Use of benthic invertebrate biological indicators in evaluating sediment deposition impairment on the Middle Truckee River, California

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Introduction and Background

Sediment pollution of the Middle Truckee River (Lake Tahoe outflow to California-Nevada state line) from a variety of different land uses, including road and urban development, gravel mining, timber harvest, and natural sources, has resulted in listing as an impaired water body (303(d) list) and the need to develop a Total Maximum Daily Load for guidance on how much siltation impairs beneficial use values of the river.

Cold water habitat is one beneficial use on the Middle Truckee River, and one way of defining impairment to the quality of this habitat condition is as impairment to resident aquatic life. Stream invertebrate communities reside on the bottom substrates or stream bed, and are sensitive to the amount and type of fine sediments that accumulate in these habitats. These organisms are appropriate as indicators of ecological health and biological integrity as they are native organisms, diverse, perform a variety of ecological roles and services in converting algae and organic matter to food for fish and riparian wildlife, and have been used extensively in the assessment of water quality throughout North America and in the local drainages of the Truckee River. These organisms may be used to define the quantities or coverage of sediments that impair ecological health relative to regional standards that have been developed for the eastern Sierra Nevada.

Sediments are transported during high flow events of snowmelt and storms, and deposited as flows decline. In order to be able to characterize the effects of sediment deposition, sampling during September low flows would best represent exposure of the benthic invertebrate community to bedded sediments. Even though the Middle Truckee River is larger than most streams used to develop eastern Sierra Index of Biological Integrity (IBI) data set, there are some large rivers in this region that are comparable: the West Walker, West Carson, East Carson Rivers, and Markleeville Creek. One context then, in which to view the Middle Truckee (MT), is to compare the IBI scoring of these reference rivers where less catchment disturbance and sediment loading occurs relative to locations on the MT where sedimentation is suspected of being a problem. These rivers may serve as references appropriate to the Middle Truckee in terms of being closer in watershed area, channel size, and discharge than most reference streams that were used to develop the Eastern Sierra IBI.

In addition to contrasting the MT to regional reference streams, reaches within this section of river having differing sediment mobility and geomorphic stability can be compared. Balance-Hydrologics has been characterizing sections of the MT according to these criteria, so 2 segments of the MT with adjacent mobile and immobile reaches were compared using both RWB and TR samples within those areas (at the Fly Fishing Club, and at Horseshoe Bend (above and below Hwy 80 bridge crossing).

Comparing sample methods is yet another way of evaluating sediment deposition effects because TR collections in erosional riffles should have less sediment cover than those from the mixed habitat RWB collections that cover all habitat types including depositional zones where sediments may accumulate.

Methods

Sampling was conducted under low flow conditions in late September of 2010. In conjunction with Balance Hydrologics, two river segments were selected for study – at the Fly Fishing Club, and at Horseshoe Bend (above and below the crossing of Highway 80). Within each segment two reaches of geomorphic stability were characterized as either mobile or immobile. These refer to long-term geomorphic stability of these reaches – immobile areas having boulders and other large substrates that do not move under most flow condtions, and mobile areas where smaller substrates including sediments (fines and sand particles less than 2 mm) may be more easily mobilized under moderate flows. These mobile zones may often be depositional areas as well. In addition to these 4 survey reaches on the Middle Truckee, large-stream reference reaches were selected on the East Carson River (below Monitor Creek), Markleeville Creek (below Markleeville), the West Carson River (below Willow Creek, Hwy 88/89 junction), and the West Walker River in the middle area of Walker Canyon. Each sample reach was selected to conform to a similar range of channel gradient (<2%).

Several bioassessment survey protocols were used to provide a comprehensive data set - the Reachwide Benthos (RWB) and Target Riffle (TR) approaches. The RWB is the standard method of the State Surface Water Ambient Monitoring Program (SWAMP), and the TR method was used to develop the eastern Sierra IBI, and has been used widely by the Forest Service and EPA. At each of 8 sites (4 on the Middle Truckee and 4 from each of the large reference streams), both RWB and TR samples were collected, and compared using the multiple metric IBI developed for the Eastern Sierra (Herbst and Silldorff 2009). For this report and others, see:
http://www.swrcb.ca.gov/rwqcb6/water_issues/programs/swamp/index.shtml

Results

Expected differences:

- Defining expectations for the Middle Truckee – compare to regional large-river reference (less disturbed) reaches:
  East Carson, West Carson, Markleeville Creek, and the West Walker >>predict Reference sites exceed MT test reaches in diversity and IBI scores
- Within selected reaches of the Middle Truckee, contrast sections of immobile-stable substrates with adjacent mobile-instable sections (geomorphology defined by Balance Hydro) >>predict lower integrity in mobile areas of instability assuming these reaches/substrates are less suitable for survival or are areas where sediments collect
- Compare samples taken from erosional riffle habitats to those from mixed-habitats >>if deposition is extensive, predict that erosional habitats will have better BMI performance, but if not, then mixed habitat samples should be more diverse (microhabitat variety fosters biological variety)

