Final Report

Benthic Macroinvertebrates & Water Quality

Quantifying the Effects of Various Parameters on BMI Communities in the Santa Monica Mountain National Recreation Area

Institute of the Environment & Sustainability at UCLA

Environment 180 | Senior Practicum

Client: Heal the Bay

Advisor: Dr. Mark Gold

June 2014

Rita Chang
Mark Chong
Nathaniel Clark
Valentina Lin
Kevin Tang
Jazmin Tostado
Alice Wong

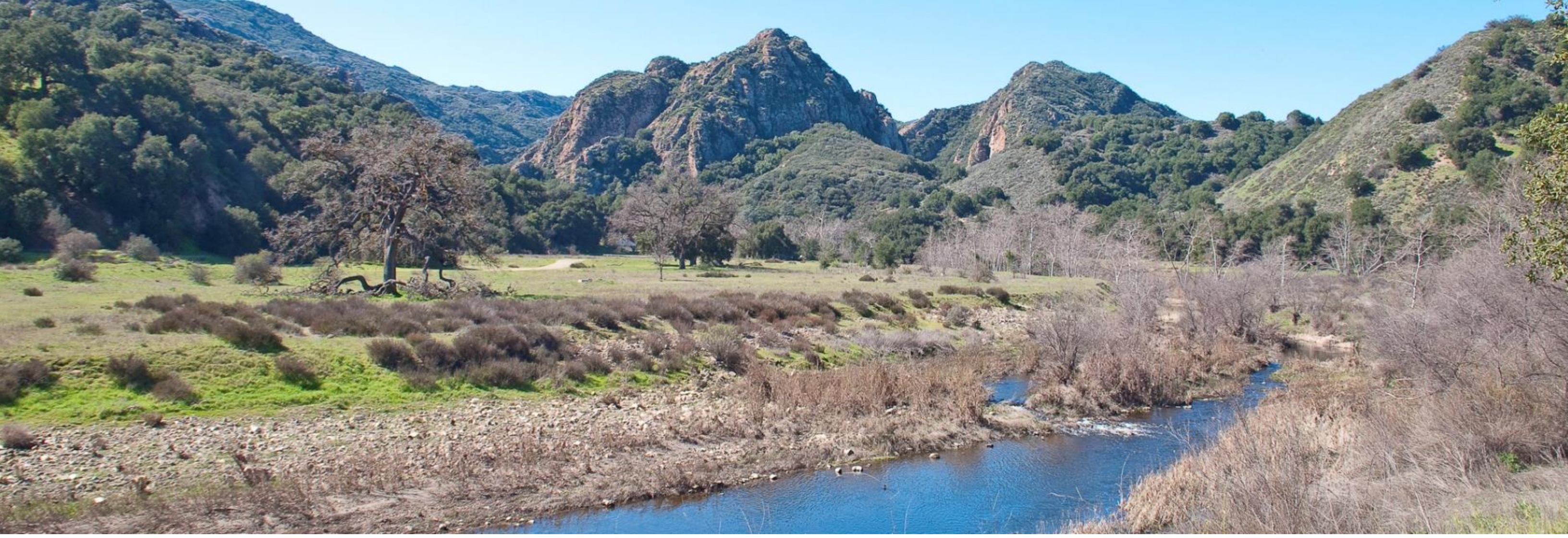
Heal the Bay

UCLA

Table of Contents

I. ABSTRACT

Benthic macroinvertebrates (BMI) tend to be particularly vulnerable to environmental perturbations; therefore, their presence or absence can provide valuable insight into the health of streams. Heal the Bay currently collects data records of water quality metrics to evaluate the biological integrity at 22 monitoring locations within the Malibu Creek Watershed. In this study, six of those parameters (pH, temperature, nutrient, conductivity, algal cover, and substrate size) were assessed to determine the impact on seven biological integrity metrics: # of EPT Taxa, # of Predator Taxa, # of Coleoptera Taxa, % Intolerant Individuals, % Collector Individuals, % Tolerant Taxa, and % non-insects Taxa. A fixed-effects statistical model was used to determine the correlation between the water quality parameters and the seven biological metrics. The fixed-effects model found that ammonia, conductivity, dissolved oxygen, pH, and water temperature were statistically significant predictors of a few biological metrics. These results, however, were unable to find a specific correlation or noticeable pattern between nutrient levels and biological integrity. Since the statistical model was unable to provide conclusive results, a narrative analysis was also conducted, which found that water chemistry may be a potential indicator of benthic macroinvertebrate distribution. Despite this outcome, given the impaired nature of the Malibu Creek Watershed, recommendations have been made to improve BMI communities and stream health.



II. INTRODUCTION

The Malibu Creek Watershed encompasses approximately 110 square miles and is the second largest subwatershed within the larger 414-square-mile Santa Monica Bay Watershed (Beyeler, 2004). This watershed is home to several threatened and endangered species, making it the most ecologically significant watershed in the Los Angeles County. Although it may appear pristine due to large undeveloped areas and robust biological and habitat diversity, the freshwater ecosystems in the Malibu Creek Watershed are continuously threatened from the effects of upstream urbanization and development. Many of the streams in the watershed are listed for several pollutants on the Clean Water Act section 303(d) list of Impaired Waterbodies for California because the streams do not meet water quality standards (Heal the Bay, 2013). The combination of high nutrient concentrations along with physical habitat parameters have been postulated to be significant contributors to the decline in water quality, and ultimately, benthic macroinvertebrate communities in the streams of the watershed. Despite observations and data indicating a relationship between high nutrient concentrations and poor biological communities, the effects of nutrients on benthic macroinvertebrates in the natural environment have not been widely studied due to the complexity of riparian systems and the numerous stressors that could impact stream health. Since the Malibu Creek Watershed discharges into Malibu Lagoon which flows to world famous Malibu Surfrider Beach, it is imperative to understand the association between biological conditions and various stressors to improve and protect stream health, and ensure that the waters continue to support riparian diversity and safe recreational use.

Research Overview

The main objective of our study is to determine whether there is a correlation between benthic macroinvertebrate biodiversity and physical (algae and substrate size) and/or chemical (nutrients, pH, and conductivity) parameters in the streams of the Malibu Creek Watershed. Through this central research question, we developed more specific sub-questions to clarify and better understand our results. The following sub-questions will be examined to understand the possible causes of stream impairment and the tolerance of BMI to stream impairment:

1. Which water quality parameter(s), if any, has/have the most significant impact on BMI communities and at what thresholds?

2. Are there water quality thresholds where certain benthic macroinvertebrate taxa drop out?

3. How will each water quality parameter affect tolerant versus intolerant BMIs?

III. BACKGROUND

Biological Indices

Benthic macroinvertebrates are a diverse group of small aquatic organisms that are visible to the naked eye, and they are largely sedentary (Hart, 1999). Because of their low motility, benthic macroinvertebrates are directly affected by substances that enter their habitat. This, along with their range of tolerance to varied environmental conditions and pollution levels, make them valuable biological indicators of stream health. Heal the Bay, along with other agencies, monitor benthic macroinvertebrates on an annual basis in the watersheds of the Santa Monica Mountains to evaluate stream health and water quality.

The California Department of Fish and Wildlife has been aggregating benthic macroinvertebrate data since 2000 to calculate an Index of Biological Integrity (IBI). An IBI is a ranking system that is used to assess the health of various streams within a watershed. A total of seven metrics are taken into consideration when calculating an IBI score for watersheds in southern California. These metrics include: *Coleoptera* taxa, *Ephemeroptera*, *Plecoptera*, and *Trichoptera* (EPT) taxa, predator taxa, percent collector individuals, percent intolerant individuals, percent non-insect taxa, and percent tolerant taxa.

Coleoptera, colloquially known as beetles, is the largest and most species-abundant group in the animal kingdom with roughly 360,000 described species (Bouchard et al. 2011). Annual and seasonal variations of rainfall have a substantial effect on the presence and profusion of

Coleoptera, so it serves as an appropriate indicator for climate variations (Smith & Golladay 2011). EPT taxa are sensitive to most types of pollution; therefore, the number of individuals in these orders tends to decrease in response to more contaminated waters (Norris & Georges 1993). The EPT score indicates the total sum of distinct taxa within the three orders. Because these orders contain pollution-intolerant species, an impacted stream is expected to include less of these taxa than a reference stream (Kitchin 2005).

Collector-gatherers and collector-filterers are typically more tolerant to pollution. Unlike certain macroinvertebrates, these functional feeding groups are generally better adapted to pollution that alter the availability of food (Rawer-Jost et al. 2000). Non-insect taxa are more reactive to human stressors; they tend to increase in response to ecological impairment (Ode et al. 2005). Non-insect communities, like percent of collector individuals, commonly flourish and thrive in large proportions when ecosystems become unsuitable for many insects.

The percent of intolerant individuals are classified as the proportion of benthic macroinvertebrates with a California Tolerance Value (CTV) lower than three. The CTV is a metric that ranges from 0 to 10, with 0 corresponding to highly intolerant and 10 to highly tolerant. These values are conventionally assigned through best professional judgment. Taxa are considered tolerant if they have a CTV greater than seven. The presence of more intolerant species signifies that the stream is not heavily impacted by anthropogenic disturbances. A few of the most sensitive BMIs include: dragonflies, mayflies, caddisflies, and stoneflies (Sikich et al. 2013). The disparity in response between different taxa to various stressors allows benthic macroinvertebrates to act as indicators of watershed disturbance and overall stream health.

Water Chemistry

The water chemistry data used for this report was from the monthly monitoring program conducted by Heal the Bay's stream team, which was comprised of skilled professional staff and trained volunteers. The volunteers directly measure pH and temperature in-stream and collect water samples for nutrient and fecal indicator bacteria analysis in the laboratory. Our report will focus specifically on: pH, conductivity, nitrate, ammonia, and phosphate. Heal the Bay also measures other water quality parameters, not included in this report, such as dissolved oxygen that may provide additional information about excess nutrient and other water quality problems.

Several studies have confirmed the detrimental effects of nutrients on benthic macroinvertebrate species; however, most of these studies do not document the synergistic effects between two or more stressors. The U.S Geological Survey (2002) analyzed the effects of ammonia and nitrate on EPT taxa richness. Based on their observations, they concluded that there was an increase in pollution tolerant taxa and a decrease in EPT taxa richness in streams where ammonia and nitrate concentrations increased. Their findings also showed that water quality and aquatic life are more affected by ammonia than nitrate. Phosphate, like nitrogen compounds, is another nutrient that affects benthic macroinvertebrates. According to Roberge and McCabes (2011), EPT richness tends to decrease with higher phosphate levels due to particulate perturbation of benthic animals that cling to rocks on stream bottom. Elevated levels of phosphate produce adverse effects on benthic macroinvertebrates; however, it produces even greater BMI response when combined with nitrogen.

