SECTION FIVE:

MACROINVERTEBRATE BIOLOGY

5.1 GENERAL STATEMENT

Bioassessments, in particular, benthic macroinvertebrate monitoring is a widely-used method for assessing the water quality and physical conditions within a watershed. This method has been used successfully in many watersheds across California, providing information for both the specific watershed, and also for the larger northern California region. Bioassessments use changes in BMI community measures to characterize the relative "health" of a watershed. Measurable changes are observed in response to greater impairment of a watershed.

Although La Honda Creek is relatively pristine compared to other more urbanized or intensely agriculturalized Bay Area watersheds, it is showing signs of degradation associated with this long history of human occupation. It seems likely that the California Stream Bioassessment Procedure might provide a benchmark of the current quality of instream habitat in La Honda Creek and assist Caltrans and DFG to better manage the creek for endangered species.

5.2 INTRODUCTION

Streams and rivers throughout the west face a number of significant problems. Among other factors, these are largely associated with inflow of contaminated water, increases in the size and frequency of floods due to the increase in impervious surfaces, and modification of in-stream and riparian habitat and processes. Many studies and reports illustrate the effects of land-use to macroinvertebrate and fish communities (Jones and Clark, 1987; Lenat and Crawford, 1994; Yoder et al., 1998; Usseglio-Polatera et al., 2000).

By their nature, physical variables within a river system present a continuous gradient of physical conditions, from headwaters to mouth (Vannote et al., 1979; Rosi-Marshall et al., 2002). Direct measurements of biological communities including plants, invertebrates, fish, and microbial life along that gradient have been used for the past 150 years as indicators of potable water supplies, sanitation, and the health of water for fisheries and recreation. In addition to these water quality implications, biological assessments (bioassessments) can be used as a watershed management tool for surveillance and compliance of land-use best management practices. Combined with measurements of watershed characteristics, land-use practices, in-stream habitat, and water chemistry, bioassessment can be a cost-effective tool for long-term trend monitoring of watershed condition (Ventura County Watershed Protection District 2001; Davis and Simon, 1996).

Biological assessments of water quality and condition examine the effects over time. They are sensitive to multiple aspects of water and habitat quality, and provide the public and landowners with more understandable expressions of ecological health than the results of chemical and toxicity tests (Barbour et al., 1999). Furthermore, biological assessments, when integrated with physical and chemical assessments, better define the effects of point-source discharges of contaminants and provide a more appropriate means of evaluating discharges of non-chemical substances (e.g. nutrients, sedimentation and habitat destruction).

Water resource monitoring using benthic macroinvertebrates (BMIs) is one of the most widely used methods throughout the world. BMIs are ubiquitous, relatively stationary along aquatic gradients, and their large species diversity provides a wide spectrum of responses to environmental stresses (Resh and Jackson, 1993). Certain BMI species reside in aquatic environments for months to several years, prior to the adult stage for many taxa, and are sensitive to temperature, dissolved oxygen, sedimentation, scouring, chemical and organic pollution, and nutrient enrichment (Resh and Jackson, 1993). BMIs are also a significant food source for aquatic and terrestrial animals, and provide a wealth of evolutionary, ecological and biogeographical information (Lammert and Allan, 1999).

Numerous researchers have audited, tested, and refined the procedure of bioassessments as a tool to assess water quality. Doberstein et al. (2000) tested the effect of fixed-count subsampling on BMI monitoring with positive results; Kobayashi and Kagaya (2002) examined the effects of various amounts and classes of litter on BMI communities; and Li et al. 2001 tested the effectiveness of the protocol at various spatial scales.

Although there are many potential methods for evaluating biotic condition from BMI data, most approaches in the U.S. use a combination of multimetric and multivariate techniques. In multimetric techniques, a set of biological measurements ("metrics"), each representing a different aspect of the BMI data, is calculated for each site. An overall site score is calculated as the sum of individual metric scores. Sites are then ranked according to their scores and classified into groups with "good", "fair" and "poor" water quality. This system, referred to as an Index of Biotic Integrity (IBI), is the end-point of a multi-metric analytical approach recommended by the EPA for development of biocriteria (Davis and Simon, 1995). The original IBI was created to assess fish communities (Karr, 1998), but was subsequently adapted for BMI communities. Comparison of scores to a local IBI has become standard practice; in northern California, the only local IBI is based upon data collected in the Russian River (Harrington, 1999).

5.3 METHODS

Field Methods

The California Department of Fish and Game (DFG) adopted the California Stream Bioassessment Procedure (CSBP) as standardized and cost-effective sampling, laboratory and quality assurance procedures for the State's bioassessment programs (Harrington, 1996). The CSBP is a regional adaptation of the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Barbour et al., 1999) and has been used in various parts of the world to measure biological integrity of aquatic systems (Davis et al., 1996). The CSBP was used to describe the benthic macroinvertebrate (BMI) community and the biotic condition of five stream reaches in La Honda Creek.

Sampling occurred on November 29 and December 3, 2002 (“Late Fall/Winter”) and again on June 3, 2003 (“Spring”). Following the CSBP, three riffles were selected within each study reach (see Section 6). Riffle length was measured for each of the three riffles, and a random number table was used to establish a point along the upstream third of each riffle at which a transect was established perpendicular to stream flow. Starting with the riffle transect furthest downstream, the benthos within a 0.2 m^2 (2 ft^2) area was sampled upstream of a 0.3 m (1 ft) wide, 0.5 mm (0.02 in) mesh D-frame kick-net. The benthos was sampled manually by rubbing cobble and boulder substrates in front of the net, and then “kicking” the upper layers of substrate to dislodge any remaining invertebrates. The duration of sampling ranged from 60-120 seconds, depending on the embeddedness and the amount of boulder and cobble-sized substrate that required rubbing by hand; more and larger substrates required more time to process. Three locations representing any habitat diversity along each transect were sampled and combined into a composite sample, representing a 0.6 m^2 (6 ft^2) area for each transect and 1.7 m^2 (18 ft^2) for the entire reach. Each composite sample was transferred into a 500 ml (16.9 fl oz) wide-mouth plastic jar containing approximately 200 ml (6.9 fl oz.) of 95% ethanol. This technique was repeated for each of three riffles in each reach. At each sampled location, general reach characteristics and simple water quality measures were recorded, including a visual estimate of surface water flow, riffle dimensions, estimated channel bed grain sizes, water temperature and dissolved oxygen concentration. These metrics were collected to help inform our general observations and understanding of each reach.

