

California Regional Water Quality Control Board North  
Coast Region

**Russian River Pathogen TMDL  
Beach Recreation  
Impact Study Report**

November 2013

## **INTRODUCTION**

The North Coast Regional Water Board staff are developing the Russian River Total Maximum Daily Loads (TMDLs) for pathogen indicators to identify and control contamination. Potential pathogen contamination has been identified in three areas of the lower and middle Russian River watershed (Hydrologic Units 114.10 and 114.20). Identification of the contamination led to the placement of waters within these areas on the federal Clean Water Act Section 303(d) list of impaired waters. The contamination identified has been linked to impairment of the contact recreation (REC-1) and non-contact recreation (REC-2) designated beneficial uses. Health advisories have been published and/or posted by Sonoma County and City of Santa Rosa authorities.

In 2012, North Coast Regional Water Board staff conducted a source analysis study for the development of the Russian River TMDL. The study was organized into individual tasks to collect information to help address the identified TMDL management questions (NCRWQCB 2012). One task involved measuring fecal indicator bacteria (FIB) concentrations on subsequent days for a week at two beaches with heavy recreational use. The results showed that no differences were observed in FIB concentrations during high intensity recreational use. This conclusion did not match the working hypothesis that high intensity recreational use would increase FIB concentrations.

Several logistical reasons were identified that may explain why observations that did not match the working hypothesis. First, all the samples were collected at the beach location at 8:00 AM, before any significant human water contact on the sample day and at least 10 hours after the beach location closed the prior day. Because the sampling time was not contemporaneous with human contact, the bacteriological conditions at the time of sampling may not reflect bacterial inputs from human recreational uses for at least 10 hours. Second, stream hydrology in the study area changed unexpectedly during the study period after the removal of the seasonal dam at Vacation Beach Road on the morning following the high intensity weekend recreational use. The unusual temporary hydrology caused by the dam removal (i.e., flow velocity rose while the stage dropped) may have resulted in nonrepresentative water quality conditions. Therefore, Regional Water Board staff repeated the study in 2013 to address these possible logistical issues identified that may have influenced the 2012 results.

## **MONITORING QUESTION**

The Beach Recreation Impact Study was designed to answer the following management question:

- Do recreational beach areas contribute fecal indicator bacteria from human sources?

## **WATER SAMPLING**

Intensive sampling events were conducted to assess the local impact of recreational activities on indicator bacteria levels at public beaches. Water samples were collected for analysis of *E. coli*, *Enterococcus*, All *Bacteroides*, and human-host *Bacteroides* bacteria concentrations. Triplicate samples were collected to assess variability of replicate samples.

Water samples were collected at Veteran's Memorial Beach in Healdsburg and Monte Rio Beach in Monte Rio (Table 1 on page 9). Water samples were collected daily from Tuesday, July 2, 2013, through Tuesday, July 9, 2013. Water samples were collected in the afternoon (between 12:00 and 14:00) when recreational use was assumed to be the highest.

Sonoma County Park staff counted recreators on the beach and in the water at Veteran's Memorial Beach each day at 14:00 hours. Regional Water Board staff took photographs of both beaches on each day of sample collection to provide a relative visual record of the recreation intensity (Appendix starting on page 30).

Ambient water quality information was also compiled for each day in the study. Daily high temperatures were measured in Santa Rosa (CDEC Station ID STA). Russian River stream flows were measured 3.5 miles upstream of Dry Creek, near Healdsburg (USGS gage 11464000). Stream flow gaging is not conducted near Monte Rio beach due to tidal influence from the Russian River Estuary. The water surface elevation of the estuary above sea level is gaged at Jenner by the Sonoma County Water Agency.

## **ASSESSMENT METHODS**

Visual comparisons and statistical hypothesis tests were made between different groupings of the measured FIB concentrations and other metrics. Distributions of the measured FIB concentrations are compared visually using box and whisker plots. The boxes represent the interquartile range of the distribution around the median and the whiskers represent the 10th and

*Russian River Monitoring Report - North Coast Regional Water Quality Control Board*

90th percentiles. Measurement results that were reported as below the analytical detection limit are shown in the figures as  $\frac{1}{2}$  the detection limit. The coefficient of variation (the standard deviation divided by the mean) was used to assess sample variability between replicate samples.

The measured FIB concentrations were used to assess whether any particular sampling day was significantly different than the other days of the measurement period. A nonparametric (i.e., distribution-free) inferential statistical method was used to assess differences between days. The hypothesis test makes no assumption about the frequency distributions of the measured data. Nonparametric methods are the most appropriate approach for assessing water quality data, which can have widely varying frequency distributions (Helsel and Hirsch 2002).

The Mann-Whitney U statistical test was applied to assess the difference between the daily measurements of FIB concentrations. For example, the test was used to determine if there was a significant difference in *E. coli* concentrations on Independence Day as opposed to the measurements collected on other days of the week. The hypothesis tests were considered statistically significantly different if the resulting probability of rejecting the null hypothesis ( $H_0$ ) was equal or lower than  $\alpha = 0.05$ .

The Mann-Whitney U test is a non-parametric hypothesis test for assessing whether two samples of observations come from the same distribution (Helsel and Hirsch 2002). The test null hypothesis is that the two samples are drawn from a single population. The test is similar to performing an ordinary parametric two-sample t test, but is based on ranking the data set. This statistical test is a nonparametric inferential statistical method that makes no assumption about the frequency distributions.

Significant differences between days for ambient conditions and recreation intensity were assessed using the statistical Control Chart approach. Control Charts are an approach where a single measurement can be compared to a related dataset of measurements to determine if it is an outlier. For example, a control chart approach was used to determine if recreation counts on the Independence Day Holiday were different than the rest of the days in the study period. A ninety-five percent (95%) confidence interval was used to identify significant outlying measurements.

Relationships between these variables were investigated using the Spearman's rank correlation coefficient ( $\rho$ ) (Helsel and Hirsch 2002). Spearman's rank correlation coefficient is a nonparametric statistical measure of the dependence between two variables. Spearman correlation

coefficients approach either plus one ( $\rho \sim +1.0$ ) or minus one ( $\rho \sim -1.0$ ), as the relationship become stronger. A small correlation coefficient (between -0.5 and 0.5) indicates a weak relationship between the variables. For example, a strong relationship means that when *E. coli* bacteria concentration is high in a sample, there is a large likelihood that *Enterococcus* bacteria concentrations will also be high.

## RESULTS

The FIB concentration measurements are presented in the following series of tables and figures. In several figures, *E. coli* and *Enterococcus* bacteria concentrations are visually compared to the USEPA (2012) guidelines for posting swimming advisories at beaches (i.e., Beach Action Values). Based on a presumptive risk of 36 illnesses per 1,000 recreators, the swimming advisory guidelines presented for *E. coli* and *Enterococcus* bacteria concentrations are 235 and 70 cfu/100mL, respectively.

The USEPA (2012) criteria are expressed as colony-forming units per sample volume (cfu/100mL) based on membrane filtration methods (USEPA 2002a; USEPA 2002b). Many laboratories, including the Regional Water Board Microbiology Laboratory, use a different analysis method to measure *E. coli* (and *Enterococcus*) bacteria concentrations (IDEXX 2001). Two of these methods, (Colilert® and Enterolert® Quanti-Tray/2000), have been shown to produce equivalent results as the membrane filtration methods (Budnick et al. 1996; Yakub et al. 2002) and have been approved by the USEPA for analysis and sampling under the Clean Water Act.

The following results are presented:

- FIB concentrations (i.e., *E. coli*, *Enterococcus*, All *Bacteroides*, and human-host *Bacteroides* bacteria) are presented in Tables 2 and 3 (pages 10 and 11) and in Figures 1 – 10 (pages 22 - 27).
- Median values and sampling variability are presented in Tables 4 and 5 (pages 12 and 13).
- Ambient water quality conditions in the Russian River Watershed (maximum daily air temperature, stream flow and estuary water surface elevation) are presented in Table 6 (page 14) and Figures 11 – 13 (pages 28 and 29).

- Recreator counts collected during the study period from Veteran's Memorial Beach in Healdsburg are presented in Table 7 (page 14) and Figure 14 (page 29).
- Results for tests of statistically significant differences between daily FIB concentrations are presented in Tables 8 -11 (pages 15 - 18).
- Results for tests of statistically significant differences between daily ambient water quality conditions (i.e., maximum air temperature, Russian River stream flow and estuary stage) are presented in Table 12 (page 19).
- Results for tests of statistically significant differences between daily recreation (i.e., people swimming, people on the shore, total recreators) are presented in Table 13 (page 19).
- Relationships between FIB concentrations, ambient conditions, and recreation intensity are presented in Tables 14 and 15 (pages 20 and 21).
- Photographs of each beach during each sampling event appear in the Appendix (starting on page 30).

## FINDINGS

Based on the assessments of FIB concentrations presented in this report, Regional Water Board staff can make the following findings:

- A much higher relative sampling variability was observed in replicate samples for *E. coli* bacteria collected from Monte Rio Beach (56%) as compared to Veteran's Memorial Beach in Healdsburg (39%).
- Sampling variability was similar at both beaches for *Enterococcus* bacteria with the mean coefficient of variation ranging from 57% - 61%. Sampling variability was similar for All *Bacteroides* and humanhost *Bacteroides* bacteria with the mean ranging from 16% - 28%. Sampling variability was similar at both beaches for the percentage of human-host *Bacteroides* bacteria with the mean ranging from 5.4% to 5.6% of All *Bacteroides* bacteria.
- USEPA (2012) Beach Action Values were exceeded for both *E. coli* and  
*Russian River Monitoring Report - North Coast Regional Water Quality Control Board*

*Enterococcus* bacteria on July 2<sup>nd</sup> at Monte Rio Beach and July 4<sup>th</sup> at Veteran's Memorial Beach in Healdsburg.

