Assessing Microbial Water Quality of the Los Angeles River Recreation Zones

Heal the Bay

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STREAM TEAM

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Table of Contents

Introduction

Recreation in streams and rivers is a popular activity throughout Los Angeles County, yet there is a deficiency in water quality data for several freshwater recreational areas (swimming holes, streams, rivers, etc.), resulting in limited information about the potential for public health risks associated with recreating in these areas. Bird watching, fishing, and wading have occurred in the Los Angeles River since humans first came upon it. However, once the river was channelized–a process that took 22 years (from 1938 to 1960)–these recreational activities all but ceased due to trespassing ordinances implemented by the US Army Corps of Engineers and the Los Angeles County Flood Control Department. However, in 2011 the Los Angeles River was designated as a destination for freshwater recreation with the Sepulveda Basin River Recreational Zone legally opened to non-motorized boating, fishing, birdwatching, and walking. In 2013, a second area, the Elysian Valley River Recreational Zone, was legally opened for recreation. Kayaking has quickly become a popular activity; four different kayak outfitters exist that provide equipment and guided tours to visitors, and each season thousands of kayakers enjoy the Los Angeles River. Recreation and education opportunities, along with the proposed Los Angeles River restoration by the U.S. Army Corps of Engineers and the City of Los Angeles, are creating widespread interest in the river. Given the number of kayakers in the river, as well as fishing activities and even swimming, information about water quality and potential public health risks is needed.

Heal the Bay has been monitoring water quality in streams and rivers since 1998 through our Stream Team program. In 2014 we initiated a pilot study to monitor human use and water quality of freshwater swimming spots in the Santa Monica Mountains, focusing on bacterial pollution and public health implications. We are currently in our third summer of monitoring water quality in those swimming locations. Further, given Heal the Bay's 25-year history of informing and educating beachgoers about beach water quality through our Beach Report Card, assessing the water quality of the Los Angeles River recreation zones is a natural next step.

Heal the Bay has a long history of work on the Los Angeles River; we have advocated for improved habitat, water quality, and recreation by weighing in on numerous policies and permits concerning the Los Angeles River such as TMDLs, the Recreational Use Reassessment (RECUR) study, permits for dredging and clearing vegetation (Clean Water Act Section 401 permits), and many more. Assessing the water quality of the Los Angeles River recreation zones falls in line with Heal the Bay's past work in the Los Angeles River and in the watersheds of the greater Los Angeles region. Further, this study is consistent with Heal the Bay's goals of understanding the current health of LA County watersheds, connecting communities to their rivers and streams, advocating for the enhancement and protection of riparian corridors, and enhancing public understanding about watershed health.

Despite recreational use of the Los Angeles River, this waterbody suffers from bacterial pollution; it is designated as impaired on California's 303(d) list of impaired waters due to excessive amounts of coliform bacteria. A bacteria total maximum daily load (TMDL), which sets limits for fecal indicator bacteria (FIB), is currently in place for the Los Angeles River.[1]

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[1] California Regional Water Quality Control Board, Los Angeles River Watershed Bacteria Total Maximum Daily Load. Available at: www.waterboards.ca.gov/losangeles/board_decisions/basin_plan_amendments/technical_documents/80_New/LARiverFinal/Staff%20Report%20LAR%20Bact%2015Jul10%20final.pdf

FIB, while not harmful themselves, indicate the possible presence of pathogenic bacteria, which have been found to cause ear infections, respiratory illnesses, and gastrointestinal illness.[2] High levels of FIB are particularly concerning in areas where people come in contact with water through activities like swimming, fishing, and kayaking. Bacteria and other pollutants enter waterways primarily through dry and wet weather runoff. Runoff is the leading source of coastal pollution throughout California.[3] The bacteria TMDL for the Los Angeles River identifies the Municipal Separate Storm Sewer System (MS4) as the principal source of bacteria to the Los Angeles River in both wet and dry weather.

Regulatory monitoring of FIB occurs on a regular basis in the Los Angeles River, but the monitoring is not specifically targeted at the recreation zones and does not occur at a frequency that is protective of public health. Monthly water quality monitoring is required in the Los Angeles River Bacteria TMDL in each segment or reach, of which there are five for the whole Los Angeles River.[4] Sampling that is designed to provide information to the public and be protective of public health is typically conducted daily to weekly; monthly sampling does not provide a clear picture of the current microbial water quality in the river, which would be necessary for making an informed decision about where to recreate. The bacteria TMDL for the Los Angeles River Watershed summarizes data of FIB levels from 1997 to 2008; exceedance rates of the Basin Plan REC-1 water quality objectives for *E. coli* were very high, ranging from 53% to 89% in the main stem of the Los Angeles River.[5] A Bacterial Source Identification Study (BSI Study) was conducted prior to the 2012 TMDL through a stakeholder process called Cleaner Rivers through Effective Stakeholder-led TMDLs (CREST).[6] This study found high bacteria levels as well as human-specific fecal indicators at numerous locations. Other studies also show similar results of high bacterial levels. Friends of the LA River (FoLAR) monitored bacteria at 23 sites in 2003-2004 and found that bacteria levels at most sites greatly exceeded AB 411 Health Department Standards.[7] 17 of the 23 sites (LA River and tributaries) had bacteria levels where 50% or more sample results were over the Health Department standards. The Council for Watershed Health found that *E. coli* exceedances of REC-1 standards were widespread and frequent at six monitoring sites in the Los Angeles River from 2009 -2012.[8] *E. coli* exceedances were over 70% at five of the six sites for all years; one site that was below a

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[2] Cabelli VJ. 1983. *Health Effects Criteria for Marine Recreational Waters*. US Environmental Protection Agency, EPA-600/1-80-031.

[3] Heal the Bay, 2013-2014 Annual Beach Report Card (2014) http://www.healthebay.org/sites/default/files/pdf/BRC_2014_WEB_.pdf ; Natural Resources Defense Council, Testing the Waters (2014) http://www.nrdc.org/water/oceans/ttw/

[4] California Regional Water Quality Control Board, Los Angeles River Watershed Bacteria Total Maximum Daily Load. Available at: www.waterboards.ca.gov/losangeles/board_decisions/basin_plan_amendments/technical_documents/80_New/LARiverFinal/Staff%20Report%20LAR%20Bact%2015Jul10%20final.pdf

[5] California Regional Water Quality Control Board, Los Angeles River Watershed Bacteria Total Maximum Daily Load. Available at: www.waterboards.ca.gov/losangeles/board_decisions/basin_plan_amendments/technical_documents/80_New/LARiverFinal/Staff%20Report%20LAR%20Bact%2015Jul10%20final.pdf

[6] Cleaner Rivers through Effective Stakeholder-led TMDLs (CREST) (2008) Los Angeles River Bacteria Source Identification Study: Final Report.

[7] http://folar.org/wp-content/uploads/2014/03/State-of-River.pdf

[8] Morris K, Johnson S, and N Steele. 2012. Los Angeles River 2012 State of the Watershed Report. Available at: http://watershedhealth.org/Files/document/881_SOW_2012_draft_revised.pdf

publicly-owned treatment works (POTW) discharge had lower exceedance rates (under 30%). Ackerman et al (2003)[9] monitored bacteria concentrations from major sources of potential pollutants in the Los Angeles River during dry weather on September 10-11, 2000, and found the highest bacteria concentrations in stormdrain discharges; bacteria inputs from discharges from water reclamation plants were negligible.

Heal the Bay initiated a pilot study over the summer of 2015 to monitor water quality at Los Angeles River freshwater recreation zones. This is the first year of the study with additional monitoring planned to grow the dataset. We assessed the water quality at three sites in the recreation zones and identified potential factors impacting water quality. Based on the water quality and known recreational use, we evaluated whether there was a risk to public health and formulated recommendations for reducing that risk. By researching the water quality at recreation zones in the Los Angeles River, Heal the Bay hopes to inform public health authorities, kayak outfitters, regulatory agencies, and policy-makers of potential health risks, advocate for recreation-targeted education, encourage improved monitoring, and recommend water quality improvements. Without monitoring of these areas on a regular basis, the public health risks at freshwater recreation zones will continue to be unknown with limited to no information readily available to the public. Further, detailed knowledge of water quality conditions can help inform municipal program and policy efforts to improve water quality and habitat in the Los Angeles River recreational zones.

Methods

Heal the Bay scientific staff selected three sampling locations (Figure 1) based on the established recreation zones, knowledge of places where people are likely to come in contact with the water (kayak points of entrance and exit), and ease of accessibility. The locations selected were:

> 1) Los Angeles River, Sepulveda Basin, downstream of Burbank Blvd. in Encino, CA (latitude: 34.170411 longitude: -118.477191):
>
> The Sepulveda Basin recreation zone has been open since 2011. Currently, the main entrance and exit points for kayak tours are at this sampling location. The recreation zone is approximately 1.6 miles long, bounded by Balboa Blvd. on the upstream end and Burbank Blvd. and Sepulveda Dam on the downstream end. The Paddle the LA River program (LA Conservation Corps) and LA River Expeditions operate kayak tours in the Sepulveda Basin, while LA River Kayaks offers kayak rentals there.
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> 2) Los Angeles River, Elysian Valley, Rattlesnake Park downstream of Fletcher Dr., Los Angeles, CA (latitude: 34.108199 longitude: -118.252743):
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> The Elysian Valley recreation zone has been open since 2013. The sampling spot near Rattlesnake Park is a primary entrance point for many kayaks and kayak tours and is the

[9] Ackerman D, Schiff K, Trim H, and M Mullin. 2003. Characterization of water quality in the Los Angeles River. *Bulletin of the Southern California Academy of Sciences* 102(1): 17-25.

upstream end of the Elysian Valley open recreation zone. The recreation zone is approximately 2.4 miles long, bounded by Fletcher Ave. on the upstream end and Oros St. and the 5 Freeway on the downstream end. LA River Kayak Safari, LA River Kayaks, and LA River Expeditions operate kayak rentals and tours in the Elysian Valley.