Observed differences:

- Collectively the sites selected on the Middle Truckee were below the threshold (63.2) indicating poor or impaired condition not supporting of reference-class biological integrity, and the group of large-size regional reference rivers selected not only were above the impairment threshold, they were just above the threshold for best biological integrity among reference streams (80.4) – Figures 1, 2 and 3 (sites and group means).
- Comparing adjacent immobile to mobile stream reaches, within sample types, the diversity and IBI scores of mobile reaches were inferior to immobile reaches in 3 of 4 cases, and near-equal in the 4th case (76.2 compared to 76.9 for Horseshoe Bend RWB) – Figures 1 and 4.
- In all cases, both in the MT and regional references, the mixed-habitat RWB samples had greater diversity and IBI scores than TR samples – Figures 1 and 5.

Discussion and Conclusions

The goal of this project is to determine whether there is biological impairment of the Middle Truckee River by sedimentation. While the preliminary results shown here do show that the MT sites surveyed, on average, are impaired by the standards of the Eastern Sierra IBI, this does not distinguish the role of sediments in producing the degradation observed. The larger rivers of the region that were selected to represent less disturbed reference watersheds did conform to the reference expectation of the Eastern Sierra IBI. Although the MT was impaired in 4 of 8 samples, the others at least were in the intermediate range of fair conditions, in partial support of this standard. Interpretation of results is limited by the small extent of river represented by the reaches surveyed. Relation to the deposited sediments measured by Balance Hydrologics should be evaluated to establish whether there is any link of particle size distributions to benthic biological integrity. More river length needs to be surveyed, and direct link of biological metrics to sedimentation needs to be made. In any case, the scores established for larger reference rivers provide a benchmark target for the levels of biological integrity that should be sought through watershed management actions on the Middle Truckee River.

The mobile, less stable reaches where sediments could accumulate, did show signs of having less biological richness than adjacent immobile reaches (3 of 4 cases). Again the sediment cover differences between these reaches should be compared. If reaches of the MT had more sediment than the reference streams, then RWB samples might have been expected to show some impairment if taken in deposition zones. The opposite, however, was observed, with RWB > TR in all cases for the MT and reference reaches. At least at the reach-scale, the RWB seemed to be sampling more variety of benthic fauna without being affected by sediments. Sediment levels over the RWB and TR locations sampled were not recorded though, so relation to invertebrate indicators is unknown.

Aside from an absence of sediment cover data, there are other problems with scale and how these observations might be interpreted. First, there is a mis-match in time and spatial scales for the responses of benthic macroinvertebrates to mobile and immobile habitat because the small-scale habitat relations and short-term life cycles of these organisms do not match the large-scale and long-term geomorphic changes in substrate stability along the river. Local patterns of deposition in patches and rapid responses to microhabitat alteration are missed when sampling randomly over large heterogeneous reaches. Seasonal changes in sediment flux are more important to benthic organisms than patterns of channel stability that develop over decades to centuries. Future studies should strive to define the connection between patch-scale levels of deposition and the extent of biological alteration in benthic invertebrate communities.

In addition to scaling problems, the Mobile-Immobile substrate surveys do not distinguish particles smaller than 2-4 mm, but sediment can be partitioned into Fines < 0.25 mm & Sand 0.25-2 mm. These classes of particle size may also affect the suitability of habitat to benthic organisms. Distinguishing fines and sand then, is another priority in determining whether there are sediment limitations on the biological integrity of the Middle Truckee River.

In conclusion, bioassessment results show that the Middle Truckee sites surveyed for these studies are in poor-to-fair condition, and usually inferior to reference rivers of the region of similar large size or catchment area. How this biological status is related to sedimentation requires further study at local scales and in relation to patterns of sediment deposition across a wider variety of river environments on the Middle Truckee.

