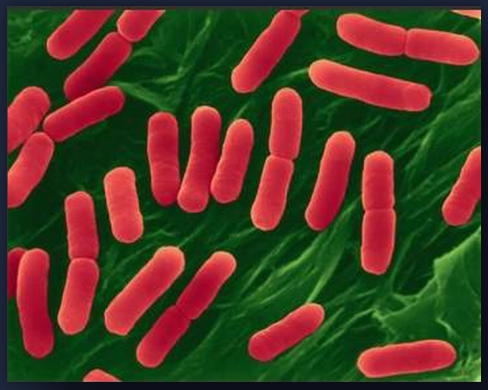
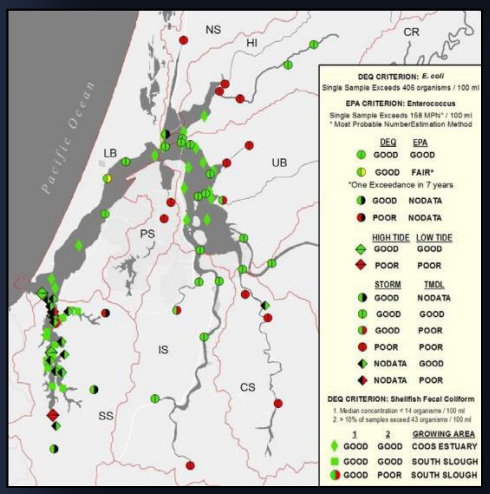
Bacteria in the Coos Estuary

Summary:

- *Bacteria concentrations are highly variable depending on the sampling location in the Coos estuary and surrounding stream systems.*
- *Approximately 20% of the sampling sites (17 of 84) did not meet state standards established for commercial fishing (including shellfish cultivation).*
- *Higher bacteria concentrations are typically correlated to areas of lower salinity and where land uses are likely sources of fecal coliform bacteria (e.g., sewage treatment, stormwater outfalls, grazing lands, areas where wildlife congregate).*





Subsystems: SS = South Slough; LB = Lower Bay; PS = Pony Slough; NS = North Slough; HI = Haynes Inlet; UB = Upper Bay; IS = Isthmus Slough; CS = Catching Slough; CR = Coos River

Evaluation

Several sites in the Coos estuary and associated streams do not meet state water quality standards while some do and others are stable or are improving. Bacteria sampling should continue to be monitored.

What's happening?

Several types of fecal bacteria are monitored as indicators of water quality status (Table 1). These bacteria are not generally harmful but they can indicate the presence of disease-causing bacteria, viruses, and protozoans that also inhabit animal and human feces. Methods for determining the presence of disease-causing pathogens in water are difficult, costly and time consuming. Therefore, rela-

Form	What is it?	Water Quality Standards	Water Quality Standard Source
Escherichia coli (E. coli)	A species of fecal coliform specific to humans and warm blooded animals	In non-shellfish* growing waters: 30-day log mean no > 126 organisms/ 100 mL; No single sample > 406 organisms/ 100 mL; Oregon state standard.	Bohaboy 2011
Enterococci spp.	Several species of this bacteria can be found in intestines of humans and other warm blooded animals. Largely used to monitor ocean waters.	Geometric mean of 35 organisms/ 100 mL; No single sample > 104 organisms/100 mL at designated bathing beaches; Federal (EPA) standard	Bohaboy 2011
Fecal Coliform	Any coliform bacteria that live in animal intestines	For shellfish* growing waters: median no > 14 organisms per 100 ml; No more than 10% > 43 organisms/100 mL; Oregon state standard	Bohaboy 2011
Total coliform	All coliform bacteria, including those that live in soils. High counts are typical relative to any other form as this group is not specific to animals.	N/A	

** The term "shellfish" refers to molluscs only (e.g., clams, oysters, mussels).*

Table 1. Accepted standards and explanation of common bacterial forms that are monitored for water quality purposes.

tively easy and cost-effective tests using the presence and abundance of fecal coliforms and *Enterococci spp.* (all found in human and animal feces) are used as indicators of pathogens to evaluate water quality.

