Bioassessment of Two Urban Creeks in the Presidio

Bonnie Lee
Environmental Sciences, University of California at Berkeley

Abstract

The first step in restoration of a creek is to establish a baseline in which to formulate future restoration management practices. As part of the restoration effort for the Tennessee Hollow Creek (THC) at the Presidio, I conducted an initial characterization of the creek and the Fort Scott Creek (FSC) in the Presidio. I hypothesized that THC will be the poorer quality of the two creeks. Using Fort Scott Creek as a reference creek, I used the California Stream Bioassessment Protocol and archived US Army data to evaluate the quality of THC and FSC. By calculating the EPT index, taxon richness, tolerant taxon index, and percent dominant taxon, I found that 3 of the 4 metrics supported the hypothesis. EPT index and taxon richness were also plotted with total dissolved nickel and copper concentrations to see if metals in surface water would affect the macroinvertebrate community. EPT index was low in presence of metals but no noticeable differences were seen in taxon richness. Although FSC has been determined to be the more pristine creek, bioassessments must be continued so that dependable restoration goals may be set.

Introduction

Degradation of rivers and streams in the form of sedimentation, excess nutrients, or anthropogenic intervention, has been the focus of restoration efforts around the world (Nolan and Guthrie 1998, Schauman and Salisbury 1998). Urbanization in South Africa has caused the accumulation of pollutants in waters and is now using Best Management Practices to minimize the impacts to the environment (Braune and Wood 1999). River Mersey, an urban creek in the UK once known for its polluted waters and heavily engineered watercourses in Europe, have re-established fish populations in certain parts of the catch (Nolan, 1998). In the US, 642,881 of the 3.5 million miles of rivers and streams have been documented in the 1992 National Water Quality Inventory with studies showing that while 56% of this stream mileage have been determined suitable for multiple uses such as drinking water supply, fish and wildlife habitat, recreation, agriculture, and flood prevention and erosion control, the other 44% have been considered degraded (Karr and Chu 1999, US Department of Agriculture et al. 1998). Due to the poor quality of bodies of waters in the US, fish advisories have increased 26% in 1996. In California Rivers, there has been a 67% decline or disappearance in fish species since the 1850s (Karr and Chu 1999).

As part of recent concerns to the continued degradation, efforts are being made to restore streams and the habitat around them. One example is the proposed restoration of Tennessee Hollow Creek (THC) in the Presidio, San Francisco by the National Park Service. The restoration effort for THC is currently in the first stages of planning, identifying the problem with the help of conducting experiments and analyzing data (Kern and Youngkin 1998). Chemical water analysis is a common way to assess water quality in streams, but dependence on this one method is often unreliable. Nationally, only 25% of the river miles were considered impaired based on chemical assessment whereas using biological methods, 50% of the river miles were categorized as impaired (Karr and Chu 1999). This discrepancy may be because chemical analysis presents only one aspect of habitat monitoring. Bioassessments offer an integrated approach in assessing aquatic ecosystems by evaluating relationships between organisms and their physical habitats with the help of biometrics. These biometrics, or measurements of biological attributes, such as taxon richness (the number of taxon present in a sample), percentage of most dominant taxon (the percent of the total number of organisms belonging to the same taxon), Ephemeroptera-Plecoptera-Trichoptera (EPT) richness (the number of individuals belonging to the EPT taxon), and organism density (the number of organisms in a known area) are just a few of the more reliable metrics (Poulton *et al.* 1995, Resh *et al.* 1995). Therefore, a biological approach or a bioassessment would more accurately assess the quality of an aquatic ecosystem.

Due to the low cost of bioassessments compared to chemical analysis, there are 42 states using multimetric assessments of biological conditions. California's Department of Fish and Game adapted an EPA protocol, the California Stream Bioassessment Procedure (CSBP) for use by citizen monitors (Karr and Chu 1999, California Department of Fish and Game 1998). Using this standard protocol, I conducted bioassessments of the two creeks in the Presidio, THC and Fort Scott Creek (FSC) to assess their aquatic habitat quality.

