Biomonitoring on the Upper Truckee River
Using Aquatic Macroinvertebrates:
Watershed Restoration Baseline Data for 1998-2000

Final Report
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Introduction

Increased sediment inputs to Lake Tahoe have been linked to increased algal growth and declining water clarity in this large oligotrophic mountain lake. Potential sediment sources include stormwater erosion from roads, ski slopes, residential and commercial developments, and erosion from unstable stream banks along sections exposed to channelization or other landscape disturbances. Many projects have been initiated to reduce sediment inputs from these sources.

The Upper Truckee River is the largest single source of stream-transported sediment to Lake Tahoe, delivering about eight tons of suspended sediment per day (median value of observations; Boughton et al. 1997). Coordinated efforts within the watershed of the Upper Truckee River are underway to control sedimentation through improved land use management and land acquisition to protect and enhance wetlands and riparian zones. In order to document the progress of stream restoration associated with these efforts, it is necessary to establish baseline ecological conditions and to measure changes over time and along the course of the river. These surveys describe the longitudinal or downstream changes in aquatic habitat conditions along the main stem of the river from Christmas Valley to South Lake Tahoe. The studies occurred during a period of changing stream flow, from above to below average run-off over 1998-2000. The data provide a basis for future contrasts of changes in habitat, water quality and aquatic biological integrity in the Upper Truckee River.

History of Watershed Restoration Efforts

As the largest tributary and contributor of sediment to Lake Tahoe, the Upper Truckee River has been the focus of much attention and management activity. Numerous public agencies and other stakeholders have funded and/or implemented restoration efforts within the river's watershed, and many additional projects are being planned. Past projects have included reconstructing stream channels to restore/mimic natural conditions, obliterating unneeded roads and constructing erosion control and infiltration facilities along remaining roads, retrofitting existing commercial and residential structures with stormwater controls, implementing improved livestock management (e.g., riparian pasture fencing, rest-rotation grazing systems, exclusion of livestock from sensitive areas), installing erosion control measures at recreation sites/areas, and reducing fuel loads in forested areas deemed unsafe or “unhealthy” in order to minimize the adverse watershed effects of severe wildfire.

The Tahoe Regional Planning Agency maintains the best-available summaries of the watershed restoration projects completed to date. For more information, see Tahoe Regional Planning Agency (1999, 2001, in press).

Background on Biological Monitoring

Aquatic invertebrates are common inhabitants of the stream bottom environment. Insects are the main types present, and commonly include mayflies, stoneflies, caddisflies, and true flies. Non-insect invertebrates include snails, leeches, worms, and scuds. Aquatic insects and other invertebrates are central to the proper ecological functioning of streams and surrounding terrestrial environments. These creatures consume decomposing organic matter (detritus, wood and leaf debris) and attached algae, and in turn become an important food resource to wildlife such as fish and riparian birds. In addition to their role as a food chain link, aquatic invertebrates also have varying degrees of ability to withstand environmental degradation and so may be used as indicators of water quality and habitat condition. For example, sediments from erosion may decrease the variety of insects and other invertebrates that are able to survive and so indicate a loss of biological health.

Use of the stream invertebrate fauna to gauge biological stream health is known as bioassessment. This technique uses collections of the bottom-dwelling (or benthic) organisms to detect changes in stream health based on the number of different types (diversity), and how tolerant they are of environmental impacts and pollution (sensitivity). Monitoring stream invertebrates in comparison to reference sites (areas having little or no impact but similar physical setting) and/or over time at targeted sites then permits an estimate of impact to aquatic systems or recovery in response to changing land use. Bioassessment may be used together with other more traditional stream channel and riparian monitoring methods to provide a tool that measures the response of stream life to habitat changes. When pollution does not originate from a single point ("nonpoint"), it can be difficult to characterize accurately using chemical methods alone, because this type of pollution usually does not occur continuously and could be missed in any given water sample. Problems may also exist upstream of a location and not be reflected in the channel or riparian conditions at that site. The advantage of using stream invertebrates is that they live in the stream and experience everything that flows over and around them and so incorporate and embody changes in water quality that occur in both local and upstream areas of the watershed. Another advantage of bioassessment is that once baseline conditions over a period of years and locations have been established, repeated sampling can be done with less frequency to document future changes.

Field and Laboratory Methods for Collection of Data

Sites were selected along the main stem of the Upper Truckee River to represent differing physical habitat conditions and restoration activities that may respond to watershed management to varying extents (Figure 1, map). Comparison of these sites will permit localization of downstream changes in biological conditions, and over time will enable an assessment of the relative effectiveness of restoration measures.

