

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 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 (ρ) (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 human-host *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 *Enterococcus* bacteria on July 2nd at Monte Rio Beach and July 4th at Veteran’s Memorial Beach in Healdsburg.

- Significantly higher *E. coli* and *Enterococcus* bacteria concentrations were observed on July 2nd at Monte Rio Beach and on July 4th at Veteran's Memorial Beach compared to other days during the sampling period.
- Significantly higher *Bacteroides* bacteria concentrations were observed on July 3rd at Monte Rio Beach and on July 5th and July 6th 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 4th as compared to the rest of the study period. The Russian River estuary elevation dropped significantly after July 2nd 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 4th 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. Human-host *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

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TABLES

Table 1. Sampling Locations

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

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

Date	<i>E. coli</i> Bacteria Concentration (MPN/100mL)			<i>Enterococcus</i> Bacteria Concentrations (MPN/100mL)		
	Replicate 1	Replicate 2	Replicate 3	Replicate 1	Replicate 2	Replicate 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	All <i>Bacteroides</i> Bacteria Concentrations (16SrRNA genes /100mL)			Human-host <i>Bacteroides</i> Bacteria Concentration (16SrRNA genes /100mL)		
	Replicate 1	Replicate 2	Replicate 3	Replicate 1	Replicate 2	Replicate 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> Bacteria Concentration (MPN/100mL)			<i>Enterococcus</i> Bacteria Concentration (MPN/100mL)		
	Replicate 1	Replicate 2	Replicate 3	Replicate 1	Replicate 2	Replicate 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	All <i>Bacteroides</i> Bacteria Concentration (16SrRNA genes/100mL)			Human-host <i>Bacteroides</i> Bacteria Concentration (16SrRNA genes /100mL)		
	Replicate 1	Replicate 2	Replicate 3	Replicate 1	Replicate 2	Replicate 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		
	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	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

Date	Daily High Air Temperature (°F)	Daily Mean Stream Flow at Healdsburg (cfs)	Daily Mean Russian River Estuary Elevation (feet)
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	0.048	39.5	0.464
7/3/2013	41	0.403	46	0.185
7/4/2013	63	0.006	59	0.012
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	0.048	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 <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	23	0.458	0	0.006
7/3/2013	15	0.150	28	0.760
7/4/2013	13	0.106	23	0.458
7/5/2013	59	0.016	63	0.006
7/6/2013	58	0.021	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 <i>Bacteroides</i> Bacteria	
	Mann-Whitney <i>U</i> Test Statistic	Probability
7/2/2013	0	0.006
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

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	0.006	63	0.005
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	0.043	8.5	0.042

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	0.006	63	0.006
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	0.021	4	0.016
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	0.006
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	0.049
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
All <i>Bacteroides</i>	7/3/2013	High
	7/8/2013	Low
Human-host <i>Bacteroides</i>	7/3/2013	High
	7/8/2013	Low
Percentage of Human-host <i>Bacteroides</i>	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	Yes
7/3/2013	No	No	No
7/4/2013	Yes	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>	<i>All Bacteroides</i>	<i>Human-host Bacteroides</i>	<i>Percent of Human-host Bacteroides</i>
<i>E. coli</i>	1.00				
<i>Enterococcus</i>	0.858	1.00			
<i>All Bacteroides</i>	-0.350	-0.326	1.00		
<i>Human-host Bacteroides</i>	-0.288	-0.162	0.772	1.00	
<i>Percent of Human-host Bacteroides</i>	0.092	0.159	0.219	0.742	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	0.723
People on the Shore	0.539	0.551	0.116	0.418	0.619
Total Recreators	0.571	0.555	0.063	0.426	0.714

