One-Year Seasonal Bacteria Study Supplemental Environmental Project Final Report 2003

by

Southern California Marine Institute
820 S. Seaside Ave.
Terminal Island, CA 90731
(310) 519-3172
fax (310) 519-1054
http://www-rcf.usc.edu/~scmi/

Acknowledgments

Southern California Marine Institute (SCMI) would like to thank D.I.V.E.R.S., Surfrider, Long Beach, and Bolsa Chica Conservancy for collecting bacterial samples from additional sites in the project area. Surfrider, Huntington/Seal Beach was especially helpful in collecting samples and donating another Quanta-tray sealer, whirl-paks, and sterile bottles to assist with SCMI's efforts. The Wrigley Institute for Environmental Studies (WIES) of the University of Southern California (USC) was also instrumental in helping with this research by collecting some samples and running all of the salinity samples along with their projects. Technical advice and support was also obtained from personnel of Southern California Coastal Water Research Project (SCCWRP) and Orange County Sanitation District. SCMI would also like to thank Santa Monica BayKeeper and the planners of California Coastal Snapshot Day for providing additional resources during the May sampling event.

Abstract

Non-point source runoff can increase the amount of bacteria in surface and coastal waters. Freshwater outlets such as storm drains are found to be especially high contributors of bacterial contamination. Total and fecal coliform and enterococcal bacteria are used to indicate the likelihood of pathogenic organisms, such as viruses, in surface waters. The presence of coliform bacteria indicates potential health risks to users of recreational waters, and specifically enterococcus bacteria have been shown to cause health risks including stomach flu and other infections. The amount of these indicator bacteria in southern California rivers and coastal waters may be dependent on season, and have been linked to rainfall amounts, especially the first major rainfall of the season (the "first flush"). The amount of total coliforms, fecal coliforms (as estimated by *E. coli*), and enterococcus were tested at several sites mainly in the LA/Long Beach harbor complex in November, February, May, August, and after the first flush (> 0.5 inches rainfall). The results yielded several overlying themes: 1) there is not an overall "seasonal" pattern – more wet vs. dry sampling event pattern; 2) health limits were exceeded for most "first flush" and fall samples; 3) there were spikes in pathogen input to the harbor at Dominguez channel and the LA River; and 4) most concentrations abated by the time plumes reached the gates of the harbor breakwaters. Bacterial concentrations were also negatively correlated with salinity and positively correlated with turbidity, agreeing with previous studies. This one-year project will serve as a model for an additional 5-year monitoring project of the same area and will provide valuable data on the dynamics of bacterial concentrations in the LA/Long Beach harbor complex.

Introduction

Non-point source runoff can increase the amount of bacteria in surface and coastal waters. Waterfowl and marine mammals can also contribute to bacterial runoff especially near coastal wetlands and other suitable habitats. Freshwater outlets such as storm drains are found to be especially high contributors of bacterial contamination (Noble et al. 2000, Gold et al. 1992, Schiff 1998). Total and fecal coliform and enterococcal bacteria are used to indicate the likelihood of pathogenic organisms, such as viruses, in surface waters. The levels of these bacteria have been correlated to the incidence of illness in swimmers. The presence of coliform bacteria indicates potential health risks to users of recreational waters, and specifically enterococcus bacteria have been shown to cause health risks including stomach flu and other infections. The amount of these indicator bacteria in southern California rivers and coastal waters may be dependent on season, and have been linked rainfall amounts (Noble et al. 2003). Seasonal environmental auditing of local rivers, harbors, and ocean provides valuable insight into bacteria content and dynamics. This study conducted seasonal monitoring of bacterial concentrations moving downstream and entering harbors and local recreation areas, specifically in the Long Beach and Los Angeles harbor areas. Some parts of these harbor areas have been largely overlooked due to the lack of recreational activity in their waters, so this study aims to start a comprehensive dataset of bacterial concentrations found in the whole system, not just bathing beaches.

The described function of the Los Angeles Regional Water Quality Control Board's (LARWQCB) basin plan includes preservation and protection of regional waters, and sets narrative and numerical objectives that must be met in order to protect the designated beneficial uses. The basin plan also provides information to the public about local water quality issues. Bacterial and coliform testing is part of the regional objectives for inland and coastal waters. Many organizations have expressed a need for more bacteriological data, both for public health interest and to better understand the conditions of the local watersheds.

This project primarily served Supplemental Environmental Project (SEP) category number 3, Environmental Auditing, and also served category number 4, Public Awareness Watershed Assessment. The specific goal of this project is to provide narrative and numerical bacteriological data for ten sample sites over five discrete times (November, February, May, August and after the first flush) over the course of a year, and to report this information to the LARWQCB, water quality affiliates, and the local community via the final report of this project. The Seasonal Bacterial Study provides both narrative and numerical bacteriological data for the Los Angeles, San Gabriel, and Dominguez Channel watersheds over seasons and first wet weather conditions. It can also be determined by this study if the sites exceed existing Total Maximum Daily Loads (TMDLs) as listed in the LARWQCB Basin Plan.

Materials and Methods

The amount of total coliforms, fecal coliforms (as estimated by *E. coli*), and enterococcus were tested at each site in February, May, August, November, and after the first flush (> 0.5 inches rainfall*) (Table 1). The sampling events were defined as wet weather events if there was rainfall up to 4 days before the sampling date, and the other dates were considered dry weather events. The ten originally proposed sites are shown in Table 2. During the two wet weather sampling dates 3 additional sites near the mouth of the LA Harbor were also analyzed for a more complete view of the dynamics of the river flow (Table 3). Throughout the study, other participating organizations have sampled additional sites of interest on our sampling dates, and the data has been added to the database (Table 3). All three indicators may not have been tested for all of these additional sites.

Table 1: Sampling Dates

Sampling Event	Sampling Date	Type of event
Winter 2003	February 4, 2003	Dry weather
Spring 2003	May 17, 2003	Dry weather
Summer 2003	August 6, 2003	Dry weather
First Flush 2003	November 4, 2003	Wet weather (rain 3 days earlier)
Fall 2003	November 17, 2003	Wet weather (rain 4 days earlier)

Table 2: Originally proposed sampling sites

Site	Latitude and Longitude
LA River at Willow St.	33.80433 N, 118.2055 W
Dominguez Channel at 223rd St.	33.82417 N, 118.242 W
Mouth of LA River (Port of LA, POLA)	33° 45’ 43’’ N, 118° 12’ 48’ W
Belmont Pier, Long Beach	33° 45’ 41’’ N, 118° 09’ 48’ W
Colorado Lagoon, Long Beach	33° 46’ 13’’ N, 118° 09’ 48’ W
Cabrillo Beach	33° 42’ 40’’ N, 118 17’ 04” W
Alamitos Bay, Long Beach	33° 45’ 00’’ N, 118 08’ 45” W
Mouth of San Gabriel River, Long Beach	33° 07’ 50’’ N, 118 45’ 31” W
Angels Gate, POLA	33° 42’ 40’’ N, 118 15’ 00” W
Queens Gate, Long Beach	33° 12’ 05’’ N, 118 43’ 25” W

Table 3: Other sites added during the duration of the study.

Site	Latitude and Longitude	Added by*	Number of times sampled
Sites added to characterize wet weather LA river runoff			
Queen Mary/Freeman Island	33.7461 N, 118.1734 W	SCMI	2
Queen Mary/Grissom Island	33.754 N, 118.1849 W	SCMI	2
Junipero Ave.	33.76241 N, 118.1648 W	SCMI	2

* The proposed threshold of >1.5 inches for a first flush event was changed to >0.5 inches after discussions with other monitoring organizations and health agencies that use the >0.5 inches level to characterize a storm event.

Site	Latitude and Longitude	Added by*	Number of times sampled
Sites added by other monitoring organizations			
11th St., Sunset Beach	33.72 N, 118.07 W	OCSurf	1
Alamitos Bay at Bayshore Dr.	33.75 N, 118.13 W	AMRF	1
Big Canyon Creek	33.63 N, 117.88 W	DIVERS	1
Bolsa Chica (foot bridge, inner bay)	33.70 N, 118.05 W	BCC	1
Cabrillo Trailer Park, Huntington Beach	33.64 N, 117.99 W	OCSurf	4
Cerritos Channel, Loynes bridge	33.77 N, 118.10 W	OCSurf	4
Edison Plant, downcoast	33.64 N, 117.97 W	OCSurf	3
Edison Plant, Huntington Beach	33.61 N, 117.98 W	OCSurf	5
Edison Plant, upcoast	33.64 N, 117.98 W	OCSurf	1
Fisher’s Gulch, Bolsa Chica	33.6846 N, 118.0254 W	BCC	2
Freeman Creek East	33.69849 N, 118.0448 W	BCC	1
Gas Plant Pond West	33.68584 N, 118.2402 W	BCC	1
Golden Shore Marine Preserve	33.76353 N, 118.2022 W	AMRF	1
Marine Stadium	33.76413 N, 118.1263 W	AMRF	1
Mother's Beach, Long Beach	33.75797 N, 118.119 W	AMRF	1
Peter’s Landing	33.72067 N, 118.0768 W	OCSurf	4
Point Fermin	33.70626 N, 118.2874 W	CMA	1
San Diego Creek	33.65083 N, 117.8672 W	DIVERS	1
Santa Ana River	33.63233 N, 117.9558 W	DIVERS	1
Seal Beach Pier	33.73767 N, 118.1081 W	OCSurf	4
Springdale Pond	33.69621 N, 118.0272 W	BCC	1
Wintersberg/Garden Grove FCC	Not available	BCC	2

***Organization codes:** AMRF=Algalita Marine Research Foundation, BCC=Bolsa Chica Conservancy, DIVERS=Divers Involved Voluntarily in Environmental Remediation and Safety, OCSurf=Surfrider, Huntington/Seal Beach chapter, SCMI=Southern California Marine Institute

The sampling methods and data conformed to the Quality Assurance Project Plan (QAPP) and Quality Assurance/Quality Control (QA/QC) protocols approved by the LARWQCB, and complement existing 319(h) and SEP projects. Total and fecal coliforms were analyzed using the IDEXX Colilert-18 method, and Enterococcus was analyzed by the IDEXX Enterolert method.

