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

Final Report

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above: unrestored meadow reach 1999 (lower meadow)
right: restored channel 2003 (upper meadow)

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Introduction

An integral component of stream restoration management is the monitoring of performance indicators that measure the progress of recovery (National Research Council 1992). Given the uncertainties inherent in the physical and biological response of a stream to restoration efforts, an effective monitoring program can form the basis of evaluating project success, as well as for planning ongoing improvements, responsive either to deficiencies in project design or environmental variability. Such monitoring also enables a project to serve as an experiment that informs future efforts in general. Indeed, without adequate monitoring and evaluation and dissemination of those results, potential lessons from a project will not be learned and the science of river restoration will not advance (Kondolf 1995).

Monitoring may include indicators that take a variety of forms representing different components of physical and biological structure and function of in-stream or bank, riparian, and floodplain condition. As part of a sound study design, monitoring should establish baseline measurements (pre-restoration action), the range of natural variability (inter-annual changes), control conditions to set context (stream locations not affected by the problem needing restoration action), and also take account of the historical setting of past channel changes and geomorphic constraints on recovery (Kondolf and Larson 1995).

The purpose of this study was to establish a biological baseline and reference conditions for a restoration project on lower Bagley Valley Creek in Alpine County, California. Within a meadow complex just upstream of its confluence with the East Carson River, the channel of this small, perennial stream had become progressively eroded and incised by flood events and slope failure following the initiation of domestic livestock grazing and the construction of irrigation ditches and roads beginning in the 19th century. A restoration project to reconfigure the geomorphic structure of a section of the channel within the meadow was completed in the summer of 2001. Restoration goals were focused on two primary elements: 1) restoring the connectivity of the stream with its historic floodplain, and 2) stopping the progressive erosion of a network of gullies (USDA Forest Service 2000). Project construction included re-routing the uppermost section of Bagley Valley Creek within the meadow into a section of reconstructed channel approximately 150 m in length, which then directed the flow into the meadow. Dimensions of an abandoned channel in the historical floodplain were used to design the reconstructed channel. Channel reconstruction involved grading the new channel structure, importing streambed substrate (i.e. gravel, cobble, boulder, etc.), installing a biodegradable erosion control fabric to control erosion and provide an enhanced growing environment for the establishment of vegetation, and the planting of willow switches. Some of the eroded and gullied portions of the meadow were re-graded as well; the borrow pit for re-grading remained to form a pond. A road on the western edge of the meadow was also repaired to improve drainage and relocate sections previously routed through wetland areas.

The channel degradation in Bagley Valley Creek produced extensive deposition of fine and sand particles. Invertebrates residing on the stream bottom are sensitive to sediments that cover and bury rock habitat, or transported particles that scour surfaces. Thus, excessive sediment transport and deposition degrades habitat quality and limits the survival of invertebrates (Waters 1995).

The primary biological indicator evaluated in this study was the resident community of stream macroinvertebrates present in the survey reaches. The diversity, taxonomic composition, and environmental sensitivity of these organisms were used to interpret the relative ecological health of these habitats, evaluate success of the restoration project, and serve as a benchmark for comparison to future conditions. Data from sites within the project area and from the external reference streams were used to compare post-project changes to natural spatial and temporal variability in biological indicators, and evaluate progress relative to the pre-existing condition of the unrestored channel, and the target condition (reference streams). The authors are aware of only one other stream restoration project in California (Trout Creek, El Dorado County; see Herbst 2004) that employed a similar study design to evaluate project success using both aquatic invertebrate and physical habitat metrics.

Measurements of aquatic life and habitat were intended to quantitatively evaluate the effectiveness of new channel construction in improving habitat and enhancing biological community integrity. This bioassessment approach to stream monitoring has been used widely to evaluate the status of stream water and habitat quality, measure the effect of pollutants on natural communities, prioritize aquatic resource management problems, develop targets for recovery, and follow the progress of restoration projects (e.g. Davis and Simon 1995).

The data presented in this report include two years of baseline, pre-project (1999 and 2000) and two years of post-project (2002 and 2003) monitoring of aquatic invertebrates on a reach within the restoration project area, as well as a reach downstream of the project area (the latter site served both as a control for environmental variability over time, and as a downstream monitoring station of project effects). Physical habitat features were also measured for one pre-project year (1999), and the two post-project years. In addition, two external reference streams were selected for contrast with lower Bagley Valley Creek to assess both environmental variability over the period, and to establish potential targets for successful ecological restoration. The external reference sites were selected in the nearby drainages of Slinkard Creek and Silver King Creek, each of which were sampled in 2000, 2002, and 2003 for both aquatic invertebrates and physical habitat. Herbst (2003) previously presented data from the first year of post-project monitoring.