Research Goal In order to restore THC, we must first determine the condition of the present aquatic habitat to base future restoration decisions. In this study, I have established an initial characterization of the aquatic habitat by conducting a bioassessment of the creek and the reference creek, Fort Scott Creek. Next, I calculated EPT index, taxon richness, percent dominant taxon, tolerant taxon index, and percent similarity to reference site. Using archival data, I studied the relationships between the EPT index and taxon richness with the total dissolved nickel and copper concentrations, two of the metals that are of concern in the surface waters of THC. I have tested the hypothesis that FSC will be the least degraded of the two creeks.

Description of Study Sites Tennessee Hollow Creek (Fig.1) is part of the Tennessee Hollow Watershed, draining 111 hectares within the Marina Groundwater Basin within the Presidio of San Francisco (Kern and Youngkin 1998). The creek has three tributaries, all of which run through landfills. The western tributary flows year round except during the summer when the groundwater level drops. This tributary emerges from Landfill E, a fill site containing hazardous materials, construction debris, and petroleum waste. The central tributary flows through the 1940s Landfill 1, filled deep with building debris, asbestos wrapped ducts, and incinerated debris related to medical units, and Landfill 2, filled with 3.05m thick of building debris and household wastes (US Army Corps of Engineers 1991). The western and central tributaries merge and transect the eastern tributary, which flows through an unofficially designated fill hypothesized to consist of construction debris, to form the main THC (Kern 1999, pers. comm.). The creek then enters a storm drain that leads directly into the San Francisco Estuary.

FSC (Fig. 1) is situated in a fairly undisturbed area; the creek is not known to flow through any landfills (Kern 1999b, pers. Comm.). Thus FSC provides a reference site comparison with the degraded study stream. Fort Scott Creek, west of the Tennessee Hollow Creek, drains 81 hectares (Castellini 1998). It has only one tributary but a second one may be present or may simply be a constructed storm drain. The creek flows over both natural and concrete substrates and is eventually channeled into a storm drain leading to the San Francisco Estuary.

Methods

I have utilized both archived and newly gathered data to study how metal contaminated water affected aquatic macroinvertebrates. Water quality data for chromium and nickel concentrations were acquired from past US Army surface water monitoring reports (US Army Corps of Engineers 1998a, 1998b, 1999). Two bioassessment sampling seasons were considered, Fall 1998, Spring 1999, and Fall 1999. Data from November 6, 1998 (Fall 1998) and May 5th and 8^{th} (Spring 1999) were collected by Laura Castellini from the Department of Biology at San Francisco State University. I conducted the Fall 1999 sampling on September 4, 1999. All three samples were done using the CSBP so that results may be comparable.

Samples were taken from three areas in the THC, the combined stretch of the main creek (TH1), the eastern tributary (TH2), and the central tributary at El Polin Springs (TH4) (Fig. 1). Two samples were taken from the FSC, the lower natural substrate (FS1) and upper concrete substrate (FS2) reaches of the creek (Fig. 1). Before samples were taken, an overall site survey of each tributary was conducted before choosing five sampling sites. Due to the narrowness of the creeks, the protocol was changed so that sites were chosen longitudinally rather than from transects across the creek. Using a random table provided by the CSBP, three numbers were randomly chosen ranging in values from one to five. Once the three sites along the tributary were chosen, I sampled the sites using a standard D-shaped 0.5mm mesh net. Starting with the sampling site furthest downstream, the net was placed on the creek bed and the substrate up to 0.5m upstream of the net was disturbed to allow macroinvertebrates to be washed into the net. A time period of disturbance of about 3 minutes was used at each sampling site. Working from downstream to upstream, this process was done at each of the three sites for each tributary. Thus, we had three samples in one net. The contents of the net were then placed into a plastic 1-liter jar. The jar was then filled with enough 95% ethanol to submerge all the contents. The entire protocol was conducted a total of five times, each at the designated tributaries or stretches of the creek. A habitat assessment of the site was then conducted.

