Swimmer Shedding Study in Newport Dunes, California

Final Report

Prepared for:
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Santa Ana Regional Water Quality Control Board

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Executive Summary

Newport Dunes Resort is one of the most popular family vacation spots in southern California. This study is to examine the contribution of bathers to fecal indicator bacteria in the water column at Dunes and to investigate if sediment resuspension could be another alternative source of fecal contamination. Water and sediment samples were collected from three locations in the Dunes during summer 2000 and 2001. Total coliform concentrations were below State of California AB411 water quality single sample limit in all samples tested during the study period. Fecal coliform and enterococcus concentrations were below State of California AB411 water quality single sample standards in over 90% of samples tested during the study period (single sample standard total coliform 10,000MPN/100ml, fecal coliform 400MPN/100ml, enterococcus 104MPN/100ml). There was no statistically significant difference in the density of fecal indicator bacteria detected at ankle and knee depths suggesting the water column at the Dunes was well mixed. Fecal indicator bacteria at Newport Dunes North was approximately 1.5-fold higher than the two Dunes East locations suggesting additional sources of fecal bacteria may contribute to the elevated level of bacteria detected in this area. Although all measurements of total coliform bacteria were well below AB411 single sample standard, elevated levels of fecal and total coliform bacteria (2 to 5 folds increases) were detected in the afternoon at Dunes East outside swimming area and Dunes North. However, these increases do not appear to be caused by the bather shedding because the numbers of bathers at these two locations were less ¼ of those observed at the Dune East Inside the swimming area. The average bather count at peak-use period (noon) was less than 20 at the Dune East Inside (high-use area), therefore, bather shedding during swimming activity may go undetected during this study due to the limited number of bathers in the water. All sediment samples exceeded the current State of California water quality single sample standard for fecal coliform and enterococcus by one to two orders of magnitudes suggesting sediment is a sink for water column bacteria.

Background

Newport Dunes Resort is one of the most popular family vacation spots in southern California. Millions of visitors visit the area camping, swimming, kayaking and sailing each year. However, the water quality in the local area is plagued by chronic sporadic elevated levels of fecal indicator bacteria. The efforts of diverting storm drain urban runoff to the local sewage treatment facility during the summer season have significantly improved the water quality and reduced the fecal bacterial contamination for most of the summer seasons. The objective of this study is to investigate if there are alternative sources of fecal pollution to the Dunes. More specifically this study is to examine the contribution of bathers to fecal indicator bacteria in the water column at the Dunes and to investigate if sediment resuspension could be an alternative source of fecal contamination. The working hypotheses for this study are following.

1. Fecal bacteria are shed during bathing/swimming activity
2. The current fecal bacterial assay method is sensitive to detect bacteria shedding during bathing/swimming
3. The water column fecal bacteria concentration increases with increasing number of bathers
4. Both direct shedding from the body of swimmers and stirring of sediment that harbors high concentration of bacteria during water activities contribute to the elevated level of fecal indicator bacteria in water column

Materials and Methods

Study area

The Newport Dunes is a R/V park with one mile of private beach along Newport Bay waterfront. Most of the water contact activities occur at the east side of the Dunes (Figure 1). A designated swimming area is roped off. A boat launching ramp and the Back Bay Café are located at the north-eastern end of the Dunes. The south side of the Dunes is used for kayaking/boating activities, while little water contact activity occurs at west side of the Dunes. The Dunes is connected with Newport Bay at the north end (Figure 1).

Sampling Program

Between August 25 and 29, 2001, water samples were taken twice daily at three sites in the Newport Dunes for fecal indicator bacteria including total coliform, fecal coliform and enterococcus. One site is located within the designated swimming area at the Dunes East (East-In), the other is located outside designated swimming area at the Dunes East (East-out) and the third one is located at north side of the Dunes (North) near foot bridge (Figure 1). The rationale of picking these sites is because the high number of swimmers is most frequently observed at Dunes East (A) and less frequently at east outside the swimming area (B). Dunes north (C) is located under a foot-bridge, near a storm drain outlet that is diverted during the study period.

At each site, water samples were collected from two depths, knee deep and waist deep. The first sample of the day was taken at 6 am before bathers entering the water, the second sample of the day was taken at 2 pm when most bathers were in the water. A total of 48 samples were taken and tested during this study period. This twice-a-day sampling design is to capture the variability of water quality before and after the swimmers entered the water. The purspose of the multiple day sampling design is to reduce/eliminate day-to-day variability and to relate daily fecal indicator bacteria temporal variability with bathing activity to illuminate the possibility of bather shedding during water recreation. The rationale of sampling at multiple locations with different levels of swimming activities is to compare the level of bather shedding with the number of bathers.