Benthic Macroinvertebrate (BMI) Laboratory Analysis

Laboratory analysis was performed by the Sustainable Land Stewardship International Institute in Sacramento. At the laboratory, each sample was rinsed through a No. 35 standard testing sieve (0.5 mm or 0.02 inch brass mesh) and transferred into a tray marked with twenty, 25 cm^2 (0.27 ft^2) grids. All sample material was removed from one randomly selected grid at a time and placed in a petri dish for inspection under a stereomicroscope. All invertebrates from the grid were separated from the surrounding detritus and transferred to vials containing 70% ethanol and 5% glycerol. This process was continued until 300 organisms were removed from each sample. The material left from the processed grids was transferred into a jar with 70% ethanol and labeled as “remnant” material. Any remaining unprocessed sample from the tray was transferred back to the original sample container with 70% ethanol and archived. BMIs collected during the late Fall and Spring were identified to a standard taxonomic level, typically genus level for insects and order or class for non-insects. QAQC was completed by DFG and the Sustainable Land Stewardship International Institute Laboratories, using standard taxonomic keys (Brown, 1972; Edmunds et al., 1976; Kathman and Brinkhurst, 1998; Klemm, 1985; Merritt and Cummins, 1995; Pennak, 1989; Stewart and Stark, 1993; Surdick, 1985; Thorp and Covich, 1991; Usinger, 1963; Wiederholm, 1983, 1986; Wiggins, 1996; Wold, 1974). A complete list of taxa identified through these methods are presented in Appendices G-4 and G-5.

Data Analysis

A taxonomic list of all aquatic macroinvertebrates identified from the samples was entered into a Microsoft Excel 9 spreadsheet program. Excel 9 was used to generate a stand-alone taxonomic list, and to calculate and summarize the aquatic macroinvertebrate community based metric values. The biological metrics are listed in Table 5-1 and have been categorized into the following types:

Richness Measures - These metrics reflect the diversity of the aquatic assemblage where increasing diversity correlates with increasing health of the assemblage and suggests that niche space, habitat and food sources are adequate to support survival and propagation of a variety of species.

Composition Measures - These metrics reflect the relative contribution of the population of individual taxa to the total fauna. Choice of a relevant taxon is based on knowledge of the individual taxa and their associated ecological patterns and environmental requirements such as those that are environmentally sensitive or a nuisance species.

Tolerance/intolerance Measures - These metrics reflect the relative sensitivity of the community to aquatic perturbations. The taxa used are usually pollution tolerant and intolerant, but are generally nonspecific to the type of stressors. The metric values usually increase as the effects of pollution in the form of organics and sedimentation increases.

Functional Feeding Groups - These metrics provide information on the balance of feeding strategies in the aquatic assemblage. The functional feeding group composition is a proxy for complex processes of trophic interaction, production and food source availability. An imbalance of the functional feeding groups reflects unstable food dynamics and indicates a stressed condition.

Index of Biological Integrity (IBI)

Data collected on BMI communities are assessed using a series of metrics that describe the characteristics of that community. Each of these community measures will have a distinct response to impairment of the watershed (Table 5-1).

The IBI used to evaluate the five La Honda Creek monitoring sites was developed from data collected on Russian River tributary streams in 1995-1997 (Harrington, 1999). This is the only Northern California IBI, and is regularly used as a metric for comparison. The scoring values used for the Russian River IBI are listed in Table 5-2. Streams in excellent condition have a total score of 30 to 24, in good condition 23 to 18, in fair condition 17 to 12 and in poor condition 11 to 6. The total IBI score for La Honda Creek is 9 for the winter sampling, and 11 for the spring sampling.

Table 5-1. Bioassessment metrics used to describe characteristics of the BMI community information for five selected reaches sampled in the Late Fall 2002 and Spring 2003 in the La Honda Creek watershed.

BMI Metric	Definition	Response Indicative of Watershed Impairment
Richness Measures		
Taxa Richness	Total number of individual taxa	Decrease
EPT Taxa	Number of taxa in the Ephemeroptera (may fly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders	Decrease
Ephemeroptera Taxa	Number of taxa in the insect order Ephemeroptera (may flies)	Decrease
Plecoptera Taxa	Number of taxa in the insect order Plecoptera (stoneflies)	Decrease
Trichoptera Taxa	Number of taxa in the insect order Trichoptera (caddisflies)	Decrease
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly, and caddisfly larvae	Decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly and caddisfly larvae with tolerance values between 0 and 3	Decrease
Shannon Diversity	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver, 1963)	Decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) or intolerant (lower values)	Increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	Decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	Increase
Percent Dominant Taxa	Percent composition of the single most abundant taxon	Increase
Percent Hydropsychidae	Percent of organisms in the caddisfly family hydropsychidae	Increase
Percent Baetidae	Percent of organisms in the may fly family Baetidae	Increase
Functional Feeding Groups (FFG)		
Percent Collectors	Percent of macrobenthos that collect or gather fine particulate matter	Increase
Percent Filterers	Percent of macrobenthos that filter fine particulate matter	Increase
Percent Grazers	Percent of macrobenthos that graze upon periphyton	Variable
Percent Predators	Percent of macrobenthos that feed on other organisms	Variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	Decrease
Abundance		
Estimated Abundance	Estimated number of BMIs in sample calculated by extrapolating from the proportion of organisms counted in the subsample	Variable

Table 5-2. Scores for the six biological metrics used to develop the Russian River IBI.

Biological Metrics	Russian River IBI Scores				
	5	3	1	La Honda Winter	La Honda Spring
Mean taxonomic Richness	≥36	35-26	<26	28	28
Mean Modified EPT Index	≥54	53-17	<17	15	17
Mean Shannon Diversity	≥3.0	2.9-2.3	<2.3	2.0	2.0
Mean Tolerance Value	≤3.0	3.1-4.6	>4.6	4.0	2.0
Mean Percent Dominant Taxon	≤14	15-39	>39	36	38
			Total IBI score for La Honda:	9	11

Total Score	30-24	23-18	17-12	11-6
Integrity Scale	Excellent	Good	Fair	Poor

Physical Habitat Quality

Physical habitat quality was assessed for the monitoring reaches using U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (RBPs) (Barbour et al., 1999). Habitat quality assessments were recorded for each monitoring reach during each macroinvertebrate sampling events within riffle/ run habitats. A description of reach-scale habitat parameters used to document local habitat conditions along stream corridors is shown in Appendix G-6.