On the first sampling event of February 4, 2003, Colilert-24 was used instead of Colilert-18. Duplicate samples using both tests for each station were completed on the May 17, 2003 sampling event to see if significant differences existed between the two tests. Colilert-18 is the preferred test for marine waters (personal communication, Charlie McGee, Orange County Sanitation District and IDEXX corporation employees).

The results were submitted with the second quarterly report. In general, Colilert-18 and Colilert-24 are comparable, but when results are found outside of the 95% confidence intervals, Colilert-24 overestimates the amount of bacteria in the sample. This trend has been taken into consideration when comparing the February 4, 2003 sampling results.

Each collector was provided with a crate containing all sampling gear required: directions to each site and proper sampling technique, a field data sheet, gloves, horizontal water sampler (if needed), a cooler with blue ice, whirl packs, a Sharpie, pen, thermometer, Dissolved Oxygen Test Kit, salinity bottle, bottle for nutrient sample, Secchi disk, and Forel-Ule Color Kit. All volunteers and SCMI staff were taught how to properly collect bacteria samples. Bacteria samples were collected using sterile, plastic sampling bottles or whirl-paks. Samples were refrigerated to 4 ^{o}C in the dark, and delivered to SCMI within 5 hours. Analysis was started within 6 hours after the sample was collected. Data quality objectives are summarized in Table 4. Whenever possible the methods with the greatest sensitivity and lowest detection limit were employed as the primary methods. One split sample was sent to a certified lab for each sampling event. One lab replicate and one blank per analysis method (Colilert-18 and Enterolert) were also analyzed for each sampling event.

Table 4. Data Quality Objectives for Biological Parameters

Parameter	**Method/range**	**Units**	**Detection Limit**	**Sensitivity**	**Precision**	**Accuracy**	**Completeness**
Total Coliform Bacteria	Colilert 18 hour	MPN/ 100ml	10	See IDEXX quantitray tables	Duplicates within 95% confidence limits	Positive standard within ½ of an order of magnitude	80%
E. coli Bacteria	Colilert 18 hour	MPN/ 100ml	10	See IDEXX quantitray tables	Duplicates within 95% confidence limits	Positive standard within ½ of an order of magnitude	80%
Entero-coccus Bacteria	Enterolert 24 hour	MPN/ 100ml	10	See IDEXX quantitray tables	Duplicates within 95% confidence limits	Positive standard within ½ of an order of magnitude	80%

In addition to taking bacteria water samples, each site was tested for air and water temperature, dissolved oxygen, pH, salinity, turbidity, nutrients (Nitrate-N and Orthophosphate), Secchi depth, Forel-Ule color, and other visual observations. Data quality objectives for these parameters are summarized in Tables 5 and 6. Temperature was measured by alcohol field thermometers by Lamotte and tested against a NIST certified thermometer. Dissolved oxygen was measured by a modified winkler titration kit by Lamotte. pH was measured by a pHTestr3 by Oakton and calibrated with pH standards by Lamotte. Turbidity was measured in EPA mode by a LaMotte 2020 Turbidimeter calibrated by AMCO Primary turbidity standards. Nutrients were measured by a SMART2 colorimeter by Lamotte, and results were compared with standards by

Lamotte. Salinity samples were analyzed by USC staff using a Guildline AutoSal Model 8400A calibrated to IAPSO Standard Seawater solutions by Ocean Scientific Institute.

Table 5. Data Quality Objectives for Conventional Water Quality Parameters

Parameter	Method/Range	Units	Detection Limit	Sensitivity *	Precision	Accuracy	Completeness
Temperature	Thermometer (-5 to 50)	^{o} C	-5	0.5 ^{o} C	± 0.5 ^{o} C	± 0.5 ^{o} C	80%
DO	Modified Winkler Titration	mg/l	0.2 mg/l	0.2 mg/l	± 10%	± 10%	80%
pH	pH meter	pH units	2.0	0.1 unit	± 0.2 units	± 0.2 units	80%
Turbidity/ Transparency	Nephelometer	NTUs		0.1	± 10%	± 10%	80%
	Secchi Disk	Secchi Depth	0.1 m	0.1 m	± 0.1 m	± 0.1 m	80%

Table 6. Data Quality Objectives for Nutrients Using Colorimeters or Spectrophotometers

Parameter	Method/Range	Units	Detection Limit	Sensitivity	Precision	Accuracy	Completeness
Nitrate Nitrogen	Cadmium reduction	mg/l	0.05	0.01	±0.2 (<2.0) ±10% (>2)	±0.2 (<2.0) ±10% (>2)	80%
Ortho-Phosphate	Ascorbic acid	mg/l	0.07	0.01	±0.2 (<2.0) ±10% (>2)	±0.2 (<2.0) ±10% (>2)	80%

* Note: Some test kits vary in sensitivity over the range of detection. The specific range of readings is noted in parentheses.

Results

Bacterial concentrations for all three indicators were significantly higher during the first flush sampling event than all other seasonal sampling events (Figure 1 and Appendix A, Table A.1 [Total coliforms p<0.04, *E. coli* p<0.03, and enterococcus p<0.08]). When the "dry" (February, May, and August) events were compared with the "wet" events (First Flush and November), bacterial concentrations were again higher for the wet events, except for enterococcus (defined as sampling events that happened within a week after a significant rain [>0.5 inches]) (Figure 2 and Appendix A, Table A.2 [Total coliforms p< 0.02, E.coli p<0.05, and enterococcus p<0.21]). The November sampling event was sampled 4 days after a rain event, while the First Flush event was sampled 3 days after a rain event. A summary of the complete data set is found in Appendix C.

Averages of all three indicators by event were then graphed versus their salinity regime (fresh, brackish, or salt). For all three indicators, fresh water had the highest concentrations and seawater had the lowest, regardless of season (Figures 3, 4, and 5). During the first flush sampling event, however, the brackish water sites had the highest concentrations of Enterococcus (Figure 5).

For all three indicators, the first flush event had the highest concentrations for most stations (Figures 6, 7, and 8). For a few stations (L.A. River at Willow, Queen Mary/Grissom Island, and Queen Mary/Freeman Island), concentrations were higher for total coliforms in the fall sampling event. These values either lie within the 95% confidence limits of each other or one sample had a greater than answer in one of the sampling events, so no significance should be assigned to this apparent change in trends. L.A. River at Willow and Queen Mary/Freeman Island were also higher in the fall for Enterococcus. The Queen Mary/Freeman Island samples were the only samples that lay outside of each other's 95% confidence limits, however. One of the reasons for this difference may be the number of days after a rain (there was a longer period between the last rain and the fall sampling event). Cabrillo Beach/Inner N had its highest concentrations of bacterial indicators during the May sampling event.

Bacterial concentrations were then graphed by sampling event from north to south. For all three indicators, there are peaks at specific sites (Figures 9, 10, and 11). From the north, the two largest inputs are from Dominguez Channel and L.A. River at Willow (sites NS02 and NS04 on the graph, respectively). By looking specifically at bacterial concentrations as they move from the L.A. river out into the harbor, a consistent decrease in concentration is seen with distance from the river mouth (Figures 12, 13, and 14).

Assembly Bill 411 (AB 411) states that the following limits should not be exceeded for bacterial indicators: 10,000 MPN/100mL for total coliforms, 400 MPN/100mL for fecal coliforms, and 104 MPN/100mL for enterococcus. Table 7 shows certain problem stations that exceeded these levels for at least one indicator on at least one sampling date. L.A. River at Willow was responsible for 22.86% of the 70 total exceedences, followed by L.A. River mouth (10%), Queen Mary/Grissom Island (8.57%), and Dominguez Channel (8.57%). By test material, surf zone and ocean sites were responsible for the least exceedences (5.71%) (Table 8). By sampling date, 48.44% of the exceedences were on the first flush sampling event, while the August sampling event had the least exceedences (6.25%) (see Table 9).

Table 7: Stations that exceeded AB 411 standards

StationID	TestMaterial	Total Coliforms	E_ coli	Enterococcus	Total	Percentage
L.A. River @ Willow	Creek water	5	6	5	16	**22.86%**
San Diego Creek	Creek water	1	1		2	**2.86%**
Bolsa Chica (foot bridge, inner bay)	Estuary	1	1		2	**2.86%**
Cerritos Channel, Loynes bridge	Estuary	1	1	1	3	**4.29%**
Colorado Lagoon	Estuary	1	1	1	3	**4.29%**
Dominguez Channel @ 223rd St.	Estuary	2	3	1	6	**8.57%**
Fisher's Gulch, Bolsa Chica	Estuary	2			2	**2.86%**
Gas Plant Pond West	Estuary	1			1	**1.43%**
Peter's Landing	Estuary	1	1	2	4	**5.71%**

StationID	TestMaterial	Total Coliforms	E_ coli	Enterococcus	Total	Percentage
S.G. River mouth	Estuary	1	1	1	3	**4.29%**
Wintersberg/Garden Grove FCC	Estuary	2			2	**2.86%**
Cabrillo Beach/Inner N	Harbor		1	2	3	**4.29%**
L.A. River mouth	Harbor	3	3	1	7	**10.00%**
Queen Mary/Freeman Island	Harbor	1		1	2	**2.86%**
Queen Mary/Grissom Island	Harbor	2	2	2	6	**8.57%**
Queen's Gate	Open Ocean	1	1		2	**2.86%**
Seal Beach Pier	Open Ocean			2	2	**2.86%**
Edison Plant, Huntington Beach	Surf Zone			1	1	**1.43%**
Junipero Ave, LB	Surf Zone	1	1	1	3	**4.29%**
Total		**26**	**23**	**21**	**70**	
Percentage		**37.14%**	**32.86%**	**30.00%**		**100.00%**

Table 8: AB 411 exceedences by test material

TestMaterial	# of Stations	Total Coliforms	E_ coli	Enterococcus	Total	Percentage
Creek water	2	6	7	5	18	**25.71%**
Estuary	9	12	8	6	26	**37.14%**
Harbor	4	6	6	6	18	**25.71%**
Open Ocean	2	1	1	2	4	**5.71%**
Surf Zone	2	1	1	2	4	**5.71%**
Total	**19**	**26**	**23**	**21**	**70**	**100.00%**

Table 9: AB 411 exceedences by Sampling Date*

SampleDate	Total Coliforms	E_ coli	Enterococcus	Total	Percentage
04-Feb-03	4	1	3	8	12.50%
17-May-03	4	3	1	8	12.50%
06-Aug-03	1	2	1	4	6.25%
04-Nov-03	10	10	11	31	48.44%
17-Nov-03	5	4	4	13	20.31%
Total	**24**	**20**	**20**	**64**	**100.00%**

*The total amount of parameters tested is not equal to the other tables due to additional samples taken at L.A. River at Willow on 3/25/03 and L.A. River mouth and L.A. River at Willow on 12/19/03.