A more systematic larger scale study was conducted during summer 2002. Water samples were once again collected from the Newport Dunes for total coliform, fecal coliform and enterococcus analysis. The dates for sample collection are as follows:

May 22, 25, 28;
June 8, 10, 12;
July 4, 6, 8, 22, 24, 26;
August 7, 10, 12, 31;
September 2, 3, 19, 22, 25

Water samples were taken from the same three locations as in summer of 2001 (Figure 1), except the sampling depth at each site was changed to ankle deep and knee deep. This change is based on the rationale that most of the bathers, mostly children, bath at knee-deep water rather than waist-deep water during recreation, and the simplicity of sample collection at knee depth rather than waist depth. Three samples were taken daily instead of two sampling times as in 2001. First sample at each site was taken in the early morning before 6 am, the second sample was taken between noon and 2 pm, and the third sample was taken in the afternoon around 4 pm. Most swimmers were observed in the noon and afternoon hours. A total of 189 water samples were collected and analyzed for fecal indicator bacteria during this study.

In additional to water samples, eight sediment samples were collected from each of the three locations in summer 2002 on the following days: May 22, 28, June 12, July 8, July 24, August 12, 31 and September 26 were analyzed for fecal indicator bacteria. A total of 24 sediment samples were analyzed during the study period.

Sampling Procedures

At each site, water samples were collected using a triple sample-rinsed bucket and poured into sterilized sampling bottles. Water samples were transported within 2 hours of collection to the Orange County Sanitation District for fecal indicator bacteria analysis.

For sediment samples, a sterile scoop was used at ankle depth water and transported in sterilized sample bottles to the Orange County Sanitation District for fecal indicator bacteria analysis within 2 hours.

Fecal Indicator Bacteria Analysis

For water samples, fecal indicator bacteria including total coliform, fecal coliform and enterococcus were assayed by the state certified microbiology lab for water quality testing at the Orange County Sanitation District. EPA approved standard protocols of most probable number as well as IDEX enterolert testing kits (IDEXX, Westbrook, MN) were used. The final results were expressed as MPN/100ml.

For sediment samples, liquid nutrient medium was added to the sediment and mixed to extract bacteria. The extracts were used for fecal bacterial analysis using standard protocols as described above. The sediment samples were dried and weighed. The final results were expressed as MPN/100g dry wt. of sediment.

Statistical Analysis

All statistical analysis was performed using SPSS software package (SPSS Inc. Chicago, IL). Both Spearman's rho for bivariable non-parametric correlation and Kruskal-Wallis test for non-parametric data analysis were applied to both spatial and temporal data. The concentrations of fecal indicators were natural log transformed to achieve normal distribution. Human viruses were used as the grouping variable and all other measured factors as independent variables in the Kruskal-Wallis analysis.

Results and Discussion

The concentrations of fecal indicator bacteria were generally low in the Dunes' water column during both summer 2001 and summer 2002 study periods (Figure 2). All samples collected during summer 2001 meet California AB411 water quality standards (single sample standard total coliform 10,000MPN/100ml, fecal coliform 400MPN/100ml, enterococcus 104MPN/100ml). All samples collected during summer 2002 also meet AB411 single sample standard for total coliform. Over 90% of the samples collected during summer 2002 study meet the water quality single sample standards for fecal coliform and enterococcus (Figure 3). The geometric mean (both studies combined) of total coliform ranged from 23 to 106 MPN per 100 ml, fecal coliform ranged from 20 to 95 MPN per 100 ml and enterococcus ranged from 10 to 28.5 MPN per 100 ml. The geometric mean of all three indicators are lower in samples collected during 2001 in comparison with those collected in summer of 2002. Between 1 to 8% of the samples collected during summer 2002 exceeded the single sample daily limit for fecal coliform or enterococcus at each study site (Figure 3). No sample exceeded the total coliform standard during the entire study period. No significant difference was observed between two different sampling depths (ankle/knee or knee/waist) at each site suggesting water column was well mixed at the time of sample collection. Therefore, all future analyses collapsed the data from two different sampling depths from each location.

The daily temporal distribution of fecal indicator bacteria collected from all sites is presented in Figure 4. Since the sampling scheme in summer 2001 is different from that of summer 2002 and only limited numbers of samples were tested during the summer 2001 study, data from this preliminary study was excluded in the daily temporal analysis. A statistically significant increase of total and fecal coliform concentration was observed in the water column towards the noon and afternoon (Figure 4). However, none of the samples at any time of the day exceeded the total

coliform single sample standard (Figure 5). This increasing trend was not observed for enterococcus, which remained constant throughout the day.

To test the hypothesis that the elevated level of fecal coliform bacteria was associated with bather shedding during swimming, the temporal distribution of indicator bacteria was broken down into each sampling location. The observed increases of fecal and total coliform density in the afternoon were statistically significant for samples collected at both Dunes East Outside swimming area and Dunes North (Figure 7 and Figure 8). However, at Dunes East Inside swimming area, the trend was less clear (Figure 6). Only limited data were available on bather numbers during each sampling time during a day. However, these data confirmed the presumptions that most bathing activities were occurring at noon and afternoon, and over 75% of the bathers swimming were within the designated swimming area at Dunes East (Figure 9). Therefore, bathing activities do not appear to be the cause of the observed increases of indicator bacteria at Dunes North and East-Outside Swimming Area.