5.4 RESULTS

The BMIs identified from the samples collected in La Honda Creek from the five sites are listed in the Species Sheet in Appendix G. The means and coefficients of variation (CV) for biological metrics calculated from BMI samples are listed in Means and Metrics Sheets of attached Excel Spreadsheet. Forms containing chemical and physical/habitat characteristic scores, and copies of the data and field notes are also on file at the SLSI office in Sacramento, and SFEI in Oakland.

BMI Community Structure

Sixty-five taxa of BMIs were identified in the 14 samples collected at the five sampling sites in the La Honda watershed. Appendix G-3 contains a list of the five most common taxa found at the five sites. Summary metrics can be found in Appendices G-1 and G-2.

Richness Measures: There were two biological metrics used to evaluate the biological condition of the La Honda Creek watershed sites that measure the richness of the BMI community. Cumulative Taxa values ranged from 32 to 48 for the five monitoring sites and are displayed in Figure 5-1. Cumulative EPT Taxa ranged from 17 to 23 for the five monitoring sites and are displayed in Figure 5-2.

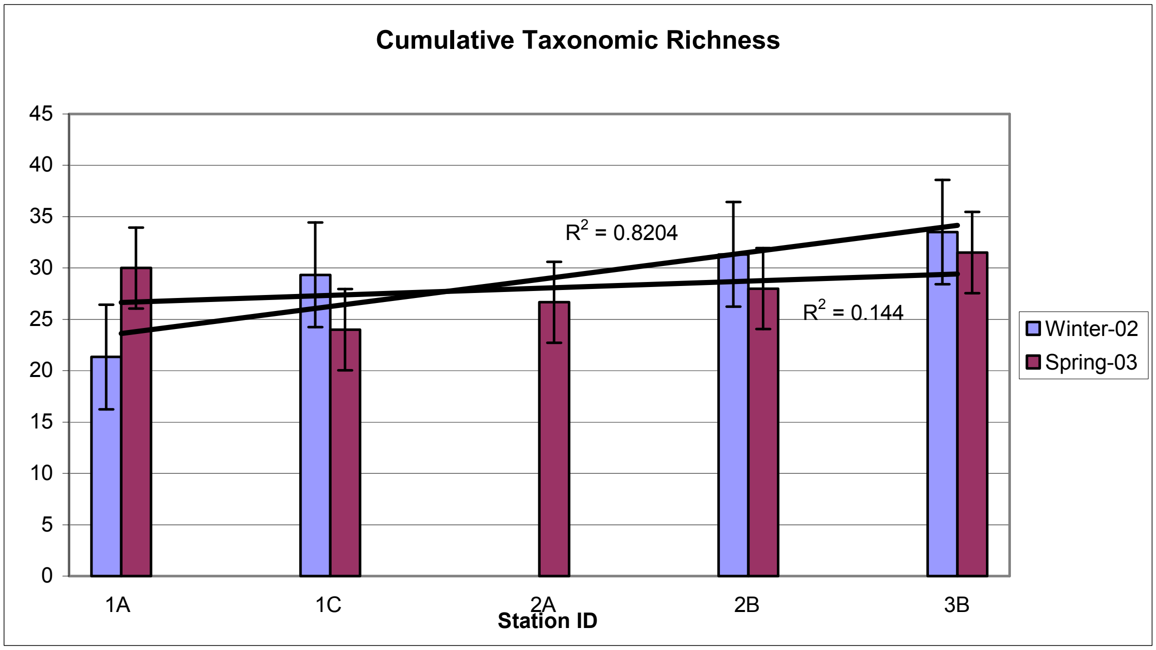


Figure 5-1. Cumulative Taxonomic Richness for BMIs collected in early Winter 2002 (r^2=.82) and Spring 2003 (r^2=.14) in the La Honda Creek Watershed, California.

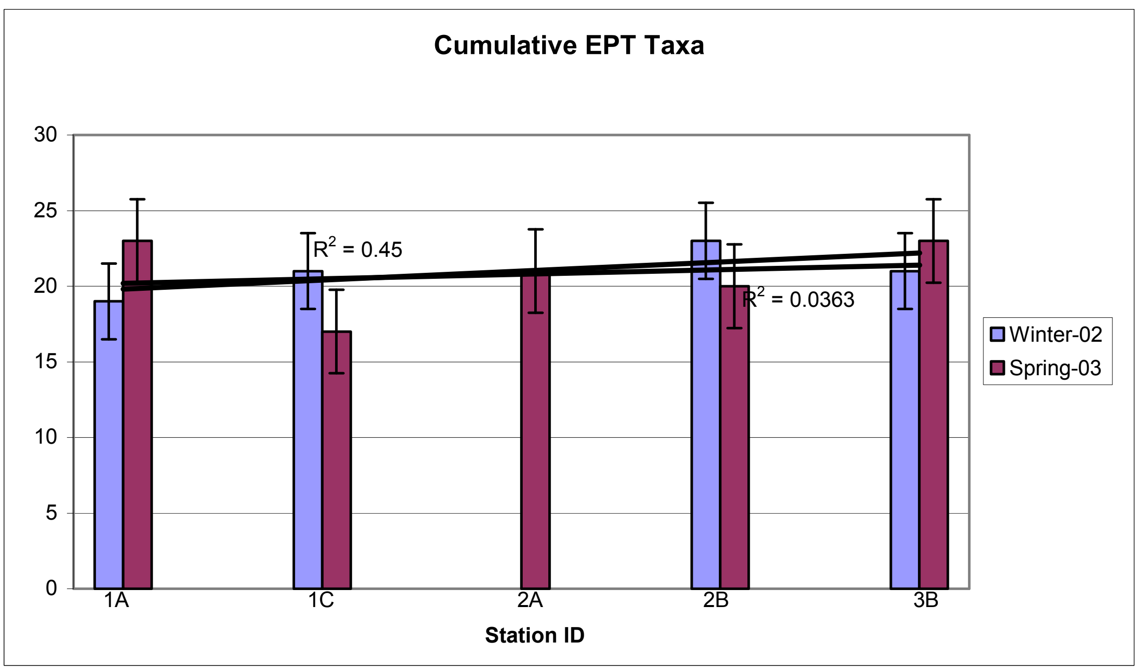


Figure 5-2. Cumulative EPT Taxa for BMIs collected in early Winter 2002 (r^2=.45) and Spring 2003 (r^2=.04) in the La Honda Creek Watershed, California.

