I. INTRODUCTION

Aquatic Consulting Services, Inc. (ACS) has completed this report for Project Clean Water (PCW), Santa Barbara County's stormwater task force. The report summarizes the findings of the 2001 Santa Barbara County Coastal Creeks Bioassessment Program (Program).

A. PURPOSE OF THE PROGRAM

The Program is envisioned by PCW as a long-term effort to monitor the health of coastal creeks in southern Santa Barbara County between Carpinteria and Gaviota. The Program involves the intensive study of local creeks in order to gain a better understanding of their physical and biological characteristics, and how they are influenced by natural and human factors. Over the long-term, the Program effort will be focused to explore the following questions:

- What biological and physical characteristics define relatively undisturbed local creeks?
- To what extent are local creek ecosystems shaped by natural factors including stream flow, order, gradient, and watershed area?
- How do biological communities in local creeks change seasonally and from year to year due to fluctuations in climate, rainfall, and stream flow?
- What impacts do different forms of human disturbance have on local creek ecosystems? Which forms of human disturbance have the most severe impacts?
- To what degree can impacted creeks be restored given the constraints posed by existing and future development? What feasible actions (e.g., improving water quality, controlling erosion, minimizing physical disturbances to habitat, restoring and protecting native riparian vegetation, removing physical barriers to wildlife movement, etc.) are most effective in restoring important creek functions and values? How much time is required for creek ecosystems to recover after restoration actions are initiated?
- Which biological and physical parameters are reliable indicators of creek ecosystem health, and can be effectively used in impact assessment and ecological monitoring?
- What are the impacts of Program monitoring efforts on creek ecosystems, and how can they be minimized?

Information provided by the Program effort will allow the County and other local agencies to assess impacts to local creeks, determine which creeks are in need of restoration, monitor ecological recovery after creek restoration actions are initiated, and determine which restoration actions are most effective. The restoration of local creeks will have numerous benefits including recovery of native plant and animal populations, improved water quality, reduced threats to human health (e.g., at local beaches), and improved aesthetics and recreational opportunities.

B. PROGRAM SCOPE OF WORK

The 2001 Program effort involved the study of 12 study reaches along six local creeks, including Carpinteria Creek, Arroyo Burro/San Roque Creek, San Jose Creek, Atascadero Creek, Arroyo Hondo, and San Onofre Creek. Field surveys, laboratory work, and literature research were conducted during the spring and summer of 2001 to gather physical and biological data for the study reaches. Data were analyzed with quantitative statistical methods to examine trends and relationships between various physical and biological parameters. In addition, data collected in 10 of the 12 Program study reaches in the spring and summer of 2000 were analyzed as part of the Program effort for this year. Thus, two years of data are presented in this report for 10 of the 12 study reaches. The 2000 data set was produced by ACS Biologist Jeff Brinkman as part of his Master's thesis work at UCSB. Mr. Brinkman gives his full consent to the use of the 2000 data as part of this year's Program effort.

C. BENTHIC MACROINVERTEBRATES AS INDICATORS OF STREAM HEALTH

The Program focuses on the use of benthic macroinvertebrates (BMIs) as indicators of the overall health of local creek ecosystems. BMIs are aquatic insects, crustaceans, gastropods, and other invertebrates that inhabit aquatic environments (e.g., streams, rivers, lakes, estuaries, and marine waters). BMIs have proven to be reliable, cost-effective biological indicators of aquatic ecosystem health and water quality (Barbour, M.T., et. al., 1999). Numerous resource agencies endorse the use of BMIs as biological indicators, including the U.S. Environmental Protection Agency (EPA), the California Department of Fish and Game (CDFG), and the State of California Water Resources Control Board (SWRCB). Some of the main reasons that BMIs are important, reliable biological indicators are the following:

- BMIs are an integral component of aquatic communities. They typically represent a large proportion of the community biomass, perform important functions in the cycling of nutrients and energy, and are food sources for predators such as fish. Thus, changes in BMI assemblages can have profound effects on the aquatic community.
- BMIs have varying tolerances to human disturbances (e.g., chemical pollution, stream channelization, etc.) that result in habitat degradation. Some BMIs are highly sensitive to disturbance, and are found only in relatively pristine aquatic habitats. Others are highly tolerant, and can thrive even in highly degraded water bodies. Thus, the presence, absence, and relative abundance of certain BMIs in a given water body reflect the overall health of the ecosystem. In addition, aquatic habitats that are relatively pristine generally support diverse BMI communities (i.e., a large number of species) including many sensitive species, whereas those that have been subjected to a great deal of human disturbance typically have low BMI diversity and are dominated by tolerant species. Thus, BMI diversity serves as another important indicator of the health of the aquatic ecosystem.
- BMIs typically have aquatic life stages lasting up to several months or years. Thus, analysis of BMI communities provides a long-term, cumulative measure of the health of aquatic ecosystems. This offers a considerable advantage over traditional water quality monitoring, which represents only a "snapshot" at the time of sampling, and must be conducted often (and at great expense) to provide an indication of long-term water quality. In addition, water quality analysis focuses on a chemical aspect of the ecosystem, and does not provide any direct information about the biological community.
- BMIs are typically abundant and diverse compared to other aquatic taxa such as fish and amphibians, are easy to collect, and can be identified quickly by trained taxonomists. It is easier to detect temporal and spatial differences in BMI communities compared to other taxonomic groups that are less diverse and abundant.
- Bioassessment using BMIs is a well-developed technique, especially in the context of streams. There is a wealth of information available on life history, distribution, habitat requirements, and disturbance tolerances of most BMIs; thus many inferences can be made about a particular stream based on the BMIs found there.

II. STUDY REACHES

The locations of the 12 Program study reaches are shown in Figures 1-4. Table 1 separates the study reaches into two groups: (1) relatively undisturbed reaches, and (2) disturbed reaches. The table also provides information for each study reach including location, level and type of human disturbance, stream order, elevation, stream gradient, and watershed area. Representative photographs taken in the study reaches during the spring field surveys are provided in Figures 5 through 9.

Table 1: Study Reaches

Group Reach	**Location**	**Level and Type(s) of Human Disturbance**	**Stream Order**	**Elevation (Feet)**	**Stream Gradient (Slope)**	**Watershed Area (Acres)**
Relatively Undisturbed Reaches						
C-3	Gobernador Creek, ¼-mile upstream of County debris basin	Low, roads	3	420	Moderate (0.033)	4,473.1
AB-2	San Roque Creek, ¼-mile upstream of Foothill Rd.	Low, agriculture, rural residential, roads	2	300	Moderate (0.025)	2,471.3
SJ-3	San Jose Creek at San Marcos Trout Club near Old San Marcos Pass Rd.	Low, rural residential, roads	2	1,000	High (0.107)	1,754.6
AH-1	Arroyo Hondo, ½-mile upstream of U.S. 101.	Low, roads	2	150	Moderate (0.040)	2,570.2
SO-1	San Onofre Creek, 1 mile upstream of U.S. 101	None	2	500	High (0.133)	1,013.2
Disturbed Reaches						
C-1	Carpinteria Creek, ¼-mile downstream of Carpinteria Ave.	High, agriculture and urban	4	15	Low (0.008)	9,638.1
C-2	Carpinteria Creek, approximately ½ -mile upstream of U.S. 101.	High, agriculture and urban	4	50	Low (0.008)	9,465.1
AB-1	Arroyo Burro just downstream of Torino Rd.	High, urban and agriculture	3	75	Low (0.010)	5,140.3
AT-1	Atascadero Creek near Patterson Rd.	High, urban and agriculture	4	15	Low (0.002)	12,106.8
AT-2	Atascadero Creek just downstream of the confluence with Cieneguitas Creek.	High, urban and agriculture	3	50	Low (0.007)	2,006.2
SJ-1	San Jose Creek, ¼ mile downstream of U.S. 101.	High, agriculture and urban	4	30	Low (0.005)	5,165.0
SJ-2	San Jose Creek, ¼-mile upstream of Patterson Rd.	High, agriculture, rural residential, roads	3	121	Low (0.014)	3,509.2

Collectively, the study reaches are subject to a wide range of natural and human factors. Studying these reaches as a group provides information on how physical and human factors interrelate and shape creek ecosystems. The Program creeks and study reaches were also selected based on their importance to the local community. Some of the reasons why the Program creeks and study reaches are especially important are the following:

- All of the Program creeks have fairly large watersheds, maintain perennial flows at least in some sections, and support diverse biological communities, including sensitive species such as steelhead trout, California newt, and southwestern pond turtle.
- San Jose Creek and Atascadero Creek feed into Goleta Slough, an important coastal estuary and wetland. Arroyo Burro and Carpinteria Creek support smaller coastal estuaries. Coastal estuaries and wetlands support productive, diverse biological communities, and have been substantially impacted by development in southern California.
- Several Program creeks are important sources of water supply, storm-water conveyance (i.e., flood control), and recreation. Program creeks recharge important groundwater sources as well.
- Several Program creeks empty into the ocean near popular beaches such as Goleta Beach (San Jose Creek and Atascadero Creek), Hendry's Beach (Arroyo Burro), and Carpinteria State Beach (Carpinteria Creek). Poor water quality (i.e., high bacteria levels) at these beaches has been a chronic problem, resulting in numerous beach closures. This is due in part to polluted runoff from the creeks.
- Arroyo Burro, Carpinteria Creek, and Goleta Slough (San Jose Creek and Atascadero Creek are tributaries) are listed as impaired by the State of California and the federal government pursuant to Section 303(d) of the Federal Clean Water Act (CWA). Per CWA, total maximum daily load (TMDL) plans will be required to reduce specific pollutants to acceptable levels in Arroyo Burro (pathogens), Carpinteria Creek (pathogens), and Goleta Slough (metals, pathogens, organic pollution and sediments) if they remain on the impaired list.
- PCW is planning habitat restoration projects along Carpinteria Creek, San Jose Creek, and Arroyo Burro. The Program is providing data that will be useful in establishing baseline conditions for these restoration projects, and eventually will be used to monitor ecological recovery in these areas after restoration activities are initiated.

Figure 1 Program Study (8 ½ x 11 color)

Figure 2 Gaviota Area Study Reaches (8 ½ x 11 color)

Figure 3 Santa Barbara/Goleta Area Study Reaches (8 ½ x 11 color)

Figure 4 Carpinteria Area Study Reaches (8 ½ x 11 color)

Figure 5 Study Reach Photographs (8 ½ x 11 color)

Figure 6 Study Reach Photographs (8 ½ x 11 color)

Figure 7 Study Reach Photographs (8 ½ x 11 color)

Figure 8	Study Reach Photographs (8 ½ x 11 color)

Figure 9 Study Reach Photographs (8 ½ x 11 color)

III. METHODS

The work completed as part of this year's Program can be divided into the following components: field surveys, laboratory work, calculation of physical parameters, calculation of biological metrics, and data analysis. The following describes the methods employed to complete each of these components.

A. FIELD SURVEYS

Field surveys were conducted by a crew of two or three people to evaluate the physical and biological conditions in each study reach. The crew included ACS Biologist Jeff Brinkman (as a subcontractor to Padre Associates, Inc.), PCW staff Tommy Liddell and Willie Brummett, and ACS Biologist Darren Howe (at the time employed by Padre Associates, Inc.). Field surveys were conducted between May 17 and June 1, 2001.

A number of tasks were completed in each study reach, including the following:

- General observations were recorded, including study reach location, date, time, weather, creek flow conditions, water clarity, and sources of human disturbance.
- A 100-meter study reach was delineated along the creek using a compass, tape and stakes. The study reach was sketched on the field data sheet. Survey points, compass bearings, and important features such as creekbed and banks, riparian vegetation, adjacent land uses, riffle/pool locations, etc., were noted on the sketch.
- Creek widths (wetted perimeter, channel bottom, and bank full) and riparian corridor width were measured at three points along the study reach, and noted on the field data sheet. Wetted perimeter width is defined as the cross-sectional distance of creekbed that is inundated with surface water. Channel bottom width is defined as the cross-sectional distance between the bottoms of the creek banks. Bank full width is defined as the cross-sectional distance from the top of one creek bank to the other, as evidenced by visible signs of stream flow such as water marks, stream-carried deposits of sediments and debris, and scour features.
- Surveys for aquatic and terrestrial plants and vertebrate species (e.g., fish, amphibians, reptiles, birds, and mammals) were conducted along the creeks and their riparian corridors. Observed species were noted on field data sheets.
- Water temperature, pH, and conductivity were measured. The sampling locations and results were noted on the field data sheet.
- Creek flow (Q) was estimated at a selected cross-section of the study reach. Q was estimated by multiplying the measured creek width times the average water depth and velocity, as measured at three to five equally spaced points along the cross-section. The measurements were recorded on the field data sheet.
- Three BMI samples were collected in each study reach based on methods provided in the EPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (1999). The three samples were collected from the downstream third, middle third, and upstream third of the study reach, respectively. Each sample represents approximately one square meter of creek bottom, collected from 10 individual, 0.1-square-meter locations. The 10 locations that make up each sample were selected based on the relative coverage area of creek bottom features (i.e., riffles, pools, falls, etc.) in the study reach. For example, if a

given creek reach contained approximately 50 percent riffles and 50 percent pools, five locations in riffles and five in pools were selected and sampled. After each composite sample was collected, it was sieved through 250 µm mesh to wash out fine sediments, transferred to a plastic container and preserved in 70 percent ethanol for laboratory analysis.

- A semi-quantitative creek habitat assessment was conducted using the protocol provided in the EPA's *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers* (1999). Per this protocol, habitat components were visually assessed and scored, including stream substrate/cover, sediment embeddedness, stream velocity/depth regime, sediment deposition, channel flow status, human alteration, channel sinuosity, habitat complexity/variability, bank stability, vegetative protection, and width and composition of riparian vegetation. Each study reach was assigned a total score of between zero and 200 based on the sum of scores assigned for each habitat component. Criteria from the EPA protocol were used to guide scoring.
- Photographs were taken to illustrate important features in the study reaches.

Quality assurance and quality control (QA/QC) measures were incorporated into the field surveys. Field crewmembers were trained to properly operate equipment, take measurements, collect BMI samples, conduct semi-quantitative creek habitat assessments, etc. Mr. Brinkman directed field surveys to ensure consistency. The lone exception to this was the survey in Arroyo Hondo on June 1, which was conducted by County staff after they were thoroughly trained during 10 previous surveys. Other QA/QC measures included calibrating water monitoring equipment and immediately preserving BMI samples in 70 percent ethanol to ensure they did not decompose before being analyzed in the laboratory.

B. LABORATORY WORK

Laboratory work was conducted to analyze BMI samples collected during the field surveys. Each BMI sample was strained through a 250-µm mesh sieve and washed with water to remove ethanol and fine sediments. The sample was then placed in a plastic tray marked with a grid pattern of 25 equally sized squares (five by five). The entire sample was spread out evenly across the 25 squares. Squares of material were randomly selected and sorted one at a time under a dissecting microscope until a total of 110 BMIs were randomly located and picked out. The proportion of the sample sorted was noted, and BMI density was estimated based on the one square meter sampling area. 100 of the 110 selected BMIs were identified to the lowest practical taxonomic level using dichotomous keys and other references. Most insects were identified to the genus level. Non-insects were typically identified to the order or class level. The results of the sample processing were recorded on laboratory data sheets. Sorted BMIs and unsorted portions of the sample were bottled separately in 70 percent ethanol for storage.

Extensive QA/QC measures were incorporated into the laboratory analysis to ensure random selection and accurate, consistent enumeration and identification of BMIs. BMI sample processing methods were clearly established and strictly followed. Only experienced, properly trained ACS staff (Jeff Brinkman and Darren Howe) processed the BMI samples. Four of the 36 BMI samples were identified independently by both Mr. Brinkman and Mr. Howe. Mr. Brinkman and Mr. Howe compared results for these samples, and together resolved any inconsistencies in identification. All of the other samples were then re-checked to ensure consistent identifications. All laboratory data sheets were double-checked to ensure proper enumeration.

C. CALCULATION OF PHYSICAL PARAMETERS

The following physical parameters were calculated for each study reach:

- Stream order
- Elevation
- Stream gradient
- Watershed area
- Watershed land use types and percent cover

Stream order, elevation, and gradient were determined by reviewing USGS 7.5 minute quadrangle topographic maps (1:24,000 scale) for the local area. Watersheds for each study reach were delineated on the maps based on the topographic contours, and individual watershed areas were calculated using a digital planimeter. Watershed land use types (i.e., open space, agriculture, and urban/suburban) and boundaries in each study reach watershed were determined using recent aerial photographs (1999) and County Assessor's parcel boundaries and zoning designations (from the County's GIS database). Total area and percent cover of each land use type within the study reach watersheds were calculated using the digital planimeter.

D. CALCULATION OF BIOLOGICAL METRICS

Seven biological metrics were calculated to facilitate comparisons between study reaches and the analysis of relationships between physical and biological parameters. The biological metrics that were calculated are the following: BMI density, number of aquatic insect families, number of aquatic insect genera, index of biotic integrity (IBI), percent sensitive BMI taxa, percent tolerant BMI taxa, and number of aquatic vertebrate species. Each metric is discussed briefly below.

1. BMI Density

BMI density (individuals per square meter) was calculated for each sample by dividing the number of individuals picked from the sample by the subsampled area. The subsampled area was estimated by multiplying the proportion of the sample sorted by one square meter, which is the total area of stream bottom represented by each sample. For the 2001 data, average BMI density for each study reach was calculated by combining the data for the three samples.

2. Number of Aquatic Insect Families and Genera

The number of aquatic insect families and genera was determined for each BMI sample, and overall for each study reach. In general, undisturbed streams support more diverse aquatic insect communities (i.e., a greater number of families and genera) compared to disturbed streams, as human disturbances typically result in the extirpation of sensitive taxa in affected areas. Diversity metrics were limited to insect taxa because they comprised the vast majority of organisms in the samples, and non-insects were identified only to coarse taxonomic levels (i.e., class or order).

