Macroinvertebrate assemblages along Milliken Creek, Napa, in relation to land-use: implications for restoration planning.

Kauaoa Fraiola

12/13/07

UC Berkeley, LA 227

First Draft

Abstract

The effects of golf courses on water quality and biotic integrity have been of interest to researchers, managers, and companies (e.g. pesticide producers) since the 1980's. In Milliken Creek, Napa, CA the impacts of golf courses on water quality are of special concern because of the creeks reputation of being one of the last few streams in Napa city to have a robust Steelhead population and it runs through a golf course. In this study I use benthic macroinvertebrates and the California Streamside Biosurvey to investigate potential effects of Silverado Country Club golf course on the health and integrity of Milliken Creek. I collected three benthic macroinvertebrate samples and conducted visual physical habitat surveys at four sites (n=12 total), upstream, downstream, and two within the course. I found no significant differences between the biotic index scores among the sites ($p=0.29$, d.f.=11, $F=1.47$) and slight differences in % EPT, taxa richness, and physical habitat. Based on the indices I was unable to show any significant effect of the golf course on benthic macroinvertebrates in Milliken Creek. However, I am unable to separate the effects of differences in habitat diversity among the sites and effects from the golf course. Therefore, further study is needed before we can say with certainty that there is not an effect. This study stresses the importance of reference sites and pre-disturbance or pre-restoration project benthic macroinvertebrate data is very important to understanding impacts, assessing success of restoration techniques, and making goals for restoration projects.

Introduction

The effects of golf courses on water quality and biotic integrity have been of interest to researchers, managers, and companies (e.g. pesticide producers) since the 1980's (Cohen et al. 1999). According to a National Golf Foundation report in 2006 there are 16,052 golf courses in the United states that occupy a small percentage of land in turf production but are the most intensively managed part of the urban environment (see reviews by Cohen et al. 19999, King et al 2007, and Winter et al 2002). In Milliken Creek, Napa, CA the impacts of golf courses on water quality are of special concern because of the creeks reputation of being one of the last few streams in Napa city to have a robust Steelhead population (Koehler 2002, pg. 110). Steelhead populations in streams of the San Francisco Bay Area are in decline and listed as a threatened pursuant to the Endangered Species Act (Leidy et al. 2005).

To date, the major impacts of golf courses on aquatic communities are from nutrient (Nitrogen and Phosphorous) and pesticide runoff in surface water. However, not all studies have found detectable reductions in water quality adjacent or down-stream from golf courses. Some studies found little or no increases in nutrient or pesticide concentrations (Cohen et al. 1999), while others found significant positive residues (King et al. 2007, Winter and Dillon 2006) as well as impacts to stream aquatic communities (Winter et al. 2003 and 2002). Therefore site-specific investigations are needed in order to determine whether or not a particular course is affecting an aquatic ecosystem in its watershed.

Benthic macroinvertebrates are considered a good choice bioindicators and may be a useful tool in helping managers detect the effects of golf courses on aquatic ecosystems. Benthic macroinvertebrates are good biological indicators because: 1) they are ubiquitous; 2) the large number of species; 3) mostly sedentary in nature; and 4) relatively long life cycles (Resh and Rosenberg 1993). It has already been speculated that bioassessment methods might be helpful in detecting subtle affects of golf courses on sediment quality of adjacent and down-stream coastal habitats (Lewis et al. 2001). Winter et al. (2002) used benthic macroinvertebrate bioassessment to evaluate the influence of golf courses in Canada and found that golf courses management practices and benthic macroinvertebrate stream communities in Canada can be significantly associated with one another. Benthic macroinvertebrates are also a good choice for bioassessments in streams, because they are an important food source for fish (Barbour 1999) including Steelhead (Leidy et al. 2005). This is of particular importance in Milliken Creek because it was identified by California Fish and Game (DFG) as one of five creeks that are "important migration corridors and or spawning or rearing areas for steelhead trout" in the City of Napa (Koehler 2002).

Due to the importance of Milliken Creek as a robust Steelhead stream, In this study I used the California Streamside Biosurvey (Herbst 2001) protocols to collect baseline data on the benthic community of Milliken Creek up- and down-stream of Silverado Country Club (SCC) golf course in order to investigate the potential effects of the golf course on Milliken Creek's health and integrity. I also address some of the implications for restoration planning within the Milliken Creek watershed. This data will serve as the beginning of a long-term project monitoring the benthic macroinvertebrate communities and the health of Milliken Creek.