Methods

Field measurements completed at each site included physical habitat surveys and biological sampling of benthic macroinvertebrates, algae, and organic matter. Each site was defined as a 150-meter length study reach, and located by GPS coordinates and elevation at downstream end of each site (subsequently revised using USGS 7.5 minute quads). The longitudinal distribution and length of riffle and pool habitats were delineated and used to determine random locations for sampling of benthic macroinvertebrates from riffle habitat. Slope over the reach was measured with a survey transit and stadia rod, and sinuosity was estimated from straight-line distance over the 150 m channel. Physical habitat characteristics were measured over the length of each reach using 15 transects spaced at ten meter intervals. Water depth, substrate type, and current velocity were measured at five equidistant points on each transect, along with stream width, bank structure (cover/substrate type and stability rating), riparian canopy cover, and bank angle. Bank structure between water level and bankfull channel level was rated as open, vegetated, or armored (rock or log), and as stable or eroded (evidence of collapse or scour scars). Bank angles were scored as shallow, moderate, or undercut (<30°, 30-90°, and >90°, respectively), and riparian cover was measured at each stream edge and at mid-stream facing up- and downstream using a densiometer (i.e. number of concave mirror grid points reflecting overhead vegetation). The type and amount of riparian vegetation along the reach was also estimated by visual evaluation. The embeddedness of cobble-size substrate was estimated as the volume of a cobble buried by silt or fine sand for 25 cobbles (encountered during transect surveys and supplemented with randomly selected cobbles as needed). Discharge was calculated from each transect as the sum of one-fifth the width times depth and current velocity at each of the five transect points, and averaged. Basic water chemistry measured included temperature, pH, alkalinity, dissolved oxygen (DO), conductivity, and turbidity. Documentation of site conditions also included photographs taken from mid-stream channel looking upstream at 0, 50, and 100 meters, and downstream at 150 meters.

Macroinvertebrates were collected in five replicate samples from separate riffles within each reach. Each replicate sample consisted of a composite of three cross-channel collections made with a 250-µm 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-µm aquarium net, and preserved in ethanol and rose bengal (a stain to aid in laboratory processing).

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) except for oligochaetes and ostracods, which were identified to order only. A minimum count of 250 organisms was removed from each replicate for identification (in practice averaging about 300-500). 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 (QAPP; Herbst 2001).

The benthic food resources of stream invertebrates were quantified by collecting three replicate samples of both organic matter and periphyton. Particulate organic matter was sampled from undisturbed, stream bottom riffles as above for invertebrates using a 250 µm mesh, D-frame net. 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 to 1,000 µm) was collected in a 100 µm mesh aquarium net, placed in a sample vial, and preserved in formalin. At the laboratory, samples were dried and ashed in a muffle furnace to quantify ash-free dry mass of fine particulate organic matter (FPOM). Algal periphyton was quantified by scrubbing attached algae off the surface of a cobble-size rock selected randomly from undisturbed, mid-stream riffle habitat. Algae was removed using a wire brush, and the rinsate homogenized using a large syringe, and scissors if needed for filamentous algae. The homogenized rinsate was subsampled for (a) chlorophyll *a* by filtration through a 1 µm pore-size glass fiber filter, recording the volume filtered, and (b) archival of algae for cell counts and taxonomic identifications (preserved in formalin and Lugol's stain). The area of the rock was estimated from measures of length, width, height, and circumference. The filters, preserved by freezing, were analyzed for chlorophyll *a* in the laboratory using cold ethanol extraction for 24 hours followed by fluorometry. Concentrations were determined using a standard curve developed using a spectrophotometric extinction coefficient found in the literature.

Results

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, 2002, and 2003 (not in 2000) and on 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) reference sites in 2000, 2002, and 2003. Discharge was of similar magnitude in Bagley Valley and Slinkard Creeks in all years (varying from 0.3 to 2.4 cfs), and up to an order of magnitude lower in the tributary to Silver King Creek (0.1 to 0.2 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 Valley reaches generally were wider with more shallow bank angles and open banks, more deposits of fine particle sizes, and greater density of algal periphyton (as chlorophyll *a*) than reference reaches. These differences are consistent with an eroded, exposed channel with limited riparian cover. As expected, the most distinct temporal change in physical habitat form was found in the re-located meadow restoration channel in Bagley Valley. In both post-project years the proportion of riffle habitat was greater and the proportion of fine and sand substrate composition was lower, compared to the original channel (Figures 1 and 2). In addition, the establishment of riparian vegetation accelerated substantially between 2002 and 2003, with the percentage of open banks declining from 63 to 10, and coverage by herbaceous plants and bushes increasing commensurately (Figure 3). Interestingly, percent cobble embeddedness was higher at all sites in 2003 than in previous years, perhaps resulting from a consistent hydrologic trend in these watersheds.

Macroinvertebrate Community Comparisons

Taxa richness (i.e. diversity) data for each site over the study period are summarized in Figure 5. In pre-project years, the diversity over all taxa was similar at each site, with 45 to 54 taxa identified at each site. In both post-project years (i.e. 2002 and 2003), the number of taxa was higher at each site, ranging from 49 to 78, with the exception of Slinkard Creek in 2002. A substantial increase in taxa was also found at the tributary to Silver King Cr in post-project years. At each site, about two-thirds of the total taxa at a site were collected in a single mean replicate sample. Although overall diversity showed little difference, more than twice as many EPT taxa were found at the restored meadow reach on Bagley Valley Creek and at reference sites, than on the unrestored Bagley meadow site or the Bagley Valley lower control site (Figure 6). 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. Sensitivity to impaired water and habitat quality can also be evaluated by the tolerance values (TVs) of all invertebrates collected – with low values indicating intolerance of poor conditions and high values indicating tolerance. In contrast with the reference sites, the unrestored and lower control sites on Bagley Valley Creek had a higher proportion of tolerant invertebrates (TVs = 7-10) and fewer sensitive taxa (TVs = 0-2, Figure 7), resulting in a higher biotic index value (Figure 8) – an indicator of composite community tolerance to environmental degradation. At the restored meadow site, the post-project community was comprised of fewer tolerant invertebrates, and more sensitive organisms, similar to Slinkard Creek and the tributary to Silver King. Invertebrate density from year-to-year was variable over all sites and showed no consistent trend before and after restoration (Figure 9). 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 (i.e. “weedy” species). The dominant taxa of Bagley and Slinkard reaches consistently comprised 25-40% of the total number of invertebrates over the study (Figure 10), but increased at the restored meadow reach to near 50% in 2002, suggesting that despite other improving patterns of biotic integrity, this newly-created stream channel was in an instable state. However, by 2003, percent dominance had decreased below pre-project levels. The percent abundance of the three most dominant taxa also decreased from 74% to 55% at the restored site, within about 2% of the lower control and Slinkard Creek site in 2003 (Table 2).