3. Index of Biotic Integrity (IBI)

The IBI is an average value of between 0 and 10 that indicates the overall "tolerance" of a given stream's BMI community to human disturbance. The IBI is calculated by adding the tolerance values of the individual BMIs collected in a sample taken from the stream, and dividing by the total number of individuals. Individual BMI taxa have been assigned tolerance values of between 0 and 10 based on their observed ability to withstand human disturbance. A tolerance value of 0 indicates that a particular BMI is extremely intolerant of human disturbance, with increasing scores indicating greater tolerance. An organism with a tolerance value of 10 is exceptionally tolerant of human disturbance. In this context, human disturbance includes both chemical pollution, which can cause physiological impairment, and physical perturbations (e.g., stream channelization, water impoundments and withdrawals, etc.) that alter or destroy stream habitat. In reality, disturbed streams are typically subjected to both chemical and physical perturbations, thus the effects of these two major forms of disturbance are often difficult to separate.

In general, IBI scores are higher for BMI samples collected from disturbed streams compared to relatively undisturbed streams. This is because disturbed streams are generally dominated by disturbance-tolerant BMIs (i.e., high tolerance values), whereas relatively undisturbed streams typically support a more diverse mix of BMIs including a solid proportion of disturbance-intolerant forms (i.e., low tolerance values). The IBI is typically a reliable indicator of the overall health of the stream ecosystem.

The IBI was calculated for each BMI sample collected in 2000 and 2001 based on the method described above. For the 2001 samples, an overall IBI was calculated for each study reach by averaging the values for the three individual BMI samples. Tolerance values for individual BMIs were obtained from *Rapid Bioassessment Protocols for Use in Creeks and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition* (Barbour, M.T., et. al. 1999). The *Rapid Bioassessment Protocols* (RBP) document provides tolerance values for a wide range of BMI taxa at the order, family, genus, and species levels. The tolerance values provided in the RBP have been synthesized from a wealth of research efforts, including a number of studies conducted by various academic researchers and local, state, and federal environmental protection agencies over the last several decades.

The RBP provides BMI tolerance values by region, including the following: Northwest (Idaho), Upper Midwest (Wisconsin), Midwest (Ohio), Southeast (North Carolina), and the Mid-Atlantic. The tolerance values provided for a given species or group sometimes vary among regions, but they are usually similar. Tolerance values are not provided for the Southwest region of the country, including California. In response to this, tolerance values for individual BMI taxa were obtained by averaging the tolerance values available for other regions of the country. Tolerance values were available for the vast majority (i.e., more than 98 percent) of the BMIs found in the samples. BMIs without tolerance values were excluded from the IBI calculations.

4. Percent Sensitive BMI Taxa

For the purposes of this study, sensitive BMIs are defined as those having a tolerance value of 3.00 or less. Percent sensitive BMI taxa was calculated for each BMI sample by adding up the number of individuals with a tolerance value of 3.00 or less, dividing by the total number of individuals, and multiplying by 100. For 2001, an overall figure was calculated for each study reach by averaging the values for the three individual BMI samples. In theory, the percent of sensitive BMI taxa should be high in relatively undisturbed streams, and lower in streams with increasing levels of human disturbance.

5. Percent Tolerant BMI Taxa

For the purposes of this study, tolerant BMIs were those having a tolerance value of greater than 7.00. Percent tolerant BMI taxa was calculated for each BMI sample by adding up the number of individuals with a tolerance value of greater than 7.00, dividing by the total number of individuals, and multiplying by 100. For 2001, an overall figure was calculated for each study reach by averaging the values for the three individual BMI samples. In theory, the percent of tolerant BMI taxa should be higher in streams with increasing levels of human disturbance.

6. Number of Native Aquatic Vertebrate Species

The number of native aquatic vertebrate species present in each study reach was determined based on direct observations recorded during the field surveys. Similar to aquatic insect diversity, the diversity of native aquatic vertebrates is typically higher in undisturbed streams compared to disturbed streams.

E. DATA ANALYSIS

The data sets for 2000 and 2001 were analyzed separately with statistical tests to evaluate the following:

- Comparisons of mean values for biological and physical parameters between two groups: relatively undisturbed reaches and disturbed reaches.
- Relationships between biological parameters (i.e., response variables) and physical parameters (i.e., independent variables) among all study reaches.
- Comparisons of mean values for BMI metrics between individual study reaches.

In addition, comparisons of mean values for selected parameters (i.e., BMI metrics and water quality) were made between the 2000 and 2001 data sets to assess whether there were changes between years. Statistical tests used in the analysis included linear regressions, t-tests, and analysis of variance (ANOVA). The following discusses analysis methods in greater detail.

1. Comparisons of Relatively Undisturbed Reaches and Disturbed Reaches

T-tests were used to compare mean values of biological and physical parameters between two groups of study reaches: relatively undisturbed reaches (C-3, AB-2, SJ-3, AH-1, and SO-1), and disturbed reaches (C-1, C-2, AB-1, AT-1, AT-2, SJ-1, and SJ-2). 2000 and 2001 data were evaluated separately. Each reach was categorized as being either relatively undisturbed or disturbed based on the following criteria:

- Relatively undisturbed reaches did not have major signs of human disturbances such as modified creek bed or banks, channelization, barriers to animal movement (e.g., debris basins), loss of native riparian vegetation, dominance of non-native vegetation, heavy sedimentation, water pollution, etc. In addition, relatively undisturbed reaches were given habitat assessment scores of 160/200 or better, and at least 90 percent of their watersheds were undeveloped open space.
- Disturbed reaches had major signs of human disturbance, were given habitat assessment scores of 125/200 or worse, and less than 90 percent of their watersheds were undeveloped open space.

2. Analysis of Relationships Between Biological and Physical Parameters

Regression analysis was used to evaluate relationships between biological parameters (i.e., response variables) and physical parameters (i.e., independent variables) using the study reaches as the units for statistical analysis. 2000 and 2001 data were evaluated separately. Examples of relationships that were examined for each year of data include number of insect families vs. habitat assessment score, IBI vs. percent of watershed developed, percent sensitive BMI taxa vs. conductivity, etc.

3. Comparisons of Individual Study Reaches (2001)

At a finer level of detail, BMI metrics for individual study reaches were compared. Comparisons were made between study reaches in individual watersheds to evaluate how BMI metrics change based on location (i.e., upstream vs. downstream) within the watershed. T-tests were used for comparisons in watersheds with only two study reaches (i.e., Atascadero Creek and Arroyo Burro). ANOVAs were used for comparisons in watersheds with three study reaches (i.e., Carpinteria Creek and San Jose Creek).

Statistical comparisons of individual study reaches were possible for the 2001 data set because BMI samples were replicated in each study reach (i.e., three separate samples were collected per reach). This level of statistical analysis could not be completed for the 2000 data set, as only one sample was collected per reach.

4. Comparisons of Selected Parameters Between 2000 and 2001

T-tests were used to compare means for selected parameters between the 2000 and 2001 data to determine whether recognizable changes occurred from year to year. BMI metrics, conductivity, and water temperature were the selected parameters.

IV. RESULTS

The following presents data collected for the study reaches in 2000 and 2001 and the results of the statistical analysis. The results discussion is divided into the following sections:

- Comparison of Relatively Undisturbed Reaches and Disturbed Reaches, and Summary of Data Collected
- Analysis of Relationships Between Biological Parameters (Response Variables) and Physical Parameters (Independent Variables)
- Comparisons of Individual Study Reaches (2001)
- Comparisons of Selected Parameters Between 2000 and 2001

A. COMPARISON OF RELATIVELY UNDISTURBED REACHES AND DISTURBED REACHES, AND SUMMARY OF DATA COLLECTED

The following section summarizes the data collected under the following headings: Physical Parameters, Vegetation, Benthic Macroinvertebrates, and Vertebrates. Where appropriate, data are provided separately for 2000 and 2001. The Appendix provides complete lists of plants, BMIs, and vertebrates found in the study reaches during the 2000 and 2001 field surveys.

This section also discusses results of the t-tests that were used to compare the means between relatively undisturbed reaches and disturbed reaches for selected physical and biological parameters. A t-test compares the mean values of a given parameter for each of the two groups (i.e., relatively undisturbed reaches vs. relatively disturbed reaches), and indicates the probability that the means for the two groups are equivalent. The probability that the means are equivalent is expressed as the p-value (p), which is between 0 and 1. A p of 0 would indicate that there is no probability that means for the two groups are equivalent; they are certainly different. A p of 1 indicates that the means are equivalent. In reality, p usually falls somewhere between 0 and 1. As an example, a p of 0.05 would indicate that there is only a five percent probability that the means for the two groups are equivalent, and there is a 95 percent probability that they are different. In scientific studies, a t-test with a p of 0.05 or less is generally accepted as indicating a "significant" difference between means. Results of the t-tests conducted to compare the two groups of study reaches are provided in Table 2. Significant *p-values* (i.e., less than 0.05) are provided in bold text and shaded cells for ease of recognition.

Separate discussions are provided for the 2000 and 2001 data where necessary. Figures 10 through 15 provide graphical illustrations of selected t-tests. The graphical illustrations provide the distributions (i.e., collection of raw data points) for the undisturbed reach group and disturbed reach group side by side. The diamonds indicate the 95 percent confidence intervals for each group, or the range that the actual mean is expected to be in with 95 percent certainty. If the 95 percent confidence intervals do not overlap, the mean values for the two groups are significantly different (i.e., p is less than or equal to 0.05). If the 95 percent confidence intervals do overlap, the mean values for the two groups are not significantly different (i.e., p is greater than 0.05).

Table 2 T-Test Results for Comparisons Between Relatively Undisturbed Reaches and Disturbed Reaches, 2000 and 2001 Data Sets		
Parameter	**2000 Data (*p* <)**	**2001 Data (*p* <)**
Stream flow (Q)	0.3856	0.7052
Order	*	**0.0009**
Elevation	*	**0.0057**
Gradient	*	**0.0082**
Watershed area	*	**0.0350**
Percent of watershed as open space	*	**0.0063**
Percent of watershed as agriculture	*	**0.0048**
Percent of watershed as urban/suburban	*	0.0722
Percent of watershed as developed	*	**0.0064**
Habitat assessment score	**0.0001**	**0.0001**
Temperature	**0.0036**	**0.0452**
pH	0.3591	0.1544
Conductivity	**0.0018**	**0.0144**
Suspended solids	0.3094	**
Dissolved oxygen	**0.0188**	**
PO_4	0.8060	**
NO_2	**0.0055**	**
NO_3	0.0682	**
NH_4	0.2852	**
BMI Density	0.8667	0.3362
Number of insect families	**0.0004**	**0.0002**
Number of insect genera	**0.0004**	**0.0002**
IBI	**0.0068**	**0.0001**
Percent sensitive BMI taxa	**0.0022**	**0.0001**
Percent tolerant BMI taxa	0.1122	0.0941
Number of aquatic vertebrate species	**0.0111**	**0.0004**

* Statistical analysis for this parameter was not conducted for 2000 data set. Analysis was conducted for 2001 data set which includes all 12 study reaches. This parameter is not subject to appreciable change in the context of this study, and thus does not need to be evaluated on a yearly basis.
** Data not collected for this parameter in 2001.
Note: Shaded and bolded cells indicate statistically significant *p-values* (i.e., *p* of 0.05 or less).

1. Physical Parameters

a. Stream Order

Collectively, the 12 study reaches ranged from 2nd to 4th order streams, with a mean value of 3.0. The relatively undisturbed reaches are all 2nd and 3rd order streams with a mean value of 2.2, whereas the disturbed reaches are all 3rd and 4th order streams with a mean value of approximately 3.6. The t-test indicates a *p*, or probability, of 0.0009 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that the relatively undisturbed reaches are of significantly lower stream order compared to the disturbed reaches.

b. Stream Flow (Q)

Q was measured during the field surveys for 2000 and 2001. For 2000, Q in the 10 study reaches (i.e., all but AT-1 and AT-2) ranged from 0.18-4.34 cubic feet per second, (cfs) at the time of the survey, with a mean value of 0.83. The disturbed reaches had a mean of 0.46 cfs, ranging from 0.18-1.09 cfs. The relatively undisturbed reaches had a mean of 1.20 cfs, ranging from 0.21–4.34 cfs. The t-test indicates a p of 0.3856 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that Q in the relatively undisturbed reaches was not significantly different from the disturbed reaches for the 2000 surveys.

For 2001, Q in the 12 study reaches ranged from 0.11-1.80 cfs, with a mean value of 0.88. The relatively undisturbed reaches had a mean of 0.80 cfs, ranging from 0.28-1.76 cfs. The disturbed reaches had a mean of 0.93 cfs, ranging from 0.11-1.80 cfs. The t-test indicates a p of 0.7052 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that Q in the relatively undisturbed reaches was not significantly different compared to the disturbed reaches for the 2001 surveys. This is consistent with the 2000 results.

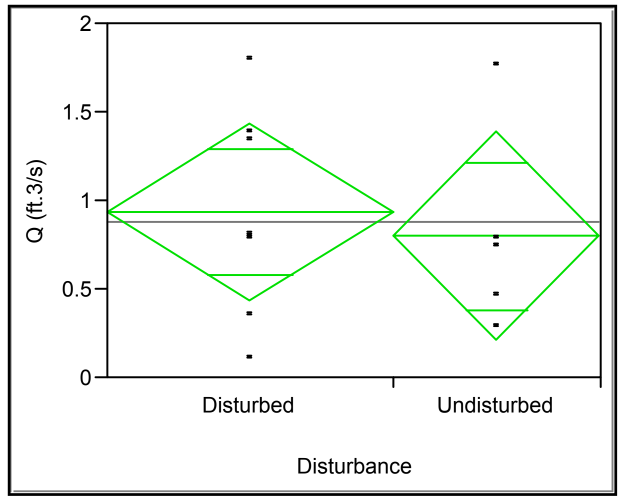

Figure 10: Comparison of Q Between Undisturbed Reaches and Disturbed Reaches, 2001 Data

c. Elevation

Elevation at the 12 study reaches ranges from 15-1,000 feet above mean sea level, with a mean value of 227 feet. The relatively undisturbed reaches have a mean elevation of 473 feet and range from 151-1,000 feet. The disturbed reaches have a mean elevation of 51 feet and range from 15-121 feet. The t-test indicates a p of 0.0057 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that elevation at the relatively undisturbed reaches is significantly greater compared to the disturbed reaches.

d. Stream Gradient

Gradient (i.e., average slope) at the 12 study reaches ranges from 0.002 (low gradient) to 0.133 (high gradient), with a mean value of 0.0327. The relatively undisturbed reaches were all of moderate to high gradient, with a mean value of 0.068 and range of 0.025 to 0.133. The disturbed reaches were all of low gradient, with a mean value of 0.008 and range of 0.002 to 0.014. The t-test indicates a p of 0.0082 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that gradient at the relatively undisturbed reaches is significantly higher compared to the disturbed reaches.

e. Watershed Area

Watershed area of the 12 study reaches ranged from 1,103.2 to 12,106.8 acres, with a mean value of 4,942.8 acres. The relatively undisturbed reaches had a mean of 2,456.5 acres and ranged from 1,103.2 to 4,473.1 acres. The disturbed reaches had a mean of 6,718.7 acres and ranged from 2,006.2 to 12,106.8 acres. The t-test indicates a p of 0.0350 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that the relatively undisturbed reaches have significantly smaller watershed areas compared to the disturbed reaches.

f. Percent of Watershed as Open Space

The percent of open space (i.e., undeveloped) land in the watersheds of the 12 study reaches ranged from 26.3 to 100 percent, with a mean value of 78.8 percent. The relatively undisturbed reaches had a mean of 97.4 percent open space, and ranged from 90 to 100 percent. The disturbed reaches had a mean of 65.5 percent, and ranged from 26.3 to 85.5 percent. The t-test indicates a p of 0.0063 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that the relatively undisturbed reaches have a significantly higher percentage of undeveloped open space in their watersheds compared to the disturbed reaches.

g. Percent of Watershed as Agriculture

The percent of agricultural land in the watersheds of the 12 study reaches ranged from 0 to 19.9 percent, with a mean value of 8.2 percent. The relatively undisturbed reaches had a mean of 1.8 percent agriculture, and ranged from 0 to 8.8 percent. The disturbed reaches had a mean of 12.8 percent, and ranged from 7.0 to 19.9 percent. The t-test indicates a p of 0.0048 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that the relatively undisturbed reaches have a significantly lower percentage of agriculture in their watersheds compared to the disturbed reaches.

h. Percent of Watershed as Suburban/Urban

The percent of suburban/urban land in the watersheds of the 12 study reaches ranged from 0 to 64.5 percent, with a mean value of 13.1 percent. The relatively undisturbed reaches had a mean of 0.8 percent suburban/urban, and ranged from 0 to 2.9 percent. The disturbed reaches had a mean of 21.8 percent, and ranged from 0.4 to 64.5 percent. The t-test indicates a p of 0.0722 (df=10, n=12) that the mean values for the two groups are equivalent. Although there does appear to be a difference in the percentage of suburban/urban space between the relatively undisturbed reaches and disturbed reaches, the p is greater than 0.05, thus the difference is not considered statistically significant.

i. Percent of Watershed Developed

The percent of developed land (i.e., agriculture and suburban/urban) in the watersheds of the 12 study reaches ranged from 0 to 73.7 percent, with a mean value of 15.9 percent. The relatively undisturbed reaches had a mean of 2.6 percent developed, and ranged from 0 to 9.9 percent. The disturbed reaches had a mean of 34.5 percent, and ranged from 14.5 to 73.7 percent. The t-test indicates a p of 0.0064 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that the relatively undisturbed reaches have a significantly lower percentage of developed land in their watersheds compared to the disturbed reaches.

j. Habitat Assessment Score

Habitat assessment scoring was conducted during field surveys in 2000 and 2001. For 2000, scores for the 10 study reaches surveyed (i.e., all but AT-1 and AT-2) ranged from 83 to 189 with a mean of 138.4. The relatively undisturbed reaches had a mean score of 175 and ranged from 163 to 189. The disturbed reaches had a mean score of 101.8 and ranged from 83 to 112. The t-test indicates a *p* of less than 0.0001 (df=8, n=10) that the mean scores for the two groups are equivalent. Therefore, it is concluded that habitat assessment scores for the relatively undisturbed reaches were significantly higher compared to the disturbed reaches in 2000.