3) Los Angeles River, Elysian Valley, Steelhead Park at Oros St., Los Angeles, CA (latitude: 34.086640 longitude: -118.228129):

The sampling spot near Steelhead Park is a primary exit point for many kayaks and kayak tours and is the downstream end of the open recreation zone in Elysian Valley.

The recreation zones are open seasonally during the dry season only due to safety concerns associated with rain events and flooding. If there is rain during the open season, the recreation zones are closed temporarily. For the 2015 season, the recreation zones were open from Memorial Day (May 25, 2015) to October 1, 2015.

We visited the three locations once a week on Thursdays from July 9, 2015, to October 1, 2015, at Elysian Valley Rattlesnake Park, and from July 16, 2015, to October 1, 2015, at Elysian Valley Steelhead Park and Sepulveda Basin. We were unable to visit Sepulveda Basin on one occasion, resulting in a total of 11 sample dates at Sepulveda Basin, 13 sample dates at Elysian Valley Rattlesnake Park, and 12 at Elysian Valley Steelhead Park. Because the two recreation zones are approximately 17 miles apart (via car), we were not able to visit all three sites at the exact same time of day. We visited sites in a specific order, starting at Elysian Valley Steelhead Park, followed by Elysian Valley Rattlesnake Park, followed by Sepulveda Basin Burbank Blvd. Samples from Steelhead Park were collected between 7:49 a.m. and 10:26 a.m. Samples from Rattlesnake Park were collected between 8:16 a.m. and 11:09 a.m. Samples from Sepulveda Basin were collected between 9:55 a.m. and 1:19 p.m.

In addition to the weekly grab samples, we also conducted time-series weekly sampling for five weeks at two sites. From August 6, 2015, to September 10, 2015, we collected samples at three time points every Thursday, approximately every two hours, from the two Elysian Valley sites. We collected samples from Steelhead Park at approximately 8 a.m., 10 a.m., and 12 p.m. Samples from Rattlesnake Park were collected at approximately 9 a.m., 11 a.m., and 1 p.m. Our goal was to determine whether fecal indicator bacteria levels were consistent or varied throughout the morning portion of the day. Bacteria levels are known to decrease with exposure to sun and UV light[10], however, it is also possible that additional sources of bacteria may be

[10] Sinton LW et al. (2002) Sunlight inactivation of fecal indicator bacteria and bacteriophages from waste stabilization pond effluent in fresh and saline waters. *Applied and Environmental Microbiology* 68: 1122-1131; Chang et al. (1985) UV inactivation of pathogenic and indicator microorganisms. *Applied and Environmental Microbiology* 49: 1361-1365.

entering the system throughout the day.

At each sampling location and time, we collected a 100mL water sample in a sterile bottle from a specified spot approximately 12 inches under the surface of the water at a knee-depth location. The water samples were placed on ice and processed within eight hours for three types of fecal indicator bacteria: total coliforms, *Escherichia coli*, and *Enterococcus*. FIB concentrations were measured with Colilert™ and Enterolert ™ (IDEXX, Westbrook, ME), following the manufacturer's protocols. Samples were diluted 1:10 and final concentrations were determined as most probable number (MPN) per 100 ml. Samples below the detection level (of 10 MPN/100ml) were set to the value of 5 MPN/100ml and samples over the detection limit of >24196 MPN/100ml were set to the value of 25000 MPN/100ml.

For quality assurance and control, laboratory blanks were run every week. We also collected duplicate field samples approximately every other week at alternating sites, for a total of five duplicate samples. Further, we split field samples in the laboratory on five occasions for alternating sites. We assessed the precision of the duplicate and split samples as described in the California State Water Resources Control Board quality control and sample handling table for Indicator Bacteria in Fresh Water.[11]

In the field, we collected data on the following parameters based on visual observations: weather conditions, substrate where the sample was taken, type of water flow, water clarity, water color, water odor, amount of trash, presence and maintenance of trashcans, presence and location of homeless encampments, presence and number of animals in and near the water, and number, age, and activity of people in and out of the water. Air temperature and water temperature were measured at each location using a thermometer. We measured water turbidity in the field with a LaMotte 2020 Turbidimeter. We took the average turbidity of two samples, which were each read three times. The turbidimeter was calibrated regularly in the lab following the manufacturer's protocol with known standards of 1.0 and 10.0 NTU. Percent algal cover was estimated for floating algae and benthic algae in the general sampling area. Type of water flow was classified as "none", "intermittent", "trickle", "steady", or "heavy." Water clarity was classified as "clear", "cloudy", "milky", "muddy", or "other." Water color was classified as: "colorless", "red", "yellow", "green", "brown", "gray", or "other." Water odor was classified as: "none", "rotten eggs", "sewage", "chlorine", "ammonia", "musty", or "other." We counted trash items and classified the trash density at each site as: "none", "light" (1-10 items), "moderate" (11-50 items), or "high" (over 50 items). To obtain a quantitative estimate of trash at each site, we took an average of trash categories, using the following numbers as estimates of the categories: none (0), light (5), moderate (30), and high (70). The number of trashcans at each site was recorded along with whether the trashcans had lids and were full or overflowing.

Presence and location of nearby homeless encampments were noted. Animals in and near the water were counted and recorded by type (dog, birds, horses, other). We collected data on human use using a "snapshot" method in which we counted the number of visitors at a single

[11] http://www.swrcb.ca.gov/water_issues/programs/swamp/docs/mqo/ind_bact_water.pdf

moment in time. Age demographics of visitors were collected in the following categories based on visual observation and best judgment of the sampling team: age (infant 0-2 yrs., child 3-12 yrs., young adult 13-21 yrs., adult 22+ yrs.), and activity/location (out of water, wader, swimmer, kayaker, fisherman/woman).

Precipitation information was obtained from www.accuweather.com for the Downtown Los Angeles and Van Nuys stations. The Downtown Los Angeles station is approximately six to eight miles from the two Elysian Valley sites. The Van Nuys station is approximately four miles from the Sepulveda Basin site. If there was rainfall of 0.1" or greater, we assessed whether our water quality sample was taken in a "wet weather day" (day of the rainfall and the following three days) or whether it was taken within seven days of the rainfall.

All field and laboratory work was performed by Heal the Bay staff and volunteers. Volunteers were trained by the Watershed Scientist directly to maintain consistency following general Stream Team training manuals and protocols (Appendices A-C).

To analyze water quality data, we compared bacteria levels measured at each site to water quality objectives from the Los Angeles River Watershed Bacteria TMDL and EPA's 2012 Recreational Water Quality Criteria (RWQC) (Table 1), and calculated averages, standard deviations, geometric means, and percent exceedances of bacteria levels for all sites. We calculated the mean, standard deviation, geometric mean, and percent exceedances of bacteria levels by site using one sample or value per week or sample date. The geometric mean is a type of average which results in a number that is not as heavily affected by very high or very low values. The geometric mean was calculated for each site using all dry weather samples over the entire study period (12 or 13 weeks). For the dates on which we collected water samples at three time points, we selected one sample that was the closest match in time to the other samples taken at that location. The freshwater regulatory limit for *E. coli* is 235 MPN/100ml for a single sample and 126 MPN/100ml for the geometric mean.[12] For *Enterococcus*, we used EPA's statistical threshold value (STV) for an illness rate of 32/1,000 (the more protective rate), which is 110 MPN/100ml for a single sample and 30 MPN/100ml for the geometric mean in a fresh waterbody designated for recreation (Table 1).[13] We separated data into dry and wet weather; we classified samples as wet weather if they had been taken within three days of a 0.1" or greater rainfall.

In order to distill the FIB data to a more user-friendly metric or grade that could be easily communicated to the public, we decided to grade each site in two different ways based on whether it was meeting 1) requirements to be listed as impaired for bacteria on California's 303(d) list and 2) numeric limits as set in the Total Maximum Daily Load (TMDL) in the Los

[12] California Regional Water Quality Control Board, Los Angeles River Watershed Bacteria Total Maximum Daily Load. Available at: www.waterboards.ca.gov/losangeles/board_decisions/basin_plan_amendments/technical_documents/80_New/LARiverFinal/Staff%20Report%20LAR%20Bact%2015Jul10%20final.pdf

[13] US EPA. 2012. Recreational Water Quality Criteria. Available at: http://water.epa.gov/scitech/swguidance/standards/criteria/health/recreation/upload/RWQC2012.pdf

Angeles River Watershed. We developed this basic grading method previously for freshwater swimming sites in the Santa Monica Mountains.[14] For Method 1, we used the Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List[15], which states that a 4% exceedance rate shall be used for inland waters, when monitoring data were collected April 1 through October 31. The listing policy utilizes a binomial distribution to determine the number of exceedances based on sample size that would warrant inclusion on the 303(d) List. For a sample size of 3-31 (applicable to our study), three or more exceedances are enough to trigger a listing. Therefore, we graded each site as either "pass" (fewer than three exceedances) or "fail" (three or more exceedances) for both *E. coli* and *Enterococcus*. For Method 2, we used the criteria in the Los Angeles River Watershed Bacteria TMDL[16] which allows for one exceedance in dry weather weekly sampling and two exceedances for wet weather weekly sampling. Wet weather days are defined in the TMDL as those which experience 0.1" of rain or more and the following three days. It is important to note that the TMDL threshold numbers have a long timeline for compliance; final compliance is expected to be met in 2037. Again, sites were graded as "pass" (0 or 1 exceedance in dry weather; 0-2 exceedances in wet weather) or "fail" (two or more exceedances in dry weather and three or more exceedances in wet weather) for both *E. coli* and *Enterococcus* (even though *Enterococcus* is not addressed in the TMDL).