This data summary describes the results of current and historic bacteria monitoring in the Coos estuary. We report on streams listed by the United States Environmental Protection Agency (USEPA) for high bacteria concentrations, analyze and report on data indicating the presence of storm runoff-enhanced bacteria levels, and summarize research investigating the local sources of bacteria (both human-generated and natural). We also analyze and report on data collected by the Oregon Department of Agriculture (ODA) (related to shellfish growing waters), the Confederated Tribes of Coos, Lower Umpqua and Siuslaw Indians (CTCLUSI)(focused on sites in the lower bay and South Slough), and the South Slough National Estuarine Research Reserve (SSNERR)(focused on South Slough). Limited stream data are reported for three streams in the South Slough watershed.

Listed Streams

All project area subsystems include water bodies that are 303(d) listed under USEPA's Clean Water Act for high bacteria concentrations (Figure 1). High fecal coliform levels are a concern for waters where commercial shellfish are grown, while *E. coli* listings indicate human contact concerns in recreational waters. In all subsystems, eight water bodies totaling approximately 30 miles are considered impaired for *E. coli*. For fecal coliform, 28 water bodies and nearly 158 miles of water are impaired. Five water bodies are listed as having insufficient data to determine if they are meeting bacteria standards (i.e., they may

Total Maximum Daily Load (TMDL)

According to USEPA's website TMDL is "a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet water quality standards."

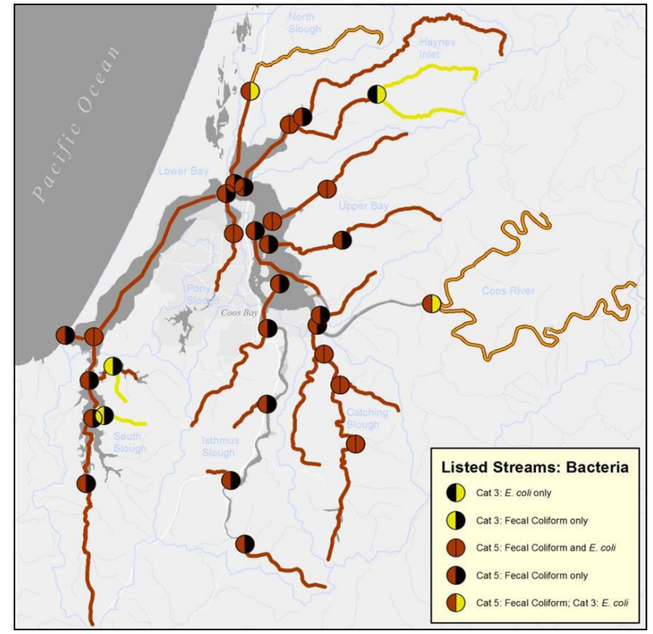


Figure 1. Streams listed as impaired for bacteria (303 (d) listed) under the Clean Water Act. Dot signifies the start of the stream segment that is listed while line shows extent of impaired stream. Category 3 indicates streams where insufficient data exist to make a determination if the water body is meeting water quality standards; category 5 indicates streams that are water quality impaired for bacteria. Report subsystems delineated and labeled in blue. Data: ODEQ 2014

Storm-Related Bacteria and Total Maximum Daily Load Bacteria Data

We summarized Coos Bay Storm-Related Bacteria and Total Maximum Daily Load (TMDL-see sidebar) datasets from the Oregon Department of Environmental Quality (ODEQ 2006, 2007)(Figures 2-5). The storm-related bacteria data were collected in January and October 2007 and the TMDL data were collected in February, March, April, November, and December 2001-2005 (months vary depending on the year) and June, August, and September 2006. South Slough results only included TMDL data.

Bacteria concentrations associated with storm events were not higher than the TMDL samples. Indeed, results here show that storm-related bacteria concentrations were lower than TMDL for many sites, such as Larson Creek (LCB), Willanch Creek (WCM), and Ross Slough (RS) in Figures 2, 3, and 4. Although not specifically associated with storms, most of the TMDL samples (2001-2005) were taken during the rainy season (Nov –Apr) with the exception of 2006 samples (Jun-Sept), so sample timing may be one reason the difference between the two is not especially great. Generally, sites with high levels of bacteria during storm-associated sampling also had high levels in the TMDL samples (Fig. 2-4). There was more variability in bacteria levels in the TMDL datasets for all three bacteria