Composition Measures: There were three biological metrics used to evaluate the biological condition of the La Honda Creek watershed sites that measure the richness of the BMI community. Mean Sensitive EPT Index values ranged from 31% to 82% for the five monitoring sites and are displayed in Figure 5-3. Mean Shannon Diversity values ranged from 1.0 to 3.0 for the five monitoring sites and are displayed in Figure 5-4. Mean Percent Dominant Taxon values ranged from 23 to 70 for the five monitoring sites and are displayed in Figure 5-5.

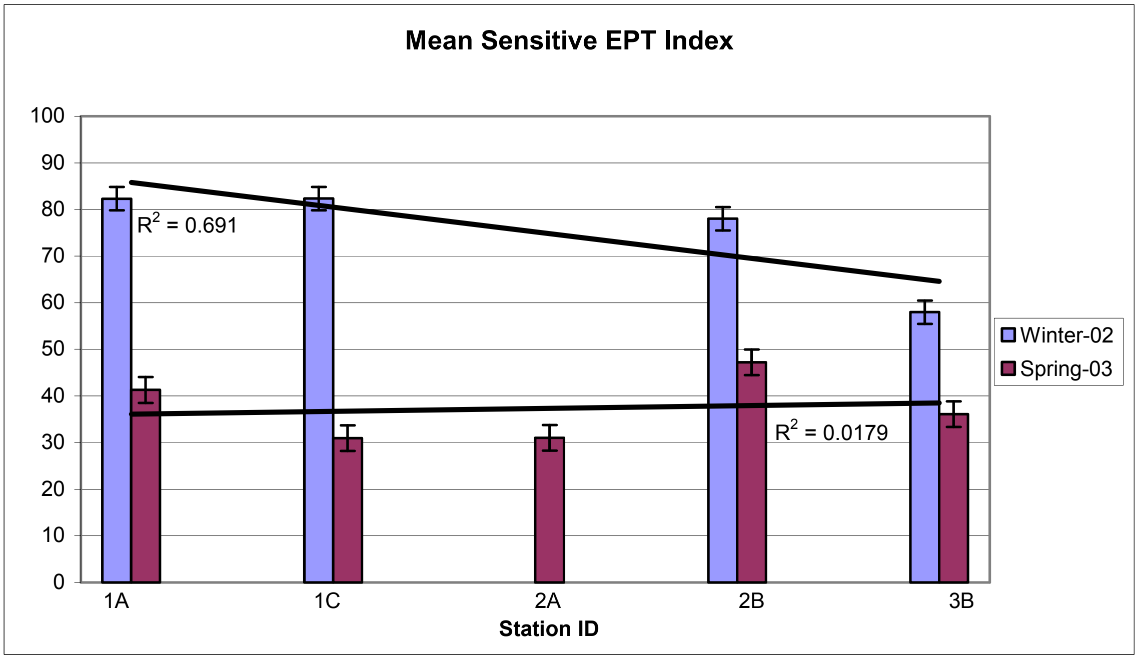


Figure 5-3. Mean Sensitive EPT Index for BMIs collected in early Winter 2002 (r^2=.69) and Spring 2003 (r^2=.02) in the La Honda Creek Watershed, California.

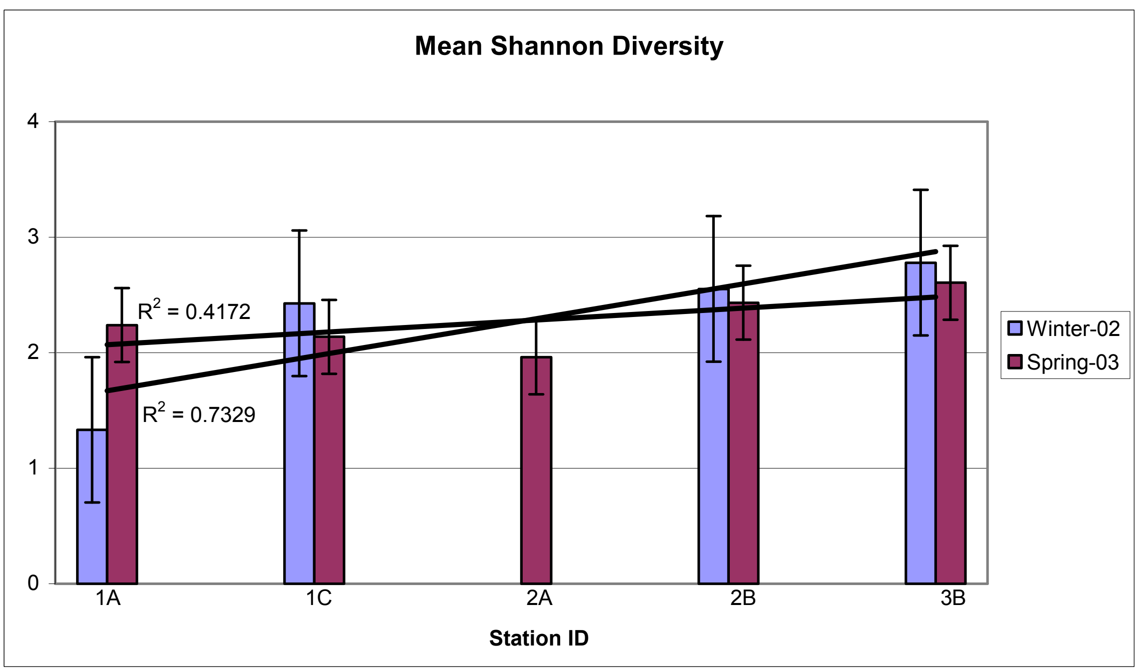


Figure 5-4. Mean Shannon Diversity for BMIs collected in early Winter 2002 (r^2=.73) and Spring 2003 (r^2=.42) in the La Honda Creek Watershed, California.