- Significantly higher *E. coli* and *Enterococcus* bacteria concentrations were observed on July 2<sup>nd</sup> at Monte Rio Beach and on July 4<sup>th</sup> at Veteran's Memorial Beach compared to other days during the sampling period.
- Significantly higher *Bacteroides* bacteria concentrations were observed on July 3<sup>rd</sup> at Monte Rio Beach and on July 5<sup>th</sup> and July 6<sup>th</sup> at Veteran's Memorial Beach compared to other days during the sampling period.
- Significantly higher *E. coli* and *Enterococcus* bacteria concentrations were followed the next day by significantly higher *Bacteroides* bacteria concentrations at both beaches.
- Daily maximum air temperature was significantly higher on July 4<sup>th</sup> as compared to the rest of the study period. The Russian River estuary elevation dropped significantly after July 2<sup>nd</sup> due to a natural breach in the sandbar at the confluence with the Pacific Ocean. No significant difference was observed during the study period in Russian River stream flows near Healdsburg which is near the Veteran's Memorial Beach.
- Both swimming recreation and number of people on shore were significantly higher on July 4<sup>th</sup> at Veteran's Memorial Beach than other days during the study period.
- *E. coli* bacteria concentrations showed a relatively strong association with *Enterococcus* bacteria concentrations at both beaches. Humanhost *Bacteroides* bacteria concentrations showed a relatively strong association with All *Bacteroides* bacteria concentrations at both beaches.
- *Enterococcus* bacteria concentrations measured at Monte Rio Beach showed a relatively strong association with Russian River estuary water surface elevation, with higher concentrations observed during higher water surface elevations.
- The percentage of human-host *Bacteroides* at Veteran's Memorial Beach showed a relatively strong association with swimming

recreation, with the higher percentages of human-host *Bacteroides* observed on days with a larger number of people swimming.

## CITATIONS

Budnick, G.E., Howard, R.T., and D.R. Mayo. 1996. Evaluation of Enterolert for enumeration of enterococci in recreational waters. *Applied and Environmental Microbiology* 62(10): 3881–3884.

Butkus, S. 2012. Russian River Human Impact Study Quality Assurance Project Plan. North Coast Regional Water Quality Control Board, Santa Rosa, CA.

Helsel, D.R. and R.M. Hirsch. 2002. Statistical Methods in Water Resources, Techniques of Water Resources Investigations, Book 4, Chapter A3, 510 p. U.S. Geological Survey, Washington DC. Available at <http://water.usgs.gov/pubs/twri/twri4a3/>

IDEXX. 2001. Colilert® and Enterolert® Test Pack Procedures IDEXX Laboratories, Inc., Westbrook, Maine.  
([http://www.idexx.com/view/xhtml/en\\_us/water/water-microbiology.jsf](http://www.idexx.com/view/xhtml/en_us/water/water-microbiology.jsf)).

NCRWQCB 2011. Water Quality Control Plan for the North Coast Region. North Coast Regional Water Quality Control Board, Santa Rosa, CA.

NCRWQCB 2012. Russian River Pathogen TMDL 2011-2012 Monitoring Report. North Coast Regional Water Quality Control Board. Santa Rosa, CA.

USEPA 2002a. Method 1600: Enterococci in Water by Membrane Filtration Using membrane-Enterococcus Indoxyl-β-D-Glucoside Agar (mEI). Available at: <http://www.epa.gov/microbes/1600sp02.pdf>

USEPA 2002b. Method 1603: Escherichia coli (E. coli) in Water by Membrane Filtration Using Modified Membrane-Thermotolerant Escherichia coli Agar (Modified mTEC). Available at: <http://www.epa.gov/microbes/1603sp02.pdf>

USEPA 2012. Recreational Water Quality Criteria. Publication No. EPA 820F-12-058. U.S. Environmental Protection Agency, Washington, DC.

Yakub, G.P., Castric, D.A., Stadterman-Knauer, K.L., , Tobin, M.J., Blazina, M., Heineman, T.N., Yee, G.Y. and L. Frazier. 2002. Evaluation of Colilert and Enterolert Defined Substrate Methodology for Wastewater Applications. *Water Environment Research* Vol. 74, No. 2 (Mar. - Apr., 2002), pp. 131-135.  
*Russian River Monitoring Report - North Coast Regional Water Quality Control Board*

## **TABLES**

Table 1. Sampling Locations

| <b>Station ID</b> | <b>Station Name</b>                    | <b>Location</b> | <b>Latitude</b> | <b>Longitude</b> |
|-------------------|----------------------------------------|-----------------|-----------------|------------------|
| 114RR2940         | Veteran's Memorial Beach<br>Healdsburg | Old Redwood Hwy | 38.604650       | -121.122922      |
| 114RR0898         | Monte Rio Beach Monte<br>Rio           | Bohemian Hwy    | 38.466258       | -122.990628      |

Table 2. FIB Concentrations Measured at Veteran's Memorial Beach in Healdsburg

| Date     | <i>E. coli</i><br>Bacteria Concentration<br>(MPN/100mL) |                |                | <i>Enterococcus</i><br>Bacteria Concentrations<br>(MPN/100mL) |                |                |
|----------|---------------------------------------------------------|----------------|----------------|---------------------------------------------------------------|----------------|----------------|
|          | Replicate<br>1                                          | Replicate<br>2 | Replicate<br>3 | Replicate<br>1                                                | Replicate<br>2 | Replicate<br>3 |
| 7/2/2013 | 97                                                      | 160            | 175            | 10                                                            | 10             | 52             |
| 7/3/2013 | 52                                                      | 63             | 85             | 10                                                            | 20             | 52             |
| 7/4/2013 | 345                                                     | 355            | 422            | 31                                                            | 31             | 86             |
| 7/5/2013 | 41                                                      | 52             | 52             | 10                                                            | 10             | 20             |
| 7/6/2013 | <10                                                     | 20             | 75             | <10                                                           | <10            | 20             |
| 7/7/2013 | 41                                                      | 52             | 52             | <10                                                           | 10             | 10             |
| 7/8/2013 | 10                                                      | 20             | 41             | <10                                                           | <10            | 10             |
| 7/9/2013 | 20                                                      | 20             | 41             | <10                                                           | 10             | 10             |

Table 2. FIB Concentrations Measured at Veteran's Memorial Beach in Healdsburg *continued*

| Date     | <i>All Bacteroides</i><br>Bacteria Concentrations<br>(16SrRNA genes /100mL) |                |                | <i>Human-host Bacteroides</i><br>Bacteria Concentration<br>(16SrRNA genes /100mL) |                |                |
|----------|-----------------------------------------------------------------------------|----------------|----------------|-----------------------------------------------------------------------------------|----------------|----------------|
|          | Replicate<br>1                                                              | Replicate<br>2 | Replicate<br>3 | Replicate<br>1                                                                    | Replicate<br>2 | Replicate<br>3 |
| 7/2/2013 | 410,819                                                                     | 256,254        | 212,061        | 7,220                                                                             | 7,726          | 6,651          |
| 7/3/2013 | 256,011                                                                     | 298,242        | 195,971        | 17,624                                                                            | 17,222         | 12,084         |
| 7/4/2013 | 274,628                                                                     | 202,410        | 252,187        | 15,639                                                                            | 12,929         | 14,552         |
| 7/5/2013 | 473,481                                                                     | 559,920        | 596,587        | 39,265                                                                            | 42,450         | 41,321         |
| 7/6/2013 | 508,299                                                                     | 601,597        | 447,774        | 23,272                                                                            | 28,859         | 21,975         |
| 7/7/2013 | 314,956                                                                     | 347,926        | 351,360        | 22,586                                                                            | 26,368         | 30,810         |

|          |         |         |         |        |        |        |
|----------|---------|---------|---------|--------|--------|--------|
| 7/8/2013 | 223,690 | 221,228 | 279,901 | 10,211 | 9,826  | 16,092 |
| 7/9/2013 | 340,509 | 430,148 | 249,224 | 13,106 | 17,897 | 9,448  |

Table 3. FIB Concentrations Measured at Monte Rio Beach in Monte Rio

| Date     | <i>E. coli</i><br>Bacteria Concentration<br>(MPN/100mL) |                |                | <i>Enterococcus</i><br>Bacteria Concentration<br>(MPN/100mL) |                |                |
|----------|---------------------------------------------------------|----------------|----------------|--------------------------------------------------------------|----------------|----------------|
|          | Replicate<br>1                                          | Replicate<br>2 | Replicate<br>3 | Replicate<br>1                                               | Replicate<br>2 | Replicate<br>3 |
| 7/2/2013 | 243                                                     | 432            | 471            | 160                                                          | 324            | 556            |
| 7/3/2013 | 10                                                      | 31             | 74             | 30                                                           | 63             | 63             |
| 7/4/2013 | 109                                                     | 148            | 173            | 10                                                           | 20             | 30             |
| 7/5/2013 | 85                                                      | 97             | 109            | 20                                                           | 20             | 20             |
| 7/6/2013 | 20                                                      | 20             | 31             | <10                                                          | 10             | 75             |
| 7/7/2013 | <10                                                     | 10             | 52             | <10                                                          | 10             | 41             |
| 7/8/2013 | <10                                                     | 10             | 20             | <10                                                          | 10             | 10             |
| 7/9/2013 | <10                                                     | <10            | 20             | <10                                                          | <10            | 10             |