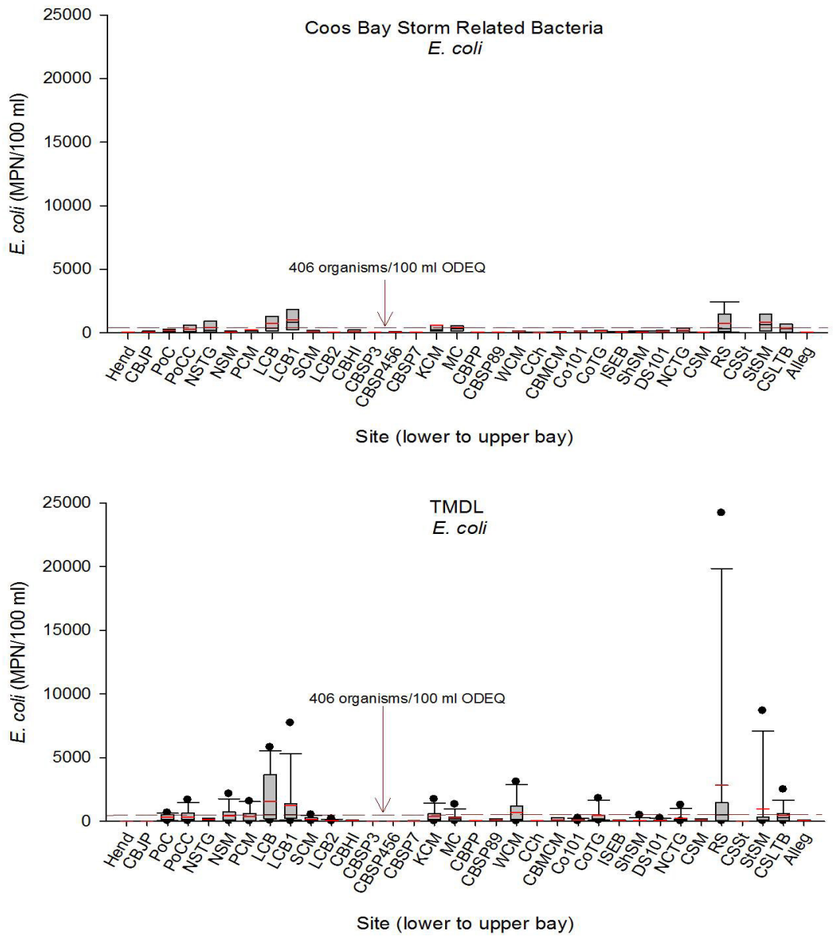


Figure 2. Box plots of *E. coli* concentrations for ODEQ Storm Related Bacteria in 2007 compared to ODEQ TMDL datasets 2001-2006 for Coos estuary sites, ordered from lower to upper Coos Bay. Gray boxes represent middle half of the dataset (top boundary is 25th percentile; bottom is 75th). Red lines within boxes indicate mean bacteria concentrations and black lines are median concentrations. Error bars represent 90th (top) and 10th (bottom) percentiles for sites with 9 samples or more. Black circles are outliers. Dark red dash line indicates ODEQ criteria for *E. coli*: No single sample may exceed 406 organisms/100 ml. See Figure 6/ Table 2 for map and site codes. Data: ODEQ 2006, 2007.

types compared to the storm-related datasets - likely due to seasonal variation.

Storm-related *E. coli* bacteria results fell short of meeting state bacteria standards (see Table 1) at 12 sites: Pony Creek south of North Bend High School (PoC), Pony Slough at Coca Cola Bottling Plant (PoCC), North Slough upstream of tide gate (NSTG), Palouse Creek at mouth (PCM), Larson Creek at mouth (LCB), Larson