Correlations were also made between bacterial concentrations and various physical and chemical parameters that were also measured (Appendix A, Table A.3). No correlations were found between bacterial indicators and temperature and dissolved oxygen. A negative correlation was found between salinity and total coliforms (-0.69) and *E. coli* (-0.67). A positive correlation was found between turbidity and total coliforms (0.84), *E. coli* (0.81), and enterococcus (0.82). Coelho et al. 1999 found similar correlations to salinity and turbidity. For nitrate nitrogen, a positive correlation was found with enterococcus (0.72) and total coliforms (0.61). For orthophosphate, a positive correlation was found with total coliforms (0.73).

Project success is dependent on the completeness of sampling and the integrity of the samples. Information on precision and accuracy of bacterial samples has been detailed in the quarterly reports. Information on the precision and accuracy of collateral measurements can be made upon request. Two stations from the first flush data set were omitted due to questionable contamination: Cerritos Channel and Peter's landing (their results were a full order of magnitude greater than all of the other samples taken). Completeness is the fraction of planned data that must be collected. It is expected that all samples will be collected at each sampling date, however measurements may not be taken when anticipated due to adverse weather conditions, safety concerns, and equipment problems. Completeness data can be found in Appendix B. All of the parameters measured fell within the completeness goal of 80% except for salinity and secchi depth. The final results for salinity for the November 17, 2003 sampling have yet to be run by USC, so once those are obtained the completeness objective will be met. As for secchi depth, several sites could not be sampled due to shallow depths or high flowing water. Secchi depth could not be collected for the following original stations: Alamitos Bay, LA River at Willow St., and Cabrillo Beach/Inner N. If these stations are omitted from the completeness equation, the completeness value falls within the 80% objective.

Conclusions

The goal of this project is to provide narrative and numerical bacteriological data for ten sample sites over five discrete times (November, February, May, August and after the first flush) over the course of a year. These results yielded several overlying themes: 1) there is not an overall "seasonal" pattern – more wet vs. dry sampling event pattern; 2) health limits were exceeded for most "first flush" and fall samples; 3) there were spikes in pathogen input to the harbor at Dominguez channel and the LA River; and 4) most concentrations abated by the time plumes reached the gates.

Wet versus dry sampling events have been compared by other studies on bacterial concentrations in the southern California region (Schiff et al. 2003; Noble et al. 2003). These studies also found a higher number of exceedences of AB 411 standards for all indicators, especially at freshwater outflows of stormwater runoff. Storm drains are a notable source of contaminants and pathogens in southern California (Gold et al. 1992; Noble et al. 2000; Noble et al. 2003; Schiff et al. 2003). The high percentage of AB 411 exceedences at L.A. River at Willow, the L.A. River mouth, Queen Mary/Grissom Island, and Dominguez Channel can be attributed to their "storm drain-like" properties. The L.A. River and Dominguez channel are both concrete lined conduits of stormwater runoff for most of their lengths, and Queen Mary/Grissom Island is a station just outside of the L.A. River mouth. As the stormwater plumes move offshore, the concentration of bacterial indicators abates as the salinity increases and mixing occurs. Some of the lowest concentrations occurred at Queen's Gate and Angel's Gate (the exits of the LA/Long Beach harbors complex). During the first flush event, however, even Queen's Gate exceeded AB 411 standards for total coliforms and *E. coli*.

Besides these general results, some stations were distinguished as having a different pattern. For example, the highest bacterial concentrations for Cabrillo Beach/Inner N were during the May sampling event. There may have been an additional input into the area during that time period (i.e., the storm drain that leads into the inner beach may have been actively flowing). The tidal height may also have played a factor. The May sampling event had the most dramatic changes between low and high tide out of all of the sampling events. An overabundance of birds or animals breeding in the area may also be another reason for the high concentrations of fecal indicators.

The February sampling event had very low numbers for Dominguez channel as compared to the other sampling times. This result may have been due to a diversion of runoff from the water desalination plant in Torrance during dry weather periods from Santa Monica Bay to the Dominguez channel.

Correlations with bacterial concentrations and salinity and turbidity agree with previous results. Decreases in total coliform and *E. coli* concentrations with salinity agree with previous findings that suggest coliform bacteria do not survive in high salinities (Hanes and Fragala 1967; Coelho et al. 1999). Coelho et al. 1999 also found positive correlations between bacterial concentrations and turbidity.

SCMI has coordinated this sampling effort with its ecopartners' water quality monitoring projects. Dates of sampling were part of larger, county and state wide sampling efforts. SCMI is a research and education facility, and the information collected from this study will continue to be disseminated to K-12 and university students in the Southern California area as part of our science curriculum. The information has been shared with our ecopartners, including Heal the Bay, Surfrider, CoastKeeper and Environment Now, among others.

Recommendations for the 5-year study

SCMI has another 5 years of this project on the SEP approved list, and several lessons have been learned from this first year. Changes that will be incorporated to the new 5-year study will be based on these lessons.

Tidal height was not kept constant at each sampling time, so it's influences could not be determined. For the 5-year study, sampling will take place at similar tidal heights to prevent this confounding influence.

More replicates per sampling event would be useful in the future, but due to the proposed budget, are not fiscally possible. If more grant money is obtained from other sources, the amount of replicates will be increased.

Initially, the trigger for sampling the first flush event was to be greater than 0.5 inches at the Long Beach Airport, however, the first storm of the season (very early morning on November 1) only registered 0.12 inches at the airport while most other areas in the watershed exceeded the 0.5 inch threshold. Since the fourth (Fall) sampling event was already scheduled for November 4 (three days after this first storm), SCMI decided to use this as the first flush event. The fall sampling event (November 17) was one week after massive thunderstorms and hailstorms in Compton and four days after a significant rain (November 13). After analyzing the data, we believe that we accurately caught the first flush event, and future first flush events will be modeled after this sampling event (i.e., 3 days after a storm that releases greater than an average of 0.5 inches across the L.A. area).

References

California Regional Water Quality Control Board. 1995. *Water Quality Control Plan: Los Angeles Region.* Monterey Park, CA: California Regional Water Quality Control Board.

California Water Resources Control Board. 1997. *Water Quality Control Plan: California Ocean Plan.* Sacramento, CA: California Environmental Protection Agency, State Water Resources Control Board.

Clesceri, L.S., A.E. Greenberg, and A.D. Eaton (eds.). 1998. *Standard Methods for the Examination of Water and Wastewater, 20th ed.* Baltimore, MD: United Book Press, Inc.

Coelho, M.P.P., M.E. Marqeus, and J.C. Roseiro. 1999. Dynamics of Microbial Contamination at a Marine Recreational Site. *Marine Pollution Bulletin* 38 (12): 1242-1246.

Gold, M., M. Bartlett, C.D. McGee, and G. Deets. 1992. *Pathogens and indicators in storm drains within the Santa Monica Bay watershed.* Santa Monica Bay Restoration Project, Monterey Park, CA.

Hanes, N.B. and C. Fragala. 1967. Effect of seawater concentration on the survival of indicator bacteria. *J Water Pollution Control Fed* 39: 97.

Noble, Rachel T., et al. 2000. A Regional Survey of the Microbiological Water Quality along the Shoreline of the Southern California Bight. *Environmental Monitoring and Assessment* 64: 435-447.

Noble, R.T., D.F. Moore, M.K. Leecaster, C.D. McGee, and S.B. Weisberg. 2003. Comparison of total coliform, fecal coliform, and enterococcus bacterial indicator response for ocean recreational water testing. *Water Research* 37: 1637-1643.

Nuzzi, Robert and Robert Burhans. 1997. The use of enterococcus and coliform in characterizing bathing-beach waters. *Journal of Environmental Health* 60 (1): 16-22.

Schiff, K., S.B. Weisberg, and J.H. Dorsey. 1998. 'Microbiological monitoring of marine recreational waters in southern California', in *Southern California Coastal Water Research Project Annual Report 1997/1998,* Weisberg, S.B. (ed.), SCCWRP, Westminster, CA, pp. 179-186.

Schiff, K., Jessica Morton, and Stephen B. Weisberg. 2003. Retrospective evaluation of shoreline water quality along Santa Monica Bay beaches. *Marine Environmental Research* 56: 245-253.