The toxicity and forms of certain nutrients depends on the pH and temperature of the stream. For instance, the relative proportion of un-ionized ammonia and ammonium ion is mainly determined by pH. When pH is low, the relatively non-toxic ammonium ion predominates, while the toxic un-ionized form of ammonia predominates when pH is high, above 8 (ATSDR, 2004). In addition to the synergistic effects of pH on nutrient, this parameter also has direct implications on benthic macroinvertebrates. Schell and Kerekes (1989) survey indicated that benthic macroinvertebrate richness is exceptionally low in acidic environments where pH values are below 5. Collectively, these studies illustrate the effects of nutrient and pH on benthic macroinvertebrate abundance and distribution.

Physical Parameters

The physical parameters examined for this study include substrate size and algal coverage. Both of these parameters were monitored on an annual basis and collected according to the State Water Resources Control Board's Surface Water Ambient Monitoring Program bioassessment protocol for physical habitat. The measurements for filamentous algae were taken five meters upstream and downstream of the monitoring locations in the Malibu Creek Watershed. Each monitoring site was divided into 11 transects labeled A-K, and a score of 0-4 (Table 1) was assigned to each transect. In contrast, substrate sizes were sampled at five locations for each transect and inter-transect— an inter-transect is the space between transects. The five sampling locations for each transect included: left bank, left center, center, right center, and right bank.

Algae Coverage	Score	Range	Percentage
Absent	0	0%	0%
Sparse	1	>10%	5%
Moderate	2	10-40%	25%
Heavy	3	40-75%	57.5%
Very Heavy	4	>75%	87.5%

Table 1: Quantifying the presence of filamentous algae in the Malibu Creek Watershed

Studies have identified algal cover as an indicator of benthic macroinvertebrate distribution and abundance (SOURCE). High algal cover results in homogenization of benthic habitats, which reduce the amount and diversity of shelter and nursery areas for BMIs such as mayflies and crayfish (Matteson 2009). Algae also indirectly impacts BMI communities by changing the pH of impaired streams (Fetscher et al. 2014). This chemical fluctuation is difficult to understand because it may be a result of the algae or extraneous sources. However, regardless of this difficultly, the impact of algal cover on benthic macroinvertebrate assemblages is potentially significant for our assessment and therefore, must be taken into consideration.

Substrate size is another physical parameter that has significant implications on the distribution of benthic macroinvertebrates (Trimble 1997; Wood & Armitage 1997). Fine substrate is a result of high sedimentation which is greatly accelerated from the effects of urbanization including, but not limited to construction, landscaping and infrastructure (Wood & Armitage 1997). It has been well studied that substrates with diameters less than 100 μm absorb more contaminants due to their high surface area to volume ratio (Wood & Armitage 1997; Brown, Ackerman & Stein 2012). The material absorbed onto the substrate as a result of urban activity can affect the benthic communities on a chemical level.

From a physical perspective, substrate size serves as a determining factor for where BMI communities distribute themselves within the stream system. Substrate sediments have the capacity to alter the benthic environments and disrupt biological processes by increasing turbidity and decreasing light penetration. In addition, substrate composition changes with respect to seasonal variation, this instability can affect benthic macroinvertebrates through the disruption of respiratory processes and feeding behavior (Wood & Armitage 1997). Therefore, when assessing the overall impact of the physical habitat on distributions of BMI communities, it is essential that substrate size be included in the analysis because its variation may result in both physical and chemical impacts on surrounding waters.

Total Maximum Daily Loads

The Regional Water Quality Control Board, State Water Resources Control Board and USEPA have long identified impaired waterbodies throughout the Malibu Creek Watershed. Some sources of water pollution include: discharge from water treatment facility, natural geological formation, horse ranches, golf courses, vineyards, agricultural runoff, and failing septic systems. Together these sources contribute to elevated levels of nutrients, sediments, fecal indicator bacteria, total dissolved solids, and sulfate. The Clean Water Act requires each state to develop a 303(d) list of threatened waters and establish priorities for development of TMDLs to correct these causes of impairment. Impairing pollutants include nutrients, sediments, trash and fecal indicator bacteria. A TMDL is the maximum amount of pollutant that a waterbody can receive and still maintain its beneficial uses. The TMDL is a sum of individual waste load allocations for point sources, load allocations for nonpoint sources, natural background levels, and a margin of safety (EPA 2013). The legal settlement between the U.S EPA, Heal the Bay, NRDC, and Santa Monica Bay Keeper in 1999, resulted in a consent decree that held the U.S. EPA accountable for the completion of TMDLs for all impaired waterbodies in the Los Angeles region by the decree deadlines (Heal the Bay).

On July 2, 2013, the U.S. EPA established an updated sediment and nutrient TMDL for the Malibu Creek Watershed and Lagoon under the consent decree. This TMDL examined the entire watershed, including the tributaries that lead into Malibu Creek. The TMDL was designed to restore the impaired beneficial use of aquatic life. A comprehensive evaluation and assessment of BMI from streams with elevated concentrations of nutrients and sediments was completed to develop the TMDL. The U.S. EPA performed statistical analysis using data sources from multiple agencies to confirm the impairment of BMI communities in the Malibu Creek Watershed. Data evaluated include water quality, biological, and habitat data. Using the preponderance of evidence in a transitive manner, EPA determined that although there was no direct correlation found between high nutrient levels and impaired BMI communities, there was a statistically significant relationship between high nutrient loading and increased algal cover. Increased algal cover had a significant impact on the BMI community. High algal cover degraded the habitats of BMIs. High nutrient levels were also indirectly correlated with dissolved oxygen and pH, which are both water quality parameters that affect ecosystem health.

The results used for the TMDL also showed that there were elevated sediment levels in the Malibu Lagoon above what was naturally expected. Elevated levels of sedimentation can create suboptimal habitat for the benthic macroinvertebrates. This addition of sediments in channels and streams can cause more algal blooms because these sediments can carry nutrients. Results from the inclusive evaluation and a multi-regression analysis also confirmed linkage of sedimentation as one of the many stressors impacting the benthic communities in the Malibu Creek Watershed. In order to protect the health of the watershed and its associated tributaries, the TMDL set a 38% sedimentation reduction rate for sediment loading.

The TMDL set numeric targets to reduce pollutants loads in order to meet water quality objectives that protect the Malibu Creek Watershed designated beneficial uses. The numerical targets in the TMDL for total nitrogen (organic and inorganic) are 0.65mg/L in the summer and 1.0mg/L in the winter. The target for total phosphorus is 0.1 mg/L in the summer and 0.2 mg/L in the winter. The numerical target for dissolved oxygen (DO) and algal cover remained consistent with the 2003 TMDL. The mean annual DO concentration was listed as 7 mg/L. Targets for algal cover were broken up into two categories: floating algae should be no more than 2cm in length and 30% in cover while bottom algae should be no greater than 0.3 cm thick and 60% in cover. By achieving these numeric targets, the Malibu Creek Watershed is expected to protect aquatic life beneficial uses and be delisted as impaired by nutrients and sediments.

The original TMDL for bacteria did not include an implementation plan. This revised TMDL, however, includes an implementation plan that requires the largest anthropogenic sources in the Malibu Creek Watershed to reduce its bacteria loading within 6 years for dry weather, and 10 years for wet weather. Additionally, the TMDL recommends the state to implement specific nutrient waste allocations (WLA) using an adaptive management approach. This approach implements recommendations over 2 different phases (Table 2). At the end of each phase, the U.S. EPA recommends an evaluation of monitoring data for each stream to assess whether numerical targets have been achieved. The U.S. EPA anticipates for these interim and final allocations to be incorporated into the applicable NPDES permits (most notably – the Tapia Water Reclamation Facility and the Los Angeles County and Ventura County municipal stormwater permits) and adopted by the communities for improvement of stream quality in Malibu Creek Watershed.

TMDL Implementation Phases	TN Summer Season	TN Winter Season	TP Year Round
Current Nutrient WLAs	1 mg/L	8 mg/L	0 lbs/day summer, no WLA set for winter
Phase 1	1 mg/L	6 mg/L	0.4 mg/L
Phase 2	1 mg/L	4 mg	0.1 mg/L OR 0.1 mg/L summer/0.2 mg/L winter

Table 2: Implementation phases as recommended by the USEPA in the 2013 TMDL for Malibu Creek and Lagoon.

IV. MATERIALS & METHODS

Data Collection and Preparation

The biological, physical, and chemical data used in this report was prepared by Heal the Bay and refined by the authors of this study. The parameters examined for this project include: IBI scores, phosphate, nitrate, ammonia, conductivity, and pH data for ten years, from 2002-2012; and substrate and algal cover percentage for a three-year period: 2009, 2010, and 2012. Each of the databases provided to us by Heal the Bay were compiled in a form that was inconsistent with the statistical software used for our analysis; therefore, we had to reformat the chemical and biological data by combining the parameters by site and date. More effort was required to format the biological data because we decided to examine both the IBI score and the seven metrics for a more comprehensive understanding of the impacts of stressors on BMI community health in the watershed. The IBI scores were divided into the seven metrics and rearranged following the same initial procedures.

The physical habitat database that contained information on algal cover and substrate size was categorized into a similar format as the biological and chemical data, but with minor modifications. Both of these parameters were organized by site, date, and transect (A-K); however, substrate size was further organized into inter-transects. Some of the substrate measurements required additional attention because there was an inconsistency in the data entry. For instance, certain substrate sizes were assigned numerical values (Table 3) while others were assigned class codes. To address this issue, we changed the class codes into numerical values by averaging the values for classes with a range of data. For size classes without a range of values, we used 5 m as the average value for substrate sizes greater than 4 m and 0.05 mm for substrate sizes below 0.06 mm.