To examine the relationship between bacteria levels and explanatory factors, we performed multivariate linear regression analyses in R (R Development Core Team 2011). The explanatory factors that we evaluated included air temperature, water temperature, turbidity, recent rainfall (within three or seven days of sample), algal cover, flow, water color, number of birds in the water, and quantitative trash levels. Again, the sample size for wet weather samples was very small and more data are needed to verify and support results. If there were no data for a given variable or no variation in a given variable, we did not include the variable in the model. We did not include variables of number of visitors, number of people in the water, and animals (besides birds) in and out of the water because we felt that there were too few data points or that they were too subjective. We did not include the qualitative measurement of water clarity in the model because we had a quantitative measure of water clarity (turbidity). Further, we tested for correlations among predictor variables and dropped one variable of two that were highly correlated (0.45 or greater in magnitude). For instance, water temperature and air temperature were highly correlated so we selected water temperature for use in the models. Because our sample size was somewhat small, we did not consider interactions among the variables. We assessed the statistical relationship between *E. coli* and *Enterococcus* and the explanatory

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[14] Heal the Bay (2015) Is it safe to swim? Assessing human use and water quality of freshwater swimming holes in the Santa Monica Mountains. Available at: http://www.healthebay.org/sites/default/files/pdf/HealtheBay_FWSwimmingStudy.pdf

[15] State of California, State Water Resources Control Board. 2004. Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List. http://www.waterboards.ca.gov/water_issues/programs/tmdl/docs/ffed_303d_listingpolicy093004.pdf

[16] California Regional Water Quality Control Board, Los Angeles River Watershed Bacteria Total Maximum Daily Load. Available at: www.waterboards.ca.gov/losangeles/board_decisions/basin_plan_amendments/technical_documents/80_New/LARiverFinal/Staff%20Report%20LAR%20Bact%2015Jul10%20final.pdf

variables for each FIB and site separately. Bacteria levels were natural log transformed for normality. We performed model selection by Akaike Information Criterion (AIC) with a stepwise algorithm.

We analyzed the time-series data separately. We performed a multivariate linear regression in R to examine the relationship between bacteria levels and time of day, treating week (or sample date) as a covariate. We performed separate regressions for each site (Rattlesnake Park and Steelhead Park) for each FIB (*E. coli* and *Enterococcus*). Bacteria levels were natural log transformed for normality.

Results

Site Conditions

The sites differed in a number of characteristics that we measured. Average water (26.2 °C) and air temperatures (27.2 °C) were higher at Sepulveda Basin (S7) compared to the other sites (Table 2). The sites also differed in their flow types; Elysian Valley, Rattlesnake Park (ERSP) had the highest flow, with steady flow 77% of the time and heavy 23% of the time (Table 3). Elysian Valley, Steelhead Park and Sepulveda Basin sites had intermittent flows on the majority of sampling days, with some steady and some trickling flows as well (Table 3). Water clarity was primarily classified as clear at both Elysian Valley sites (92% of the time for Steelhead and ERSP), while it was described as cloudy 64% of the time at the Sepulveda Basin site (Table 3). Further, water color was classified as green on 18% of the visits to the Sepulveda Basin (Table 4) and colorless on 100% of the visits to the two Elysian Valley sites. We did not detect odors from the water at the Sepulveda Basin site and Elysian Valley, Rattlesnake Park (ERSP) (data not shown). However, we did detect sewage odors at Elysian Valley, Steelhead Park 17% of the time (data not shown). Trash levels were generally classified as light (1-10 items) and moderate (11-50) for all sites; Elysian Valley, Steelhead Park had lower amounts of trash than Elysian Valley, Rattlesnake Park and Sepulveda Basin (Table 5). However, Elysian Valley Rattlesnake Park was the only site where we observed high trash levels (over 50 items) on one occasion. We did not observe any floating algae at any of the sites but benthic algae cover was over 50% at all sites (Table 6). The Sepulveda Basin site had the highest benthic algal cover, with an average of 80% cover, Elysian Valley, Steelhead Park had an average of 74% cover and Elysian Valley, Rattlesnake Park had the lowest algal cover (58%) (Table 6). Turbidity was higher at Sepulveda Basin (average of 9.2 NTU) than at the two Elysian Valley sites (Table 7). Turbidity was lowest at Elysian Valley, Steelhead Park (average of 3.8 NTU).

Rainfall of 0.1” or greater occurred on two occasions during our study period. On July 18th, 2015, Downtown Los Angeles received 0.36 inches of rainfall and Van Nuys received 0.54 inches of rain. We sampled water quality on July 23, 2015, which was greater than 3 days after the rainfall but within 1 week of the rain. On September 15, 2015, Downtown Los Angeles received 2.39 inches of rain and Van Nuys received 1.02 inches. We sampled water quality on September 17, 2015, within three days of the rainfall.

Animals, People and Demographics

Over the course of the study, we saw many birds in the water at two sites, Elysian Valley, Rattlesnake Park and Sepulveda Basin (Table 8). We also frequently saw fish at Sepulveda Basin and Elysian Valley, Steelhead Park (Table 8).

Over the course of the study, we counted 61 people on 11-13 sample days at all sites (Table 9). The most people were observed at Sepulveda Basin, due to the kayak tours that occurred there on our sampling day, Thursday. We did not observe any kayakers at the Elysian Valley sites during our sampling events. We did see two fishermen at Elysian Valley, Steelhead Park on one occasion and one swimmer who was also a kayaker at Sepulveda Basin. We did not see any other waders or swimmers during the study.

Bacteria Results

Bacteria levels varied among the sites, but overall were quite high (Table 10, Figure 2). Sepulveda Basin had the lowest average and geometric mean concentrations of two of the three fecal indicator bacteria while Elysian Valley Rattlesnake Park had the highest levels (Table 10, Figure 2). The average *Enterococcus* concentrations at all three sites were over the single sample EPA STV of 110 MPN/100ml; further, the geometric mean concentrations for all three sites for *Enterococcus* were also all over EPA's geometric mean recommendation of 30 MPN/100ml (Table 10). For *E. coli*, the average concentration at Elysian Valley Rattlesnake Park was over the limit identified in the bacteria TMDL of 235 MPN/100ml for a single sample (Table 10). Both of the sites in the Elysian Valley were over the TMDL limit for the *E. coli* geometric mean level of 126 MPN/100ml (Table 10). Exceedances for *Enterococcus* were very frequent - samples from both sites in the Elysian Valley exceeded EPA's STV of 110 MPN/100ml 100% of the time while samples from Sepulveda Basin exceeded 50% of the time (Table 10). Exceedances for single sample limits for *E. coli* were highest at Rattlesnake Park (67% of the time), moderate at Sepulveda Basin (20%), and lowest at Steelhead Park (9%).

The one sample date that occurred within three days of a significant rainfall showed high levels of bacteria at all three sites (Table 11, Figure 2). *E. coli* and *Enterococcus* levels were all over the single sample limits; because it was just one sample, we could not calculate a geometric mean. Interestingly, the values for *E. coli* after the rain event (week 11) were much higher than values seen in samples from other weeks (Figure 2a, excluding week eight which showed an exceptionally high *E. coli* level at Rattlesnake Park); in contrast the values for *Enterococcus* in week 11 were no higher than seen in other weeks, all of which were quite high (Figure 2b). However, given that the wet weather dataset is very limited in size, we need to collect more data before we are able to make conclusions about these trends.

As mentioned above, quality control included taking field sample duplicates, running laboratory split samples, and running laboratory blank controls. All blank controls were negative for the presence of any fecal indicator bacteria. Of the five field duplicates, only one sample, for one fecal indicator bacteria (total coliform) was out of the acceptable range of precision. All other duplicate samples for all three types of fecal indicator bacteria showed an acceptable level of precision between the two samples. Of the five samples that were split in the laboratory, only one sample, for one fecal indicator bacteria (total coliform) was out of the acceptable range of precision. All other split samples for all three types of fecal indicator bacteria showed an acceptable level of precision between the two samples.

Multivariate Linear Regression Results

For the Sepulveda Basin site, we found that the best model that explained *E. coli* levels included whether there had been rain within the last week, benthic algae cover, and number of birds in the water, together explaining 86% of the variation in *E. coli* levels (Table 12). Whether there had been rain within the last week was the only significant predictor of *E. coli* levels, with samples taken within a week of rain corresponding with higher levels of *E. coli* (Table 12). Whether there had been rain within the last week was correlated with turbidity levels (R=0.87) and also flow categories. Flow was only categorized as "steady" on the two dates when there had been rain within the last week; all other flow was categorized as "trickle" or "intermittent".

The best model that explained *Enterococcus* levels at Sepulveda Basin included water temperature, benthic algae cover, trash amount, flow, and number of birds in the water, explaining 91% of the variation in *Enterococcus* levels (Table 13). Benthic algae cover was a significant predictor of *Enterococcus* levels at the Sepulveda Basin site (Table 13). Benthic algae cover showed a positive relationship with *Enterococcus* levels, holding other factors constant.

For the Elysian Valley Rattlesnake Park site, we found that the best model that explained *E. coli* levels included water temperature, benthic algae cover, whether there had been rain within the last week, and number of birds in the water, explaining 86% of the variation in *E. coli* levels (Table 12). Whether there had been rain within the last week was the only significant predictor of *E. coli* levels, with samples taken within a week of rain corresponding with higher levels of *E. coli* (Table 12).