The Silver King tributary, though differing with respect to size and slope, is indicative of 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 features of this small stream relative to the others was 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 site, 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.

Discussion and Conclusions

Effective monitoring of stream restoration projects has often been neglected or received a low priority in the past (Kondolf 1995; Bernhardt *et al* 2004). Reasons include logistical challenges, costs of conducting studies, and a tendency for managers to avoid publicizing failures. Monitoring may also be perceived as “intangible” relative to the more “tangible” aspects of project construction. Examples are emerging of comprehensive monitoring approaches that publicize both the successes and failures of a project, contribute to the science of river restoration, and even inform future efforts for a particular project being monitored through an adaptive management approach (e.g. Lüderitz et al 2004; Gerard and Hellenthal 2004).

One example previously reported by Herbst (2004) found results similar to those of the Bagley Valley Creek study. At Trout Creek, a restoration project was undertaken to reconstruct a channelized portion of the stream in 2001, including restoring channel sinuosity, pool-riffle sequences, substrate composition, bank stability, and hydrologic function. Pre- and post-project monitoring was conducted using a similar bioassessment technique. After two years, overall invertebrate richness and diversity increased, dominance decreased, EPT diversity increased, and the diversity, abundance, and frequency of larger-sized (i.e. >5 mm) invertebrates increased (large invertebrates usually have longer life cycles, requirements for stable substrates and food resources, and are the preferred prey of fish, amphibians, and riparian birds). The data suggested that an important element of channel reconstruction contributing to ecological restoration was the addition of large and diverse streambed substrate sizes. It was unclear whether the upstream landscape disturbance and the bedload characteristics of Trout Creek would enable the persistence of such favorable substrate conditions, and thus whether the ecological recovery measured would be sustainable in the long term.

To date, similar ecological recovery and enhancement is evident in the restored portion of Bagley Valley Creek. The data indicate that the reconstructed stream channel in Bagley Valley showed consistent signs of improved biological integrity in the diversity and types of aquatic invertebrates present relative to the pre-project stream reach, and in accelerated establishment of riparian vegetation. In addition, the downstream control reach, where sediment or hydrologic disturbance from the construction project would have been received, showed little or no sign of impairment relative to the pre-project baseline. In summary, in-stream ecological restoration of Bagley Valley Creek within the meadow progressed without detrimental side effect in the two years following project completion.

The Slinkard restoration site, used here as a reference, was expected to provide 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 was expected to provide the type of habitat supportive of benthic macroinvertebrate communities with greater diversity of sensitive EPT taxa and less dominance by more tolerant fauna. In many respects, including total and EPT diversity, proportion of tolerant taxa, invertebrate density, and dominance, the restored meadow reach was in a very similar condition to the Slinkard Creek site in 2003. Recovery of biological integrity may still be an ongoing process at the Slinkard restoration site (established 10 years prior to the 1999-2000 surveys), so this reference location may not represent the best conditions attainable (e.g. dominance remains high).

It appears that macroinvertebrate community establishment occurred relatively rapidly at the restored meadow site, similar to the Trout Creek restoration site. As appeared to be the case at Trout Creek, 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, further colonization by sensitive taxa, and stabilization of productivity and invertebrate biomass. Thus, further establishment of riparian vegetation and the accumulation of organic matter at the restored site may lead to a condition similar to that of the tributary to Silver King Creek.

Importation of heterogeneous substrate suited to a diverse invertebrate community and re-vegetation efforts that included the use of geotextile fabric to aid plant establishment and limit bank erosion, likely contributed to the relatively rapid re-establishment of the invertebrate community. However, degraded and incised channels in the upstream portions of Bagley Valley continue to be eroded and deliver sediments into the lower channel, so there is some question whether the ecological response measured thus far will be sustainable. We recommend continued monitoring of the Bagley Valley restoration site and reference sites to further evaluate the extent and persistence of ecological recovery over time.

References

Bernhardt, E.S., M.A. Palmer, J.D. Allan, and THE National River Restoration Science Synthesis. 2004. Characterizing river restoration in our nation: initial results from the National River Restoration Science Synthesis (abstract). *Bulletin of the North American Benthological Society* **21**(1): 359-360.

Davis, W.S. and T.P. Simon (Ed.s). 1995. *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making*. Lewis Publishers, Boca Raton, Florida. 415 pp.

Gerard, K.J. and R.A. Hellenthal. 2004. The biological response of benthic macroinvertebrates to stream restoration (abstract). *Bulletin of the North American Benthological Society* **21**(1): 331.