Size Class Code	Size Class Range	Size Class Description	Common Size Reference	Assigned Value
RS	> 4 m (4000 mm)	bedrock, smooth	larger than a car	5 m (5000 mm)
RR	> 4 m (4000 mm)	bedrock, rough	larger than a car	5 m (5000 mm)
XB	1-4 m (1000 – 4000 mm)	boulder, large	meter stick to car	2.5 m (2500 mm)
SB	25cm – 1 m (250 – 1000 mm)	boulder, small	basketball to meter stick	625 mm
CB	64 – 250 mm	cobble	tennis ball to basketball	157 mm
GC	16 – 64 mm	gravel, coarse	marble to tennis ball	40 mm
GF	2 – 16 mm	gravel, fine	lady bug to marble	9 mm
SA	0.06 – 2 mm	sand	gritty to ladybug	1.03 mm
FN	< 0.06 mm	fines	not gritty	0.05 mm
HP	< 0.06 mm	hardpan (consolidated fines)		0.05 mm
WD	NA	wood		
RC	NA	concrete/ asphalt		
OT	NA	other		

Table 3: Substrate size classifications

Site Selection Process

To provide an adequate representation of the Malibu Creek Watershed for the analysis in our study , we established site selection criteria (Table 4) using factors such as availability of data and site location. The database provided by Heal the Bay contained gaps for biological and water quality data at certain sites. The missing values in the monitoring data were overcome by narrowing the scope of our project to examining 8 of the 30 monitoring sites (Table 5). Although there is a substantial decrease in the number of sites available for analysis and some sites still contain years of missing data, these 8 sites contain enough data points to perform sufficient statistical analysis. Our site selection was based off based off of a set of criteria which encompasses three components:

1. The site must be located in the Malibu Creek Watershed.

2. The site must have IBI scores calculated for at least 7 years.

3. The site must have at least 6 years of water quality data.

Sites ID:	Name:	Site Type:	Missing Data:
HTB #1	Malibu Creek	Outlet	None
HTB #2	Cold Creek	Outlet	None
HTB #3	Cold Creek	Upper	None
HTB #5	Las Virgenes Creek	Outlet	Missing 3 years IBI - 2008, 2011, 2012
HTB #12	Malibu Creek	Upper Middle	None
HTB #13	Las Virgenes Creek	Upper Middle	Missing 3 years IBI - 2008 2011, 2012
HTB #15	Malibu Creek	Middle	No Water Quality from 2002-2007
HTB #17	Triunfo Creek	Outlet	Missing 2008 Data

Table 4: Selected sites in our study

Statistical Test and Tools

Prior to selecting a statistical model for our analysis, we consulted Dr. Phil Ender of the UCLA Statistical Consulting Center who facilitated the statistical analysis component of our report. Dr. Ender recommended the fixed effects model for our study after exploring various models. Both a mixed effects model and a random effects model were considered, but ultimately deemed inappropriate for our dataset. These models treat each variable as an independent value, which was not appropriate for this analysis due to the complexity of the ecosystem. The fixed effect model, however, represents observed, non-random, dependent quantities in terms of explanatory variables. The fixed-effects model was chosen because it takes into account repeated measurements and represents each site as its own control. The model also makes fewer assumptions in its analysis and is effective in controlling both observed and unobserved variables. A multivariate mixed effects model was used in our attempt to correlate substrate size with BMI health, but this analysis did not garner any results.

Narrative Analysis

The main objective for the narrative analysis is to locate large fluctuations within the raw metric and IBI scores between years for each site. Special attention was given to BMI metrics with a value of zero. The biological analysis from the raw metric and IBI scores for each site was compared to those from upper Cold Creek – the monitoring program's reference location at the top of the tributary sub-watershed.. We then computed and analyzed the yearly average water chemistry in attempt to find a trend between benthic macroinvertebrate abundance and water chemistry. The purpose of this effort was to determine whether biological fluctuations were associated with variability in water chemistry. Additionally, selected sites were compared to a mid-watershed location for further analysis.

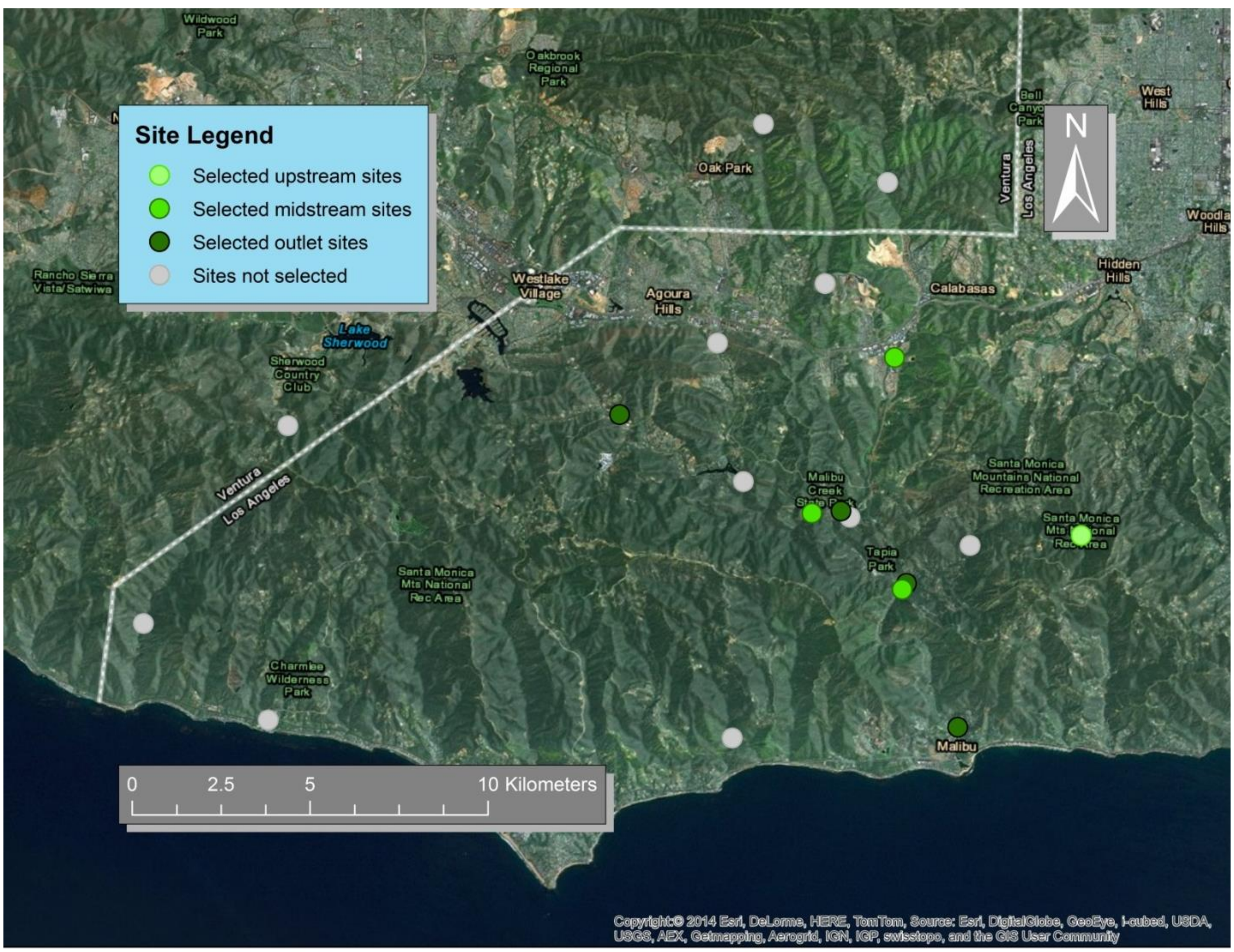


Figure 1: Map of our selected study sites in the Malibu Creek Watershed

V. STATISTICAL RESULTS

The fixed effects model yielded several correlations between the biological metrics and the water quality parameters. For our analysis, we considered a p-value below 0.05 to be significant. The model showed that ammonia predicted EPT taxa with a p-value of 0.04, conductivity predicted predator taxa with a P-value of 0.009, dissolved oxygen predicted percent non-insecta with a p-value of 0.047, pH predicted both predator taxa with a P-value of 0.00 and percent CF+CG with a P-value of 0.00, turbidity predicted percent non-insecta with a P-value of 0.00, and water temperature predicted percent tolerant with a P-value of 0.017. These correlations are displayed in Table 6.

Predictor	Predicted	P-value
Ammonia	EPT Taxa	0.040
Conductivity	Predator Taxa	0.009
Dissolved Oxygen	Percent Non-Insecta	0.047
pH	Predator Taxa	0.000
pH	Percent CFCG	0.000
Water Temperature	Percent Tolerant	0.017

Table 5: Water quality predictors of the biological metrics predicted.

