Trout Creek Restoration Monitoring: Initial Post-Project Assessment Using Benthic Invertebrates as Indicators of Ecological Recovery

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Project Description and Background:

An integral component of stream restoration management is the monitoring of performance indicators that measure the progress of recovery. This study of the stream invertebrate community of Trout Creek (El Dorado County, California) was undertaken as part of the monitoring program for a channel restoration project on the lower portion of this creek. The data collected represent a biological baseline for evaluating the effectiveness of new channel construction in improving habitat and enhancing biological diversity. The bottom-dwelling invertebrates of the stream are used here as indicators of the quality of habitat and the capacity of the stream to support life. 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 (Davis and Simon 1995).

Site Description and Sampling:

The project site is located on lower Trout Creek, just above and just below confluence with Cold Creek (refer to map). Restoration of the upper channelized section of stream (above Cold Creek) to control erosion and stabilize the channel involved complete replacement of the upstream reach with a reconstructed sinuous channel. This landscape engineering and partial reconfiguration of the downstream reach (below Cold Creek) was completed during 2000-2001, with flow of the creek re-directed into the new channels in summer of 2001. Pre-project monitoring of the stream invertebrate community was conducted in the early fall of 1999 and 2000, and the first year of post-project monitoring in 2002. Silt and sand deposits, forming a shifting unstable stream bottom environment, dominated both reaches prior to restoration. The post-project streambed has been engineered to provide alternating riffle-pool habitat in a sinuous channel along with larger and more stable substrate particle sizes (gravel to small cobble). In addition to these restored reaches, an upstream control reach above the project area (above the Pioneer Trail road crossing) was also sampled in 2002 to quantify the natural invertebrate community expected for Trout Creek in an area not subjected to channelization but representing the intrinsic geomorphic and hydrologic setting of the lower portion of this stream.

Substrate composition from silt through sand and coarse sand to small (0.5-2.5 cm) and medium-sized (2.5-5.0 cm) gravel and small cobble (ca. 6.5 to 10 cm) was recorded for each set of invertebrate collections. Natural large substrate sizes were rare or absent over the pre-project reaches (some cement rip-rap formed large substrate in a few locations). In each of the three study reaches (upper project above Cold Creek, lower project below Cold Creek, and above project upstream of Pioneer Trail) five transects were sampled when surveys were conducted. Each sample consisted of a composite collection from three square-foot locations across a channel transect in shallow erosional riffle habitats. A standard D-frame net of 250 micron mesh size and 12 inch opening was placed on the stream bottom just below of each sample area and the substrate disrupted by hard to release inhabitant invertebrates which then were swept with the current into the collection net. The three composites per transect (samples taken across the stream cross-section profile in uniform substrate type) were then collected in a bucket and the contents mixed/swirled and the floating organisms and organic debris poured off through a fine-mesh aquarium net, leaving sand and gravel behind (this is known as elutriation). Elutriation was repeated until no further organic matter could be separated from sand gravel. The remnant sand and gravel was then visually inspected in shallow white pans to remove any remaining sand-case caddisflies or other invertebrates that do not come off with elutriation. These field-processed samples were then preserved with alcohol and Rose Bengal stain and returned to the laboratory for detailed sorting under a 10X stereomicroscope. Prior to sorting, subsampling of field samples was conducted using a rotating drum sample splitter, so that the number of organisms sorted was usually in the range of 250-1000 total. Organisms were identified to genus level (or species/ species group), including midges and mites, with the exception of oligochaetes and ostracodes (seed-shrimp and segmented worms, collectively <1% of all organisms). The body lengths of sorted and counted organisms were also measured to quantify the frequency and density of organisms larger than 5 mm. These 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 (when adult insects emerge). Data analysis also included measures of taxonomic richness (diversity), sensitive indicator groups, and dominance of the most common taxa.

Monitoring Results

Over the two years of pre-project sampling, 1 post-project year, and three study reaches, a total of 117 taxa were identified from the invertebrates collected (Table 1). Mean richness diversity per site for the 2-year pre-project period was about 32 taxa in both the upper and lower project areas and increased to 40 to 43 in the first post-project year 2002 (Figure 1), equivalent to the diversity found in the above-project control. The pre-project levels of richness are comparable to those found in the channelized lower reaches of the nearby Upper Truckee River (Herbst 2001). Two taxa comprised nearly 46% of all specimens found during the pre-project period - the mayfly *Baetis* sp. (mostly *bicaudatus*) and the stonefly *Haploperla* sp. (probably *H. chilnualna*). Though these taxa remained common in the post-project samples, their dominance declined to 16% of the total (Table 1). High dominance is often an indicator of imbalance in community composition produced by poor habitat quality or limited food resource variety. Dominance declines in both reconstructed stream reaches to a level similar to the upstream control reach (Figure 2)

The EPT taxa (mayflies, stoneflies and caddisflies) are found primarily in unpolluted habitats with cold temperatures, varied food resources, and turbulent flows over heterogeneous substrates. The diversity of these generally sensitive insects increased in the post-project period (>15 taxa), and again to a level found in the above-project control reach (Figure 3). The 10-15 EPT found on average in the pre-project period also matches that found in the lower Upper Truckee (Barton meadows, adjacent to the airport) where much sediment deposition has occurred. Further evidence of enhanced ecological conditions is the increased density of large-bodied organisms in the reconstructed stream (Figure 4). A four-fold increase was found in the complete channel replacement area upstream of Cold Creek, and a 50% increase in the partial reconstruction downstream.