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

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

FIGURES

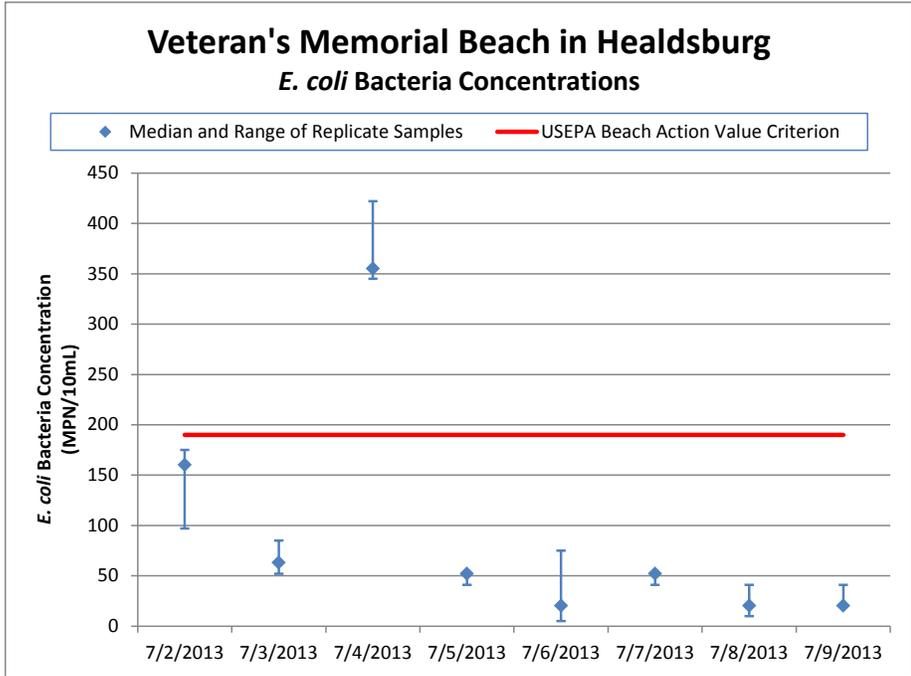


Figure 1. *E. coli* Bacteria Concentrations Measured at Veteran’s Memorial Beach in Healdsburg

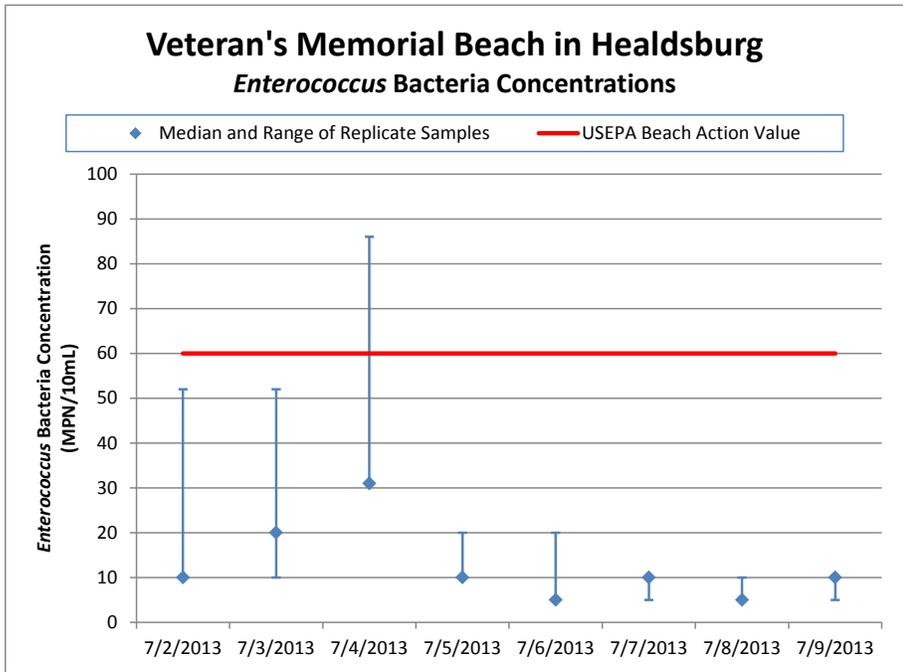


Figure 2. *Enterococcus* Bacteria Concentrations Measured at Veteran’s Memorial Beach in Healdsburg