Table 3. FIB Concentrations Measured at Monte Rio Beach in Monte Rio  
*continued*

| Date     | <i>All Bacteroides</i><br>Bacteria Concentration<br>(16SrRNA genes/100mL) |                |                | <i>Human-host Bacteroides</i><br>Bacteria Concentration<br>(16SrRNA genes /100mL) |                |                |
|----------|---------------------------------------------------------------------------|----------------|----------------|-----------------------------------------------------------------------------------|----------------|----------------|
|          | Replicate<br>1                                                            | Replicate<br>2 | Replicate<br>3 | Replicate<br>1                                                                    | Replicate<br>2 | Replicate<br>3 |
| 7/2/2013 | 291,032                                                                   | 100,513        | 240,338        | 16,694                                                                            | 4,008          | 12,081         |
| 7/3/2013 | 515,771                                                                   | 1,350,840      | 1,152,990      | 55,932                                                                            | 230,744        | 131,396        |
| 7/4/2013 | 263,062                                                                   | 258,241        | 304,757        | 14,784                                                                            | 14,227         | 16,471         |

|          |         |         |         |        |        |        |
|----------|---------|---------|---------|--------|--------|--------|
| 7/5/2013 | 436,653 | 360,675 | 476,626 | 20,360 | 15,545 | 18,712 |
| 7/6/2013 | 319,557 | 330,139 | 307,608 | 14,611 | 13,786 | 15,296 |
| 7/7/2013 | 487,683 | 246,136 | 381,618 | 26,216 | 11,589 | 21,630 |
| 7/8/2013 | 183,527 | 185,162 | 134,491 | 7,301  | 6,481  | 6,244  |
| 7/9/2013 | 188,328 | 237,167 | 178,982 | 6,971  | 12,434 | 7,830  |

Table 4. Sample Statistics of FIB Concentrations Measured at Veteran's Memorial Beach in Healdsburg

| Date     | <i>E. coli</i> Bacteria          |                              | <i>Enterococcus</i> Bacteria     |                              |
|----------|----------------------------------|------------------------------|----------------------------------|------------------------------|
|          | Median Concentration (MPN/100mL) | Coefficient of Variation (%) | Median Concentration (MPN/100mL) | Coefficient of Variation (%) |
| 7/2/2013 | 160                              | 29%                          | 10                               | 101%                         |
| 7/3/2013 | 63                               | 25%                          | 20                               | 80%                          |
| 7/4/2013 | 355                              | 11%                          | 31                               | 64%                          |
| 7/5/2013 | 52                               | 13%                          | 10                               | 43%                          |
| 7/6/2013 | 20                               | 111%                         | <10                              | 87%                          |
| 7/7/2013 | 52                               | 13%                          | 10                               | 35%                          |
| 7/8/2013 | 20                               | 67%                          | <10                              | 43%                          |
| 7/9/2013 | 20                               | 45%                          | 10                               | 35%                          |
| Mean     | 93                               | 39%                          | 10                               | 61%                          |

Table 4. Sample Statistics of FIB Concentrations Measured at Veteran's Memorial Beach in Healdsburg *continued*

| Date | All <i>Bacteroides</i> Bacteria            |                              | Human-host <i>Bacteroides</i> Bacteria     |                              |                                                          |
|------|--------------------------------------------|------------------------------|--------------------------------------------|------------------------------|----------------------------------------------------------|
|      | Median Concentration (16SrRNA genes/100mL) | Coefficient of Variation (%) | Median Concentration (16SrRNA genes/100mL) | Coefficient of Variation (%) | Median Percentage of All <i>Bacteroides</i> Bacteria (%) |

|          |         |     |        |     |      |
|----------|---------|-----|--------|-----|------|
| 7/2/2013 | 256,254 | 36% | 7,220  | 7%  | 3.0% |
| 7/3/2013 | 256,011 | 21% | 17,222 | 20% | 6.2% |
| 7/4/2013 | 252,187 | 15% | 14,552 | 9%  | 5.8% |
| 7/5/2013 | 559,920 | 12% | 41,321 | 4%  | 7.6% |
| 7/6/2013 | 508,299 | 15% | 23,272 | 15% | 4.8% |
| 7/7/2013 | 347,926 | 6%  | 26,368 | 15% | 7.6% |
| 7/8/2013 | 223,690 | 14% | 10,211 | 29% | 4.6% |
| 7/9/2013 | 340,509 | 27% | 13,106 | 31% | 3.8% |
| Mean     | 343,100 | 18% | 19,159 | 16% | 5.4% |

Table 5. Sample Statistics of Replicate FIB Concentrations Measured at Monte Rio Beach

| Date     | <i>E. coli</i> Bacteria          |                              | <i>Enterococcus</i> Bacteria     |                              |
|----------|----------------------------------|------------------------------|----------------------------------|------------------------------|
|          | Median Concentration (MPN/100mL) | Coefficient of Variation (%) | Median Concentration (MPN/100mL) | Coefficient of Variation (%) |
| 7/2/2013 | 432                              | 32%                          | 324                              | 57%                          |
| 7/3/2013 | 31                               | 85%                          | 63                               | 37%                          |
| 7/4/2013 | 148                              | 23%                          | 20                               | 50%                          |
| 7/5/2013 | 97                               | 12%                          | 20                               | 0%                           |
| 7/6/2013 | 20                               | 27%                          | 10                               | 130%                         |
| 7/7/2013 | 10                               | 116%                         | 10                               | 104%                         |
| 7/8/2013 | 10                               | 65%                          | 10                               | 35%                          |
| 7/9/2013 | 5                                | 87%                          | 5                                | 43%                          |
| Mean     | 94                               | 56%                          | 58                               | 57%                          |

Table 5. Sample Statistics of FIB Replicate Concentrations Measured at Monte Rio Beach *continued*

| Date | All <i>Bacteroides</i> Bacteria | Human-host <i>Bacteroides</i> Bacteria |
|------|---------------------------------|----------------------------------------|
|------|---------------------------------|----------------------------------------|

|          | <b>Median<br/>Concentration<br/>(16SrRNA<br/>genes/100mL)</b> | <b>Coefficient<br/>of<br/>Variation<br/>(%)</b> | <b>Median<br/>Concentration<br/>(16SrRNA<br/>genes/100mL)</b> | <b>Coefficient<br/>of<br/>Variation<br/>(%)</b> | <b>Median<br/>Percentage<br/>of All<br/><i>Bacteroides</i><br/>Bacteria<br/>(%)</b> |
|----------|---------------------------------------------------------------|-------------------------------------------------|---------------------------------------------------------------|-------------------------------------------------|-------------------------------------------------------------------------------------|
| 7/2/2013 | 240,338                                                       | 47%                                             | 12,081                                                        | 59%                                             | 5.0%                                                                                |
| 7/3/2013 | 1,152,990                                                     | 43%                                             | 131,396                                                       | 63%                                             | 11.4%                                                                               |
| 7/4/2013 | 263,062                                                       | 9%                                              | 14,784                                                        | 8%                                              | 5.5%                                                                                |
| 7/5/2013 | 436,653                                                       | 14%                                             | 18,712                                                        | 13%                                             | 4.3%                                                                                |
| 7/6/2013 | 319,557                                                       | 4%                                              | 14,611                                                        | 5%                                              | 4.6%                                                                                |
| 7/7/2013 | 381,618                                                       | 33%                                             | 21,630                                                        | 38%                                             | 5.4%                                                                                |
| 7/8/2013 | 183,527                                                       | 17%                                             | 6,481                                                         | 8%                                              | 4.0%                                                                                |
| 7/9/2013 | 188,328                                                       | 16%                                             | 7,830                                                         | 32%                                             | 4.4%                                                                                |
| Mean     | 395,759                                                       | 23%                                             | 28,441                                                        | 28%                                             | 5.6%                                                                                |

Table 6. Ambient Conditions during the Study Period

| <b>Date</b> | <b>Daily High<br/>Air Temperature<br/>(°F)</b> | <b>Daily Mean<br/>Stream Flow at<br/>Healdsburg<br/>(cfs)</b> | <b>Daily Mean Russian<br/>River Estuary<br/>Elevation (feet)</b> |
|-------------|------------------------------------------------|---------------------------------------------------------------|------------------------------------------------------------------|
| 7/2/2013    | 92                                             | 78                                                            | 7.64                                                             |
| 7/3/2013    | 84                                             | 77                                                            | 4.89                                                             |
| 7/4/2013    | 96                                             | 85                                                            | 1.83                                                             |
| 7/5/2013    | 81                                             | 82                                                            | 2.12                                                             |
| 7/6/2013    | 76                                             | 87                                                            | 1.87                                                             |
| 7/7/2013    | 75                                             | 91                                                            | 1.78                                                             |
| 7/8/2013    | 78                                             | 93                                                            | 1.49                                                             |
| 7/9/2013    | 89                                             | 96                                                            | 1.31                                                             |
| Mean        | 84                                             | 86                                                            | 2.87                                                             |