Biological recovery in the reconstructed stream segments will be related to many interconnected habitat improvements including substrate variety, channel form and pool-riffle sequences, and riparian cover among others. The increased presence of large invertebrates and the sensitive EPT taxa in this early phase of recolonization appears to be related to substrate size (Figures 5 and 6). If data from all samples are pooled irrespective of time and location, the relation of these biological indicators to substrate size becomes clear. Larger and mixed substrates provide more interstitial space supporting an increased diversity of the more sensitive EPT organisms, and the more protected and stable surfaces of gravel and cobble also harbors larger organisms compared to sand. Unstable silt and sand is a poor substrate for retaining any but transient occupation by large-bodied invertebrates. The variability in body size measures from each substrate size class reflects variation between different transects collected in different years and the proportion of gravel to sand present in the areas sampled. It should be noted that gravel habitat became common only after project completion in the upper project reach (though some was selectively sampled in earlier years). Substrate particle sizes on the pre-and post-project reaches are detailed in separate geomorphic monitoring reports.

A measure of tolerance of the invertebrate community to stress or habitat disturbance is the biotic index. This index is the weighted average of the composite tolerance scores of each taxon and its abundance. Tolerance scores range from 0-10 (sensitive to tolerant) such that the biotic index increases as the overall community increases in the proportion of tolerant taxa present (or loses sensitive taxa). Higher biotic index values on transect comprised of silt and sand alone indicate this instable habitat is inhabited mainly by disturbance-tolerant organisms (Figure 7). Small chironomid larvae (midge flies) typically have higher tolerance values and are the dominant inhabitants of the silt-sand substrate type (5 of 9 samples with >60% chironomidae, all others ≤40%, Figure 8).

The monitoring results indicate overall that small substrate sizes and instable habitat support only a limited range of organisms. Small-bodied organisms are the only abundant inhabitants, and sensitive or large organisms may only be transient or localized on small patches of gravel substrate. The low EPT diversity community dominated by few taxa indicates instability in habitat and food web structure. These data suggest that an important element ensuring that channel restoration results in ecological restoration is large and diverse substrate sizes. The last project report (Herbst 2001) concluded:

> "Cobble substrate size will provide the optimum habitat and should be stocked in shallow riffles. This along with the reconfigured channel morphology should provide habitat that will be quickly colonized by invertebrates and result in significant improvements in community diversity, food web balance, and size distribution."

The project did indeed change the substrate distribution from dominance by sand to gravel and some cobble-size substrates. The initial results clearly show that biological colonization and recovery in Trout Creek is underway.

The previous project progress report also included some explicit predictions:

> <u>Predictions for the Post-Project Monitoring of Aquatic Macroinvertebrates</u>
> Geomorphic changes of most significance to the benthic invertebrate community are likely to result from larger more stable substrates and sinuous, riffle-pool habitat structure. These substrate and channel features are also likely to support more retention of organic matter (leaves, wood debris) and substrate for growth of algal periphyton. The restored channels should therefore provide more physical habitat complexity and food resources (decomposing organic matter and algae) to stream invertebrates. Relative to the pre-project baseline, the following changes can be predicted:
>
> - Greater diversity of sensitive EPT taxa and possibly all taxa
> - Increased frequency of organisms with body size > 5mm length
> - Decreased proportion of midges and other disturbance-tolerant organisms

Each of the changes predicted in the bioassessment indicators has in fact been realized after only 1 year after restoration project completion. Post-project monitoring is planned to continue in 2003 so that 2 years of data incorporating natural inter-annual variation are available for contrasting changes before and after the project. Using concurrent data from the adjacent Upper Truckee River it may also be possible to incorporate a before-after / control-impact (BACI) statistical design in comparing restoration-related changes. Periodic biological assessment beyond 2003 will be important to confirm sustained ecological integrity since sand and sediment transport and deposition in Trout Creek remain a potential source of watershed degradation.

References

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.

Herbst, D.B. 2001. Biomonitoring on the Upper Truckee River using aquatic macroinvertebrates: baseline data for 1998-2000. Report to the Lahontan Regional Water Quality Control Board.