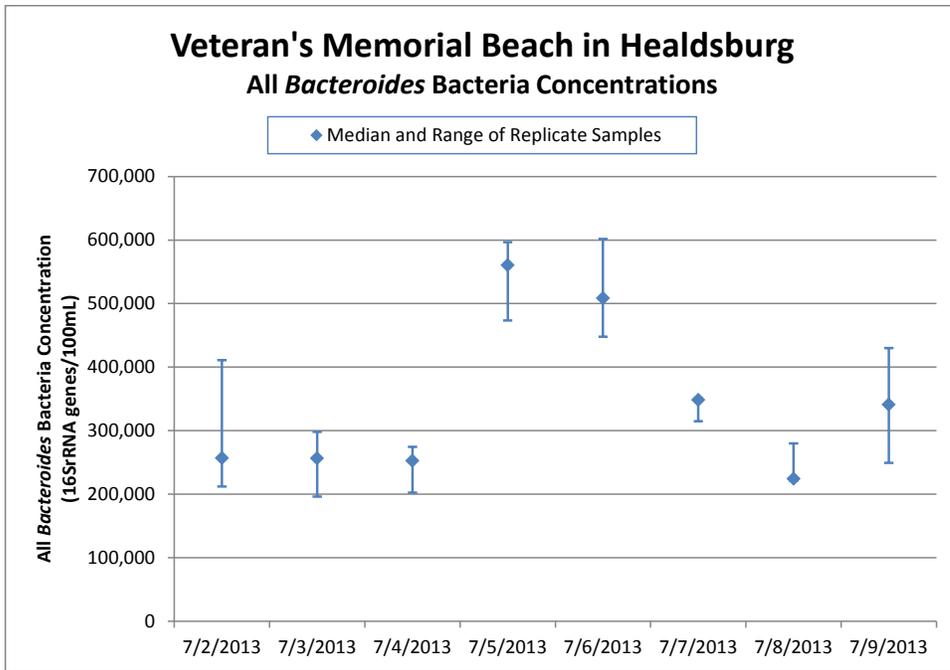


Figure 3. All *Bacteroides* Bacteria Concentrations Measured at Veteran's Memorial Beach in Healdsburg

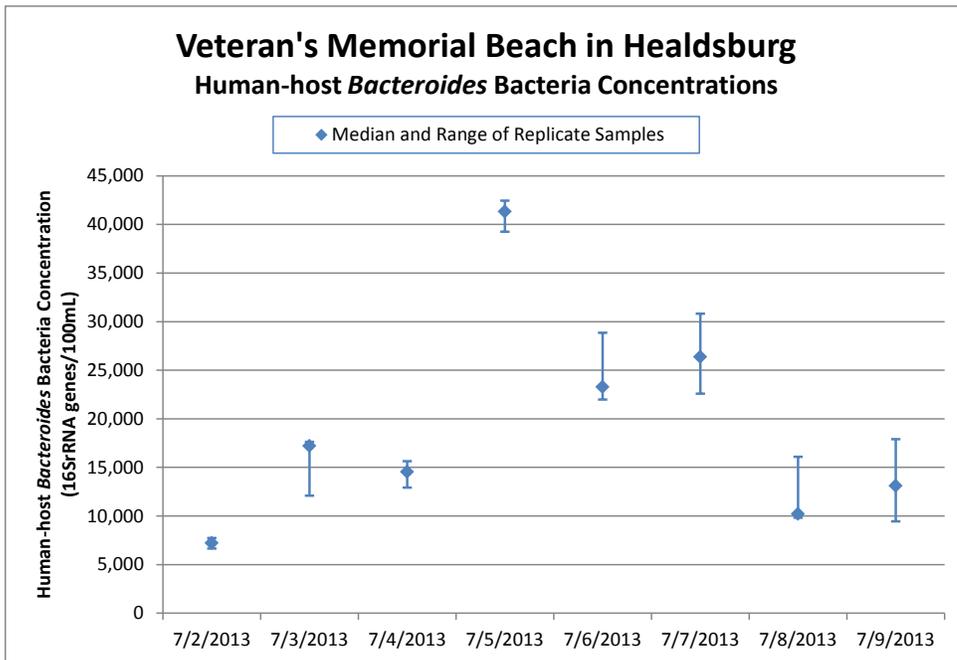


Figure 4. Human-host *Bacteroides* Bacteria Concentrations Measured at Veteran's Memorial Beach in Healdsburg