The best model that explained *Enterococcus* levels at Rattlesnake Park included water temperature, time of day, turbidity, benthic algae cover, and number of birds in the water, explaining 90% of the variation in *Enterococcus* levels (Table 13). Water temperature, turbidity, and benthic algae cover were all significant predictors of *Enterococcus* levels at the Rattlesnake Park site (Table 13). Water temperature showed a negative relationship with *Enterococcus* levels (R=-0.36), holding other factors constant, indicating that *Enterococcus* levels were lower at higher temperatures (Table 13). In contrast, turbidity and benthic algae cover both showed a positive relationship with *Enterococcus* levels (R=0.45; R=0.39, respectively), holding other factors constant, indicating that *Enterococcus* levels were higher when turbidity was higher and when benthic algae cover was higher (Table 13).

Through the multiple regression analysis, the best model that explained *E. coli* levels at Elysian Valley Steelhead Park site included water temperature, time of day, and turbidity levels, explaining 86% of the variation in *E. coli* levels (Table 12). Turbidity was the only significant predictor of *E. coli* levels, with higher turbidity levels associated with higher levels of *E. coli* (Table 12).

The best model that explained *Enterococcus* levels at Steelhead Park included time of day and turbidity, explaining 73% of the variation in *Enterococcus* levels (Table 13). Both time of day and turbidity were significant predictors of *Enterococcus* levels at the Steelhead Park site (Table 13). Time showed a negative relationship with *Enterococcus* levels, holding turbidity constant, indicating that *Enterococcus* levels were lower at later sampling times, despite an attempt to sample at the same time of day. In contrast, turbidity showed a positive relationship with *Enterococcus* levels, holding time constant, indicating that *Enterococcus* levels were higher when turbidity was higher. We also found that turbidity was correlated with the variable of whether there had been rain within the previous three days (R= 0.80) and whether there has been rain within the last week (R= 0.93) at Steelhead Park.

We specifically tested for the effect of time of day on bacteria levels through multiple regression analyses of the time-series monitoring data. We did not find a significant impact of time on *E. coli* levels, holding sample date or week constant, at the two Elysian Valley sites where we conducted this monitoring, Rattlesnake Park and Steelhead Park (Table 14 and Figure 3). However, time was a significant predictor of *Enterococcus* levels, holding week constant, at both Rattlesnake Park and Steelhead Park (Table 15). At both sites, *Enterococcus* levels showed a negative relationship with time of day, with the highest levels of *Enterococcus* at the first sampling point of the day, between 8:10-8:23 a.m. at Steelhead Park and between 8:37–9:05 a.m. at Rattlesnake Park (Figure 3). *Enterococcus* levels typically decreased over the next two sampling times however, all samples at Rattlesnake Park and most at Steelhead Park were over EPA's standard of 110 MPN/100ml.

We graded each site using the two methods described above in the Methods section (Table 16) for *E. coli* and *Enterococcus* exceedances. Steelhead Park received a failing grade for *Enterococcus* using both methods but received a passing grade for *E. coli* using both methods (Table 16). Both Rattlesnake Park and Sepulveda Basin received failing grades for both *E. coli* and *Enterococcus* for both methods (Table 16).

Conclusions

Through this pilot study, Heal the Bay found that microbial water quality was very poor at recreational zones in the Los Angeles River, frequently exceeding health standards, particularly for *Enterococcus*. Previous bacterial studies of the Los Angeles River have also documented high levels of fecal indicator bacteria and high exceedance rates.[17] The site at Rattlesnake Park in the Elysian Valley had the highest rate of exceedances for both *E. coli* and *Enterococcus*. Water quality was somewhat better at Steelhead Park, compared to Rattlesnake Park and

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[17] http://folar.org/wp-content/uploads/2014/03/State-of-River.pdf ; Morris K, Johnson S, and N Steele. 2012. Los Angeles River 2012 State of the Watershed Report. Available at: http://watershedhealth.org/Files/document/881_SOW_2012_draft_revised.pdf ; Ackerman D, Schiff K, Trim H, and M Mullin. 2003. Characterization of water quality in the Los Angeles River. *Bulletin of the Southern California Academy of Sciences* 102(1): 17-25.

Sepulveda Basin, for *E. coli*, but all sites had very poor water quality when examining levels of *Enterococcus*. The exceedance rates of *Enterococcus* at all three sites indicate a likely public health risk. EPA recommends that there should not be greater than a 10 percent exceedance of the STV in a 30-day period.[18] We used the STV corresponding to an illness rate of 32 per 1,000 primary contact recreators. The exceedance rates in this pilot study were well over that 10% rate for Steelhead Park (100%), Rattlesnake Park (100%), and Sepulveda Basin (50%) for the entire study period, which would correspond to an increased rate of illness for those individuals contacting water in the river.

For comparison, we sampled two swimming holes in Malibu Creek State Park in the summer of 2014[19] and 2015[20]. Exceedance rates for *Enterococcus* at Rock Pool were 22% in 2014 and 7% in 2015, and at Las Virgenes Creek, 61% in 2014 and 79% in 2015. Exceedance rates for *E. coli* at Rock Pool were 11% in 2014 and 0% in 2015, and at Las Virgenes Creek, 28% in 2014 and 36% in 2015. The Council for Watershed Health monitored eight popular freshwater swimming locations in the upper San Gabriel River Watershed from 2007 to 2010 and found fairly low levels of *E. coli* exceedances; the average exceedance rate was 5% and ranged from 0% to 22% depending on site and year.[21] The 67% *E. coli* exceedance rate at Rattlesnake Park is clearly much higher than any of these other comparator sites.

Through statistical analysis, we identified factors for each site that were associated with high bacteria levels. It is important to note that the explanatory factors explored in this study should not be considered definite causes of high bacteria, because a statistical relationship does not indicate causation. Our sample sizes were also small for this pilot study. These are the results of the first year of an ongoing study; we hope that additional data points will elucidate clearer and more robust patterns. *E. coli* levels were related to turbidity levels and whether there had been rain within the last week. We found that *Enterococcus* levels were also related to turbidity as well as time, water temperature, flow, and benthic algal coverage. It is no surprise that rainfall and the turbidity associated with it, were associated with poor water quality. Dry and wet weather runoff are the leading source of pollution to California's waterbodies[22] and rainfall is known to be associated with high levels of fecal indicator bacteria pollution.[23] Turbidity has

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[18] US EPA. 2012. Recreational Water Quality Criteria. Available at: http://water.epa.gov/scitech/swguidance/standards/criteria/health/recreation/upload/RWQC2012.pdf

[19] http://www.healthebay.org/sites/default/files/pdf/HealtheBay_FWSwimmingStudy.pdf

[20] To be released on www.healthebay.org

[21] Morris K, Johnson S, and N Steele. 2010. San Gabriel River 2010 State of the Watershed Report. Available at: http://watershedhealth.org/Files/document/737_SOW_2010_web.pdf

[22] Heal the Bay, 2013-2014 Annual Beach Report Card (2014) http://www.healthebay.org/sites/default/files/pdf/BRC_2014_WEB_.pdf ; Natural Resources Defense Council, Testing the Waters (2014) http://www.nrdc.org/water/oceans/ttw/

[23] Cho KH et al. 2010. Meteorological effects on the levels of fecal indicator bacteria in an urban stream: A modeling approach *Water Research* 44: 2189-2202; Marsalek J & Q Rochfort. 2004. Urban wet-weather flows: sources of fecal contamination impacting on recreational waters and threatening drinking-water sources. *Journal of Toxicology and Environmental Health, Part A* 67: 1765-1777; Gannon JJ & MK Busse. 1989. *Water Research* 23: 1167-1176.

also previously been found to be correlated with fecal indicator bacteria levels.[24] In Lake Michigan, algal mats were associated with increased levels of *E. coli* compared to levels in the water and were a possible source of further contamination.[25]

Time of day appeared to have an effect on *Enterococcus* but not on *E. coli* levels. While *Enterococcus* levels did decline from 8 a.m. to 12 noon, the levels were still very high, almost all over the health limit. Further, given that *E. coli* levels did not show any pattern with time of day, there does not appear to be a "safer" time of day to recreate in the Los Angeles River. Previous studies have shown that sunlight inactivates fecal indicator bacteria in fresh and marine water.[26] Cho et al. (2010) found that levels of both *E. coli* and *Enterococcus* decreased with increasing solar radiation during dry weather in an urban stream but rapidly increased overnight due to inputs; however Sinton et al (2007) state that *E. coli* levels tend to decrease more rapidly due to solar radiation than *enterococci* levels, but that this relationship is stronger in marine water than fresh water. Our results indicate that there are likely regular inputs of fecal contamination to the Los Angeles River and that solar radiation is not a primary factor in regulating levels of fecal indicator bacteria in dry weather.

We are currently continuing monitoring for the 2016 open recreation season, collecting similar data to increase sample sizes and assess whether the previously described factors continue to be significant predictors of fecal indicator bacteria levels. We also recommend monitoring nearby outfalls to assess whether they are flowing, how often they are flowing, and to sample them for fecal indicator bacteria levels. However, it has been shown previously that stormdrain inputs to the Los Angeles River have very high levels of fecal indicator bacteria and we expect additional monitoring will show a similar trend.[27] The frequency at which a stormdrain is flowing during dry weather may be a good indicator of inputs of bacteria to the river. In addition to sampling stormdrain outfalls, we would like to assess whether bacteria levels vary depending on the day of the week; for instance, whether water quality differs on weekdays or weekends, when more people are typically using the river for recreation. We would also like to pursue time series

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[24] Muirhead RW et al. 2004. Faecal bacteria yields in artificial flood events:quantifying in-stream stores. *Water Research* 38: 1215-1224; Mallin MA et al. 2000. Effect of human development on bacteriological water quality in coastal watersheds. *Ecological Applications* 10:1047-1056.

[25] Olapade OA et al .2006. Microbial communities and fecal indicator bacteria associated with *Cladophora* mats on beach sites along Lake Michigan shores *Applied and Environmental Microbiology* 72: 1932-1938.