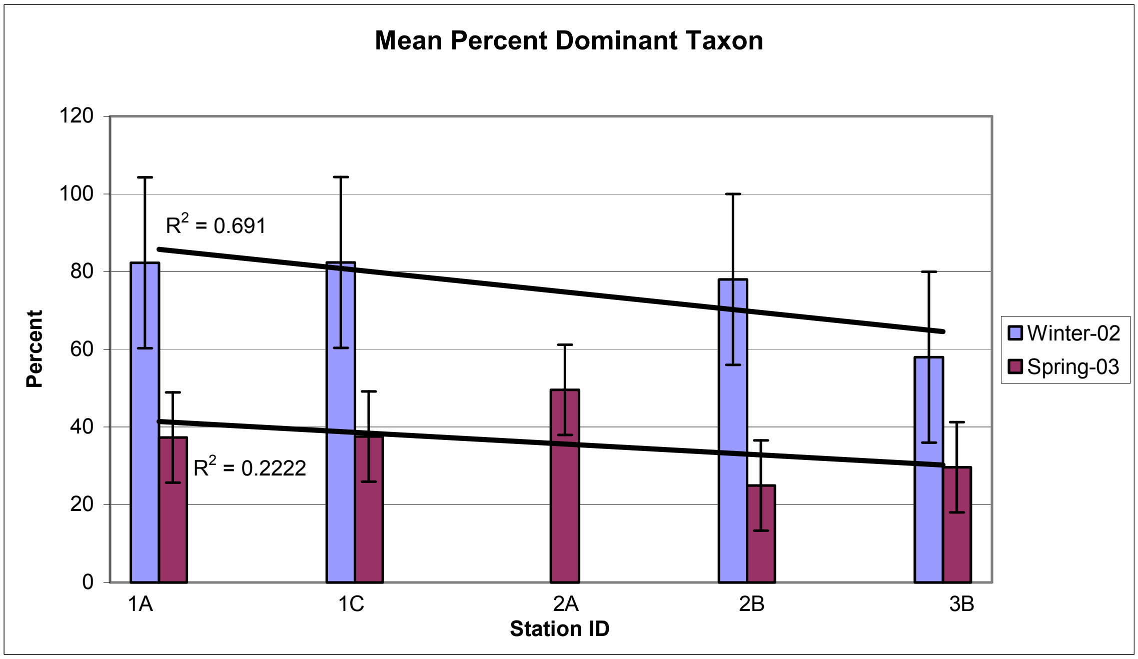


Figure 5-5. Mean Percent Dominant Taxon for BMIs collected in early Winter 2002 (r^2=.69) and Spring 2003 (r^2=.22) in the La Honda Creek Watershed, California.

Tolerance Measures: One biological metric was used to evaluate the biological condition of the La Honda Creek watershed sites that measure the richness of the BMI community. Mean Intolerant Taxa values ranged from 0 to 43 for the five monitoring sites and are displayed in Figure 5-6.

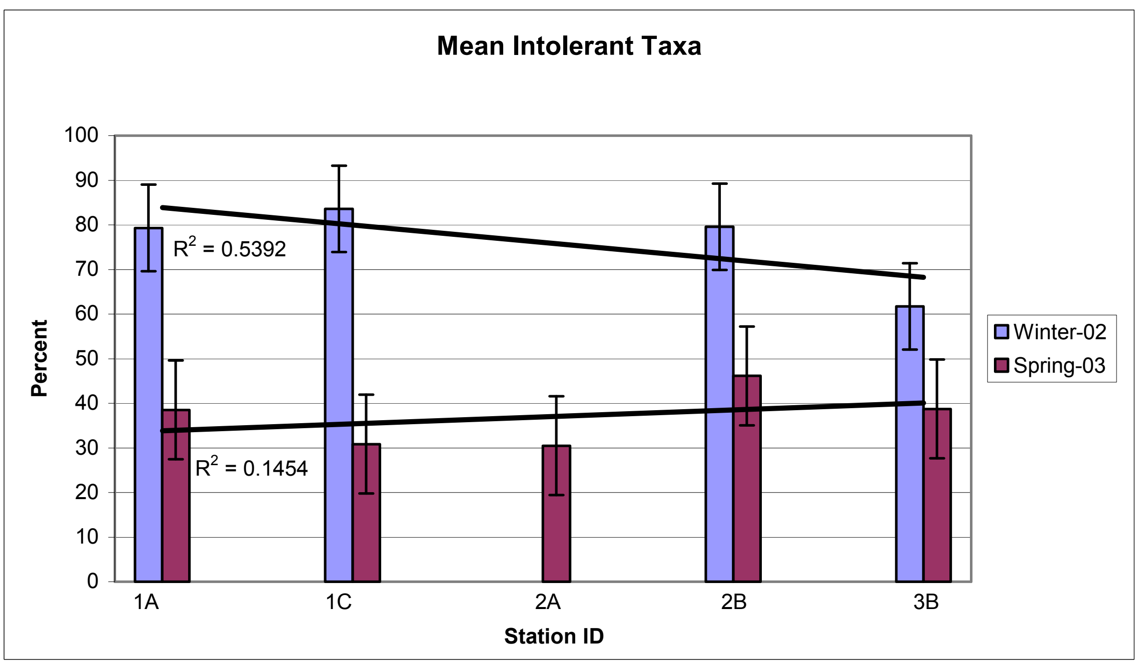


Figure 5-6. Mean Intolerant Taxa values for BMIs collected in early Winter 2002 (r^2=.54) and Spring 2003 (r^2=.15) in the La Honda Creek Watershed, California.

Functional Feeding Groups: Five biological metrics were used to evaluate the biological condition of the La Honda Creek watershed sites that measure the richness of the BMI community. Mean Percent Collectors values ranged from 5% to 71%, Filterers from 4% to 14%, Grazers from 8% to 43%, Predators from 2% to 14%, and Shredders values ranged from 11% to 77% for the five monitoring sites and are displayed in Figures 5-7 through 5-11.

