

Liberty Bay Marina Study 2010

Abstract

The purpose for the Liberty Bay Marina study was to assess the impact to water quality from untreated sewage discharges that may occur from transient and permanently moored vessels within three Liberty Bay marinas. Additionally, the study results provided information regarding the effectiveness of the “Marina Sewage Regulations” ordinance 1999-13, promulgated by the Kitsap County Board of Health.

The marina study tested two hypotheses. The first was that there is no significant difference in water quality inside versus outside marinas, and the second hypothesis was that there was a significant difference in water quality when there were high numbers of transient boaters present in areas outside the marina (e.g. weekends) compared to low transient boat use (e.g. weekdays).

The results showed higher levels of fecal coliform (FC) bacteria inside marinas compared to areas outside the marinas during both weekend and weekday sampling events. This difference was found to be statistically significant during weekend events ($p = 0.02$). However, regarding the secondary hypothesis, the results showed that there was not a significant difference in FC bacteria levels when there were high numbers of transient boaters present during weekend sampling events compared to weekdays.

The results from this study will be used to inform the Kitsap County Board of Health about the status of water quality in and around Liberty Bay marinas. It will also provide evidence to inform policy decisions regarding the effectiveness of the marina sewage ordinance.

Introduction

The objective of the study was to quantitatively characterize the current water quality conditions in and near three marinas in Liberty Bay, Poulsbo WA. The primary objective of the study was to test the null hypothesis that there is no difference in concentrations of FC bacteria inside compared to outside a marina. The alternative hypothesis was that the water quality inside the marina had higher concentrations of bacteria as a result of boat sewage discharges inside the marina. To test the null hypothesis, a sampling study was designed to factor out other sources of contamination to the maximum extent possible. Sampling occurred only during defined tide, weather, and boater-use periods.

The primary hypotheses tested were:

H_0 : $\mu_{\text{marina}} = \mu_{\text{external}}$ (the mean FC inside marina equals mean outside marinas)

H_1 : $\mu_{\text{marina}} > \mu_{\text{external}}$ (the mean FC inside marina is greater than outside marinas)

Additionally, data from the study was used to address a secondary null hypothesis that FC bacteria levels are equal on heavy boat-use days (weekends/holidays) compared to

lower boat-use days (weekday/non-holidays). This question was answered separately for the marina areas and the external areas. The secondary hypotheses tested were:

H₀: $\mu_{\text{weekend}} = \mu_{\text{weekday}}$ (mean FC concentration weekends is equal to mean weekdays)

H₁: $\mu_{\text{weekend}} > \mu_{\text{weekday}}$ (mean FC concentration weekends is greater than the mean on weekdays)

Background

In 1991, the Health District completed a water quality study of four (4) Kitsap County marinas to test the hypothesis that a significant difference in water quality existed inside a marina as opposed to outside a marina. The results from that study found that FC bacteria levels were significantly higher within marinas compared to areas outside of marinas. This finding led to the development of the Health District's Boat Waste Control Program and the Bremerton-Kitsap County Board of Health Ordinance 1999-13, "Marina Sewage Regulations," which were intended to govern the collection and disposal of sewage generated by vessels in Kitsap County.

Since its inception in 1999, all of the Kitsap County marinas have been inspected and come into compliance with the Marina Sewage Regulations. Since facilities change over time, re-inspections of marinas have been conducted on a rotational basis.

In 2006, the Health District conducted another water quality study to evaluate the effectiveness of the Marina Sewage Regulations and assess the need for revisions to the ordinance. The Health District analyzed FC bacteria in marine waters within and near selected Kitsap County marinas.

The findings from the 2006 study showed higher levels of FC bacteria inside marinas compared to outside the marinas, during both weekday and weekend sampling events. Additionally, it was found that there was a statistically significant difference between weekday and weekend FC concentrations for waters outside of marinas.

In 2010, a water quality marina study was conducted as part of the Liberty Bay Restoration and Protection project. One of the goals of the Liberty Bay project is the restoration and protection of beneficial uses in the Liberty Bay watershed. Since there are four marinas within Liberty Bay, an assessment of the water quality within these marinas and waters outside the marinas was conducted, in support of the project but also to conduct another assessment of the marina sewage regulations.