Herbst, D.B. 2001. Quality assurance project plan - Aquatic invertebrate bioassessment monitoring in the Eastern Sierra Nevada [California State Water Resources Control Board, Lahontan Region]. Download: http://www.swrcb.ca.gov/rwqcb6/files.htm

Herbst, D.B. 2003. *Macroinvertebrate Monitoring for the Bagley Valley Watershed Restoration Project on the Humboldt-Toiyabe National Forest: First Year Post-Project Assessment.* Submitted to Lahontan Regional Water Quality Control Board and US Forest Service in partial completion of Lahontan Contract 00-091-160-1. 14 April.

Herbst, D.B. 2004. *Trout Creek Restoration Monitoring: Assessment of Channel Reconstruction Using Benthic Invertebrates as Indicators of Ecological Recovery*. Report to City of South Lake Tahoe. 21 June.

Kondolf, G.M. 1995. Five elements for effective evaluation of stream restoration. *Restoration Ecology* **3**(2): 133-36.

Kondolf, G.M. and M. Larson. 1995. Historical channel analysis and its application to riparian and aquatic habitat restoration. *Aquatic Conservation: Marine and Freshwater Ecosystems* **5**:109-126.

Lüderitz, V., R. Jüpner, S. Müller, and C.K. Feld. 2004. Renaturalization of streams and rivers – the special importance of integrated ecological methods in measurement of success; An example from Saxony-Anhalt (Germany). *Limnologica* **34**: 249-263.

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

United States Department of Agriculture Forest Service. 2000. *Bagley Valley Project: Stream and meadow restoration* (pamphlet). Humboldt-Toiyabe National Forest: Carson Ranger District.

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

TABLE 1. HABITAT FEATURES	Bagley Valley Creek lower control			Bagley Valley Creek meadow restoration			Slinkard Creek restoration area			Trib.1 -Silver King above Silver King		
Elevation (m)	1,935			1,945			1,877			2,024		
Latitude	38.592			38.599			38.600			38.552		
Longitude	-119.655			-119.647			-119.568			-119.608		
	PRE-PROJECT	POST-PROJECT		PRE-PROJECT	POST-PROJECT		PRE-PROJECT	POST-PROJECT		PRE-PROJECT	POST-PROJECT	
	8 VII 99	24 VII 02	30 VII 03	8 VII 99	24 VII 02	30 VII 03	27 VII 00	5 VIII 02	29 VII 03	23 VIII 00	23 VII 02	31 VII 03
Mean Width (cm)	136	119	135	133	158	151	66	87	89	75	86	92
Mean Depth (cm)	18	20	20	13	6	8	21	23	22	9	5	7
Mean Velocity (cm/s)	25	9	8	51	12.4	14	41	18.7	20	8	2.1	6
Discharge (cfs) [non-zero mean]	1.5	0.3	0.4	2.4	0.4	0.5	1.8	1.0	1.2	0.1	0.1	0.2
Sinuosity	1.20	1.27	NM	1.24	1.13	NM	1.24	1.27	NM	1.21	1.23	NM
Slope (%)	1.8	1.8	NM	2.4	2.4	NM	1.3	1.2	NM	8.4	8.2	NM
Conductivity (uS)	242	244	263	283	195	224	216	218	224	179	178	181
D.O. (mg/L)	8.3	7.0	7.2	8.0	7.9	7.0	8.2	7.5	7.6	8.8	7.8	7.7
Turbidity (NTU)	1.2	2.35	0.32	0.79	2.46	0.15	0.05	2.23	0.43	1.42	2.43	0.83
Temperature (^{o}C)	21.9	21.4	15.3	22.0	18.2	20.6	14.6	16.0	16.0	15.0	17.8	12.9
Alkalinity (mg/L)	180	151	189	166	124	144	136	123	154	115	112	124
Riparian Index herb cover (1-5)	5	5	5	5	1	4	5	5	5	5	5	5
Riparian Index woody Cover (1-15)	1	1	1	1	3	2	0	0	0	9	8	6
%Riparian Cover (mean)	28	47	61	18	13	48	63	78	93	77	75	96
%Eroded bank (mean)	10	0	0	10	10	0	0	0	0	0	3	7
%Cobble Embeddedness (mean)	32	37	55	23	23	33	13	14	25	30	26	50
% Free Cobble (mean)	44	44	24	52	56	40	72	76	52	28	68	24
FPOM (g AFDM/m^2)	0.9	0.9	3.8	1.4	1.2	1.6	0.8	1.0	1.7	2.0	2.8	7.0
CPOM (wet g/m^2)	46	104	77	203	33	22	64	37	25	696	183	698
Periphyton Chl a (ug/cm^2)	1.9	9.9	7.3	2.2	0.6	0.7	0.4	0.7	0.1	0.5	2.5	0.3

Note: "NM" = measurement not repeated in 2003

Table 2: Three most dominant taxa and proportion of total at each site pre- (1999 and 2000) and post-project (2002 and 2003).

