

# IS IT SAFE TO SWIM?

## Assessing Human Use and Water Quality of Freshwater Swimming Holes in the Santa Monica Mountains

Heal the Bay

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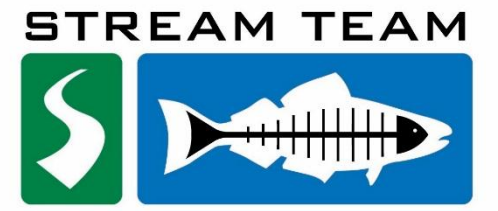


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# Introduction

Freshwater swimming is a popular activity in the Santa Monica Mountains, yet there is currently a lack of data on human use of and water quality in local swimming holes. The Malibu Creek Watershed is the largest watershed in the Santa Monica Mountains, draining an area of 109 square miles into the Santa Monica Bay. Malibu Creek and its tributaries are listed as impaired for bacteria on California's 303(d) list of Impaired Water Bodies, indicating that fecal indicator bacteria (FIB) levels are high and that water bodies are not meeting their designated beneficial uses. Recreational waters polluted with fecal bacteria can lead to illnesses such as gastroenteritis and upper respiratory infections as well as more serious diseases. Currently, there are no regulations requiring routine water quality testing at freshwater swimming areas in the Santa Monica Mountains. The Malibu Creek Bacteria Total Maximum Daily Load (TMDL) requires municipalities to monitor FIB levels at a variety of discharge points along the creek and its tributaries; however, these sites do not overlap with swimming spots. Additionally, there is no signage at known swimming locations warning swimmers about potential water quality hazards to protect public health.

In order to address these data gaps, we performed a pilot study assessing water quality at three freshwater swimming locations in the Santa Monica Mountains over the summer of 2014. During the pilot study, we assessed how many people visit and swim in these spots as well as the demographics of the visitors. We also assessed the water quality and identified potential factors impacting water quality. Based on the water quality and human use data, we evaluated whether there is a risk to public health and formulated recommendations for reducing that risk.

By researching the water quality at swimming holes in the Santa Monica Mountains, Heal the Bay hopes to inform public health authorities and land-owners of potential health risks, advocate for swimmer-targeted education, encourage improved monitoring by land owners, and recommend water quality improvements. Demographic information about swimmers may also help inform outreach methods and messages. Without monitoring these areas, the public health risks at freshwater swimming locations will continue to be unknown.

# Methods

Heal the Bay scientific staff selected three sampling locations (Figure 1) based on our previous observations and knowledge of swimming locations as well as input from California State Parks, Angeles District and the National Park Service (NPS), Santa Monica Mountains National Recreation Area. The locations selected were:

1) Rock Pool, Malibu Creek in Malibu Creek State Park (lat: 34.093996 lon: -118.732933): Malibu Creek is listed as impaired for bacteria on California's 303(d) list of impaired water bodies. Rock Pool is an approximately 1.5 mile hike from the Malibu Creek State Park parking lot. There are no bathrooms located at the site, but there are trashcans with lids. The pool used for swimming at this site is large and deep (approximately 6-20 ft.). The pool is surrounded by cliffs and is a popular location for cliff jumping and rock climbing.

2) Las Virgenes Creek at the bridge culvert in Malibu Creek State Park (lat: 34.096318 lon: -118.717585): Las Virgenes Creek is listed as impaired for bacteria on California's 303(d) list of impaired water bodies. Las Virgenes Creek at the bridge culvert is approximately 100 m (330 ft.) from the Malibu Creek State Park parking lot and easily accessible. There are park bathrooms and trashcans with lids between the parking lot and swimming location. The water is deep (approximately 6 ft.) directly downstream of the bridge but is otherwise shallow in the area used by swimmers. There is also a sandy "beach" along the western stream bank.

3) Solstice Canyon waterfall in National Park Service land (lat: 34.050362 lon -118.753523): Solstice Creek is a small coastal watershed outside of the Malibu Creek Watershed. Solstice Creek is not listed as impaired for bacteria on California's 303(d) list of impaired water bodies. Solstice Canyon waterfall is an approximate 1-mile hike from the NPS parking lot. There are no bathrooms or trashcans at the site. The pool is very small and shallow (approximately 3 ft. maximum).

We visited the three locations approximately twice a week, typically on Wednesdays and Sundays, from June 30, 2014 to September 28, 2014 for a total of 18 sample dates at Rock Pool and Las Virgenes Creek, and 10 at Solstice. Solstice was monitored less frequently because fewer swimmers were observed there during the first few months of the study. We aimed to monitor sites midday to early afternoon, when we expected the most visitors; all sites were sampled between the hours of 9:45 AM to 3:00 PM with 83% of sampling occurring between 11am-3pm.

At each sampling location, we collected data on the following based on visual observations: weather conditions, type of water flow, water clarity, water color, water odor, amount of trash, presence and maintenance of trashcans, proximity and conditions of nearest bathroom, presence and number of animals in and near the water, and number, sex, race, and age of visitors in and out of the water. Air temperature and water temperature were measured at each location using a thermometer. 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: "clear", "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.

Conditions of the nearest bathrooms were noted such as whether they were closed or out of order, as well as cleanliness. Animals in and near the water were counted and recorded by type (dog, aquatic birds, horses, other). We collected data on human use using a "snapshot" method in which we counted the number of visitors at a single moment in time as best we could.

Demographics of visitors were also collected in the following categories based on visual observation and best judgment of the sampling team: sex (male, female, unsure), race (Hispanic, Caucasian, Asian, Black, other/unsure), age (infant 0-2 yrs., child 3-12 yrs., young adult 13-21 yrs., adult 22+ yrs.), and location (out of water, wader, swimmer non-submerged, and swimmer submerged). We also took two photographs at each site in a specified spot.

We collected a 100mL water sample in a sterile bottle from a specified spot approximately twelve inches under the surface of the water at a knee-depth location. The water samples were placed on ice and processed within 8 hours for three types of fecal indicator bacteria: total coliforms, *Escherichia coli*, and *Enterococcus*. FIB concentrations were measured with Colilert-18™ 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.

To determine a conservative estimate of visitation over the entire sampling period (July – September), we extrapolated our "snapshot" data on number of visitors. We grouped visitor counts performed at each site according to whether they were collected on a weekend or a weekday, and then calculated the average values (holidays were counted as weekend days). We conservatively assumed that these average snapshot values were representative of the total number of daily visitors on weekends and weekdays. We then multiplied this average daily visitor figure by the number of weekend days and weekdays (64 weekdays and 28 weekend/holiday days for July, August, September), and then added those two numbers to get a total number of visitors for 3 months at each site. Since weekday snapshots were taken in the middle of the week, and the estimation method assumes that our average visitor counts (which were snapshots taken over a very short period of the day) were an estimate of an entire day's visitation, the final tally for visitation likely underestimates the true number of visitors over the entire three month time period.