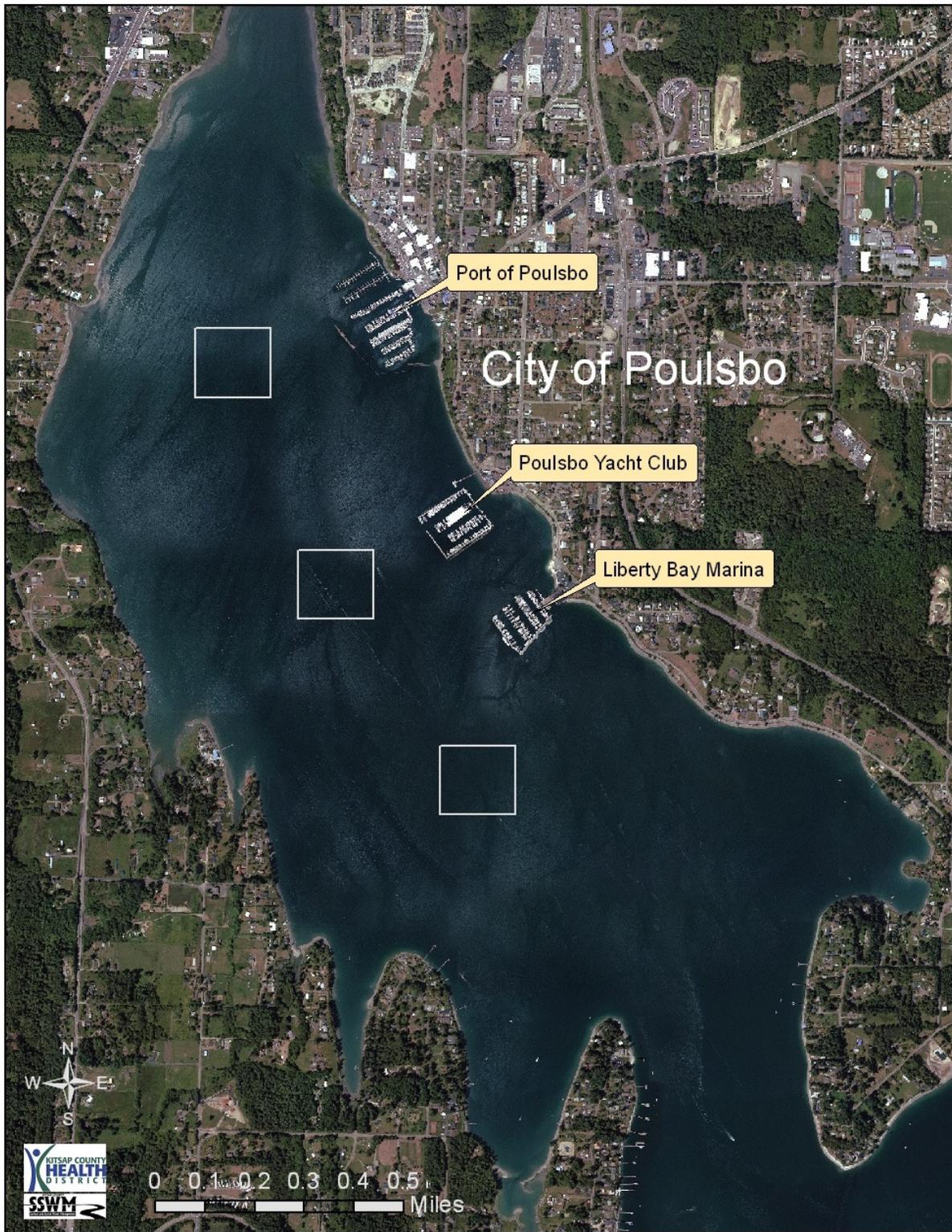
Methods

Three (3) marinas in Liberty Bay were selected for this study. Information about each of these marinas is included below.

Marina	Number of Slips	Number of Live-Aboards	Number Stationary Pumpouts	Number Portable Pumpouts	Disposal method
Port of Poulsbo	399	9	1	1	Discharge to sewer
Poulsbo Yacht Club	155	15	2	1	Discharge to sewer
Liberty Bay Marina	177	8	1	1	Discharge to sewer

A map showing the location of the three study marinas is provided in Figure 1.