The habitat assessment required the completion of a worksheet that included 10 parameters by categorizing them as poor, marginal, suboptimal, and optimal using scales of either 1-10 or 1-20. These parameters include epifaunal substrate or available cover, embeddedness, velocity or depth of regime, sediment deposition, channel flow, channel alteration, frequency of riffles, bank stability, vegetative protection, and riparian vegetative zone width. The sum of the score for the ten parameters constituted one score for each sample site. The median scores of FS1 and FS2 were considered the reference-site score. Scores for TH1, TH2, and TH4 were considered test-site scores. Percent similarity, test-site score/reference-site score x 100, was then calculated. The values obtained would allow you to categorize the test-site as “comparable” to the reference habitat (greater than or equal to 90%), “supporting” the reference habitat (greater than or equal to 75%), “partially supporting” (greater then or equal to 60%) or “not supporting” (less than or equal to 59%) the reference habitat (Hannaford and Resh 1995). By making the assumption that our reference site is pristine, the higher the percent similarity, the better the quality of the habitat.

After the habitat assessment was completed at the end of each sampling, the jars were then brought into the laboratory to be processed. Samples were passed through 5mm, 2mm, 0.8mm, and 0.4mm sieve and the contents were distributed evenly onto a dry number-grid tray. Next, a subsample was prepared by choosing five numbers randomly from the random numbers table. The first number chosen corresponded to the sector of the grid where the contents were to be removed. This subsample was placed onto a number-grid petri dish. Again, another five random numbers were chosen and the remains of that grid removed from the petri dish. Contents were then placed into separate dish so that the first 100 macroinvertebrates seen through a dissecting scope were taken from the sample. Additional grids with their corresponding random numbers were used if the first grid did not yield 100 macroinvertebrates.

I identified the previously chosen 100-macroinvertebrates to either the class or order level. After this sorting and identification process was completed for all the collected samples, taxon richness, EPT (Ephemeroptera, Plecoptera, and Trichoptera) index, Percent Dominant Taxon, and tolerant taxon index were calculated. EPT Index is the total of EPT, which consists of three of the pollution sensitive orders, divided by the total number of organism and multiplied by 100. The higher the EPT Index value, the better the quality of the creek (US EPA 1999). This is also true for taxon richness, which is the total number of taxon identified. Percent Dominant Taxon is the number of the most abundant organisms divided by the total number of organisms in the sample multiplied by 100. This value gives you a sense of the composition of the sample. Tolerant taxon index is obtained by multiplying the t-value assigned on the CSBP for each taxon and adding them up. This subtotal is then divided by the total number of organisms. Organisms not on the CSBP sheet were subtracted from the total number of organisms. The higher the tolerant taxon index value, however, the poorer the quality of the creek (California Department of Fish and Game 1998).

The most appropriate site to study biometrics and metal concentration was TH4 because of its proximity to the two surface water monitoring sites, LF01SP01 and LS02SP01. The other sampled sites would not be representative of the macroinvertebrate community response because they are farther away. Surface water monitoring for FS was not available. Since current data were not available, data for the concentrations of nickel and copper were taken from US Army's surface water monitoring events on January 23, 1998, April 17, 1998, and February 10, 1999 (US Army Corps of Engineers 1999). By studying groundwater elevation hydrographs, the first and last dates were found to correspond to low groundwater levels while the second date represented groundwater levels comparable to a typical wet season. Since metal chemistry in water remains fairly consistent year to year, these data may be comparable to the values we expect if data for the year of 1999 were available. The EPT index and taxon richness were plotted against total dissolved nickel and copper concentrations so that macroinvertebrate community response to metal contaminated waters may be observed. These biometrics were chosen based on Poulton *et al* (1995) findings that they were good indicators of aquatic health in determining metals-related impacts.

Results

Calculations for standard error and t-tests were not conducted due to the lack of replicated samples to do such statistical analysis. Taking three samples from each designated sampling site as stated in the CBSP is intended to reduce sampling bias. For Table 1 below, there are values that represent half of an individual. This is so because each half shell found was counted as half of an organism.

Sampling Site	TH1	TH2	TH4	FS1	FS2
Phylum Arthropoda					
Class Insecta					
Order Diptera					
Family Chironomidae	1	3	0	1	0
Family Simuliidae	9	0	0	1	9
Order Plecoptera					
Family Nemouridae	0	0	0	1	0
Class Arachnoidea					
Order Acari	0	1	0	30	0
Subphylum Crustacea					
Order Amphipoda	76	0	89	0	50
Order Ostracoda	2	25	1.5	53	3
Phylum Mollusca					
Class Bivalvia	9	68.5	4.5	10.5	3
Class Gastropoda	1	3	0	1	13
Phylum Annelida					
Order Oligochaeta	2	0	3	0	24
Total Number of Organisms	100	100.5	98	97.5	102
Taxon Richness	7	5	4	7	6
EPT Index	0	0	0	1	0
Percent Dominant Taxon	76	68.2	90.8	54.4	49.0
Dominant Taxon	Amphipoda	Bivalvia	Amphipoda	Ostracoda	Amphipoda
Tolerant Taxon Index (t-value)	4.2	3.3	4.1	3.6	5.5

Table 1: Organism inventory and the bioassessment for the Fall 1999 sampling.