An alternative explanation to these trends may be due to the low level of overall bacterial concentrations at the study sites, which were within the confidence interval of our current diagnostic methods. Other possible explanations of the elevated level of fecal indicator bacteria observed in the afternoon at Dunes North and East outside swimming area, include local sources such ground seepage, small spills from nearby vessel waste pump-out stations, inputs from small storm drains and other drainages and feces of local wild animal population.

Furthermore, local sediments can also be an important source of fecal indicator bacteria. Figure 10 compares the geometric mean of fecal indicator bacteria detected in sediments and their immediate overlying water column at three sampling sites in the Dunes. The concentrations in the sediments were more than two orders of magnitudes greater than those detected in the water column. Even though there is not a Federal and State bacterial indicator standard for bacterial contamination in the sediment, using the current State of California water quality standard as a guideline, all sediment samples tested exceeded current AB411 water quality standards for fecal coliform and enterococcus by one to two orders of magnitudes suggesting sediment can be a sink of fecal bacteria in water column. Alternatively, the large-scale resuspension of sediment can be an important source for water column bacterial contamination during storm events or highly turbulence conditions. However, total coliform counts in the sediment samples were well below the single sample daily limit.

It is also important to keep in mind that the level of indicator bacteria detected during this study period was low (over 90% of the samples were below water quality standards) in comparison with episodic pulse pollution events found at Dunes previously. These near background levels of fecal indicator bacteria have little or no impact with regard to water quality management and human health risk. To fully understand the variability of fecal pollution in the Dunes, a systematic study with a high frequency of sampling effort, coupled with a detailed water circulation pattern investigation, microbial decay rate and sediment resuspension rates investigation may be necessary.

Conclusions

- Total coliform concentrations were below State of California AB411 water quality single sample standard in *all samples tested* during the summer 2002 study period, and fecal coliform and enterococcus concentrations were below State of California AB411 water quality single sample standard in *over 90% of samples tested* during the summer 2002 study period.
- There was no statistically significant difference in the density of fecal indicator bacteria detected at ankle and knee depths suggesting the water column at Dunes were well mixed.
- Fecal indicator bacteria at Newport Dunes North was approximately 1.5-fold higher than the two Dunes East locations suggesting additional sources of fecal bacteria may contribute to the elevated level of bacteria detected in this area.
- Although all measurements of total coliform bacteria were well below AB411 single sample standards, elevated levels of fecal and total coliform bacteria (2 to 5 folds increases) were detected in the afternoon at Dunes East outside swimming area and Dunes North. However, these increases do not appear to be caused by the bather shedding because the numbers of bathers at these two locations were less ¼ of those observed at the Dune East Inside the swimming area, (and these increased concentrations were still mostly below the AB411 single sample standards).
- The average bather counts at peak-use period (noon) were less than 20 at the Dunes East Inside (high-use area), therefore, bather shedding during swimming activity may go undetected during this study due to the limited number of bathers in the water and the confidence interval level of our current fecal indicator bacteria detection methods.
- All sediment samples exceeded the current State of California AB411 water quality single sample standard by one to two orders of magnitudes suggesting that sediment may be a sink for bacteria. and therefore, sediment resuspension can be an important source of water column bacterial contamination.