To analyze water quality data, we compared bacteria levels measured at each site to water quality objectives from the Malibu Creek Watershed Bacteria TMDL and EPA's 2012 Recreational Water Quality Criteria (RWQC), and calculated percent exceedances for all sites. The freshwater regulatory limit for *E. coli* is 235 MPN/100ml for a single sample.[1] 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 in a fresh waterbody designated for recreation.[2] 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

[1] US EPA Region 9, Total Maximum Daily Loads for Bacteria, Malibu Creek Watershed. Available at: http://www.epa.gov/region9/water/tmdl/malibu/final_bacteria.pdf
[2] US EPA. 2012. Recreational Water Quality Criteria. Available at: http://water.epa.gov/scitech/swguidance/standards/criteria/health/recreation/upload/RWQC2012.pdf

California's 303(d) list and 2) numeric limits as set in the Total Maximum Daily Load (TMDL) in the Malibu Creek Watershed. For Method 1, we used the Water Quality Control Policy for Developing California's Clean Water Act Section 330(d) List[3], 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 3 exceedances) or "fail" (3 or more exceedances) for both *E. coli* and *Enterococcus*. For Method 2, we used the criteria in the Malibu Creek Watershed Bacteria TMDL[4] which allows for 0 exceedances in dry summer days from April 1 to October 31. Again, sites were graded as "pass" (0 exceedances) or "fail" (1 or more exceedances) for both *E. coli* and *Enterococcus*.

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, total number of visitors, number of people in the water, day type (whether the sample was taken on a weekday or weekend/holiday), flow, water clarity, water color, trash levels, and animals in and out of the water (dogs and birds). Water temperature and air temperature were highly correlated so we selected water temperature for use in the models. We also chose to use number of people in the water and not the total number of people at the site; these variables were highly correlated also but we saw higher correlations between bacteria levels and number of people in the water. Because our sample size was somewhat small, we did not consider interactions among the variables. Animal data were only included in the model if animals were observed at that site; similarly qualitative data were only included if more than one category was observed at the site. We assessed the statistical relationship between *E. coli* and *Enterococcus* and the explanatory variables for each FIB and site separately. We did not run a regression analysis for Solstice because there were too few samples. Bacteria levels were log transformed for normality. We performed model selection by Akaike Information Criterion (AIC) with a stepwise algorithm.

# Results

## Site Conditions

The sites differed in a number of characteristics that we measured. Average water (24.6 °C) and air temperatures (26.9 °C) were higher at Rock Pool compared to the other sites (Table 1). Temperatures were lowest at Solstice with an average of 20.0 °C water temperature and 22.7 °C air temperature (Table 1). However, we stopped monitoring Solstice near the end of August and

[3] 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

[4] US EPA Region 9, Total Maximum Daily Loads for Bacteria, Malibu Creek Watershed. Available at: http://www.epa.gov/region9/water/tmdl/malibu/final_bacteria.pdf

did not sample during some of the hottest days in September. The sites also differed in their flow types; Rock Pool was classified as having no flow at all on 100% of the sample visits while Las Virgenes was classified as having steady flow 56% of the time and intermittent flow 39% of the time (Table 2). Solstice Canyon flow was primarily classified as a trickle (80% of time) (Table 2). Water clarity was primarily classified as clear for Las Virgenes and Solstice Canyon (56% and 80% of the time, respectively), while it was described as cloudy 83% of the time at Rock Pool (Table 3). Further, water color was classified as green on 78% of the visits to Rock Pool (Table 3). Solstice Canyon primarily had clear water (80%), while Las Virgenes had green water 56% and clear water 39% of the time (Table 3). We did not detect odors from the water at any sites (data not shown). Trash levels were generally classified as light (1-10 items) and moderate (11-50) for all sites; Solstice had lower amounts of trash than Rock Pool and Las Virgenes (Table 4). Rock Pool was the only site where we observed high trash levels (over 50 items) and overflowing trashcans.

## People and Demographics

Over the course of the study, we did not see many animals in or near the water. In total, 4 dogs were observed in the water at all sites: 3 at Solstice and 1 at Rock Pool (Table 5). We observed 13 dogs near the water: 5 at Solstice, 5 at Rock Pool, and 3 at Las Virgenes (Table 5). Malibu Creek State Park does not allow dogs within its boundaries, so they are not allowed at the Rock Pool or Las Virgenes sites. Dogs are allowed on-leash at Santa Monica Mountains National Recreation Area, however they are only allowed on trails in Solstice Canyon. Dogs are specifically prohibited at the waterfall at Solstice. We only saw birds on 2 occasions in or near the water at all three sites. No other animals were observed (Table 5).

Over the course of the study, we counted 1365 visitors on 18 sample days at all sites (Table 6). This number is most likely an underestimate, given the difficulty that we had in counting the large crowds at Rock Pool and that not all locations and visitors were visible. When comparing the three sites, the majority of visitors were seen at the Rock Pool site. A little under half (48%) of the swimming hole visitors at the Malibu Creek State Park sites - Rock Pool and Las Virgenes Creek - were in the water (waders and swimmers) (Table 6). Solstice Canyon had the fewest number of visitors and very low numbers of people in the water (2 people or 3%), all of whom were waders (Table 6). To determine a rough estimate of visitors at each site over the 3 month study, we extrapolated data based on survey observations which resulted in a total estimated visitor number for the time period of July 1 – September 30, 2014 of 1064 people at Las Virgenes Creek, 4221 at Rock Pool, and 714 at Solstice Canyon waterfall (Table 6).

Visitors were identified as predominantly Hispanic at Rock Pool (60%) and Las Virgenes (73%), while Solstice Canyon was visited by a slight majority of Caucasians (47%) (Table 7). Age groups also differed among the sites, with adults and young adults (ages 13 and older) comprising over 75% of the visitors at Rock Pool and Solstice, while Las Virgenes had more children (3-12 years old) (Table 8). At Las Virgenes Creek, children and adults made up 90% of the visitors, indicating a presence of families.

## Bacteria Results

Bacteria levels varied among the sites. Solstice had the lowest average concentrations for all three FIB, while Rock Pool and Las Virgenes had higher and similar average concentrations of all three FIB (Table 9). The average concentrations of *Enterococcus* and *E. coli* at Solstice were under the limits set by EPA and the Malibu Creek Bacteria TMDL, respectively. The average *Enterococcus* concentration at Rock Pool (119.44 MPN/100ml) and Las Virgenes (209.61 MPN.100ml) were both over the EPA STV of 110 MPN/100ml and the average *E. coli* concentration at Rock Pool (278.47MPN/100ml) was over the TMDL limit of 235MPN/100ml. Frequent exceedances of limits were observed in Las Virgenes Creek; 61% of the samples exceeded the limit for *Enterococcus*, while 28% of the samples were over the limit for *E. coli* (Table 9). At Rock Pool, 22% of the samples exceeded the limit for *Enterococcus*, while 11% of the samples were over the limit for *E. coli*. At Solstice Canyon, 10% of the samples exceeded the limit for *Enterococcus*, while none of the samples were over the limit for *E. coli* (Table 9).