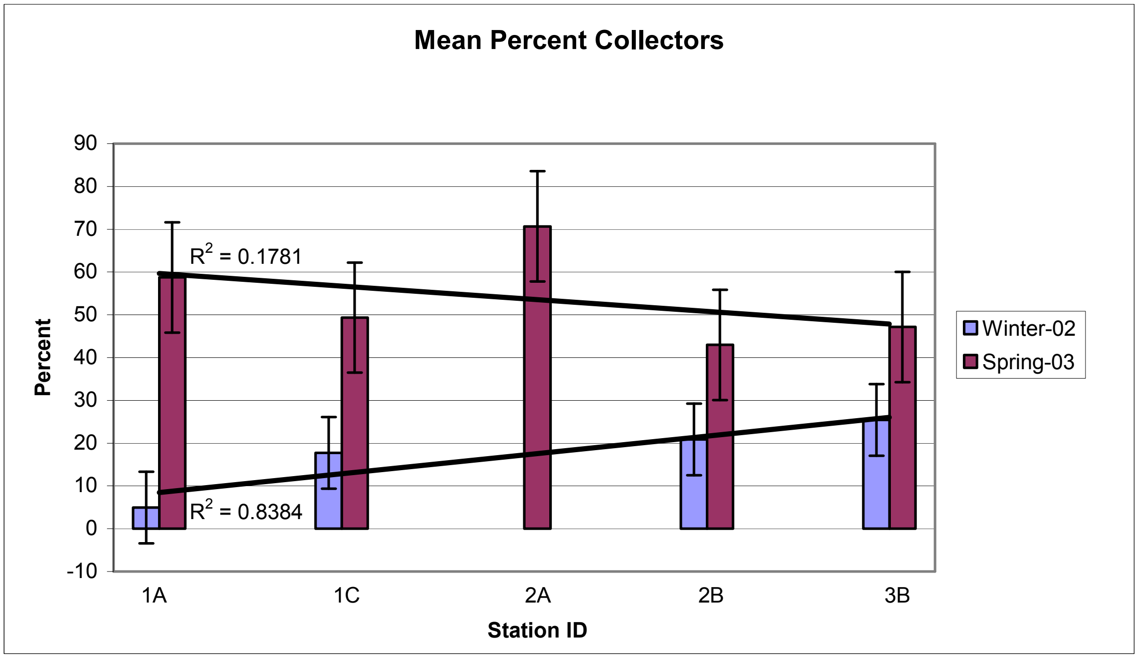


Figure 5-7. Mean Percent Collectors values BMIs collected in early Winter 2002 (r^2=.83) and Spring 2003 (r^2=.18) in the La Honda Creek Watershed, California.

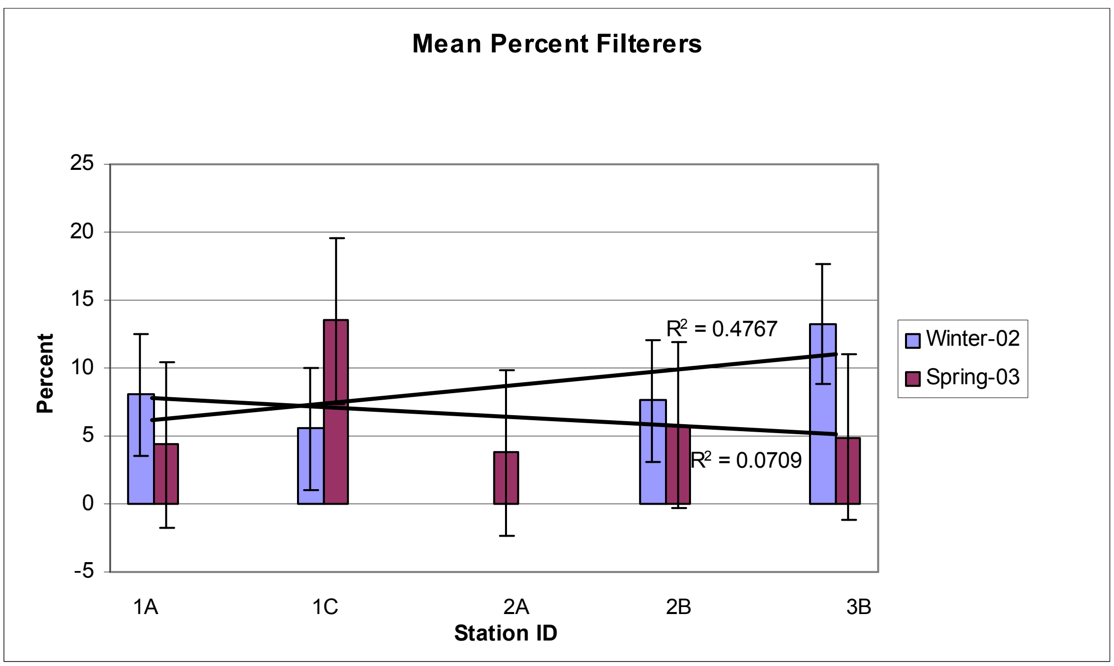


Figure 5-8. Mean Percent Filterers values BMIs collected in early Winter 2002 (r^2=.48) and Spring 2003 (r^2=.07) in the La Honda Creek Watershed, California.