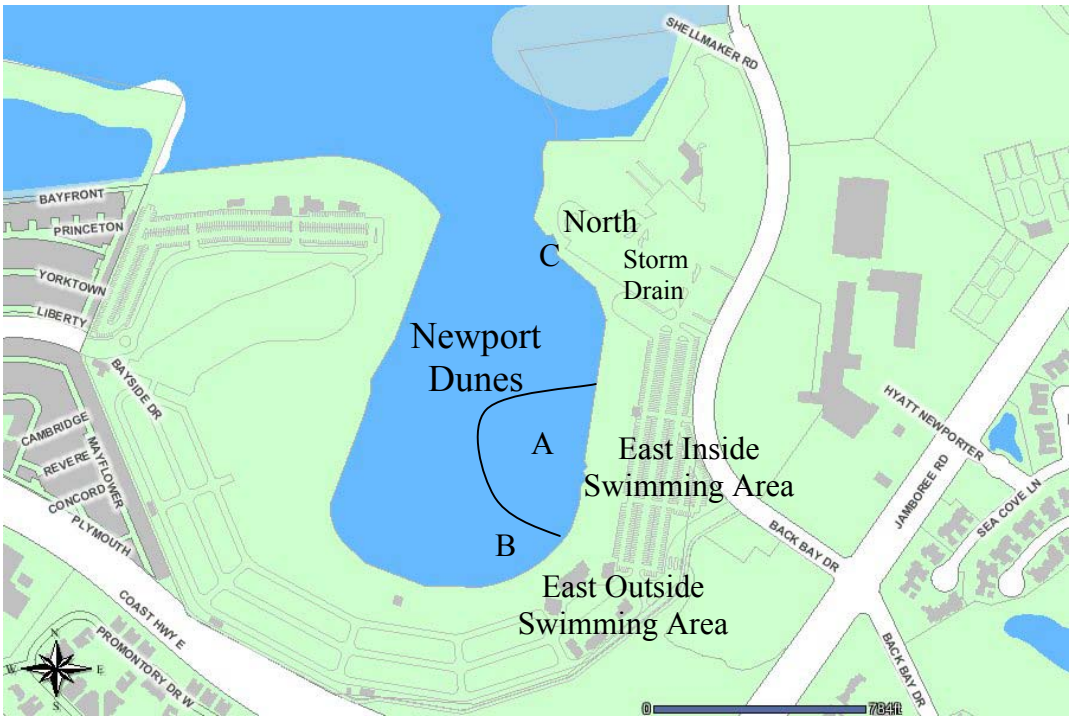

Figure 1. Sampling locations at Newport Dunes during summer 2001 and summer 2002.
A: Dunes east inside swimming area; B: Dunes east outside swimming area; C: Dunes north.

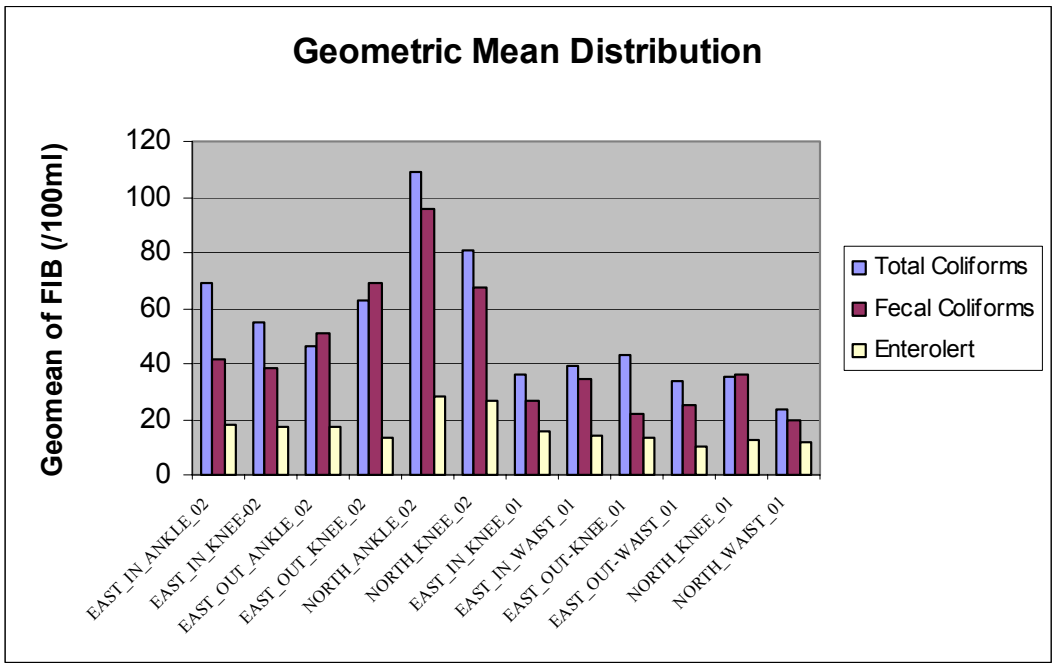

Figure 2. Geometric mean distribution of fecal indicator bacteria (total coliform, fecal coliform and enterococcus) in Newport Dunes waters. Water samples were collected during the summer of 2001 and 2002. Details of samples dates and locations are in text.