[26] Cho KH et al. 2010. Meteorological effects on the levels of fecal indicator bacteria in an urban stream: A modeling approach *Water Research* 44: 2189-2202; Sinton W et al. 2007. Sunlight inactivation of *Campylobacter jejuni* and *Salmonella enterica*, compared with *Escherichia coli*, in seawater and river water. *Journal of Water and Health* 5: 357-365; Sinton LW et al. 1999. Sunlight inactivation of fecal bacteriophages and bacteria in sewage-polluted seawater. *Applied and Environmental Microbiology* 65: 3605-3613.

[27] Ackerman D, Schiff K, Trim H, and M Mullin. 2003. Characterization of water quality in the Los Angeles River. *Bulletin of the Southern California Academy of Sciences* 102(1): 17-25; California Regional Water Quality Control Board, Los Angeles River Watershed Bacteria Total Maximum Daily Load. Available at:
www.waterboards.ca.gov/losangeles/board_decisions/basin_plan_amendments/technical_documents/80_New/LARiverFinal/Staff%20Report%20LAR%20Bact%2015Jul10%20final.pdf

sampling further into the day to determine whether solar radiation has an impact on FIB levels. If there are rainfall events during future monitoring efforts, we would like to sample during the rain event and every day after the rain for at least one week to determine how long it takes for bacteria levels to return to average levels. In the future, we also plan to release water quality data on a weekly basis on Heal the Bay's website and calculate rolling geometric means throughout the summer, instead of a single season geometric mean. Through future work and collaboration with additional Los Angeles River stakeholders, we hope to further elucidate sources of bacteria and solutions for reducing or eliminating those sources.

Recommendations

The Los Angeles River currently provides excellent opportunities for recreational activities such as kayaking, fishing, and bird watching; however, water quality improvements are needed to maintain and improve these opportunities. We envision a Los Angeles River that is swimmable in the future, but the water quality is not yet at a level for which swimming is recommended. Further, while we are excited about and strongly support the plans for restoration of the Los Angeles River, these efforts must also be accompanied by efforts to improve water quality. Continuing to promote recreation without providing outreach about and improving water quality will likely lead to public health risks in the future. The proposed restoration plan by the Army Corps of Engineers focuses on habitat and recreational improvements, which are greatly needed but should also be accompanied by a watershed-wide plan to improve water quality such as the Enhanced Watershed Management Plan (EWMP) developed for the watershed. Furthermore, efforts by cities to manage pollution associated with urban runoff through implementation of their EWMP must be tracked and supported to ensure that they happen according to schedule. Although these are regulatory requirements, they risk not being met due to lack of dedicated funding. This study highlights the importance of obtaining support for stormwater best management practices (BMPs), and implementing, maintaining, and assessing BMP projects to improve water quality and watershed health.

Heal the Bay proposes the following recommendations to ensure that beneficial uses, such as recreation, wildlife habitat, groundwater recharge, and wetland habitat, in the Los Angeles River are maintained and enhanced.

1. Outreach and Education

Heal the Bay recommends outreach and education about Los Angeles River water quality to communities and groups that live along, recreate in, and enjoy its uses. The public has a right to be informed about water quality and use the information to make decisions about how they enjoy the river.

Based on our study, and historic fecal indicator bacteria data, Heal the Bay has developed a list of recommendations that address public health concerns and community needs.

Best practices for River-Swimmers: Avoid swimming in the Los Angeles River, particularly submersing your head underwater; and limit water contact, especially avoiding hand-to-face water contact. If there is water contact, then simply rinse off with soap and water afterwards.

Best practices for Kayakers and Anglers: Limit water contact, especially avoiding hand-to-face water contact or entering the water with an open wound, if immunocompromised, or after a rainfall. If there is water contact, then simply rinse off with soap and water afterwards.

Provide water quality information to the public: All groups promoting recreation in the Los Angeles River should provide water quality information and best practices to all participants, using accurate and consistent language. Heal the Bay recommends an outreach and education plan (e.g., additional signage as seen in Figure 4, suggested targeted audiences, and partner messaging opportunities) about Los Angeles River water quality and recreation be developed and implemented by Los Angeles River stakeholders.

2. Water Quality Monitoring, Source Tracking, and Abatement

To protect public health, we recommend that, at a minimum, weekly testing of water quality for fecal indicator bacteria occur in the recreation zones during the open season. Monitoring should occur at locations where water contact is known to occur such as at popular fishing locations, swimming locations, and at all points where kayaks enter and exit the river. For instance, a newer location where kayaks enter the river exists between our two monitoring locations in Elysian Valley. Swimming spots are known to exist in the Sepulveda Basin recreation zone near Lake Balboa. Water quality data collected in the recreation zones should be made publically available in a timely manner.

Further, we recommend source investigation and identification analysis to elucidate sources of bacterial pollution to the Los Angeles River in order to develop specific plans for water quality improvements. Monitoring of stormdrain outfalls is recommended to assess whether they are flowing, how often they are flowing, and to sample them for fecal indicator bacteria levels. The 2008 Bacterial Source Identification Study[28] has already conducted some of this monitoring and the results of the study were used to help inform the TMDL and prioritize certain reaches of the LA River. However, new, more modern techniques currently exist for bacterial source identification that were not used in the BSI study. Further, given that recreational use in the Los Angeles River has changed drastically since 2008, there is an increased urgency to improve water quality and see results of bacterial abatement measures. Any effort to reduce bacterial inputs in the short-term should be fully explored, particularly in dry weather. The final compliance deadline for the Los Angeles River Watershed Bacteria TMDL is not until 2037.

[28] Cleaner Rivers through Effective Stakeholder-led TMDLs (CREST) (2008) Los Angeles River Bacteria Source Identification Study: Final Report.

Clearly, we need more immediate water quality improvements and pollution abatement, particularly in the recreation zones.

3. Support for Multi-benefit Watershed Health Projects

Heal the Bay supports projects that improve watershed health and water quality, such as projects that address stormwater runoff and expand and improve green space. Most parks represent the only open space we have left in our dense, concrete landscape of Los Angeles. Parks have the capacity to help protect and restore local water resources, capture stormwater, create linear greenways along our rivers, and cool our cities–in addition to their traditional roles of creating safe places to play. Heal the Bay supports projects that not only create new parks in regions with high need but ones that ensure that existing parks are safer and our region more resilient. Creating and improving parks in the Los Angeles River Watershed has the potential to ameliorate the negative effects of pollution from stormwater and urban runoff, resulting in improved water quality in the Los Angeles River. Improving water quality will help ensure that recreational opportunities in the Los Angeles River are maintained and enhanced in addition to other beneficial uses that the river provides such as wildlife habitat, groundwater recharge, and wetland habitat.

Achieving healthy watersheds may require addressing social as well as environmental issues; providing services for the homeless throughout Los Angeles County is a social and an environmental justice issue. Over 45,000 individuals are homeless in Los Angeles County. Essential services, such as mental health services, rental subsidies, and short-term housing, are needed to provide a basic quality of life to homeless individuals. First and foremost, we see homelessness as a complex social problem that needs a collaborative solution with dedicated funding. Homeless individuals are also at a greater risk of exposure to environmental hazards; further, homelessness itself has an impact on our natural environment, including our rivers and ocean. Additional support is needed for essential homeless services, and would benefit all Angelenos and the watersheds of Los Angeles County.

Urban runoff is the main reason why many of our beaches, rivers, and creeks, including the Los Angeles River, remain chronically polluted. To fully realize healthy watersheds, we must address urban runoff. Each day roughly 10 million gallons of urban runoff flow through LA County stormdrains, picking up pollutants and eventually reaching the ocean without the benefit of any treatment. On a rainy day, that volume can escalate to 10 billion gallons. Heal the Bay's science and policy team is working to ensure stormwater management planning and implementation includes multi-benefit solutions that improve greenspace, beautify communities, and capture water onsite for reuse or recharging groundwater. This includes working with state and local governments to find creative ways to fund stormwater programs that capture and clean polluted runoff and then recycle it or use it to recharge our aquifers.

Table 1. Limits for freshwater fecal indicator bacteria.

	Los Angeles River Bacteria TMDL[a]		EPA 2012 Recreational Water Quality Criteria[b]			
			For illness rate of 32 per 1000		Beach Action Value (BAV) for illness rate of 32 per 1000	
Fecal Indicator Bacteria	Single Sample	Geometric Mean	Statistical threshold value (STV)	Geometric Mean	Single Sample	Geometric Mean
Enterococcus	NA	NA	110 cfu/100ml	30 cfu/100ml	60 cfu/100ml	NA
E. coli	235/100ml	126/100ml	320 cfu/100ml	100 cfu/100ml	190 cfu/100ml	NA

[a] California Regional Water Quality Control Board, Los Angeles River Watershed Bacteria Total Maximum Daily Load. Available at: www.waterboards.ca.gov/losangeles/board_decisions/basin_plan_amendments/technical_documents/80_New/LARiverFinal/Staff%20Report%20LAR%20Bact%2015Jul10%20final.pdf

[b] US EPA. 2012. Recreational Water Quality Criteria. Available at: http://water.epa.gov/scitech/swguidance/standards/criteria/health/recreation/upload/RWQC2012.pdf

Table 2. Air and water temperature data for the sites over the study period.

Site	**n**	**Air temperature (°C)**		**Water Temperature (°C)**	
		Average	**Range**	**Average**	**Range**
Sepulveda Basin	11	27.2	20-32.5	26.2	24-28
Elysian Valley, Rattlesnake Park	13	24.9	19.5-29	23.5	21.4-26.3
Elysian Valley, Steelhead Park	12	23.2	20-26	25.1	23-28

Table 3. Qualitative assessments of flow.

Site	***n***	**Flow Type by Percentage***				
		None	***Trickle***	***Intermittent***	***Steady***	***Heavy***
Sepulveda Basin	11	0	18	**64**	18	0
Elysian Valley, Rattlesnake Park	13	0	0	0	**77**	23
Elysian Valley, Steelhead Park	12	0	17	**50**	33	0

* The highest percentage for each site is shown in bold.