Sampling Site	TH1	TH2	TH4	FS1	FS2
Total Number of Organisms	107	86	94	104	93
Taxon Richness	7	7	5	7	8
EPT Index	1	0	0.0	22	8
Percent Dominant Taxon	86	53.0	85.0	48.0	57
Dominant Taxon	Amphipoda	Bivalvia	Amphipoda	Amphipoda	Gastropoda
Tolerant Taxon Index (t-value)	4	6	4	4	22

Table 2. Bioassessment from November 16, 1998 – Fall 1998 (from Castellini 1999).

Sampling Site	TH4	FS2
EPT Index	0	7
Taxon Richness	6	14
Percent Dominant Taxon	79	19
Dominant Taxon	Amphipoda	Chironomidae

Table 3. Bioassessment results from May 5, 1999 and May 8, 1999, the Spring 1999 sample (from Castellini 1999).

Sampling Site	Reference/Test-Site Score	% Similarity	Comparability to Reference Site
TH1	49	73.7	Supporting
TH2	84	126.0	Comparable
TH4	8	12.0	Not Supporting
FS1	28	N/A	N/A
FS2	105	N/A	N/A

Table 4. Habitat Assessment for Fall 1999. Median, and in this case is the mean, reference test-site score for FS1 and FS2 was 66.5.

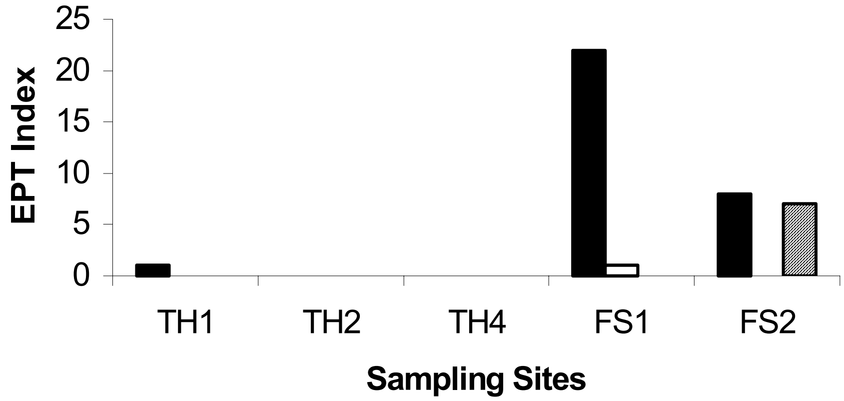

Figure 2. EPT Index for Fall 1998, Spring 1999, and Fall 1999. The shaded bars represent results from Fall 1998 (from Castellini 1999); the diagonally stripped lines represent results from Spring 1999; the white bars correspond to Fall 19999 sampling. Values at TH2 and TH4 are zeros.

Based on the EPT index (Fig. 2), we can say that FSC provided a better aquatic habitat than THC. The EPT Index values were almost all zeros except for a value of 1.0 in the Fall 1998 sample. On the other hand, FSC had EPT Index values higher than those obtained from THC sites during the same sampling periods.

Macroinvertebrate diversity was determined by a combination of biometrics including taxon richness and percent dominant taxon. Again, comparisons between the two creeks show that FSC was in better condition than THC. On average the number of taxa collected in fall 1998 for FSC was 7. 5 while THC was 6; in Spring 1999 the value for FSC was 14 and THC was 6; Fall 1999, FSC taxon richness was 6.5 and THC was 5.3. Percent dominant taxon also demonstrated the more pristine habitat in FSC. Although both creeks had dominant taxon in the order of Crustacea and Mollusca, relatively low corresponding t-values, or tolerant taxon index, FSC had a lower percent dominant taxon in all sampling seasons (US EPA 1999). The lower the percent dominant taxon, the greater diversity there exists in the creek. The biometric that did not evidently support either creek being in better condition was the tolerant taxon index, or t-value. The higher the t-value, the poorer the quality of the creek (US EPA 1999) In the Fall 1998 sampling period, the tolerant taxon index for THC ranged from 4 to 6 while FSC ranged from 4 to 22. In Fall 1999, THC had t-values ranging from 3.3 to 4.2 and FSC had values from 3.6 to 5.5.