VI. STATISTICAL DISCUSSION

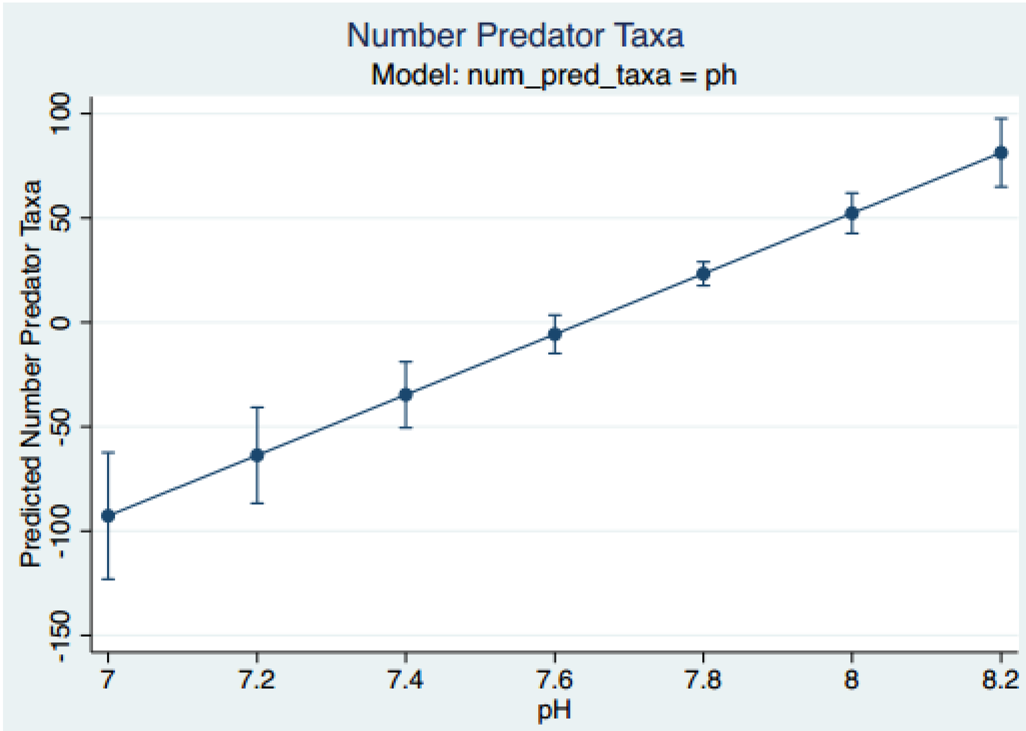


Figure 2: Predicted correlation between Predator Taxa and pH

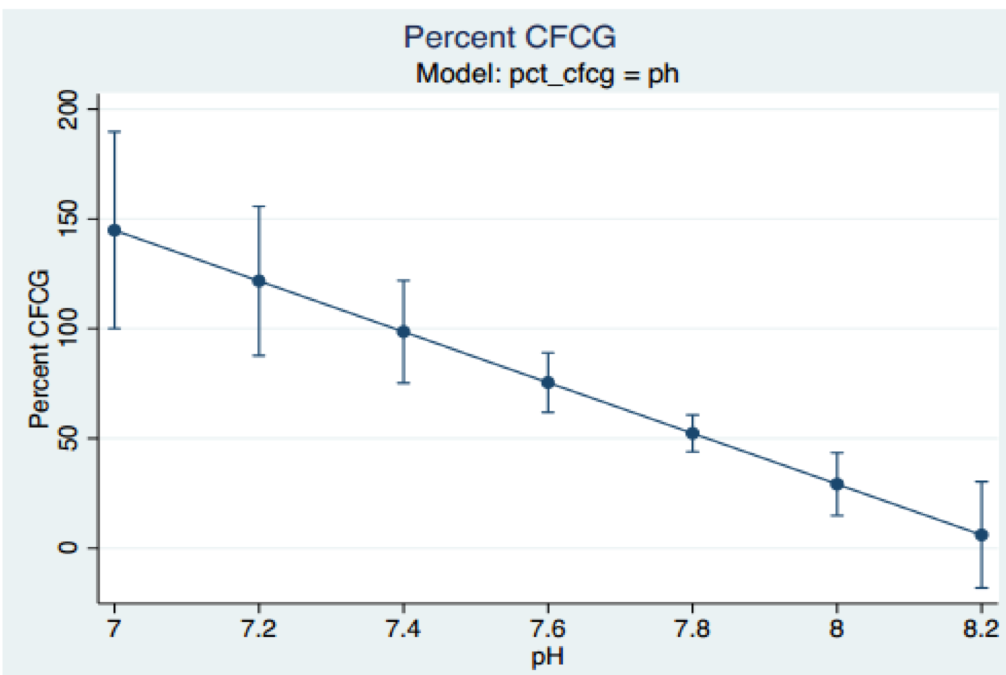


Figure 3: Predicted correlation between Percent CFCG and pH

The fixed effects model yielded some correlations between the water quality data and biological metrics. One correlation was between pH as a significant predictor of collector-filterer and collector-gatherer (CF+CG) health. As Figure 1 shows, CF+CG are predicted to do much better in more neutral conditions, and decline as conditions become more basic. pH also predicted the presence of predator taxa, as seen in Figure X, with more predators present at higher pH levels. Note that this graph represents a model, which is why predator numbers are negative below a pH of 7.6. These two correlations are unexpected since a pH range of 7 to 8.4 as shown in our data, is a healthy range for most benthic macroinvertebrates. Additionally, this mild change in pH is quite small to yield biological changes and response.

In addition to pH serving as a significant predictor of filter feeder/gatherer and predator health, the results of our statistical analysis also found significance of biological taxa with other water quality parameters. For instance, the fixed effects model found that there was some correlation between conductivity serving as a predictor for predator taxa. In addition, some correlation was also found between dissolved oxygen and percent non-insecta taxa.

Based on our literature review, we found that acidic environments have been associated with the decline of benthic macroinvertebrate richness and distribution (Collins et al. 1981). Schell and Kerekes' (1989) study showed that the mean abundance and species richness of non-tolerant benthic macroinvertebrates greatly declined in streams where pH was between 5.0 and 3.6. Their result was reinforced by Courtney and Clement's (1998) study. Courtney and Clement's study examined the exposure at four distinct pH levels, 4.5, 5.5, 6.5 and 7.4. Their results indicated that only the most acidic treatment had an effect on the abundance and species richness of benthic macroinvertebrates, while pH 5.5 and above did not have a significant impact.

The results from these scientific studies were different from the results yielded by the fixed effects model. This disparity in results could possibly be explained by algal blooms caused by eutrophication. Eutrophic lakes tend to exhibit pH values between 7.5 and 8 (Department of Ecology). Eutrophication occurs when excess nutrients accumulate in aquatic environments and saturate the aquatic plant life. The high nutrient concentrations result in increased levels of primary productivity characterized by the excessive growth of algae. When the algae population decays, microbial decomposition severely depletes oxygen from the water, creating a hypoxic zone that is insufficient to support most aerobic organisms, which eventually leads to major changes in aquatic community (Mitsch Gosselink, 2000). This can possibly explain the decrease in collector filterer and collector gatherers; however, the increase of predator taxa with pH is unexpected since it is an intolerant metric.

As previously mentioned, eutrophication can adversely affect aquatic organisms through toxin production and decomposition, which is accompanied by oxygen consumption. Oxygen depletion will have a significant impact on the benthic macroinvertebrates because they have low mobility and cannot easily escape to the surface of the water column where dissolved oxygen concentrations are higher (Wilhm, 1967).

Additionally, the streams in the Malibu Creek Watershed receive pollution from urban and agricultural runoff, failing septic systems, wastewater treatment discharge, erosion and sedimentation associated with development (Walsh et al. 2005). Together these alter the water chemistry, habitat, hydrology, and biotic richness of streams. Urban streams are known to contain high levels of nutrients, suspended solids, calcium, magnesium, zinc, and sodium; these stressors collectively interact to degrade stream health and water quality (Paul & Meyer 2001). Most studies, however, only focus on the effects of individual chemical constituents rather than a combination or collective sum of the chemical parameters. Although studies of isolated parameters provide insight to the effects of pH and dissolved oxygen on benthic macroinvertebrates, the studies do not consider the synergistic effects that can occur between two or more stressors. Thus, synergistic studies should be conducted to provide a better depiction of riparian habitats.

In addition, we also analyzed the effects of substrate size and algal cover on BMI health, but found that three years of robust data was not enough to garner any conclusive results. In addition, the physical habitat data was organized by location in the stream bed and listed 22 variables for each site for each year, in comparison to the one variable listed for biological or water quality parameters. This unbalanced variable ratio resulted in an unsuccessful statistical analysis linking biological health to substrate size and algal cover. Our biological dataset did not include the location in the stream where the BMIs were observed, rendering any sort of linkage between invertebrates and their preferred substrate size and algal cover impossible. Because of the known effects of substrate size and algal cover on BMI communities, we recommend further expansion of this dataset to include the observed physical habitat conditions when cataloging taxa or an overall average of physical habitat that could be easily modeled with the existing biological metrics.

Because our results did not yield any specific correlation between nutrients and benthic macroinvertebrates, we decided to conduct a narrative analysis to examine the effects of nutrients on the seven biological metrics. Further research should also be conducted using the Heal the Bay's database to confirm and evaluate our results.

VII. NARRATIVE RESULTS

Location	Site	2002	2003	2005	2006	2008	2009	2010	2011	2012	Average IBI Score
		Spring	Spring	Winter	Spring	Spring	Spring	Spring	Spring	Spring	2002-2012
Reference Sites											
Cold Creek	3	83	84	61	73	67	79	82	66	76	75
Middle Sites											
Malibu Creek	12	33	21	20	17	29	17	3	13	26	20
Las Virgene s Creek	13	26	21	11	18	-	8	13	-	-	16
Malibu Creek	15	40	34	-	17	-	18	6	16	13	21
Outlet Sites											
Malibu Creek	1	19	26	26	26	20	27	6	-	-	21
Cold Creek	2	53	44	27	31	-	27	20	19	36	32
Las Virgene s Creek	5	39	20	17	14	-	26	10	-	-	21
Triunfo Creek	17	19	4	0	20	-	18	3	11	26	13

Table 6: IBI Scores for Bioassessment Sites in the Malibu Creek Watershed (2002-2012)

Location	**Site**	**2002**	**2003**	**2004**	**2005**	**2006**	**2008**	**2009**	**2010**	**2011**	**2012**	**Overall Avg. (2002-2012)**
Reference Sites												
Cold Creek	3	0.009	0.014	0.013	0.077	0.024	0.011	0.028	0.009	0.011	0.012	0.021
Middle Sites												
Malibu Creek	12	0.039	0.031	0.027	0.174	0.156	0.025	0.105	0.101	0.620	0.026	0.135
Las Virgenes Creek	13	1.29	1.35	1.10	1.73	1.17	1.37	1.09	1.05	0.93	1.07	1.20
Malibu Creek	15	-	-	-	-	-	1.56	1.99	2.68	1.48	0.63	1.62
Outlet Sites												
Malibu Creek	1	3.00	2.55	2.18	1.33	2.65	0.82	1.84	2.01	1.05	1.57	1.90
Cold Creek	2	0.33	0.83	1.01	0.51	0.38	0.77	0.51	0.51	0.60	0.52	0.61
Las Virgenes Creek	5	4.77	4.06	3.76	3.67	4.01	3.86	3.99	3.63	3.65	2.75	3.85
Triunfo Creek	17	0.078	0.177	0.156	0.253	0.272	-	0.191	0.267	0.228	0.08	0.190

Table 7: Average yearly nitrate concentrations (mg/L) for selected sites in the Malibu Creek Watershed (2002-2012)

Location	Site	2002	2003	2004	2005	2006	2008	2009	2010	2011	2012	Overall Avg. (2002-2012)
Reference Sites												
Cold Creek	3	0.055	0.063	0.067	0.066	0.062	0.081	0.089	0.118	0.066	0.128	0.081
Middle Sites												
Malibu Creek	12	0.238	0.363	0.226	0.304	0.33	0.21	0.256	0.211	0.287	0.285	0.272
Las Virgenes Creek	13	0.706	0.812	0.791	0.672	0.64	0.41	0.78	0.698	0.64	0.881	0.740
Malibu Creek	15	-	-	-	-	-	1.01	1.67	1.68	1.22	0.73	1.26
Outlet Sites												
Malibu Creek	1	2.27	2.13	2.08	1.13	1.55	1.44	1.73	1.77	1.46	2.10	1.79
Cold Creek	2	0.24	0.26	0.30	0.16	0.20	0.31	0.32	0.25	0.24	0.45	0.28
Las Virgenes Creek	5	0.357	0.433	0.558	0.434	0.578	0.497	0.444	0.395	0.382	0.629	0.459
Triunfo Creek	17	0.335	0.317	0.282	0.333	0.338	-	0.323	0.310	0.288	0.267	0.311

Table 8: Average phosphate concentrations (mg/L) for selected sites in the Malibu Creek Watershed (2002-2012)