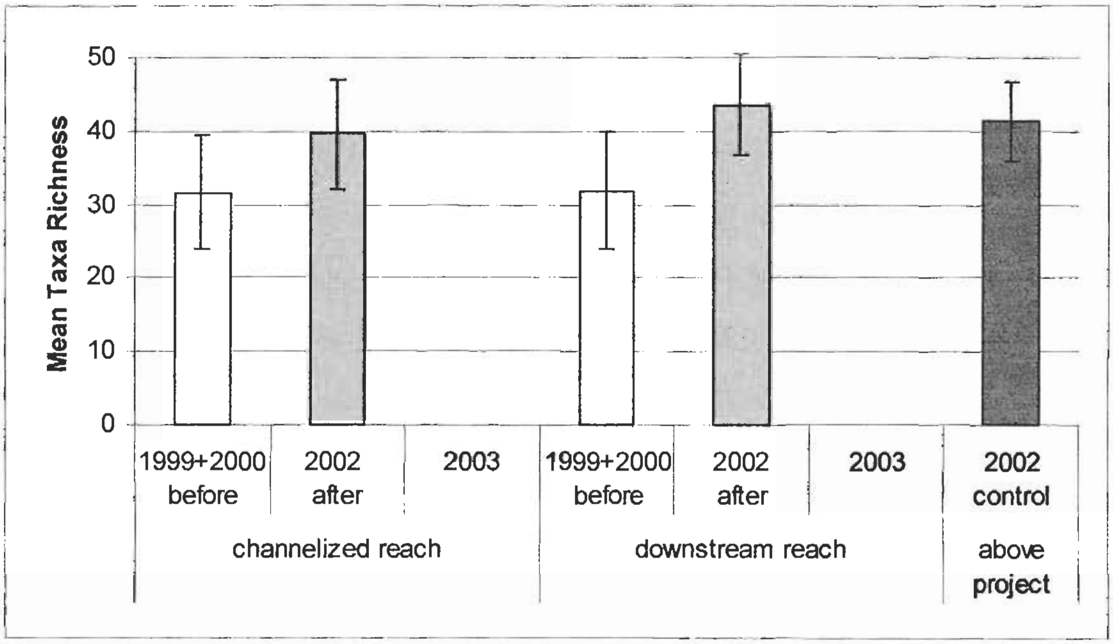

Figure 1. Richness diversity of all taxa as mean per reach (error bars = standard deviation) for Trout Creek restoration (before, after, and above-project control). The 1999+2000 before phase combine the 10 samples from these years, and year 2002 includes the 5 replicates only of the first post-project monitoring.

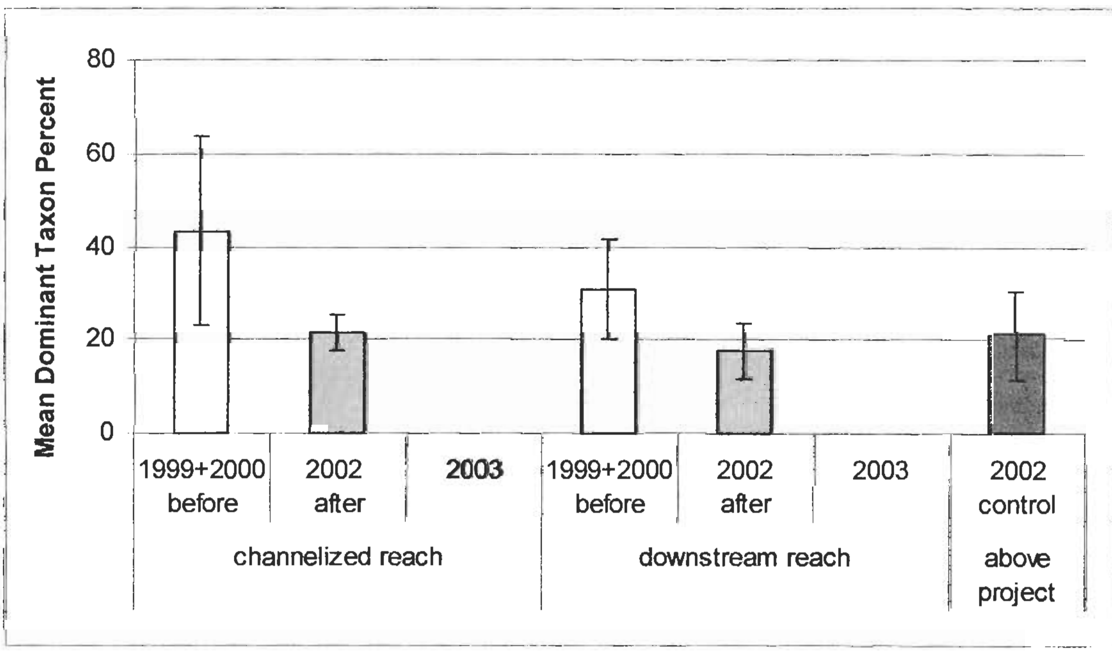

Figure 2. Percent of the community comprised by the most dominant taxon as mean per reach (error bars = standard deviation) for Trout Creek restoration (before, after, and above-project control). The 1999+2000 before phase combine the 10 samples from these years, and year 2002 includes the 5 replicates only of the first post-project monitoring.