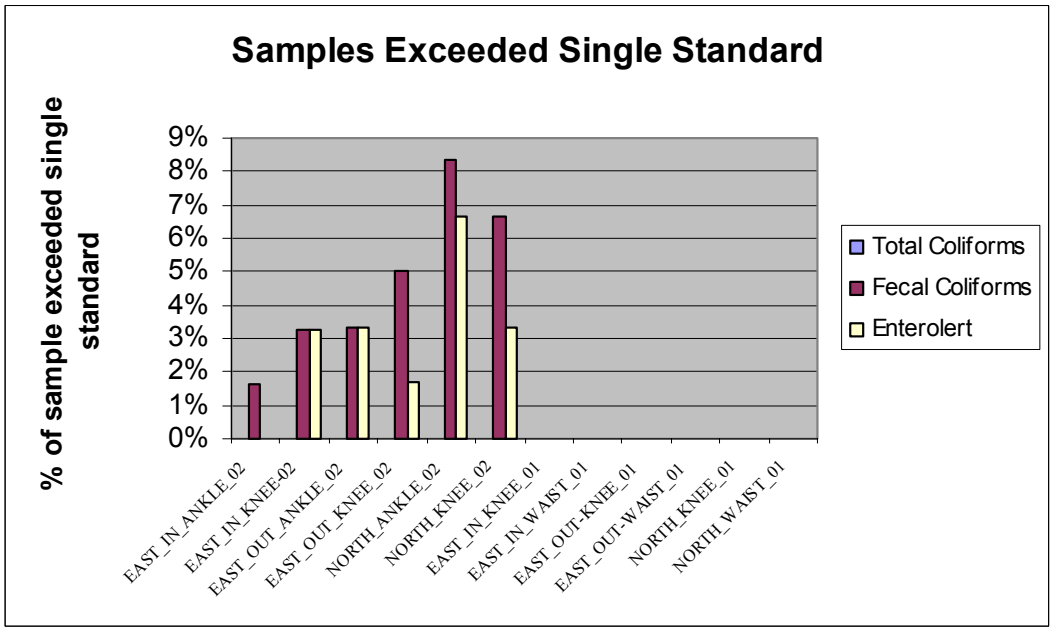

Figure 3. Frequency of water samples that exceeded State of California AB411 water quality single sample standard during the two-year study period. Note: none of the water sample collected during summer of 2001 exceeded the AB411 single sample standard. All total coliform counts were well below state standard.

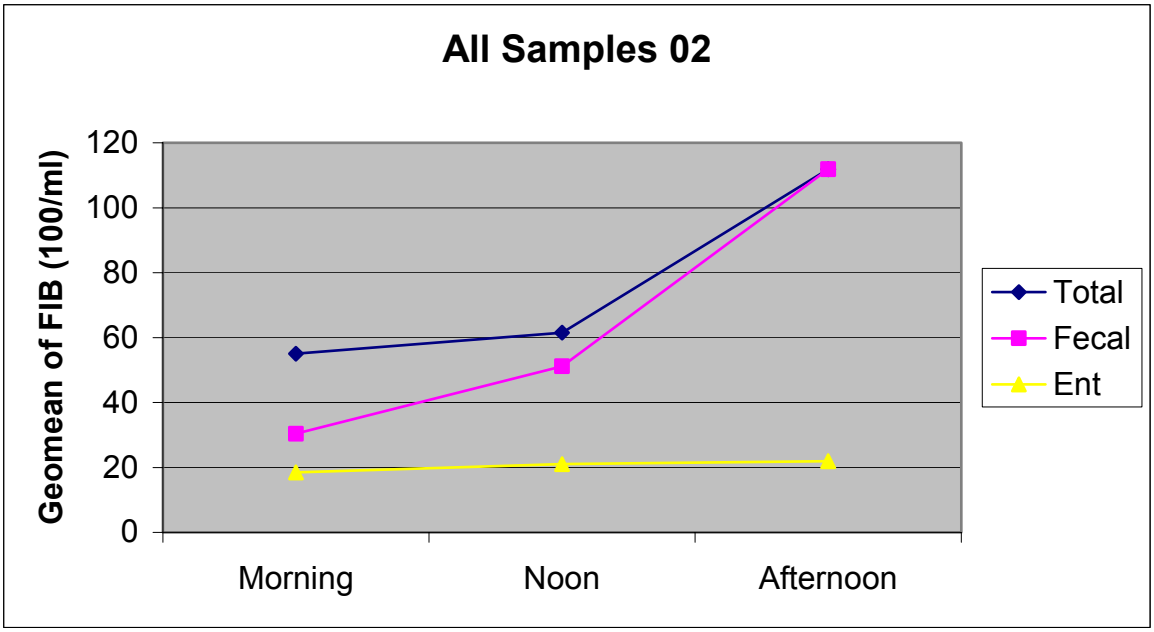

Figure 4. Daily temporal distribution of water column total coliform, fecal coliform and enterococcus (geometric means) at three sampling sites collected during summer of 2002. Note: elevation of total coliform and fecal coliform concentrations were detected in the samples collected in the afternoon.