Table 4 shows that TH2 is the only site with a percent similarity value greater than 90% and is "comparable" to the FSC habitat. This is most likely due to similar vegetation, substrate, and the other parameters between these two sites that were measured in the assessment. The individual reference test-site score of FS2 was actually higher than any of the other sites.

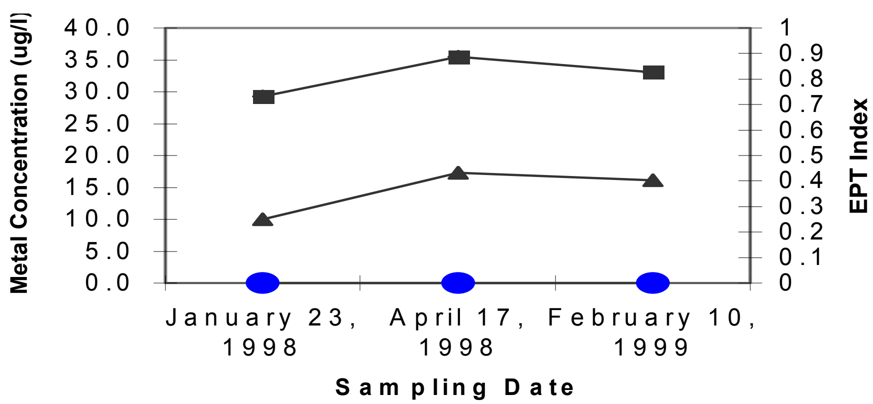

Figure 3. Comparisons of metal concentrations and EPT indexes for Fall 1998, Spring 1998, and Fall 1999 (Castellini 1999). ■ = total dissolved nickel; ▲ = total dissolved copper; ● = sampling results at TH4. For simplicity, I used 10ug/l to represent the actual recorded value of <10ug/l on January 23, 1998 (US Army Corps of engineers 1998a, 1998b, 1999).

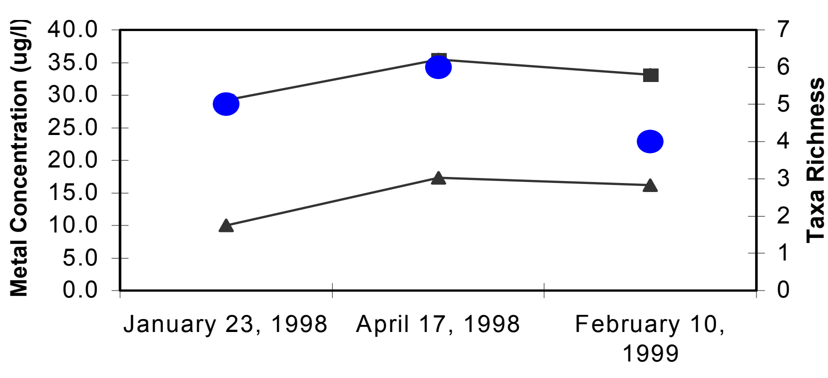

Figure 4. Total dissolved Metal Concentrations vs. Taxon Richness at TH4. Comparisons of metal concentrations and taxon richness for Fall 1998, Spring 1998, and Fall 1999 (Castellini 1999). ■ = total dissolved nickel; ▲ = total dissolved copper; ● = sampling results at TH4. For simplicity, I used 10ug/l to represent the actual recorded value of <10ug/l on January 23, 1998 (US Army Corps of engineers 1998a, 1998b, 1999).

The total dissolved nickel and copper detected in the surface water (Fig. 3 and 4) exceeds the contract-required quantitative limits (CRQLs) set by the US EPA for the Presidio monitoring, 20ug/l and 10ug/l, respectively (US Army Corps of Engineers 1998a, 1998b, 1999). The zero values for the EPT index at TH4 for all three sampling periods (Fig. 3) may indicate an effect of metal pollution on creeks. The pollution sensitive organisms in the taxon EPT could not survive the high metal concentrations. Taxon richness (Fig. 4), however, does not seem to differ significantly in the presence of metals.