List of Figures

Figure 1: Average bacteria concentrations by sampling event

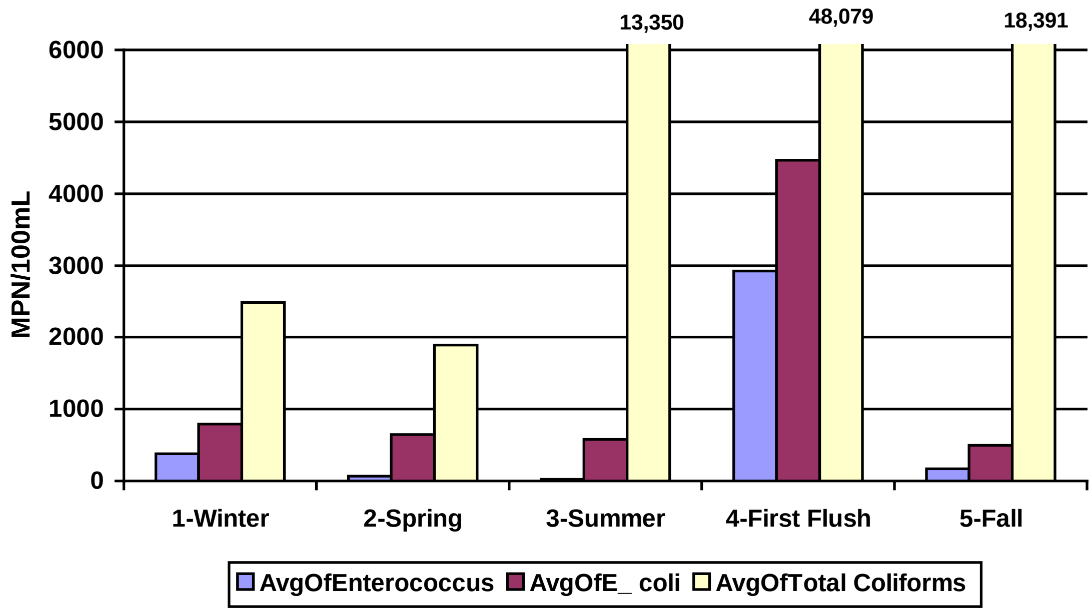


Figure 2: Average bacteria concentrations by "season"