Table 4. Qualitative assessments of water clarity and color.

		Water Clarity by Percentage*				**Water Color by Percentage**		
Site	**n**	***Clear***	***Cloudy***	***Milky***	***Muddy***	***Colorless***	***Brown***	***Green***
Sepulveda Basin	11	27	**64**	0	9	**82**	0	18
Elysian Valley, Rattlesnake Park	13	**92**	8	0	0	**100**	0	0
Elysian Valley, Steelhead Park	12	**92**	8	0	0	**100**	0	0

* The highest percentage for each site is shown in bold.

Table 5. Qualitative and quantitative assessment of trash.

		Trash Type by Percentage*				Trash quantitative†
Site	**n**	***None***	***Light (1-10 items)***	***Moderate (11-50 items)***	***High (50+ items)***	***Average Number of Items***
Sepulveda Basin	11	0	40	**60**	0	20
Elysian Valley, Rattlesnake Park	13	0	**46**	**46**	8	21
Elysian Valley, Steelhead Park	12	0	**58**	42	0	16

***** The highest percentage for each site is shown in bold.
† Quantitative averages of trash were calculated by assigning a number to each category: none=0; light=5, moderate=30, high=70.

Table 6. Percent algal cover for each site.

Site	n	Floating Algae	Benthic Algae
Sepulveda Basin	11	0	81
Elysian Valley, Rattlesnake Park	13	0	58
Elysian Valley, Steelhead Park	12	0	74

Table 7. Turbidity for each site.

Site	n	Turbidity (NTU) average	Standard Deviation turbidity (NTU)
Sepulveda Basin	11	9.2	2.0
Elysian Valley, Rattlesnake Park	13	5.7	2.0
Elysian Valley, Steelhead Park	12	3.8	2.0

Table 8. Animals observed in and near the water at the sample sites. Raw numbers are shown for dogs and birds. For birds and fish, the percent of samples that had birds or fish present in the water is also shown.

		Dogs		**Birds**			**Fish**
Site	**n**	***In water***	***Out of water***	***In water***	***Percent of samples with birds in water***	***Out of water***	***Percent of samples with fish in water***
Sepulveda Basin	11	1	0	284	91%	0	45
Elysian Valley, Rattlesnake Park	13	1	1	114	92%	19	0
Elysian Valley, Steelhead Park	12	0	0	4	25%	7	58

Table 9. Number, average, and standard deviation (SD) for of visitors in and out of the water.

Site	**n**	**People in the Water**	***Average # (SD) people in the water***	**People out of the Water**	***Average # (SD) people out of the water***
Sepulveda Basin	11	42	3.8 (7.9)	3	0.3 (0.6)
Elysian Valley, Rattlesnake Park	13	0	0 (0)	13	1 (2.2)
Elysian Valley, Steelhead Park	12	0	0 (0)	3	0.2 (0.9)

Table 10. Average bacteria levels* with standard deviation (SD), geometric means, and percent exceedances for *Enterococcus*, *E. coli*, and Total Coliform for dry weather samples.

		Enterococcus				***E. coli***				**Total Coliform [a]**		
Site	**n**	**Average (MPN/100 mL)**	**SD**	**% Exceedances[b]**	**Geometric Mean (MPN/100 mL)[c]**	**Average (MPN/100 mL)**	**SD**	**% Exceedances [d]**	**Geometric Mean (MPN/100 mL)[e]**	**Average (MPN/100 mL)**	**SD**	**Geometric Mean (MPN/100 mL)**
Sepulveda Basin	10	486	648	50%	**185**	183	204	20%	110	17087	5046	16377
Elysian Valley, Rattlesnake Park	12	641	750	100%	**401**	529	924	67%	**312**	24933	232	24932
Elysian Valley, Steelhead Park	11	497	528	100%	**337**	178	112	9%	**157**	24708	406	24705

* Samples below the detection level (of 10 MPN/100ml) were set to the value of 5 MPN/100ml and samples over the detection limit of >24196 MPN/100ml were set to the value of 25000 MPN/100ml.

[a] Percent exceedances were not calculated for Total Coliform because there is no regulatory limit.

[b] Based on the EPA STV threshold of 110 MPN/100ml.

[d] Bolded values are over EPA's geometric mean threshold of 30 MPN/100ml.

[d] Based on the Bacteria TMDL single sample limit of 235 MPN/100ml.

[e] Bolded values are over the Bacteria TMDL's geometric mean limit of 126 MPN/100ml.

Table 11. Bacteria levels* during wet weather sampling event and whether the sample was in exceedance.

		Enterococcus	*E. coli*	Total Coliform [a]
Site	**n**	**Value (MPN/100 mL)[b]**	**Value (MPN/100 mL)[c]**	**Value (MPN/100 mL)**
Sepulveda Basin	1	**660**	**1296**	25000
Elysian Valley, Rattlesnake Park	1	**1572**	**1303**	25000
Elysian Valley, Steelhead Park	1	**1989**	**1935**	25000

* Samples below the detection level (of 10 MPN/100ml) were set to the value of 5 MPN/100ml and samples over the detection limit of >24196 MPN/100ml were set to the value of 25000 MPN/100ml.

[a] Exceedances were not indicated for Total Coliform because there is no regulatory limit.

[b] Bolded values over the EPA STV of 110 MPN/100ml.

[c] Bolded values are over the Bacteria TMDL single sample limit of 235 MPN/100ml.

Table 12. Multiple regression analysis of *E. coli* levels (natural log transformed) at three sites. Regressions were performed with explanatory factors followed by AIC stepwise model selection.

Independent Variable	Coefficient	Std. Error	t-value	p-value*
Sepulveda Basin				
Intercept	0.31	1.38	0.22	0.83
Rain within the last week	2.46	0.69	3.53	**0.01**
Benthic algae coverage	0.04	0.02	2.40	0.05
Birds in water	0.12	0.03	4.11	**0.006**
R^2 adjusted = 0.86				
Elysian Valley, Rattlesnake Park				
Intercept	8.26	1.44	5.71	**0.002**
Water temperature	-0.09	0.06	-1.53	0.19
Benthic algae coverage	-0.02	0.01	-2.46	0.06
Rain within the last week	1.28	0.20	6.53	**0.001**
Birds in water	0.03	0.01	1.83	0.13
R^2 adjusted = 0.86				
Elysian Valley, Steelhead Park				
Intercept	5.48	2.02	2.71	**0.03**
Water temperature	-0.12	0.08	-1.54	0.16
Time	0.002	0.001	1.58	0.15
Turbidity	0.34	0.06	5.90	**0.0004**
R^2 adjusted = 0.86				

* Bold indicates significance at the 0.05 level.

Table 13. Multiple regression analysis of *Enterococcus* levels (natural log transformed) at three sites. Regressions were performed with explanatory factors followed by AIC stepwise model selection.

Independent Variable	**Coefficient**	**Std. Error**	**t-value**	**p-value***
Sepulveda Basin				
Intercept	22.63	11.18	2.02	0.18
Water temperature	-1.11	0.41	-2.72	0.11
Benthic algae coverage	0.14	0.03	5.05	**0.04**
Trash amount	-0.08	0.02	-3.98	0.06
Flow (steady)	5.08	1.28	3.95	0.06
Flow (trickle)	3.71	0.98	3.78	0.06
Birds in water	0.10	0.07	1.46	0.28
R^2 adjusted = 0.91				
Elysian Valley, Rattlesnake Park				
Intercept	-0.63	3.54	-0.18	0.87
Water temperature	-0.23	0.08	-2.91	**0.04**
Time	0.005	0.002	2.29	0.08
Turbidity	0.52	0.08	6.54	**0.003**
Benthic algae coverage	0.08	0.02	4.53	**0.01**
Birds in water	-0.02	0.02	-1.07	0.34
R^2 adjusted = 0.90				
Elysian Valley, Steelhead Park				
Intercept	8.06	1.42	5.67	**0.0003**
Time	-0.004	0.002	-2.57	**0.03**
Turbidity	0.43	0.08	5.45	**0.0004**
R^2 adjusted = 0.73				

* Bold indicates significance at the 0.05 level.

Table 14. Multiple regression analysis of time-series analysis of *E. coli* levels (natural log transformed) at two sites over five weeks. Regressions were performed with explanatory factors of time and covariate of week or sample date.

Independent Variable	**Coefficient**	**Std. Error**	**t-value**	**p-value***
Elysian Valley, Rattlesnake Park				
Intercept	5.28	0.23	22.53	**<0.0001**
Time	-0.08	0.08	-0.91	0.38
Week	0.11	0.05	2.24	**0.05**
R^2 adjusted = 0.22				
Elysian Valley, Steelhead Park				
Intercept	4.88	0.37	13.33	**<0.0001**
Time	-0.17	0.13	-1.26	0.23
Week	0.03	0.08	0.39	0.70
R^2 adjusted = -0.02				

Table 15. Multiple regression analysis of time-series analysis of *Enterococcus* levels (natural log transformed) at two sites over five weeks. Regressions were performed with explanatory factors of time and week.

Independent Variable	**Coefficient**	**Std. Error**	**t-value**	**p-value***
Elysian Valley, Rattlesnake Park				
Intercept	6.96	0.53	13.17	**<0.0001**
Time	-0.42	0.19	-2.19	**0.05**
Week	0.07	0.11	0.62	0.54
R^2 adjusted = 0.19				
Elysian Valley, Steelhead Park				
Intercept	6.48	0.45	14.46	**<0.0001**
Time	-0.57	0.16	-3.53	**0.004**
Week	0.013	0.09	0.14	0.89
R^2 adjusted = 0.43				

* Bold indicates significance at the 0.05 level.