Methods

I collected three benthic macroinvertebrate samples from four sites (n=12 total) along Milliken Creek (Figure 1) along with conducting visual estimates of physical and habitat characterization. I used the California Streamside Biosurvey (CSB) (Herbst 2001) protocols to collect benthic macroinvertebrate samples. In short, at each site three riffles with a D-net from a ~250cm^2 area. I then conducted visual estimates of substrate composition, physical features of the bank (e.g. substrate composition, % embededness, bank slope, etc).

I conducted all sampling on conducted on November 16, 2007, and preserved samples in 95% ethanol and taken back to the lab for sorting with a dissecting scope. The sites were chosen in order to sample riffles downstream and upstream of Silverado Country Club (SCC) golf course and near unique habitats. Site A was upstream of site B and the golf course, and also had a relatively open canopy however, the substrate was mainly bedrock, and the channel was at the start of a deep and narrow valley. Site B was further downstream and adjacent to some condos at the upper end of the golf course, and had a small flood plane on the right bank (looking up stream) and a relatively open canopy. Site C was chosen because it was at the upstream edge of the reservoir and in the middle of the golf course. During sampling the reservoir empty. Site "D" was approximately ~ 100m downstream of the golf course reservoir and was hypothesized to receive the most influence from the course. I hypothesized that biological index scores, % EPT and taxa richness would be highest at the most upstream sites A and B because they were less impacted and to be lowest at the most downstream site because due to it being downstream of the golf course.

Benthic macroinvertebrate samples were sorted into the groups specified by the CSB. Sorting at the lab was necessary because the invertebrates were too small to see easily with the naked eye. The normal protocol for the CSB is to pick out the first 100 organisms encountered in a sample out in the field. After sorting the macroinvertebrates into different groups and counting them I calculated a biological index score using the California Streamside Biosurvey methods with benthic macroinvertebrate data. I did not assign ratings for water quality because it assumes that you have an appropriate reference site for calibrating the ranking of the streams. To calculate the biological index score I assigned each taxa group in a sample a S-score based on abundance and the appropriate category (sensitive, intermediate, ad tolerant) and summed the scores in the sample. The categories were the CSB's. The sensitive category was mayflies, stoneflies, caddisflies, and hellgrammites. The intermediate category was riffle beetles, net-spinning caddisfies, alderflies, crane flies, other water beetles, flatworms, and other/unknown invertebrates. The tolerant category was midges, black flies, dragon- and damselflies, leeches, snails, clams, amphipods, and segmented worms. I then compared the mean biological index values of the four sites and tested for statistically significant differences with a one-way analysis of variance (ANOVA) assuming unequal variances. I then calculated the total taxa richness and the percent of the taxa groups at each site composed of Ephemeroptera, Plecoptera, and Trichoptera (% EPT) for each site (lumping all three riffle samples together into one total) and related differences in the biological index scores to differences in the physical characterizations and habitat assessments at each site.

Results

A total of 15 taxa were collected from across all four sites (Table 1). Total taxa richness and percent EPT among sites differed very little among sites and the ranged between 10 to 12 and 25% to 30% (Table 2). The scores for the mean biotic index for each site ranged from 14 to 18, indicating poor to fair water quality based on the CSB ranking (Table 2) on a scale of 0 to >25. None of the biotic index scores among the sites were significantly different ($p=0.29$, d.f.=11, $F=1.47$) from each other based on the one-way ANOVA.

For the physical habitat parameters estimated there were several trends based on visual assessments following the CSB. The first trend was an increase in the % embededness from upstream to downstream sites. A second trend was a gradual shift in the dominant substrate size from smaller size (fines and sand) to larger sizes (bedrock and boulders). Stream banks at all sites had similar slopes, undercutting, and erosion except for site D, the most upstream site, which seemed to have steeper and taller banks.

