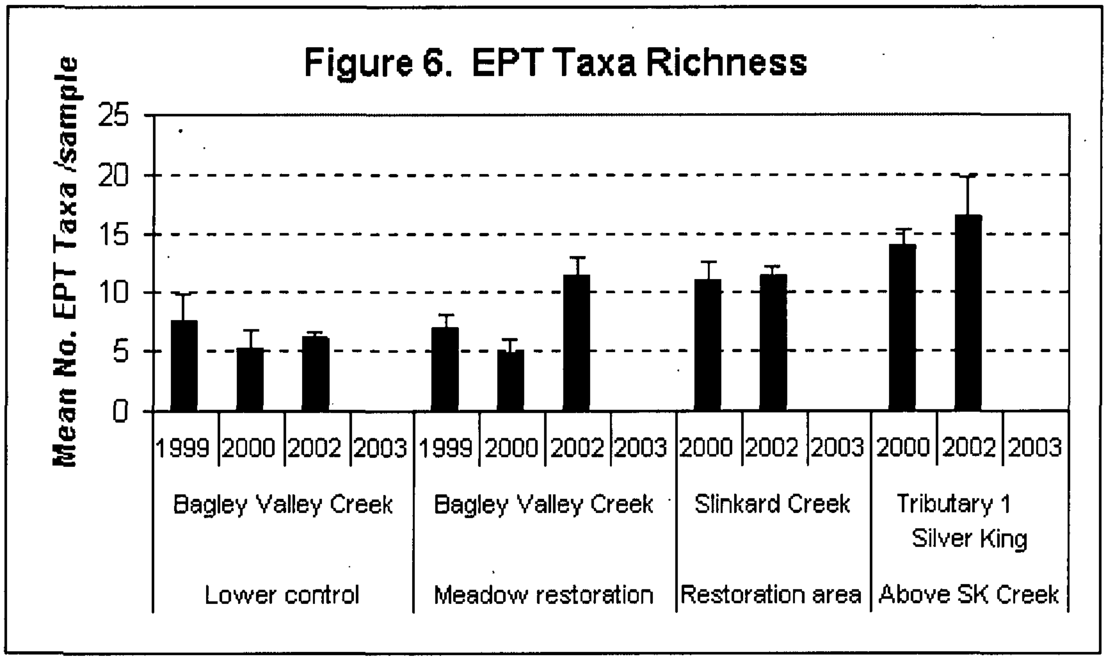
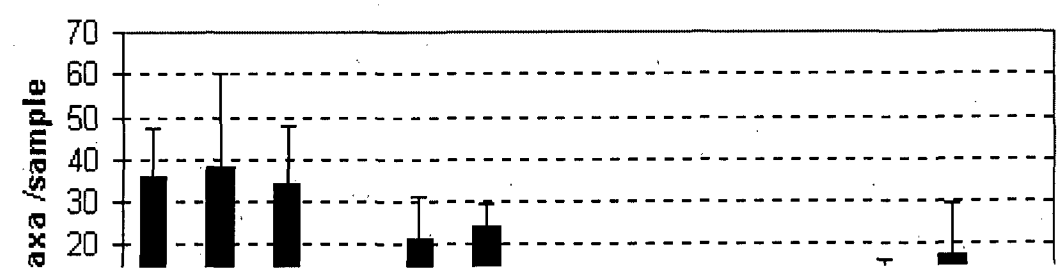


Figure 6. EPT Taxa Richness
Mean No. EPT Taxa /sample
25
20
15
10
5
0
1999 2000 2002 2003 1999 2000 2002 2003 2000 2002 2003 2000 2002 2003
Bagley Valley Creek
Bagley Valley Creek
Slinkard Creek
Tributary 1 Silver King
Lower control
Meadow restoration
Restoration area
Above SK Creek