Table 7. Recreator Counts at Veteran's Memorial Beach in Healdsburg

| Date     | People Swimming | People on the Shore | Total Potential Recreators |
|----------|-----------------|---------------------|----------------------------|
| 7/2/2013 | 72              | 116                 | 188                        |
| 7/3/2013 | 96              | 224                 | 320                        |
| 7/4/2013 | 376             | 1,413               | 1,789                      |
| 7/5/2013 | 173             | 411                 | 584                        |
| 7/6/2013 | 82              | 212                 | 294                        |
| 7/7/2013 | 102             | 209                 | 311                        |
| 7/8/2013 | 42              | 91                  | 133                        |
| 7/9/2013 | 48              | 72                  | 120                        |
| Mean     | 124             | 343                 | 467                        |

Table 8. Mann-Whitney *U* Hypothesis Test Results of FIB Concentrations Measured at Veteran's Memorial Beach in Healdsburg  
**Bold Blue** font indicates a statistically significant difference

| Date     | <i>E. coli</i> Bacteria              |              | <i>Enterococcus</i> Bacteria         |              |
|----------|--------------------------------------|--------------|--------------------------------------|--------------|
|          | Mann-Whitney <i>U</i> Test Statistic | Probability  | Mann-Whitney <i>U</i> Test Statistic | Probability  |
| 7/2/2013 | 54                                   | <b>0.048</b> | 39.5                                 | 0.464        |
| 7/3/2013 | 41                                   | 0.403        | 46                                   | 0.185        |
| 7/4/2013 | 63                                   | <b>0.006</b> | 59                                   | <b>0.012</b> |
| 7/5/2013 | 28.5                                 | 0.792        | 35                                   | 0.749        |
| 7/6/2013 | 16.5                                 | 0.187        | 19                                   | 0.253        |
| 7/7/2013 | 28.5                                 | 0.792        | 20.5                                 | 0.314        |

|          |      |              |      |       |
|----------|------|--------------|------|-------|
| 7/8/2013 | 9    | <b>0.048</b> | 12.5 | 0.082 |
| 7/9/2013 | 11.5 | 0.078        | 20.5 | 0.314 |

Table 8. Mann-Whitney *U* Hypothesis Test Results of FIB Concentrations Measured at Veteran's Memorial Beach in Healdsburg *continued*  
**Bold Blue** font indicates a statistically significant difference

| Date     | All<br><i>Bacteroides</i> Bacteria      |              | Human-host<br><i>Bacteroides</i> Bacteria |              |
|----------|-----------------------------------------|--------------|-------------------------------------------|--------------|
|          | Mann-Whitney <i>U</i><br>Test Statistic | Probability  | Mann-Whitney <i>U</i><br>Test Statistic   | Probability  |
| 7/2/2013 | 23                                      | 0.458        | 0                                         | <b>0.006</b> |
| 7/3/2013 | 15                                      | 0.150        | 28                                        | 0.760        |
| 7/4/2013 | 13                                      | 0.106        | 23                                        | 0.458        |
| 7/5/2013 | 59                                      | <b>0.016</b> | 63                                        | <b>0.006</b> |
| 7/6/2013 | 58                                      | <b>0.021</b> | 48                                        | 0.150        |
| 7/7/2013 | 38                                      | 0.570        | 51                                        | 0.089        |
| 7/8/2013 | 14                                      | 0.127        | 17                                        | 0.206        |
| 7/9/2013 | 32                                      | 0.965        | 22                                        | 0.407        |

Table 8. Mann-Whitney *U* Hypothesis Test Results of FIB Concentrations Measured at Veteran's Memorial Beach in Healdsburg *continued*  
**Bold Blue** font indicates a statistically significant difference

| Date     | Percentage of Human-host<br><i>Bacteroides</i> Bacteria |              |
|----------|---------------------------------------------------------|--------------|
|          | Mann-Whitney <i>U</i><br>Test Statistic                 | Probability  |
| 7/2/2013 | 0                                                       | <b>0.006</b> |

|          |      |       |
|----------|------|-------|
| 7/3/2013 | 43   | 0.315 |
| 7/4/2013 | 38   | 0.570 |
| 7/5/2013 | 57   | 0.026 |
| 7/6/2013 | 23.5 | 0.484 |
| 7/7/2013 | 59.5 | 0.014 |
| 7/8/2013 | 22   | 0.406 |
| 7/9/2013 | 9    | 0.049 |

Table 9. Summary of Dates showing a Significant Difference in Concentration and Magnitude Measured at Veteran's Memorial Beach in Healdsburg

| Bacteria Concentration                      | Date     | Magnitude |
|---------------------------------------------|----------|-----------|
| <i>E. coli</i>                              | 7/2/2013 | High      |
|                                             | 7/4/2013 | High      |
|                                             | 7/8/2013 | Low       |
| <i>Enterococcus</i>                         | 7/4/2013 | High      |
| All <i>Bacteroides</i>                      | 7/5/2013 | High      |
|                                             | 7/6/2013 | High      |
| Human-host <i>Bacteroides</i>               | 7/2/2013 | Low       |
|                                             | 7/5/2013 | High      |
| Percentage of Human-host <i>Bacteroides</i> | 7/2/2013 | Low       |
|                                             | 7/5/2013 | High      |
|                                             | 7/7/2013 | High      |
|                                             | 7/9/2013 | Low       |

Table 10. Mann-Whitney *U* Hypothesis Test Results of FIB Concentrations Measured at Monte Rio Beach in Monte Rio

*Russian River Monitoring Report - North Coast Regional Water Quality Control Board*

**Bold Blue** font indicates a statistically significant difference

| Date     | <i>E. coli</i> Bacteria              |              | <i>Enterococcus</i> Bacteria         |              |
|----------|--------------------------------------|--------------|--------------------------------------|--------------|
|          | Mann-Whitney <i>U</i> Test Statistic | Probability  | Mann-Whitney <i>U</i> Test Statistic | Probability  |
| 7/2/2013 | 63                                   | <b>0.006</b> | 63                                   | <b>0.005</b> |
| 7/3/2013 | 27.5                                 | 0.725        | 49.5                                 | 0.111        |
| 7/4/2013 | 53.5                                 | 0.053        | 32.5                                 | 0.929        |
| 7/5/2013 | 45.5                                 | 0.219        | 34.5                                 | 0.790        |
| 7/6/2013 | 25.5                                 | 0.598        | 26.5                                 | 0.658        |
| 7/7/2013 | 16.5                                 | 0.188        | 23.5                                 | 0.479        |
| 7/8/2013 | 12                                   | 0.087        | 14                                   | 0.121        |
| 7/9/2013 | 8.5                                  | <b>0.043</b> | 8.5                                  | <b>0.042</b> |

Table 10. Mann-Whitney *U* Hypothesis Test Results of FIB Concentrations Measured at Monte Rio Beach in Monte Rio *continued*

**Bold Blue** font indicates a statistically significant difference

| Date     | All <i>Bacteroides</i> Bacteria      |              | Human-host <i>Bacteroides</i> Bacteria |              |
|----------|--------------------------------------|--------------|----------------------------------------|--------------|
|          | Mann-Whitney <i>U</i> Test Statistic | Probability  | Mann-Whitney <i>U</i> Test Statistic   | Probability  |
| 7/2/2013 | 15                                   | 0.150        | 20                                     | 0.315        |
| 7/3/2013 | 63                                   | <b>0.006</b> | 63                                     | <b>0.006</b> |
| 7/4/2013 | 28                                   | 0.760        | 34                                     | 0.827        |
| 7/5/2013 | 50                                   | 0.106        | 46                                     | 0.206        |
| 7/6/2013 | 39                                   | 0.513        | 30                                     | 0.896        |
| 7/7/2013 | 42                                   | 0.359        | 42                                     | 0.359        |

|          |    |              |    |              |
|----------|----|--------------|----|--------------|
| 7/8/2013 | 5  | <b>0.021</b> | 4  | <b>0.016</b> |
| 7/9/2013 | 10 | 0.061        | 13 | 0.106        |

Table 10. Mann-Whitney U Hypothesis Test Results of FIB Concentrations Measured at Monte Rio Beach in Monte Rio *continued*  
**Bold Blue** font indicates a statistically significant difference

| Date     | Percentage of Human-host <i>Bacteroides</i> Bacteria |              |
|----------|------------------------------------------------------|--------------|
|          | Mann-Whitney <i>U</i> Test Statistic                 | Probability  |
| 7/2/2013 | 32.5                                                 | 0.930        |
| 7/3/2013 | 63                                                   | <b>0.006</b> |
| 7/4/2013 | 47.5                                                 | 0.162        |
| 7/5/2013 | 15.5                                                 | 0.162        |
| 7/6/2013 | 23                                                   | 0.458        |
| 7/7/2013 | 42.5                                                 | 0.336        |
| 7/8/2013 | 9                                                    | <b>0.049</b> |
| 7/9/2013 | 19                                                   | 0.275        |

Table 11. Summary of Dates showing a Significant Difference in Concentration and Magnitude Measured at Monte Rio Beach in Monte Rio

| Bacteria Concentration | Date     | Magnitude |
|------------------------|----------|-----------|
| <i>E. coli</i>         | 7/2/2013 | High      |
|                        | 7/9/2013 | Low       |
| <i>Enterococcus</i>    | 7/2/2013 | High      |
|                        | 7/9/2013 | Low       |

|                                                            |          |      |
|------------------------------------------------------------|----------|------|
| <b>All<br/><i>Bacteroides</i></b>                          | 7/3/2013 | High |
|                                                            | 7/8/2013 | Low  |
| <b>Human-host<br/><i>Bacteroides</i></b>                   | 7/3/2013 | High |
|                                                            | 7/8/2013 | Low  |
| <b>Percentage of<br/>Human-host<br/><i>Bacteroides</i></b> | 7/3/2013 | High |
|                                                            | 7/8/2013 | Low  |