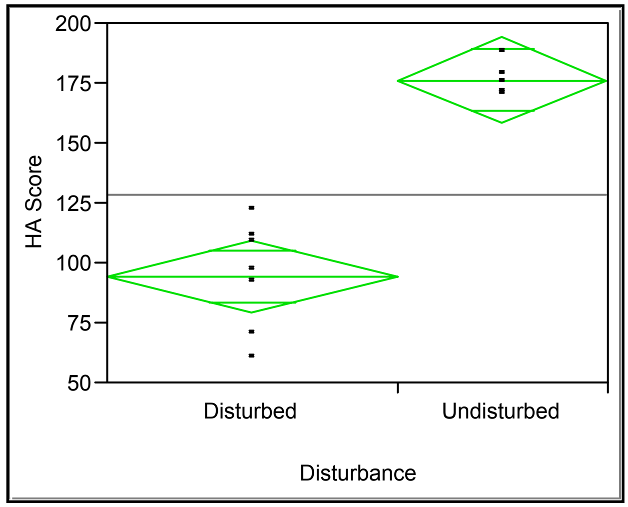

Figure 11: Comparison of Habitat Assessment Scores, Undisturbed Reaches vs. Disturbed Reaches, 2001 Data

For 2001, habitat assessment scores for the 12 study reaches ranged from 60 to 188 with a mean of 128.7. The relatively undisturbed reaches had a mean score of 176.6 and ranged from 170 to 188. The disturbed reaches had a mean score of 94.4 and ranged from 60 to 122. The t-test indicates a *p* of less than 0.0001 (df=10, n=12) that the mean scores for the two groups are equivalent. Therefore, it is concluded that habitat assessment scores for the relatively undisturbed reaches were significantly higher compared to the disturbed reaches in 2001. This is consistent with the results for 2000.

k. Stream Temperature

Stream temperature was measured during field surveys for 2000 and 2001. For 2000, stream temperatures in the 10 study reaches surveyed (i.e., all but AT-1 and AT-2) ranged from 60.8 to 72.3° Fahrenheit (° F), with a mean value of 65.0° F. The relatively undisturbed reaches had a mean of 62.0° F and ranged from 60.8 to 63.7° F. The disturbed reaches had a mean of 68.0° F and ranged from 65.1 to 72.3° F. The t-test indicates a *p* of 0.0036 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that stream temperature in the relatively undisturbed reaches was significantly lower compared to the disturbed reaches for the 2000 surveys.

For 2001, stream temperatures in the 12 study reaches ranged from 59.2 to 66.7° F, with a mean value of 62.7° F. The relatively undisturbed reaches had a mean of 61.1° F and ranged from 59.2 to 65.1° F. The disturbed reaches had a mean of 63.9° F and ranged from 61.0 to 66.7° F. The t-test indicates a *p* of 0.0452 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that stream temperature in the relatively undisturbed reaches was significantly lower compared to the disturbed reaches for the 2001 surveys. This is consistent with the results for 2000, although the difference between groups was stronger in the 2000 data.

l. pH

pH was measured during field surveys in 2000 and 2001. In 2000, pH in the 10 study reaches surveyed ranged from 6.6 to 8.6, with a mean value of 7.8. The relatively undisturbed reaches had a mean of 8.0 and ranged from 7.5 to 8.6. The disturbed reaches had a mean of 7.6 and ranged from 6.6 to 8.0. The t-test indicates a *p* of 0.3591 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that pH in the relatively undisturbed reaches and disturbed reaches was not significantly different for the 2000 surveys.

For 2001, pH in the 12 study reaches ranged from 7.5 to 8.4, with a mean value of 8.0. The relatively undisturbed reaches had a mean of 7.9 and ranged from 7.8 to 8.1. The disturbed reaches had a mean of 8.1 and ranged from 7.5 to 8.4. The t-test indicates a *p* of 0.1544 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that pH in the relatively undisturbed reaches and disturbed reaches was not significantly different for the 2001 surveys. This is consistent with the results for 2000.

m. Conductivity

Conductivity is a measure of the ability of water to pass an electrical current, and indicates the concentration of dissolved ions (e.g., metals, salts, etc.) that are present in the water. The higher the conductivity, the higher the concentration of dissolved ions, and vice versa. Elevated conductivity is a common problem in disturbed streams due to releases of large amounts of salts, metals, nutrients, and other dissolvable ions and solids from agricultural and urban lands.

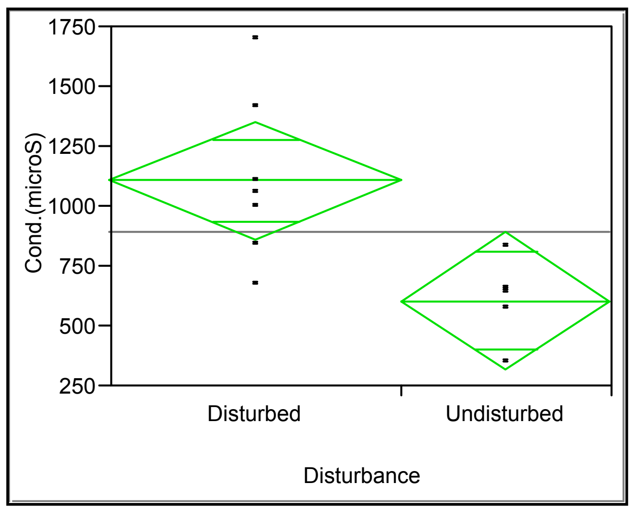

Figure 12: Comparison of Conductivity, Undisturbed Reaches vs. Disturbed Reaches, 2001 Data

Conductivity was measured during field surveys in 2000 and 2001. In 2000, conductivity in the 10 study reaches surveyed ranged from 539 to 1,580 µS, with a mean value of 1,049.8. The relatively undisturbed reaches had a mean of 783.4 µS and ranged from 539 to 1,026 µS. The disturbed reaches had a mean of 1,316.2 µS and ranged from 1,083 to 1,580 µS. The t-test indicates a *p* of 0.0018 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that conductivity in the relatively undisturbed reaches was significantly lower compared to the disturbed reaches for the 2000 surveys.

In 2001, conductivity in the 12 study reaches ranged from 345 to 1,692 µS, with a mean value of 899.4 µS. The relatively undisturbed reaches had a mean of 606.8 µS and ranged from 345 to 828 µS. The disturbed reaches had a mean of 1,108.4 µS and ranged from 667 to 1,692 µS. The t-test indicates a *p* of 0.0144 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that conductivity in the relatively undisturbed reaches was significantly lower compared to the disturbed reaches for the 2001 surveys. This is consistent with the results for 2000.

n. Suspended Sediments

Suspended sediment concentrations in the water column were measured during the 2000 surveys only. Suspended sediment concentrations in the 10 study reaches surveyed ranged from 3.4 to 12.3 milligrams per liter (mg/l), with a mean value of 7.9 mg/l. The relatively undisturbed reaches had a mean of 6.7 mg/l, and ranged from 3.4 to 11.5 mg/l. The disturbed reaches had a mean of 9.1 mg/l and ranged from 4.5 to 12.3 mg/l. The t-test indicates a p of 0.3094 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that suspended sediments in the relatively undisturbed reaches were not significantly different compared to the disturbed reaches during the field surveys.

o. Dissolved Oxygen

Dissolved oxygen (DO) concentrations in the water column were measured during the 2000 surveys only. DO concentrations in the 10 study reaches surveyed ranged from 7.3 to 11.9 mg/l, with a mean value of 9.7 mg/l. The relatively undisturbed reaches had a mean of 8.6 mg/l and ranged from 7.3 to 9.8 mg/l. The disturbed reaches had a mean of 10.9 mg/l and ranged from 8.8 to 11.9 mg/l. The t-test indicates a p of 0.0188 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that DO levels in the relatively undisturbed reaches were significantly lower compared to the disturbed reaches.

p. Phosphate (PO_4)[1]

PO_4 concentrations in the water column were measured during the 2000 surveys only. PO_4 concentrations in the 10 study reaches surveyed ranged from 0.16 to 0.56 micromoles per liter (µM/l), with a mean value of 0.27 µM/l. The relatively undisturbed reaches had a mean of 0.26 µM/l and ranged from 0.18 to 0.47 µM/l. The disturbed reaches had a mean of 0.28 µM/l and ranged from 0.16 to 0.56 µM/l. The t-test indicates a p of 0.8060 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that PO_4 concentrations in the relatively undisturbed reaches were not significantly different compared to the disturbed reaches.

q. Nitrite (NO_2)

NO_2 concentrations in the water column were measured during the 2000 surveys only. NO_2 concentrations in the 10 study reaches surveyed ranged from 0.03 to 3.60 µM/l, with a mean value of 1.07 µM/l. The relatively undisturbed reaches had a mean of 0.11 µM/l and ranged from 0.03 to 0.31 µM/l. The disturbed reaches had a mean of 2.04 µM/l and ranged from 1.00 to 3.30 µM/l. The t-test indicates a p of 0.0055 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that NO_2 concentrations in the relatively undisturbed reaches were significantly lower compared to the disturbed reaches.

r. Nitrate (NO_3)

NO_3 concentrations in the water column were measured during the 2000 surveys only. NO_3 concentrations in the 10 study reaches surveyed ranged from 1.20 to 1,136.76 µM/l, with a mean value of 206.87 µM/l. The relatively undisturbed reaches had a mean of 10.52 µM/l and ranged from 1.20 to 46.02 µM/l. The disturbed reaches had a mean of 403.21 µM/l and ranged from

[1] Phosphate, nitrite, nitrate, and ammonium are ions, or charged particles. To account for their respective charges, technically correct notations for these ions are as follows: phosphate (PO_4^{3-}), nitrite (NO_2^-), nitrate (NO_3^-), and ammonium (NH_4^+). For simplicity, charge signs for these ions are not shown in the main text.

146.98 to 1,136.76 µM/l. The t-test indicates a *p* of 0.0682 (df=8, n=10) that the mean values for the two groups are equivalent. Despite the obvious differences in NO_3 levels between the two groups of study reaches, the *p* for the t-test is greater than 0.05, and thus not considered significant. This is due in part to the high variance of NO_3 concentrations, especially amongst the disturbed reaches, and the low number of sampling units (i.e., 10 reaches).

s. Ammonium (NH_4)

NH_4 concentrations in the water column were measured during the 2000 surveys only. NH_4 concentrations in the 10 study reaches surveyed ranged from 0.80 to 4.06 µM/l, with a mean value of 1.56 µM/l. The relatively undisturbed reaches had a mean of 1.20 µM/l and ranged from 0.81 to 2.39 µM/l. The disturbed reaches had a mean of 1.93 µM/l and ranged from 0.80 to 4.06 µM/l. The t-test indicates a *p* of 0.2852 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that NH_4 concentrations in the relatively undisturbed reaches were not significantly different compared to the disturbed reaches.

2. Vegetation

Vegetation was identified in each study reach during the field surveys. Botanical surveys are not the focus of this study, and were not exhaustive. Collectively, 90 plant species from 45 families were identified in the study reaches, including 61 native species and 29 non-native species. Table A-1 in the Appendix lists all plant species identified and the study reaches in which they occurred. Native overstory riparian trees commonly found in the study creeks include California sycamore (*Platanus racemosa*), white alder (*Alnus rhombifolia*), California bay (*Umbellularia californica*), coast live oak (*Quercus agrifolia*), southern black walnut (*Juglans californica*), black cottonwood (*Populus balsamifera*), arroyo willow (*Salix lasiolepis*), and red willow (*Salix laevigata*). Common native riparian shrubs and herbs found in the study creeks include Mexican elderberry (*Sambucus mexicana*), mulefat (*Baccharis salicifolia*), toyon (*Heteromeles arbutifolia*), poison oak (*Toxicodendron diversilobum*), California blackberry (*Rubus ursinus*), mugwort (*Artemisia douglasiana*), California figwort (*Scrophularia californica*), canyon sunflower (*Venegasia carpesioides*), California rose (*Rosa californica*) and cocklebur (*Xanthium spinosum*). Emergent native plants commonly found along creek edges include cattails (*Typha spp*.), horsetails (*Equisetum spp*.), bulrush (*Scirpus spp*.), umbrella sedge (*Cyperus sp*.) and watercress (*Rorippa nasturtium-aquaticum*). Non-native (i.e., introduced) species typically compose a small proportion of the plant community in relatively undisturbed reaches, but are common and sometimes dominant in the disturbed reaches. Common non-native plants include eucalyptus (*Eucalyptus spp*.), giant reed (*Arundo donax*), black mustard (*Brassica nigra*), poison hemlock (*Conium maculatum*), sweet fennel (*Foeniculum vulgare*), castor bean (*Rincus communis*), wild radish (*Raphanus spp*.), prickly ox-tongue (*Picris echoides*), periwinkle (*Vinca major*), Bermuda grass (*Cynodon dactylon*) brome grasses (*Bromus spp.)* oats *(Avena spp.)* and smilo grass (*Pipatherum milaceum*).

3. Benthic Macroinvertebrates

a. Overview

Collectively, a wide diversity of BMIs was found in the study reaches in 2000 and 2001. Tables A-2 through A-5 in the Appendix list all of the BMI taxa found in the study reaches in 2000 and 2001, and the respective taxa and numbers of individuals identified for each sample and study reach. Eight aquatic insect orders were commonly encountered: Ephemeroptera (mayflies), Plecoptera (stoneflies), Tricoptera (caddisflies), Coleoptera (beetles), Diptera (true flies), Hemiptera (true bugs), Odonata (dragonflies and damselflies), and Megaloptera (Dobson flies and alder flies). In addition, three semi-aquatic insect orders were found in very small numbers: Collembola (springtails), Orthoptera (grasshoppers), and Hymenoptera (wasps). In total, 58 insect families and 89 insect genera were identified. Non-insect BMIs identified include Nematocera (horsehair worms), Gastropoda (snails), Ostracoda, Copepoda, Cladocera, Oligochaeta (segmented worms), Acari (water mites), and Hirudinea (leeches). The following paragraphs discuss occurrences of the above BMI groups in the study reaches in greater detail.

Mayflies were among the most common BMIs found in the study reaches. Overall, six families and 10 genera of mayflies were identified. Most of the mayflies are intolerant to moderately tolerant of human disturbance. *Baetis* (Baetidae), *Caenis* (Caenidae), and *Tricorythodes* (Leptohyphidae) were all common in most study reaches, and appear to be moderately tolerant of disturbance. *Paraleptophlebia* (Leptophlebidae) was also fairly common, but was found in significant numbers only in relatively undisturbed reaches. Genera from the families Heptagenidae (*Heptagenia*, *Ironodes* and *Eperous*) were uncommon to common in relatively undisturbed reaches, but were generally absent from disturbed reaches. Ephemerellidae was rare, and found only in relatively undisturbed reaches. *Callibaetis* (Baetidae) was also rare, but was found in highly disturbed reaches.

Stoneflies are generally very intolerant of human disturbance, and were found only in relatively undisturbed reaches, where they were found in low to moderate numbers. Overall, four families and four genera of stoneflies were identified. Of these, *Malenka* (Nemouridae) was most commonly found. *Sweltsa* (Chloroperlidae), *Calineuria* (Perlidae) and *Isoperla* (Perlodidae) were less common.

Caddisflies were found in greater numbers and diversity compared to stoneflies, but were rare to uncommon in disturbed reaches. Most caddisflies are intolerant to moderately tolerant of human disturbance. In total, 11 families and 12 genera of caddisflies were found in the study reaches. *Hydropsyche* (Hydropsychidae) was the most commonly found caddisfly, occurring in relatively undisturbed and moderately disturbed reaches. *Lepidostoma* (Lepidostomatidae), *Micrasema* (Brachycentridae) and *Rhyacophila* (Rhyacophilidae) were all somewhat common in relatively undisturbed reaches, but generally were absent from disturbed reaches. *Helicopsyche* (Helicopsychidae), *Agapetus* (Glossostomatidae), *Wormaldia* (Philoptomatidae), *Tinodes* (Psychomyiidae) and *Polycentropus* and *Cyrnellus* (Polycentropodidae) were rare to uncommon, and found only in relatively undisturbed creek reaches. *Ochrotrichia* (Hydroptillidae) was also uncommon, but was found mostly in disturbed reaches. Limnephilidae (unidentified genus) was rare, and represented by one specimen from a disturbed reach.

Water beetles were common in most study reaches. Most are moderately to highly tolerant of human disturbance. Seven families and 16 genera of beetles were identified in the study reaches. Dytiscidae were very common and diverse (five genera identified), and found in all study reaches. Elmidae were also diverse (five genera identified) and fairly common, although they were absent or rare in highly disturbed reaches. *Eubrianax* (Psphenidae) was uncommon to common in relatively undisturbed reaches, and absent or rare in disturbed reaches. *Peltodytes* (Halipidae), *Berosus* and *Hydrobius* (Hydrophilidae) were uncommon, and were found in greatest numbers in highly disturbed, low-gradient reaches.

True flies were the most common and diverse order of insects found in the study reaches. In total, 13 families and 29 genera of true flies were identified. Most Dipterans are moderately to highly tolerant of human disturbance. Chironomidae were by far the most common Dipteran, and the most common BMI for that matter, found in the study reaches. They were found in significant numbers in all study reaches, and dominated most of the samples from highly disturbed reaches. Other true flies that were common in relatively undisturbed and disturbed reaches include *Simulium* (Simulidae), Ceratopogonidae (seven genera identified) and Stratiomyidae (three genera identified). Tipulidae (five genera identified) were uncommon to common in relatively undisturbed creek reaches, but were absent or rare from disturbed reaches with the exception of the genus *Tipula*, which was found in several samples from disturbed reaches. *Pericoma* (Psychodidae) was uncommon, and found in greatest numbers in highly disturbed creek reaches. Other disturbance tolerant Dipterans that were rarely to uncommonly found in the study reaches include Culicidae, Ephydridae, Muscidae, and Dolichopodidae. *Blepharicera* (Blephariceridae) *Dixa* and *Merringodixa* (Dixidae) were also rare, and were found only in relatively undisturbed reaches.