Test Sites:

	Bagley Valley Creek			**Bagley Valley Creek**	
	Lower Control			Meadow Site	
1999			1999		
1	*Oligochaetes*		1	*Baetis sp.*	
2	*Cricotopus-Orthocladius spp.*		2	*Simulium spp.*	
3	*Hyalella azteca*	**45%**	3	*Hyalella azteca*	**59%**
2000			2000		
1	*Cricotopus-Orthocladius spp.*		1	*Simulium spp.*	
2	*Simulium spp.*		2	*Optioservus quadrimaculatus*	
3	*Optioservus quadrimaculatus*	**52%**	3	*Optioservus divergens*	**57%**
2002			2002		
1	*Simulium spp.*		1	*Baetis sp*	
2	*Baetis sp.*		2	*Simulium spp.*	
3	*Tvetenia bavarica grp.*	**40%**	3	*Zapada sp.*	**74%**
2003			2003		
1	*Simulium spp.*		1	*Baetis sp.*	
2	*Hyallela azteca*		2	*Optioservus quadrimaculatis*	
3	*Cricotopus-Orthocladius spp.*	**52%**	3	*Simulium spp.*	**55%**

Reference sites:

	Slinkard Creek			**Tributary 1 Silver King**	
	Restoration Area			Above SK Creek	
2000			2000		
1	*Optioservus quadrimaculatus*		1	*Baetis sp.*	
2	*Baetis sp.*		2	*Yoraperla sp.*	
3	*Zapada sp.*	**75%**	3	*Ironodes sp.*	**32%**
2002			2002		
1	*Optioservus quadrimaculatus*		1	*Simulium spp.*	
2	*Optioservus divergens*		2	*Yoraperla sp.*	
3	*Baetis sp.*	**59%**	3	*Oligochaetes*	**32%**
2003			2003		
1	*Optioservus divergens*		1	*Simulium spp.*	
2	*Optioservus quadrimaculatus*		2	*Pisidium sp.*	
3	*Diphetor hageni*	**57%**	3	*Heterlimnius corpulentus*	**33%**