Table 12. Control Chart Test Results of Ambient Conditions Measured in the Russian River Watershed during the Study Period

**Bold Blue** font indicates a statistically significant difference

| Date     | Daily Value Exceeds 95% Confidence Level |                                      |                  |
|----------|------------------------------------------|--------------------------------------|------------------|
|          | Daily Maximum Air Temperature            | Daily Mean Russian River Stream Flow | Daily Mean Stage |
| 7/2/2013 | No                                       | No                                   | <b>Yes</b>       |
| 7/3/2013 | No                                       | No                                   | No               |
| 7/4/2013 | <b>Yes</b>                               | No                                   | No               |
| 7/5/2013 | No                                       | No                                   | No               |
| 7/6/2013 | No                                       | No                                   | No               |
| 7/7/2013 | No                                       | No                                   | No               |
| 7/8/2013 | No                                       | No                                   | No               |
| 7/9/2013 | No                                       | No                                   | No               |

Table 13. Control Chart Hypothesis Test Results of Ambient Conditions Measured in the Russian River Watershed during the Study Period

**Bold Blue** font indicates a statistically significant difference

| Date | Value Exceeds 95% Confidence Level |                     |                            |
|------|------------------------------------|---------------------|----------------------------|
|      | People Swimming                    | People on the Shore | Total Potential Recreators |

|          |     |     |     |
|----------|-----|-----|-----|
| 7/2/2013 | No  | No  | No  |
| 7/3/2013 | Yes | Yes | Yes |
| 7/4/2013 | No  | No  | No  |
| 7/5/2013 | No  | No  | No  |
| 7/6/2013 | No  | No  | No  |
| 7/7/2013 | No  | No  | No  |
| 7/8/2013 | No  | No  | No  |
| 7/9/2013 | No  | No  | No  |

Table 14. Spearman Correlation Coefficient Matrix for Bacteria Concentrations Measured at Veteran's Memorial Beach in Healdsburg  
**Bold Blue** font indicates a relatively strong relationship between variables

| Correlated Variables                     | <i>E. coli</i> | <i>Enterococcus</i> | All <i>Bacteroides</i> | Humanhost <i>Bacteroides</i> | Percent of Humanhost <i>Bacteroides</i> |
|------------------------------------------|----------------|---------------------|------------------------|------------------------------|-----------------------------------------|
| <i>E. coli</i>                           | 1.00           |                     |                        |                              |                                         |
| <i>Enterococcus</i>                      | <b>0.858</b>   | 1.00                |                        |                              |                                         |
| All <i>Bacteroides</i>                   | -0.350         | -0.326              | 1.00                   |                              |                                         |
| Human-host <i>Bacteroides</i>            | -0.288         | -0.162              | <b>0.772</b>           | 1.00                         |                                         |
| Percent of Human-host <i>Bacteroides</i> | 0.092          | 0.159               | 0.219                  | <b>0.742</b>                 | 1.00                                    |
| Russian River Stream Flow                | -0.633         | -0.547              | 0.074                  | 0.042                        | -0.178                                  |
| Maximum Air Temperature                  | 0.595          | 0.560               | -0.447                 | -0.599                       | -0.422                                  |
| People Swimming                          | 0.545          | 0.507               | 0.171                  | 0.499                        | <b>0.723</b>                            |

|                            |       |       |       |       |              |
|----------------------------|-------|-------|-------|-------|--------------|
| <b>People on the Shore</b> | 0.539 | 0.551 | 0.116 | 0.418 | 0.619        |
| <b>Total Recreators</b>    | 0.571 | 0.555 | 0.063 | 0.426 | <b>0.714</b> |

Table 15. Spearman Correlation Coefficient Matrix for Bacteria Concentrations Measured at Monte Rio Beach in Monte Rio

**Bold Blue** font indicates a relatively strong relationship between variables

| <b>Correlated Variable</b>               | <b><i>E. coli</i></b> | <b><i>Enterococcus</i></b> | <b>All <i>Bacteroides</i></b> | <b>Humanhost <i>Bacteroides</i></b> | <b>Percent of Humanhost <i>Bacteroides</i></b> |
|------------------------------------------|-----------------------|----------------------------|-------------------------------|-------------------------------------|------------------------------------------------|
| <i>E. coli</i>                           | 1.00                  |                            |                               |                                     |                                                |
| <i>Enterococcus</i>                      | <b>0.764</b>          | 1.00                       |                               |                                     |                                                |
| All <i>Bacteroides</i>                   | 0.082                 | 0.249                      | 1.00                          |                                     |                                                |
| Human-host <i>Bacteroides</i>            | 0.177                 | 0.343                      | <b>0.947</b>                  | 1.00                                |                                                |
| Percent of Human-host <i>Bacteroides</i> | 0.229                 | 0.421                      | 0.547                         | <b>0.716</b>                        | 1.00                                           |
| Russian River Estuary Stage              | 0.684                 | <b>0.781</b>               | 0.473                         | 0.462                               | 0.341                                          |
| Maximum Air Temperature                  | 0.552                 | 0.325                      | -0.250                        | -0.081                              | 0.210                                          |

## FIGURES

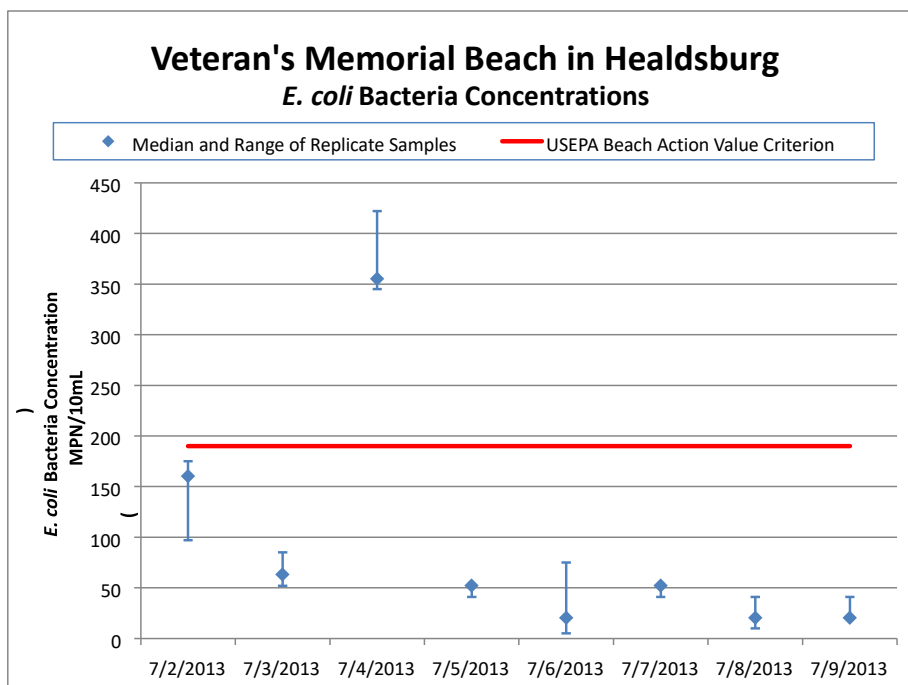


Figure 1. *E. coli* Bacteria Concentrations Measured at Veteran's Memorial Beach in Healdsburg

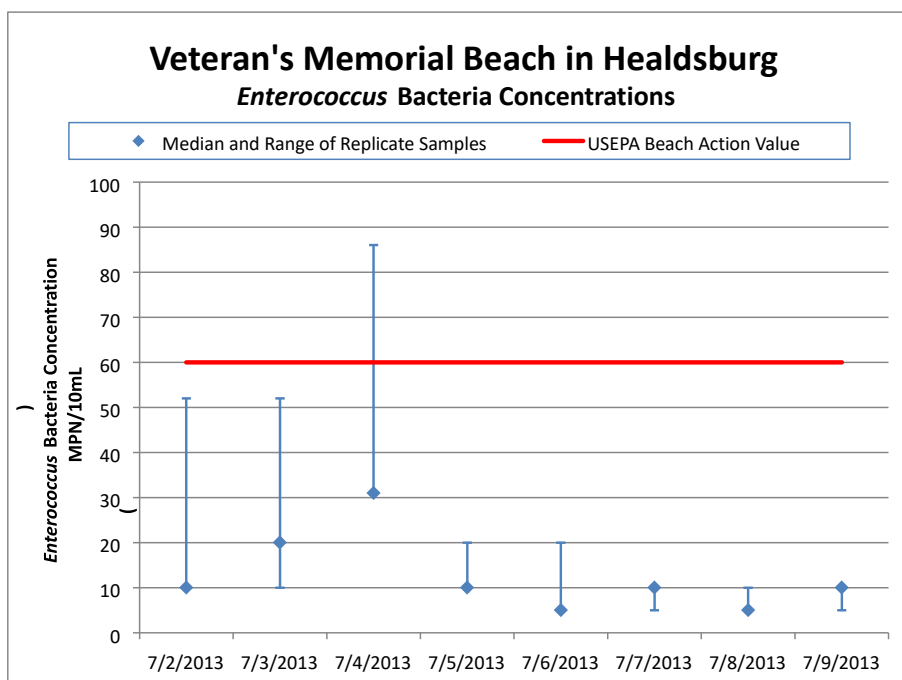


Figure 2. *Enterococcus* Bacteria Concentrations Measured at Veteran's Memorial Beach in Healdsburg