Baseline studies were conducted at eight sites during late September of 1998-2000 (the two lower sites sampled in all three years, the six upper sites in 1999-2000 only). The data gathered consisted of physical habitat surveys and biological sampling of benthic macroinvertebrates. Each site was defined as a 150-meter length study reach, located by GPS-UTM coordinates and elevation (near lower end of each site). The longitudinal distribution and length of riffle and pool habitats were first defined, then used to determine random sample locations for benthic macroinvertebrates from riffle habitat. Slope of the reach was measured with an autolevel and stadia rod, and sinuosity was estimated from aerial photographs of 500-1000 meters of stream length centered on each study reach. Physical habitat was measured over the length of each reach along 15 transect cross-sections spaced at 10 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 from vegetation reflected on a grid in a concave mirror densiometer (sum of grid points for measurements taken at each stream edge and at mid-stream facing up- and downstream). The type and amount of riparian vegetation along the reach was also estimated by qualitative visual evaluation. The embeddedness of cobble size substrate was estimated as the volume of the rock buried by silt or fine sand for 25 cobbles (encountered during transect surveys or supplemented with random selected cobbles). 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 and related measures consisted of dissolved oxygen, conductivity, pH, temperature, and turbidity. Documentation also included photographs taken at mid-stream looking upstream at 0, 50, and 100 meters, and downstream at 150 meters. Biological sampling consisted of 5 replicate benthic samples taken in riffle zones with a 30-cm wide D-frame kick-net. Each replicate was comprised of a composite of three 30x30 cm sample areas taken across the riffle transect or over riffle areas of varied depth, substrate and current. This composite of microhabitats provides a more representative sampling and reduces the variability among replicate samples. Samples were processed in the field by washing and removing large organic and rock debris in sample buckets followed by repeated elutriation of the sample to remove invertebrates from remnant sand and gravel debris. Remaining debris was inspected in a shallow white pan to remove any remaining cased caddisflies (e.g., Glossosomatidae), snails or other molluscs. Elutriated and inspected sample fractions were then preserved in ethanol, and a small volume of rose bengal stain was added to aid in lab 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). 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.

The benthic food resources of stream invertebrates were also quantified by sampling 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 was quantified by scrubbing attached algae off rock surfaces using a wire brush, homogenizing the algae removed using a large syringe, and subsampling the homogenate for (a) chlorophyll-a by filtration through 1-micron pore-size glass fiber filters, and (b) archival of algae for cell counts and taxonomic identifications (preserved in formalin and Lugol's stain). This was performed on three replicate cobble-size rocks from mid-stream riffle habitats. 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 stored frozen filters in ethanol and reading light absorbance of the extract in a fluorometer relative to a standard curve.

For full documentation of the field and laboratory methods used in these surveys and outlined in this report, refer to the Quality Assurance Project Plan (QAPP) for Aquatic Macroinvertebrate Bioassessment Monitoring in the Eastern Sierra Nevada developed by D.B. Herbst (U.C. Sierra Nevada Aquatic Research Laboratory) for the Lahontan Regional Water Quality Control Board (Herbst, 2001; unpublished).

Monitoring Results and Trends in Stream Habitat and Biological Indicators

Interpretation of results from this study of baseline conditions emphasizes contrasts of sites between years and along the downstream river gradient because the expected or potential communities of unimpaired reference streams were not evaluated.

Over the three-year period of the study, the flow regime of the Upper Truckee River was changing from above- to below-average discharge conditions. Flows monitored at USGS gauging station #10336610 averaged 105 cubic feet per second (cfs) over the period 1972 to 2000 (ca.water.usgs.gov/data/ records by year for network of sample stations in state by station number). Average mean streamflow in 1998 was 146 cfs, 122 cfs in 1999, and 78 cfs in 2000. This represents a range from about 40% above, to 25% below average. Changes over time and between sites along the course of the river were apparent also in differences observed in physical habitat features. Decreasing flows were evident not only in lower instantaneous discharge observed at most stations (Figure 2) but also in reduced stream width (Table 1). Increasing conductivity (Figure 3) showed the increasing contribution of groundwater inputs as surface run-off declined over the years, and in the downstream section of the river below its upper crossing of Highway 50 (refer to map, Figure 1).

Primary substrate size distribution was stable for each station between years (Figure 4) but substrate cover changed substantially in the form of increased detritus-silt deposition during the low flows of 2000 (Figure 5). Habitat changed most along the gradient of sampling stations below the upper crossing of Highway 50. Upstream of this location the channel had more riparian vegetation cover (see Riparian Index and % Riparian Cover of Table 1), less bank erosion (see % Eroded Bank of Table 1), less embedding (burial) of cobble by fine and sand substrates (see cobble embeddedness and % free cobble of Table 1), and more cobble and boulder substrate type comprising streambed (Figure 4). The channelized Barton Meadows sites, and Sunset Stable sites just above, had the smallest particle size distributions (gravel and sand dominant, Figure 4). The Barton Meadows sites also had extensive bank erosion (Table 1) and flow status filled only a limited portion of the wide channel (refer to photo-point documentation). Food resources available to invertebrates also differed along the gradient and tended to be dominated at the more wooded upstream stations by coarse particulate organic matter (decomposing leaf and wood substrate, see CPOM of Table 1), and by algae in the downstream sites that are less shaded (see periphyton of Table 1).

Monitoring of the benthic invertebrate community showed slight increases in overall diversity across all sites from 1999-2000, and greater diversity on the upper sites compared to the lower sites (Figure 6). Diversity of sensitive EPT taxa at the upper four stations all had a mean of 20 or more, and dropped below 20 taxa in the lower four stations, falling to a minimum of 10 at the Barton Lower station (Figure 7).

The biotic index is an indicator of the composite tolerance of the community to degradation, and generally increases with exposure to impaired or polluted conditions. In this study, the biotic index values were highest at the two Barton Meadows stations, though the index declined here over time. At the other sites, the biotic index values were lower and more stable year-to-year, except at State Park, where the index increased from 1999 to 2000 (Figure 8).

Intolerant taxa (sensitive organisms with low tolerance values) are more frequent in the upper four sites than the lower four, where these taxa continued to decline with distance downstream (Figure 9). This was accompanied by a greater fraction of tolerant taxa (those with high tolerance values) appearing in the Barton Meadows stations, but these also decrease over the 1998-2000 period (Figure 10).