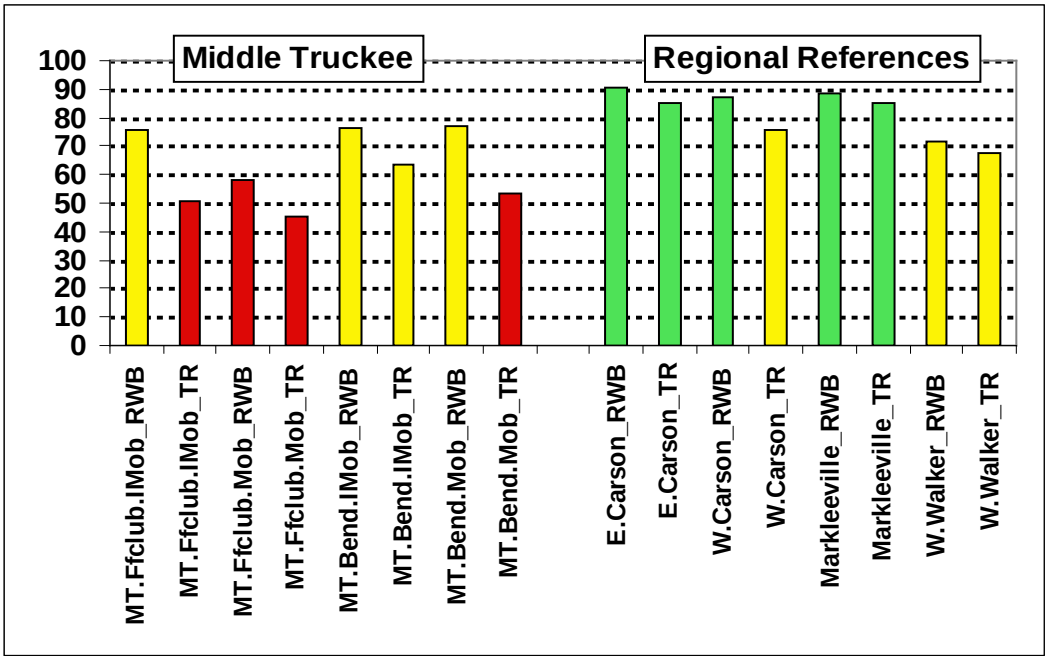

Figure 1. Eastern Sierra multimetric IBI (index of biological integrity) for RWB and TR samples collected from the Middle Truckee River and regional reference larger rivers as a context for evaluating the Middle Truckee. Red indicated sites that are impaired, not supporting, or poor in condition (less than threshold of 63.2); yellow indicated sites that are in fair condition, partially supporting and between 63.2 and 80.4; green indicates sites in good condition, fully supporting of biological integrity as defined by reference distribution used to develop IBI (not inclusive of the sites shown here).

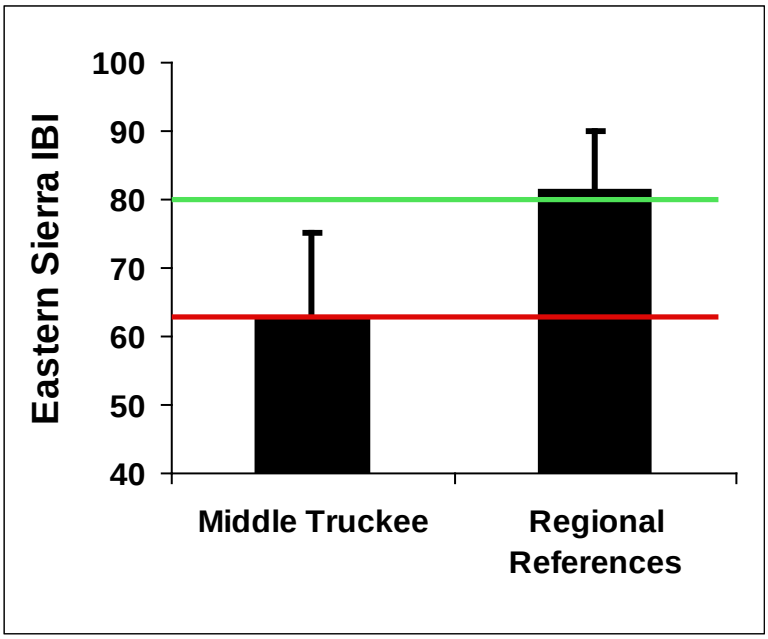

Figure 2. Combined samples from Middle Truckee and from regional references. As a group the MT samples average just below the limit indicating impaired condition (red line), but large rivers average just above the median of IBI references (green line). ±SD