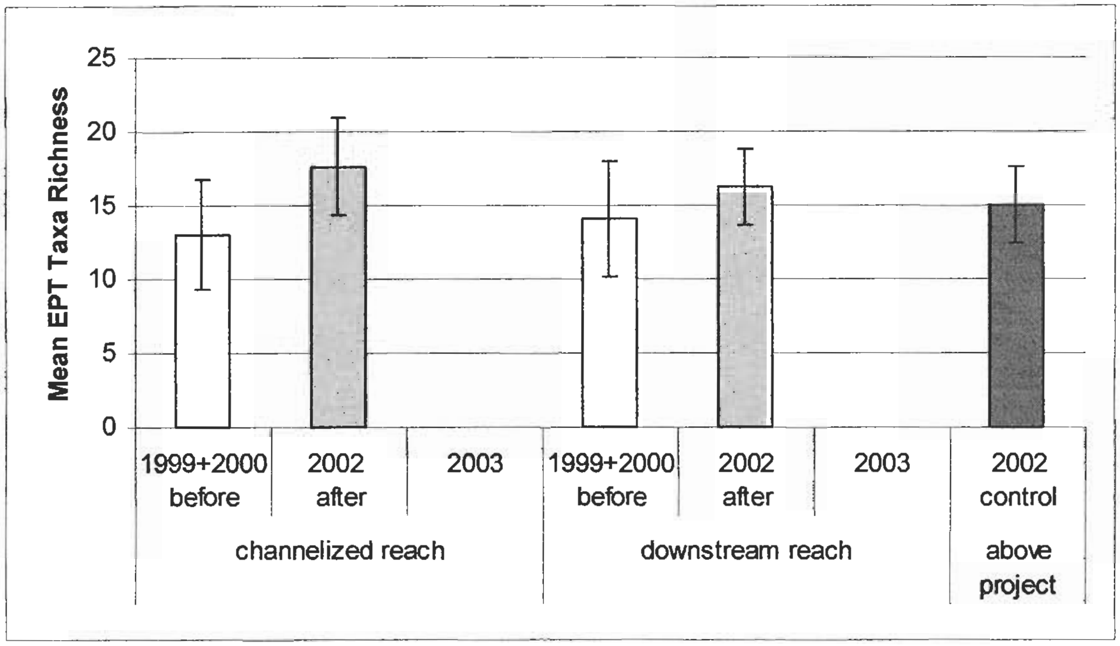

Figure 3. Richness diversity of sensitive mayfly, stonefly and caddisfly taxa as mean per reach (error bars = standard deviation) for Trout Creek restoration (before, after, and above-project control). The 1999+2000 before phase combine the 10 samples from these years, and year 2002 includes the 5 replicates only of the first post-project monitoring.

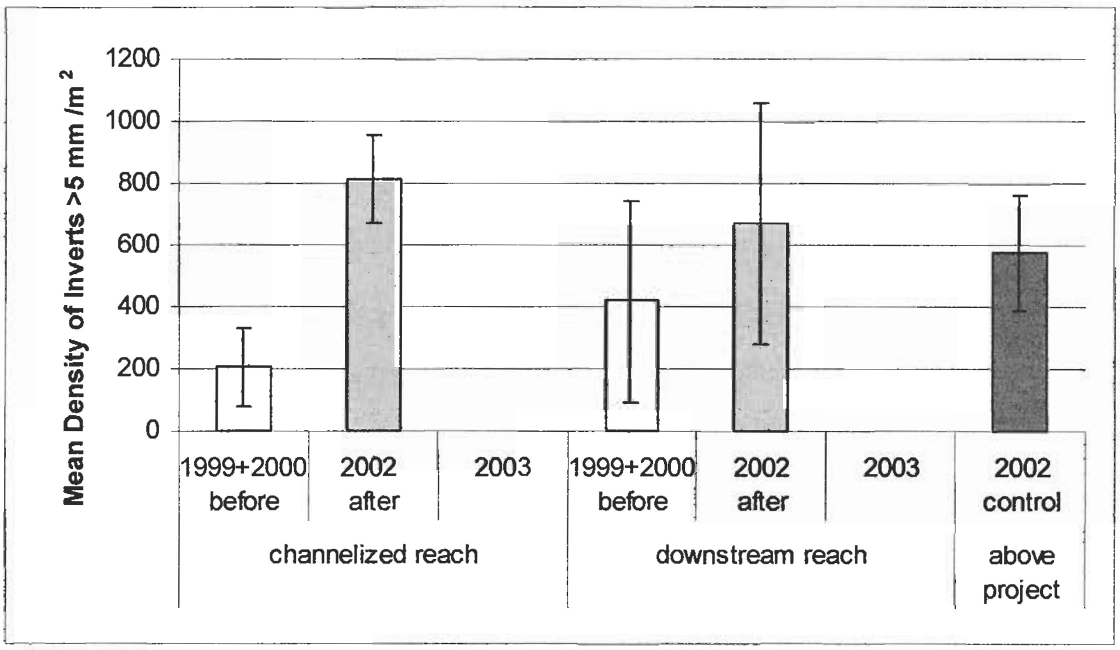

Figure 4. Density (#/m^2) of large invertebrates (more than 5 millimeters long) as mean per reach (error bars = standard deviation) for Trout Creek restoration (before, after, and above-project control). The 1999+2000 before phase combine the 10 samples from these years, and year 2002 includes the 5 replicates only of the first post-project monitoring.