Through the multiple regression analysis, the best model that explained *E. coli* levels at Las Virgenes included day type (weekend vs. weekday) and number of dogs out of the water, explaining 42% of the variation in *E. coli* levels (Table 10). Day type was the only significant predictor of *E. coli* levels, with higher levels of *E. coli* on weekends (Table 10). The best model that explained *Enterococcus* levels at Las Virgenes included day type and number of people in the water, explaining 62% of the variation in *Enterococcus* levels (Table 11). Again, day type was the only significant predictor of *Enterococcus* levels in Las Virgenes Creek (Table 11). Bacteria levels were higher on the weekends and holidays (*E. coli* 339 MPN/100ml; *Enterococcus* 307.15 MPN/100ml) than on weekdays (*E. coli* 82.37 MPN/100ml; *Enterococcus* 87.69 MPN/100ml) (Figure 2). When we tested the bivariate relationship between bacteria levels and day type (weekend vs. weekday), we found a significant difference in log-transformed bacteria levels between weekend and weekday samples (t-test *E. coli* $t_{13.84}$= -3.14, p=0.007; t-test *Enterococcus* $t_{14.39}$= -5.36, p<0.0001) (Figure 2).

For the Rock Pool site, the multiple regression analysis revealed that *E. coli* levels were best explained by the number of people in the water and number of dogs out of the water, which together explained 51% of the variability in *E. coli* concentrations (Table 10). Number of people in the water was a significant predictor of *E. coli* levels (Table 10). We examined the bivariate relationship between *E. coli* and number of people and there is a clear positive relationship (Figure 3). We determined the best fit trendline for the relationship through simple regression analysis to estimate the number of people in the water that corresponds to the *E. coli* regulatory limit of 235 MPN/100ml, which was 59 people (Figure 3). *Enterococcus* levels at Rock Pool were best explained by air temperature, day type (weekend vs. weekday), number of people in the water, water color, and number of dogs in the water (Table 6). Together these factors explained 71% of the variation in *Enterococcus* concentrations, however, the only variable that was significant was number of people in the water (Table 6). We also examined the bivariate relationship between *Enterococcus* levels and number of people in the water to assess the number of people that corresponds to an *Enterococcus* level of 110 MPN/100ml, which was 51 people in the water (Figure 4).

We did not run regression analyses on Solstice Creek due to the limited number of samples. It should also be noted that the sample sizes for Rock Pool and Las Virgenes Creek are somewhat small at N=18 for both sites and each type of bacteria.

We graded each site using the two methods described above in the Methods section (Table 12) for *E. coli* and *Enterococcus* exceedances. Las Virgenes received a failing grade for both FIB for both methods (Table 12). Rock Pool received a failing grade for *Enterococcus* using both methods but received a passing grade using Method 1 (303(d) listing) and a failing grade using Method 2 (Bacteria TMDL) for *E. coli*. Solstice received a passing grade for *E. coli*, with zero exceedances, but received a mixed grade for *Enterococcus* (Table 12), passing using Method 1 and failing using Method 2.

# Conclusions

Through this pilot study, Heal the Bay found that Malibu Creek State Park, specifically the Rock Pool and Las Virgenes Creek, are used heavily during the summer by swimmers. Solstice Canyon was used regularly by hikers but very minimally by swimmers. Since our objective was to assess water quality at sites that were popular for freshwater swimming, this discussion will focus on the two sites where the most swimmers were observed, Rock Pool and Las Virgenes. However, water quality was quite good at Solstice, with only one exceedance of *Enterococcus* but water levels are so low currently that swimming is not very feasible even if it was recommended.

The demographic data that we collected showed that the two sites in Malibu Creek State Park are heavily visited by the Hispanic community. We also found that while Rock Pool was visited by adults and young adults, Las Virgenes Creek was visited by more children and adults. Children are known to be more vulnerable to water pollution than adults[5] and the high percentage of children at Las Virgenes along with its poor water quality are concerning for public health. Demographic information gives us insight into at-risk populations and may help indicate demographic groups that could potentially be prioritized for outreach and education about water quality.

Water quality was very poor at Las Virgenes Creek, frequently exceeding limits, particularly for *Enterococcus*. Overall, water quality was poor to moderate at Rock Pool. Rock Pool did have lower levels of bacteria and fewer exceedances than Las Virgenes, which was a bit unexpected given the large number of people visiting the site, as well as the apparent lack of water circulation. The water at Rock Pool appears to be stagnant, with no surface flow downstream of the pool (Table 3). In contrast, Las Virgenes Creek at the bridge showed consistent and steady flow throughout the summer (Table 3). However, the exceedances of *Enterococcus* levels at both Rock Pool and Las Virgenes Creek indicate a likely public health risk. EPA recommends

[5] Wade, T.J. et al (2008) High sensitivity of children to swimming-associated gastrointestinal illness: results using a rapid assay of recreational water quality. *Epidemiology* 19(3): 375-383.

that there should not be greater than a ten percent exceedance of the STV in a 30-day period[6]. 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 Rock Pool (22%) and Las Virgenes Creek (61%) for the entire study period, which would correspond to an increased rate of illness.

Through statistical analysis, we identified factors for each site that were associated with high bacteria levels. It is interesting that these explanatory factors differ for each site. At Rock Pool, the number of people in the water was the most important predictor of bacteria levels, while at Las Virgenes Creek the sample day (weekday vs. weekend) was the most important predictor of bacteria levels. At Rock Pool, the results indicate that bacteria levels are affected by more site-specific conditions, such as the number of people in the water at a specific time. It is possible that the bacteria originates from the swimmers themselves[7]. At Las Virgenes Creek, our results indicated that bacteria levels are affected less by site-specific conditions because the sample day (whether it is a weekend or a weekday) is not specific data about that site. We considered the possibility that number of visitors may be higher on the weekends, contributing to the higher bacteria concentrations on the weekends; however, we did not find the number of people in the water to be a significant predictor of bacteria at Las Virgenes Creek. Potential contributing factors to higher bacteria concentrations on the weekends at Las Virgenes Creek should be further explored, such as upstream inputs. For instance, higher volumes of runoff could be entering Las Virgenes Creek on weekends when residents are home (e.g. possibly watering more, hosing down driveways, or washing their cars). To really understand the bacteria contributions, further sampling and investigation of additional explanatory factors should be undertaken as well as a possible source assessment of fecal indicator bacteria in Las Virgenes Creek. 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. The explanatory factor of number of people in the water should also be interpreted cautiously because it is based on the "snapshot" method of counting and does not necessarily provide an accurate representation of total number of visitors. A more accurate method of counting visitors may improve the models. Further, due to the pilot nature of this study, the sample sizes were limited (N=18); we recommend conducting additional monitoring to determine if the patterns remain consistent.