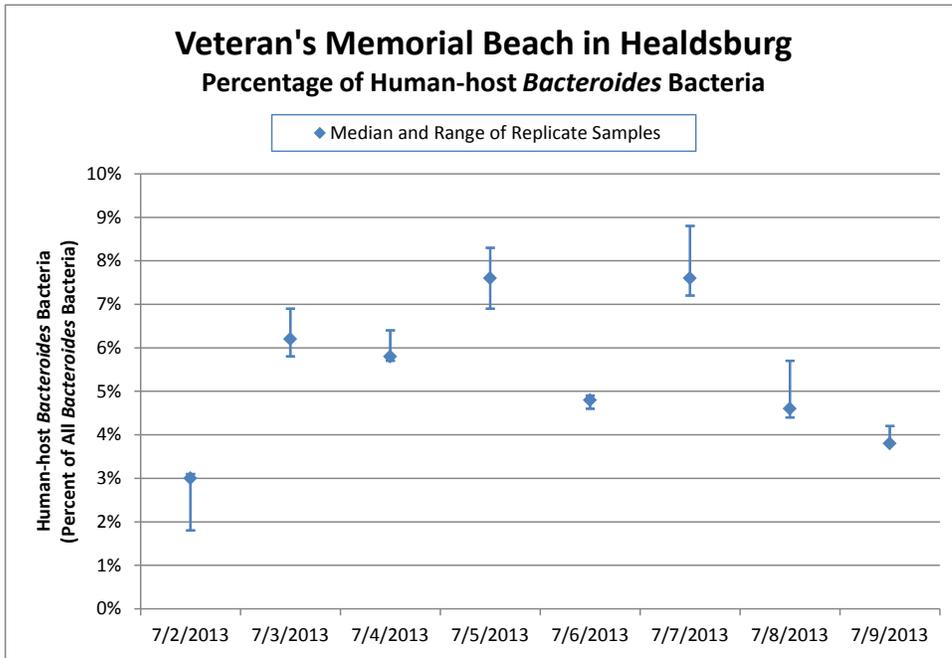


Figure 5. Percentage of Human-host *Bacteroides* Bacteria Measured at Veteran's Memorial Beach in Healdsburg

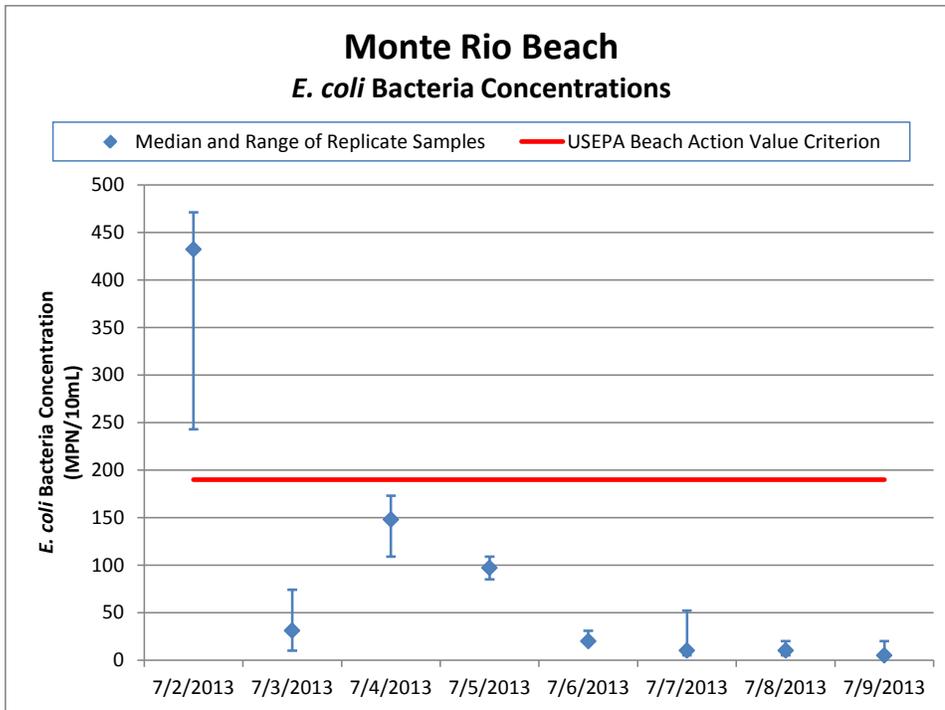


Figure 6. *E. coli* Bacteria Concentrations Measured at Veteran’s Memorial Beach in Healdsburg