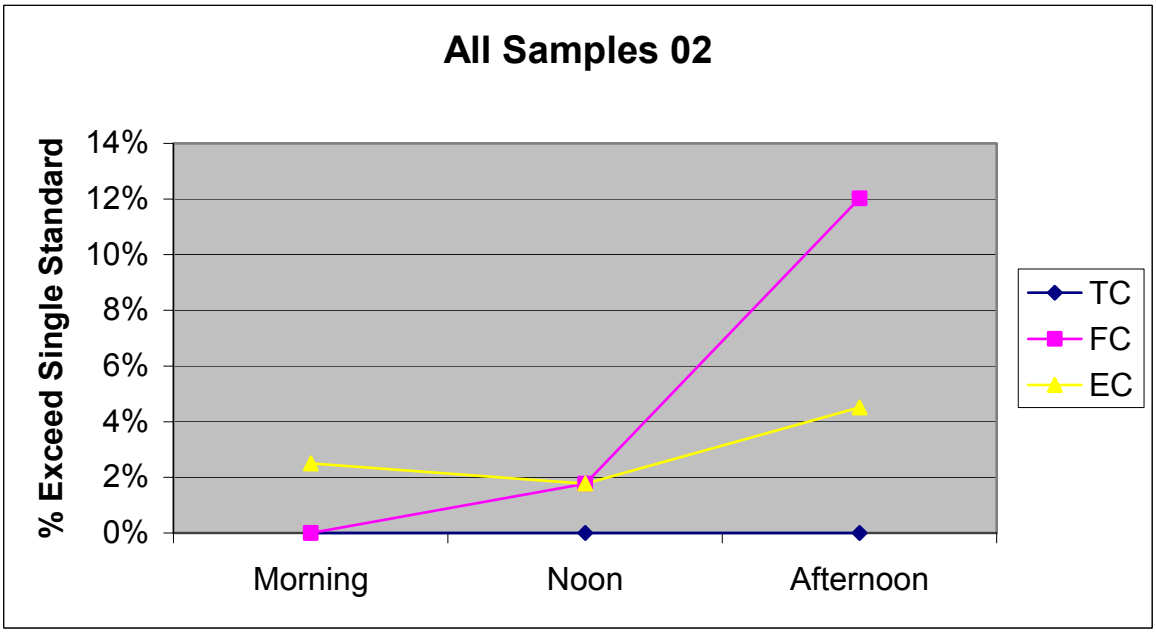

Figure 5. Frequency of water samples collected at different times of the day that exceeded the California AB411 single sample standard. Note: none of the water sample exceeded the total coliform single sample standard.

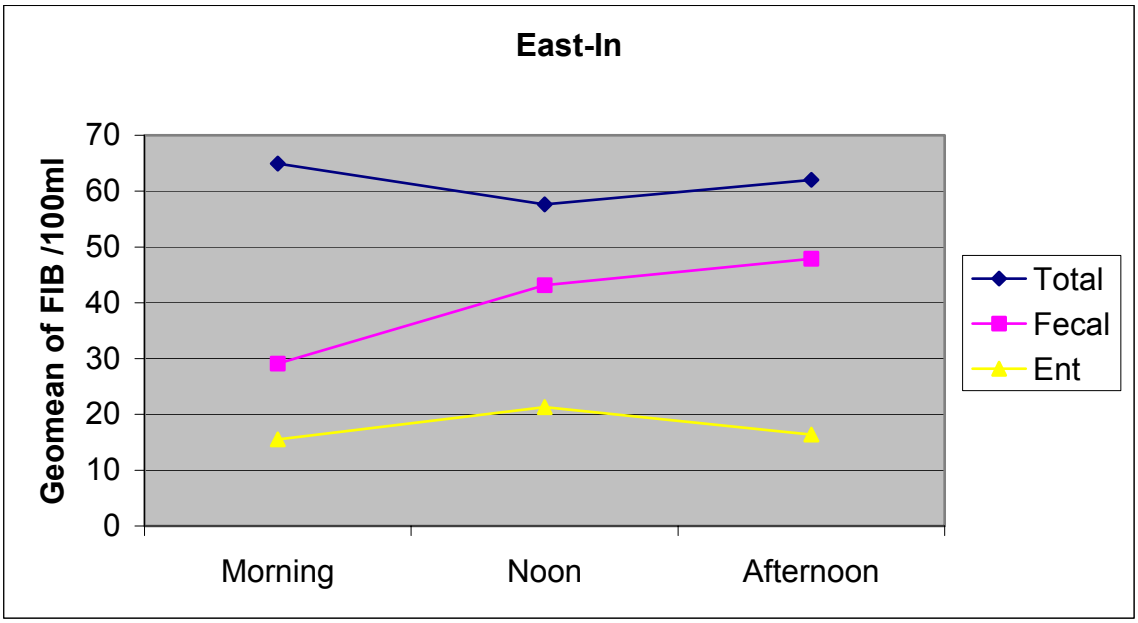

Figure 6. Daily temporal distribution of water column total coliform, fecal coliform and enterococcus at Dunes East Inside designated swimming area. All water samples were collected during summer of 2002.