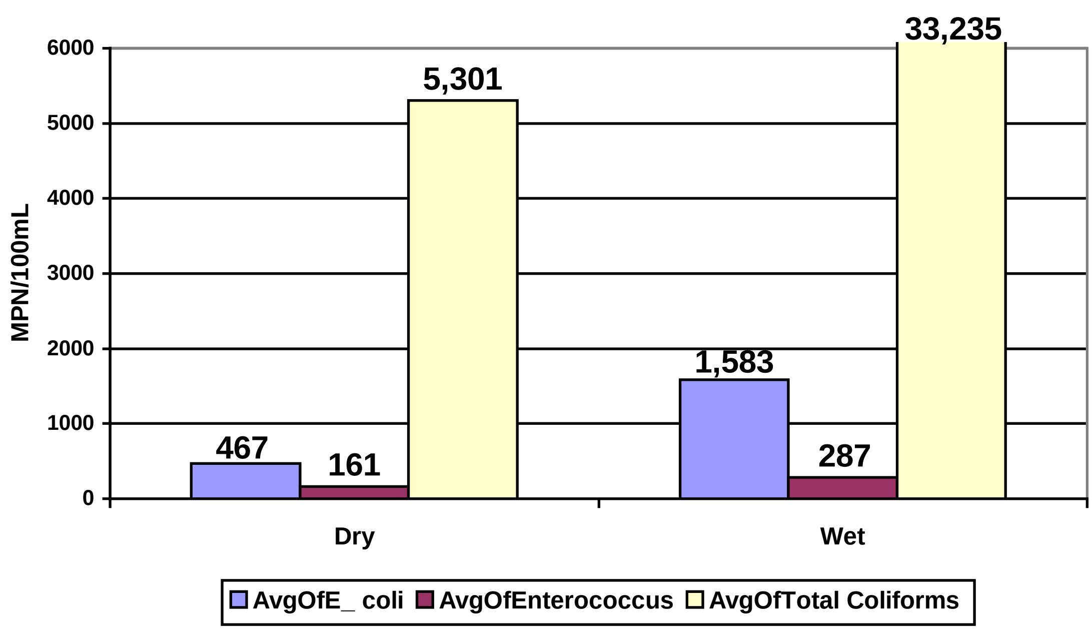


Figure 3: Averages of *E. coli* by salinity

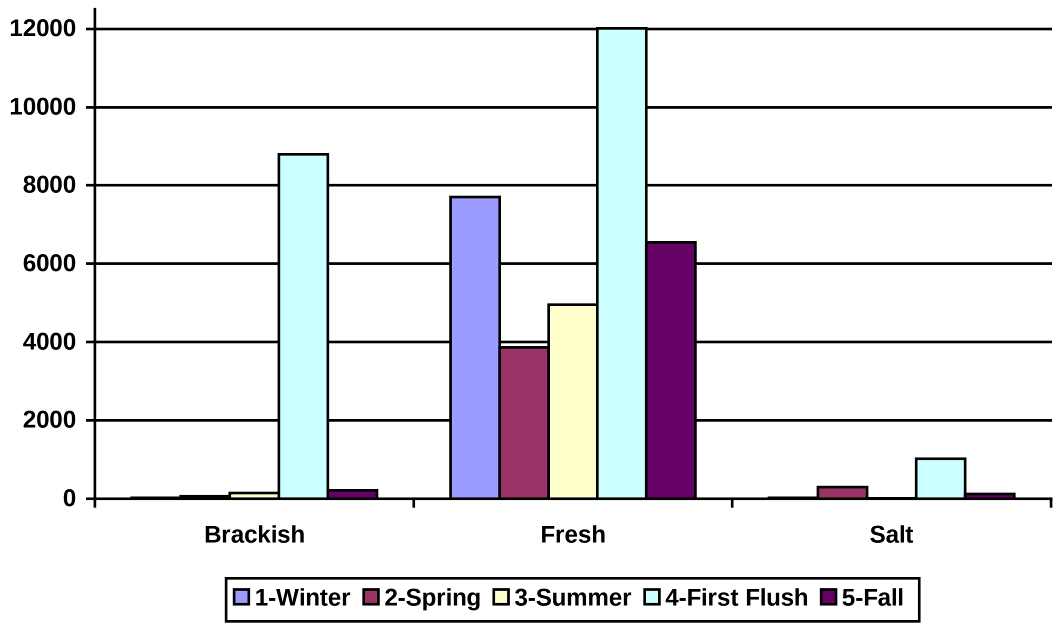


Figure 4: Total Coliform concentration by Salinity

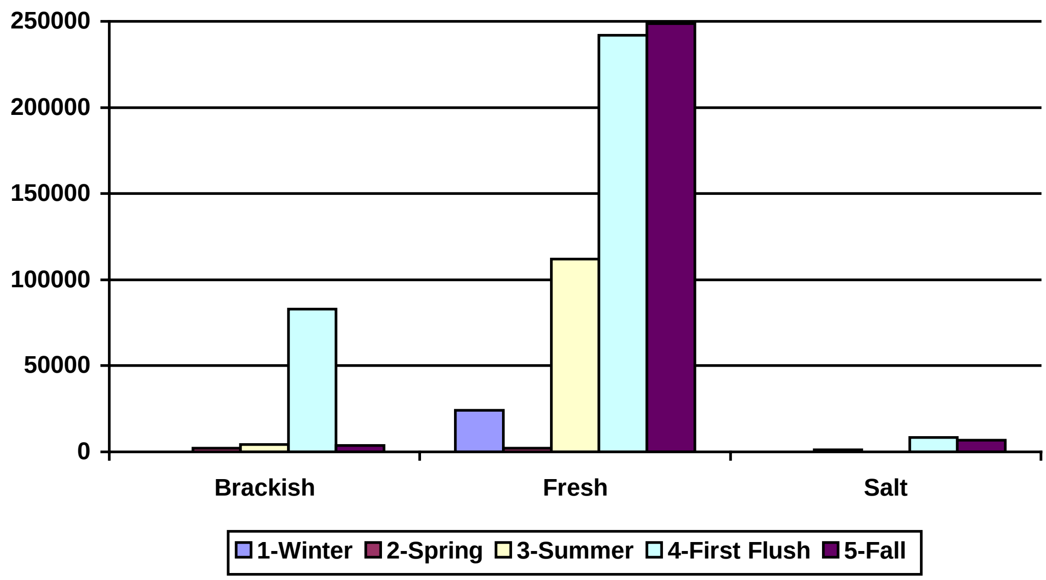


Figure 5: Enterococcus concentrations by salinity

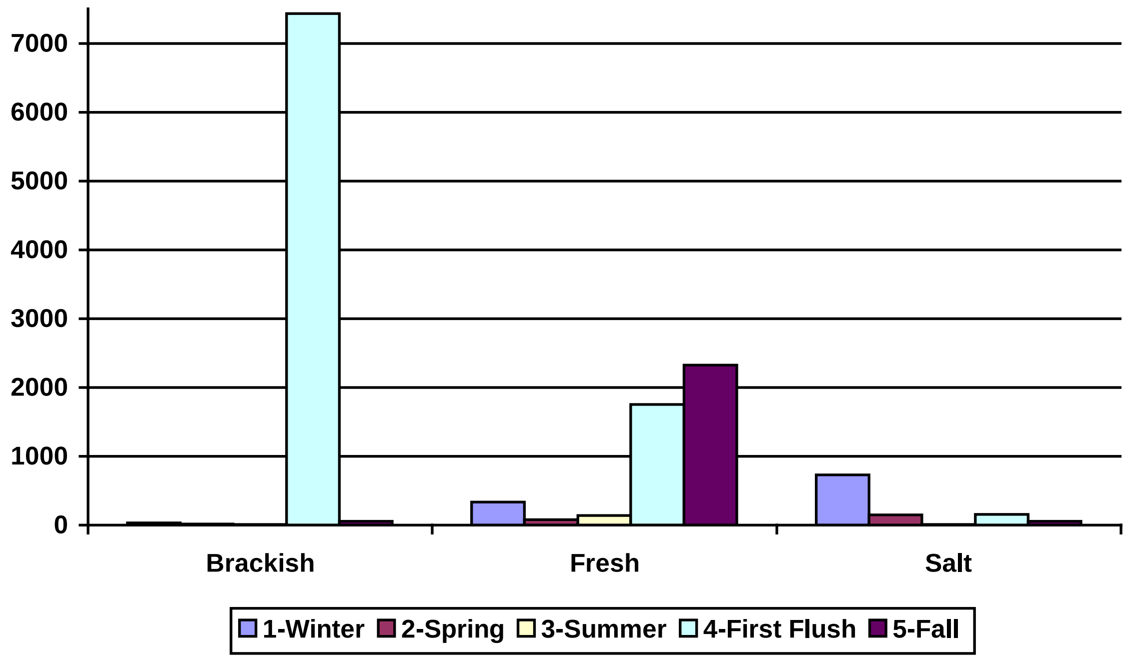


Figure 6: Total Coliform concentrations by Sampling event

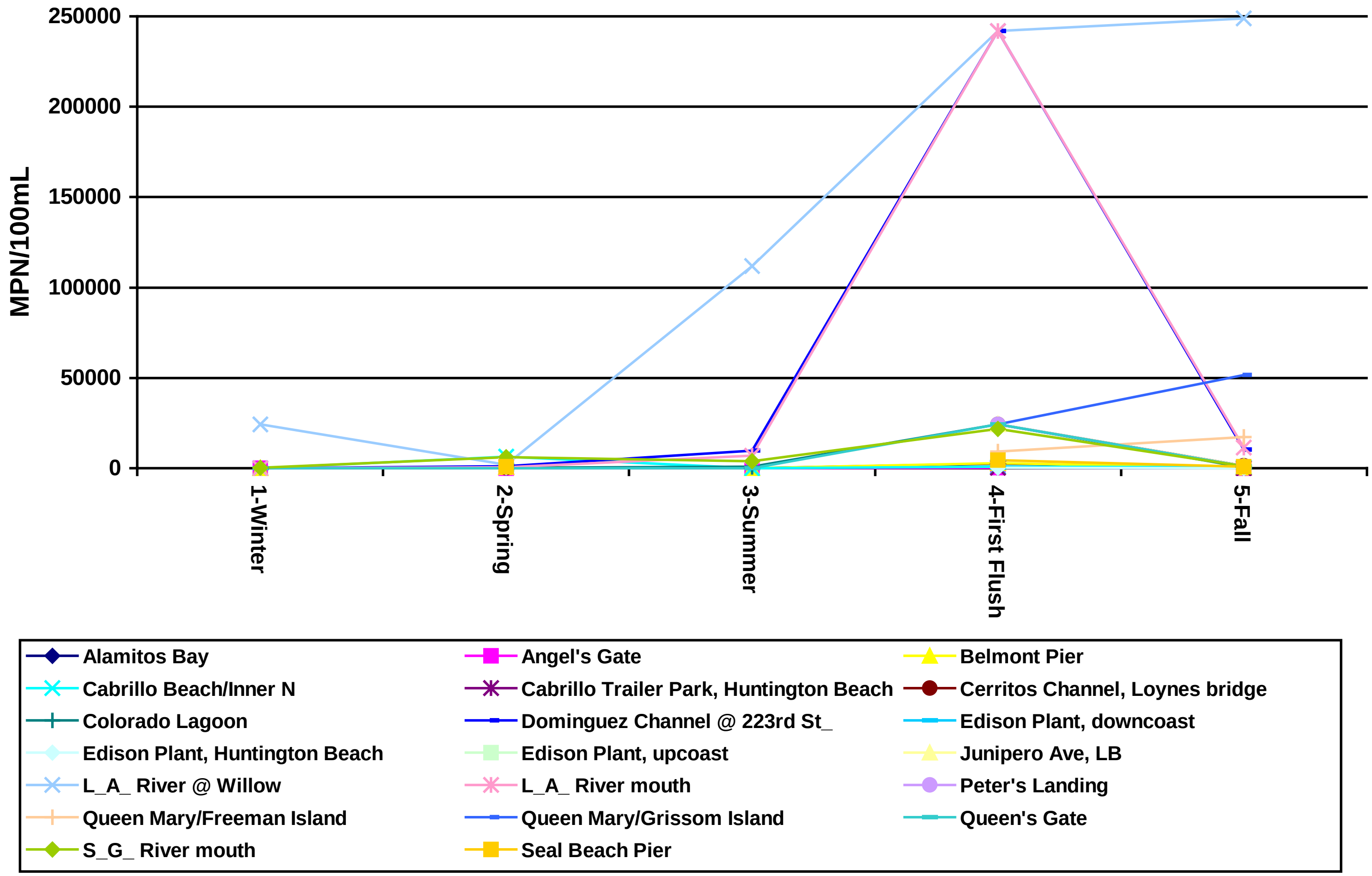


Figure 7: *E. coli* concentrations by sampling event

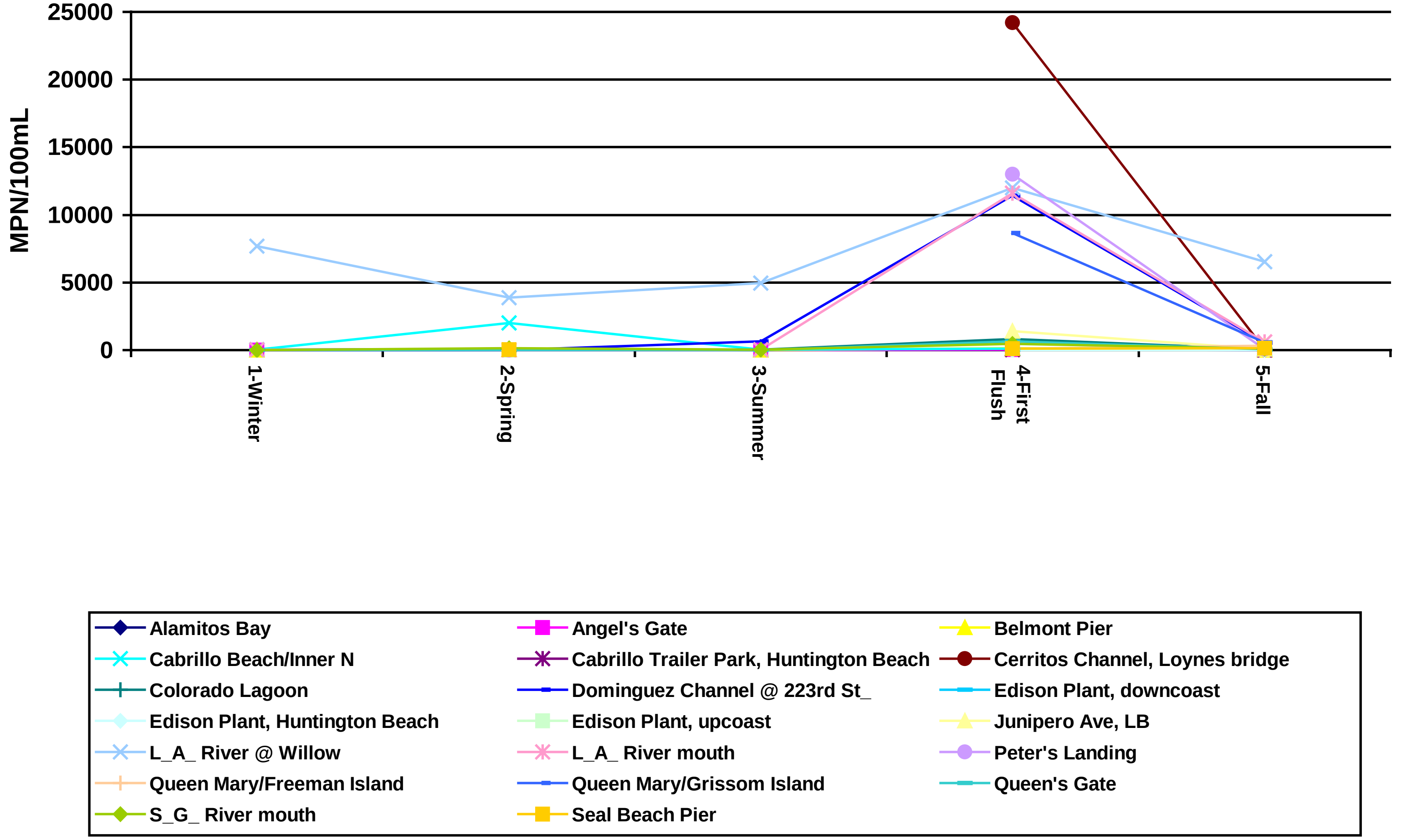


Figure 8: Enterococcus concentrations by Sampling event

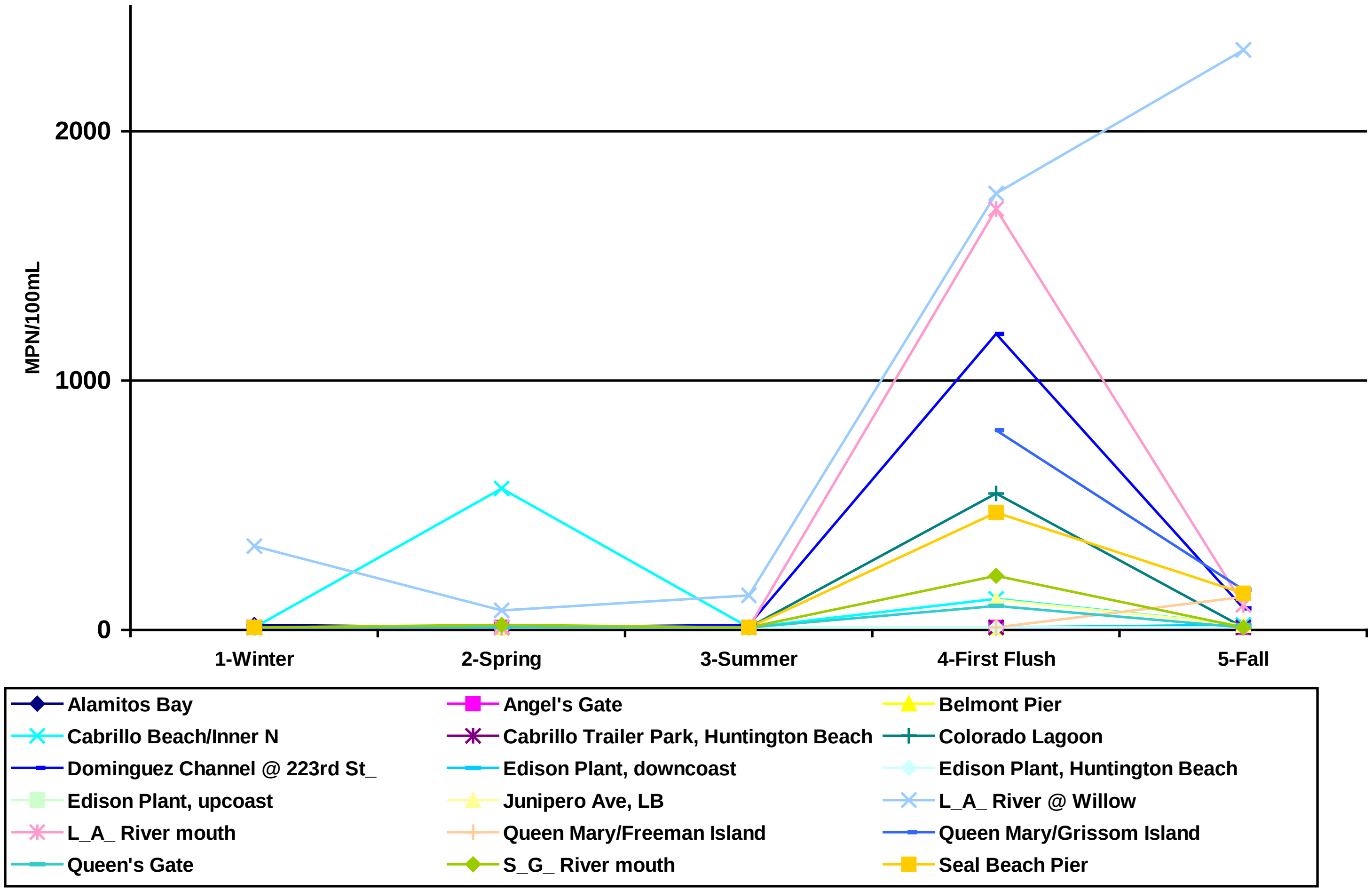


Figure 9: Total Coliform concentrations from North to South

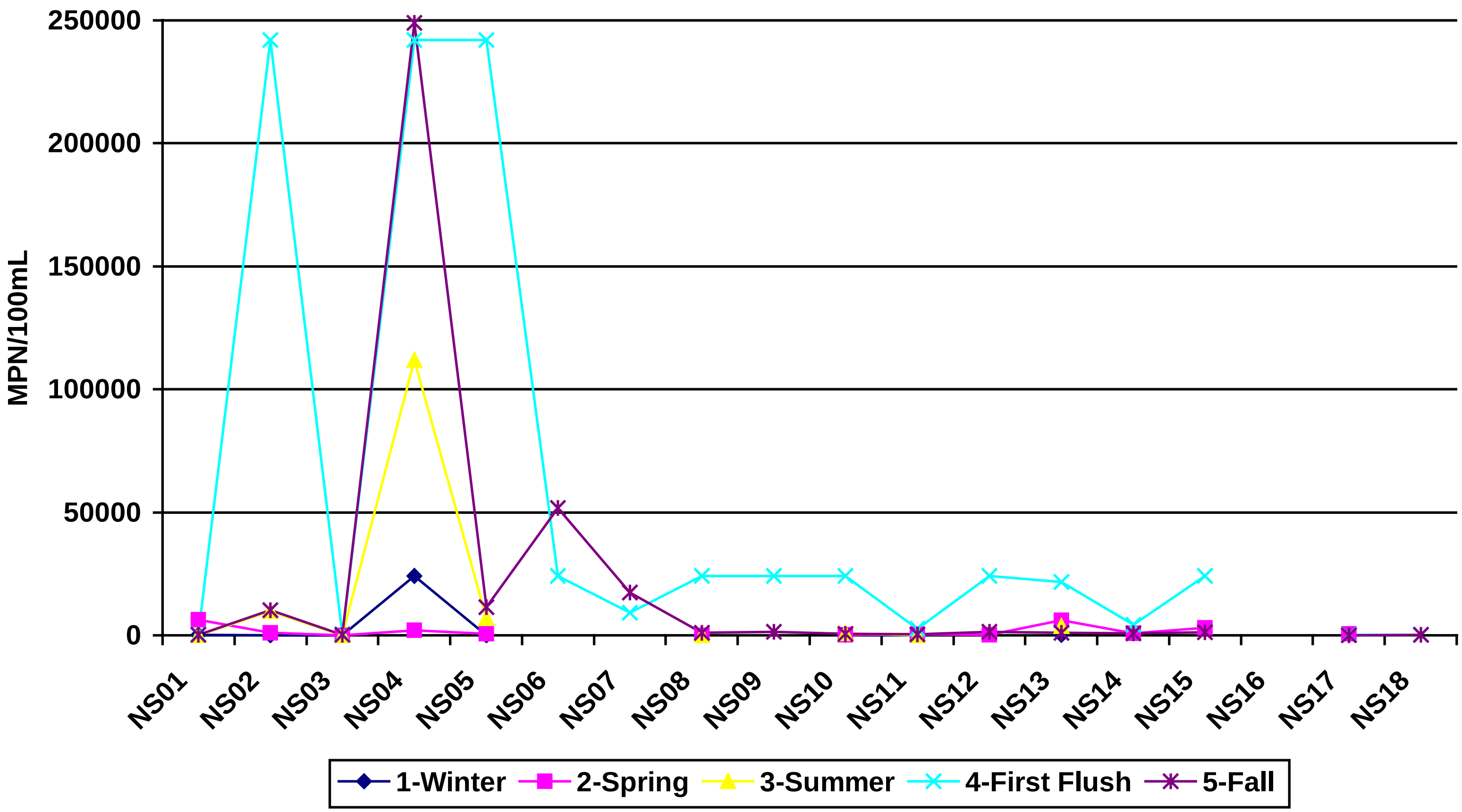


Figure 10: *E. coli* concentrations from North to South

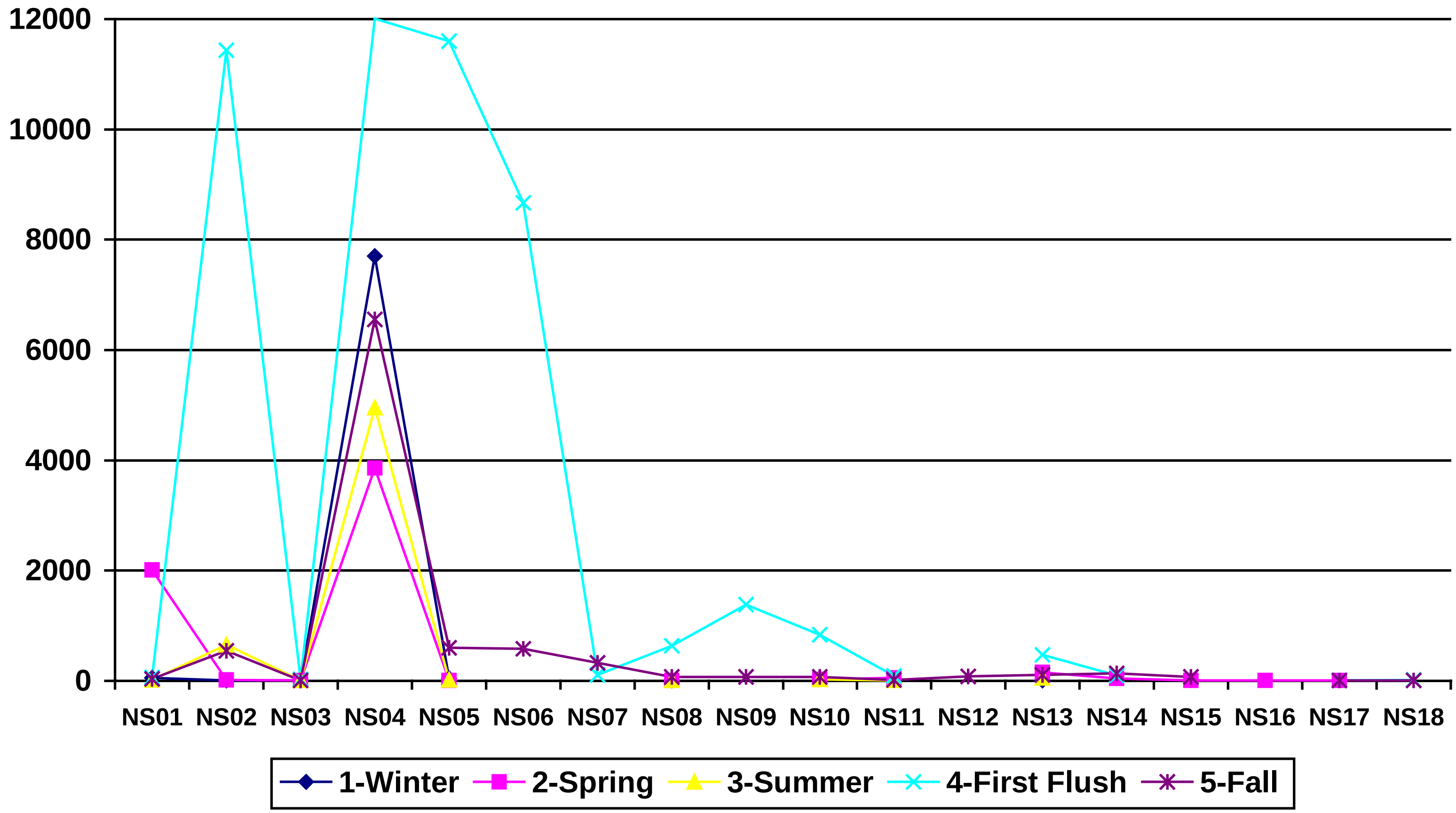


Figure 11: Enterococcus concentrations from North to South

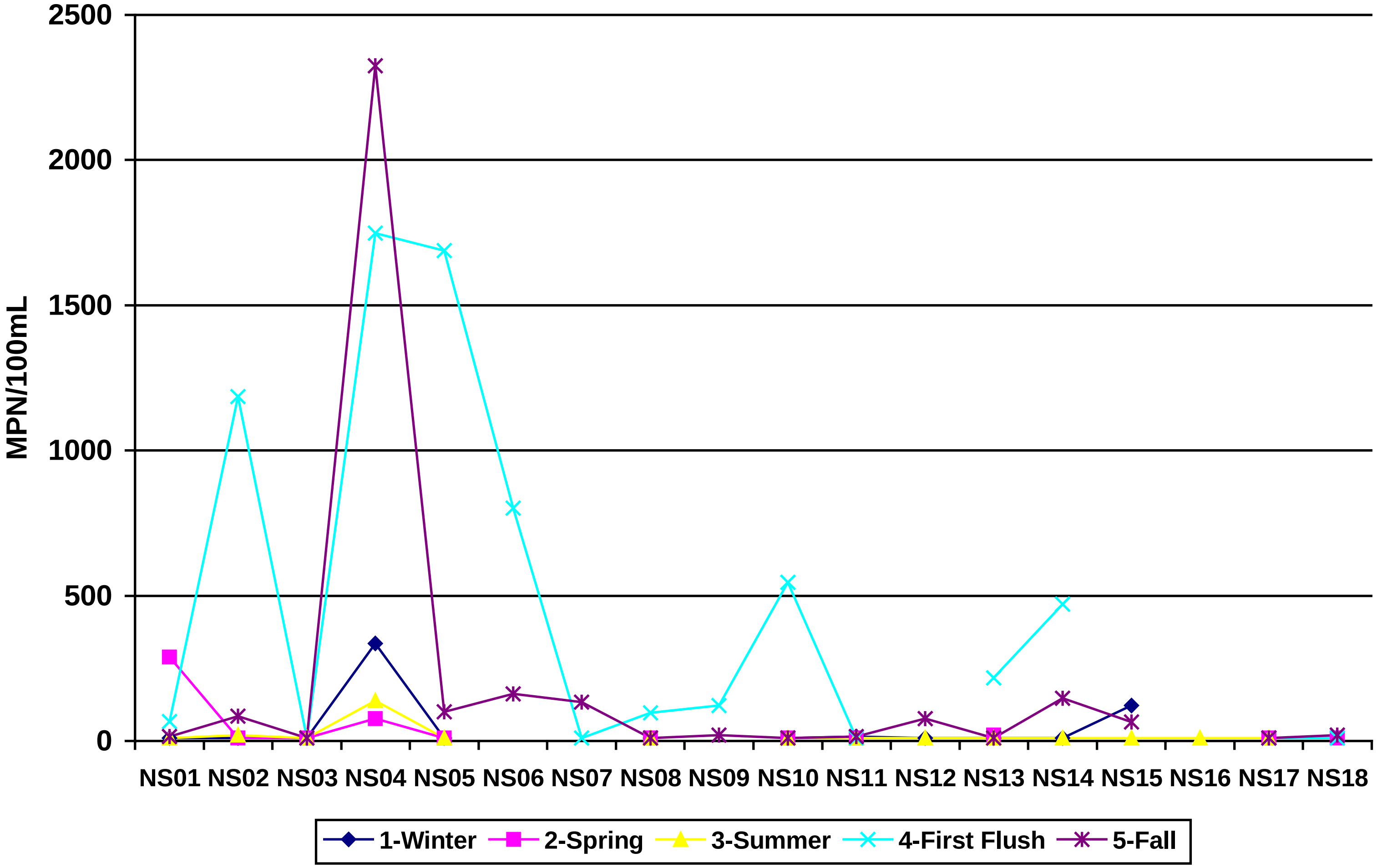


Figure 12: LA River watershed Total Coliform concentrations by Sampling Event

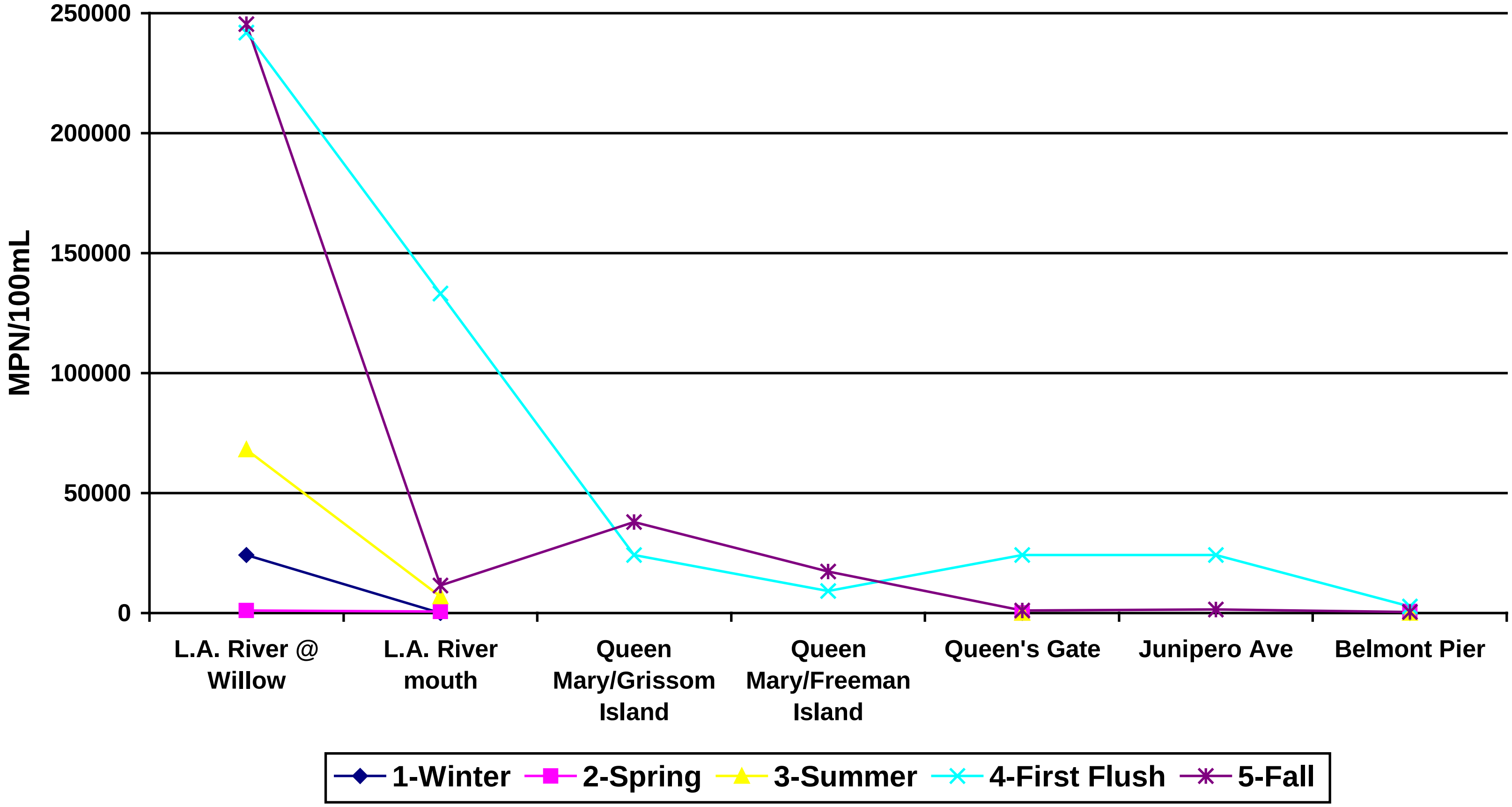


Figure 13: L.A. River Watershed *E. coli* concentrations by Sampling Event

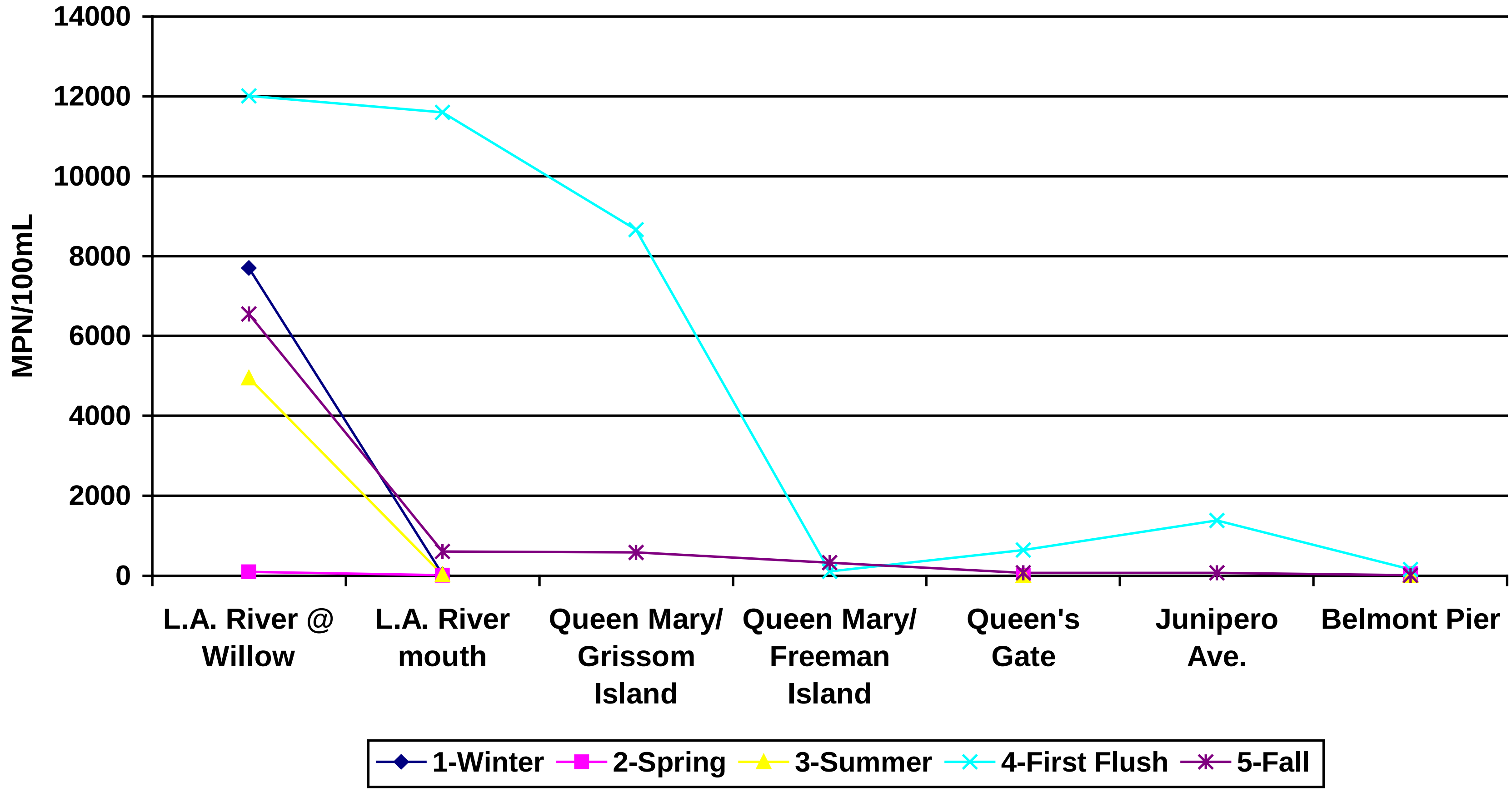
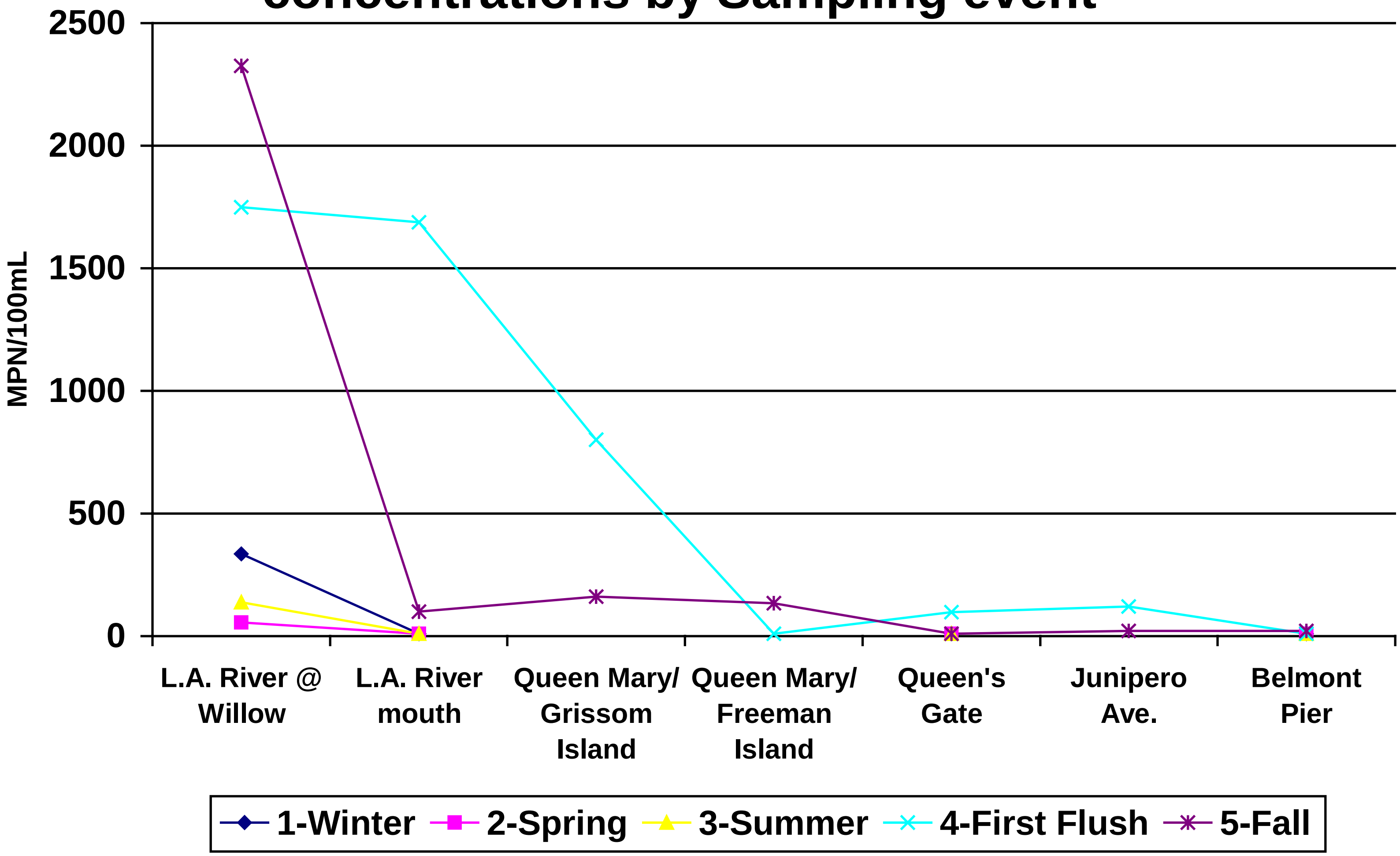


Figure 14: LA River Watershed Enterococcus concentrations by Sampling event



Appendices

A. Statistical Analyses
B. QA/QC data
C. Raw Data Summary

Appendix A: Statistical Analyses