However, the results of this pilot study indicate potential water quality concerns, which should be considered by management agencies to inform possible public health protection measures. For instance, the data indicate that if there are more than 51 people in the water at Rock Pool, it is likely that the *Enterococcus* level is over 110 MPN/100ml and that if there are more than 59 people in the water, it is likely that the level of *E. coli* will be over 235 MPN/100ml. These results should be further explored to determine if a swimmer number threshold should be considered to avoid bacteria exceedances and the associated public health risks. Again, these

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

[7] Gerba, C.P. (2000) Assessment of enteric pathogen shedding by bathers during recreational activity and its impact on water quality. *Quantitative Microbiology* 2: 55-68.

possible threshold numbers should be interpreted cautiously given the uncertainty of the visitor count data and the limited sample sizes. Additional factors that may predict bacteria levels should also be explored. The relationship between water quality and day of week (weekend vs. weekday) also needs to be further explored at Las Virgenes Creek. Bacteria concentrations were highest on weekends at Las Virgenes Creek and our grading methods gave this site failing grades across the board. As such, we recommend that resource management agencies, at a minimum, consider signage at Las Virgenes Creek and Rock Pool to warn swimmers that these waters are known to exceed regulatory limits for fecal indicator bacteria, so that visitors can make an informed decision on whether or not to swim at these locations. Further, we recommend outreach and education to communities at risk, particularly targeting the Hispanic community as well as families. We recommend that signs be in both English and Spanish to reach the widest audience that is likely to swim in the Santa Monica Mountains.

In conclusion, we found that there are likely public health risks at popular swimming spots in the Santa Monica Mountains, particularly in Malibu Creek State Park. The community most at risk is the Hispanic community and there is a need for signage, education, and outreach. At a minimum, all visitors to Malibu Creek State Park should be informed of the potential health risks associated with swimming in waters with elevated bacteria levels.

**Table 1.** Air and water temperature data for the sites over the study period.

| | | Air temperature (°C) | | Water Temperature (°C) | |
|---|---|---|---|---|---|
| **Site** | **n** | **Average** | **Range** | **Average** | **Range** |
| *All sites* | 46 | 25.3 | 20-40 | 21.9 | 17.7-26 |
| *Rock Pool* | 18 | 26.9 | 20-40 | 24.6 | 21.5-26 |
| *Las Virgenes* | 18 | 25.1 | 20-32 | 20.3 | 17.7-22.5 |
| *Solstice* | 10 | 22.7 | 20-26 | 20.0 | 19-21 |

**Table 2.** Qualitative assessments of flow.

**Flow Type by Percentage***

| **Site** | ***n*** | ***None*** | ***Trickle*** | ***Intermittent*** | ***Steady*** |
|---|---|---|---|---|---|
| *All sites* | 46 | **39** | 20 | 15 | 26 |
| *Rock Pool* | 18 | **100** | 0 | 0 | 0 |
| *Las Virgenes* | 18 | 0 | 6 | 39 | **56** |
| *Solstice* | 10 | 0 | **80** | 0 | 20 |

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

**Table 3.** Qualitative assessments of water clarity and color.

| | | **Water Clarity by Percentage*** | | | | **Water Color by Percentage** | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Site** | **n** | ***Clear*** | ***Cloudy*** | ***Milky*** | ***Muddy*** | ***Clear*** | ***Brown*** | ***Green*** | ***Green/Brown*** |
| *All sites* | 46 | 43 | **48** | 2 | 7 | 35 | 2 | **54** | 9 |
| *Rock Pool* | 18 | 11 | **83** | 0 | 6 | 6 | 0 | **78** | 17 |
| *Las Virgenes* | 18 | **56** | 28 | 6 | 11 | 39 | 0 | **56** | 6 |
| *Solstice* | 10 | **80** | 20 | 0 | 0 | **80** | 10 | 10 | 0 |

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

**Table 4.** 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*** |
| *All sites* | 46 | 0 | **59** | 37 | 4 | 17 |
| *Rock Pool* | 18 | 0 | **44** | **44** | 11 | 23 |
| *Las Virgenes* | 18 | 0 | **56** | 44 | 0 | 16 |
| *Solstice* | 10 | 0 | **90** | 10 | 0 | 7 |

***** 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 5.** Animals observed in and near the water at the sample sites.

| | | **Dogs** | | **Birds** | | **Horses** | |
|---|---|---|---|---|---|---|---|
| **Site** | **n** | ***In water*** | ***Out water*** | ***In water*** | ***Out water*** | ***In water*** | ***Out water*** |
| *All sites* | 46 | 4 | 13 | 1 | 1 | 0 | 0 |
| *Rock Pool* | 18 | 1 | 5 | 0 | 0 | 0 | 0 |
| *Las Virgenes* | 18 | 0 | 3 | 1 | 1 | 0 | 0 |
| *Solstice* | 10 | 3 | 5 | 0 | 0 | 0 | 0 |

**Table 6**. Number of visitors counted, percentage of visitors in or out of the water, and estimated number of visitors for the entire study period from July 1 to September 30th for each site.

| Site | n | Total number of people counted | People in the Water (%) | People out of the Water (%) | Estimated Number of Visitors July-Sept |
|---|---|---|---|---|---|
| *All sites* | 46 | 1365 | 45% | 55% | 5999 |
| *Rock Pool* | 18 | 1034 | 48% | 52% | 4221 |
| *Las Virgenes* | 18 | 252 | 48% | 52% | 1064 |
| *Solstice* | 10 | 79 | 3% | 97% | 714 |

**Table 7**. Number of visitors counted and percentages* of different races for each site.

| Site | n | Total number of people counted | Caucasian (%) | Hispanic (%) | Asian (%) | Black (%) | Other/unsure (%) |
|---|---|---|---|---|---|---|---|
| *All sites* | 46 | 1365 | 27 | **61** | 3 | 3 | 6 |
| *Rock Pool* | 18 | 1034 | 28 | **60** | 2 | 3 | 8 |
| *Las Virgenes* | 18 | 252 | 19 | **73** | 3 | 3 | 2 |
| *Solstice* | 10 | 79 | **47** | 41 | 11 | 1 | 0 |

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

**Table 8**. Number of visitors counted and percentages* of different age groups for each site.

| Site | n | Total number of people counted | Infant: 0-2 yrs. (%) | Child: 3-12 yrs. (%) | Young Adult: 13-21 yrs. (%) | Adult: 22+ yrs. (%) |
|---|---|---|---|---|---|---|
| *All sites* | 46 | 1365 | 2 | 25 | 31 | **41** |
| *Rock Pool* | 18 | 1034 | 2 | 19 | 38 | **42** |
| *Las Virgenes* | 18 | 252 | 4 | **49** | 6 | 41 |
| *Solstice* | 10 | 79 | 0 | 22 | **39** | **39** |