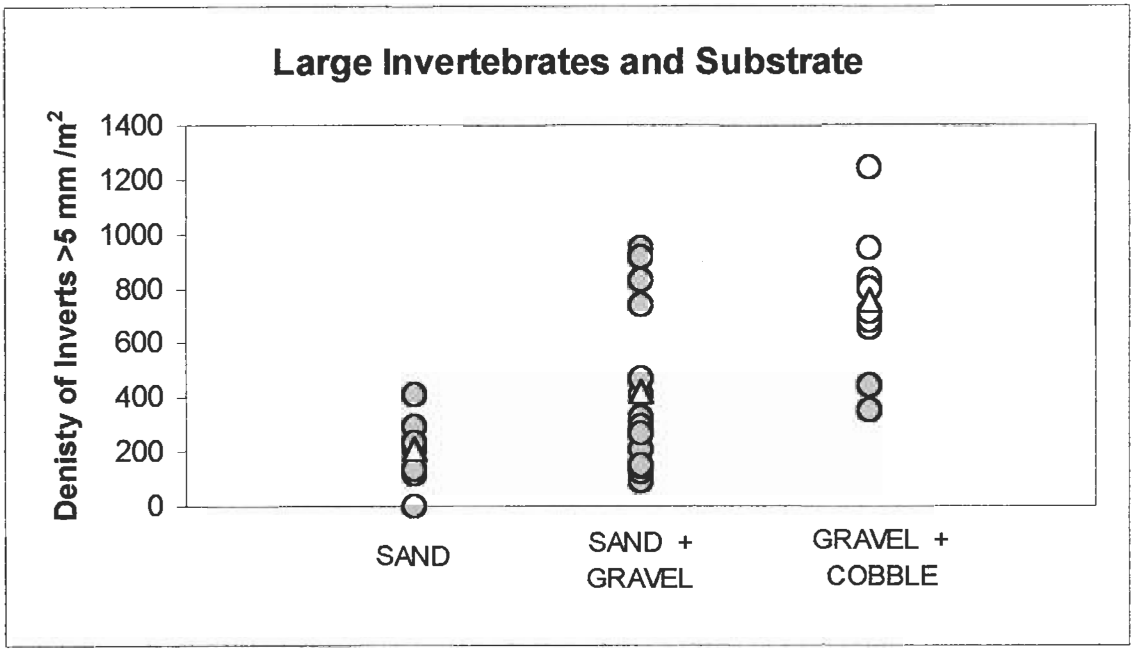

Figure 5. Density distribution of large invertebrates with respect to increased substrate size classes from all sample periods and reaches surveyed on Trout Creek in 1999, 2000, and 2002. Open triangle indicates the mean for the range shown.

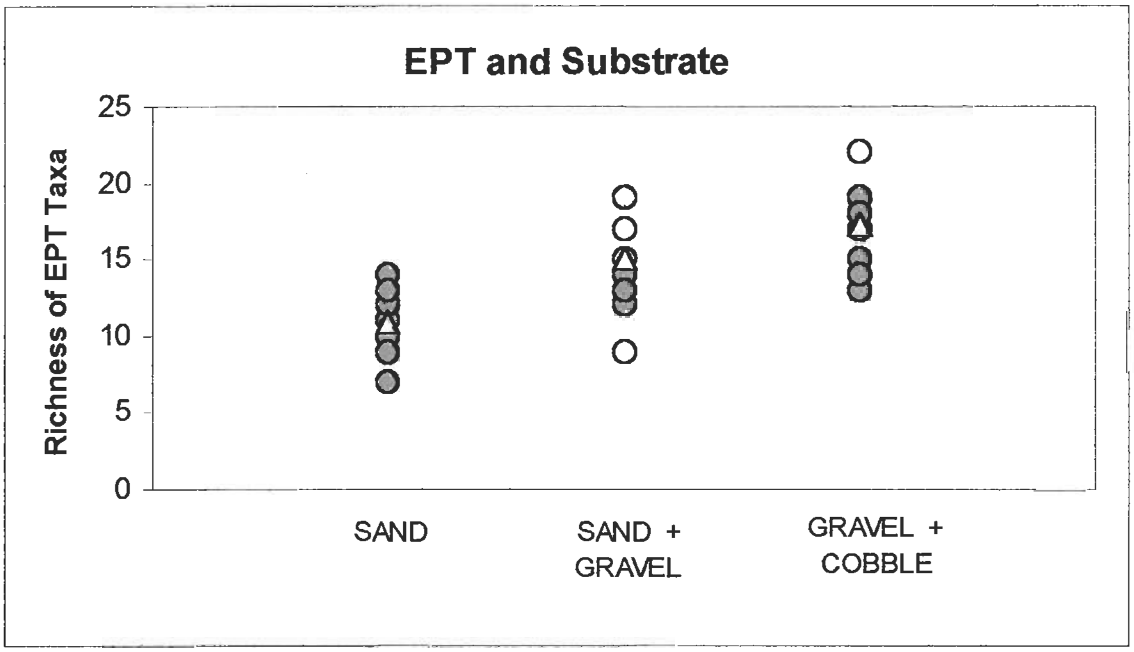

Figure 6. The range of EPT diversity values over increased substrate size classes from all sample periods and reaches surveyed on Trout Creek in 1999, 2000, and 2002. Open triangle indicates the mean for the range shown.

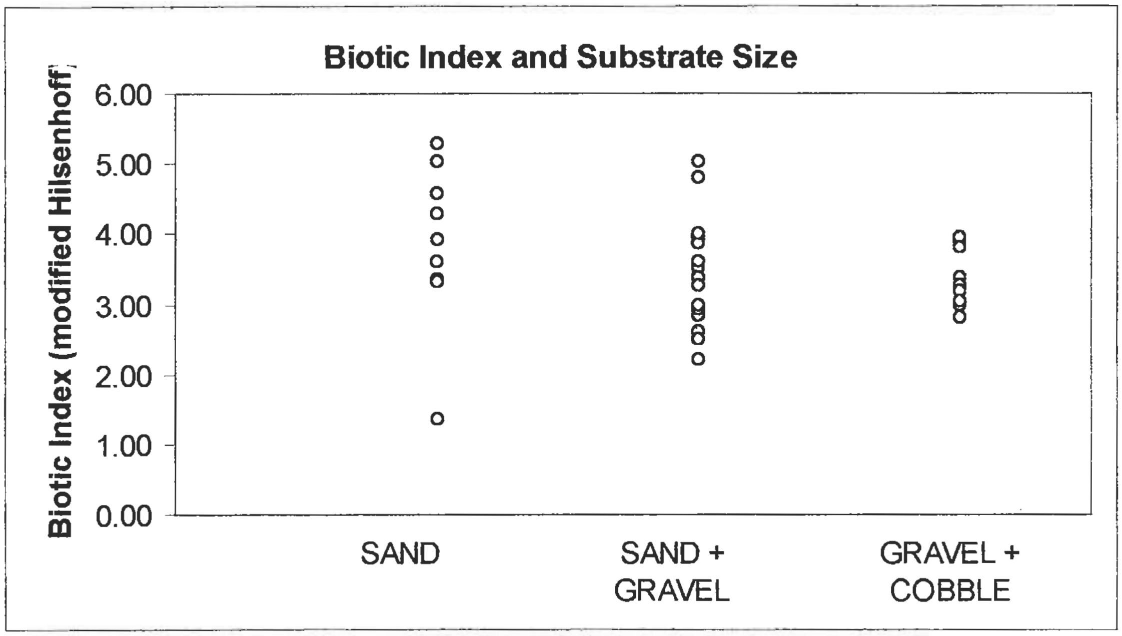

Figure 7. Range of tolerance (biotic index) of community to disturbance or degradation in relation to substrate size classes from all sample periods and reaches surveyed on Trout Creek in 1999, 2000, and 2002.