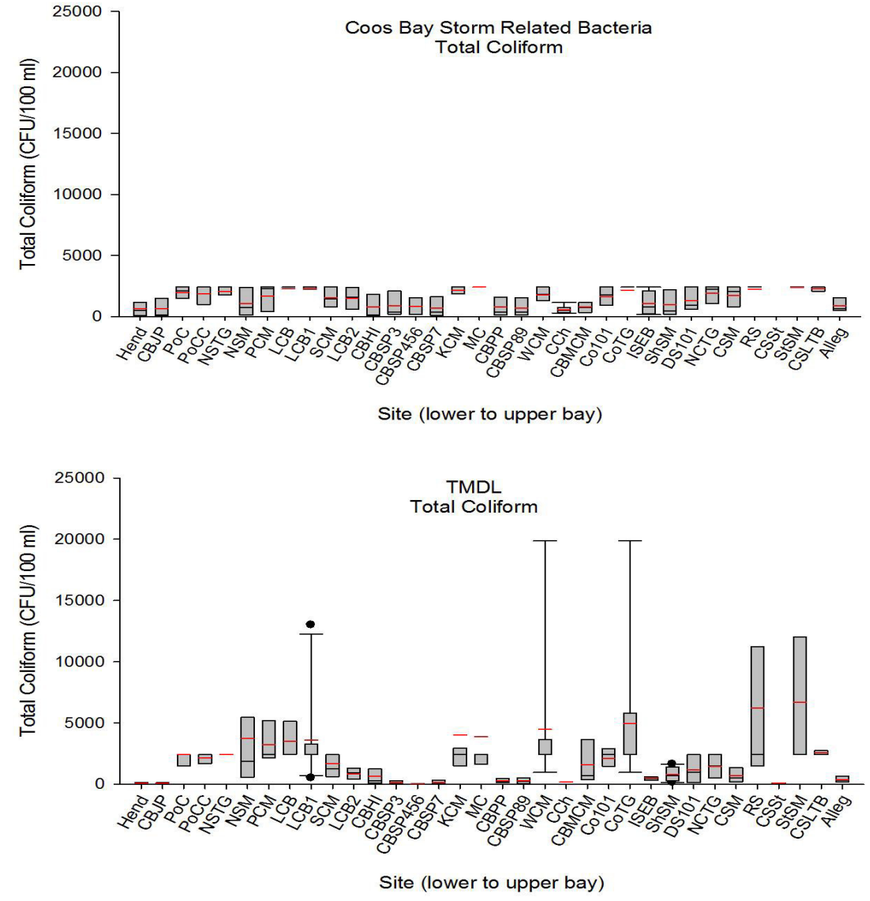
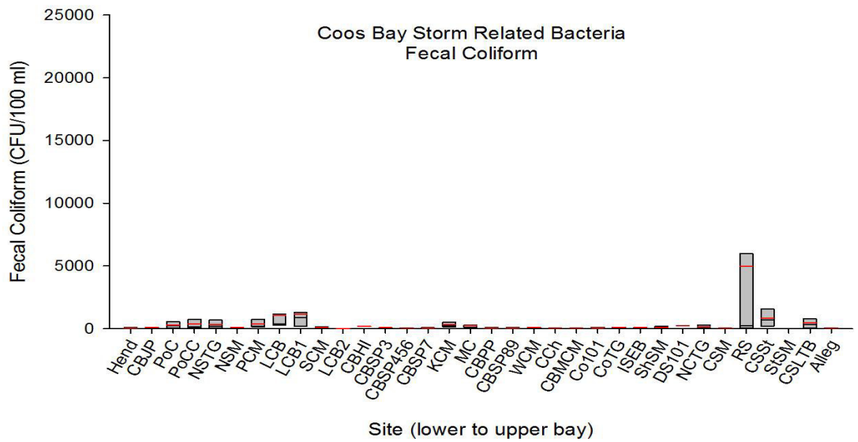


Figure 3. Box plots of Total Coliform concentrations for ODEQ Storm Related Bacteria in 2007 compared to ODEQ TMDL datasets 2001-2006 for Coos estuary sites, ordered from lower to upper Coos Bay. Gray boxes represent middle half of the dataset (top boundary is 25% percentile; bottom is 75th). Red lines within boxes indicate mean bacteria concentrations and black lines are median concentrations. Error bars represent 90th (top) and 10th (bottom) percentiles for sites with 9 samples or more. Black circles are outliers. See Figure 6/Table 2 for map and site codes. Data: ODEQ 2006, 2007.

Creek at first bridge upstream of mouth (LCB1), Kentuck Creek at mouth (KCM), Mettman Creek at mouth (MC), Noble Creek at tide gate (NCTG), Ross Slough at Ross Slough Road (RS), Stock Slough at mouth (StSM), and Catching Slough at Lone Tree Bridge (CSLTB) (Figures 2 and 6). These sites are located higher in the watershed and thus bacteria levels are likely driven by land use and facilitated by lower salinities than sites located in the estuary or lower watershed.