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

**Table 9.** Average bacteria levels* with standard deviation (SD) for *E. coli*, *Enterococcus* (ENT), and Total Coliform (TC).

| | | ***Enterococcus*** | | | ***E. coli*** | | | **Total Coliform [a]** | |
|---|---|---|---|---|---|---|---|---|---|
| **Site** | **Number samples** | **Average (MPN/100 mL)** | **SD** | **% Exceedances[b]** | **Average (MPN/100 mL)** | **SD** | **% Exceedances [c]** | **Average (MPN/100 mL)** | **SD** |
| *Rock Pool* | 18 | 119 | 241 | 22% | 278 | 694 | 11% | 24230 | 1872 |
| *Las Virgenes* | 18 | 210 | 170 | 61% | 225 | 369 | 28% | 25000 | 0 |
| *Solstice* | 10 | 59 | 62 | 10% | 7 | 5 | 0 | 3178 | 765 |

* 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 TC because there is no regulatory limit.

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

[c] Based on the Bacteria TMDL limit of 235 MPN/100ml.

**Table 10**. Multiple regression analysis of *E. coli* levels (log transformed) at Rock Pool and Las Virgenes sites. Regressions were performed with explanatory factors followed by AIC stepwise model selection.

| **Independent Variable** | **Coefficient** | **Std. Error** | **t-value** | **p-value*** |
|---|---|---|---|---|
| Rock Pool | | | | |
| Intercept | 1.77 | 0.53 | 3.36 | **0.004** |
| # People in the water | 0.09 | 0.02 | 4.08 | **0.001** |
| # Dogs out of the water | -1.66 | 0.82 | -2.01 | 0.06 |
| $R^2$ adjusted = 0.51 | | | | |
| Las Virgenes Creek | | | | |
| Intercept | 3.55 | 0.41 | 8.66 | **<0.0001** |
| Day type (weekend vs. weekday) | 1.92 | 0.54 | 3.55 | **0.003** |
| # Dogs out of the water | -1.25 | 0.72 | -1.74 | 0.10 |
| $R^2$ adjusted = 0.42 | | | | |

* Bold indicates significance at the 0.05 level.

**Table 11.** Multiple regression analysis of *Enterococcus* levels (log transformed) at Rock Pool and Las Virgenes sites. Regressions were performed with explanatory factors followed by AIC stepwise model selection.

| **Independent Variable** | **Coefficient** | **Std. Error** | **t-value** | **p-value*** |
|---|---|---|---|---|
| Rock Pool | | | | |
| Intercept | 1.79 | 1.43 | 1.26 | 0.23 |
| Air temperature | 0.08 | 0.04 | 1.73 | 0.11 |
| Day type (weekend vs. weekday) | -1.04 | 0.47 | -2.19 | 0.05 |
| # People in the water | 0.05 | 0.01 | 4.21 | **0.001** |
| Water color (green) | -1.51 | 0.92 | -1.63 | 0.13 |
| Water color (green brown) | -0.30 | 1.18 | -0.26 | 0.80 |
| # Dogs in the water | -1.61 | 1.18 | -1.37 | 0.20 |
| $R^2$ adjusted = 0.71 | | | | |
| Las Virgenes Creek | | | | |
| Intercept | 4.61 | 0.20 | 22.64 | **<0.0001** |
| Day type (weekend vs. weekday) | 1.16 | 0.22 | 5.26 | **<0.0001** |
| # People in the water | -0.03 | 0.02 | -1.48 | 0.16 |
| $R^2$ adjusted = 0.62 | | | | |

* Bold indicates significance at the 0.05 level.

**Table 12.** 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** |
| *Rock Pool* | 4 | FAIL | FAIL | 2 | PASS | FAIL |
| *Las Virgenes* | 11 | FAIL | FAIL | 5 | FAIL | FAIL |
| *Solstice* | 1 | PASS | FAIL | 0 | PASS | PASS |

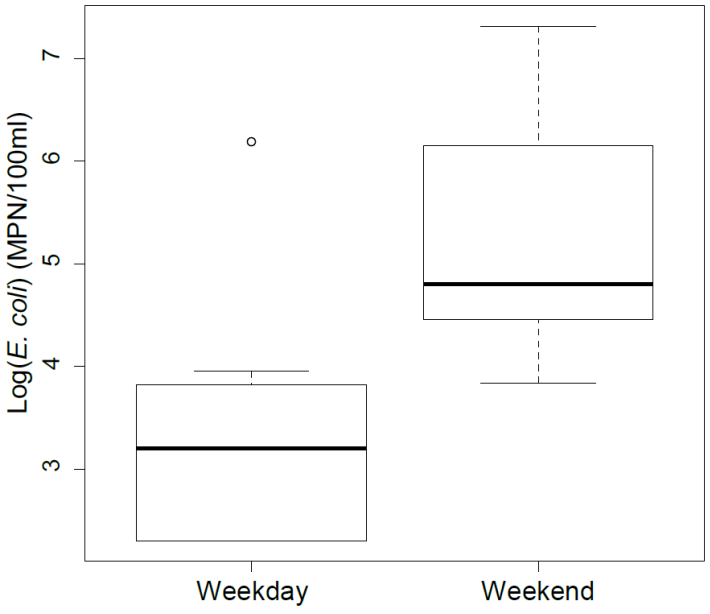
[a] Method 1 compares number of exceedances observed to the number of exceedances that would trigger a listing on California's 303(d) list as impaired. For a sample size of 3-31, this number of exceedances is 3 or greater.

[b] Method 2 compares number of exceedances observed to the number of exceedances that are allowed under the Malibu Creek Watershed Bacteria TMDL. For April 1- October 31, the number of allowable exceedances is zero. Solstice Creek is not in the Malibu Creek Watershed but is still graded for comparison. 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 Santa Monica Mountains of Southern California. Site 1 is Rock Pool; Site 2 is Las Virgenes Creek; Site 3 is Solstice Canyon.