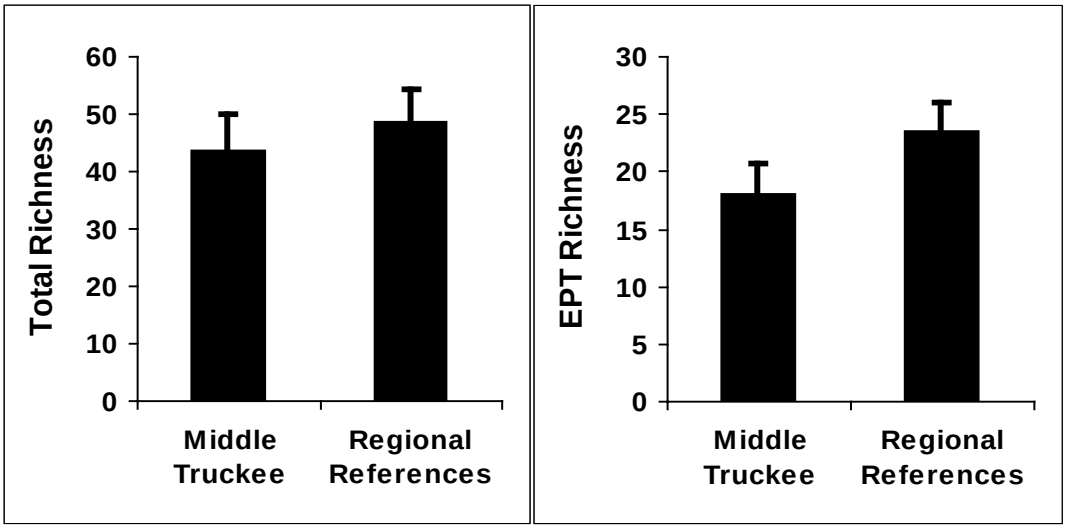

Figure 3. Total (left) and EPT (right) richness of Middle Truckee. ±SD

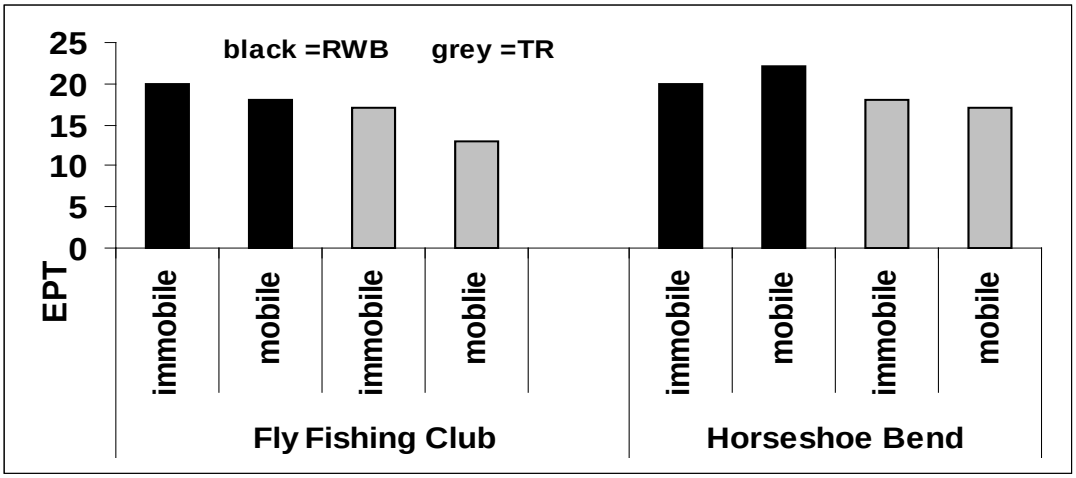

Figure 4. Contrast of immobile to adjacent mobile reaches within each sample type.

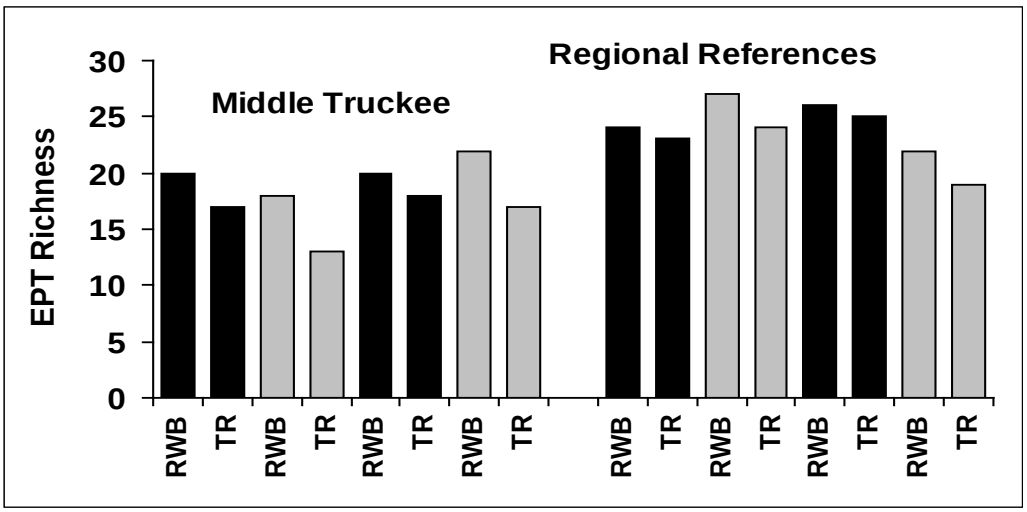

Figure 5. Contrast of RWB and TR within each site (sites aligned with Fig 4).