Table 16. Number of exceedances and grade received using two methods for the three sites.

	Enterococcus			*E. coli*		
Site	**Number of Exceedances**	**Method 1 [a] Grade**	**Method 2 [b] Grade**	**Number of Exceedances**	**Method 1 Grade**	**Method 2 Grade**
Sepulveda Basin	6 (5 dry, 1 wet)	FAIL	FAIL	3 (2 dry, 1 wet)	FAIL	FAIL
Elysian Valley, Rattlesnake Park	13 (12 dry, 1 wet)	FAIL	FAIL	9 (8 dry, 1 wet)	FAIL	FAIL
Elysian Valley, Steelhead Park	12 (11 dry, 1 wet)	FAIL	FAIL	2 (1 dry, 1 wet)	PASS	PASS

[a] Method 1 compares number of exceedances observed to the number of exceedances that would trigger a listing on California's 303(d) list as impaired. For a sample size of 3-31, this number of exceedances is 3 or greater.

[b] Method 2 compares number of exceedances observed to the number of exceedances that are allowed under the Los Angeles River Watershed Bacteria TMDL which allows for 1 exceedance in dry weather weekly sampling and 2 exceedances for wet weather weekly sampling. Wet weather days are defined in the TMDL as those which experience 0.1 inch of rain or more and the following three days. Again, sites were graded as "pass" (0 or 1 exceedance in dry weather; 0-2 exceedances in wet weather) or "fail" (2 or more exceedances in dry weather and 3 or more exceedances in wet weather) for both *E. coli* and *Enterococcus* (even though *Enterococcus* is not addressed in the TMDL). The TMDL does not specify levels for *Enterococcus* but we used EPA's recommended statistical threshold value.

Figure 1. Map of sampling sites in the Los Angeles River, identified with red stars. The most upstream site is Sepulveda Basin at Burbank Blvd. Going downstream, the next site is Rattlesnake Park, Elysian Valley, followed by Elysian Valley, Steelhead Park. Base maps obtained from: http://www.waterboards.ca.gov/rwqcb4 and http://www.lariverrecreation.org/.

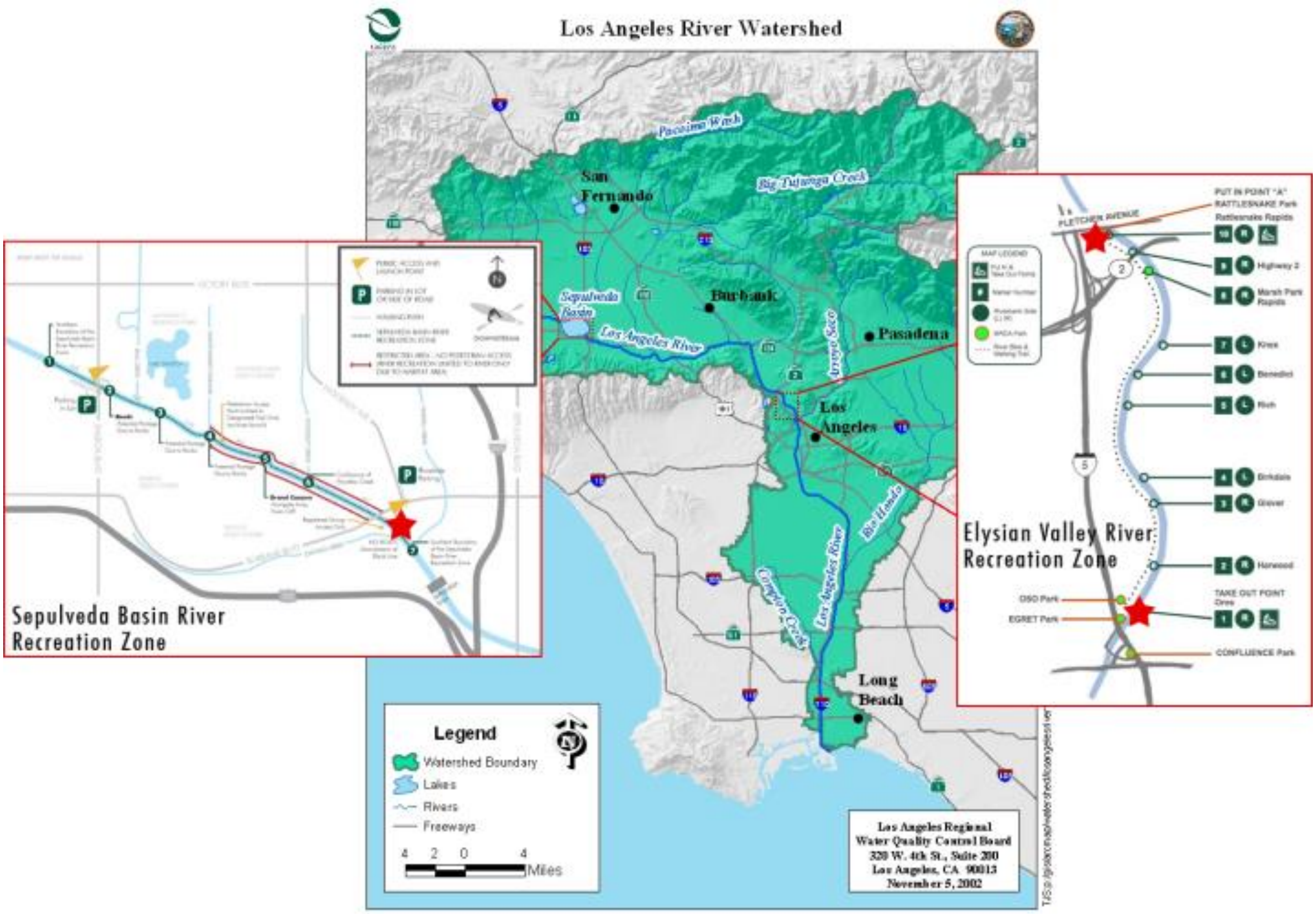
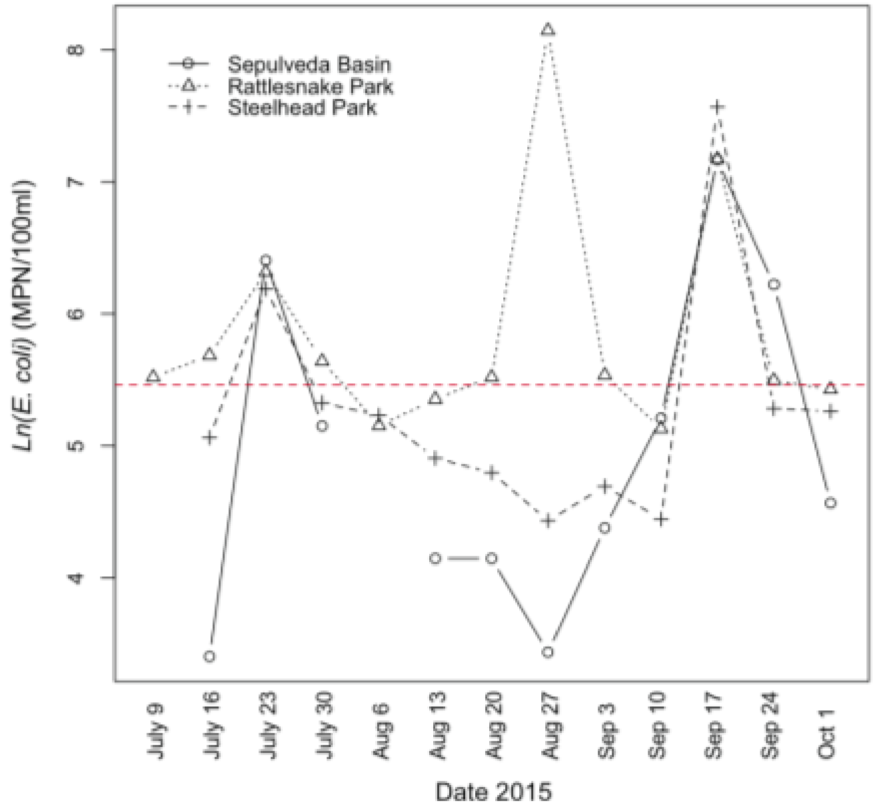


Figure 2. Bacteria levels by week for the three sites for a) *E. coli* and b) *Enterococcus*. Bacteria levels were natural log transformed for normality. Samples were taken over 13 weeks from July 9 to October 1, 2015. Rain events occurred on July 18th (between weeks 2 and 3) and on September 14th (between weeks 10 and 11). The red dashed lines represent limits based on the Los Angeles River Bacteria TMDL limit of 235 MPN/100ml for *E. coli* and the EPA STV of 110 MPN/100ml for *Enterococcus*.

a)



b)