**Figure 2**. Bacteria levels by sample day (weekday and weekend) for a) *E. coli* and b) *Enterococcus* for Las Virgenes Creek site. Bacteria levels were log transformed for normality. Weekend samples were all taken on Sundays; one holiday sample taken on Labor Day, a Monday, was included in the weekend samples. Weekday samples were taken on six Wednesdays, one Thursday, and one Monday.

a)




b)

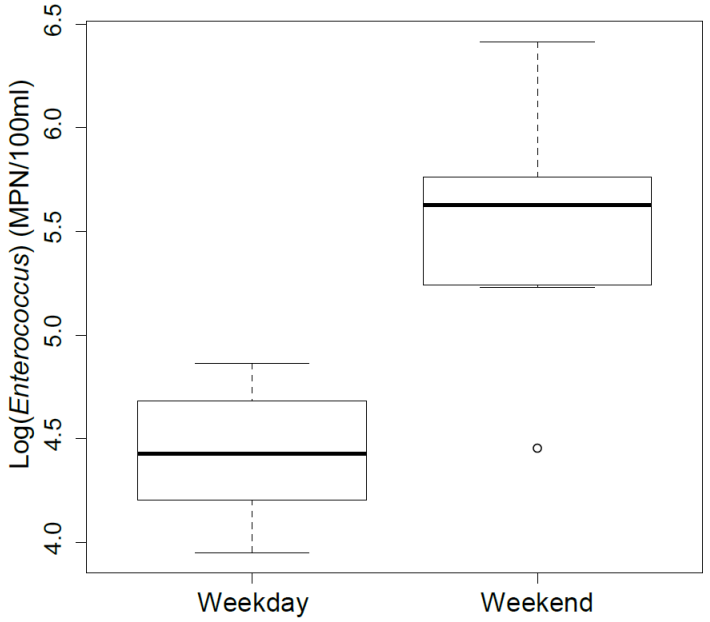


**Figure 3.** Relationship between *E. coli* levels (log transformed) and number of people in the water at Rock Pool. The best fit trendline is shown in a solid line and the regulatory limit for *E. coli* is shown in the dashed line (5.46=log(235 MPN/100ml)). The two lines meet when number of people in the water=59. When examined in a simple regression, the number of people in the water is a significant predictor of *E. coli* concentration ($p<0.01$, Adjusted $R^2=0.42$).

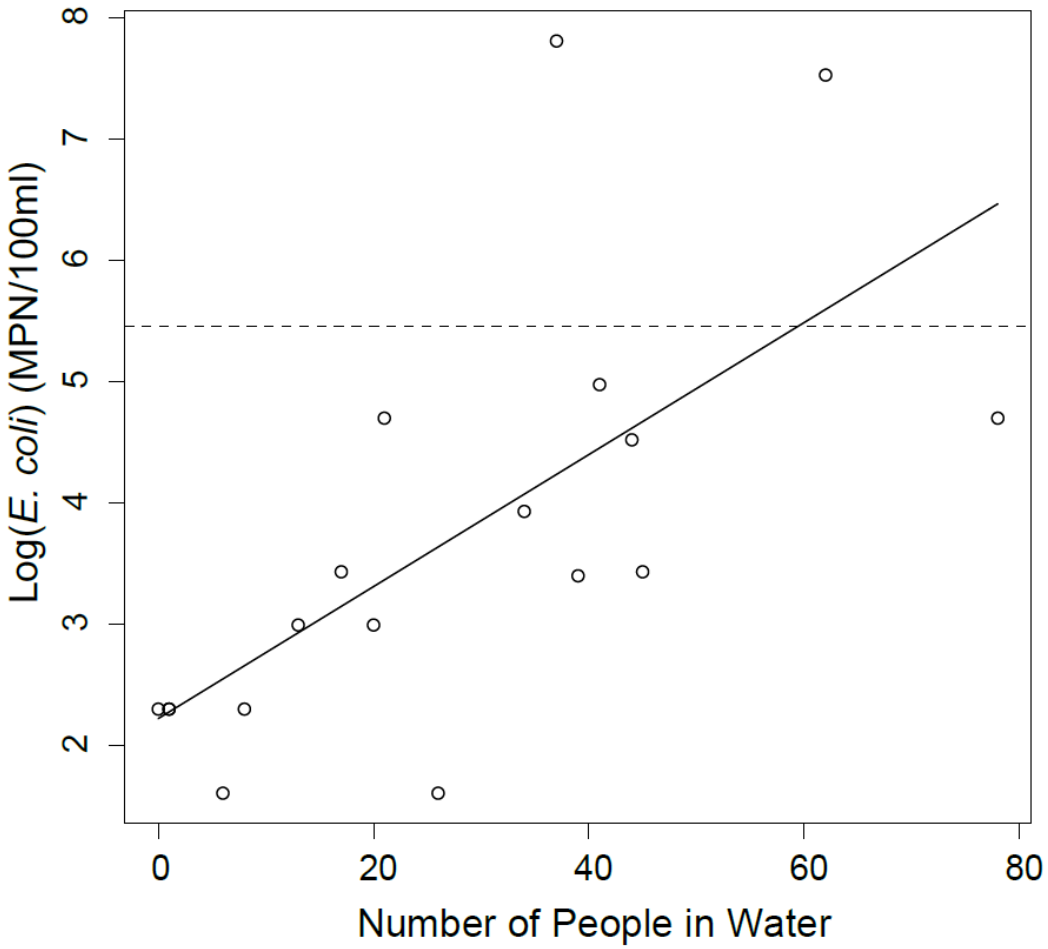
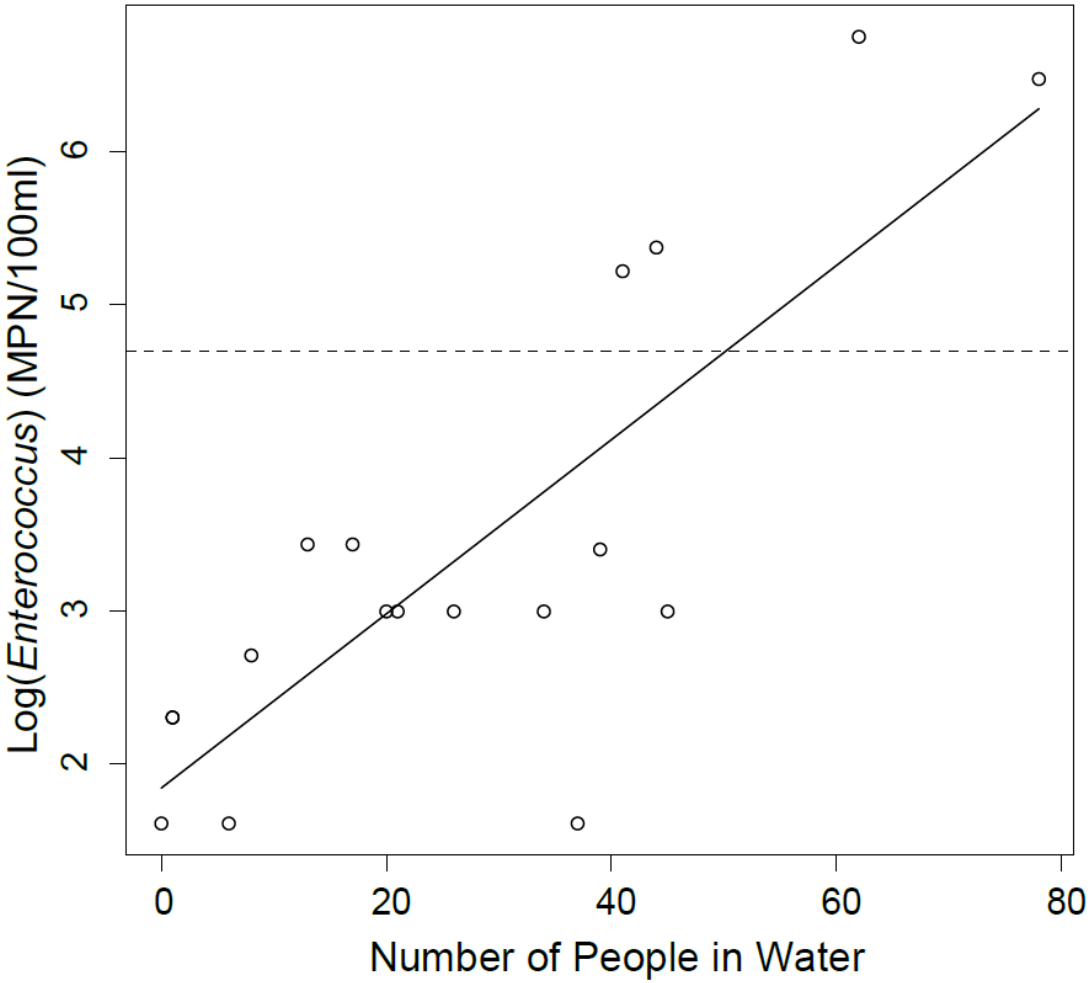