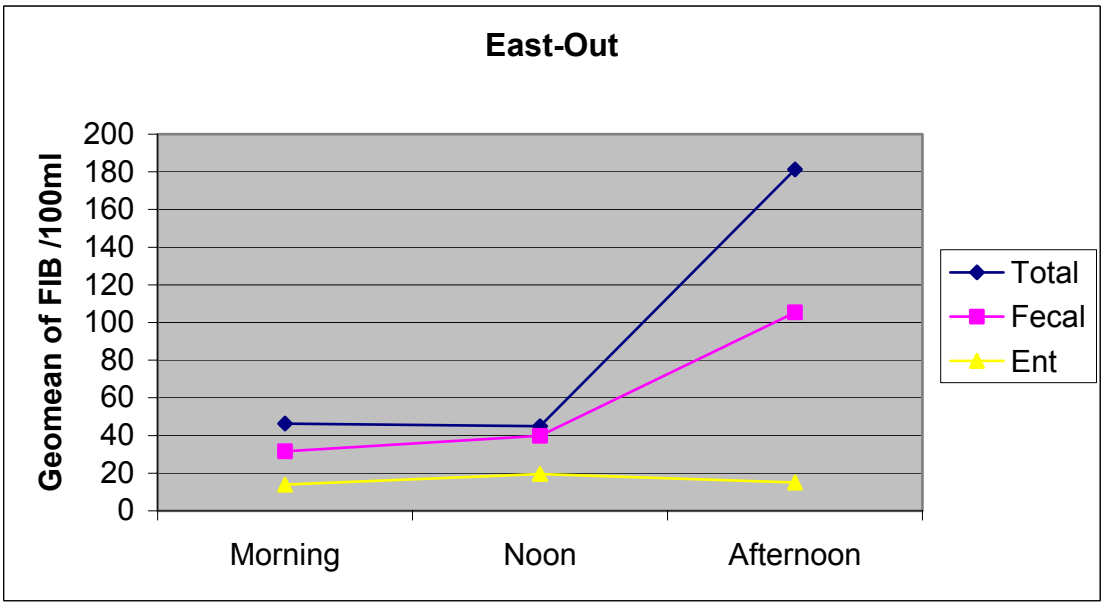

Figure 7. Daily temporal distribution of water column total coliform, fecal coliform and enterococcus at Dunes East Outside designated swimming area. All water samples were collected during summer of 2002.

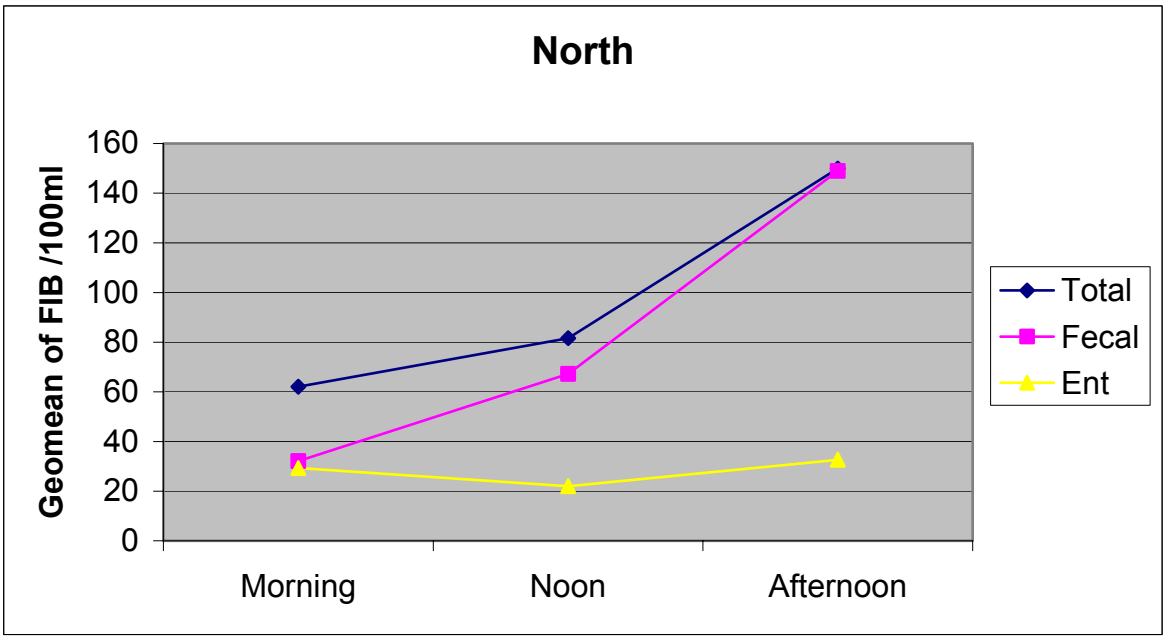

Figure 8. Daily temporal distribution of total colifom, fecal coliform and enterococcus in water column at Dunes North. All samples were collected during summer of 2002.