Location	Site	2002	2003	2004	2005	2006	2008	2009	2010	2011	2012	Overall Avg. (2002-2012)
Reference Sites												
Cold Creek	3	0.036	0.033	0.028	0.026	0.023	0.065	0.053	0.087	0.131	0.043	0.050
Middle Sites												
Malibu Creek	12	0.034	0.042	0.063	0.080	0.062	0.033	0.128	0.062	0.094	0.213	0.082
Las Virgenes Creek	13	0.060	0.095	0.085	0.104	0.088	0.000	0.078	0.070	0.064	0.209	0.104
Malibu Creek	15	-	-	-	-	-	0.048	0.341	0.357	0.102	0.100	0.197
Outlet Sites												
Malibu Creek	1	0.112	0.060	0.062	0.063	0.066	0.035	0.145	0.070	0.034	0.081	0.075
Cold Creek	2	0.083	0.052	0.041	0.035	0.033	0.050	0.052	0.0440	0.033	0.075	0.050
Las Virgenes Creek	5	0.120	0.064	0.054	0.067	0.076	0.025	0.118	0.051	0.043	0.093	0.073
Triunfo Creek	17	0.065	0.061	0.045	0.072	0.048	-	0.036	0.062	0.078	0.091	0.062

Table 9: Average ammonia concentrations (mg/L) for selected sites in the Malibu Creek Watershed (2002-2012)

VIII. NARRATIVE DISCUSSION

Site 1 | Outlet of Malibu Creek

The outlet of Malibu Creek is located downstream of Tapia Water Reclamation Facility, commercial and residential land, septic systems, the 101 freeway, and a major dam. This site has low biotic integrity as indicated by the poor IBI scores from 2002 through 2010, the scores ranged from 6 to 27. The impaired biotic conditions were also reflected through the seven biological metrics used to calculate the IBI score. This site was dominated by pollution tolerant metrics: percent collector-filter and collector gatherers (CF+CG) individuals, percent noninsecta taxa, and percent tolerant taxa. The fluctuations between these pollution tolerant metrics were not as significant as the sensitive BMI metrics.

The number of *Coleoptera* decreased from 1 in 2002 to 0 in 2003, it recurred in 2005 and dropped out the following year. This reemergence and drop out for the number of *Coleoptera* occurred again in 2009. In addition, the percent intolerant individuals increased from 0% to 8% in 2006. This increase is unexpected considering the site's proximity to major anthropogenic sources. Monitoring locations near multiple sources of impairment generally have low to no percent intolerant individuals because these benthic macroinvertebrates are exceptionally sensitive to disturbances (UC Davis).

The outlet of Malibu Creek had higher average nutrient concentrations than upper Cold Creek. In 2002, the outlet of Malibu Creek had nitrate and phosphate levels of 2.55 mg/L and 2.13 mg/L while upper Cold Creek had nitrate and phosphate levels of 0.01 mg/L and 0.06 mg/L, respectively. The outlet of Malibu Creek had consistently high nitrate concentrations. The phosphate concentration decreased from 2.1 mg/L in 2004 to 1.55 mg/L in 2006. This reduction of phosphate levels can potentially be used to explain the sudden increase in percent intolerant individuals. The difference in nutrient concentrations between upper Cold Creek and outlet of Malibu Creek can possibly be used to explain the variability in biological conditions between the two sites; however, a more holistic analysis that factors in multiple stressors must be examined to confirm this result.

Site 2 | Outlet of Cold Creek

The outlet of Cold Creek is located downstream of rural residential areas, septic systems, and moderate equestrian use. Outlet sites are highly impacted by anthropogenic sources and they tend to exhibit the most degraded stream conditions, but there is not a great deal of development within the sub-watershed. On average, the outlet of Cold Creek exhibits impacted to poor biotic conditions. From 2002 through 2011, the site has exhibited a decrease in IBI score; the site received an IBI score of 53 in 2002 and a score of 19 in 2011. Despite having the highest concentrations of phosphate in 2012, there was a slight increase in IBI scores for that year.

Based on the site-by-site analysis for biological metrics, there was a decrease in percentage of intolerant individuals to 0% in 2010. *Coleoptera* taxa returned in the year of 2010 after receiving an individual taxa score of 0 in 2009. Although there were variations between biological metrics, there was no obvious fluctuation in water quality to explain the change of sensitive BMI for this timeframe. The percentage of CF+CG declined steeply from 84% in 2011 to 13% in 2012. A similar trend was observed at upper Cold Creek, the CF+CG individuals decreased from 70% in 2011 to 27% in 2012. During this period, the phosphate concentrations doubled. The phosphate concentrations for Upper Cold Creek went from 0.066mg/L to 0.128mg/L while the Cold Creek outlet went from 0.24 mg/L to 0.45 mg/L.

In comparison to Upper Cold Creek, this site had consistently less EPT taxa, *Coleoptera* taxa, intolerant individuals, and number of predator taxa and more percentages of CF+CG individuals, non-insecta taxa, and pollution tolerant taxa. These variations are expected because the outlet of Cold Creek is more degraded, and therefore, should contain more tolerant benthic macroinvertebrates. The Cold Creek outlet site experienced higher nitrate and phosphate concentrations than upper Cold Creek, but the ammonia levels were comparable. Although there is no definite proof that the impairment of the BMI communities is a result of elevated nutrient concentrations, there is an indication that higher nutrient concentrations may be a stressor on the benthic macroinvertebrate population.

Site 3 | Upper Cold Creek

Upper Cold Creek drains a restricted-access nature preserve and there is no development above the monitoring site. For this reason, this site exhibits good biotic conditions and maintains a high IBI score. While there have been some fluctuations in the IBI scores, the scores have been consistently good or excellent. The lowest score for this site was 61 in 2005 and the highest score was 84 in 2003. In addition, there was not much variability within the seven biological metrics. Because this site has the healthiest IBI scores and biological metrics, it was selected as our reference site for in-between site comparison. This site exhibits a cobble substrate, lush surrounding riparian vegetation, and minimal urban features.

Reference sites have low nutrient concentrations. Upper Cold Creek had an average nitrate concentration of 0.02 mg/L and average phosphate concentration of 0.08 mg/L between 2002 and 2012. By a large margin, this was the lowest decadal average between the eight selected monitoring sites.

Site 5 | Outlet of Las Virgenes Creek ||||| Site 13 | Mid-Las Virgenes Creek

Site 5 and 13 are both located in Las Virgenes Creek, which is downstream of high density commercial and residential areas. This attribute is generally associated with impaired water bodies and low biological integrity as confirmed by the poor IBI scores. Site by site analysis for the outlet of Las Virgenes Creek has shown that EPT taxa, percent non- insecta taxa, percent CF+CG individuals, and number of predator taxa have been relatively consistently poor between the years, 2002-2010. However, the presence of *Coleoptera*, percent tolerant taxa, and percent intolerant individuals varied throughout this 8-year sampling period. The percent tolerant taxa increased from 13 in 2002 to 36 in 2010 with minor fluctuations in-between the years. Neither *Coleoptera* nor intolerant taxa were observed during the 8-year sampling period. The number of *Coleoptera* dropped from 4 in 2002 to 0 in 2003. Although the percent of intolerant individuals briefly rose to 1 in 2006, it dropped out the following year the site was monitored.

A similar trend was observed in Mid-Las Virgenes Creek; the EPT taxa, percent non- insecta taxa, number of predator taxa, and percent CF+CG individuals had minor fluctuations while the number of *Coleoptera* and pollution tolerant taxa varied significantly. The pollution tolerant benthic macroinvertebrates such as the percent tolerant taxa gradually increased from 9 in 2003 to 46 in 2009. Although, the *Coleoptera* briefly rose to 2 in 2006, it dropped out the following year the site was monitored. This site contained 0% of intolerant individuals. Because these two sites are located within close proximity of one another, it is reasonable for similar results to be achieved.

The low IBI score and lack of biotic diversity for the two sites in Las Virgenes Creek could be partially attributed to elevated nutrient concentrations as well as other stressors. These two sites have significantly higher average nutrient concentrations when compared to the reference site. In 2003, the outlet of Las Virgenes Creek had nitrate concentrations of 4.06 mg/L and Mid-Las Virgenes Creek had nitrate values of 1.34 mg/L while upper Cold Creek had concentrations of 0.01 mg/L. Additionally, the sites in Las Virgenes Creek consistently had higher nutrient concentrations than upper Cold Creek throughout the 2002-2012 monitoring period. This difference in nitrate concentration could be a stressor that contributed to the absence of *Coleoptera* and percent of intolerant individuals for the two sites in Las

Virgenes Creek. *Coleoptera* and percent of intolerant individuals represent pollution sensitive benthic macroinvertebrates; therefore, they tend to decrease in response to environmental stress and impaired conditions. The BMI impairment in Las Virgenes Creek includes the presence of more pollution tolerant benthic macroinvertebrates as indicated by more percent tolerant taxa and percent collectors when compared to upper Cold Creek.

Site 12 | Upper Mid-Malibu Creek

Upper Mid-Malibu Creek is located downstream of the 101freeway, rural residential areas, and high-density residential and commercial areas. Because this site is situated in the vicinity of urban development, it has consistently failed to meet water quality standards as indicated by the water quality data and low IBI scores. Site-by-site analysis for upper Mid-Malibu Creek has shown that there is a high proportion of pollution tolerant to intolerant species. The number of *Coleoptera* for this site was 1 in 2002, 2011, and 2012, and 0 for all other years between 2002 and 2012. Additionally, there was only 1% intolerant individual found throughout the 10-years. Overall, both intolerant and *Coleoptera* taxa remained at relatively low to non-existent levels throughout our decade of measurements. The percent of CF+CG individuals, percent noninsecta taxa, and percent tolerant taxa were significantly higher when compared to the reference site. The average scores from 2002 to 2012 for the CF+CG metric was 37 at the reference site versus 71 at site 12. For noninsecta taxa, the average scores over the decade was 14 at the reference site versus 45 at site 12. Finally, the average score over the decade for tolerant taxa was 14 at the reference site versus 35 at site 12.

Upper Mid-Malibu Creek had higher nutrient values than upper Cold Creek. The nutrient concentrations for upper Mid-Malibu Creek in 2010 were 0.10 mg/L for nitrate and 0.21 mg/L for phosphate and 0.009 mg/L and 0.09 mg/L for upper Cold Creek. Upper Mid-Malibu Creek had consistently lower nutrient concentrations than outlet of Malibu Creek; however, the variability in biological metrics between these two sites was relatively the same. For instance, nitrate and phosphate concentration in 2012 for Mid-Malibu Creek was 0.03 mg/L and 0.28 mg/L while Outlet of Malibu Creek had concentrations of 1.57 mg/L and 2.10 mg/L, respectively. Over the decade, both nitrate and phosphate increased slightly. Although there was variability in the water chemistry, the distribution between the biological metrics was very similar. This trend was seen in most of the 2002-2012 data for the two sites. This indicates that water chemistry may not be the only stressor causing impairment of benthic macroinvertebrate communities and additional stressors must be examined.