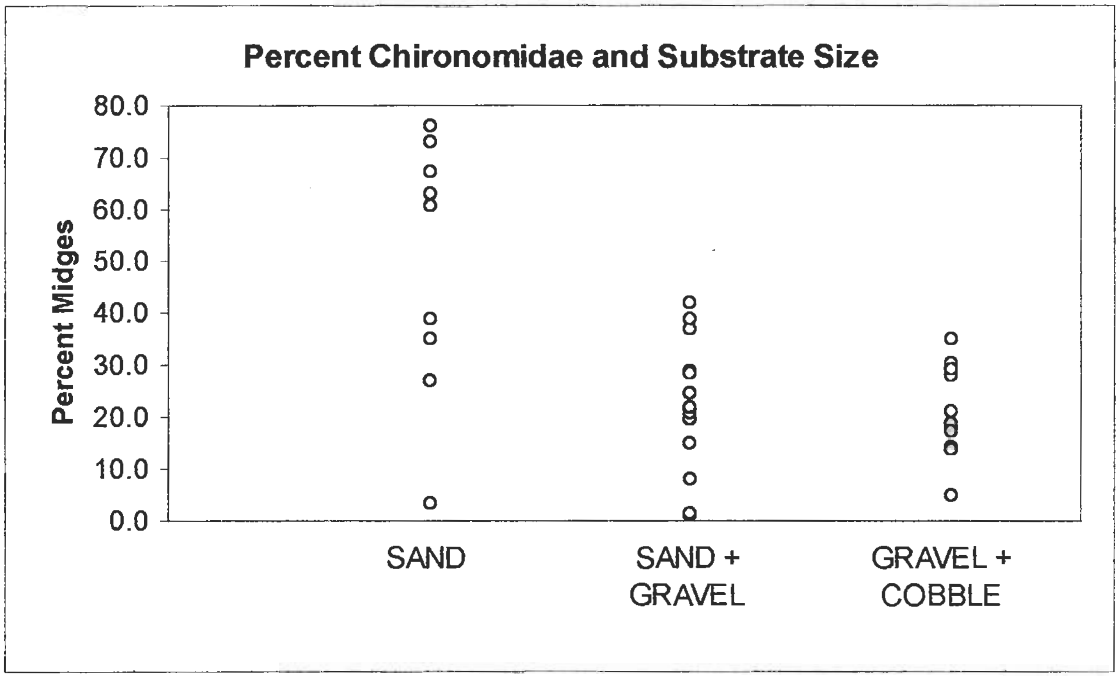

Figure 8. Range of values for the percent chironomidae (small, often tolerant flies) in relation to substrate size classes from all sample periods and reaches surveyed on Trout Creek in 1999, 2000, and 2002.

TABLE 1. Trout Creek Restoration Monitoring: List of Aquatic Invertebrates Collected and Percent Compostion

Table 1. List of taxa collected in Trout Creek restoration monitoring.