**Figure 4.** Relationship between *Enterococcus* levels (log transformed) and number of people in the water at Rock Pool. The best fit trendline is shown in a solid line and the regulatory limit for *Enterococcus* is shown in the dashed line (4.70=log(110 MPN/100ml)). The two lines meet when number of people in the water=51. When examined in a simple regression, the number of people in the water is a significant predictor of *E. coli* concentration ($p<0.0001$, Adjusted $R^2=0.62$).



## Volunteer Instructions for Freshwater Swimming Study

1. Sign up for sampling at:
    https://docs.google.com/spreadsheet/ccc?key=0Ai9MW4I_IKdzdEZTb1BQWXk4ang1b2I5bTVXdnhMelE&usp=sharing
    Sign up in pairs for safety
    Sampling will take place on Wednesday and Sunday
    Three sites: Rock Pools in Malibu Creek SP, Las Virgenes Bridge at Malibu Creek SP, Solstice Canyon

2. Pick up equipment from Heal the Bay office (1444 9th St. Santa Monica, CA) before sampling
    Coordinate with partner for pick up arrangement
    Pick up M-Thursday 9-5pm or Friday 9-2pm
    Equipment
        **Backpack**: clipboard, instructions, datasheets, parking permits, gloves, air/water thermometer, hand sanitizer, clickers, pens, Sharpies, first aid kit
        **Cooler**: ice packs, sterile bacteria bottles (3 or 4 if duplicate)

3. Go to site(s) on specified day with your partner
    Aim to go late morning to late afternoon when most people will be there
    Directions will be given to you
    Take precautions: wear sunscreen, bring water, avoid poison oak, rattlesnakes, stay on trails, be sensible!
    **If you are sampling on a weekend, call or text Frankie or Katherine with an estimated time that you will bring the sample back to the lab**
    **Katherine: 213-631-8495; Frankie 310-801-1327**

4. Collect data
    a) Record basic info: date, Site name (Rock Pools or Century Lake), Start time, Recorders (both names), Weather conditions

    b) Collect site condition data
        Water temp: Record water temperature at two different locations
            Immerse the thermometer in water for ~1minute and read
        Air temperature: hang in a shady spot, record temp at end of survey
        Flow: circle most appropriate category
        Water clarity: circle most appropriate category, tip – look at the water in bacteria bottle to assess clarity
        Water color: circle most appropriate category, tip - look at water in bacteria bottle to assess color
        Water odor: circle most appropriate category

    d) Debris/trash: survey the area (in the water and approximately 10m/30ft

away from water on all visible banks), count number of items and circle most appropriate category

Trashcans: count and record the number of trashcans that you see, record whether they have lids, and whether they are filled/overflowing

e) Bathroom Conditions: the bathroom nearest the site has been previously determined and is noted on the data sheet; note if there are any changes or unusual conditions of bathroom (out of order, cleanliness, not open, etc.)

f) Animal Use

Count the number of dogs, aquatic birds, and horses in and out of the water. This is a **snapshot in time** – if more animals arrive to the site while you are counting, you can add them to the data. If you are finished and more animals arrive, do not count them. You can make a note of this.

Record and count any other animals and make a note of type of animal

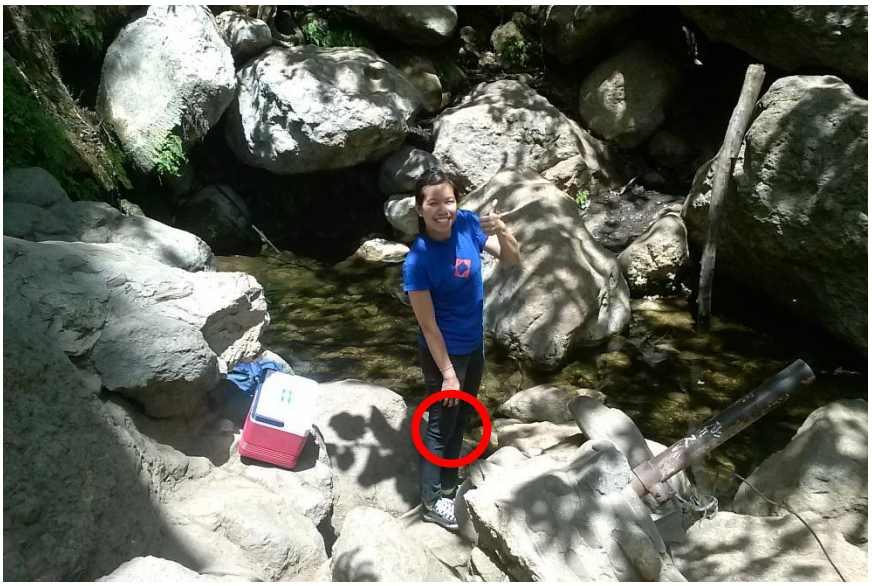
g) Collect bacteria sample near end of survey

Collect from specified spot:

**Rock Pools:** Near area where people are entering and exiting the pool to the left of the tree

**Las Virgenes:** On the downstream side of the bridge in the middle of "beach" area

**Solstice:** Around rocks near entrance to the waterfall



**How to sample:**
Wear gloves (not required)
Remove plastic seal from bottle and discard properly
Collect sample in approximately knee depth water
Take sample 6 inches below surface – **try not to just skim the surface** as sunlight kills bacteria at the surface and this won't give an accurate representation of bacteria levels
Do not rinse bottle – just fill once