Discussion

Based on the indices used in this study, I was unable to detect any significant effect of the Silverado Country Club golf course on the benthic macroinvertebrate community in Milliken Creek. If the golf course had been altering the benthic macroinvertebrate community I would have expected to see a decrease in the biological index scores from upstream to downstream as the stream ecosystem became impacted by the golf course. However, there may be differences driven by variability in habitat complexity, with sites A and D having lower habitat complexity (bedrock dominated and sand/gravel dominated) than the two middle sites. Another possible explanation for the lack of significant differences may be to due to small sample size and low statistical power.

My findings are contrary to findings in Canada which showed benthic macroinvertebrate communities in streams draining golf courses were significantly different from reference streams (Winter et al. 2002). Despite the benefits of using benthic macroinvertebrates in investigating the health and integrity of stream ecosystem it has not been used much to investigate the impacts of golf courses on stream ecosystems. For example, the Winter et al (2002) study was the only article that used benthic macroinvertebrates to investigate the effects of golf courses on stream ecosystems in the Web of Science databases when I used the key words "golf," or "golf course*."

However, not all studies have found detectable reductions in water quality adjacent or down-stream from golf courses. Some studies found little or no increases in nutrient or pesticide concentrations (Cohen et al. 1999), while others found significant positive residues (King et al. 2007, Winter and Dillon 2006). It is therefore a possibility that management practices at Silverado Golf Course may not be having any impacts on the Milliken Creek ecosystem.

Both water quality and physical habitat are important predictors of benthic macroinvertebrate. Thus, limitations of my projects design it impossible for me to differentiate between potential effects of the golf course and natural differences in habitat complexity. Natural changes in physical habitat along the stream longitudinal gradient often result in corresponding changes in the biotic community (e.g. Vannote et al 1980).

Another shortcoming of this design is psuedoreplicated (Hurlbert 1984). Comparing each of these sites with a reference site in a nearby stream with a similar physical habitat but no golf course would help distinguish between the effects of differences in physical habitat and the effects of the golf course. Another possible design would be to see if there is any pre golf course data on benthic macroinvertebrates and then sample those same areas and compare the results. Take together, a more statistically robust study design such as a paired or asymmetric Before-After Control-Impact (BACI) design is better at detecting differences between control and reference streams and sites. However, it is not always possible to collect data prior to construction or to find appropriate reference streams.

These steps would help restoration practitioners assess what stream reaches are most impacted (according to benthic macroinvertebrate metrics) and to enable examination of project success on the relevant target (biological communities). All too often restoration projects are conducted and the measure of success is whether or not the construction plans were followed. Such a narrow scope of assessment will limit the ability of resource managers to determine how restoration projects affect the biotic component of stream ecosystems. Reference sites and pre project data may also help practitioners establish goals for their restoration projects in terms of the benthic macroinvertebrate community.

Conclusion

Based on benthic macroinvertebrate indices I was unable to detect any negative effects of Silverado Country Club golf course on the Milliken Creek stream ecosystem integrity and health. Because of the limitations of my study design in space and time, I was unable to rule out other possible explanations for observed results. Therefore, further study is needed before we can say with certainty that there is not an effect. This study stresses the importance of reference sites and pre-disturbance or pre-restoration project benthic macroinvertebrate data is very important to understanding impacts, assessing success of restoration techniques, and making goals for restoration projects.

Acknowledgements:

This project would not have come to fruition without the help of many people. I would like to give special thanks to Tyler York for helping with the fieldwork and taking care of all the logistics. And I would also like to thank Laurel Marcus for providing maps and background reports on Milliken Creek. And lastly I would like to thank Matt Kondolf for suggesting this project and for helping to edit earlier drafts, which greatly improved the manuscript.

References

Barbour, M.T., Gerritsen, J., Snyder, B.D., and J.B. Stribling. 1999. Rapid bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, second edition. EPA 841-B-99-002. *U.S. Envitonmental Protection Agency*; Office of Water; Washington, D.C.

Cohen, S., Svrjcek, A., Durborow T., and N.L. Barnes. 1999. Water quality impacts by golf courses. *Journal Of Environmental Quality* 28 (3): 798-809.

Herbst, D.B., Feng, A.Y., Gregorio, D.E., M. Buckler. 2001. The California streamside biosurvey, an introduction to using aquatic invertebrates as water quality indicators. Clean water team citizen monitoring program, Division of Water Quality, State water Resources Control Board, Sacramento, CA 95812-0100.