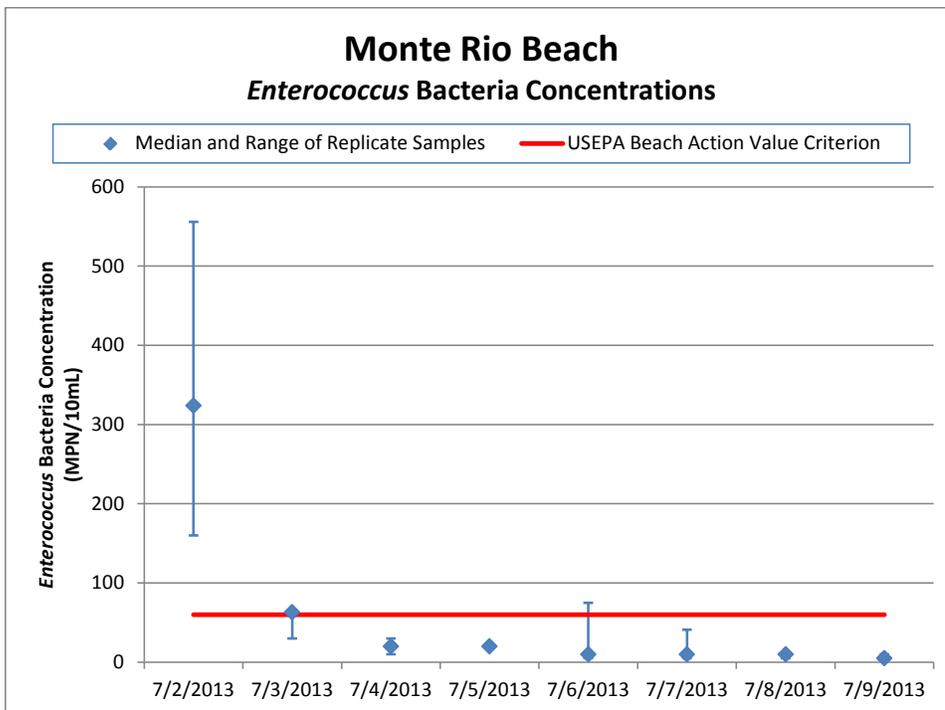


Figure 7. *Enterococcus* Bacteria Concentrations Measured at Veteran’s Memorial Beach in Healdsburg

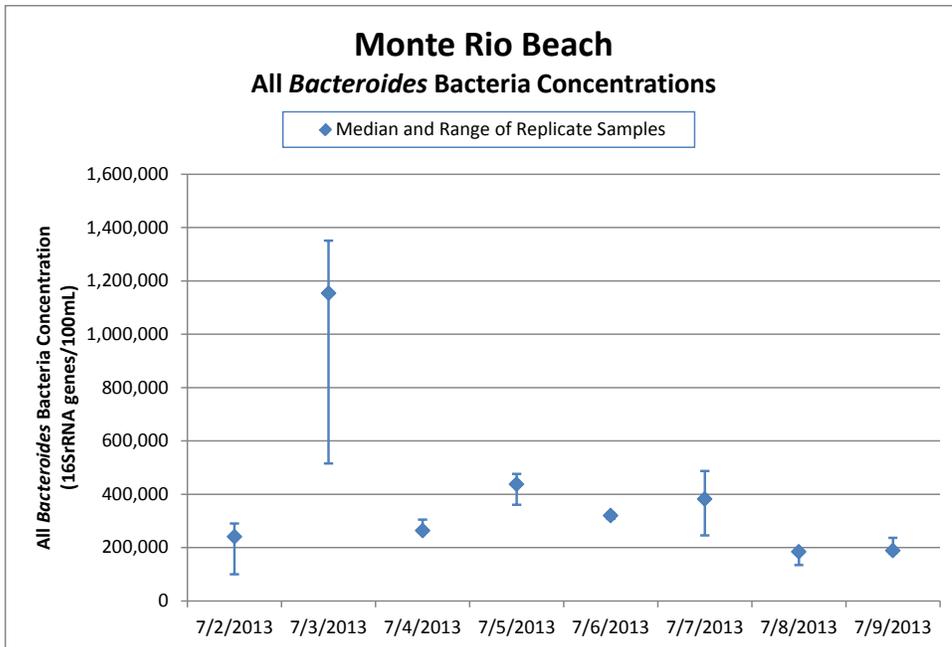


Figure 8. All *Bacteroides* Bacteria Concentrations Measured at Veteran’s Memorial Beach in Healdsburg