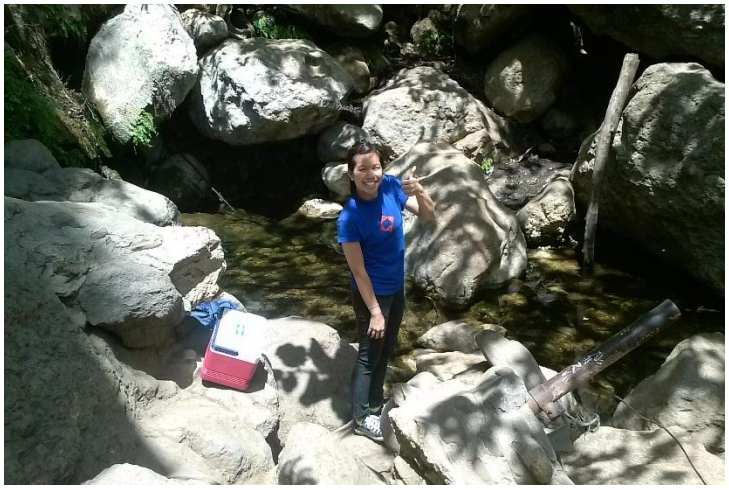
Fill bottle to line (100ml) – air bubbles are fine
Place bottle in cooler immediately
Record time sampled and on ice on datasheet
Sample must be processed within 8 hours

h) Photographs(s)- Take at designated spot(s)

**Rock Pools:** Take 2 photographs approximately mid-way between the trash cans and the water. Take one photo facing the water and one photo facing the trashcan.

**Las Virgenes**: Take 2 photographs from the middle of the "beach" where you sampled. Take one photo facing upstream (the bridge) and one photo facing downstream.

**Solstice:** Take 1 photograph of the pool.



Please text or email the pictures to Katherine as soon as possible at (213) 631-8495 or kpease@healthebay.org.

i) Human Use

You will be counting and recording visitors to the area, their use of the water, and visitor demographics. This is a **snapshot in time** – if more people arrive to the site while you are counting, you can add them to the data. If you are finished and more people arrive, do not count them. You can make a note of this.

You will be recording the age, race, and gender of individuals and marking whether they are out of the water or in the water. You can do a total count or hash marks under the appropriate column. If the area is crowded, work with your partner and do your best. Start at one side and work your way to the other side or end. Tip – if the area is crowded, you may take a photograph of the area and record human use based on the picture.

Age categories – estimate to the best of your ability

- Infant – 0 to 2 years
- Child – 3 to 12 years
- Young adult – 13 to 21years
- Adult – 22 years and over

Race categories – use your best judgement

- Caucasian
- Hispanic
- Asian

Black
Other/unsure

Gender
M – male
F – female
U – unsure (baby or hard to tell)

Location
Out of the water – currently out of the water
In the water – differentiate among 3 categories below
Wader – in water less than knee depth
Swimmer non-submerge – in deeper than knee depth but head is or has not gone under water
Swimmer submerge – in deeper than knee depth or greater you see their head go under or their hair is wet

j) Record air temperature
Remove thermometer and place in backpack

k) Fill in any notes
Evidence of toilet paper
Evidence of animals (feces, droppings, etc.)
Anything different, unusual, or interesting

5. Repeat for all sites

6. Return to car and bring samples to the Heal the Bay: 1444 9th St. Santa Monica 90401
Contact Katherine or Frankie for access to lab on weekend
Call or text designated person when you are headed back to the lab

7. Process samples or hand off to Katherine, Frankie, or other designated person
Turn on incubators immediately
Follow instructions in lab
Be sure to run a negative control (lab water)

**Helpful information to say if a visitor asks what you are doing:**
- We don't know the current levels of bacteria in these swimming sites yet
- Taking part in a citizen science program for Heal the Bay – measuring human use and water and bacterial conditions of popular swimming sites in the Malibu Creek Watershed
- Testing bacteria (E. coli, coliform, enterococcus) levels in the water
- For more information go to www.healthebay.org

# Freshwater Swimming Field Data Sheet

**Date**:_____ **Site Name**:_____ **Time**: Start: _____ End: _____

***Recorders***:_____

***Weather Conditions*:** Clear Overcast Showers Rain

***Water Temp (°C)*:** 1) _____ 2) _____ ***Air Temp (°C)*:** _____

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***Type of Flow*:** None Intermittent Trickle Steady Heavy

***Water Clarity*:** Clear Cloudy Milky Muddy Other_____

***Water Color*:** Clear Red Yellow Green Brown Gray Other_____

***Water Odor*:** None Rotten Eggs Sewage Chlorine Ammonia Musty Other_____

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***Debris/Trash*** *(circle density)*: None Light (1-10 items) Moderate (10-50 items) High (50+ items)

***Trashcans:*** Number at site _____ Do they have lids? _____ Are they full or overflowing? ____

***Conditions of nearest bathroom:*** note cleanliness, if open/closed, anything unusual

Conditions: _____

Rock Pools & Century Lake: Port-a-potties across bridge from visitor's center
Las Virgenes: Bathrooms (flush) in lower parking lot
Solstice Creek: Bathrooms (pit) just up from parking lot and amphitheater

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***Animal Use:*** Count the number of animals at the site in and out of the water

| | Dogs | Birds | Horses | Other (specify) |
|---|---|---|---|---|
| Out of water | | | | |
| In water | | | | |

***Time Samples Taken/ Time On Ice*:** Bacteria _____/_____

***Photograph(s) Taken:*** Yes ____ No ____

***Human Use:*** Count the number in each group and record. M=male; F=female; U=unsure

| | | Caucasian | | | Hispanic | | | Asian | | | Black | | | Other/ unsure | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | M | F | U | M | F | U | M | F | U | M | F | U | M | F | U |
| Infant (0-2 yrs) | Out of water | | | | | | | | | | | | | | | |
| | Wader | | | | | | | | | | | | | | | |
| | Swimmer non-submerge | | | | | | | | | | | | | | | |
| | Swimmer submerge | | | | | | | | | | | | | | | |
| Child (3-12 yrs) | Out of water | | | | | | | | | | | | | | | |
| | Wader | | | | | | | | | | | | | | | |
| | Swimmer non-submerge | | | | | | | | | | | | | | | |
| | Swimmer submerge | | | | | | | | | | | | | | | |
| Young Adult (13-21 yrs) | Out of water | | | | | | | | | | | | | | | |
| | Wader | | | | | | | | | | | | | | | |
| | Swimmer non-submerge | | | | | | | | | | | | | | | |
| | Swimmer submerge | | | | | | | | | | | | | | | |
| Adult (22+ yrs) | Out of water | | | | | | | | | | | | | | | |
| | Wader | | | | | | | | | | | | | | | |
| | Swimmer non-submerge | | | | | | | | | | | | | | | |
| | Swimmer submerge | | | | | | | | | | | | | | | |

*Notes:*_____
_____
_____
_____