True bugs found in the study reaches consisted of six families and seven genera, all of which are very tolerant of human disturbance. Hemipterans found in the study reaches included *Abedus* (Belostomatidae), *Neocorixa* (Corixidae), *Trepobates* (Gerridae), *Notonecta* (Notonectidae), *Microvelia* (Veliidae), and *Pelocoris* and *Cryptocricos* (Naucoridae).

Odonates were found in most study reaches, but typically in low numbers. In total, six families and six genera were identified. Dragonflies (Suborder Anisoptera) including *Aesha* (Aeshidae), *Cordulegaster* (Cordulegastridae), *Neurocordulia* (Corduliidae), and *Octogomphus* (Gomphidae) were found mostly in undisturbed reaches. Damselflies (Suborder Zygoptera) including *Argia* (Coenagrionidae) and *Archilestes* (Lestidae) were more ubiquitous, occurring in disturbed and undisturbed reaches.

Megalopterans were rare to uncommon in the study reaches. Two families and two genera were identified. *Neohermes* (Corydalidae) was rare, and found mostly in undisturbed reaches. *Sialis* (Sialidae) was more common, and was found in undisturbed and disturbed reaches.

Hymenoptera, Collembola, and Orthoptera were absent to rare in the study reaches. Hymenoptera was found in two study reaches. Collembola was represented by a total of three individuals found in three different disturbed reaches. Orthoptera was represented by one individual found in a relatively undisturbed reach.

Non-insect BMIs including Nematocera, Gastropoda, Ostracoda, Copepoda, Cladocera, Oligochaeta, Acari and Hirudinea were absent or found in low numbers in the relatively undisturbed reaches. They were more common in disturbed reaches, in some cases composing a significant portion of the samples collected.

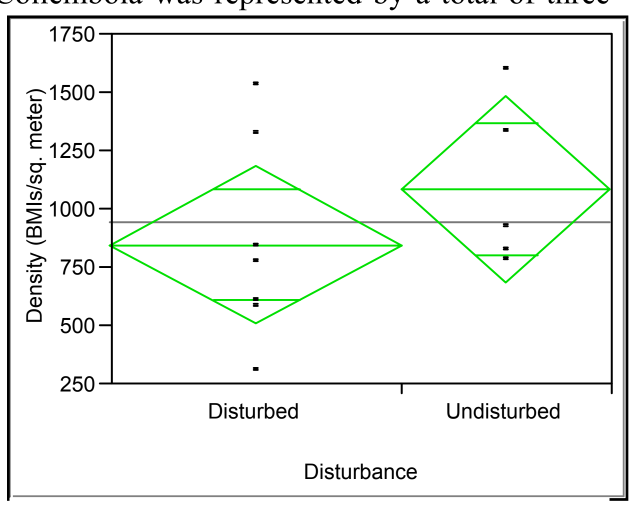

Figure 13: Comparison of BMI Density, Undisturbed Reaches vs. Disturbed Reaches, 2001 Data

b. BMI Density

For 2000, BMI density in the 10 creek reaches surveyed ranged from 321.8 to 6,017.9 individuals per square meter (m^2), with a mean density of 2,064.7. The relatively undisturbed reaches had a mean density of 2,171.3 and ranged from 358.7 to 3,670.2. The disturbed reaches had a mean density of 1,958.2 and ranged from 321.8 to 6,017.9. The t-test indicates a *p* of 0.8667 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that BMI density in the relatively undisturbed reaches was not significantly different compared to the disturbed reaches for the 2000 data.

For 2001, BMI density in the 12 creek reaches ranged from 303.3 to 1,594.2 individuals per m^2, with a mean density of 948.4. The relatively undisturbed reaches had a mean density of 1,087.7 and a range of 782.0 to 1,594.2. The disturbed reaches had a mean density of 848.9 and ranged from 303.3 to 1,527.8. The t-test indicates a *p* of 0.3362 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that BMI density in the relatively undisturbed reaches was not significantly different compared to the disturbed reaches for the 2001 data. This is consistent with the results for 2000.

c. Number of Aquatic Insect Families

For 2000, the number of aquatic insect families in the 10 creek reaches surveyed ranged from 12 to 33, with a mean of 20.8. The relatively undisturbed reaches had a mean of 26.6 families, ranging from 23 to 33. The disturbed reaches had a mean of 15.0 families, and ranged from 12 to 18. The t-test indicates a *p* of 0.0004 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that aquatic insect family diversity in the relatively undisturbed reaches was significantly higher compared to the disturbed reaches for the 2000 data.

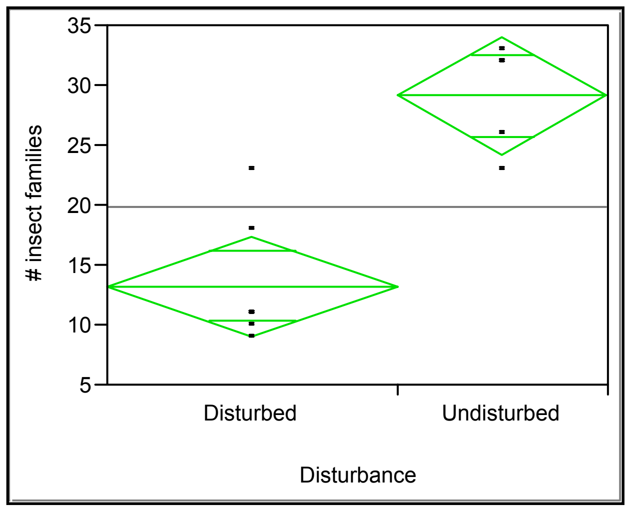

Figure 14: Comparison of Number of Aquatic Insect Families, Undisturbed Reaches vs. Disturbed Reaches, 2001 Data

For 2001, the number of aquatic insect families in the 12 creek reaches ranged from 9 to 33, with a mean of 19.9. The relatively undisturbed reaches had a mean of 29.2 families, ranging from 23 to 33. The disturbed reaches had a mean of 13.3 families, and ranged from 9 to 23. The t-test indicates a *p* of 0.0002 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that aquatic insect family diversity in the relatively undisturbed reaches was significantly higher compared to the disturbed reaches for 2001. This is consistent with the results for 2000.

d. Number of Aquatic Insect Genera

For 2000, the number of aquatic insect genera in the 10 creek reaches surveyed ranged from 13 to 36, with a mean of 23.6. The relatively undisturbed reaches had a mean of 29.8 genera, ranging from 26 to 36. The disturbed reaches had a mean of 17.4 genera, and ranged from 13 to 21. The t-test indicates a *p* of 0.0004 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that aquatic insect generic diversity in the relatively undisturbed reaches was significantly higher compared to the disturbed reaches for the 2000 data.

For 2001, the number of aquatic insect genera in the 12 creek reaches ranged from 11 to 40, with a mean of 23.8. The relatively undisturbed reaches had a mean of 34.4 genera, ranging from 27 to 40. The disturbed reaches had a mean of 16.3 genera, and ranged from 11 to 25. The t-test indicates a *p* of 0.0002 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that aquatic insect generic diversity in the relatively undisturbed reaches was significantly higher compared to the disturbed reaches for 2001. This is consistent with the results for 2000.

e. IBI

For 2000, the IBI in the 10 creek reaches surveyed ranged from 3.02 to 6.19, with a mean of 4.65. The relatively undisturbed reaches had a mean IBI of 3.89, ranging from 3.02 to 4.61. The disturbed reaches had a mean IBI of 5.41, and ranged from 4.53 to 6.19. The t-test indicates a *p* of 0.0068 (df=8, n=10) that the mean values for the two groups are equivalent. It is concluded that IBI in the relatively undisturbed reaches was significantly lower compared to the disturbed reaches for the 2000 data.

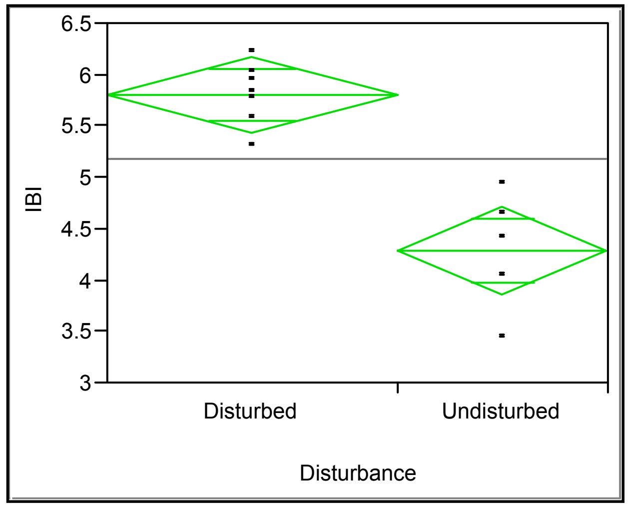

Figure 15: Comparison of IBI, Undisturbed Reaches vs. Disturbed Reaches, 2001 Data

For 2001, IBI in the 12 creek reaches ranged from 3.44 to 6.22, with a mean value of 5.18. The relatively undisturbed reaches had a mean IBI of 4.30, ranging from 3.44 to 4.94. The disturbed reaches had a mean IBI of 5.81, ranging from 5.31 to 6.22. The t-test indicates a *p* of 0.0001 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that the relatively undisturbed reaches had a significantly lower IBI compared to the disturbed reaches for 2001. This is consistent with the results for 2000.

f. Percent Sensitive BMI Taxa

For 2000, sensitive BMI taxa in the 10 creek reaches surveyed ranged from 0 to 48 percent, with a mean of 14 percent. The relatively undisturbed reaches had a mean of 27 percent sensitive BMI taxa, ranging from 14 to 48 percent. The disturbed reaches had a mean of 1 percent sensitive BMI taxa, and ranged from 0 to 3 percent. The t-test indicates a *p* of 0.0022 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that the relatively undisturbed reaches had a significantly higher percentage of sensitive BMI taxa compared to the disturbed reaches for the 2000 data.

For 2001, sensitive BMI taxa in the 12 creek reaches ranged from 0 to 27 percent, with a mean of 8 percent. The relatively undisturbed reaches had a mean of 19 percent sensitive BMI taxa, ranging from 9 to 27 percent. The disturbed reaches had a mean of one percent sensitive BMI taxa, and ranged from 0 to 2 percent. The t-test indicates a *p* of less than 0.0001 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that the relatively undisturbed reaches had a significantly higher percentage of sensitive BMI taxa compared to the disturbed reaches for the 2001 data. This is consistent with the results for 2000.

g. Percent Tolerant BMI Taxa

For 2000, tolerant BMI taxa in the 10 creek reaches surveyed ranged from 0 to 18 percent, with a mean of 7 percent. The relatively undisturbed reaches had a mean of 3 percent tolerant BMI taxa, ranging from 0 to 11 percent. The disturbed reaches had a mean of 10 percent tolerant BMI taxa, and ranged from 1 to 18 percent. The t-test indicates a p of 0.1122 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, although there appear to be differences in this parameter between the two groups for the 2000 data, the difference is not considered to be statistically significant.

For 2001, tolerant BMI taxa in the 12 creek reaches ranged from 0 to 13 percent, with a mean of 4 percent. The relatively undisturbed reaches had a mean of 2 percent tolerant BMI taxa, ranging from 0 to 5 percent. The disturbed reaches had a mean of 6 percent tolerant BMI taxa, and ranged from 0 to 13 percent. The t-test indicates a p of 0.0941 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, although there appear to be differences in this parameter between the two groups for the 2001 data, the difference is not considered to be statistically significant. This is consistent with the results for 2000.

4. Vertebrates

a. Overview

Collectively, a wide diversity of vertebrate species were identified in the study reaches in 2000 and 2001. Table A-6 in the Appendix lists all of the vertebrate species identified, and indicates the study reaches in which they occurred. A total of 58 vertebrate species from 38 families were identified through direct observation, vocalizations or sign (i.e., tracks or scat). Of these, six native aquatic species were identified: steelhead/rainbow trout (*Oncoryhynchus mykiss*), three-spine stickleback (*Gasterosteus aculeatus*), California newt (*Taricha torosa*), California tree frog (*Pseudacris cadaverina*), Pacific tree frog (*Pseudacris regilla*), and southwestern pond turtle (*Clemmys marmorata*).

b. Number of Aquatic Vertebrate Species

For 2000, the number of aquatic vertebrate species observed in the 10 creek reaches surveyed ranged from one to four, with a mean of 2.7. The relatively undisturbed reaches had a mean of 3.6 species, ranging from two to four. The disturbed reaches had a mean of 1.8 species, and ranged from one to three. The t-test indicates a p of 0.0111 (df=8, n=10) that the mean values for the two groups are equivalent. Therefore, it is concluded that aquatic vertebrate species diversity in the relatively undisturbed reaches was significantly higher compared to the disturbed reaches for the 2000 data.

For 2001, the number of aquatic vertebrate species in the 12 creek reaches ranged from one to four, with a mean of 2.3. The relatively undisturbed reaches had a mean of 3.6 species, ranging from two to four. The disturbed reaches had a mean of 1.4 species, and ranged from one to two. The t-test indicates a p of 0.0004 (df=10, n=12) that the mean values for the two groups are equivalent. Therefore, it is concluded that aquatic vertebrate species diversity in the relatively undisturbed reaches was significantly higher compared to the disturbed reaches for the 2001 data. This is consistent with the results for 2000.

B. ANALYSIS OF RELATIONSHIPS BETWEEN BIOLOGICAL PARAMETERS (RESPONSE VARIABLES) AND PHYSICAL PARAMETERS (INDEPENDENT VARIABLES)

This section provides the results of the regression analysis conducted for the 2000 and 2001 data sets. Regression analysis was used to evaluate the nature of relationships between biological parameters (response variables) and physical parameters (independent variables) using the study reaches as sampling units. A regression involves plotting data for two variables on a two-dimensional axis (i.e., a response variable on the y-axis and an independent variable on the x-axis) and determining the equation for the line that best represents the relationship between the two variables.

Four types of regressions were run for each combination of variables to determine the best-fit equation: linear (i.e., no transformation) and y vs. log (x), y vs. square root (x) and y vs. x^2 transformations. In all cases, x represented the physical parameter (i.e., independent variable), whereas y represented the biological parameter (i.e., response variable). In addition to the best-fit equation, the correlation coefficient (r^2) and the *p* were calculated for each regression.

r^2 is given as a value between 0 and 1, and indicates the proportion of the variation in the data that is explained by the model. In other works, r^2 is a measure of how well the model fits the data. The higher the r^2, the better the fit of the line.

The probability that a cause-effect relationship between x and y does not exist is expressed as the *p*, which is between 0 and 1. The lower the *p*, the higher the probability is that x and y are related as indicated by the best-fit model (i.e., equation of the best-fit line).

Tables 3 through 6 summarize the results of the regression analysis for the 2000 and 2001 data, respectively. For each relationship tested, the tables indicate the nature of the relationship between the two variables (i.e., positive or negative), the type of regression [i.e., linear, x^2, log (x), or square root (x)] that best fit the data, r^2 and *p*. Significant *p-values* (i.e., 0.05 or lower) are in bold and highlighted in gray. Discussion of the regression test results is provided below. Figures 16-20 provide graphical illustrations of selected regressions.

1. BMI Density vs. Physical Parameters

The regression tests for the 2000 and 2001 data indicate that BMI density was not significantly related to any of the physical parameters. In general, r^2 was low, and *p* was high for the regressions, indicating no obvious patterns.