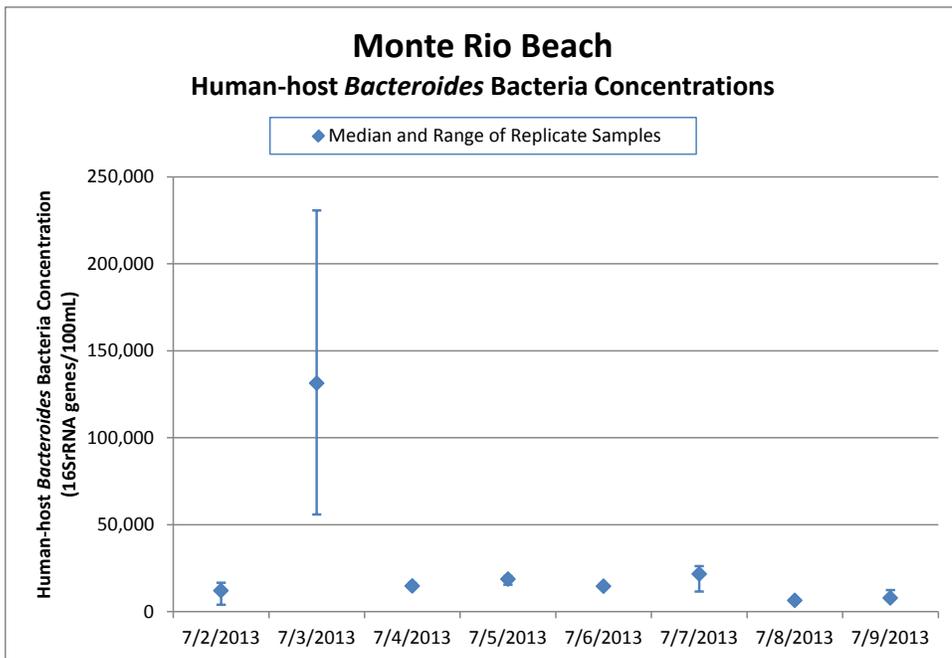


Figure 9. Human-host *Bacteroides* Bacteria Concentrations Measured at Veteran’s Memorial Beach in Healdsburg

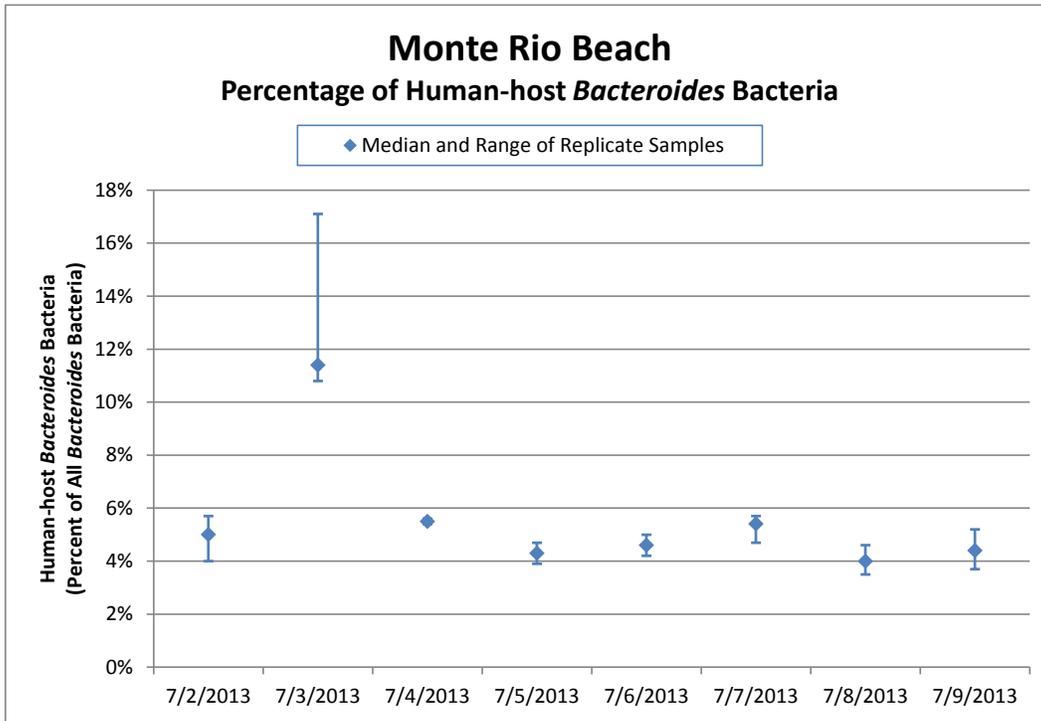


Figure 10. Percent of Human-host *Bacteroides* Bacteria Measured at Veteran’s Memorial Beach in Healdsburg