Figure 1. Liberty Bay Marinas and Sample Grid Locations Outside of Marinas



A sampling grid was used to randomly select the sampling locations within the defined areas. Five (5) samples were collected from within each marina area and five (5) samples from a nearby area away from the marina's influence. For each location, a grid with five (5) columns and ten (10) rows was applied to the area. The grid was pre-set in size to have columns that are one hundred (100) feet wide and rows that are fifty (50) feet tall. A sample was collected from each column, and a row within that column was randomly selected using a spreadsheet formula. During the random selection process, if any grid cell selection fell outside the marina area based on the grid application and selected marina shape, a new cell was reselected. The sample was collected as close as possible to the center of the grid cell. Health District staff used GIS mapping to determine the latitude and longitude coordinates of the center of each grid cell.

To decrease the influence of outside pollutant sources and test only the water quality differences between internal and external marina waters, as well as collect samples during representative use conditions, sampling events were planned to meet the following conditions:

1. Dry weather (no more than 0.3 inches of rain in the last 48 hours).
2. High or low slack tides (slack tides are one hour on either side of a low or high tide peak).
3. Three events during a high boater use period (dry-weather weekend) and three events during a low boater use period (Monday through Thursday, non-holiday).

Six sampling events were conducted between May 2010 and September 2010. The holiday events occurred on May 16 (Viking Festival), July 5 (4th of July weekend), and September 5 (Labor Day). The weekday events occurred on June 15, July 29, and August 25.

Samples were collected in accordance with Health District monitoring procedures as described in the Liberty Bay Marina water quality study monitoring plan May 2010. Internal samples were collected from the marina floats and external samples from the Health District boat. During sample collection, Health District staff noted any other bacteria pollution sources that were present in the area (birds, sea mammals, etc). The number of transient boats in or near the sample grids was also noted.

The samples were collected in separate 100-milliliter sterile water bottles, stored at 4⁰ Celsius, and transported to the Health District contract laboratory for analysis. Fecal Coliform Procedure 9221-D, fecal coliform membrane filter procedure described in Standard Methods for the Examination of Water and Wastewater (APHA, 1998) was used to analyze the samples. Table 1 shows the method detection limits and accuracy.

Table 1. Analysis Methods, Detection Limits, and Accuracy

Parameter	Method of Analysis	Method Detection Limits	Accuracy
Fecal Coliform (FC) Bacteria	APHA Procedure 9221-D, Membrane Filter fecal coliform	<1 to >200 colonies/100 mL (marine)	1 cfu/100 mL

The Washington State Department of Ecology (Ecology) surface water quality standards are described in Chapter 173-201A of the Washington Administrative Code (WAC). There are two designations and sets of standards for surface waters: extraordinary primary and primary contact waters. According to Ecology, surface waters in Liberty Bay are designated as Extraordinary Primary Contact waters. These marine water quality standards are summarized in Table 2.

Table 2. Marine Surface Water Quality Standards for Washington State

Parameter	Extraordinary Primary Contact
Fecal coliform bacteria	<p><u>Part 1:</u> ≤ 14 FC/100 ml (Geometric mean)</p> <p><u>Part 2:</u> not more than 10% of all samples obtained for calculating a geometric mean > 43 FC/100ml</p>

Results

The results from all sampling events are shown in the following tables. The statistical test used for the study was a 2 sided t-test for independent samples with a level of significance of $\alpha=0.05$.

Table 3. FC Bacteria Results Inside and Outside Marinas: Weekends

Location	Sample Size	Mean (FC/100ml)	Range (FC/100ml)	95% CI Lower bound	95% CI Upper bound	Standard deviation
Inside Marinas	51	10.06	1-163	2.77	17.35	26.55
Outside Marinas*	48	1.21	1-3	1.07	1.35	0.504

*There were 10-50 boats anchored outside the marinas during sampling events.

The t-test result showed a statistically significant difference in FC concentrations inside marinas and areas outside the marinas during weekend events ($p=0.02$), with higher FC bacteria results collected inside marina areas.

Table 4. FC Bacteria Results Inside and Outside Marinas: Weekdays

Location	Sample Size	Mean (FC/100ml)	Range (FC/100ml)	95% CI Lower bound	95% CI Upper bound	Standard deviation
Inside Marinas	50	14.4	1-332	0.39	28.41	50.53
Outside Marinas*	47	1.74	1-24	0.77	2.71	0.49

*There were 3 to 5 boats anchored outside the marinas during sampling events.