Discussion

In the bioassessment of THC and FSC, three out of the four biometrics measured, EPT index, taxon richness, tolerant taxon index, and percent dominant taxon, support the hypothesis that FSC is the less degraded of the two. In our comparison with nickel and copper, the absence of any EPT taxon organism and the low taxon diversity were good indicators that the quality of THC must be poor. This is not surprising because THC is a fairly accessible area where human interactions with the creek may aggravate the degradation process. In addition, the tributaries of THC flow through various Army landfills and culverts via old pipes or storm drains made out of clay. Groundwater seeping through these landfills contains high metal concentrations that may have contributed to the high metal concentrations of the surface water of the creek (US Army Corps of Engineers 1998a, 1998b). Studies have shown that heavy metal concentrations such as copper, iron, nickel, and chromium, have reduced the density of native plants, taxonomic diversity, and the abundance of aquatic insects (Mackay *et al*. 1998, Schultheis *et al* 1997, and Plenet *et al*. 1996). The U.S. Fish and Wildlife Service (1985) reported that cadmium, a teratogen and carcinogen, has caused “deleterious effects” on fish and wildlife.

On the other hand, the higher taxon richness, low percent dominant taxon, and high habitat assessment score clearly indicates that FSC is the healthier of the creeks. FSC, unlike THC, is not known to have been disturbed historically and therefore situated in a more natural environment. FSC provides a much better habitat for pollution sensitive species such as those in the order Ephemeroptera, Plecoptera, and Trichoptera, to exist in its waters. This is because a natural substrate would be able to provide more microhabitats for different organisms to inhabit. Studies indicate that by restoring your microhabitat, you improve the conditions for specific life cycle stages of fishes (Maddock 1999).

An important aspect of the bioassessment that should be changed for future biomonitoring of the creeks is the need to conduct multiple samples or subsamples. During the initial scan of the samples, (order/family) Plecoptera Chloroperlidae (TH4), Odonata Coenagrionidae (TH4), and Trichoptera Hydropsychidae (FS1) were identified. They are not, however, identified in the 100-macroinvertebrate subsample for Fall1999. According to the results, there were no EPT taxon organisms for TH4. As a result, the addition of these pollution sensitive species would affect the results of this paper. A study conducted by G. L. Phipps *et al.* 1995 also suggested doing multiple samples to improve accuracy. The revised version, as of November 1, 1999, of the EPA's Rapid Bioassessment Protocol also support the need to conduct multiple samples to ensure better quality of results (US EPA 1999).

In this paper, I have determined that FSC is more pristine than THC. Although the need to restore THC is evident, continuous bioassessments are needed so that an inventory of reliable data, temporally and spatially, may be compiled, the first step of the restoration process. The ultimate goal is the collaboration of scientists and restoration managers so that daylighting THC may lie in the near future (Carpenter and Lathrop 1999).

Acknowledgments

I would like to thank Doug Kern of the Urban Watershed Project for his advice, patience, and time in helping me out with the project. I also thank Laura Castellini for her generosity in allowing use of her data. Finally, I would like to thank all the advisors in ES196A/B for their valuable advice!

References

Braune, M. J. and A. Wood. June 1999. Best Management Practices applied to urban runoff quantity and quality control. Water Science and Technology. 39: 117-121.

California Department of Fish and Game. 1998. California Stream Bioassessment Procedure. California.

Carpenter, S. R. and R. C. Lathrop. 1999. Lake restoration: capabilities and needs. Hydrobiologia. 395/396: 19-28.

Castellini, L. J. 1998. Stream bioassessment in Presidio watersheds as a baseline for riparian restoration plans. Research Proposal. Department of Biology - San Francisco State University.

Castellini, L. J. 1999. Stream bioassessment in Presidio watersheds as a baseline for riparian restoration plans. Unpublished thesis paper. Department of Biology – San Francisco State University.

Eisler, R. 1985. Cadmium hazards to fish, wildlife, and invertebrates: A Synoptic Review. Contaminant Hazard Reviews Report No. 2, Biological Report 85(1.2). Patuxent Wildlife Research Center, US Fish and Wildlife Service, Maryland.