Table A.1: Bacteria concentrations for first flush vs. all other sampling events

E.coli

t-Test: Two-Sample Assuming Unequal Variances

	Other	*First flush*
Mean	476.9622	2801.285
Variance	2268951	22160659
Observations	54	17
Hypothesized Mean Difference	0	
df	17	
t Stat	-2.00374	
P(T<=t) one-tail	0.030651	
t Critical one-tail	1.739606	
P(T<=t) two-tail	0.061301	
t Critical two-tail	2.109819	

Total Coliforms

t-Test: Two-Sample Assuming Unequal Variances

	Other	*First flush*
Mean	9906.701	48078.56
Variance	1.38E+09	7.55E+09
Observations	54	19
Hypothesized Mean Difference	0	
df	20	
t Stat	-1.85654	
P(T<=t) one-tail	0.039085	
t Critical one-tail	1.724718	
P(T<=t) two-tail	0.078169	
t Critical two-tail	2.085962	

Enterococcus

t-Test: Two-Sample Assuming Unequal Variances

	Other	*First flush*
Mean	165.1583	415.8941
Variance	506921.6	351545.1
Observations	60	17
Hypothesized Mean Difference	0	
df	30	
t Stat	-1.46914	
P(T<=t) one-tail	0.076102	
t Critical one-tail	1.69726	
P(T<=t) two-tail	0.152205	
t Critical two-tail	2.04227	

Table A.2: Bacteria concentrations for dry vs. wet sampling events

E. coli

t-Test: Two-Sample Assuming Unequal Variances

	Dry	*Wet*
Mean	467.721	1583.544
Variance	2375626	12623142
Observations	35	36
Hypothesized Mean Difference	0	
df	48	
t Stat	-1.7248	
P(T<=t) one-tail	0.045499	
t Critical one-tail	1.677224	
P(T<=t) two-tail	0.090998	
t Critical two-tail	2.010634	

Total Coliforms