There was not a statistically significant difference of FC concentrations inside the marina areas compared to outside the marinas during weekday events ($p=0.08$).

Figure 2 shows these results graphically. The confidence intervals of the means are shown as error bars. Note that during weekend sampling events, the confidence intervals are not overlapping which indicate a statistically significant difference. This was confirmed by calculating the p-value. The confidence intervals during weekday sampling events are overlapping, which indicates that there was no statistically significant difference.

Figure 2. Mean FC results Inside and Outside Marinas During Weekend and Weekday Sampling Events

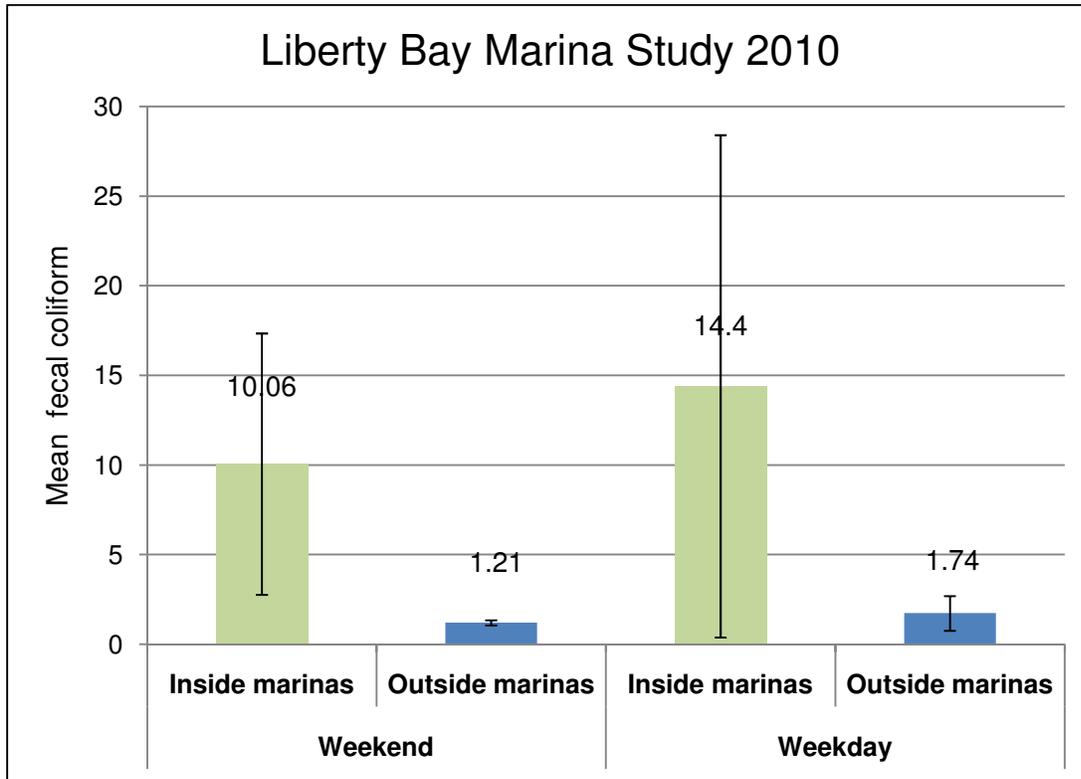


Table 5. FC Bacteria Results Inside Marinas on Weekend Versus Weekday Sampling Events.

Inside Marinas	Sample Size	Mean (FC/100ml)	Range (FC/100ml)	95% CI Lower bound	95% CI Upper bound	Standard Deviation
Weekend	51	10.06	1-163	2.77	17.35	26.55
Weekday	50	14.4	1-332	0.39	28.41	50.53

The difference between weekday and weekend FC results inside the marinas was not statistically significant (p=0.58).