Figure 1. Channel Habitat Composition

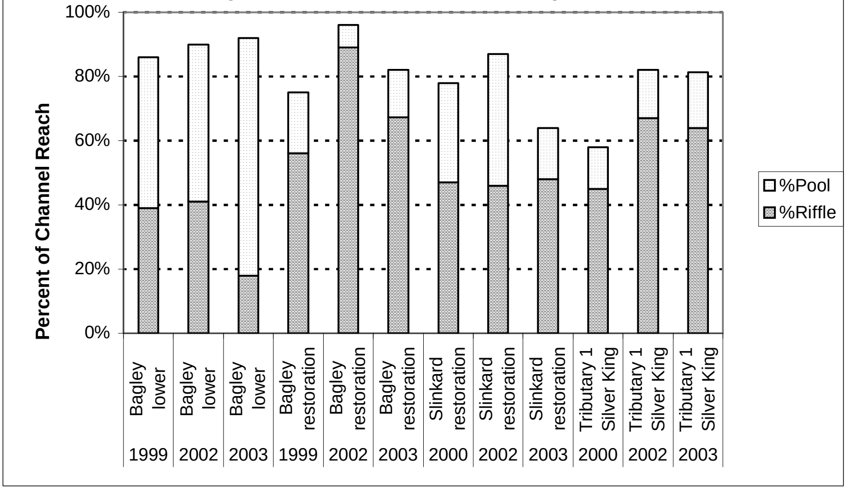


Figure 3. Bank Cover

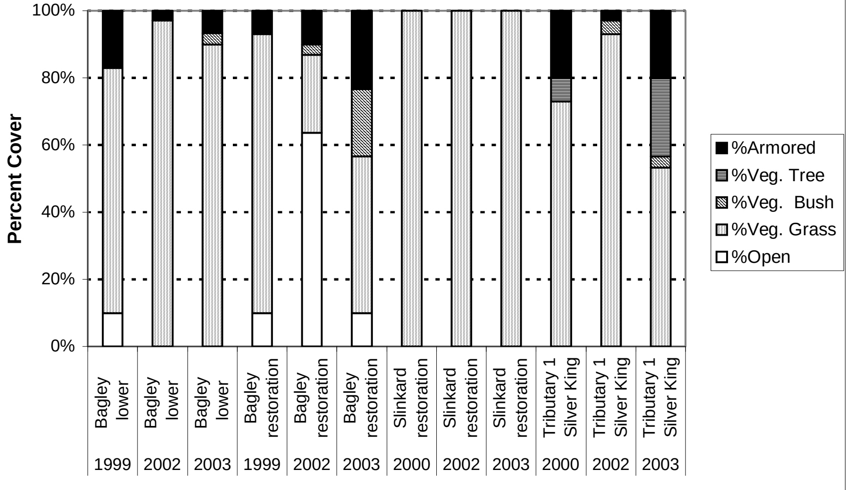


Figure 2. Substrate Composition

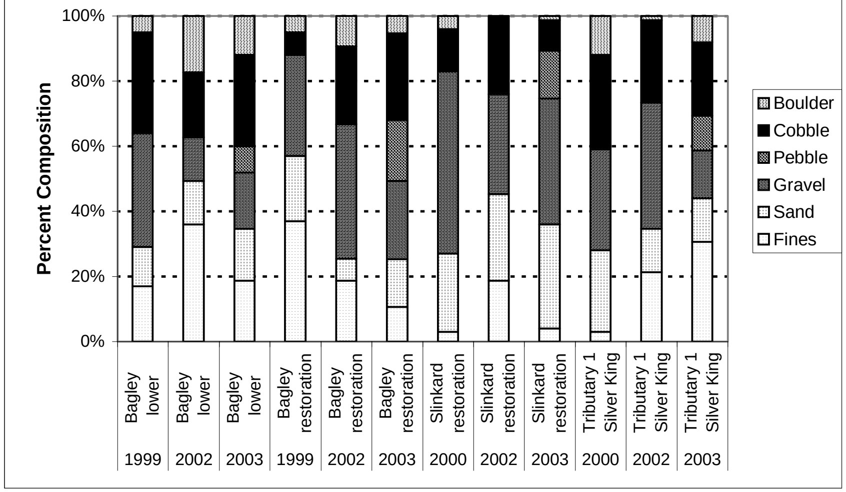
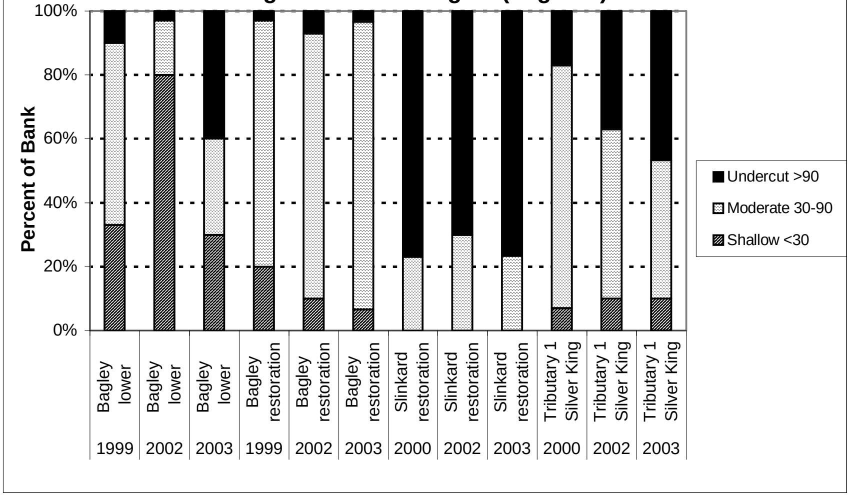


Figure 4. Bank Angles (degrees)



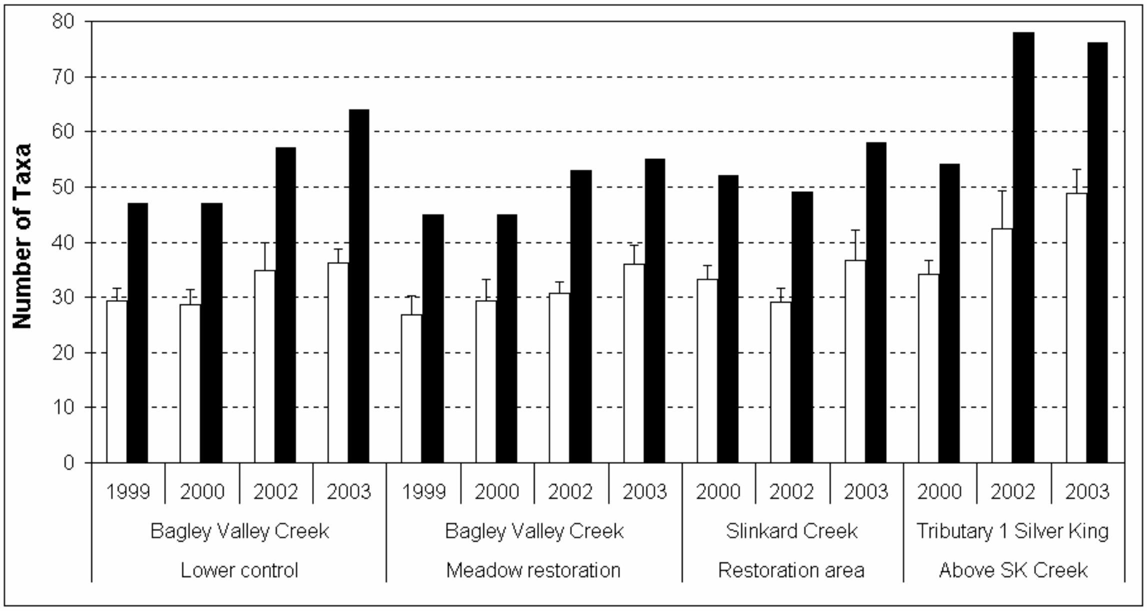


Figure 5: Mean (white bars) and total (black bars) taxa richness at each site pre- (1999 and 2000) and post-project (2002 and 2003). Error bar represents one standard deviation.