Phylum or Class	Class or Order	Family-Subfamily	Genus (and species)	Pre-Project PERCENT	Post-Project PERCENT	Above-Project PERCENT
Insecta	Ephemeroptera	Baetidae	Baetis spp.	19.473	7.460	1.791
			Diphetor	0.000	0.396	0.215
			Centroptilum sp.	0.008	0.000	0.000
		Ephemerellidae	Serratella sp.	8.770	14.003	6.772
			Ephemerella aurivilli	0.023	0.000	0.000
			Drunella doddsi	0.023	0.000	0.000
			Drunella grandis	0.444	1.000	0.358
			Drunella spinifera	0.008	0.000	0.000
			Caudatella hystrix	0.023	0.000	0.000
			Attenella delantala	1.084	0.458	0.573
		Leptophlebiidae	Paraleptophlebia sp.	0.148	7.814	3.332
		Heptageniidae	Cinygmula sp.	0.281	6.543	14.618
			Rhithrogena sp.	0.514	0.021	0.000
			Epeorus sp.	0.000	0.021	0.000
		Ametropodidae	Ametropus sp.	0.016	0.000	0.000
		Ameletidae	Ameletus sp.	0.288	0.104	0.322
	Plecoptera	Chloroperlidae	Haploperla sp.	26.606	8.731	6.127
			Sweltsa sp.	0.343	1.334	0.752
		Capniidae	Capniidae undetermined	0.000	0.438	0.502
			Eucapnopsis brevicauda	1.871	1.021	3.153
		Nemouridae	Zapada sp.	0.016	1.021	0.000
		Peltoperlidae	Yoraperla sp.	0.078	0.063	0.358
		Perlodidae	Isoperla sp.	0.023	0.000	0.000
			Kogotus nonus	0.101	0.104	0.036
			Skwala sp.	0.070	0.167	0.215
		Perlidae	Calineuria californica	0.016	0.000	0.000
			Doroneuria baumanni	0.000	0.021	0.000
		Pteronarcyidae	Pteronarcys sp.	0.000	0.042	0.000
	Trichoptera	Rhyacophilidae	Rhyacophila acropedes grp.	0.117	0.083	0.107
			Rhyacophila arnaudi grp.	0.023	0.000	0.000
			Rhyacophila betteni grp.	0.016	0.021	0.000
			Rhyacophila sibirica grp. cf. valuma	0.016	0.000	0.000
			Rhyacophila vofixa	0.016	0.000	0.000
		Hydropsychidae	Hydropsyche sp.	0.008	0.042	0.000
			Ceratopsyche sp.	0.000	0.042	0.036
		Limnephilidae	undetermined large pupae	0.000	0.083	0.000
		Lepidostomatidae	Lepidostoma sp.	0.000	0.000	0.143
		Arctopsychidae	Arctopsyche californica	0.008	0.000	0.000
			Arctopsyche grandis	0.000	0.063	0.000
		Hydroptilidae	Hydroptila sp.	0.226	1.063	0.036
		Phryganeidae	Yphria californica	0.023	0.000	0.000
		Brachycentridae	Brachycentrus americanus	0.460	0.834	0.107
			Micrasema sp.	0.203	1.292	6.700
			Amiocentrus sp.	0.000	0.021	0.000
		Apataniidae	Apatania sp.	0.382	0.042	0.107
			Pedomoecus sierra	0.055	0.063	0.000
		Uenoidae	Neophylax sp.	0.195	0.000	0.000
		Glossosomatidae	Glossosoma sp.	0.296	0.229	0.179
	Coleoptera	Elmidae	Optioservus quadrimaculatus	2.362	2.188	10.211
			Heterlimnius corpulentus	0.140	0.000	0.000
			Lara avara	0.008	0.000	0.000
		Hydraenidae	Ochthebius cf. rectus	0.023	0.000	0.000
		Dytiscidae	Oreodytes rivalis	0.047	0.000	0.000
	Megaloptera	Sialidae	Sialis sp.	0.016	0.000	0.000
	Diptera	Tipulidae	Dicranota sp.	0.171	0.125	0.107
			Antocha sp.	0.000	0.021	0.000
			Hesperoconopa sp.	0.780	0.125	0.107
			Hexatoma sp.	0.826	0.125	1.075
			Limnophila sp.	0.000	0.104	0.107
			Rhabdomastix sp.	0.000	0.000	0.036
		Tanyderidae	Protanyderus sp.	0.008	0.000	0.000
		Empididae	Chelifera sp.	0.234	0.250	0.107
		Muscidae	Limnophora sp.	0.000	0.021	0.000
		Psychodidae	Pericoma sp.	0.109	0.668	0.752
		Simuliidae	Simulium sp.	0.023	1.229	0.215
		Ceratopogonidae	Bezzia-Palpomyia sp.	0.016	0.063	0.251
		Chironomidae- Diamesinae	Diamesa sp.	0.016	0.063	0.000
			Pagastia sp.	0.062	0.667	0.251
		Chironomidae- Prodiamesinae	Odontomesa sp.	0.039	0.000	0.000
		Chironomidae-Tanypodinae	Thienemannimyia sp.	4.514	2.063	1.433
		Chironomidae- Orthocladiinae	Corynoneura cf. lobata	0.016	0.042	0.143
			Cricotopus-Orthocladius spp.	12.067	6.230	4.264
			Cricotopus (Nostococladius) sp.	0.039	0.167	0.287
			Eukiefferiella claripennis grp.	0.000	0.542	0.143
			Eukiefferiella brehmi grp.	2.089	0.188	0.287
			Eukiefferiella gracei grp.	0.008	0.000	0.000
			Heleniella sp.	0.530	1.271	0.143
			Heterotrissocladius marcidus grp.	0.070	0.000	0.000
			Limnophyes sp.	0.008	0.104	0.000
			Lopescladius sp.	0.117	0.042	1.003
			Rheocricotopus sp.	0.023	0.125	0.107
			Nanocladius sp.	4.342	1.104	1.899
			Parametriocnemus sp.	0.023	0.250	0.179
			Paraphaenocladius sp.	0.000	0.021	0.000
			Psectrocladius psilopterus grp.	0.000	0.000	0.036
			Synorthocladius sp.	0.000	5.209	0.394