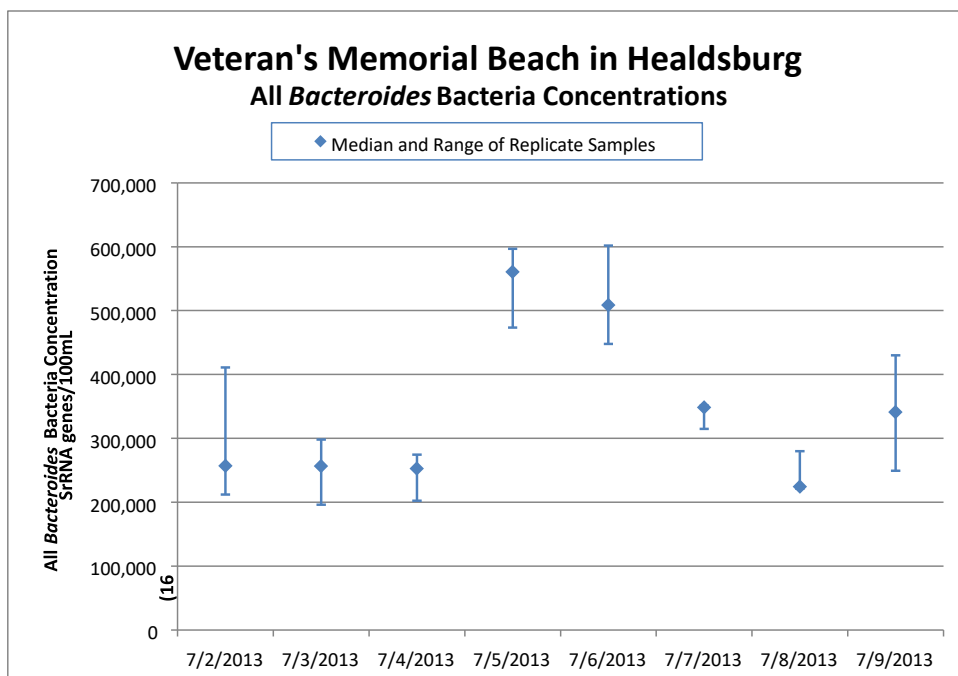


Figure 3. All *Bacteroides* Bacteria Concentrations Measured at Veteran's Memorial Beach in Healdsburg

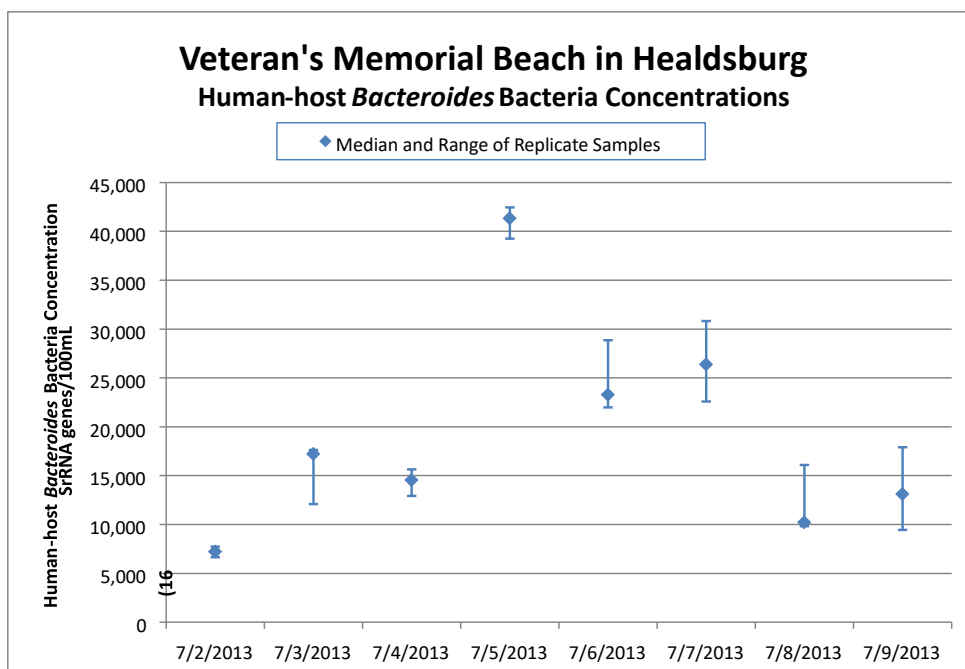


Figure 4. Human-host *Bacteroides* Bacteria Concentrations Measured at Veteran's Memorial Beach in Healdsburg

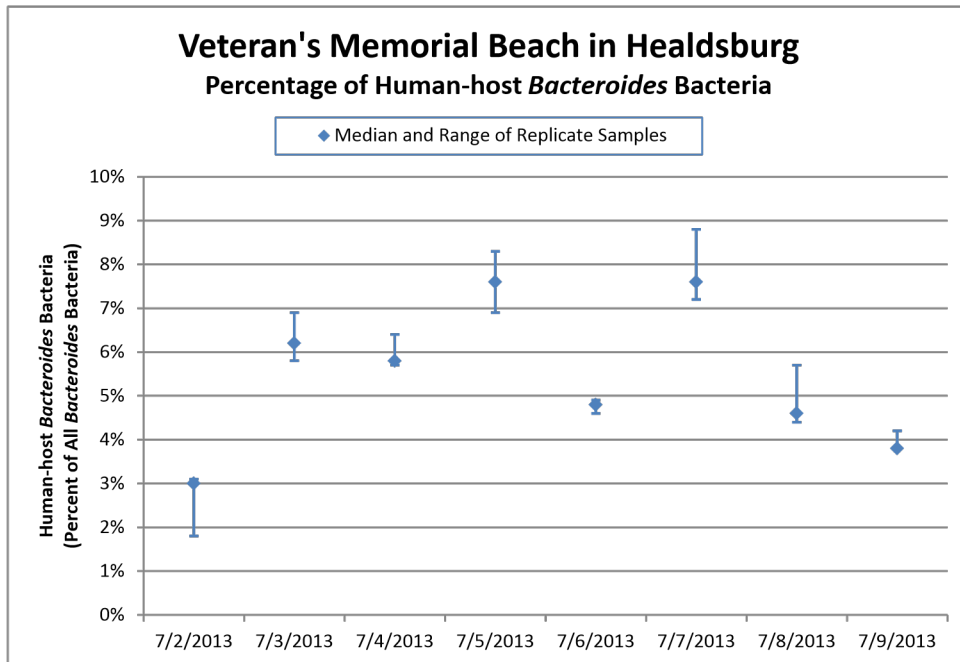


Figure 5. Percentage of Human-host *Bacteroides* Bacteria Measured at Veteran's Memorial Beach in Healdsburg

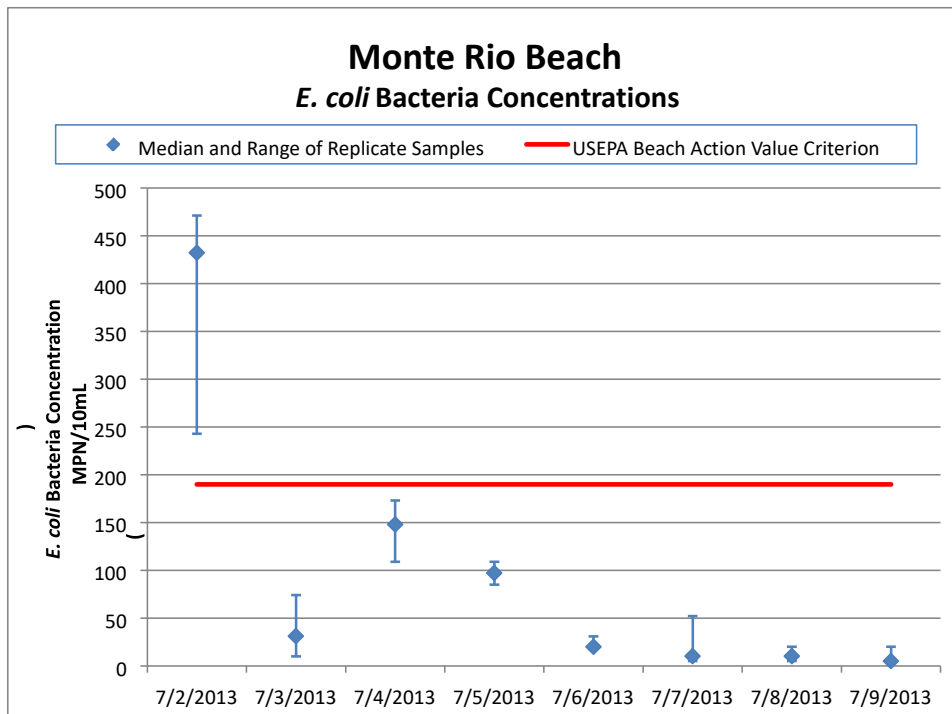


Figure 6. *E. coli* Bacteria Concentrations Measured at Veteran's Memorial Beach in Healdsburg

Russian River Monitoring Report - North Coast Regional Water Quality Control Board