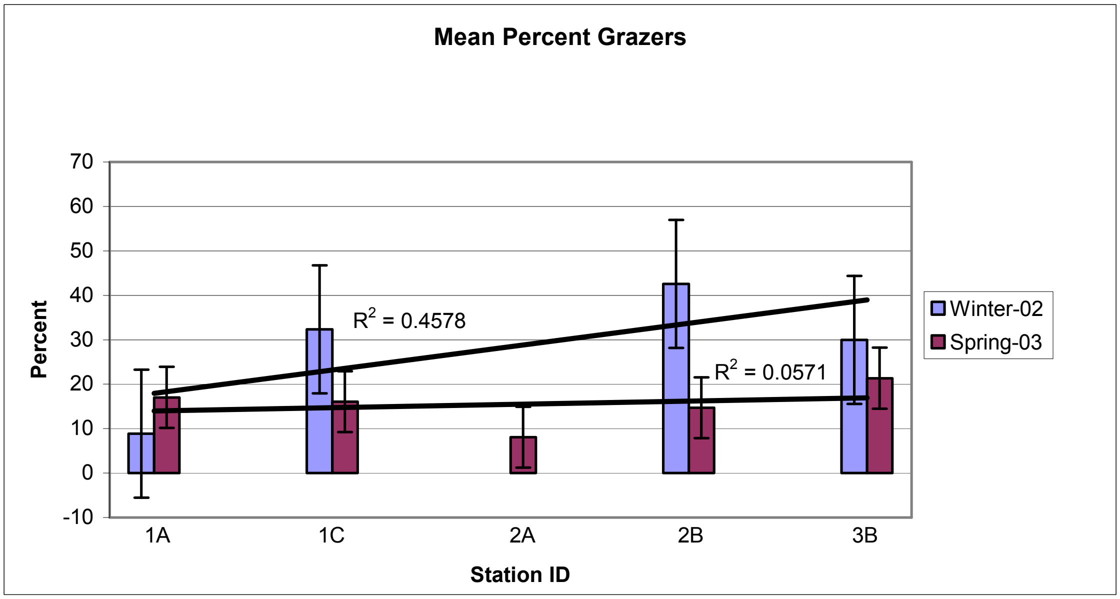
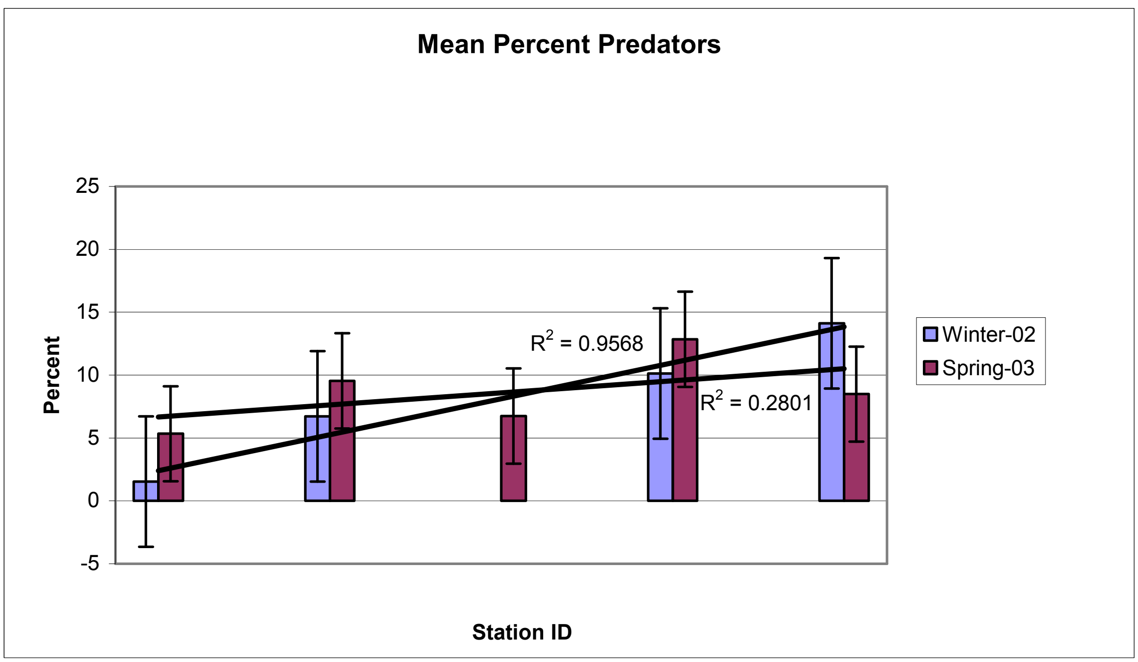


Figure 5-9. Mean Percent Grazers values BMIs collected in early Winter 2002 (r^2=.46) and Spring 2003 (r^2=.06) in the La



Honda Creek Watershed, California.

Figure 5-10. Mean Percent Predators values BMIs collected in early Winter 2002 (r^2=.96) and Spring 2003 (r^2=.28) in the La Honda Creek Watershed, California.

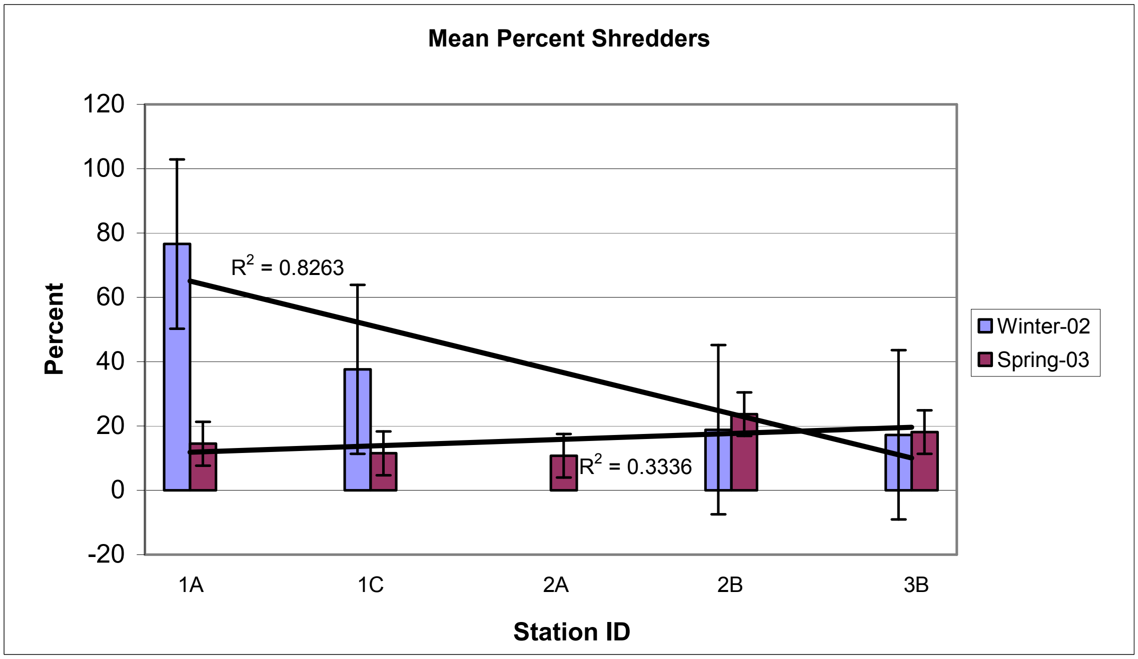


Figure 5-11. Mean Percent Shredders values BMIs collected in early Winter 2002 (r^2=.82) and Spring 2003 (r^2=.33) in the La Honda Creek Watershed, California.