The three taxa most dominant in the benthic communities from one year to the next at each site are shown in Table 2. This provides an indication of stability in community structure over time. Two of three or all three taxa are the same in all sites above Barton Meadows except State Park, while the Barton stations show only one to two in common at the Upper site, and one or none in common at the Lower site.

Filter feeders utilize suspended particles of organic matter as a food supply, removing these particles from the current by a variety of filtration adaptations. Four of five of the sites downstream of the upper crossing of Highway 50 show an increase in the fraction of filter feeders in the community (from 1998 to 2000 at the Barton Meadows stations, and from 1999 to 2000 at the Sunset Lower and State Park stations; Figure 11). The deposition of detritus and silt observed in 2000 is consistent with an increased accumulation of fine organic particles, much of which may have settled because low current velocity failed to transport this material downstream. Filter feeders such as the chironomid *Rheotanytarus*, which became abundant in 2000, utilize such detritus particles both as a food resource and to construct cases. The upstream stations did not show an increase in filter feeders even though detritus cover was also increased.

Interpretation of Data and Conclusions

Several indicators of biological integrity declined along the downstream series of sample stations on the river. The most pronounced changes occurred between the group of 3 stations above the upper crossing of Highway 50, and those below. The furthest downstream sites, located in Barton Meadows, were distinguished by the poorest conditions of habitat and ecological health. Sites above the upper crossing of Highway 50 were similar in having higher levels of biological diversity and little change between years. The Barton Meadows sites showed lower diversity, and substantial shifts in community structure between years. The general downstream trend can be summarized as a loss of diversity, sensitive organisms, and community stability.

Differences between stations were consistent with changes in the environmental setting of the habitats. The three upper sites were relatively undisturbed reaches while the others have been exposed to a history of more intensive land use and disturbance of bank and channel conditions. The lower Barton Meadows sites, adjacent to the airport, have been channelized and possess consistently poorer habitat (e.g., more eroded banks and smaller substrate sizes). Biological conditions on the upper three sites showed greater diversity, especially among the sensitive mayfly-stonefly-caddisfly groups (EPT taxa), and lower biotic index values (also associated with fewer tolerant taxa and more frequent presence of sensitive taxa). With progress downstream, these measures of biological integrity deteriorate somewhat, especially on the lowermost Barton Meadows sites. The composition of communities was also more stable at the upstream stations, as shown in the identities of dominant taxa at each station between years (Table 2). While the Barton Meadows sites showed less stability, they showed improvement in biological conditions over the 1998-2000 period. Habitat in a channelized stream reach may be less stable under high flow conditions because there is more erosive disturbance of streambed substrates, increased sediment movement, increased transport of organic matter resources out of the system (and little capacity for retention in an open, straight channel), and greater exposure of shallow streambed as flows recede. The low flow conditions during 2000 may thus have enhanced food resource availability in the form of retained detritus (Figure 5), permitting development of more abundant and diverse populations of organisms that feed by filtering and collecting organic particles (seen in Figure 11).

Food webs in streams often display a transition from riparian litter dominance of food resources in upstream areas to algal dominance in downstream areas with more open canopy and streambed exposed to sunlight supporting photosynthesis. The upstream stations contained greater amounts of coarse particulate organic matter (decomposing leaf and wood matter) while the sites with open canopy showed higher periphyton densities (as chlorophyll-a, Table 1). Despite an increase in fine detritus particle cover in 2000, CPOM still appeared to dominate the food resources at upstream locations. Though filter-feeding organisms did not increase at the upstream stations, an increase in diversity at all stations from 1999 to 2000 suggests that reduced flow conditions may have been favorable for all organisms and food resource conditions (note that aquatic vegetation, leaves, and wood also increased in 2000 relative to 1999, Figure 5).

This baseline data set may be applied as a contrast for the monitoring of future conditions along the Upper Truckee River. Land management effectiveness along the river and planned restoration of the channelized section in Barton Meadows may be evaluated in terms of improvements in the biological indicators documented here. This study should provide an adequate representation of the natural range of variability in aquatic invertebrate communities between years because it was conducted over a period of above- and below-average flow regimes. Provided that within-station contrasts are conducted at the same time – late summer to early fall baseflow conditions (late September) - changes over time may be established relative to the baseline range of the indicators. Without reference streams to serve as a basis for identifying target levels for biological indicators, the changes that will signify enhancement or recovery of ecological status will be qualitative and expected to occur in successive stages:

Indicator	Qualitative change in value expected with restoration	Stage of recovery
Total diversity	Increase	Early
EPT diversity	Increase	Late
Community stability	Increase	Late
Biotic Index	Decrease	Early
Frequency of intolerant taxa	Increase	Late
Frequency of tolerant taxa	Decrease	Early
Dominance of taxa	Decrease	Early