Hannaford, M. J. and C. H. Resh. 1995. Variability in macroinvertebrate rapid-bioassessment surveys and habitat assessment in a northern California stream. Journal of North American Benthological Society 14: 430-439.

Karr, J. R. and Ellen W. Chu. 1999. Restoring life in running waters: Better biological monitoring. Island Press, Washington D.C. 206 pp.

Kern, D. and Mark Y. 1998. Watershed Monitoring Program - Presidio of San Francisco. Revised Draft Version 1/19/98 San Francisco.

Mackay, W. P., E. C. Freedman, J. Gardea, R. Mena, H.Navarro, H. Newman, N. E. Pingitore, and K. Redetzke. 1998. Seasonal changes in concentration and distribution of heavy metals in creosetebush, Larrea tridentata (Zgyophyllaceae), tissues in the El Paso, TX/Ciudad Juarez, Mexico area. SIDA Contributions to Botany. 18: 287-296.

Maddock, I. 1999. The importance of physical habitat assessment for evaluating river health. Freshwater Biology. V41; 373-391 *In* Muhar S. 1996. Habitat improvement of Austrian rivers with regard to different scales. Regulated Rivers: Research and Management. 12: 471-482.

Nolan, P. A. and N. Guthrie. 1998. River rehabilitation in an urban environment: examples from the Mersey Basin, North West England. Aquatic Conservation: Marine and Freshwater Ecosystems. 8: 685-700.

Phipps, G. L., G. T. Ankley, and V. R. Mattson. 1995. Relative sensitivity of three freshwater benthic macroinvertebrates to ten contaminants. Archives of Environmental Contamination and Toxicology. 28: 282-286.

Plenet, S, J. G. Huguey, and H. Hugueny. 1996. Invertebrate community responses to physical and chemical factors at the river-aquifer interaction zone II: Downstream from the city of Lyon. Archiv fuer Hydrobiologie. 136: 65-88.

Poulton, B. C., W. G. Brumbaugh, D. P. Monda, M. L. Wildhaber, and Daniel F. Woodward. 1995. Relations between benthic community structure and metals concentrations in aquatic macroinvertebrates: Clark Fork River, Montana. Journal of Freshwater Ecology. 10: 277-293.

Resh, Vincent H., Michael T. Barbour, and Richard H. Noris. 1995. Design and implementation of rapid assessment approaches for water resource monitoring using benthic macroinvertebrates. Australian Journal of Ecology. 20: 108-121.

Schauman S. and S. Salisbury. 1998. Restoring nature in the city: Puget Sound experiences. Landscape and Urban Planning. 42: 287-295.

Schultheis, A.S., A. C. Hendricks and M. Sanchez. 1997. Structural and functional responses of stream insects to copper pollution. Hydrobiologia. 346: 85-93.

US Army Corps of Engineers. 1991. Base Closure Final Environmental Impact Statement. US Army Corps of Engineers - Sacramento District.

US Army Corps of Engineers. 1998a. Landfill E - Groundwater Monitoring Program July 1998 Quarterly Report. Presidio of San Francisco, California.

US Army Corps of Engineers. 1998b. Fill Site 1 and Landfill 2 - Groundwater Monitoring Program July 1997 – April 1998 Quarterly Report. Presidio of San Francisco, California.

US Army Corps of Engineers. 1999. Fill Site 1 and Landfill 2 – Groundwater Monitoring Program July 1998 – April 1999 Quarterly Report. Presidio of San Francisco, California.

US Department of Agriculture, US Department of Commerce, US Department of Defense, US Department of Housing and Urban Development, US Department of the Interior. 1998. Stream Corridor Restoration - Principles, Processes, Practices. US

Department of Agriculture World Wide Website. http://www.usda.gov/stream_restoration/newtofc.html accessed March 24, 1999.

US Environmental Protection Agency. 1999. Rapid Bioassessment Protocols for Use in Streams and Rivers. US Environmental Protection Agency Website. http://www.epa.gov/owow/monitoring/rbp/ accessed November 1, 1999.

Figure 1. Tennessee Hollow Creek and Fort Scott Creek. The arrows **indicate the location of the creeks**