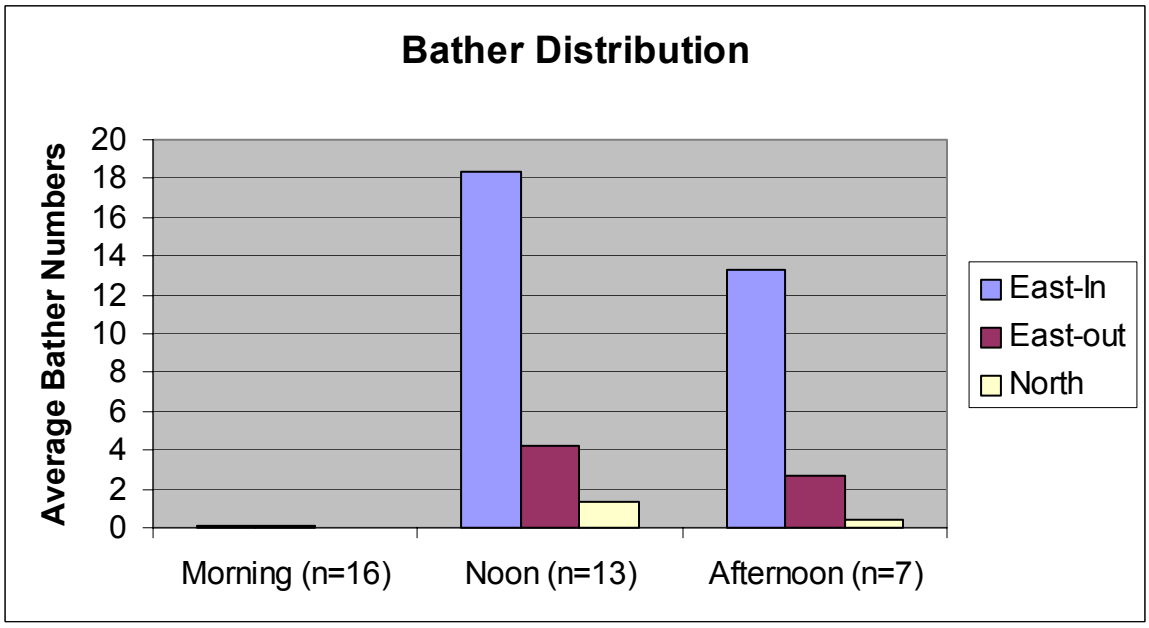

Figure 9. Daily temporal distribution of bathers at Dunes. All data were collected during summer of 2002.

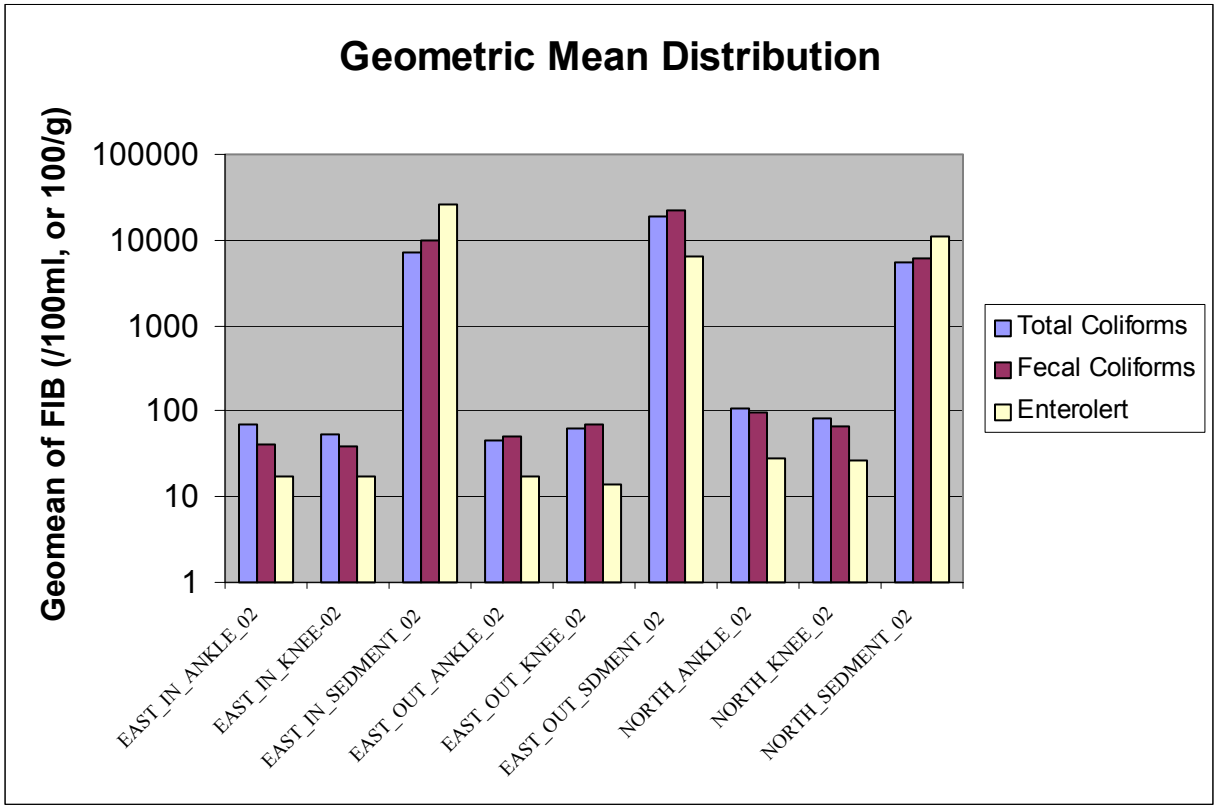

Figure 10. Comparison of geometric mean distribution of fecal indicator bacteria in water column and in sediment samples at Dunes East Inside, Outside and North locations collected during summer of 2002.