A regional reference stream database is currently under development for the Lahontan Regional Water Quality Control Board (Herbst, in progress since 1999). This may provide a context for establishing quantitative targets for the stream locations sampled in these surveys by comparison to streams of similar size with minimal watershed land use impacts. Until such reference stream standards are available, qualitative changes in the indicators above can be used as guidance for evaluating the progress of restoration. It may be expected that physical changes will accompany restoration of lower reaches of the Upper Truckee River. These changes may include increased substrate particle size (less sand and fines), decreased bank erosion, reduced channel width, increased riparian cover, increased channel sinuosity, and greater heterogeneity of habitat structure (e.g. frequent riffle and pool alternation, retention structures such as large wood debris and rock, variety in depth-substrate-velocity profiles across the channel). The benthic invertebrate community is expected to respond to such habitat improvements, progressing in early stages from a low diversity assemblage of taxa to one with more taxa (species) distributed more evenly (dominant taxa reduced in abundance; more balance in feeding groups) and containing fewer pollution-tolerant representatives. In later stages the community may become more stable in year-to-year composition, acquire more sensitive taxa such as the mayfly-stonefly-caddisfly complex, and yield lower biotic index values. Reduced inorganic sediment deposition through erosion control management should eventually produce stream-bottom invertebrate communities with measurably enhanced ecological integrity on the lower portions of the Upper Truckee River.

Acknowledgements

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TABLE 1. Habitat Features	Barton Lower	Barton Upper	Sunset Lower	Sunset Upper	State Park	Celio Lower	Celio Upper	Forest
Mean Width change (cm)	1127 - 885	927 - 847	948 - 904	949 - 929	1016 - 921	808 - 736	841 - 813	931 - 737
Mean Depth change (cm)	23 - 21	26 - 25	22 - 22	29 - 22	24 - 26	30 - 21	36 - 29	25 - 26
Mean Velocity change (cm/s)	11.7 - 18.8	6.7 - 9.2	23.1 - 8.1	16.8 - 7.0	6.5 - 11.6	21.0 - 9.6	10.2 - 7.0	5.0 - 7.0
Sinuosity	1.19	1.04	1.3	1.18	1.03	1.26	1.26	1.25
Elevation (ft)	6210	6220	6230	6240	6280	6350	6360	6500
GPS northing UTM	4311000	4310500	4308133	4307598	4305609	4302840	4302505	4298016
GPS easting UTM	11240600	11240500	11240017	10760063	10758305	10758530	10758530	10759050
Slope (%)	0.20	0.20	0.18	0.18	0.19	0.44	0.33	0.19
Riparian Index Range (of 18)	6 - 7.5	5 - 5	6 - 6.5	6 - 9.5	10 - 10	13 - 13.5	7 - 10	14 - 15.5
%Riparian Cover (avg.)	10.7	12.0	8.5	18.5	9.0	38.0	24.0	55.0
%Eroded Bank (avg.)	54	65	30	24	7	7	7	2
%Cobble Embeddedness (avg.)	16.9	12.9	16.0	14.1	20.1	5.5	11.9	13.4
% Free Cobble (avg.)	52.0	60.0	50.0	62.0	52.0	82.0	74.0	68.0
FPOM (g AFDM/m^2) 99-00	2.35 - 0.5	0.26 - 0.38	1.39 - 0.67	0.59 - 1.36	0.58 - 1.55	0.79 - 0.56	1.39 - 1.32	1.23 - 0.69
CPOM (wet g/m^2) 99-00	10.4 - 5.3	12.0 - 12.0	30.0 - 12.7	9.7 - 6.7	29.2 - 9.9	29.3 - 119.3	43.0 - 22.7	421.3 - 81.3
Periphyton Chl a (ug/cm^2) 99-00	3.29 - 0.16	0.78 - 0.39	1.3 - 1.22	0.36 - 0.26	0.9 - .74	0.32 - 0.57	0.56 - 0.65	0.32 - 0.35

Summary of habitat features for Upper Truckee River monitoring stations. Changes from 1999 to 2000 surveys (late September) are shown for mean width, depth, and current velocity; and for fine and coarse particulate organic matter (FPOM-CPOM) and algal periphyton chlorophyll density on rock surfaces. Averages over all years of surveys at each site are shown for the riparian index, % riparian cover, % bank eroded, % cobble embeddedness and percent free cobble.

Table 2. Changes in Dominant Taxa on the Upper Truckee River
(three most abundant taxa in each site by year – community stability indicator)

SITE:	1998	1999	2000
Barton Lower	Eurycercus sp. Thienemannimyia grp. Lepidostoma sp.	Cladotanytarsus vanderwulpi grp Lepidostoma sp. Cricotopus-Orthocladius spp.	Baetis sp. Serratella sp. Simulium aureum
Barton Upper	Tricorythodes sp. Optioservus quadrimaculatus Serratella sp.	Baetis sp. Cricotopus-Orthocladius spp. Serratella sp.	Baetis sp. Serratella sp. Paraleptophlebia sp.
Sunset Lower		Serratella sp. Cinygmula sp. Optioservus quadrimaculatus	Serratella sp. Optioservus quadrimaculatus Rheotanytarsus sp.
Sunset Upper		Serratella sp. Cinygmula sp. Optioservus quadrimaculatus	Serratella sp. Optioservus quadrimaculatus Cinygmula sp.
State Park		Cinygmula sp. Serratella sp. Cricotopus-Orthocladius spp.	Rheotanytarsus sp. Baetis sp. Cricotopus-Orthocladius spp.
Celio Lower		Cinygmula sp. Baetis sp. Serratella sp.	Cinygmula sp. Serratella sp. Baetis sp.
Celio Upper		Cinygmula sp. Rhithrogena sp. Serratella sp.	Cinygmula sp. Baetis sp. Serratella sp.
Forest		Baetis sp. Micropsectra sp. Stempellinella sp.	Caudatella heterocaudata californica Baetis sp. Stempellinella sp.