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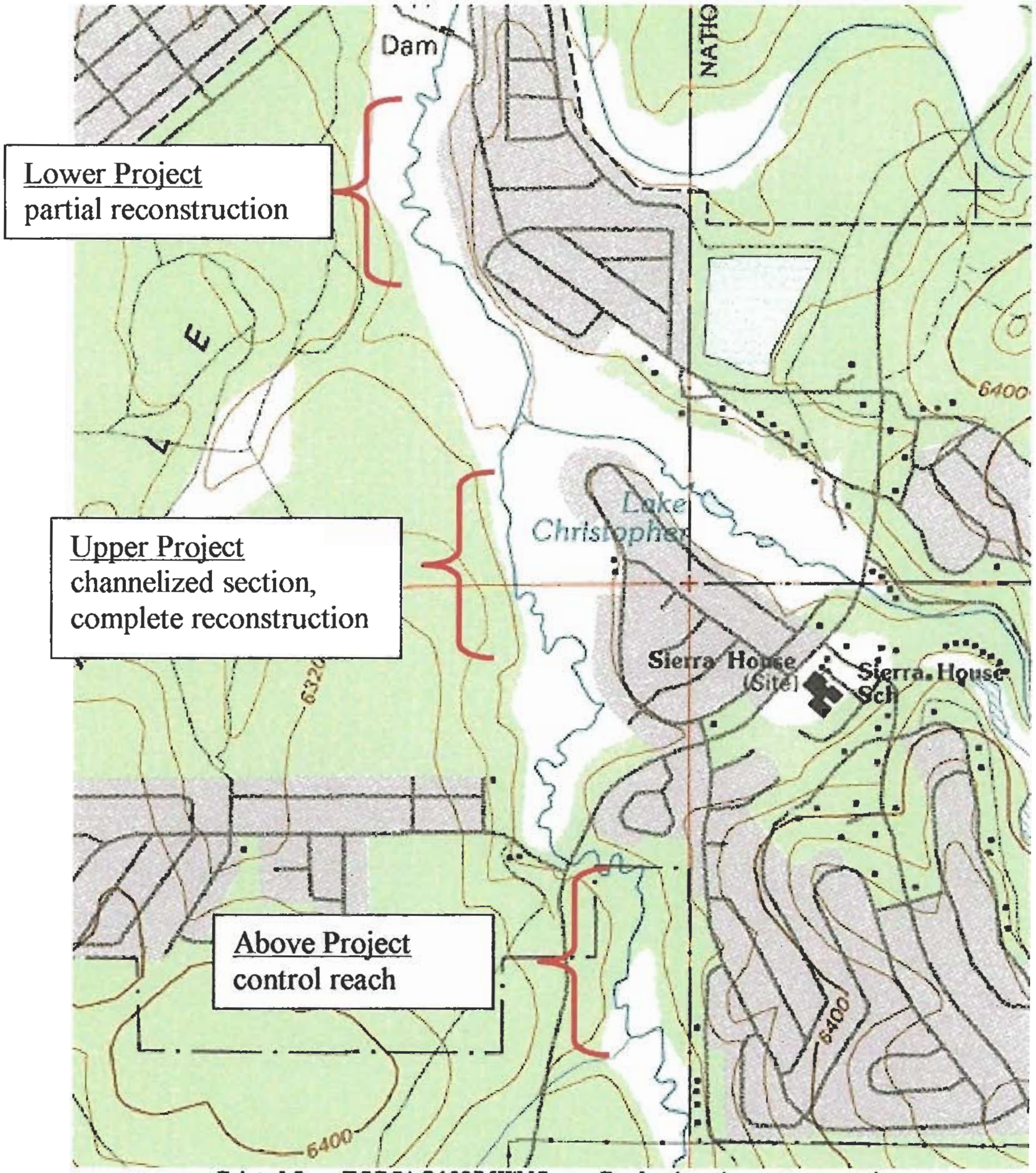
Phylum or Class	Class or Order	Family-Subfamily	Genus (and species)	Pre-Project PERCENT	Post-Project PERCENT	Above-Project PERCENT
			Thienemanniella cf. xena	1.107	3.480	1.254
			Tvetenia bavarica grp.	0.078	0.021	0.000
		Chironomidae-Pseudochironomi	Pseudochironomus sp.	0.008	0.000	0.036
		Chironomidae- Chironomini	Polypedilum cf. scalaenum	0.101	0.042	0.000
			Polypedilum aviceps	0.000	0.083	0.251
			Paracladopelma sp.	0.008	0.000	0.000
		Chironomidae- Tanytarsini	Micropsectra sp.	0.164	0.146	0.036
			Tanytarsus sp.	5.075	2.771	11.573
			Stempellinella sp.	0.117	0.021	0.179
			Stempellina sp.	0.000	0.063	0.000
			Rheotanytarsus sp.	0.008	2.375	2.938
			Cladotanytarsus vanderwulpi grp.	0.086	7.106	8.922
Arthropoda-Crustacea	Ostracoda	undetermined	undetermined ostracode taxa	0.437	0.125	0.466
Mollusca	Bivalvia	Sphaeriidae	Pisidium sp.	0.101	0.021	0.107
	Gastropoda	Planorbiidae	Gyraulus sp.	0.000	0.042	0.000
Annelida-Oligochaeta	undetermined	undetermined	undetermined oligochaete taxa	0.226	2.084	0.072
Turbellaria	Tricladida	Planariidae	Dugesia tigrina	0.320	0.042	0.000
Coelenterata	Hydroida	Hydridae	Hydra sp.	0.000	0.042	0.000
Arachnoidea	Trombidiformes	Sperchonidae	Sperchon sp.	0.039	0.021	0.036
			Sperchonopsis sp.	0.000	0.000	0.036
		Aturidae	Aturus sp.	0.257	0.313	0.430
			Ljania sp.	0.000	0.000	0.036
		Feltriidae	Feltria sp.	0.000	0.000	0.036
		Protziidae	Wandesia sp.	0.000	0.000	0.036
		Hygrobatidae	Hygrobates sp.	0.055	0.042	0.000
			Atractides sp.	0.078	0.250	0.215
		Lebertiidae	Lebertia sp.	0.624	2.917	2.365
		Torrenticolidae	Torrenticola sp.	0.101	0.000	0.215
			Testudacarus sp.	0.000	0.292	0.645
	Oribatida	Eremaeidae	Hydrozetes sp.	0.008	0.000	0.000
		undetermined	undetermined water mites	0.008	0.042	0.036



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TROUT CREEK RESTORATION MONITORING STATIONS