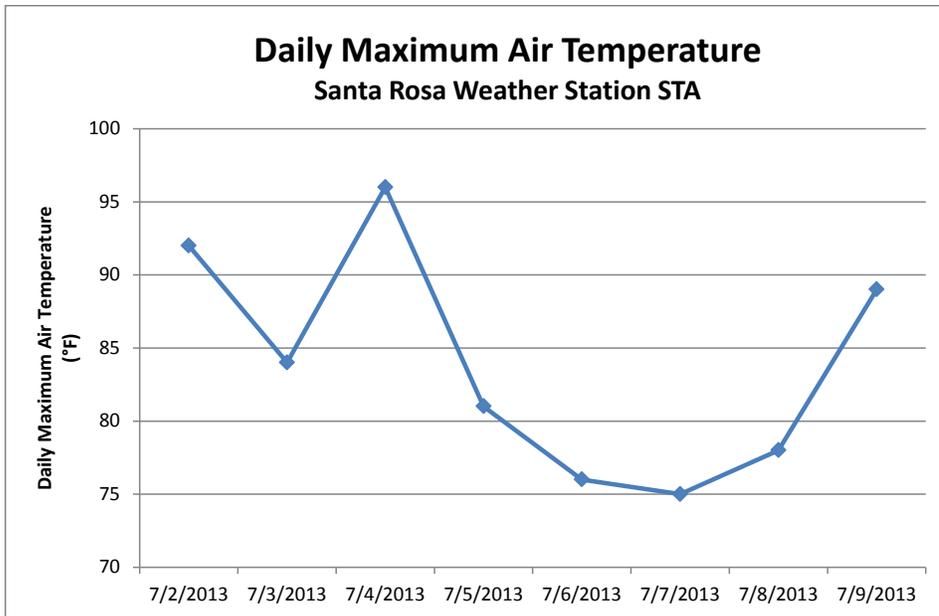


Figure 11. Daily Maximum Air Temperature Measured in Santa Rosa

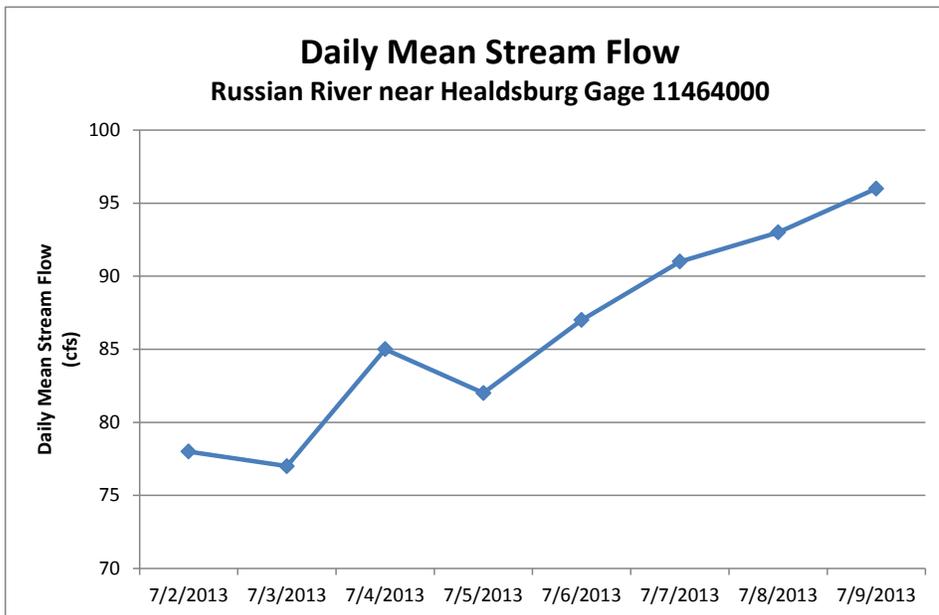


Figure 12. Daily Mean Stream Flow Measured in the Russian River near Healdsburg

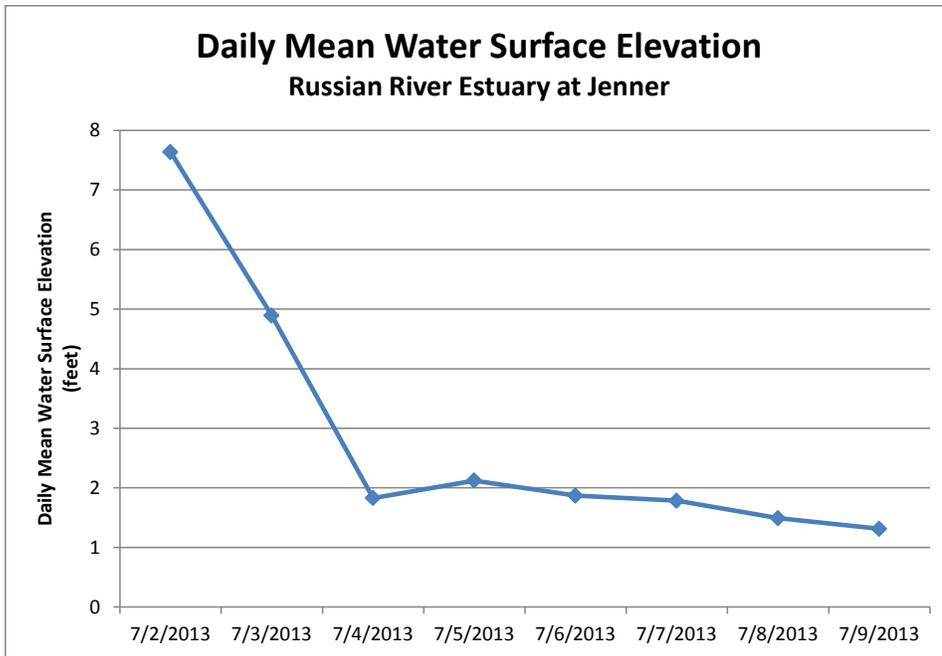


Figure 13. Daily Mean Water Surface Elevation Measured in the Russian River Estuary at Jenner