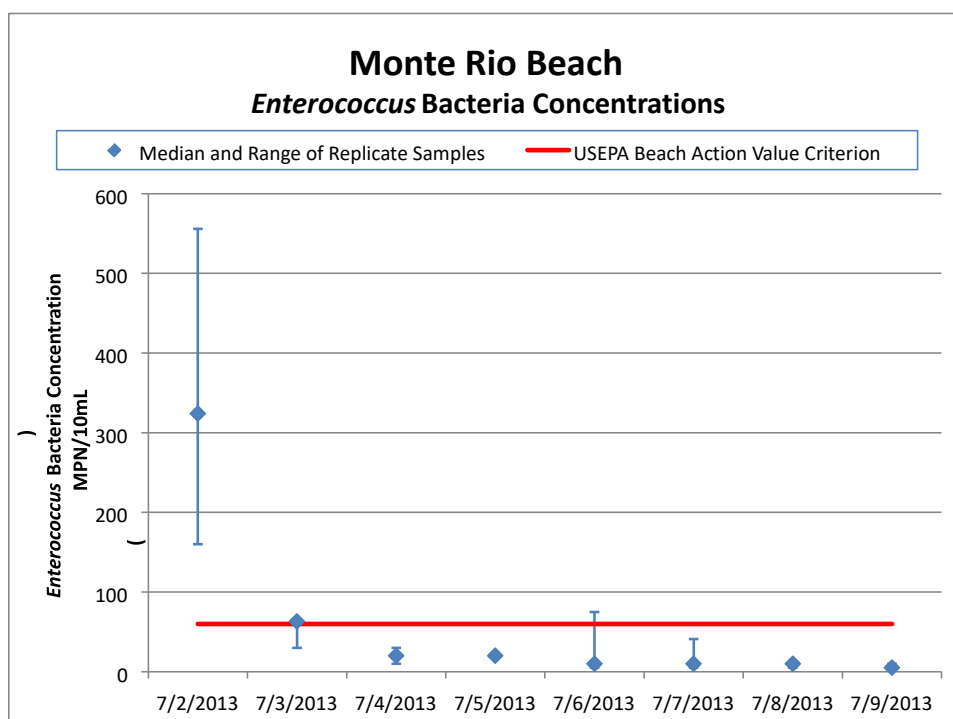


Figure 7. *Enterococcus* Bacteria Concentrations Measured at Veteran's Memorial Beach in Healdsburg

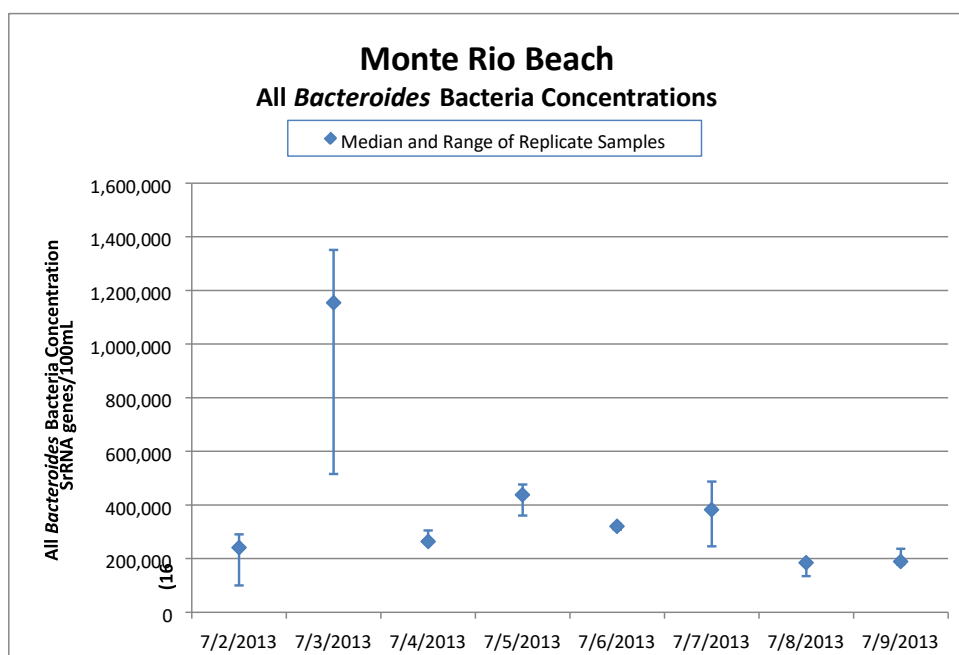


Figure 8. All *Bacteroides* Bacteria Concentrations Measured at Veteran's Memorial Beach in Healdsburg

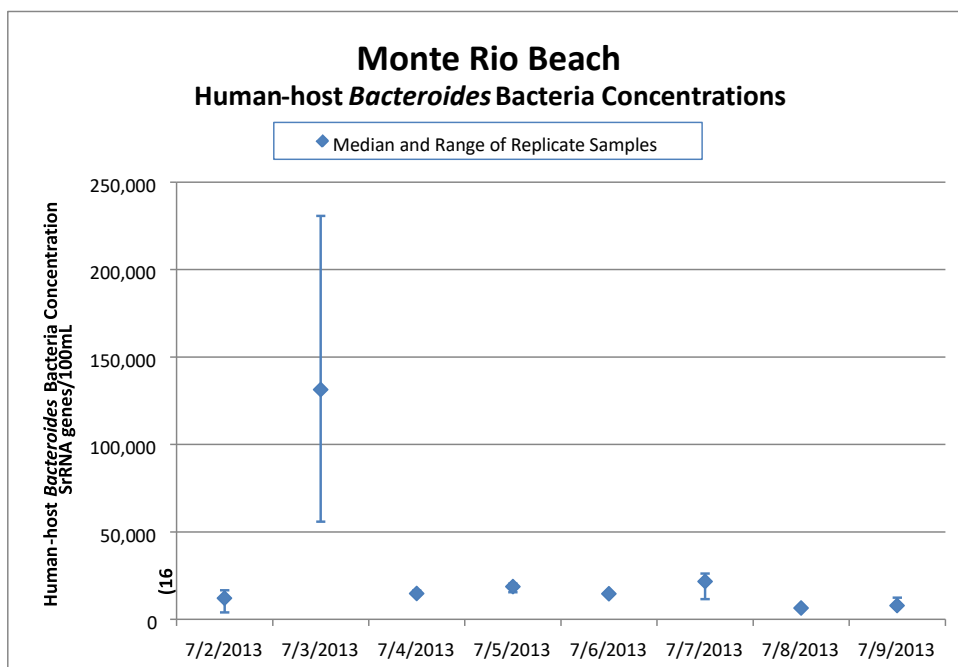


Figure 9. Human-host *Bacteroides* Bacteria Concentrations Measured at Veteran's Memorial Beach in Healdsburg

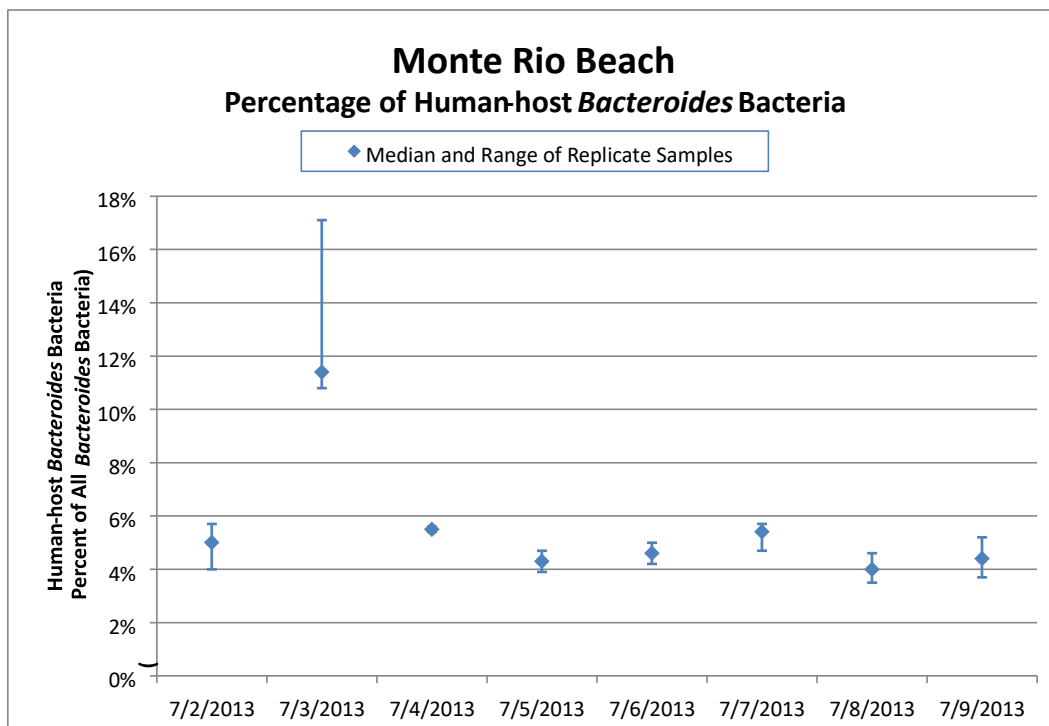


Figure 10. Percent of Human-host *Bacteroides* Bacteria Measured at Veteran's Memorial Beach in Healdsburg