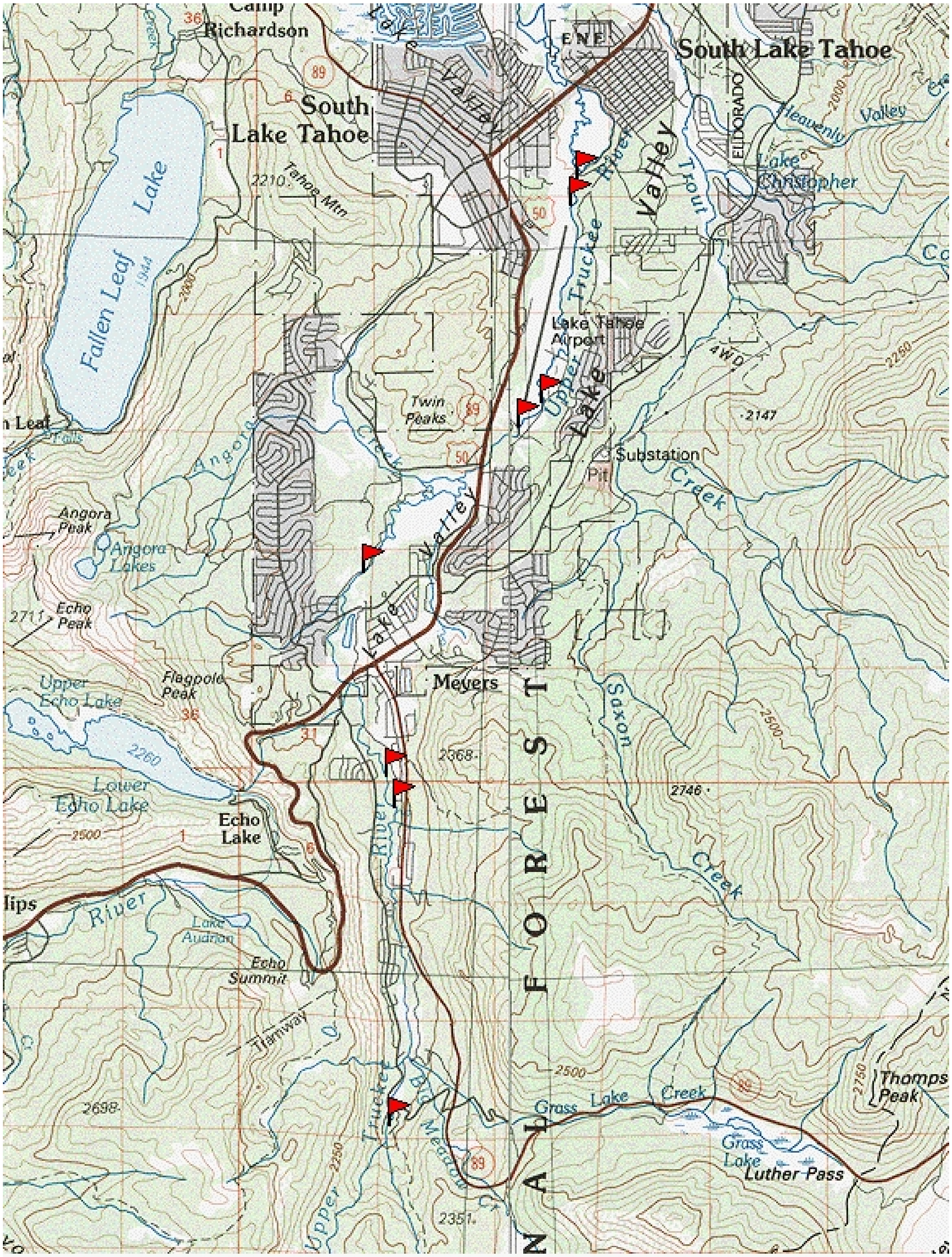

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Figure 1. Location of bioassessment monitoring stations along Upper Truckee River. Flags indicate stream reaches surveyed in 1998 to 2000.

Figure 2. Estimated Late September Discharge: Upper Truckee River Monitoring Stations