Figure 7. % Tolerant Taxa



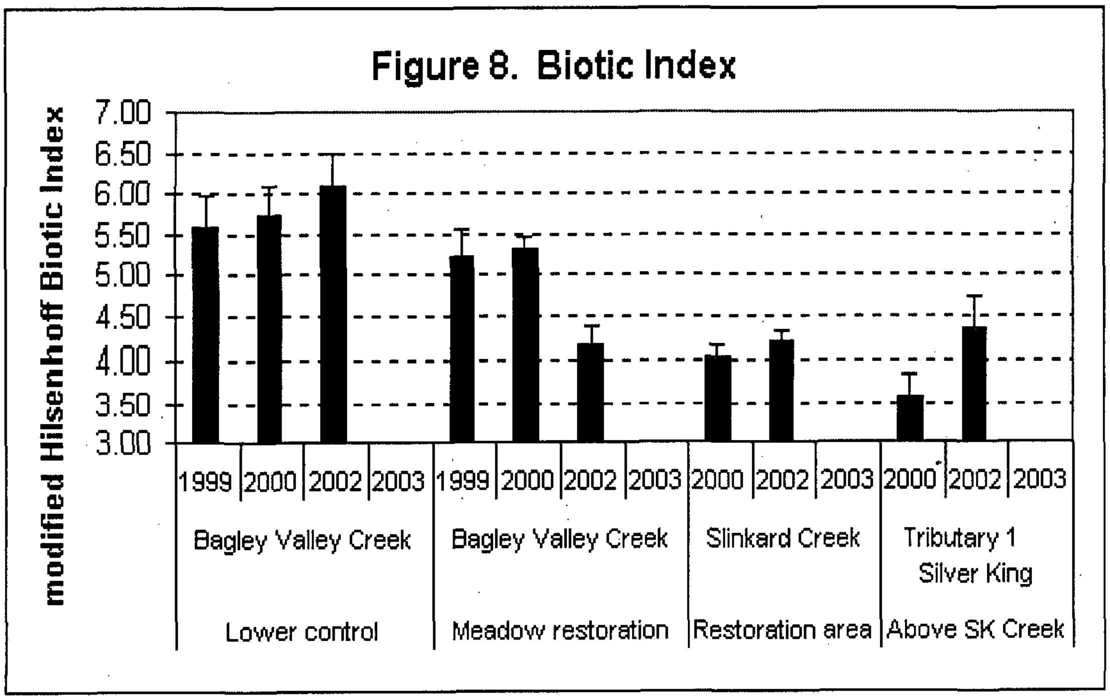


Figure 8. Biotic Index
modified Hilsenhoff Biotic Index
7.00
6.50
6.00
5.50
5.00
4.50
4.00
3.50
3.00
1999 2000 2002 2003 1999 2000 2002 2003 2000 2002 2003 2000 2002 2003
Bagley Valley Creek
Lower control
Bagley Valley Creek
Meadow restoration
Slinkard Creek
Restoration area
Tributary 1
Silver King
Above SK Creek

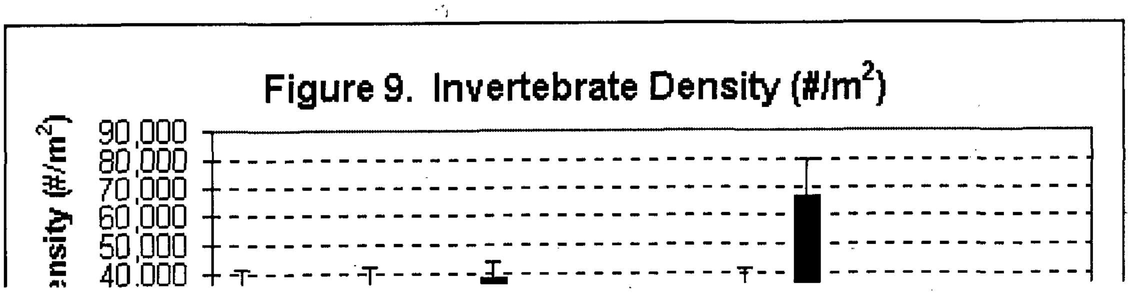


Figure 9. Invertebrate Density (#/m2)
90,000
80,000
70,000
60,000
50,000
40,000

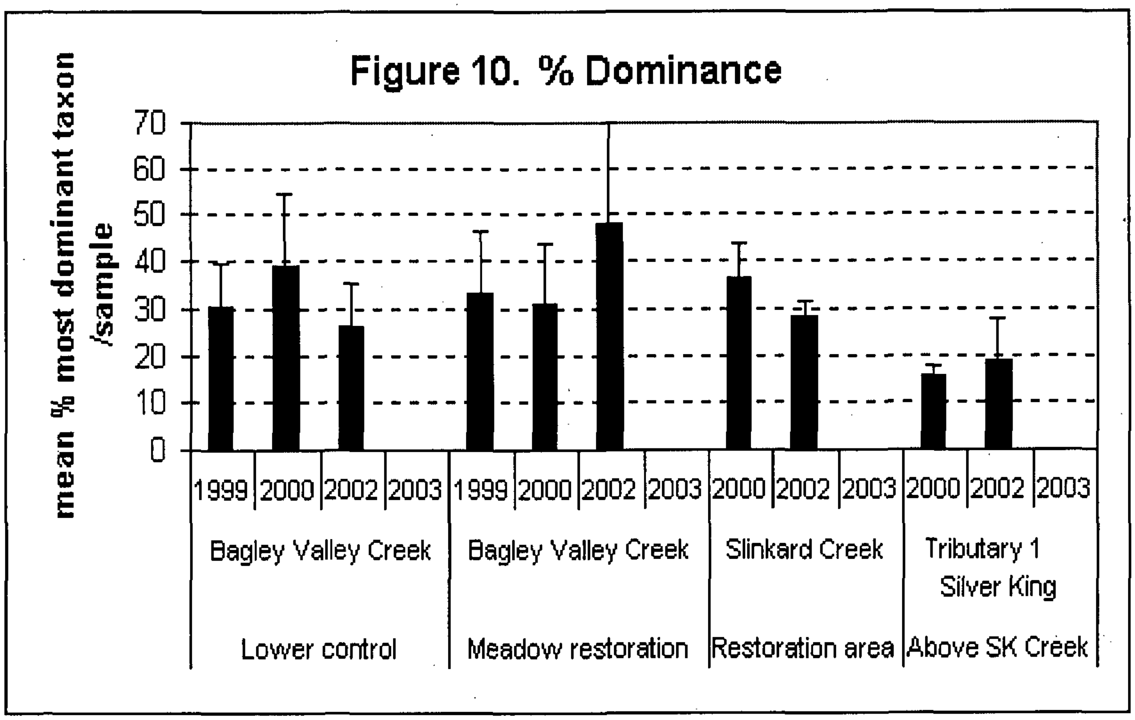


Figure 10. % Dominance
mean % most dominant taxon /sample
70
60
50
40
30
20
10
0
1999
2000
2002
2003
1999
2000
2002
2003
2000
2002
2003
2000
2002
2003
Bagley Valley Creek
Bagley Valley Creek
Slinkard Creek
Tributary 1 Silver King
Lower control
Meadow restoration
Restoration area
Above SK Creek