t-Test: Two-Sample Assuming Unequal Variances

	Dry	*Wet*
Mean	5300.981	33234.74
Variance	3.66E+08	5.48E+09
Observations	35	38
Hypothesized Mean Difference	0	
df	42	
t Stat	-2.24523	
P(T<=t) one-tail	0.015038	
t Critical one-tail	1.681951	
P(T<=t) two-tail	0.030076	
t Critical two-tail	2.018082	

Enterococcus

t-Test: Two-Sample Assuming Unequal Variances

	Dry	*Wet*
Mean	162.5598	286.5208
Variance	624021.4	317442.6
Observations	41	36
Hypothesized Mean Difference	0	
df	72	
t Stat	-0.79953	
P(T<=t) one-tail	0.213305	
t Critical one-tail	1.666294	
P(T<=t) two-tail	0.42661	
t Critical two-tail	1.993462	

Table A.3: Correlation with physical/chemical parameters

	Salinity	*E_ coli*	*Enterococcus*	*Total Coliforms*
Salinity	1			
E_ coli	-0.668047144	1		
Enterococcus	-0.554049276	0.940300993	1	
Total Coliforms	-0.696972131	0.928817651	0.899292485	1

	TURB	*E_ coli*	*Enterococcus*	*Total Coliforms*
TURB	1			
E_ coli	0.81181448	1		
Enterococcus	0.8229185	0.940300993	1	
Total Coliforms	0.844281076	0.928817651	0.899292485	1

	Temp	*E_ coli*	*Enterococcus*	*Total Coliforms*
Temp	1			
E_ coli	0.005895918	1		
Enterococcus	0.102839683	0.744909691	1	
Total Coliforms	0.011475141	0.579757321	0.106259601	1

	DO	*E_ coli*	*Enterococcus*	*Total Coliforms*
DO	1			
E_ coli	-0.047158649	1		
Enterococcus	-0.222095757	0.744727373	1	
Total Coliforms	0.009919876	0.579524005	0.105745414	1