Table 6. FC Bacteria Results Outside Marinas on Weekend Versus Weekday Sampling Events

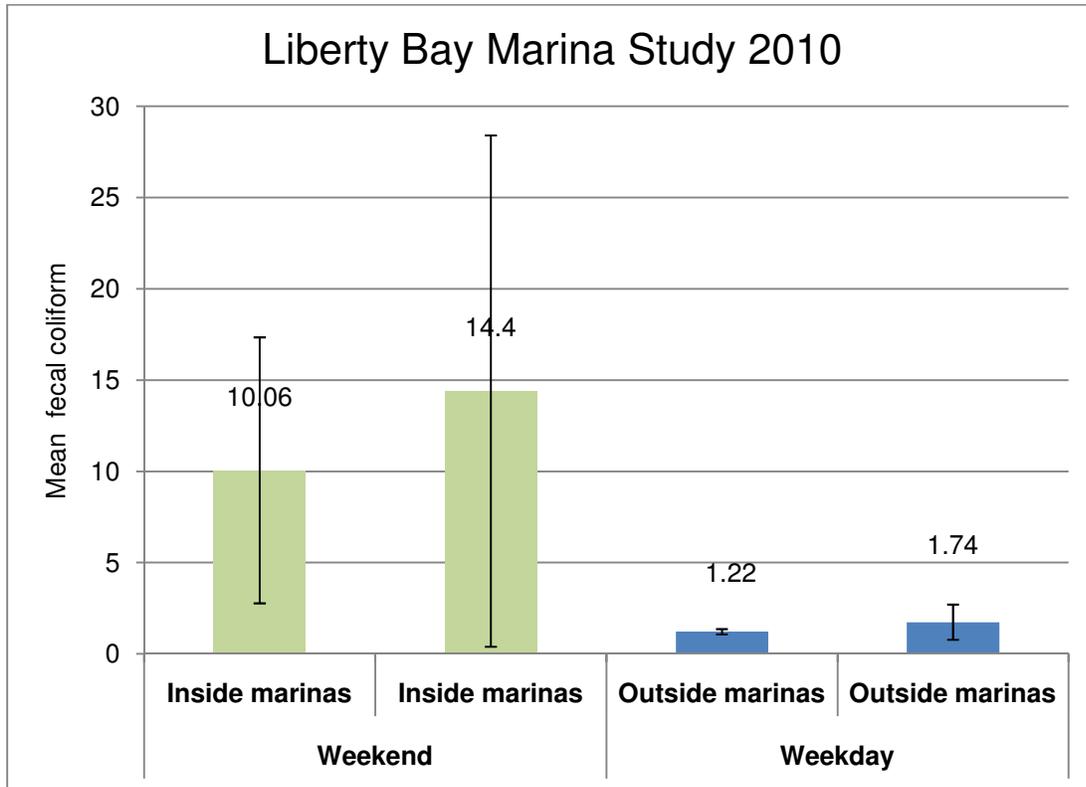
Outside Marinas*	Sample Size	Mean (FC/100ml)	Range (FC/100ml)	95% CI Lower bound	95% CI Upper bound	Standard Deviation
Weekend	48	1.22	0.5-1.0	1.08	1.36	0.504
Weekday	47	1.74	1-24	0.77	2.71	0.49

*There were 10-50 boats anchored during weekend events, and 3-5 boats anchored during weekday sampling events.

The difference between weekday and weekend FC results outside the marinas was also not statistically significant (p=0.28).

Figure 3 shows these results graphically. The confidence intervals of the mean are shown as error bars. Note that during weekend and weekday events, the confidence intervals were overlapping for both inside the outside the marinas, indicating that there was not a statistically significant difference.

Figure 3. Mean FC Results During Weekend and Weekday Sampling Events



Conclusion

The results from this study showed that concentrations of fecal bacteria were higher inside the marinas compared to the waters external to the marinas. This difference was shown to be statistically significant ($p=0.02$). During both weekday and weekend sampling events the levels of fecal bacteria also remained higher inside the marinas versus outside the marinas (even during high boater use days).

During this study there were only five samples collected in the sampling grids for each marina per sampling event. This was done to utilize the same sampling methodology as previous studies (1991, 2006). However, since FC bacteria levels continue to be higher inside marinas, which was also shown in the previous studies, additional sampling is warranted to more fully assess the water quality inside marinas. This additional sampling should also include follow-up sampling and pollution source identification to determine whether FC sources are originating from boaters, wildlife, or other sources.

These results also support the need to continue to conduct marina inspections to assess the effectiveness of the marina sewage regulations and determine whether revision(s) to these regulations is needed.