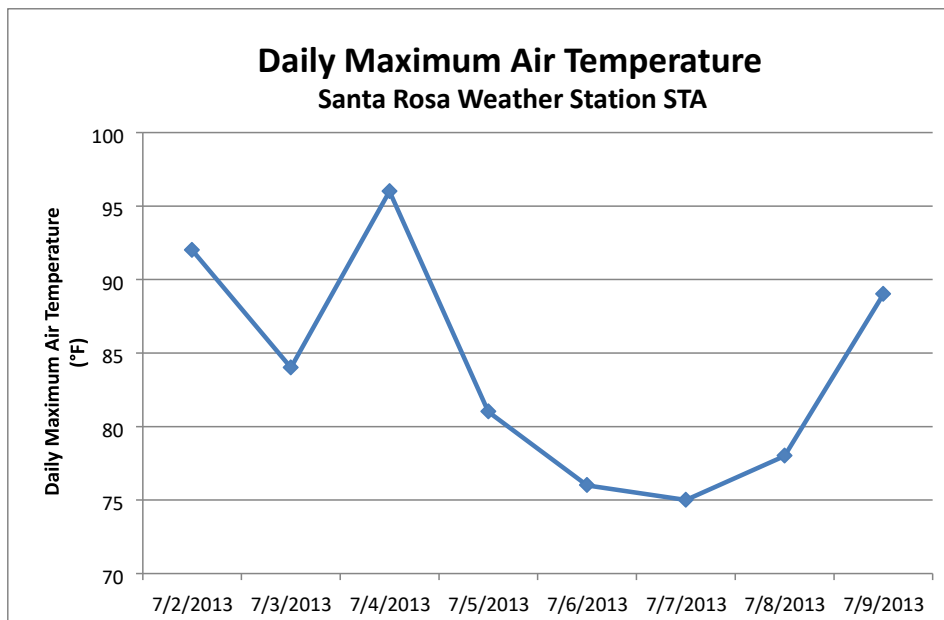


Figure 11. Daily Maximum Air Temperature Measured in Santa Rosa

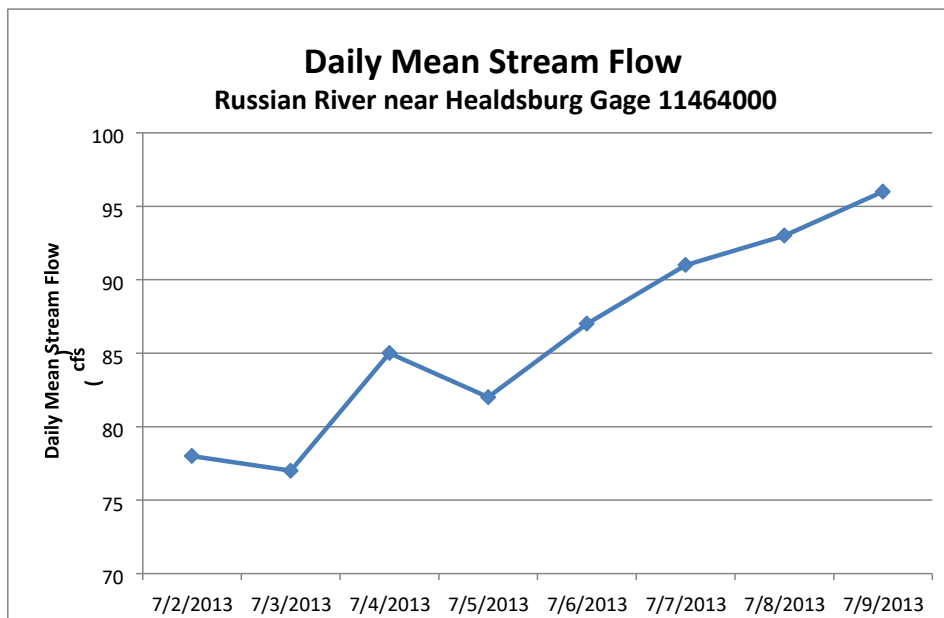


Figure 12. Daily Mean Stream Flow Measured in the Russian River near Healdsburg

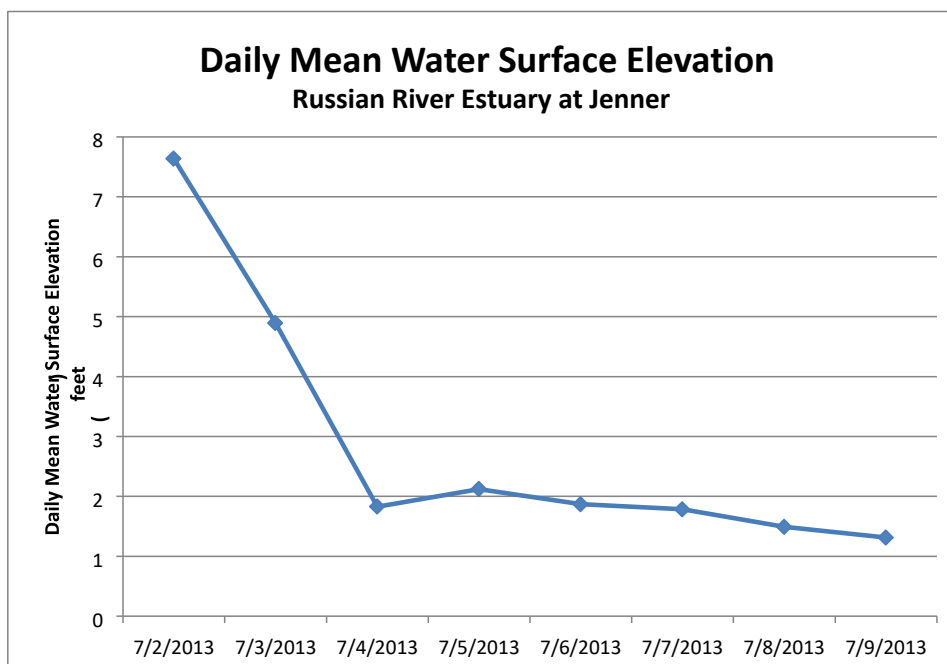


Figure 13. Daily Mean Water Surface Elevation Measured in the Russian River Estuary at Jenner

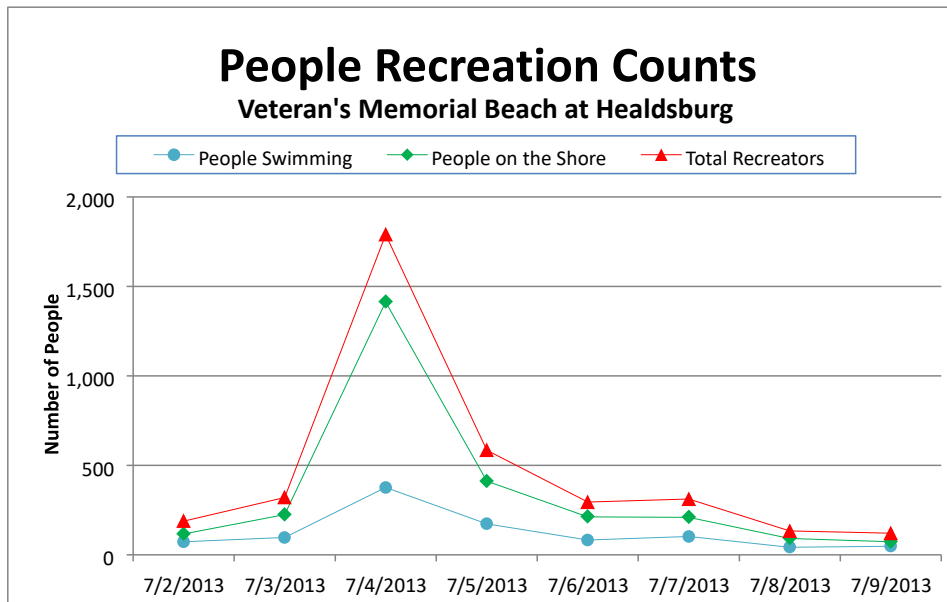


Figure 14. Counts of People Recreating at Veteran's Memorial Beach in Healdsburg.

## **APPENDIX**

Photographs of each beach at the time of sampling.



West Monte Rio Beach on Tuesday, July 2, 2013 at 14:30



West Monte Rio Beach on Wednesday, July 3, 2013 at 14:00



West Monte Rio Beach on Thursday, July 4, 2013 at 14:00



West Monte Rio Beach on Friday, July 5, 2013 at 14:00



West Monte Rio Beach on Saturday, July 6, 2013 at 14:00



West Monte Rio Beach on Sunday, July 7, 2013 at 1400  
:



West Monte Rio Beach on Monday, July 8, 2013 at 14:00



West Monte Rio Beach on Tuesday, July 9, 2013 at 13:30



East Monte Rio Beach on Tuesday, July 2, 2013 at 14:30



East Monte Rio Beach on Wednesday, July 3, 2013 at 14:00



East Monte Rio Beach on Thursday, July 4, 2013 at 14:00



East Monte Rio Beach on Friday, July 5, 2013 at 14:00



East Monte Rio Beach on Saturday, July 6, 2013 at 14:00



East Monte Rio Beach on Sunday, July 7, 2013 at 14:00



East Monte Rio Beach on Monday, July 8, 2013 at 14:00



East Monte Rio Beach on Tuesday, July 9, 2013 at 13:30



Veteran's Memorial Beach in Healdsburg on Tuesday, July 2, 2013 at 13:00



Veteran's Memorial Beach in Healdsburg on Wednesday, July 3, 2013 at 13:00 (note the foggy camera lens)



Veteran's Memorial Beach in Healdsburg on Thursday, July 4, 2013 at 12::30



Veteran's Memorial Beach in Healdsburg on Friday, July 5, 2013 at 12:30



Veteran's Memorial Beach in Healdsburg on Saturday, July 6, 2013 at 12:30



Veteran's Memorial Beach in Healdsburg on Sunday, July 7, 2013 at 12:30



Veteran's Memorial Beach in Healdsburg on Monday, July 8, 2013 at 12:30



Veteran's Memorial Beach in Healdsburg on Tuesday, July 9, 2013 at 12:30