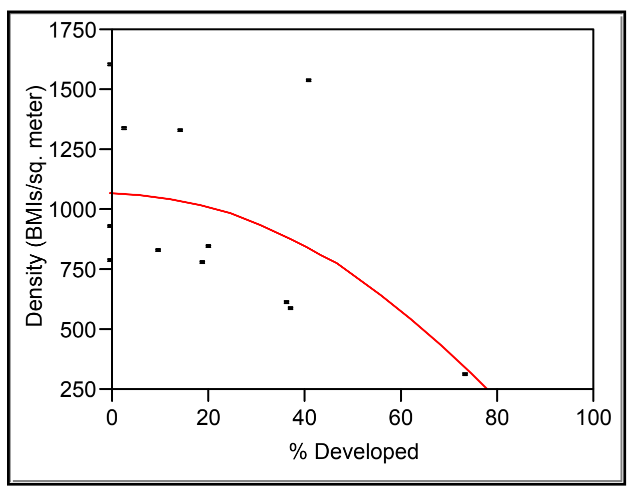

Figure 16: X^2 Regression of BMI Density vs. Percent Watershed Developed, 2001 Data

Table 3: Summary of Regression Test Results, 2000 Data								
Physical Parameter	Value	Biological Parameters						
		BMI Density	# Insect Families	# Insect Genera	IBI	Percent Sensitive Taxa	Percent Tolerant Taxa	# Aquatic Vertebrate Species
Order	Regression	x^2	Log (x)	Log (x)	Log (x)	Log (x)	Log (x)	x^2
	r^2	0.1864	0.7906	0.6168	0.6122	0.5857	0.4101	0.4083
	P	0.2128	**0.0006**	**0.0071**	**0.0075**	**0.0099**	**0.0461**	**0.0467**
	Relationship	-	-	-	+	-	+	-
Gradient	Regression	x^2	Log (x)	Log (x)	Log (x)	Log (x)	Log (x)	Log (x)
	r^2	0.0156	0.7719	0.7141	0.6524	0.5793	0.274	0.6609
	P	0.7311	**0.0008**	**0.0021**	**0.0047**	**0.0106**	0.1204	**0.0042**
	Relationship	-	+	+	-	+	-	+
Creek Flow (Q)	Regression	x^2	x^2	x^2	Log (x)	Linear	x^2	Log (x)
	r^2	0.1026	0.0084	0.0549	0.0664	0.0272	0.0517	0.2109
	P	0.3669	0.8014	0.5145	0.4724	0.6492	0.5277	0.1818
	Relationship	-	+	+	-	+	+	+
Watershed Area	Regression	x^2	Sq. rt. (x)	Log (x)	Log (x)	Sq. rt. (x)	Sq. rt. (x)	Sq. rt. (x)
	r^2	0.2857	0.5714	0.387	0.618	0.4122	0.5243	0.4992
	P	0.1114	**0.0114**	0.0548	**0.007**	**0.0453**	**0.0179**	**0.0224**
	Relationship	-	-	-	+	-	+	-
Percent Open Space (Watershed)	Regression	Log (x)	x^2	x^2	x^2	x^2	Linear	x^2
	r^2	0.02563	0.6706	0.7585	0.7166	0.6953	0.2911	0.7238
	p <	0.6586	**0.0038**	**0.001**	**0.002**	**0.0027**	0.1075	**0.0018**
	Relationship	+	+	+	-	+	-	+
Percent Agriculture (Watershed)	Regression	x^2	Linear	Sq. rt. (x)	Sq. rt. (x)	Sq. rt. (x)	Sq. rt. (x)	Sq. rt. (x)
	r^2	0.1163	0.6257	0.6136	0.6613	0.7216	0.1424	0.7536
	P	0.335	**0.0064**	**0.0074**	**0.0042**	**0.0019**	0.2824	**0.0011**
	Relationship	-	-	-	+	-	+	-
Percent Suburban/Urban (Watershed)	Regression	x^2	Sq. rt. (x)	Sq. rt. (x)	Sq. rt. (x)	Sq. rt. (x)	x^2	Sq. rt. (x)
	r^2	0.01901	0.2693	0.4152	0.4013	0.4047	0.3234	0.3235
	P	0.704	0.1243	**0.0443**	**0.0493**	**0.048**	0.0863	0.0862
	Relationship	-	-	-	+	-	+	-
Percent Developed (Watershed)	Regression	x^2	Linear	Linear	Sq. rt. (x)	Sq. rt. (x)	Linear	Sq. rt. (x)
	r^2	0.04205	0.6598	0.7533	0.76	0.7807	0.2911	0.7762
	P	0.5698	**0.0043**	**0.0011**	**0.001**	**0.0007**	0.1075	**0.0008**
	Relationship	-	-	-	+	-	+	-
Habitat Assessment Score	Regression	Log (x)	x^2	Linear	Sq. rt. (x)	Linear	Log (x)	x^2
	r^2	0.0010	0.7602	0.7765	0.6863	0.6687	0.4057	0.6611
	P	0.9319	**0.001**	**0.0008**	**0.0031**	**0.0038**	**0.0477**	**0.0042**
	Relationship	+	+	+	-	+	-	+

Table 3: Summary of Regression Test Results, 2000 Data

Physical Parameter	Value	Biological Parameters						
		BMI Density	# Insect Families	# Insect Genera	IBI	Percent Sensitive Taxa	Percent Tolerant Taxa	# Aquatic Vertebrate species
Creek Temperature	Regression	Log (x)	Log (x)	Log (x)	Log (x)	Log (x)	x^2	Log (x)
	r^2	0.0030	0.4891	0.5691	0.3929	0.5902	0.2719	0.6161
	P	0.8805	**0.0244**	**0.0117**	0.0525	**0.0094**	0.1221	**0.0072**
	Relationship	+	-	-	+	-	+	-
pH	Regression	Log (x)	Log (x)	x^2	Log (x)	Linear	Log (x)	Log (x)
	r^2	0.0311	0.0528	0.0299	0.0011	0.00456	0.0023	0.1725
	P	0.6263	0.5231	0.633	0.9275	0.853	0.8965	0.2326
	Relationship	-	+	+	-	+	-	+
Conductivity	Regression	Log (x)	x^2	Linear	x^2	x^2	x^2	Log (x)
	r^2	0.0779	0.5152	0.6685	0.4885	0.5227	0.1964	0.5916
	P	0.4349	**0.0194**	**0.0039**	**0.0245**	**0.0182**	0.1996	**0.0093**
	Relationship	+	-	-	+	-	+	-
Suspended Sediments	Regression	Linear	Log (x)	Log (x)	Log (x)	Linear	x^2	Log (x)
	r^2	0.0078	0.0382	0.0575	0.0080	0.1390	0.08158	0.0021
	P	0.8081	0.5882	0.5047	0.8057	0.2887	0.4237	0.8988
	Relationship	+	-	-	+	-	-	-
Dissolved Oxygen	Regression	x^2	x^2	x^2	x^2	Linear	x^2	x^2
	r^2	0.0242	0.3125	0.2581	0.4345	0.2599	0.4037	0.5897
	P	0.6680	0.0930	0.1338	**0.0382**	0.1323	**0.0484**	**0.0095**
	Relationship	-	-	-	+	-	+	-
PO_4	Regression	Log (x)	x^2	x^2	x^2	Linear	x^2	Linear
	r^2	0.1260	0.0.0028	0.0517	0.0162	0.0225	0.1910	0.1208
	P	0.3141	0.6415	0.5278	0.7262	0.6791	0.2066	0.3250
	Relationship	-	-	-	+	-	+	-
NO_2	Regression	x^2	Log (x)	Log (x)	Log (x)	Log (x)	Sq. rt. (x)	Log (x)
	r^2	0.2216	0.7813	0.7294	0.6923	0.7339	0.3330	0.7655
	P	0.1697	**0.0007**	**0.0017**	**0.028**	**0.0015**	0.0807	**0.0009**
	Relationship	-	-	-	+	-	+	-
NO_3	Regression	x^2	Log (x)	Log (x)	Log (x)	Log (x)	Sq. rt. (x)	Log (x)
	r^2	0.1098	0.6382	0.6318	0.6067	0.7012	0.1857	0.8169
	P	0.3497	**0.0056**	**0.006**	**0.0079**	**0.0025**	0.2137	**0.0003**
	Relationship	-	-	-	+	-	+	-
NH_4	Regression	Log (x)	Log (x)	Sq. rt. (x)	Log (x)	Linear	x^2	Log (x)
	r^2	0.0086	0.1109	0.1373	0.3471	0.2333	0.336	0.4477
	P	0.799	0.3471	0.2918	0.0731	0.1573	0.079	**0.0343**
	Relationship	+	-	-	+	-	+	-

Table 4: Summary of Regression Test Results, 2001 Data

Physical Parameter	Value	Biological Parameters						
		BMI Density	# Insect Families	# Insect Genera	IBI	Percent Sensitive Taxa	Percent Tolerant Taxa	# Aquatic Vertebrate species
Order	**Regression**	x^2	Sq. rt. (x)	Linear	Log (x)	Log (x)	Log (x)	Log (x)
	r^2	0.0012	0.5405	0.5271	0.6367	0.6256	0.3365	0.4489
	P	0.9147	**0.0064**	**0.0075**	**0.0019**	**0.0022**	**0.048**	**0.0171**
	Relationship	-	-	-	+	-	+	-
Gradient	**Regression**	Linear	Log (x)	Log (x)	Sq. rt. (x)	Sq. rt. (x)	Log (x)	Linear
	r^2	0.0486	0.6254	0.6054	0.9104	0.9425	0.5046	0.5832
	P	0.4912	**0.0022**	**0.0029**	**0.0001**	**0.0001**	**0.0096**	**0.0038**
	Relationship	+	+	+	-	+	-	+
Creek Flow (Q)	**Regression**	x^2	Linear	Linear	Linear	Linear	Linear	Linear
	r^2	0.1197	0.0180	0.0130	0.0179	0.0604	0.0130	0.0003
	P	0.2707	0.6773	0.7245	0.6787	0.4413	0.7247	0.9606
	Relationship	+	+	+	+	-	+	-
Watershed Area	**Regression**	x^2	Linear	Linear	Log (x)	Log (x)	x^2	Log (x)
	r^2	0.0667	0.4537	0.4717	0.5994	0.5166	0.4905	0.3485
	P	0.4178	**0.0163**	**0.0136**	**0.0031**	**0.0084**	**0.0112**	**0.0433**
	Relationship	+	-	-	+	-	+	-
Percent Open Space (Watershed)	**Regression**	Sq. rt. (x)	x^2	x^2	x^2	x^2	Linear	x^2
	r^2	0.2680	0.6018	0.5224	0.6739	0.6357	0.4580	0.7223
	P	0.0847	**0.003**	**0.0079**	**0.0011**	**0.0019**	**0.0156**	**0.0005**
	Relationship	+	+	+	-	+	-	+
Percent Agriculture (Watershed)	**Regression**	Linear	Sq. rt. (x)	Sq. rt. (x)	Sq. rt. (x)	Sq. rt. (x)	Linear	Sq. rt. (x)
	r^2	0.1992	0.4464	0.4532	0.6849	0.7673	0.0471	0.7154
	P	0.1459	**0.0176**	**0.0164**	**0.0009**	**0.002**	0.4979	**0.0005**
	Relationship	-	-	-	+	-	+	-
Percent Suburban/Urban (Watershed)	**Regression**	x^2	Sq. rt. (x)	Linear	Sq. rt. (x)	Sq. rt. (x)	Linear	Sq. rt. (x)
	r^2	0.2001	0.3654	0.2391	0.4183	0.3698	0.4484	0.4780
	P	0.1448	**0.0373**	0.1066	**0.023**	**0.0359**	**0.0172**	**0.0128**
	Relationship	-	-	-	+	-	+	-
Percent Developed (Watershed)	**Regression**	x^2	Sq. rt. (x)	Sq. rt. (x)	Sq. rt. (x)	Sq. rt. (x)	Linear	Sq. rt. (x)
	r^2	0.2622	0.5825	0.5162	0.7390	0.7042	0.4594	0.8178
	P	0.0888	**0.0039**	**0.0085**	**0.0003**	**0.0006**	**0.0154**	**0.0001**
	Relationship	-	-	-	+	-	+	-
Habitat Assessment Score	**Regression**	x^2	x^2	x^2	x^2	x^2	Log (x)	x^2
	r^2	0.0547	0.7229	0.7285	0.8488	0.8415	0.4764	0.7715
	P	0.4645	**0.0005**	**0.0004**	**0.0001**	**0.0001**	**0.013**	**0.0002**
	Relationship	+	+	+	-	+	-	+

Table 4: Summary of Regression Test Results, 2001 Data

Physical Parameter	Value	Biological Parameters						
		BMI Density	# Insect Families	# Insect Genera	IBI	Percent Sensitive Taxa	Percent Tolerant Taxa	# Aquatic Vertebrate species
Creek Temperature	Regression	Log (x)	Log (x)	Log (x)	Log (x)	Log (x)	Linear	Linear
	r^2	0.2988	0.5491	0.5056	0.4961	0.4298	0.1937	0.31
	P	0.0659	**0.0058**	**0.0095**	**0.0106**	**0.0206**	0.1522	0.0601
	Relationship	-	-	-	+	-	+	-
pH	Regression	x^2	Linear	Linear	Linear	Linear	Linear	Linear
	r^2	0.0411	0.1452	0.1510	0.0950	0.1245	0.02251	0.0912
	P	0.5277	0.2217	0.2119	0.3297	0.2605	0.6416	0.3400
	Relationship	-	-	-	+	-	+	-
Conductivity	Regression	Log (x)	Log (x)	Log (x)	Sq. rt. (x)	Log (x)	x^2	Log (x)
	r^2	0.0816	0.4750	0.4557	0.5669	0.4835	0.5687	0.5396
	P	0.3682	**0.0132**	**0.016**	**0.0047**	**0.012**	**0.0046**	**0.0065**
	Relationship	-	-	-	+	-	+	-

2. Biological Diversity vs. Physical Parameters

The regression tests for the 2000 and 2001 data indicate that measures of biological diversity, including number of aquatic insect families, number of aquatic insect genera, and number of aquatic vertebrate species were negatively related to percent watershed developed, percent watershed agriculture, and percent watershed suburban/urban. In other words, biological diversity decreased with increasing levels of human development within the respective study reach watersheds. As shown in Tables 3 and 4, r^2 values for these relationships ranged from 0.2693 to 0.8178, indicating that the regression models generally fit the data fairly well to very well. *P* ranged from 0.0001 to 0.1243, with statistically significant *p-values* (i.e., less than 0.05) for most of these relationships. The results were especially convincing for percent watershed developed, which is an overall measure of watershed development.

Regression tests for the 2000 and 2001 data indicate that measures of biological diversity were positively related to habitat assessment score and percent watershed open space. In other words, biological diversity increased with increasing habitat assessment scores and increasing percent watershed open space. As shown in Tables 3 and 4, r^2 values for individual relationships ranged from 0.5224 to 0.7765, indicating that the regression models generally fit the data very well. *P* ranged from 0.0002 to 0.0079, with statistically significant *p-values* for all relationships.

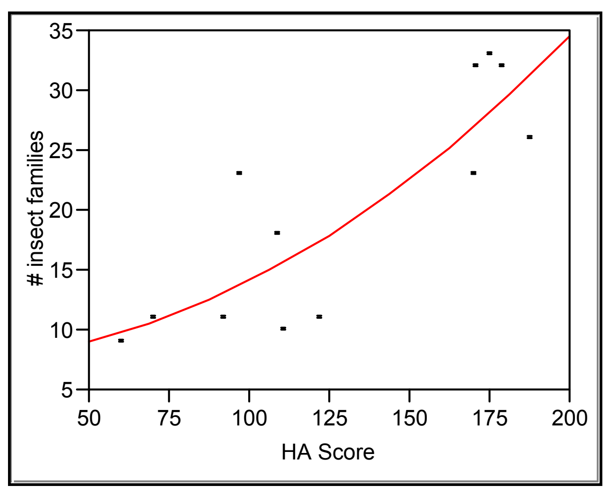

Figure 17: Regression (x^2 transformation) of # Aquatic Insect Families vs. Habitat Assessment Score, 2001 Data

Measures of biological diversity were significantly, negatively related to several water quality parameters including water temperature, conductivity, NO_2 and NO_3 in 2000, 2001, or both. In other words, biological diversity decreased with increasing values of these parameters. As shown in Tables 3 and 4, r^2 values for relationships involving these parameters ranged from 0.3100 to 0.7813, whereas *p* ranged from 0.0007 to 0.0601. Measures of biological diversity were also negatively related to NH_4 concentration (2000 data). The relationship between number of aquatic vertebrate species and NH_4 concentration was significant (r^2 = 0.4477, *p* = 0.0343). Suspended sediment concentration, pH, and PO_4 were not markedly related to any of the biological diversity metrics.

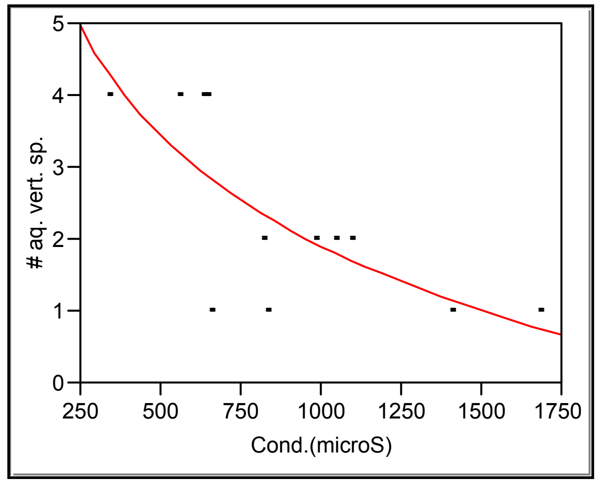

Figure 18: Log (x) Regression, # Aquatic Vertebrate Species vs. Conductivity, 2001 Data

Measures of biological diversity were significantly related to the following physical parameters in 2000, 2001 or both: gradient (positively related), and stream order, watershed area, and DO concentration (negatively related). R^2 values for these relationships ranged from 0.2581 to 0.7906, whereas *p* ranged from 0.0006 to 0.1338. However, these physical parameters were highly correlated with patterns of human disturbance, as indicated by the t-test results. The relatively undisturbed study reaches had significantly lower stream order, significantly higher gradient and DO concentration, and significantly smaller watershed area compared to the disturbed reaches. In an effort to separate the influences of these physical parameters from those of human disturbance, regressions were used to test relationships between them and the biological parameters among the relatively undisturbed reaches only. These regressions did not detect any significant relationships between biological diversity metrics and gradient, stream order, watershed area, and DO concentration (see Tables 5 and 6). It is important to note that these regressions were limited in that the ranges of gradient, stream order, watershed area, and DO concentration among the undisturbed reaches were smaller compared to all of the study reaches as a whole. Also, the ability to detect significant relationships (i.e., statistical power) was lower in these regressions because a smaller number of units were analyzed (i.e., five reaches instead of 12).

The test results indicate that Q was not markedly related to measures of biological diversity.

3. IBI vs. Physical Parameters

The regression tests for the 2000 and 2001 data indicate that IBI was positively related to percent watershed developed, percent watershed agriculture, and percent watershed suburban/urban. In other words, IBI increased with increasing levels of human development within the respective study reach watersheds. As shown in Tables 3 and 4, r^2 values for these relationships ranged between 0.4013 and 0.7390, indicating that the regression models generally fit the data fairly well to very well. *P* ranged from 0.0003 to 0.0493, with statistically significant *p-values* (i.e., less than 0.05) for all of these relationships. The results were especially convincing for percent watershed developed.