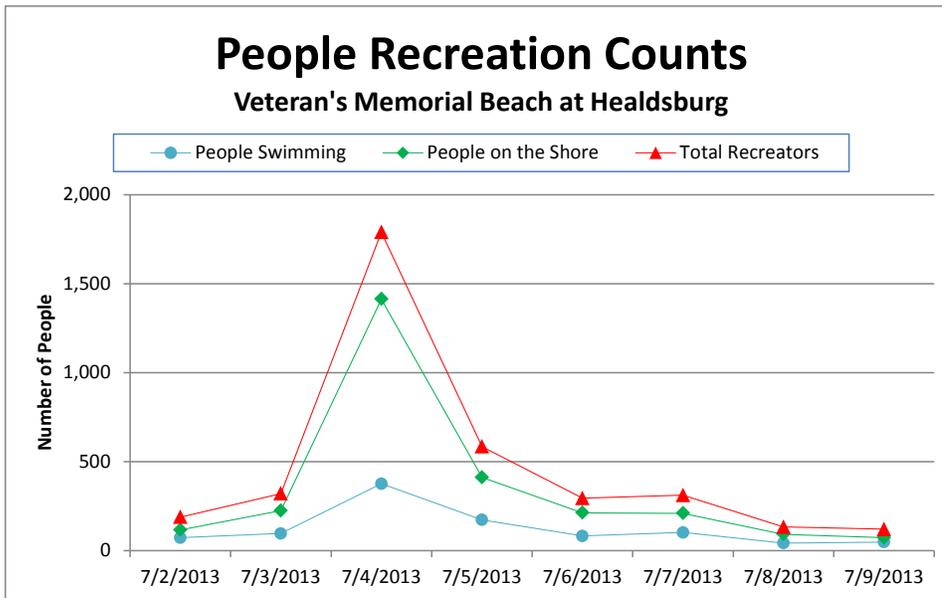


Figure 14. Counts of People Recreating at Veteran's Memorial Beach in Healdsburg.

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

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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

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