Site 15 | Mid-Malibu Creek at LA County Stream Gage

Mid-Malibu Creek at LA County Stream Gage is predicted to have elevated nutrient levels during the winter months because it is located downstream of the Tapia Water Reclamation Facility. As expected, this site had relatively low biological diversity with very few pollution intolerant metrics. *Coleoptera* was absent from this site following 2002. Of the BMIs sampled in 2011, 3% were classified as pollution intolerant individuals, a very small increase from 0% in 2006, but it dropped to 0% again in 2012. The percent of CF+CG individuals steadily increased over the 10-year monitoring period; they were recorded to comprise 46% of the sample in 2002 and by 2012 that number escalated to 91%. The other four metrics remained relatively constant over the 2002-2012 period.

Since there was no water chemistry data for the Mid-Malibu Creek site in 2002-2006, the biological and chemical comparison will be limited for this site. Mid-Malibu Creek at LA County Stream Gage only has water chemistry data available for 2008 through 2013. The nutrient concentrations in Mid-Malibu Creek for these 6-years were higher than those from upper Cold Creek, but the nitrate levels in Mid-Malibu Creek were lower than those from outlet of Las Virgenes Creek. The average nitrate and phosphate concentration in Mid-Malibu Creek for the 6 years was 1.68 mg/L and 1.40 mg/L while the average nitrate and phosphate concentration in outlet of Las Virgenes Creek was 3.64 mg/L and 0.45 mg/L, respectively. Although Tapia Water Reclamation Facility is the largest and most obvious source of nutrients in the watershed, this result is not unexpected because Tapia is only allowed to discharge into the creek during the wet season from November to March. In addition, Tapia has made improvements to implement denitrification systems to reduce total nitrogen concentrations to less than 8 mg/l in its effluent.

Site 17 | Triunfo Creek

Triunfo Creek is located downstream of high-density commercial development, residential areas, the 101 freeway, a man-made lake and dam, vineyards, and equestrian use. Triunfo Creek has also undergone streambank modification, which has contributed to the high levels of fine sediments. The multitude of human influences on this site contributes to its poor biotic conditions. This creek is the most degraded of the monitoring sites and has the poorest BMI community health. Based on the absence of *Coleoptera* taxa and intolerant individuals for this site, it is evident that this site is not conducive for the presence of sensitive BMI taxa . The BMI present are largely comprised of CF+CG and high levels of non-insect taxa as well as pollution tolerant taxa. In 2005, the site received an IBI score of 0. This is not to say that there were no BMI present, it signifies that only highly pollution tolerant organisms could exist in those conditions.

The comparison of the Triunfo Creek Outlet to the Malibu Creek Outlet showed that both sites had 0% intolerant individuals with the exception of 2008 when 8% of the Malibu Creek Outlet sample was comprised of intolerant individuals. Similarly, both sites had 0-1 *Coleoptera* taxa and low EPT and predator taxa. The lack of sensitive organisms in these locations is not directly associated with a particular nutrient concentration threshold as we see a relatively higher nutrient load in the Malibu Creek Outlet as we do in the Triunfo Creek Outlet. The percent CF+CG individuals, percent non-insect taxa, and percent tolerant taxa experienced similar fluctuations between the two outlet sites and their proportions were consistent with those expected from impaired streams.

For the 2002-2012 monitoring period, the reference location had average nitrate and phosphate levels of 0.021 mg/L and 0.081 mg/L, respectively. In contrast, the nitrate and phosphate levels at Triunfo Creek outlet were 0.19 mg/L and 0.31 mg/L, respectively, while Malibu Creek outlet had corresponding high concentrations of 1.90 mg/L and 1.79 mg/L. The ammonia concentrations were relatively consistent between the three sites. Although Triunfo consistently received the worst IBI scores in the watershed, it is interesting that the water quality is not as bad as some of the other sites. There are other monitoring sites that consistently exhibit higher nutrient concentrations but have less impaired BMI communities. This could potentially be attributed to the sites fine-grained substrates and algal cover. Because of this, we suggest further studying the impacts of physical habitat parameters on each of the sites and looking to see if substrate size and the percentage of algal cover provide any further information.

IX. RECOMMENDATIONS

Assessing the direct impacts of nutrient concentrations on BMI communities continues to be a challenge; therefore, we highly recommend that further research be done to better determine the causal relationship between water quality and physical habitat parameters and BMI community health. In addition, because there are numerous sources of nutrients that have led to poor water quality in comparison to the Cold Creek reference location, a range of recommendations are proposed to control nutrient levels in the streams. These recommendations consist of enhanced local engagement to reduce nutrient loadings, engineered solutions, execution of the Santa Monica Mountains land use plan, and better implementation of existing TMDL requirements. A brief explanation will be provided for each of the proposed recommendations:

1. The US EPA established TMDLs in the Malibu Creek Watershed. Currently, the Los Angeles Regional Water Quality Control Board needs to complete their Implementation Plan which would include clear timelines to meet pollution limits for nutrients in the watershed.

2. Low Impact Development (LID) requirements are in the Ventura County and Los Angeles county municipal storm water permits. Also, the Santa Monica Mountains LUP has LID requirements. Implementation of these requirements for new and redevelopment is required. A retrofit program for existing development needs to be created and implemented by a date certain. Depending on the LID that is employed, removal rates for phosphorus can range from 0–87% for phosphorus, <0–92% for ammonium and for nitrate <0–26% (EPA, 2000).

3. The Coastal Commission approval of the Santa Monica Mountains Land Use Plan during the course of our study was a critical step towards understanding and protecting ecosystem health from the effects of urbanization and development; therefore, further consideration will be given this plan.**

Home to approximately 11,300 residents, wildlife and flora, the 81-square mile Santa Monica Mountains Coastal Zone District received a big win on April 10th. The California Coastal Commission's monumental decision to pass Land Use Plan (LUP) is an amendment to the Local Coastal Program (LCP) for the coastal zone within the Santa Monica Mountains. The LUP allows Los Angeles County to manage the development and conservation of the Santa Monica Mountains through the comprehensive regulatory program and shifts power for observing land use plans to many agencies as well as County Department of Regional Planning from the California Coastal Commissions (LACDRP 2014).

Finally moving past the Malibu/Santa Monica Mountains Interim Area Plan and previous county/state/federal plans, the plan is meant to spare ridgelines from unrestrained development, protect native vegetation, ban certain pesticides that are harmful to wildlife, protect watershed integrity from urban pollution and prohibit large-scale urban construction (Villacorte, 2014). Because the LUP enforces ground rules for future development in the coastal zone, will have more stringent zoning ordinances that will prevent future large scale urbanization and minimize impairment of the watersheds in the Santa Monica Mountains (LACDRP 2014). To ensure all measures move forward, the Local Implementation Program (LIP) will be the primary implementation mechanism for the LUP. The LUP and LIP together make up the LCP.

Established regulations for new urban development and improvement will be reviewed to avoid potential degradation of water quality, and ensure that any land developers meet the requirements of the NPDES Municipal Stormwater Permit's Low Impact Development Requirement, included as part of the LIP (LACDRP 2014). If any conflict should arise, the LIP would prevail previous provisions. If one policy should violate another, provisional steps and preexisting public codes will be utilized to resolve the conflict and the more restrictive standard the better protects biological integrity will be considered greater (LACDRP 2014).

For any land use conversion, property owners now go through more stringent processes to receive approval. With a more rigorous process and thorough application process for land use conversion, it will indirectly manage and improve stream ecosystem and health through Best Management Practices (BMP) that will reduce stream nutrient run-off, sedimentation and sediment erosion issues, which are the common parameters that usually affect the success of benthic macroinvertebrates.

As well as use of private land, regulations for Low-Impact campgrounds, public access ways and trails are considered resource dependent uses and will be implemented to prevent further encroachment and avoid biologically sensitive habitats (Environmentally Sensitive Habitat Areas – ESHA) where feasible. Developments will need to receive a Coastal Development Permit (CDP), riparian habitat ESHA maps, zoning maps that were included in the LUP will help also aide in the implementations. Unless it's a resource dependent use development, no development will be allowed within 100 feet from marine and Environmentally Sensitive Habitat areas to create a habitat buffer, which will also attribute to the Quiet Zone (H1 habitat) (LACDRP 2014). This, along with the goal to reduce light and sound pollution for clearer night skies, will also provide a healthier environment for wildlife while also preventing future geologic and topographical instability, development activities that would lead to erosions and preserve hydrological resources.

The LUP will be a major step to improve and protect benthic macroinvertebrate communities in the Santa Monica Mountains. Because BMI are highly susceptible to chemical and hydrological changes, many of the assemblages downstream of existing development will be spared from the impacts of future urbanization. Increased BMI biodiversity will improve ecosystem health in the streams by enhancing the population of native fishes that consume them.

LIDs in the location should aid with natural hydrological functions, discharge and recharge while still enabling future, more sustainable development. The integrated BMPs will be employed to mitigate storm water runoff, address grading activities, erosion, and clustering development to minimize water quality impacts.

Major Aspects of the Land Use Plan (LUP)

Equestrian Activities

Horse and ranch owners have a long history in the Santa Monica Mountains for setting up corrals and stables adjacent to streams. The LUP, however, will prohibit them from setting up stables within 100 feet from riparian corridors. This will minimize nutrient runoff and erosion in the streams of the watersheds. Existing stables and private animal confinement are allowed to continue as they bring their confined animal facilities to standard BMPs, such as controlled sensor lighting and permission to have structures on natural slopes of 3:1 (horizontal: vertical) or less steep LACDRP 2014). If in H1 Quiet Zone or H2 habitats, existing pasture facilities will need to comply to have no lighting, irrigation, and removal of native vegetation; however vegetation can be removed if in approval for fencing and gates and if they are at most four feet high (LACDRP 2014) New or additional equestrian pasture, stables, barns, corrals, pens, sheds, water troughs, etc. may be permitted depending on each case.

Ban on new Agricultural Uses

Agricultural uses will become more restrictive. The Plan prohibits new crop-based non-livestock use, vineyards, orchards and such to prevent further erosion of the topography and landscape. Existing agricultural uses such as long-standing vineyards will be exempt and shall continue. Viticulture became extremely prevalent in the Santa Monica Mountains. However, the increasing wine industry has increased water consumption, pesticide usage, nutrient runoff, sedimentation, and erosion. The LUP expects to manage this issue by banning the construction of new hillside vineyards and setting more stringent management plans to current vineyards (Villacorte 2014).