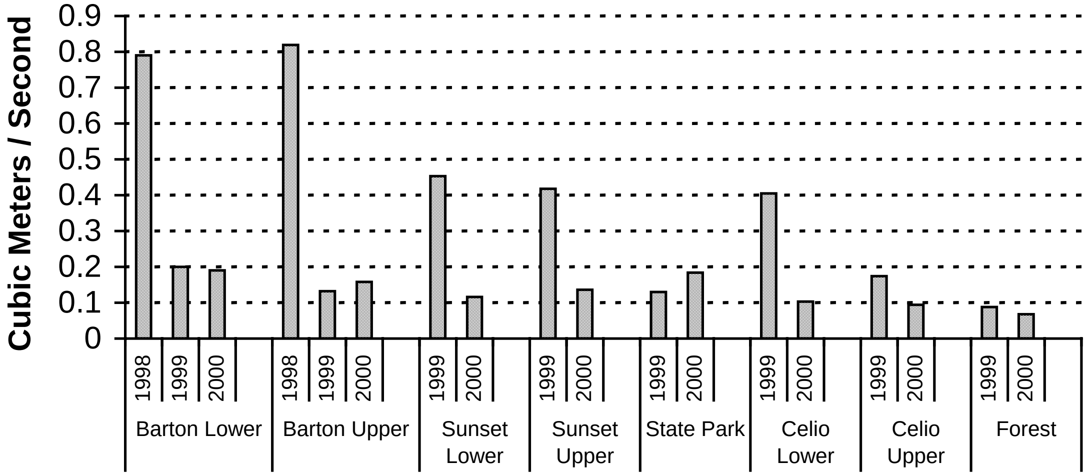


Figure 3. Conductivity: Upper Truckee River Monitoring Stations

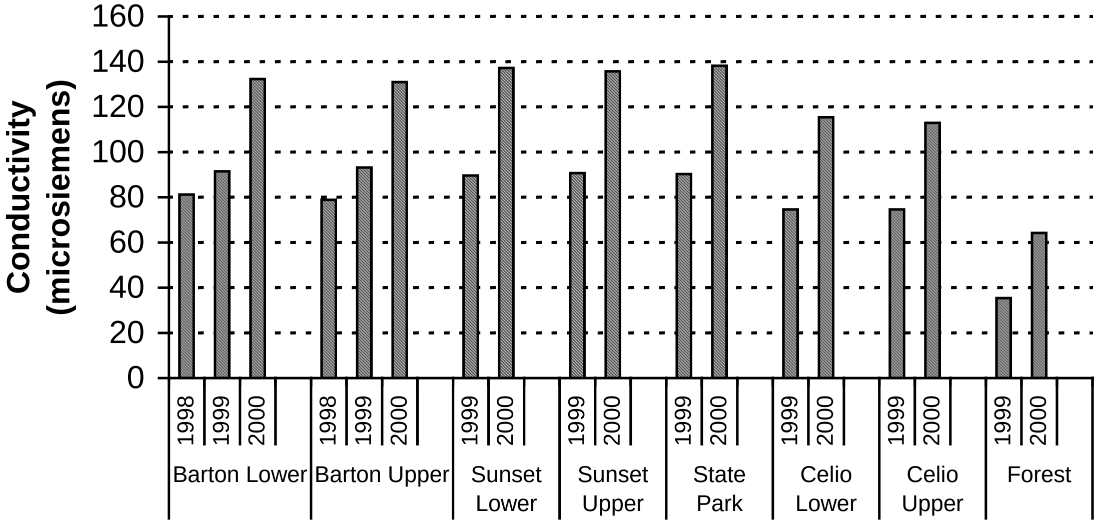


Figure 4. Substrate Composition: Upper Truckee River Monitoring Stations

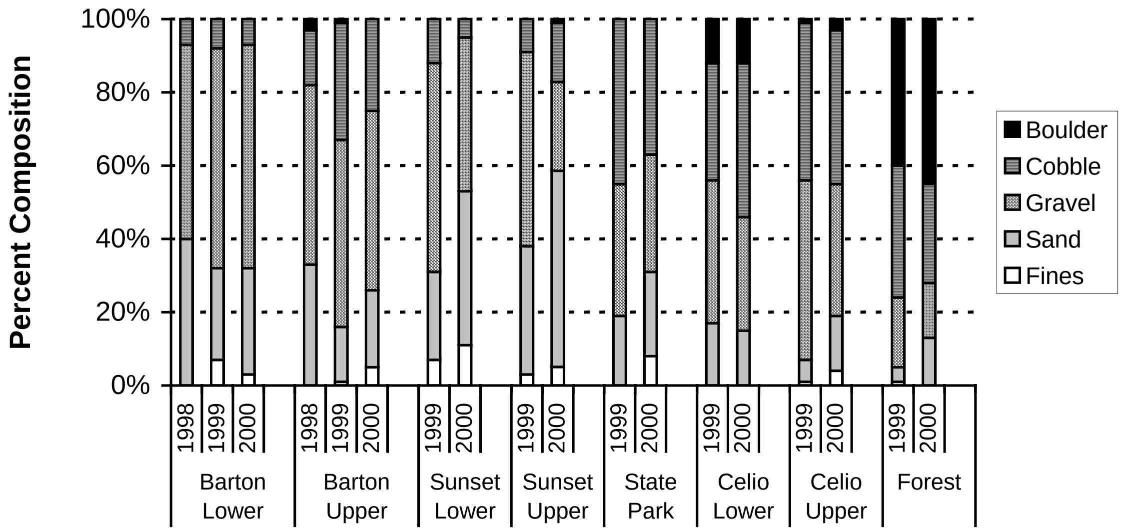
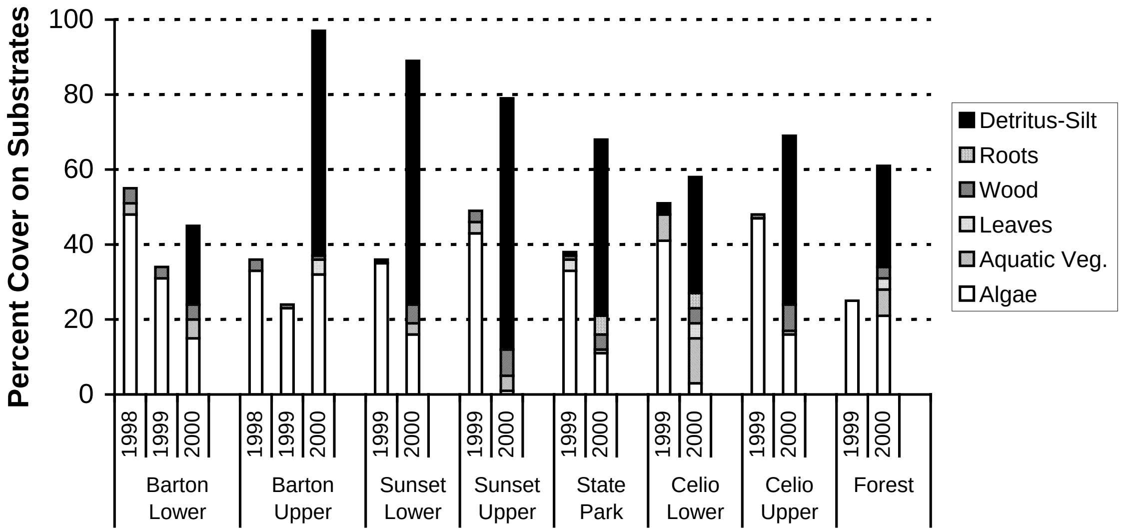