Table 5: Summary of Regression Test Results, Relatively Undisturbed Reaches Only, 2000 Data

Physical Parameter	Value	Biological Parameters					
		# Insect Families	# Insect Genera	IBI	Percent Sensitive Taxa	Percent Tolerant Taxa	# Aquatic Vertebrate species
Order	**Regression**	Linear	Linear	Linear	Linear	Linear	Linear
	r^2	0.2647	0.0146	0.1393	0.0447	0.9651	0.0625
	P	0.3751	0.8465	0.4857	0.7329	**0.0028**	0.6850
	Relationship	-	-	+	-	+	+
Gradient	**Regression**	Log (x)	Log (x)	Log (x)	Log (x)	Linear	Log (x)
	r^2	0.1002	0.0353	0.1795	0.0073	0.0603	0.2362
	P	0.6038	0.7623	0.4772	0.8913	0.6905	0.4065
	Relationship	+	+	-	-	-	+
Watershed Area	**Regression**	Sq. rt. (x)	x^2	Log (x)	x^2	x^2	Log (x)
	r^2	0.1560	0.0100	0.1900	0.0134	0.7818	0.0152
	P	0.5053	0.8729	0.4861	0.8531	**0.0465**	0.8436
	Relationship	-	-	+	-	+	-
Dissolved Oxygen	**Regression**	Log (x)	Log (x)	x^2	x^2	x^2	Log (x)
	r^2	0.1825	0.1482	0.0085	0.2052	0.2901	0.1188
	P	0.4732	0.5222	0.9295	0.4765	0.3490	0.5700
	Relationship	+	+	-	+	-	-

Conversely, regression tests for the 2000 and 2001 data indicate that IBI was negatively related to habitat assessment score and percent watershed open space. As shown in Tables 3 and 4, r^2 values for individual relationships ranged between 0.6863 and 0.8488, indicating that the regression models generally fit the data well. *P* generally ranged from 0.0001 to 0.0038, with statistically significant *p-values* (i.e., less than 0.05) for all of the tests of these relationships.

IBI was significantly, positively related to several water quality parameters including water temperature, conductivity, NO_2 and NO_3. R^2 values for relationships involving these parameters ranged between 0.3929 and 0.6923, whereas *p* ranged from 0.0079 to 0.0525. IBI was also positively related to NH_4 concentration, but not significantly (r^2 = 0.3471, *p* = 0.0731, 2000 data). IBI was not markedly related to suspended sediment concentration, pH, or PO_4.

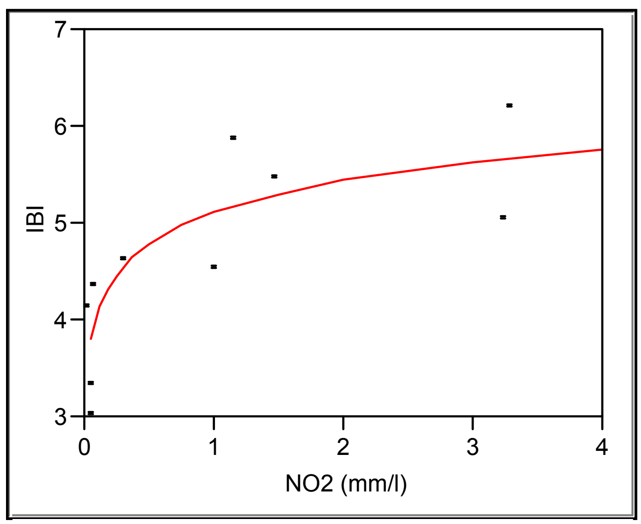

Figure 19: Log (x) Regression, Nitrite Concentration vs. IBI, 2000 Data

IBI was significantly related to the following physical parameters in 2000, 2001, or both:

gradient (negatively related), and stream order, watershed area, and DO concentration (positively related). However, as indicated above, these physical parameters were highly correlated with patterns of human disturbance, as indicated by the t-test results. Regressions of IBI vs. these physical parameters using only the relatively undisturbed reaches indicate only one significant relationship: IBI vs. gradient in 2001 ($r^2 = 0.8922$, $p = 0.0155$, negatively related). The regression for 2000 did not indicate a significant relationship between IBI and gradient ($r^2 = 0.1795$, $p = 0.4772$). As discussed above, the undisturbed-reaches-only regressions were limited in range and statistical power compared to the regressions that evaluated all of the study reaches.

The test results indicate that Q was not markedly related to IBI.

Table 6: Summary of Regression Test Results, Relatively Undisturbed Reaches Only, 2001 Data

Physical Parameter	Value	Biological Parameters					
		# Insect Families	# Insect Genera	IBI	Percent Sensitive Taxa	Percent Tolerant Taxa	# Aquatic Vertebrate species
Order	Regression	Linear	Linear	Linear	Linear	Linear	Linear
	r^2	0.2291	0.2737	0.0101	0.0425	0.7031	0.0625
	p	0.4148	0.3656	0.8725	0.7395	0.0760	0.6850
	Relationship	+	+	+	-	+	+
Gradient	Regression	Log (x)	x^2	x^2	Log (x)	Log (x)	Log (x)
	r^2	0.0566	0.0649	0.8922	0.9578	0.2961	0.3400
	p	0.7000	0.6792	**0.0155**	**0.0037**	0.3431	0.3021
	Relationship	-	-	-	+	-	+
Watershed Area	Regression	x^2	x^2	Log (x)	Log (x)	x^2	Log (x)
	r^2	0.1903	0.2433	0.5312	0.4842	0.6753	0.0152
	p	0.4797	0.3985	0.1625	0.1919	0.0879	0.8436
	Relationship	+	+	+	-	+	-

4. Percent Sensitive BMI Taxa vs. Physical Parameters

The regression tests for the 2000 and 2001 data indicate that percent sensitive BMI taxa was negatively related to percent watershed developed, percent watershed agriculture, and percent watershed suburban/urban. In other words, percent sensitive BMI taxa decreased with increasing levels of human development within the respective study reach watersheds. R^2 values for these relationships ranged from 0.3698 to 0.7807, indicating that the regression models generally fit the data fairly well to very well. *P* ranged from 0.0006 to 0.0480, with statistically significant *p-values* (i.e., less than 0.05) for all of these relationships. The results were especially convincing for percent watershed developed.

Regression tests for the 2000 and 2001 data indicate that percent sensitive BMI taxa was positively related to habitat assessment score and percent watershed open space. R^2 values for individual relationships ranged from 0.6357 to 0.8415, indicating that the regression models fit the data well. *P* ranged from 0.0001 to 0.0038, with statistically significant *p-values* for all of the tests of these relationships.

Percent sensitive BMI taxa was significantly, negatively related to several water quality parameters including water temperature, conductivity, NO_2 and NO_3. R^2 values for relationships involving these parameters ranged from 0.4298 to 0.7339, whereas *p* ranged from 0.0015 to 0.0206. Percent sensitive BMI taxa was also negatively related to NH_4 concentration, but not significantly ($r^2 = 0.3360$, $p = 0.0790$, 2000 data). Percent sensitive BMI taxa was not markedly related to suspended sediment concentration, pH, or PO_4.

Percent sensitive BMI taxa was significantly related to gradient (positively related), stream order (negatively related), and watershed area (negatively related) in 2000 and 2001. R^2 values for these relationships ranged from 0.4122 to 0.9425, whereas *p* ranged from 0.0001 to 0.0453. Percent sensitive BMI taxa was negatively related DO concentration, but not significantly ($r^2 = 0.2599$, $p = 0.1323$, 2000 data). As indicated above, these physical parameters were highly correlated with patterns of human disturbance, as indicated by the t-test results. Regressions of percent sensitive BMI taxa vs. gradient, stream order, watershed area, and DO concentration using only the relatively undisturbed reaches indicate only one significant relationship: percent sensitive BMI taxa vs. gradient in 2001 ($r^2 = 0.9578$, $p = 0.0037$, positively related). This relationship was not significant in 2000 ($r^2 = 0.0073$, $p = 0.8913$), and was negative rather than positive. As discussed above, the undisturbed-reaches-only regressions were limited in range and statistical power compared to the regressions that evaluated all of the study reaches.

The test results indicate that Q was not markedly related to percent sensitive BMI taxa.

5. Percent Tolerant BMI Taxa vs. Physical Parameters

In general, the regression tests for the 2000 and 2001 data indicate similar results for percent tolerant BMI taxa vs. physical parameters as was found for IBI vs. physical parameters. However, the results are not as conclusive for percent tolerant taxa. This biological metric was positively related to percent watershed developed, percent watershed agriculture, and percent watershed suburban/urban in all cases. However, r^2 values for these relationships generally ranged between 0.05 and 0.5, indicating that the regression models generally fit the data poorly to fairly well. *P* generally ranged from 0.015 to 0.5. Statistically significant relationships were found for percent watershed suburban/urban ($r^2 = 0.4484$, p=0.0172) and percent watershed developed ($r^2 = 0.4594$, p=0.0154) for the 2001 data only.

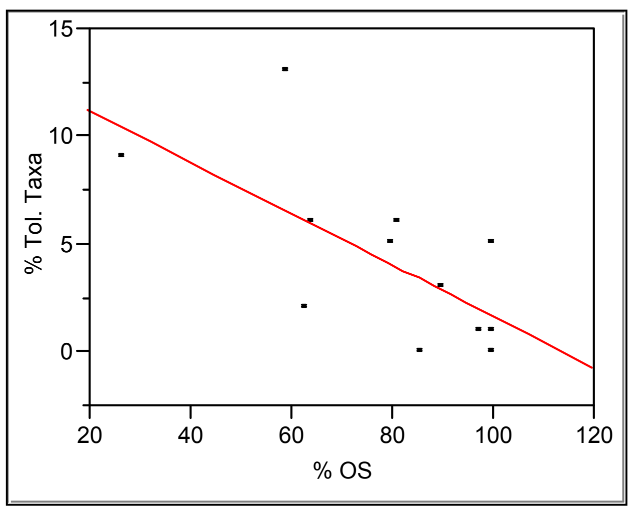

Figure 20: Linear Regression, Percent Watershed as Open Space (OS) vs. Percent Tolerant BMI Taxa, 2001 Data

Percent tolerant BMI taxa was negatively related to habitat assessment score and percent watershed open space. R^2 values for individual relationships generally ranged between 0.6 and 0.7, indicating that the regression models generally fit the data well. *P* ranged from 0.013 to 0.1075, with statistically significant *p-values* (i.e., less than 0.05) for percent tolerant BMI taxa vs. habitat assessment score in 2001, and both relationships in 2001.

Percent tolerant BMI taxa was positively related to several water quality parameters including water temperature, conductivity, NO_2, NO_3, and NH_4. R^2 values for relationships involving these parameters generally ranged from 0.2 to 0.4, whereas *p* generally ranged from 0.005 to 0.2.

However, only conductivity was significantly related to percent tolerant BMI taxa (r^2 = 0.5687, p=0.0046, 2001 data). Percent tolerant BMI taxa was not markedly related to suspended sediment concentration, pH, or PO_4.

Percent tolerant BMI taxa was significantly related to the following physical parameters in 2000, 2001, or both: gradient (negatively related), and stream order, watershed area, and DO concentration (positively related). R^2 values for these relationships generally ranged from 0.3 to 0.5, whereas *p* generally ranged from 0.01 to 0.12. As indicated above, these physical parameters were highly correlated with patterns of human disturbance, as indicated by the t-test results. Regressions of percent tolerant BMI taxa vs. gradient, stream order, watershed area, and DO concentration using only the relatively undisturbed reaches indicate two significant relationships in 2000: percent tolerant BMI taxa vs. order (r^2 = 0.9651, p = 0.0028, positively related) and percent tolerant BMI taxa vs. watershed area (r^2 = 0.7818, p = 0.0465, positively related). These relationships were also positive in 2001, but were not significant (see Table 6). As discussed above, the undisturbed-reaches-only regressions were limited in range and statistical power compared to the regressions that evaluated all of the study reaches.

The test results indicate that Q was not markedly related to percent tolerant BMI taxa.

C. COMPARISONS OF INDIVIDUAL CREEK REACHES (2001 DATA)

As discussed in III. Methods, statistical comparison of BMI metrics in individual study reaches using t-tests and ANOVAs is possible for the 2001 data set because BMI samples were replicated in each study reach. The following discusses the results of these statistical tests. The discussion is organized by Program watershed, including Carpinteria Creek, Arroyo Burro/San Roque Creek, Atascadero Creek and San Jose Creek. Arroyo Hondo and San Onofre Creek each had only one study reach, thus no comparisons within these watersheds could be made.

Table 7 summarizes the results of the reach-level t-tests and ANOVAs. For each test, the table indicates the mean value for each sampling point (i.e., each study reach), the standard error (calculated using a pooled estimate of error variance) and *p*, or the probability that the mean values for the study reaches within a particular watershed are the same. Figures 21 and 22 provide graphical illustrations of selected t-tests and ANOVAs.

1. Carpinteria Creek

Mean BMI densities in C-1, C-2, and C-3 were not significantly different from one another (p = 0.1230). Mean values for percent tolerant BMI taxa were almost identical in C-1, C-2 and C-3 (p = 0.9443). Conversely, mean values for number of aquatic insect families (p = 0.0006), number of aquatic insect genera (p = 0.0011), IBI (p = 0.0008) and percent sensitive taxa (p = 0.0033) were all significantly different. For all of these, mean values for C-3 were significantly different compared to C-1 and C-2, whereas values for C-1 and C-2 were not significantly different.

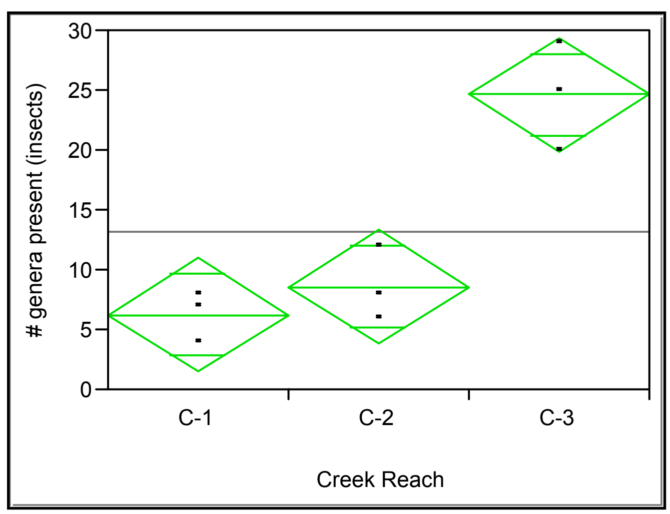

Figure 21: ANOVA Comparison of # Aquatic Insect Genera, Carpinteria Creek Study Reaches, 2001 Data

Table 7: Summary of Reach-Level T-Test and ANOVA Results						
Watershed/Reach	**Biological Parameters**					
	BMI Density (individuals/m²)	**# Insect Families**	**# Insect Genera**	**IBI**	**Percent Sensitive Taxa**	**Percent Tolerant Taxa**
Carpinteria Creek						
C-1 (mean value)	1,041.5	5.3	6.3	6.03	0.0	5.0
C-2 (mean value)	780.7	7.3	8.7	5.77	1.7	6.0
C-3 (mean value)	1,705.4	21.0	24.7	4.40	15.7	5.3
Standard Error[1]	273.8	1.5	1.9	0.16	2.0	2.1
p-value[2]	0.1230	**0.0006**	**0.0011**	**0.0008**	**0.0033**	0.9443
Arroyo Burro/ San Roque Creek						
AB-1 (mean value)	614.3	7.0	8.0	5.83	0.3	6.3
AB-2 (mean value)	843.2	22.0	24.0	4.94	8.3	3.3
Standard Error[1]	81.1	2.3	2.3	0.15	0.7	1.6
p-value[2]	0.1165	**0.0101**	**0.0080**	**0.0131**	**0.0011**	0.2595
Atascadero Creek						
AT-1 (mean value)	1,616.9	4.7	5.3	6.22	0	12.7
AT-2 (mean value)	403.6	8.0	10.7	5.94	0	9.0
Standard Error[1]	223.0	1.0	1.0	0.19	0	6.9
p-value[2]	**0.0183**	0.0835	**0.0178**	0.3489	1.0	0.7269
San Jose Creek						
SJ-1 (mean value)	901.6	10.3	11.7	5.57	1.0	1.7
SJ-2 (mean value)	1,608.1	11.7	12.0	5.31	2.0	0.3
SJ-3 (mean value)	1,396.8	20.3	22.3	4.05	26.0	1.0
Standard Error[1]	410.2	1.3	1.6	0.20	1.3	0.6
p-value[2]	0.4993	**0.0030**	**0.0050**	**0.0033**	**0.0001**	0.3944

[1] The value plus or minus the mean that indicates, with 95percent percent confidence, the range within the true mean falls. Calculated based on a pooled estimate of variance from all of the sampling points being tested (i.e., each reach within the watershed).

[2] The probability that the means are the same (i.e., for the study reaches within the watershed). P-values (i.e., 0.05 or lower) showing significant differences between means are bolded and highlighted in grayscale.

2. Arroyo Burro/San Roque Creek

Mean BMI densities in AB-1 and AB-2 were not significantly different from one another (p = 0.1165), nor were mean values for percent tolerant BMI taxa (p = 0.2595). Conversely, mean values for number of aquatic insect families (p = 0.0101), number of aquatic insect genera (p = 0.0080), IBI (p = 0.0131) and percent sensitive taxa (p = 0.0011) were all significantly different.

3. Atascadero Creek

Mean BMI densities in AB-1 and AB-2 were significantly different from one another (p = 0.0183), as was the case for number of aquatic insect genera (p = 0.0101). Mean values for number of aquatic insect families were also fairly different between AT-1 and AT-2, but not significantly (p = 0.0835). Mean values for IBI (p = 0.3489) percent sensitive taxa (p = 1.0) and percent tolerant BMI taxa (p = 0.7269) were similar in AT-1 and AT-2.