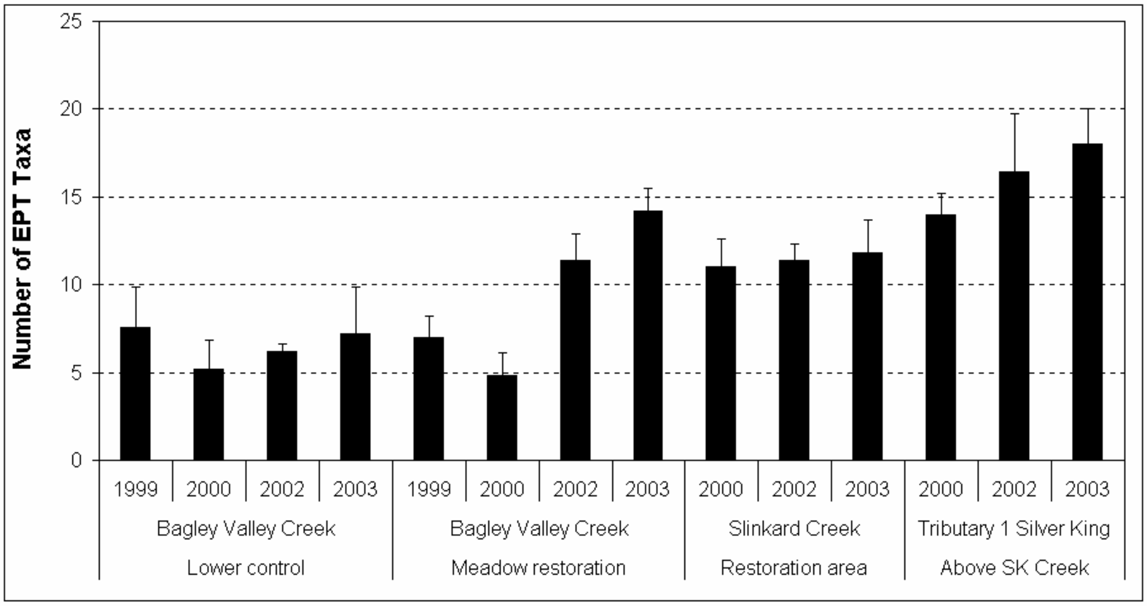


Figure 6: Mean number of EPT taxa per sample at each site pre- (1999 and 2000) and post-project (2002 and 2003). Error bar represents one standard deviation.

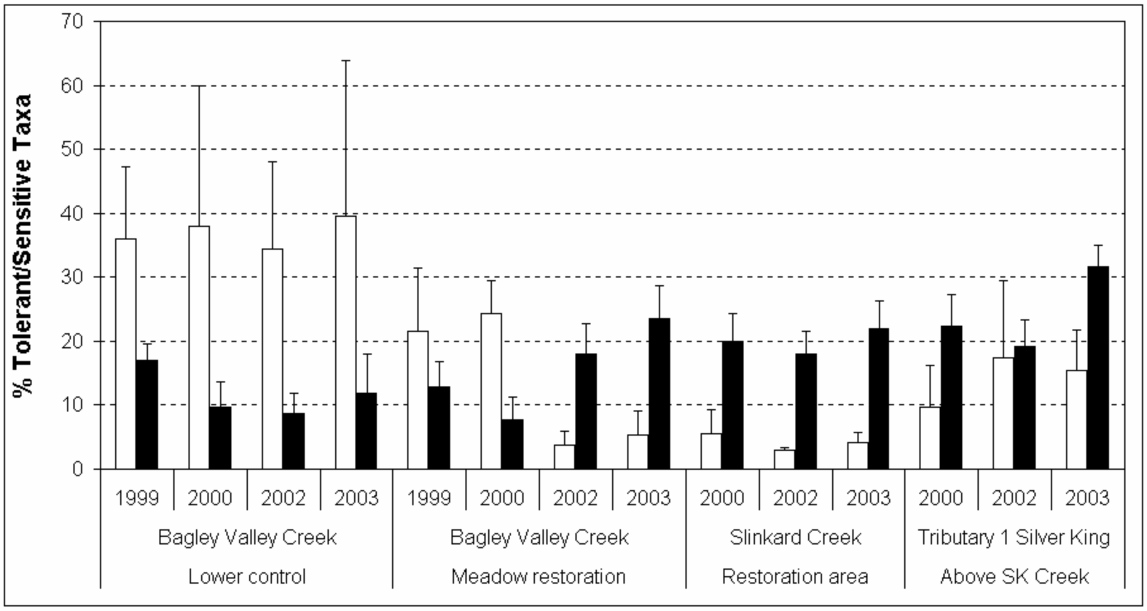


Figure 7: Mean proportion of tolerant (white bars; tolerance value 7-10) and sensitive (black bars; tolerance value 0-2) organisms at each site pre- (1999 and 2000) and post-project (2002 and 2003). Error bar represents one standard deviation.

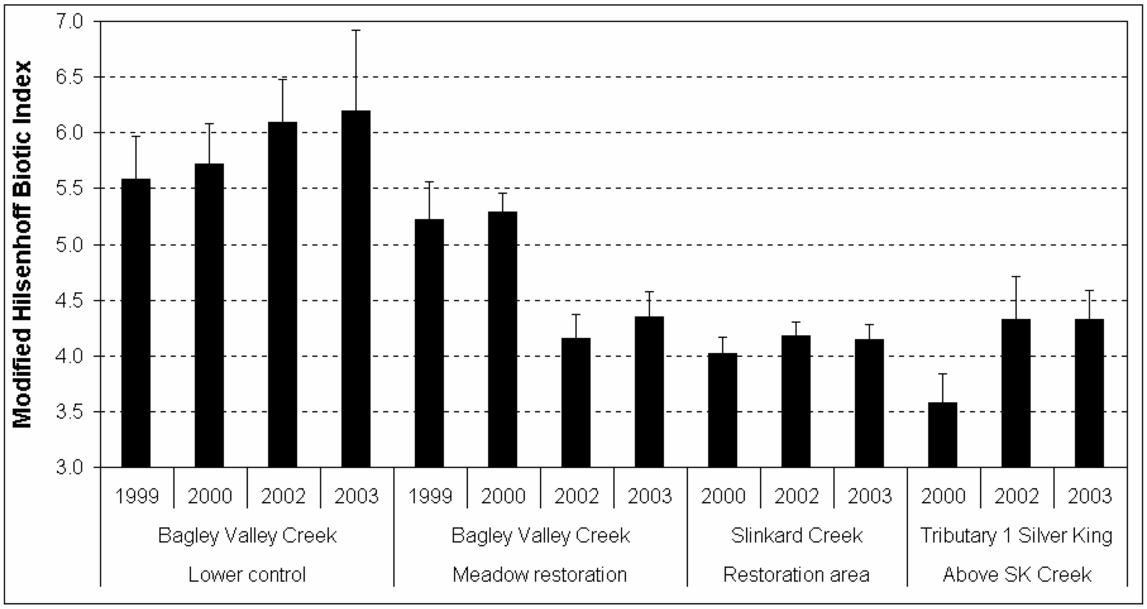


Figure 8: Mean modified Hilsenhoff Biotic Index for each site pre- (1999 and 2000) and post-project (2002 and 2003). Error bar represents one standard deviation.