IBI Scores

The IBI scores calculated for the five La Honda Creek watershed sites were found to be fair to poor for each reach (Table 5-2). This indicates that macroinvertebrate habitat may be impaired within this watershed if compared to the Russian River IBI. Table 5-3 depicts trends observed with regard to change in functional feeding groups among the study reaches.

Table 5-3. Trends in diversity and functional feeding groups.

Biological Metrics	**Winter r^2**	**Spring r^2**
Cumulative Taxonomic Richness	.82	.14
Mean Sensitive EPT Index	.69	.02
Mean Shannon Diversity	.73	.42
Mean Percent Dominant Taxon	.69 (neg)	.22
Mean Percent Collectors	.83	.18
Mean Percent Predators	.96	.28
Mean Percent Shredders	.82 (neg)	.33

Physical Habitat Quality

Physical habitat quality scores are listed in Table 5-4 for 2002-2003. Physical habitat, as reflected by the invertebrate metrics, ranks quite well. The only noteworthy impairment (20-year-old landslide) was observed in the left bank stability in Reach 1C.

Table 5-4. Physical Habitat Scores for Study Reaches (see Section 6) within the La Honda Creek watershed.

Habitat	1A	1C	2A	2B	3B
Epifaunal Cover	11	10	14	12	18
Embeddedness	10	9	9	13	16
Velocity/Depth	8	10	10	10	7
Sediment Deposition	17	15	16	16	12
Channel Flow	10	10	11	10	13
Channel Alteration	19	20	19	20	20
Riffle Frequency	19	16	16	17	14
Bank Stability-left	7	2	8	7	8
Bank Stability-right	9	8	7	5	8
Vegetative protection - left	7	6	7	8	4
Vegetative protection - right	7	8	6	8	3
Riparian Zone Width – left	7	8	9	10	9
Riparian Zone Width – right	7	9	5	10	8
Total Habitat Score	**138**	**139**	**137**	**146**	**140**
Physical Condition Rating	**Good**	**Good**	**Good**	**Good**	**Good**

5.5 DISCUSSION

The overall assessment of the benthic macroinvertebrate community in La Honda Creek, based upon five sites sampled in the watershed, indicates an aquatic system of marginal health if compared to biological metrics from the Russian River. Whether or not this is an adequate comparison however, is a topic of some discussion. There is no IBI for La Honda Creek, thus making the Russian River the nearest comparable watershed. There are significant differences in geology, hydrology and sediment sources/contributions between these systems, so strict comparisons should perhaps be avoided until more locally-relevant data are developed.

The overall trends in distribution of functional feeding groups and taxonomic richness should be noted. Differences between early winter and spring sampling appear to be quite significant. The most noticeable, altitudinal trends were observed in winter sampling. Percent dominant taxa and shredders increased with elevation, as one may expect. Cumulative Taxonomic Richness, Mean Sensitive EPT Index, Mean Shannon Diversity, Mean Percent Collectors, and Mean Percent Predators all declined with elevation. All other metrics did not appear to vary significantly. These trends are consistent with those one might expect given concepts of the "river continuum" (Vannote et al., 1979), however this data reflects only one season of data collection. Additional sampling should occur before broad conclusions are drawn with regard to BMI's in this watershed.

Aquatic organisms can respond as negatively to inorganic sediment as they do to other environmental contaminants. For example, fish can sometimes avoid sediment discharge events by relocating. But for less mobile communities of benthic macroinvertebrates, the health of the community depends on a diverse substrate particle size, available interstitial spaces and a complex habitat. This habitat can be significantly affected or eliminated by sediment deposition. While most of the invertebrates collected in the monitoring reaches are able to tolerate sediment to some degree, based on preliminary sampling, it appears that the community is being somewhat negatively affected by fine sediment deposition. A fairly diverse population was sampled, suggesting that BMIs are having moderate success in the watershed, but comparatively, a greater number and diversity of taxa could be achieved.

Benthic macroinvertebrates can be killed directly by suffocation or affected indirectly through loss of food sources and habitat. Eventually, fish, amphibians and many terrestrial animals will be affected when macroinvertebrate abundance decreases. There is considerable evidence supporting aquatic invertebrates as a major food source of other aquatic organisms and terrestrial animals

There does not appear to be significant organic enrichment (excess runoff or nutrient contribution) in the five La Honda sites, as would be indicated by a high percentage of collector and filterers and the presence of tubificids.

Lack of adequate flows can cause a variety of poor water quality conditions for aquatic invertebrate communities including low dissolved oxygen, high water temperatures, lack of mobility for downstream drift of organisms and decrease in food supply. Although tolerant of sedimentation, baetid mayflies do require adequate flow to maintain their life history requirements. Based upon the BMI samples and observations of the physical stream condition in five selected reaches, La Honda Creek appears to provide adequate conditions for these important indicator taxa, but given the relatively low IBI when compared to the Russian River, additional sampling would seem warranted.

5.6 CONCLUSIONS

Two sampling events that occurred in the winter of 2002, and the spring of 2003 provide baseline data on the condition of benthic macroinvertebrates (BMIs) in the La Honda Creek watershed. Based upon the collected data, the total IBI score for La Honda Creek is 9 for the winter sampling, and 11 for the spring sampling. These scores correspond to the fair to poor category based upon the IBI that was developed for the Russian River. This suggests that aquatic habitat in La Honda Creek may be impaired compared to the Russian River. The benthic community is likely being somewhat affected by sediment deposition in the substrate of the creek. However, these conclusions are drawn from only two sets of samples, making trend detection and statistical analysis difficult. Additional data (multiple seasons of sampling in the same five locations) should be collected in La Honda Creek to gain a better understanding of the status of the benthic community.