Hurlbert, S.H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54 (2): 187-211.

J.T. Koehler. 2002. Northern Napa River Watershed Plan. Napa County Resource Conservation District for California Department of Fish and Game. Contract # P9985160.

King, K. W., Balogh, J. C., Hughes, K. L., and R. D. Harmel. 2007. Nutrient load generated by storm event runoff from a golf course watershed. *Journal of Environmental Quality*, 36 (4): 1021-1030.

Leidy, R.A., G.S. Becker, B.N. Harvey. 2005. Historical distribution and current status of steelhead/rainbow trout (*Oncorhynchus mykiss*) in streams of the San Francisco Estuary, California. Center for Ecosystem Management and Restoration, Oakland, CA.

Lewis, M.A., Foss, S.S., Harris, P.S., Stanley, R.S., and J.C. Moore. 2001. Sediment chemical contamination and toxicity associated with a coastal golf course complex. Source: Environmental Toxicology and Chemistry 20 (7): 1390-1398.

Rosenberg, D.M. and Resh, V.H. 1993. Freshwater biomonitoring and benthic macroinvertebrates. New York: Chapman and Hall.

Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R., and C.E. Cushing. 1980. River continuum concept. *Canadian Journal Of Fisheries and Aquatic Sciences* 37 (1): 130-137.

Winter, J.G., Dillon, P.J., Paterson, C., Reid, R.A., and K.M. Somers. 2003. Impacts of golf course construction and operation on headwater streams: Bioassessment using benthic algae. *Canadian Journal of Botany-Revue Canadienne de Botanique*, 81 (8): 848-858.

Winter, J.G., Somers, K.M., Dillon, P.J., Paterson, C., and R.A. Reid. 2002. Impacts of golf courses on macroinvertebrate community structure in Precambrian Shield streams. *Journal of Environmental Quality* 31 (6): 2015-2025.

Figures and Tables

Figure 1. Map showing the location of the four sampling locations along Milliken Creek.

Table 1. Summary of the taxa found at each site and the mean and standard error (SE) across the three samples at each site

	Site A		Site B		Site C		Site D	
Taxa Groups	*mean*	*SE*	*mean*	*SE*	*mean*	*SE*	*mean*	*SE*
Mayflies (Ephemeroptera)	3.7	3.2	8.3	3.9	26.3	4.1	22.0	4.0
Stoneflies (Plecoptera)	2.0	0.6	5.3	0.7	1.0	1.0	2.3	0.7
Caddislfies (Tricoptera)	0.3	0.3	0.7	0.3	0.0	--	0.0	--
Flatworms	2.7	1.2	0.7	0.3	6.3	3.2	1.0	1.0
Blackflies (Simulidae)	25.3	14.3	28.0	3.2	24.3	9.2	50.0	7.4
Crane Flies (Tipulidae)	0.0	--	0.3	0.3	0.7	0.3	1.0	0.6
Hydropsychidae (net spinning Caddisflies)	0.7	0.7	4.7	2.7	21.3	3.8	19.0	6.5
Odonata	0.7	0.3	1.7	0.9	5.3	1.7	0.3	0.3
Riffle Beetles	0.0	--	0.7	0.3	4.0	1.5	0.0	--
Midges (Chironomidae)	17.0	7.0	42.7	1.2	4.7	3.3	1.7	0.9
Hellgramites (Megaloptera)	0.0	--	0.0	--	0.0	--	0.0	--
Snails	0.3	0.3	0.0	--	1.7	0.9	0.0	--
Amphipods	0.7	0.3	0.0	--	0.0	--	0.0	--
Segmented worms	24.7	12.5	7.0	0.6	4.0	1.0	2.0	1.5
Lepidoptera (Crambidae)	0.0	--	0.0	--	0.3	0.3	0.3	0.3
Dixidae (Order Diptera)	0.0	--	0.0	--	0.0	--	0.3	0.3

Table 2. Summary table of mean biological index score and its standard error (SE) along with the percent EPT and taxa richness for each site (total across all three riffle locations at each site).

Site	Mean Biological Index Score	SE	% EPT	Taxa Richness
A	14	0.7	30	10
B	18	2.3	30	10
C	17	1.7	25	12
D	14	1.2	27	11