Stream Protection

Channelization and other huge change of streams shall be prohibited except only for feasible resources such as flood protection and improvement of fish and wildlife habitat. Stream road crossings (bridges) will be prohibited and all these will allow minimal effect to coastal resources and preserves hydrological functions such as preventing groundwater depletion.

Hillside Management

Hillside developments have proven to be unstable and unsustainable and are better off as open space (LACDRP 2014). The Plan will implement restrictions of hillside development of 50 percent or greater. Slopes that have been disturbed by previous construction activities will be landscaped and revegetated before the wet season. Along with protection of ridgelines and minimizing the lengths of roads and private driveways, this requirement will maintain native vegetation population, reduce soil erosion and disturb less wildlife corridors.

Ban on Hazardous and Toxic Materials

The LUP has set restrictions and prohibitions on insecticides, herbicides, blood thinning rodenticides and any other toxic substance that is detrimental to biological resources. Anticoagulant rodenticide has been prohibited while use of herbicide application will be used when necessary to prevent non-native vegetation growth such as the giant reed/cane (*Arundo donax*) where the least toxic-product/brand will be used. This hopes to minimize herbicide in aquatic bodies and on native vegetation. If on-site wind speed is greater than five miles per hours or if in 48 hours prior to expected rain and wet-season, herbicide use will be prohibited (LACDRP 2014). They can be used 72 hours after a rain event. All pesticides used as pest control will be banned and use of pesticides will hopefully no longer take a toll on native mammalian and vegetative wildlife; therefore, the ban will benefit native wildlife in the Santa Monica Mountains.

Other requirements in the LUP

Many other important measures fall under the LUP. For instance, this regulatory plan will protect 10,000 acres of native vegetation habitat (20 percent of the plan area), which can only be developed for resource dependent uses and public works projects (Christensen & Gold 2014).

There are several water quality goals and policies to maintain and restore coastal water quality and the biological success of marine and freshwater populations so they can achieve optimum success.

Once implemented, the many policies will protect coastal waters and watersheds from non-point source pollution, reduce impervious surfaces, decrease runoff rate and volume, and provide long-term post construction water quality protection. The County hopes to spend at least $2,000,000 over a ten-year period for land acquisitions that contain significant biological habitats that are identified in the Biological Resources Map, which include land adjacent to streams and coastal waters (LACDRP 2014).

The LCP has been a great undertaking from interagency joint planning and the approval and implementation of the LUP in conjunction with ours study are prime steps towards understanding and protecting ecosystem health from the effects of future urbanization and develop. We highly recommend the strict enforcement of the LUP and quick follow through for citing those who do not comply with LUP using the LIP to protect the Santa Monica

Mountains and its watersheds while enabling residents, outdoorsmen, and private landowners to enjoy these resources sustainably.

Understanding that BMIs live long enough to show effects of chronic pollution and short enough to respond to immediate changes in their aquatic system is key for adequate policies of the Santa Monica Mountains and accurate biomonitoring to access true effects of urbanization near sensitive environmental resources areas. The many efforts to avoid impacting valuable and versatile coastal resources should reduce the adverse effects of urbanization on stream health quality, wildlife and encourage the success BMIs and marine productivity.

X. RECOMMENDATIONS FOR FUTURE STUDIES

Expansion of site-by-site Narrative Analysis

Expanding the site-by-site narrative analysis for the inclusion of physical and other chemical parameters is needed to provide a more comprehensive understanding of stressors affecting benthic macroinvertebrates. The bulk of our narrative analysis was focused on the comparison of individual sites to the reference location. Because our analysis focused specifically on the reference location, we recommend for an expansion of our study to include comparisons for all sites. This will give a more thorough understanding of the effects of nutrients on the distributions of BMI.

Physical Habitat Data

The physical habitat data taken over three years, from 2010 to 2012, was not large or robust enough to show statistical significance against the IBI scores and the individual metrics. In addition, the datasets were not comprehensive and contained too many missing data points. For this reason, we recommend the continuation of physical habitat monitoring to yield better statistical results.

The limited physical habitat data also prevented us from conducting a narrative analysis between the variables. From our narrative analysis, we found that nutrient levels did not consistently explain the fluctuations in benthic macroinvertebrate metrics, so further monitoring of physical habitat could also be used to expand the narrative analysis.

Future Studies on Urban Features that affect BMI

Even though scientific literature has shown that flow rate, directionality, and erosion have detrimental effects on BMI, our research did not cover these analysis. Thus, we recommend future studies to research the effects of urban features such as stream bank armoring, percent impermeable area, and proximity of storm drain outfalls on benthic macroinvertebrate diversity.

XI. CONCLUSION

Based on our results from the fixed effects model, there were several significant correlations between water quality data and the biological metrics. However, these numerous correlation did not result in any clear patterns or trends that were explainable within the watershed. Although the results of this study did not yield any specific correlation between nutrient and benthic macroinvertebrates, the literature review conducted during the course nevertheless indicate that high nutrient levels leads to degraded stream health. In order to further explore these relationships, a narrative analysis was conducted on the eight monitoring sites in an attempt to explain some of the associations we observed. Mid-reference site-by-site comparison yielded similar biological metrics despite differences in water chemistry data. Indicating that water chemistry may be a potential indicator of benthic macroinvertebrate health and distribution. Generally the statistical analysis and narrative analysis showed that streams with good biotic condition and high IBI scores, such as Upper Cold Creek, had a greater abundance of benthic macroinvertebrate biodiversity. In more degraded streams that were located downstream of commercial and residential areas, yearly IBI fluctuation were observed and certain taxas dropped out, such as *Coleoptera* and pollution intolerant individuals, but percent CF+CG individuals, percent noninsecta taxa, and percent tolerant taxa increased.

Further research should focus on conducting more analysis on the physical habitat such as substrate size and algal cover in order to evaluate whether there is any significant correlation to biological metrics. Physical habitat data such as substrate size and algal data have shown in previous literature to have significant effects on benthic macroinvertebrate communities and its habitat. The analysis conducted in our research did not show conclusive results, therefore a more robust data set should be assessed in future studies. In addition, it may be beneficial to investigate the relationship of other factors such as impermeable area, stream hardening, stormdrain discharges, and dump sites to the biological metrics and benthic macroinvertebrate distribution.

To better protect stream health, more stringent regulatory regulations and enhanced implementation plans should be placed on nutrient loading within the Malibu Creek Watershed. The recommendations from this study will be useful in assisting in the restoration and cleanup efforts of the Malibu Creek Watershed. Benthic macrovintevertrate communities are essential to the health of waterbody and the protection and restoration efforts are an integral component in maintaining the ecosystem.

XII. ACKNOWLEDGEMENTS

We greatly appreciate the help of a number of professionals and experts who guided and provided us with information on varying topics for our project. We thank Dr. Cindy Lin for providing insight and knowledge on Malibu Creek TMDLs for the recommendation section of our report. In addition, we thank Dr. Randall Orton for providing the team with data and insight from the perspective of the Tapia Water Reclamation Facility. We thank Dr. James Harington from the California Department of Fish and Wildlife for clarifying the metrics which compose the IBI score. We thank Dr. Eric Stein for providing expertise and insight from the Southern California Coastal Water Research Project. We thank Dr. Phil Ender of the UCLA Department of Statistics for serving as our statistical consultant and guiding our team in choosing and executing our statistical analysis. Next, we thank Katherine Pease of Heal the Bay for providing us with guidance about the overall project and the rest of the Stream Team volunteers and Heal the Bay staff for contributing to data collection and compilation. Finally, we greatly thank our advisor Dr. Mark Gold of the UCLA Institute of the Environment and Sustainability for serving as our advisor.

XIII. REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR). 2004. Toxicological profile for Ammonia. U.S. Department of Health and Human Services Public Health Service. ATSDR , Atlanta, GA.

American Public Health Association (APHA). 1992. Standard methods for the examination of water and wastewater. 18th edition. APHA, Washington, D.C.

Arnold, C., and J. Gibbons, 1996. Impervious Surface Coverage: The Emergence of a Key Environmental Indicator. *Journal of the American Planning Association* 62: 243-258.

Ballard, A. and P. Ode. Adapting SWAMP's Bioassessment Infrastructure to Support Bio-Objectives Implementation. California State Water Boards.

Barbour, M.T., B. Boonsoong, N. Sangpradub. 2009. Development of rapid bioassessment approaches using benthic macroinvertebrates for Thai streams. *Environmental Monitoring and Assessment* 155: 129-147.

Barbour, M.T., J. Gerritsen, B.D. Snyder and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002.

Barrett, A. K., C. Guyer, and D. Watson. 2010. Water from urban streams slows growth and speeds metamorphosis in Fowler's Toad (*Bufo fowleri*) larvae. *Journal of Herpetology* 44: 297-300.

Beyeler, Marc. 2004. Staff report: Malibu Creek Watershed habitat restoration. Coastal Conservancy.

Born, M. and J. Harrington. 2000. Measuring the health of California streams and rivers: A methods manual for water resource professionals, citizen monitors and natural resources students. 2nd Edition.

Busse, L., J. Simpson, S. Cooper, K. Kamer and E. Stein. 2003 A Survey of algae and nutrients in the Malibu Creek Watershed. Los Angeles Regional Water Quality Control Board.

California Department of Fish & Game (CDFG). 1999. Physical Habitat Quality, California Stream Bioassessment. Aquatic Bioassessment Laboratory. CDFG, California.

California Regional Water Board (CRWB). 2013. Total Maximum Daily Load Progress Report. CRWB, California.

California Regional Water Quality Control Board (CRWQCB). 2004. Total Maximum Daily Loads for Bacteria Malibu Creek Watershed. CRWQCB, California.

Camargo, J.A., A. Alonso, and A. Salamanca. 2005. Nitrate toxicity to aquatic animals: a review with new data for freshwater invertebrates. *Chemosphere* 58: 1255-1267.

Carter, J.L., and V.H. Resh. 2001. After site selection and before data analysis: sampling, sorting, and laboratory procedures used in stream benthic macroinvertebrate monitoring programs by USA state agencies. *The North American Benthological Society* 20: 658-682.

Christensen, Jon & Gold, Mark. 2014. Yaroslavsky Brings Home a Big Victory for the Santa Monicas. LA Observed.

Collins, N.C., A.P. Zimmerman, and R. Knoechel. 1981. Comparisons of benthic infauna and epifauna biomass in acidified and non-acidified Ontario lakes. In: R. Singer edition. Effects of Acidic Precipitation on Benthos. North American Benthological Society. Hamilton, New York.