Figure 5. Substrate Cover: Upper Truckee River Monitoring Stations



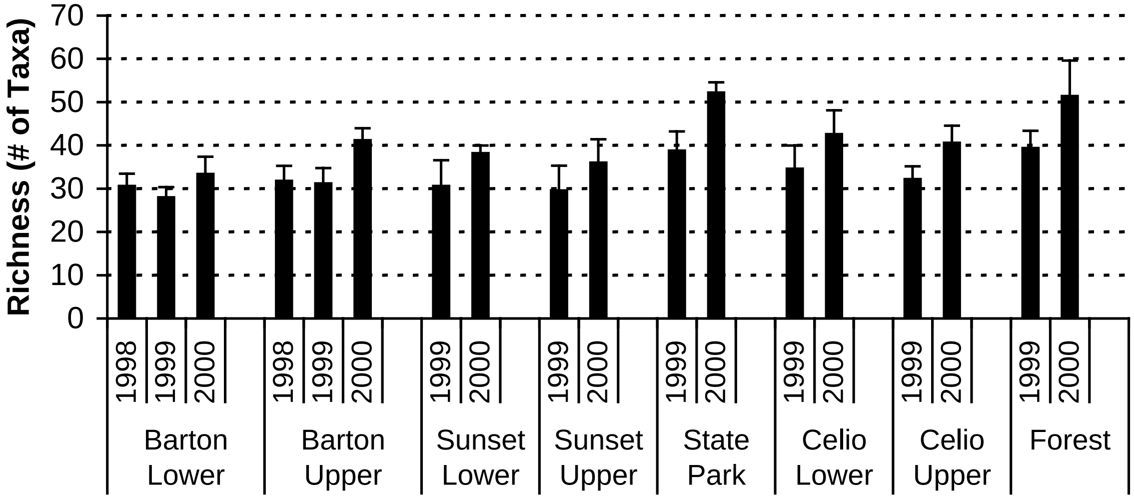


Figure 6. Upper Truckee River:
Taxa Richness (Diversity) at Monitoring Stations

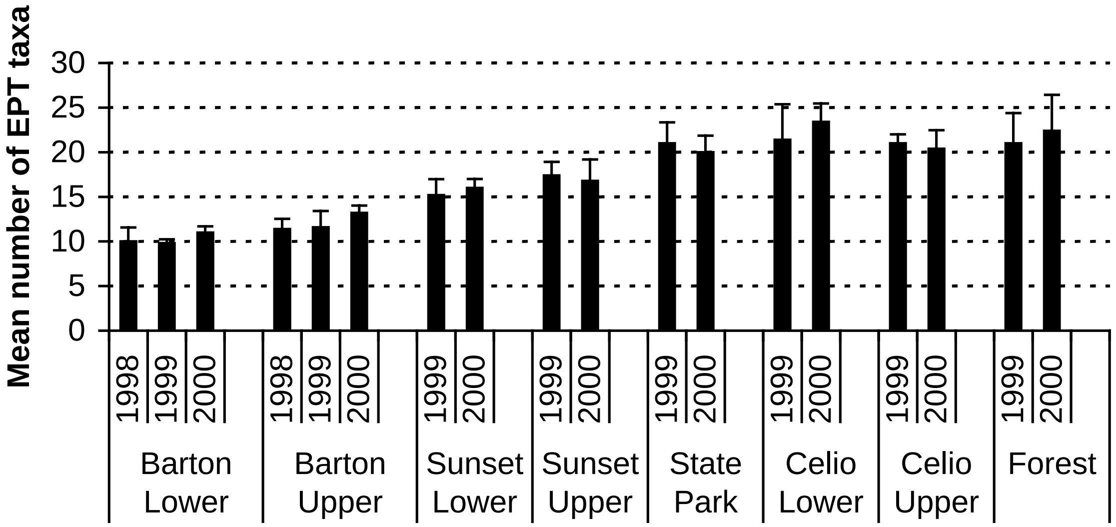


Figure 7. EPT Taxa Richness:
Upper Truckee River Monitoring Stations

Figure 8. Biotic Index: Upper Truckee River Monitoring Stations