	Nitrate Nitrogen	*E_ coli*	*Enterococcus*	*Total Coliforms*
Nitrate Nitrogen	1			
E_ coli	0.409654461	1		
Enterococcus	0.724967586	0.86616299	1	
Total Coliforms	0.611393876	0.902892466	0.916194023	1

	OrthoPhosphate	*E_ coli*	*Enterococcus*	*Total Coliforms*
OrthoPhosphate	1			
E_ coli	0.448736495	1		
Enterococcus	0.09149398	0.773064278	1	
Total Coliforms	0.728550914	0.586439417	0.086770913	1

Appendix B: QA/QC Data

Completeness

StationID	DO	Nitrate Nitrogen	Ortho-Phosphate	pH	Salinity	Secchi	Temp	TURB	E_ coli	Enterococcus	Total Coliforms
Alamitos Bay	5	3	4	4	4	2	5	4	5	5	5
Angel's Gate	5	4	4	4	4	5	5	4	5	5	5
Belmont Pier	5	4	4	4	4	5	5	4	5	5	5
Cabrillo Beach/Inner N	5	4	4	4	4	0	5	4	5	5	5
Colorado Lagoon	5	4	4	4	4	5	5	4	5	5	5
Dominguez Channel @ 223rd St.	4	4	4	4	4	1	5	4	5	5	5
Junipero Ave, LB	2	2	2	2	1	0	2	2	2	2	2
L.A. River @ Willow	6	4	4	5	4	0	6	4	6	6	6
L.A. River mouth	5	4	4	3	4	5	5	4	5	5	5
Queen Mary/Freeman Island	2	2	2	2	1	2	2	2	2	2	2
Queen Mary/Grissom Island	2	2	2	2	1	2	2	2	2	2	2
Queen's Gate	5	4	4	4	4	5	5	4	5	5	5
S.G. River mouth	6	4	5	5	5	4	6	5	6	6	6
Actually collected	**57**	**45**	**47**	**47**	**44**	**36**	**58**	**47**	**58**	**58**	**58**
Expected	**58**	**48**	**48**	**48**	**58**	**58**	**58**	**48**	**58**	**58**	**58**
Completeness	**98.28%**	**93.75%**	**97.92%**	**97.92%**	**75.86%**	**62.07%**	**100.00%**	**97.92%**	**100.00%**	**100.00%**	**100.00%**

Appendix C. Data Summary