County of Los Angeles Department of Regional Planning. 2014. Santa Monica Mountains: Land Use Plan.

County of Los Angeles Department of Regional Planning. 2014. Santa Monica Mountains: Local Coastal Program - Local Implementation Program.

Courtney, L.A., and W.H. Clements. 1998. Effects of acidic pH on benthic macroinvertebrate communities in stream microcosms. *Hydrobiologia* 379: 135-145.

CRWQCB. California Regional Water Quality Control Board. 2010. Waste Discharge Requirements for the Las Virgenes Municipal Water District, Tapia Reclamation Facility Discharge to Malibu Creek and Los Angeles River.

Department of Ecology. A citizen's guide to understanding and monitoring lakes and streams. Chapter 2: lakes. Department of Ecology, State of Washington.

Environmental Protection Agency (EPA). 2000. Low impact development (LID): A literature review. EPA, Washington, D.C.

Environmental Protection Agency (EPA). 2013. Malibu Creek & Lagoon TMDL for Sedimentation and Nutrients to Address Benthic Community Impairments. Region IX. EPA, Washington, D.C.

Environmental Protection Agency (EPA). 2006. Total Maximum Daily Loads for Nutrients Malibu Creek Watershed. EPA, Washington, D.C.

Environmental Protection Agency (EPA). 2013. Rodenticide Products for Consumers: EPA moves to Ban 12 D-Con Mouse and Rat Control Products. EPA, Washington, D.C.

Environmental Protection Agency (EPA). 2006. Wadeable Streams Assessment A Collaborative Survey of the Nation's Streams. Office of Water and Office of Research and Development. EPA, Washington, D.C.

Gillett, D.J., Mazor, R.D., Ritter, K., Schiff, K., Stein, E.D. 2009. Ecological Condition of Watersheds in Coastal Southern California: Progress Report of the Stormwater Monitoring Coalition's Stream Monitoring Program First Year. Southern California Stormwater Monitoring Coalition.

Hart, D. D., and C. M. Finelli. 1999. Physical-biological coupling in streams: the pervasive effects of flow on benthic organisms. *Annual Review of Ecology and Systematics* 30: 363–395.

Hatt, B., Fletcher, D., Walsh, C., & Taylor, S. 2004. The Influence of Urban Density and Drainage Infrastructure on the Concentrations and Loads of Pollutants in Small Streams. *Environmental Management* 34: 112-124.

Hesson, W.C., T.E. Johnson, D.F. Charles, D.D. Hart, R.J. Horwitz, D.A. Kreeger, J.E. Pizzuto, D.J. Velinsky, J.D. Newbold, C. Cianfrani, T. Clason, A.M. Compton, N. Coulter, L. Fuselier, B.D. Marshall and J. Reed. 2000. Ecological Benefits of Riparian Reforestation in Urban Watershed: Study design and Preliminary Results. *Environmental Monitoring* 63: 211-222.

Johnson, P.T.J. and J. M. Chase. 2004. Parasites in the food web: linking amphibian malformations and aquatic eutrophication. *Ecology Letters* 7: 521–526.

Kerekes, J., B. Freedman, G. Howell, and P. Clifford. 1984. Comparison of the characteristics of an acidic eutrophic and acidic oligotrophic lake near Halifax, Nova Scotia. *Water Pollution Research Journal of Canada* 19: 1-10.

Kitchin, P.L. 2005. Measuring the amount of statistical information in the EPT index. *Environmetrics* 16: 51–59.

L.A. Supervisors Approves New Zoning for Santa Monica Mountains. 2014. Beverly Hills Courier.

Las Virgenes Municipal Water District (LVMWD). 2010. Water quality in the Malibu Creek Watershed, 1971-2010. LVMWD, Calabasas, CA.

Los Angeles County Department of Regionals Planning. 2014. Santa Monica Mountains Local Coastal Program.

Mattson, R.A. 2009. Relationships between benthic algae and benthic macroinvertebrate communities in Florida spring-run streams. St. Johns River Water Management District. Palatka, Florida.

McMahon, G., and T. Cuffney. 2000. Quantifying urban intensity in drainage basins for assessing stream ecological conditions. *Journal of the American Water Resources Association* 36: 1247-1261.

Mitsch, W.J., and J.G. Gosselink. 2000. *Wetlands*. 4th ed. New York: John Wiley & Sons.

Nebeker, A.V., S.T. Onjukka, D.G. Stevens, and G.A. Chapman. 1996. Effect of low dissolved oxygen on aquatic life stages of the caddisfly *Clistoronia magnifica* (*Limnephilidae*). *Archives of Environmental Contamination and Toxicology* 31: 453-458.

Pierce, B.A. 1993. The effects of acid precipitation on amphibians. *Ecotoxicology* 77: 65-77.

Norris R.H. and A. Georges. 1993. Analysis and interpretation of benthic macroinvertebrate surveys. Pages 234–286. Chapman & Hall, New York, NY.

Ode, P.R. 2007. Standard operating procedures for collecting macroinvertebrate samples and associated physical and chemical data for ambient bioassessments in California. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 001.

Ode, P.R., A.C. Rehn, and J.T. May. 2005. A quantitative tool for assessing the integrity of southern California coastal streams. *Environmental Management* 35: 493-504.

Orton and Dougall. The Monterey Formation: Influence on Water Quality and Aquatic Life in Malibu Creek, California. Las Virgenes Municipal Water District.

Paul, M.J., and J.L. Meyer. 2001. Streams in the urban landscape. *Annual Review of Ecological Systems* 32: 333–365.

Pease, K.M., S. Sikich, M. Maggio, S. Diringer, M, Abramson, and M. Gold. 2013 Impact of Development on Aquatic Benthic Macroinvertebrate Communities in the Santa Monica Mountains of Southern California. *Urban Coast- The Journal of Center for Santa Monica Bay Studies* 4: 52-62.

Pond, Gregory J., M.E. Passmore, F.A. Borsuk, L. Reynolds, and C. Rose. 2008. Downstream effects of mountaintop coal mining: comparing biological conditions using family- and genus-level macroinvertibrate bioassessment tools. *The North American Benthological Society* 27(3): 717-737.

Rawer-Jost, C., Böhmer, J., Blank, J., and H. Rahmann. 2000. Macroinvertebrate functional feeding group methods in ecological assessment. *Hydrobiologia* 422/423: 225-232.

Rehn, A.C., P.R. Ode and C.P. Hawkins. 2007. Comparisons of targeted-riffle and reach-wide benthic macroinvertebrate samples: implications for data sharing in stream-condition assessments. *Journal of the North American Benthological Society* 26: 000–000. (in press).

Resh, V.H. and D.M. Rosenberg. 1993. Freshwater Biomonitoring and Benthic Macroinvertebrates. Chapman & Hall, London.

Roberge, J.J and D.J McCabe. 2011. The effects of land use on phosphorus and benthic macroinvertebrates in the Lake Champlain Basin. Saint Michael's College.

Rouse, J.D., C.A. Bishop, and J. Struger. 1999. Nitrogen pollution: an assessment of its threat to amphibian survival. *Environmental Health Perspectives* 107:799-803.

Ryther, J. H., and W.M. Dunstan. 1971. Nitrogen, phosphorus, and eutrophication in the coastal marine environment. *Science* 171: 1008-1013.

Said, A., D. K. Stevens, and G. Sehlke. 2004. An innovative index for evaluating water quality in streams. *Environmental Managemen*t 34: 406–414.

Schell, V.A., and J.J. Kerekes. 1989. Distribution, abundance, and biomass of benthic macroinvertebrates relative to pH and nutrients in eight lakes of Nova

Scotia, Canada. *Water, Air, and Soil Pollution* 46: 359-374.

Schubauer-Berigan, M.K., P.D. Monson, C.W. West, and G.T. Ankley. 1995. Influence of pH on the toxicity of ammonia to Chironomustentans and Lumbriculus variegatus. *Environmental Toxicology Chemistry* 14:713–717.

Sherman, E., and K.V. Munster. 2012. Pond pH, acid tolerance, and water preference in Newts of Vermont. *Northeastern Naturalist* 19: 111–122.

Sikich, S., K. Pease, S. Diringer, M. Abramson, M. Gold, and S. Luce. 2013. Malibu Creek Watershed: Ecosystem on the Brink. Heal the Bay, Santa Monica, CA.

Smith N.D., and S.W. Golladay. 2011. Coleoptera indicator species in wet vs. dry climate regimes in three southwestern Georgia wetland types. Proceedings of the 2011 Georgia Water Resources Conference.

Tiefenhaler, L.L., E.D. Stein, and G.S. Lyon. 2009. Fecal Indicator bacteria (FIB) levels during dry weather from Southern California reference stream. *Environment Monitoring Assessment* 155: 477-492.

University of California, Davis. Benthic macroinvertebrates as indicators of watershed condition. *California Watershed Assessment Manual* Volume II: Chapter 6

U.S. Geological Survey (USGS). 2002. Assessment of stream quality using biological indices at selected sites in the Big Elk and Octoraro Creek Basins, Chester County, Pennsylvania. USGS, New Cumberland, Pennsylvania.

Van de Meutter, F., R. Stoks, and L.D. Meester. 2005. The effects of turbidity state and microhabitat on macroinvertebrate assemblages: a pilot study of six shallow lakes. *Hydrobiologia* 542: 379-390.

Van den Berg, M.S., H. Coops, R. Noordhuis, J.V. Schie, and J. Simons. 1997. Macroinvertebrate communities in relation to submerged vegetation in two Chara-dominated lake. *Hydrobiologia* 342/343:143-150.

Villacorte, C. County Moves to Stop 'Unrestrained' Development in Santa Monica Mountains. 2014. Los Angeles Daily News.

Walsh, C.J., A.H. Roy, J.W. Feminella, P.D. Cottingham, P.M. Groffman, and R.P. Morgan. 2005. The urban stream syndrome: current knowledge and the search for a cure. J*ournal of North American Benthological Society* 24: 706–723.

Walsh, C.J., Waller, K.A., Gehling, J., & MacNally, R. 2007. Riverine invertebrate assemblages are degraded more by catchment urbanization than by riparian deforestation. *Freshwater Biology* 52: 574-587.

Wilhm, J.L. 1967. Comparison of some diversity indices applied to populations of benthic macroinvertebrates in a stream receiving organic wastes. *Water Pollution Control Federation* 39: 1673-1683.

Wilhm, J., and N. McClintock. 1978. Dissolved oxygen concentration and diversity of benthic macroinvertebrates in an artificially destratified lake. *Hydrobiologia* 57:163-166.

Wood, P.J., and P.D. Armitage.1997. Biological effects of fine sediment in the lotic environment. *Environmental Management* 21: 203-217.