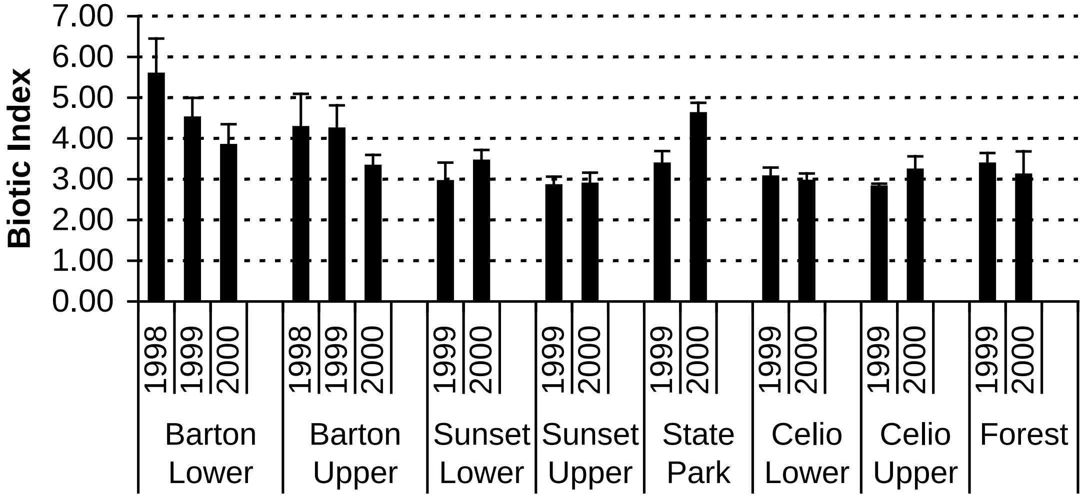


Figure 9. Sensitive or Intolerant Taxa: Upper Truckee River Monitoring Stations

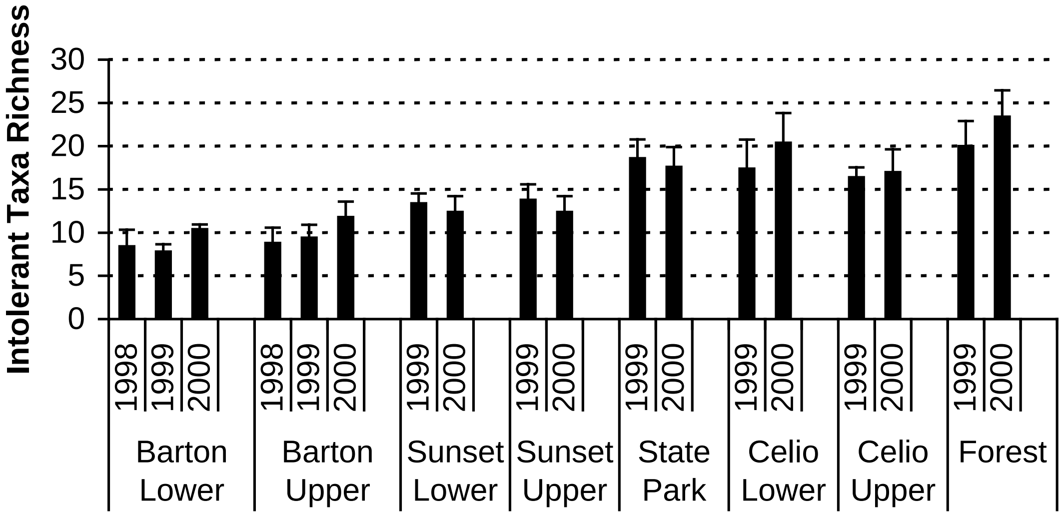


Figure 10. Percent Tolerant Organisms in Community: Upper Truckee River Monitoring Stations

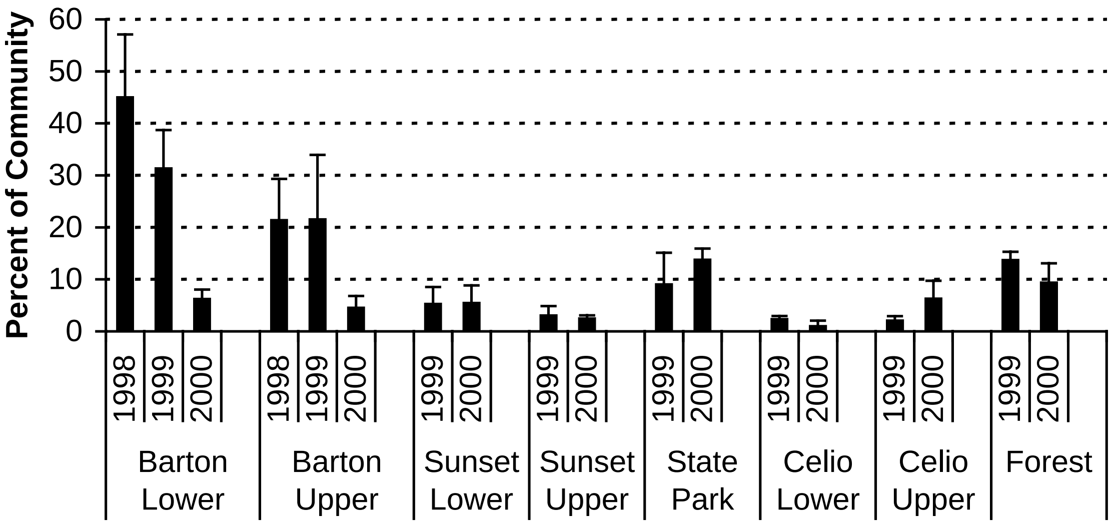


Figure 11. Percent Particulate Filter Feeders: Upper Truckee River Monitoring Stations