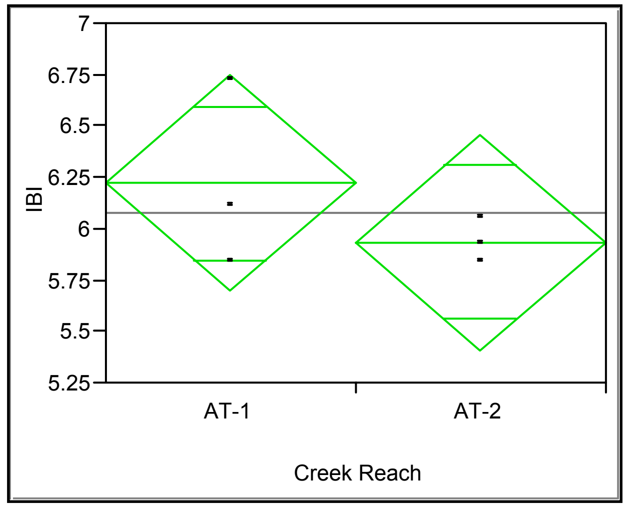

Figure 22: T-test Comparison of IBI, Atascadero Creek Study Reaches, 2001 Data

4. San Jose Creek

The results for San Jose Creek closely mirrored those for Carpinteria Creek, which also had three study reaches: two disturbed reaches and one relatively undisturbed reach. Mean BMI densities in SJ-1, SJ-2, and SJ-3 were not significantly different from one another (p = 0.4993). Neither were mean values for percent tolerant BMI taxa (p = 0.3944). Conversely, mean values for number of aquatic insect families (p = 0.0030), number of aquatic insect genera (p = 0.0050), IBI (p = 0.0033) and percent sensitive taxa (p = 0.0001) were all significantly different. For all of these, mean values for SJ-3 were significantly different from SJ-1 and SJ-2, whereas SJ-1 and SJ-2 were not significantly different from one another.

D. COMPARISONS OF SELECTED PARAMETERS BETWEEN 2000 AND 2001

T-tests were used to compare means for selected parameters between the 2000 and 2001 data sets to determine whether recognizable changes occurred from year to year. Q, habitat assessment score, water temperature, pH, conductivity, and BMI metrics were the parameters selected for analysis. All of these parameters were measured in both 2000 and 2001, and are subject to year-to-year variability due to independent factors such as weather, rainfall, human impacts, etc. The results of the t-tests are summarized in Table 8, and are discussed below. Figures 23 through 25 provide graphical illustrations of selected tests.

1. Stream Flow (Q)

For 2000, Q in the 10 study reaches surveyed (i.e., all but AT-1 and AT-2) ranged from 0.18-4.34 cfs, with a mean value of 0.83. For 2001, Q in the 12 study reaches ranged from 0.11-1.80 cfs, with a mean value of 0.88. The t-test indicates a p of 0.8943 (df=20, n=22) that the mean values for 2000 and 2001 are equivalent. Therefore, Q was very similar during the 2000 and 2001 surveys.

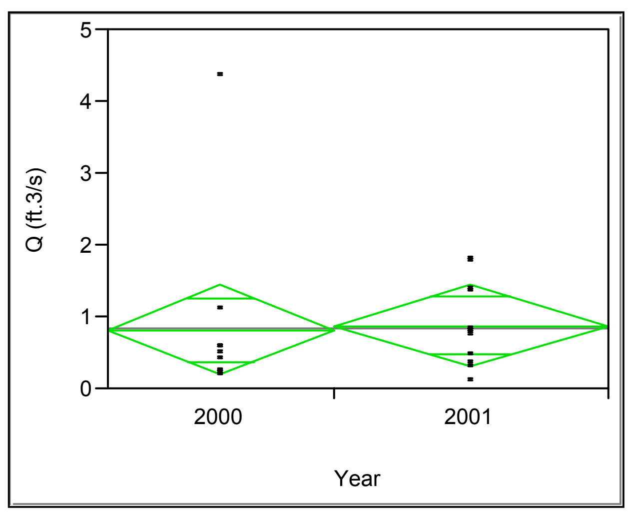

Figure 23: T-test Comparison of Q at all Study Reaches, 2000 vs. 2001

2. Habitat Assessment Score

In 2000, habitat assessment scores for the 10 study reaches surveyed ranged from 83 to 189 with a mean of 138.4. In 2001, habitat assessment scores for the 12 study reaches ranged from 60 to 188 with a mean of 128.7. The t-test indicates a *p* of 0.6045 (df=20, n=22) that the mean scores for 2000 and 2001 are equivalent. Therefore, the small difference in mean habitat assessment score between 2000 and 2001 was not statistically significant.

Table 8
T-test Results For Comparisons Between 2000 and 2001 Data Sets

Parameter	2000 Mean Value	2001 Mean Value	*p*
Q (ft^3/s)	0.83	0.88	0.8943
Habitat assessment score	138.4	128.7	0.6045
Temperature (°F)	65.0	62.7	0.1069
PH	7.8	8.0	0.2416
Conductivity (µS)	1,049.8	899.4	0.3376
BMI Density (individuals/m^2)	2,064.7	948.4	0.0531
Number of insect families	20.8	19.9	0.8075
Number of insect genera	23.6	23.8	0.9540
IBI	4.65	5.18	0.2031
Percent sensitive BMI taxa	14.1	8.5	0.3111
Percent tolerant BMI taxa	6.5	4.3	0.3295

3. Stream Temperature

For 2000, stream temperatures in the 10 study reaches surveyed ranged from 60.8 to 72.3° F, with a mean value of 65.0° F. For 2001, stream temperatures in the 12 study reaches ranged from 59.2 to 66.7° F, with a mean value of 62.7° F. The t-test indicates a *p* of 0.1069 (df=20, n=22) that the mean values for 2000 and 2001 are equivalent. Therefore, while stream temperatures appeared to be lower in 2001, the difference between 2000 and 2001 was not statistically significant.

4. pH

For 2000, pH in the 10 study reaches surveyed ranged from 6.6 to 8.6, with a mean value of 7.8. For 2001, pH in the 12 study reaches ranged from 7.5 to 8.4, with a mean value of 8.0. The t-test indicates a *p* of 0.2416 (df=20, n=22) that the mean values for 2000 and 2001 are equivalent. Therefore, the small difference in mean pH between 2000 and 2001 was not statistically significant.

5. Conductivity

For 2000, conductivity in the 10 study reaches surveyed ranged from 539 to 1,580 µS, with a mean value of 1,049.8. For 2001, conductivity in the 12 study reaches ranged from 345 to 1,692 µS, with a mean value of 899.4 µS. The t-test indicates a *p* of 0.3376 (df=20, n=22) that the mean values for 2000 and 2001 are equivalent. Therefore, the difference in mean conductivity between 2000 and 2001 was not statistically significant.

6. BMI Density

For 2000, BMI density in the 10 creek reaches surveyed ranged from 321.8 to 6,017.9 individuals per m^2, with a mean density of 2,064.7. For 2001, BMI density in the 12 creek reaches ranged from 303.3 to 1,594.2 individuals per m^2, with a mean density of 948.4. The t-test indicates a *p* of 0.0531 (df=20, n=22) that the mean values for 2000 and 2001 are equivalent. Therefore, whereas there did appear to be a difference in mean BMI density between 2000 and 2001, the difference was not statistically significant.

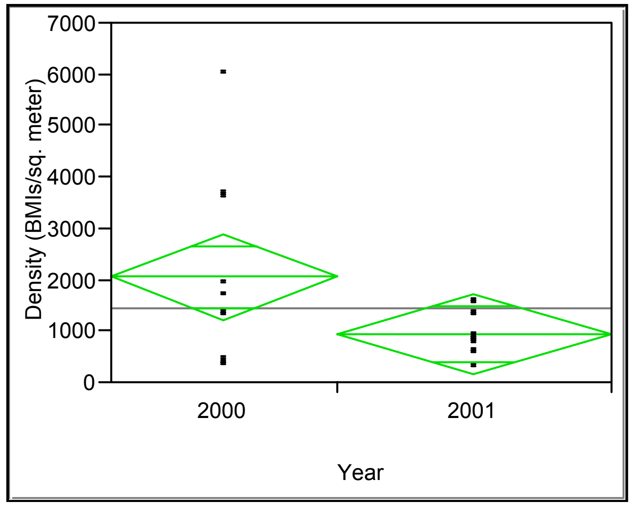

Figure 24: T-test Comparison of BMI Density at all Study Reaches, 2000 vs. 2001

7. Number of Aquatic Insect Families

For 2000, the number of aquatic insect families in the 10 creek reaches surveyed ranged from 12 to 33, with a mean of 20.8. For 2001, the number of aquatic insect families in the 12 creek reaches ranged from 9 to 33, with a mean of 19.9. The t-test indicates a *p* of 0.8075 (df=20, n=22) that the mean values for 2000 and 2001 are equivalent. Therefore, the small difference in aquatic insect family diversity between 2000 and 2001 was not statistically significant.

8. Number of Aquatic Insect Genera

For 2000, the number of aquatic insect genera in the 10 creek reaches surveyed ranged from 13 to 36, with a mean of 23.6. For 2001, the number of aquatic insect genera in the 12 creek reaches ranged from 11 to 40, with a mean of 23.8. The t-test indicates a *p* of 0.9540 (df=20, n=22) that the mean values for 2000 and 2001 are equivalent. Therefore, the small difference in aquatic insect genera diversity between 2000 and 2001 was not statistically significant.

9. IBI

For 2000, the IBI in the 10 creek reaches surveyed ranged from 3.02 to 6.19, with a mean of 4.65. For 2001, IBI in the 12 creek reaches ranged from 3.44 to 6.22, with a mean value of 5.18. The t-test indicates a *p* of 0.2031 (df=20, n=22) that the mean values for 2000 and 2001 are equivalent. Therefore, the difference in IBI between 2000 and 2001 was not statistically significant.

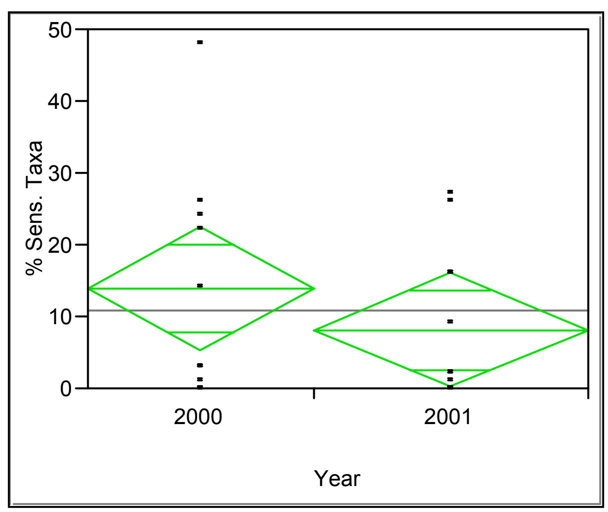

Figure 25: T-test comparison of Percent Sensitive BMI Taxa at all Study Reaches, 2000 vs. 2001

10. Percent Sensitive BMI Taxa

For 2000, sensitive BMI taxa in the 10 creek reaches surveyed ranged from 0 to 48 percent, with a mean of 14 percent. For 2001, sensitive BMI taxa in the 12 creek reaches ranged from 0 to

27 percent, with a mean of 8 percent. The t-test indicates a *p* of 0.3111 (df=20, n=22) that the mean values for 2000 and 2001 are equivalent. Therefore, the difference in percent sensitive BMI taxa between 2000 and 2001 was not statistically significant.

11. Percent Tolerant BMI Taxa

For 2000, tolerant BMI taxa in the 10 creek reaches surveyed ranged from 0 to 18 percent, with a mean of 7 percent. For 2001, tolerant BMI taxa in the 12 creek reaches ranged from 0 to 13 percent, with a mean of 4 percent. The t-test indicates a *p* of 0.3295 (df=20, n=22) that the mean values for 2000 and 2001 are equivalent. Therefore, the difference in percent tolerant BMI taxa between 2000 and 2001 was not statistically significant.

V. DISCUSSION

This section discusses the study results in the context of the questions the Program effort is intended to explore (see I. Introduction). Answers to these questions are discussed to the degree possible using the information gained from the Program effort thus far. Gaps in understanding are also discussed, as are needs for further study. As is the case with many ecological studies, it will likely take several years of Program research to gain a firm grasp on the answers to many of these questions.

A. What biological and physical characteristics define relatively undisturbed local creeks?

In general, the relatively undisturbed creek reaches studied in 2000 and 2001 were characterized by excellent habitat conditions, including intact native riparian vegetation, stable creek banks, complex aquatic habitat, and stable substrate consisting of bedrock, large boulders, deposits of cobbles, gravels, and sand, woody debris, accumulations of leaves and plant material, and minimal deposits of fine sediments (i.e., silts and clays). The relatively undisturbed reaches also had good water quality, as evidenced by excellent water clarity, relatively low water temperature, conductivity and nutrient levels, moderate pH, and optimal DO levels. In addition, the relatively undisturbed reaches generally supported diverse communities of BMIs and aquatic vertebrates, including an abundance of disturbance sensitive taxa such as stoneflies (e.g., *Sweltsa*, *Calineuria*, *Isoperla* and *Malenka*), caddisflies (e.g., *Rhyacophila*, *Lepidostoma*, *Helicopsyche*, *Agapetus* and *Micrasema*) mayflies (e.g., *Paraleptophlebia*, Ephemerellidae and Heptagenidae), rainbow trout, California newts, California tree frogs, and southwestern pond turtles.

None of the relatively undisturbed reaches evaluated in 2000 and 2001 are of low gradient (i.e., average slope of less than 0.02). This reflects a general trend along the South Coast; there is a lack of relatively undisturbed low-gradient creeks because flat lands (i.e., the coastal plains) have been largely developed for agricultural and urban uses. As such, it has proven very difficult to locate healthy creek reaches in the low-gradient category. Given this, the general description of undisturbed creeks provided above may be somewhat skewed because low-gradient creeks are not represented. This is particularly the case for geomorphologic characteristics. For example, bottom substrates in low-gradient streams naturally have a greater component of cobble, gravel, sand, and finer material compared to moderate- and high-gradient creeks. As another example, stream depth and velocity tend to be less variable (i.e., more homogenous) in low-gradient streams compared to moderate- and high-gradient streams.

In order to fully describe the range of conditions present in relatively undisturbed creeks of the South Coast, it will be necessary to locate and study some low-gradient reaches that are relatively pristine. As indicated above, there are few if any creeks on the South Coast that fit this description. There may be some examples in relatively undeveloped areas such as the Hollister Ranch and Bixby Ranch just south of Point Conception. There also may be examples in Gaviota Coast streams such as El Capitan Creek, Gaviota Creek, Dos Pueblos Creek, Eagle Canyon Creek, Gato Canyon Creek, Refugio Creek, and several others. If no suitable creeks can be located on the South Coast, streams outside the study area (e.g., in the Santa Ynez River and Ventura River watersheds) may be considered for study. More research will be needed to evaluate these options. Many of these creeks are located on private land, thus studying them would require the permission of private landowners in many cases.

B. To what extent are local creek ecosystems shaped by natural factors including stream flow, order, gradient, and watershed area?

As indicated in IV. Results, clear relationships were not evident between Q and any of the biological parameters including aquatic insect diversity, IBI, percent sensitive BMI taxa, percent tolerant BMI taxa, and aquatic vertebrate diversity. Q was of low to moderate levels in all of the study reaches at the time of the surveys. Obviously, very high flows (i.e., scouring storm flows) and periods of very low flow or no flow (i.e., dry) would be expected to have effects on the biological community.

The regressions involving all of the study reaches indicate many significant correlations between biological response variables and the following natural physical variables: stream order, gradient, and watershed area. However, it is thought that these significant correlations are more an artifact of human disturbance than the result of natural variability in stream order, gradient, and watershed area. These natural physical parameters were highly correlated with patterns of human disturbance, as indicated by the t-test results. The relatively undisturbed study reaches had significantly lower stream order, significantly higher gradient, and significantly smaller watershed area compared to the disturbed reaches. In general, the disturbed reaches are larger 3rd and 4th order streams located on the coastal plain at low gradients, whereas the relatively undisturbed reaches are smaller 2nd and 3rd order streams situated in the mountains and foothills at moderate to high gradients. This reflects a general pattern on the South Coast; mountain and foothill creeks are typically undisturbed, whereas main-stem creeks on the coastal plain are typically moderately to heavily impacted by human development.

As discussed in IV. Results, regressions were used to test relationships between the biological response variables and gradient, stream order, and watershed area among the relatively undisturbed reaches only. Again, this was done in an effort to separate the influences of these natural physical variables from those of human disturbance. In general, regression analysis of the 2000 and 2001 data did not indicate consistent, significant relationships between the biological response variables and any of these natural physical variables. However, these regressions were limited in that the ranges of gradient, stream order, and watershed area among the undisturbed reaches were smaller compared to the whole group of study reaches, and South Coast creeks in general. Also, the statistical power (i.e., ability to detect significant relationships) of these regressions was low because relatively few units were analyzed (i.e., only five reaches).

The analysis leaves uncertainty regarding the nature of relationships between the biological response variables and gradient, stream order, and watershed area. Further study would be required to provide more definitive information. In theory, it would be possible to determine the nature of these relationships if a larger group of relatively undisturbed creek reaches (perhaps 10 or more) with a higher range of variability in these natural physical parameters was studied. As discussed above, it may prove difficult to assemble such a group of creek reaches in the South Coast region, as there are very few if any low gradient creeks with high order and large watershed area that have not been at least moderately impacted by human development.

C. How do biological communities in local creeks change seasonally and from year to year in response to fluctuations in climate, rainfall and stream flow?

Field surveys have been conducted as part of the Program effort in the spring and early summer only. Thus, seasonal succession of creek biota has not yet been explored. Similarly, the responses of creek biota to long-term fluctuations in rainfall and stream flow have not been determined because only two years of Program data have been collected so far, both of which had similar overall rainfall and stream flows.