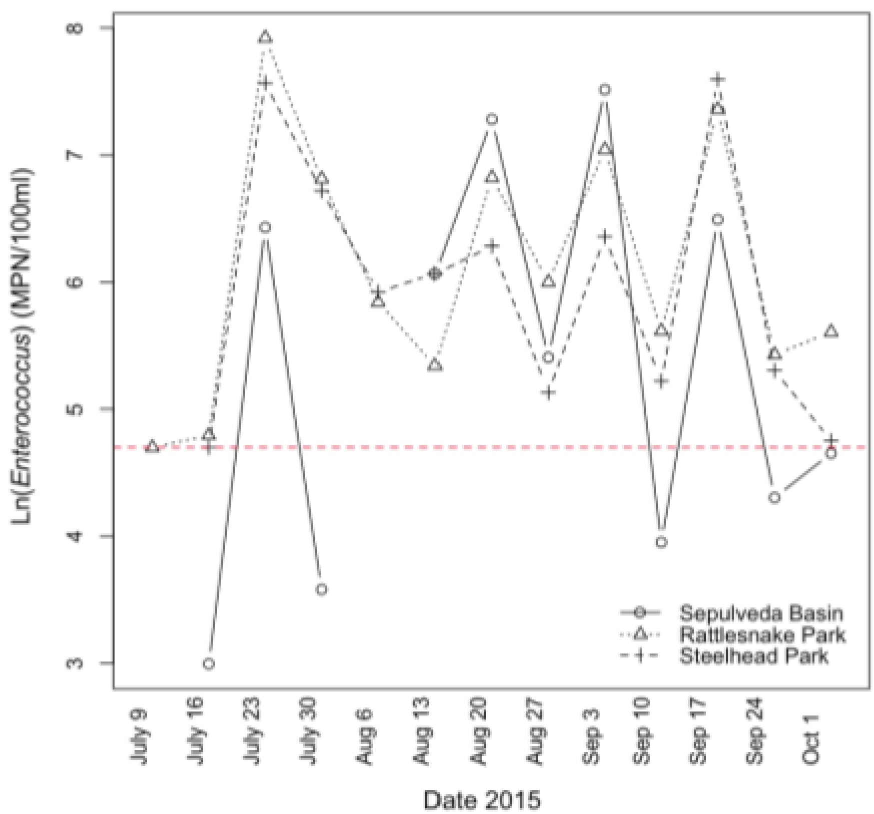
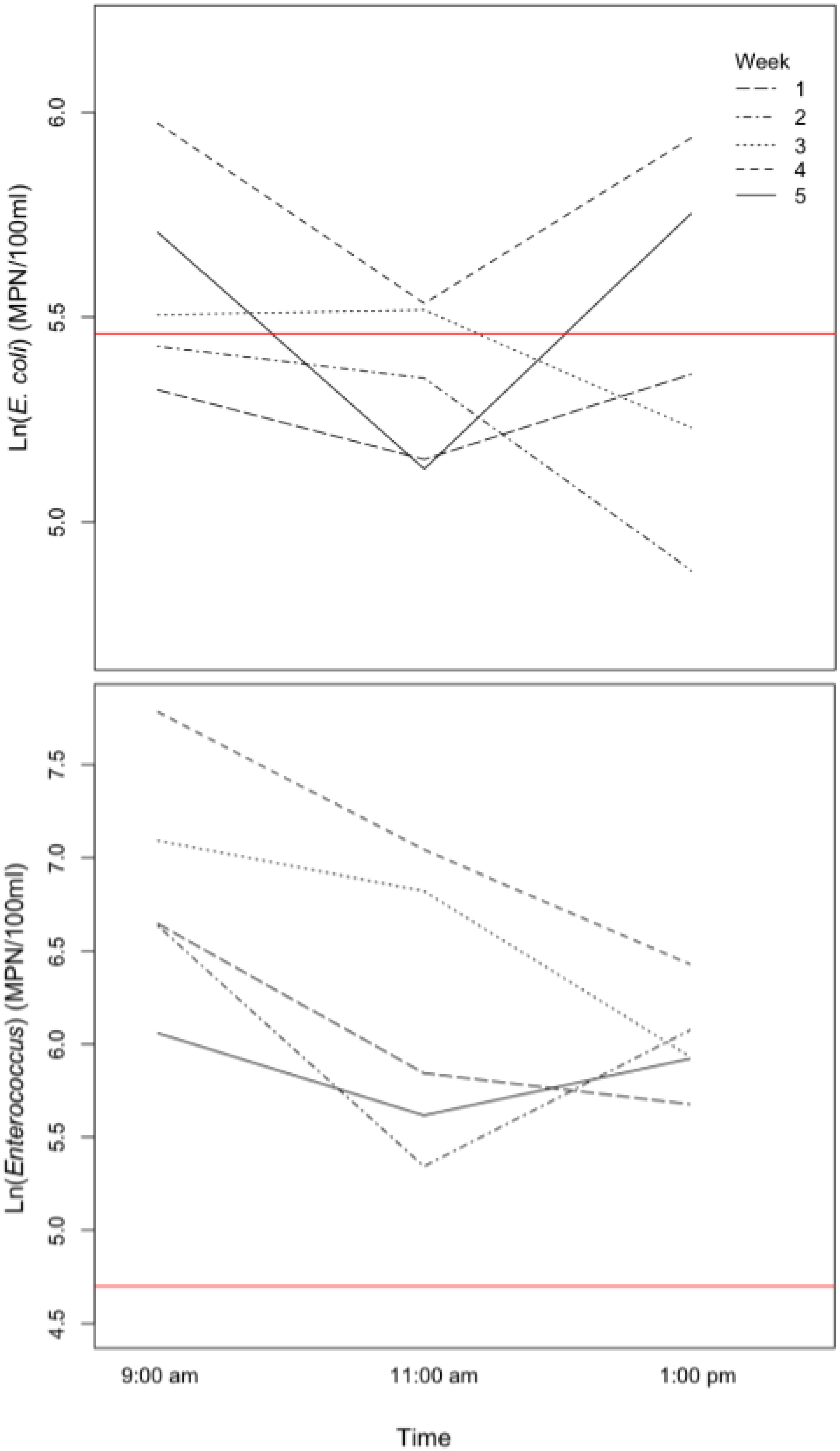
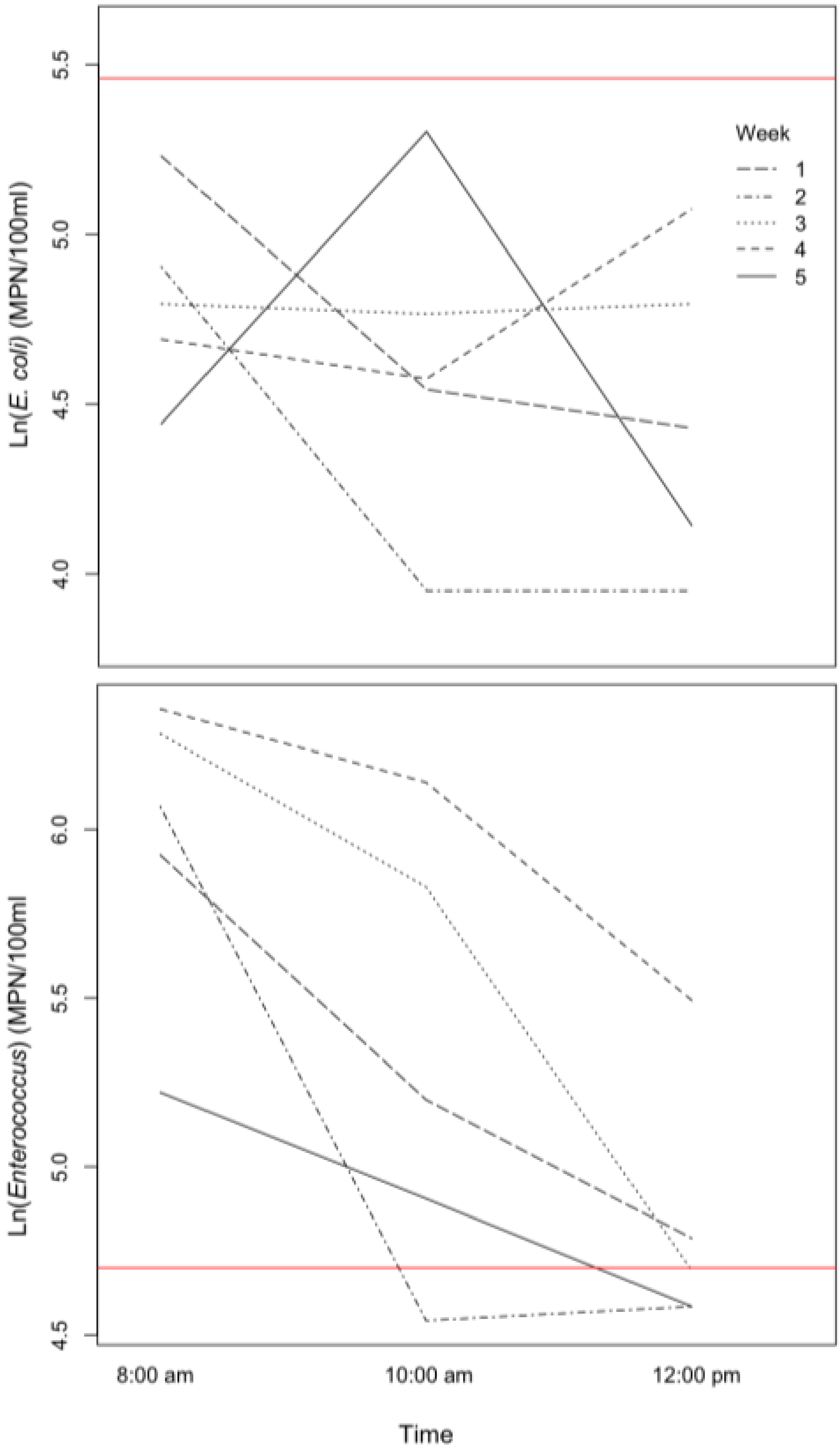


Figure 3. Bacteria levels (*E. coli* and *Enterococcus*) over time at a) Elysian Valley Rattlesnake Park and b) Elysian Valley Steelhead Park. Bacteria levels were natural log-transformed. Bacteria was monitored at three time points weekly for 5 weeks. Red lines indicate bacteria standards based on the bacteria TMDL (for *E. coli*) and EPA's STV (for *Enterococcus*).

a)



b)



5.5
5.0
4.5
4.0
Ln(E. coli) (MPN/100ml)
Week
1
2
3
4
5
6.0
5.5
5.0
4.5
Ln(Enterococcus) (MPN/100ml
8:00 am
10:00 am
12:00 pm
Time

Figure 4. Signage along the Los Angeles River near Rattlesnake Park, Elysian Valley concerning water quality.