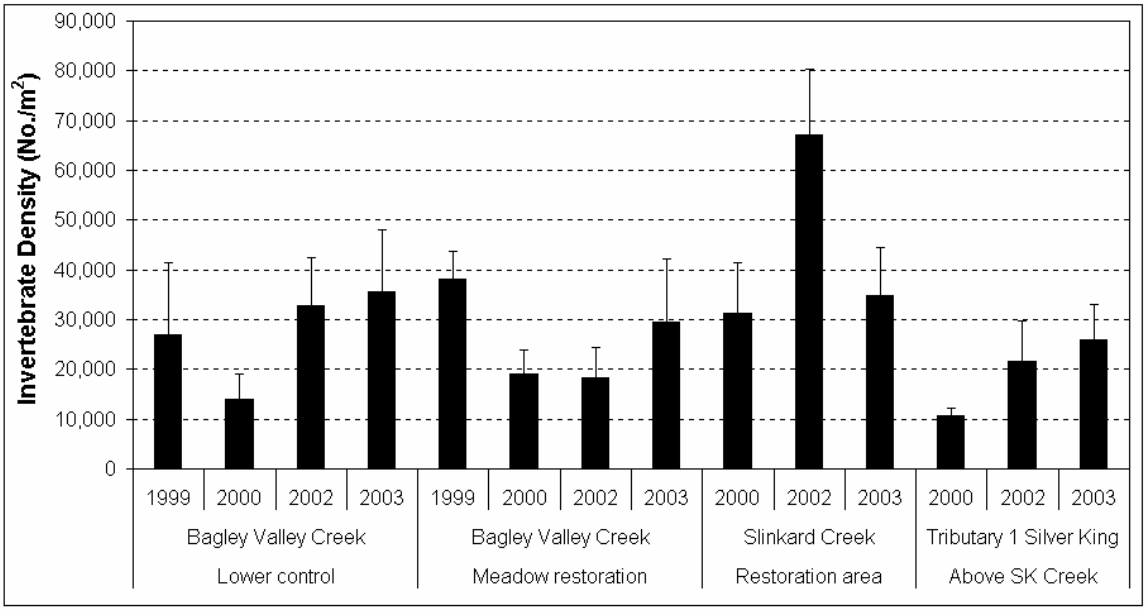


Figure 9: Mean invertebrate density (No. organisms per m^2) at each site pre- (1999 and 2000) and post-project (2002 and 2003). Error bar represents one standard deviation.

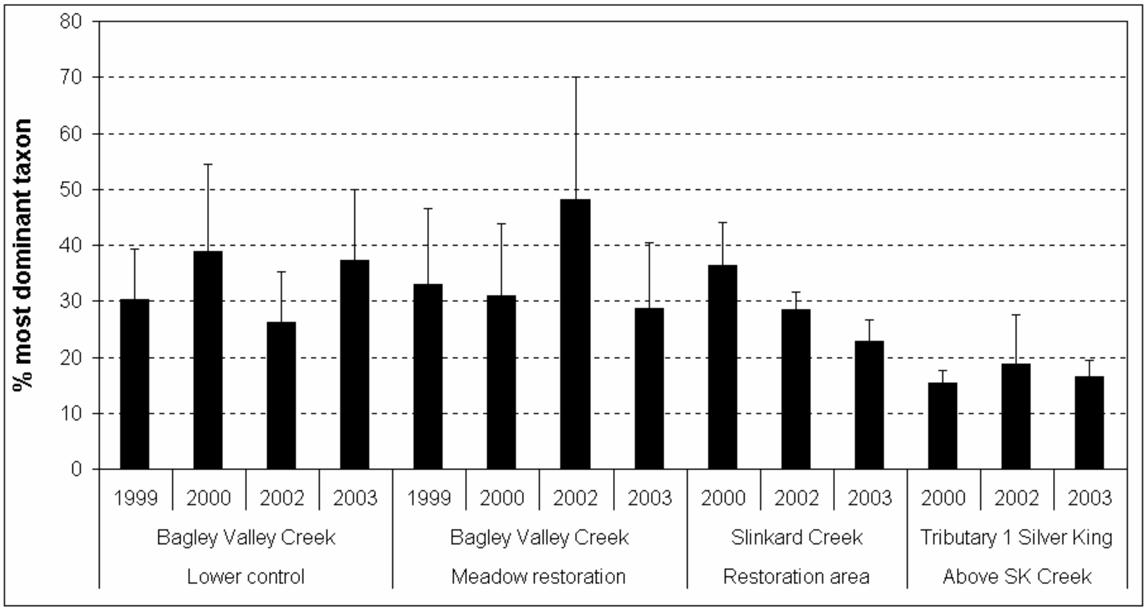


Figure 10: Mean proportion of the most dominant taxon at each site pre- (1999 and 2000) and post-project (2002 and 2003). Error bar represents one standard deviation.