Researchers at UCSB have studied the biological effects of seasonal and year-to-year fluctuations in rainfall and stream flow in Rattlesnake Creek, a tributary of Mission Creek located in the Santa Ynez Mountains north of the City of Santa Barbara. These studies suggest that biological assemblages in Rattlesnake Creek vary considerably in response to stream flows (Dudley, et. al., 1986). In general, peak winter storm flows scour creek-bottom substrate and the organisms that colonize them. As flow levels and velocities drop, stream substrates are quickly colonized by various diatoms. As flows continue to diminish into the spring, summer, and fall, colonial algae increase in abundance, replacing diatoms as the dominant algae in some areas. As with algae, there is a distinct seasonal succession of BMIs and vertebrates in Rattlesnake Creek. During the rainy season (i.e., winter and spring), conspicuous riffle inhabitants include mayflies from the families Ephemerellidae and Baetidae, stoneflies *Calineuria*, *Sweltsa* and *Malenka*, midge larvae (*Blephnaricera*), and blackfies (*Simulium spp.*). Dragonflies from the genus *Paltothemis* and various stoneflies are conspicuous winter inhabitants in pools. During the dry season (i.e., summer and fall), pools are dominated by the damselfly *Archilestes*, tadpoles (*Psuedacris spp.*), newt larvae (*Taricha torosa),* various dytiscid beetles, and the mayflies *Tricorythodes* and *Caenis*. Riffles are dominated by *Hydropsyche*, *Baetis*, Chironomidae, and hydroptilid caddisflies. Although many taxa such as rainbow trout, *Notonecta*, *Baetis*, *Simulium*, *Abedus*, and *Paraleptophlebia* are found year-round in Rattlesnake Creek, most tend to be more abundant in particular seasons (Dudley, et. al., 1986).

In general, winter/spring taxa in Rattlesnake Creek persist into the summer in wet years with high stream flows, whereas summer taxa appear earlier in the spring in drought years with low rainfall and low flows. Year-to-year changes not only affect the timing of the appearance and disappearance of stream organisms, but also their abundances. In wet years when storm flows are especially severe and frequent, taxa which are aquatic throughout their lives (e.g., rainbow trout, *Notonecta*, gastropods, and ostracods) are drastically reduced in number, and can take years to recover to their previous abundances. Organisms with terrestrial life stages (e.g., newts, mayflies, caddisflies, stoneflies, true flies, etc.) recover more quickly from scouring flows. Taxa that thrive in fast currents (e.g., *Simulium and Blephnaricera)* are more abundant in wet years, whereas the opposite is true for taxa (e.g., *Paltothemis*) that are adapted to slow-moving waters (Dudley, et. al., 1986).

It seems reasonable to assume that the patterns of biological succession documented in Rattlesnake Creek are similar to what occurs in other local creeks. However, there is no doubt that geographic variability exists because each creek is somewhat unique. To more completely understand temporal patterns of biological succession and how they vary spatially, it will be necessary to study several creek reaches through time, including surveys at different times of the year.

D. What impacts do different forms of human disturbance have on local creek ecosystems? Which forms of human disturbance have the most severe impacts?

Based on the results of the study, the disturbed creek reaches are clearly degraded in terms of habitat quality, water chemistry, and biological integrity compared to the relatively undisturbed reaches. In comparison to the relatively undisturbed reaches, the disturbed reaches exhibited:

- Degraded physical habitat quality as indicated by significantly lower habitat assessment scores. The most common causes of physical habitat degradation in the disturbed reaches include alteration of natural creek bed and banks (i.e., periodic grading/clearing of creekbed and banks, installation and use of bank protection structures, road crossings, and debris basins, etc.), increased sedimentation (especially from agricultural lands), destruction of native riparian and upland vegetation, and invasion by non-native plant species.
- Degraded water quality as evidenced by significantly higher electrical conductivity, water temperature, and nutrient concentrations. Polluted runoff from agricultural and urban lands is thought to be the primary cause of elevated conductivity and nutrient concentrations. The loss of riparian vegetative cover and exposure of bare creekbeds to higher sunlight levels likely contributes to stream temperature increases.
- Degraded biological communities as indicated by significantly lower diversity of aquatic insects and vertebrates, lower percentage of sensitive BMI taxa, and higher IBI.

The observed "degradation" of physical, chemical, and biological parameters at the disturbed reaches is thought to be primarily the result of human disturbances. This hypothesis is supported by direct observations and the many significant relationships shown between physical, chemical, and biological parameters vs. measures of human disturbance. However, as indicated in the discussions for questions A and B, human disturbance was highly correlated with stream order, gradient, and watershed area in the creek reaches studied. Regressions using the undisturbed reaches only did not show clear relationships between these natural physical parameters and the biological response parameters. However, these regressions were of lower statistical power, and did not test the full ranges of the natural physical variables (see discussions for questions A and B). Given this, the analysis did not definitively separate the influences of human disturbance from those of stream order, gradient, and watershed area. In theory, this could be done by carefully studying paired groups of undisturbed reaches and disturbed reaches with similar stream orders, gradients, and watershed areas. However, there appear to be few if any high order, low-gradient creeks with large watershed areas on the South Coast that are in a relatively undisturbed condition. There is probably also a shortage of low order, high-gradient creeks with small watershed areas that are heavily disturbed. Thus, this type of study may have to be limited primarily to creeks of moderate order, gradient, and watershed area.

Based on a qualitative analysis of the data collected in 2000 and 2001, ecological impacts generally appear to be greater in creeks in urban areas compared to creeks in agricultural areas. This hypothesis could be subject to robust statistical testing by expanding the number of Program study reaches in the future to include at least four or five urban creek reaches and four or five agricultural creek reaches, and comparing the two groups using t-tests. Only two agricultural reaches were studied in the 2000 and 2001, thus statistical comparisons between agricultural and urban study reaches were not attempted (i.e., statistical power would be very low).

E. To what degree can impacted creeks be restored given the constraints posed by existing and future development? What feasible actions (e.g., improving water quality, controlling erosion, minimizing habitat alteration, restoring and protecting native riparian vegetation, removing barriers to wildlife movement, etc.) are most effective in restoring important creek functions and values? How much time is required for creek ecosystems to recover after restoration actions are initiated?

At this point in time, restoration projects have not been studied as part of the Program. However, study reaches along Carpinteria Creek, Arroyo Burro, and San Jose Creek were selected due to their proximity to the locations of several creek restoration projects planned by the County. Program data collected prior to the implementation of these restoration projects will be invaluable in establishing baseline (i.e., pre-project) conditions in the restoration sites. After the restoration projects are implemented, the Program can be used to monitor them and assess ecological recovery over time. It also will be important to monitor nearby control sites (preferably within the same creek), which will provide reference conditions to compare with the restoration site through time.

F. Which biological and physical parameters are reliable indicators of creek ecosystem health, and can be effectively used in impact assessment and ecological monitoring?

Based on the first two years of Program data, the following biological parameters appear to be very reliable indicators of creek health: number of aquatic insect families, number of aquatic insect genera, IBI, percent sensitive BMI taxa, and number of native aquatic vertebrate species. The results indicate that these parameters were significantly greater (except IBI, which was significantly lower) in the undisturbed reaches compared to the disturbed reaches. In addition, the results show clear relationships between these parameters and measures of human disturbance such as habitat assessment score, percent of watershed developed, percent of watershed as open space, conductivity, water temperature, and NO_2 and NO_3 concentrations. Percent tolerant BMI taxa was a less effective indicator of creek health. This parameter did show some significant relationships with measures of human disturbance, but most were not significant and/or not as strong as with the other biological parameters. BMI density did not show any clear relationships with measures of human disturbance, and does not appear to be a reliable indicator of local creek health.

Based on the statistical analysis, physical parameters that are reliable indicators of local creek health include habitat assessment score, percent of watershed as open space, percent of watershed developed, conductivity, water temperature, and NO_2 and NO_3 concentrations. These parameters were clearly different in the relatively undisturbed reaches compared to the disturbed reaches, and showed clear relationships with biological parameters. In general, the following physical/chemical parameters do not appear to be reliable indicators of creek health: pH and concentrations of suspended sediments, PO_4, and NH_4.

Because depressed DO levels are typically associated with disturbed aquatic ecosystems, the fact that DO levels were significantly higher in the disturbed reaches was surprising. The higher DO levels in the disturbed reaches may be due to increased release of oxygen by photosynthesizing algae during the daytime. Algae tended to be much more abundant in the disturbed reaches, presumably due to higher nutrient concentrations and higher ambient light levels. If this is true, DO levels in disturbed reaches would be expected to drop to very low levels at night due to algal respiration. If this is the case, low nighttime DO concentrations in disturbed creeks would be expected to have serious impacts to oxygen-sensitive species such as steelhead/rainbow trout. This issue could be investigated further by determining algal biomass and monitoring DO concentrations over a 24-hour period in selected study reaches.

G. What are the impacts of Program monitoring efforts on creek ecosystems, and how can they be minimized?

In general, the impacts of Program monitoring efforts on creek ecosystems are:

- Minor, temporary disturbances to aquatic and terrestrial species due to human presence and noise during the field survey (approximately three hours in duration).
- A temporary increase in turbidity due to the disturbance of creekbed material during the collection of BMI samples, especially in creeks with extensive deposits of fine sediments. Turbidity typically subsides to normal levels within an hour or two of sample collection.
- Collection of a small number of BMIs (i.e., small relative to the total population present in a given creek reach) during sample collection. Unintentional take of a few small vertebrates such as frog and toad tadpoles also occurs on occasion.

The following measures have been incorporated into the field survey protocols to minimize the impacts of Program monitoring:

- Field surveys are conducted only once per year in each study reach, and last for only three hours on average. Thus, monitoring impacts occur at low frequency and are of short duration.
- Disturbance of creek and riparian habitat is minimized to the greatest degree possible during the field surveys. This includes avoiding unnecessary trampling of vegetation, exposed creek banks, and the wetted creek bottom, and refraining from yelling or making loud noises. All survey equipment and materials are removed from the study reach at the end of the survey. No substances that are potentially hazardous to plants or wildlife are introduced to the creek ecosystem.
- The field leader possesses extensive education, training, and experience in stream assessment, and holds the appropriate scientific collection permits from the State of California. He is very familiar with local creek ecosystems and the habitat requirements of potentially occurring sensitive species such as steelhead/rainbow trout, red-legged frog, California newt, and southwestern pond turtle. The field leader disseminates this information to all field assistants. At the beginning of each survey, the field leader and field assistants assess and survey the study reach for sensitive species. Areas known or suspected of supporting sensitive species are avoided to the greatest degree possible, particularly during the collection of BMI samples, which is when the greatest potential for impact exists.
- All vertebrates including common species are avoided to the greatest degree possible during the survey, especially during the collection of the BMI samples. After a BMI sample is collected, the material is placed into a tub with water and carefully sorted through to locate any vertebrates that may have been caught. Any vertebrates found in the sample are separated out and relocated to suitable habitat areas.

Using this approach, Program monitoring efforts have resulted in only very minor, temporary impacts to the study creeks thus far. With the exception of losing a relatively small number of aquatic plants and invertebrates, and occasionally a few small, common vertebrates, conditions in the study creeks appear to be normal within an hour or two of the survey. The use of this approach must continue to ensure that Program monitoring impacts are minimized in the future.

VI. RECOMMENDATIONS

As indicated in IV. Results and V. Discussion, collection and analysis of the 2000 and 2001 Program data has provided a great deal of information about local creeks, and has partially answered the questions presented in the Introduction. However, further study is needed to more fully answer these questions. The following are recommendations for further study:

- Continue monitoring the 12 established Program study reaches. Continue conducting the majority of the field surveys in the spring for year-to-year consistency because creek conditions change with the seasons. However, at least a few reaches should be surveyed at different times of the year (i.e., summer, fall and winter). Long-term, multi-seasonal monitoring will provide more information about local creek ecology, human development impacts, and how local creek ecosystems change through time due to seasonal and year-to-year variability in climate, rainfall and stream flow.
- Continue collecting replicate BMI samples (preferably three or more samples) in each creek reach, which allows for statistical comparisons at the reach-to-reach level. This level of analysis is especially useful for statistical comparisons between two or more creek reaches that are of particular interest, such as a creek restoration site and a reference (control) site, and for evaluating changes that occur in individual creek reaches through time.
- Continue monitoring the following water quality parameters during field surveys: temperature, conductivity, pH, DO, NO_2, and NO_3. Also consider monitoring other water constituents such as bacteria, pesticides, hydrocarbons, heavy metals, chloride, etc., during the field surveys. This would allow further analysis of relationships between specific pollutants and biological parameters. This may allow especially harmful pollutants to be identified for pollution reduction efforts.
- Continue analyzing the following biological parameters for the study reaches: number of insect families, number of insect genera, IBI, percent sensitive BMI taxa, and number of native aquatic vertebrates. Other metrics such as number of EPT taxa (i.e., Ephemeroptera + Plecoptera + Tricoptera taxa) could also be evaluated.
- Identifying aquatic insects to genus is important in the first few years of the Program at least in the context of inventorying local biota. However, based on the first two years of Program data, it is highly questionable whether genus-level identification is needed for the purposes of detecting spatial and temporal differences in creek conditions. Identifying to genus did not produce a greater ability to detect differences between study reaches, or relationships between physical/chemical and biological parameters compared to family-level identification. This is evidenced by the statistical results, which generally indicate very similar p and r^2 values for parallel tests involving number of aquatic insect genera and number of aquatic insect families. Should this continue to be the case in the next few years of Program monitoring, a strong case will exist for identifying aquatic insects to the family-level only. Identifying insects to family instead of genus would reduce BMI sample processing costs by approximately 20 to 25 percent, and total Program costs by approximately 10 percent.
- As funding permits, use the County's new Hydrogeomorphic Assessment Method (HGM) during field surveys for the purposes of assessing physical habitat conditions at

the study reaches. The HGM was developed specifically for local creeks, and is highly detailed compared to the EPA habitat assessment method used in the 2000 and 2001 field surveys. However, the HGM is also much more time intensive; thus Program costs will increase if the HGM is used in place of the EPA method.

- As funding permits, increase the number of Program study reaches. This would expand the scope of the Program to include more creeks on the South Coast, and possibly other important watersheds in the County such as the Santa Ynez River. Studying a larger number of reaches would allow more in-depth analysis of relationships between biological parameters and natural physical parameters including elevation, gradient, order, and watershed area. In addition, impacts to local creeks from different forms of human disturbance could be analyzed in greater detail. To save on costs, additional creek reaches could be studied on a rotating basis to address specific questions.
- As funding permits, expand statistical testing to include multiple regressions and multi-variate analyses. Conducting these tests will allow a more thorough understanding of correlations between physical/chemical parameters, and more definitive identification of those physical/chemical parameters that have the greatest effect on local creek ecosystems.
- As funding permits, consider testing the State protocol for collecting BMI samples, as endorsed by CDFG's Aquatic Bioassessment Laboratory. The State protocol involves sampling riffles only, as opposed to the current Program protocol, which involves sampling all habitats (e.g., riffles, pools, falls, runs, snags, etc.) found in a given study reach. The developers of the State protocol provide the following arguments for using their method throughout the State:
  - Of all the habitats found in a given stream, riffles typically support the most diverse assemblage of BMIs, and are thus most appropriate for sampling if only one habitat is to be considered.
  - Use of a single sampling protocol (i.e., the State protocol) will provide standardization to monitoring efforts, and allow direct "apples to apples" comparisons of streams throughout the State.

  However, there would be a number of disadvantages to using the State protocol instead of the current Program protocol for monitoring local creeks, including the following:
  - Because only one stream habitat type (i.e., riffles) is sampled with the State protocol, BMIs adapted to other stream habitats (e.g., pools, runs, snags, etc.) typically are not detected. Thus, using the State protocol would yield less information about the BMI community compared to the current Program protocol, which involves the sampling of all habitats found in a given study reach. Also, because fewer BMI taxa would be detected with the State protocol, there may be less ability to detect spatial and temporal differences in the BMI community (e.g., diversity, IBI, percent sensitive taxa, etc.).
  - It can be argued that the State protocol is inappropriate for use in local creeks because the classic riffle habitat targeted for sampling, such as what occurs in larger streams and rivers, is sometimes absent from local creeks, particularly in high- and low-gradient reaches. In some cases, use of the State protocol in local creeks would

require sampling of an alternative habitat (e.g., a pool, snag, sand run, etc.) that is "professionally" judged to support the highest diversity of BMIs in a given study reach. This would add more subjectivity to the sampling, and would result in comparisons of BMI assemblages from riffles in some stream reaches versus alternative habitats (e.g., pools, snags, sand runs, etc.) in other stream reaches. This would not allow standardized, "apples to apples" comparisons. Rather, the authors of this report argue that the current Program protocol, which involves sampling all habitats found in a given study reach, provides more standardized, "apples to apples" comparisons, at least in the context of local creeks.

- The "professional-level" State protocol requires the collection and identification of 900 BMIs per study reach (i.e., three samples of 300 BMIs), whereas the current Program protocol requires the identification of only 300 BMIs per reach (i.e., three samples of 100 BMIs). BMI processing costs would increase substantially (two- or three-fold) if the State method were used.

Whether or not the current Program protocol or the State protocol should be used to monitor local creeks is a matter of debate. At this point, there is not enough information available to clearly support either argument. The County should consider limited testing of the State protocol side-by-side with the current Program protocol. The abilities of each protocol to detect differences in BMI assemblages through space and time could then be directly compared. This information would be invaluable in determining which protocol is most suitable for use in monitoring local creeks.

- Conduct public outreach to recruit volunteers for the Program. Volunteers could be quickly trained as field assistants and laboratory technicians to perform some of the more basic tasks under the supervision of professional staff. This would help reduce costs, involve the community in the Program effort, and thereby improve public awareness and support for the Program and other efforts to study, protect, and restore local creeks and water quality.

- Form partnerships and share resources with other local groups to expand and improve creek biomonitoring efforts. Potential partners with an interest in local creek monitoring include UCSB's Long-Term Ecological Research team (LTER), the Cities of Santa Barbara and Carpinteria, local environmental groups, and state agencies including the RWQCB and State Parks Department.

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