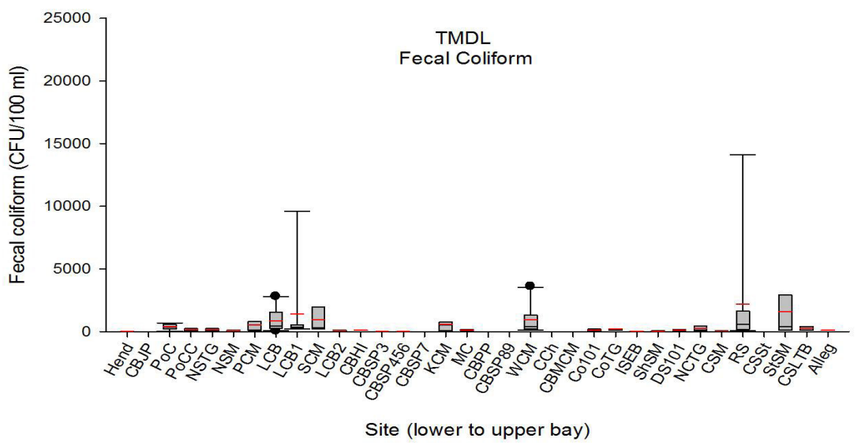


Figure 4. Box plots of Fecal Coliform concentrations for ODEQ Storm Related Bacteria in 2007 compared to ODEQ TMDL datasets 2001-2006 for Coos estuary sites, ordered from lower to upper Coos Bay. Gray boxes represent middle half of the dataset (top boundary is 25% percentile; bottom is 75th). Red lines within boxes indicate mean bacteria concentrations and black lines are median concentrations. Error bars represent 90th (top) and 10th (bottom) percentiles for sites with 9 samples or more. Black circles are outliers . See Figure 6/Table 2 for map and site codes. Data: ODEQ 2006, 2007.

TMDL *E. coli* bacteria results fell short of meeting state bacteria standards at 18 sites: Pony Creek south of North Bend High School (PoC), Pony Slough at Coca-Cola Bottling Plant (PoCC), North Slough at mouth (NSM), Palouse Creek at mouth (PCM), Larson Creek at mouth (LCB), Larson Creek at first bridge upstream of mouth (LCB1), Sullivan Creek at mouth (SCM), Kentuck Creek at mouth (KCM), Mettman Creek at mouth (MC), Willanch Creek at mouth (WCM), Coalbank Slough at tide gate (CoTG), Shinglehouse Slough at mouth (ShSM), Noble Creek at tide gate (NCTG), Ross Slough at Ross Slough Road

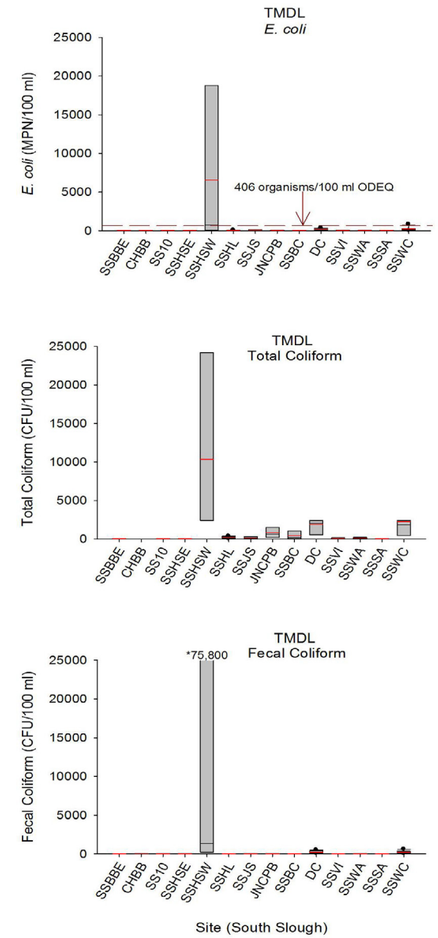


Figure 5. Box plots of *E. coli*, Total Coliform, and Fecal Coliform concentrations for ODEQ TMDL datasets 2001-2006 for South Slough; sites are ordered from north to south. Gray boxes represent middle half of the dataset (top boundary is 25th percentile; bottom is 75th). Red lines within boxes indicate mean bacteria concentrations and black bars are median concentrations. Error bars represent 90th (top) and 10th (bottom) percentiles for sites with 9 samples or more. Black circles are outliers. Dashed line (top graph only) indicates ODEQ criteria for *E. coli*: No single sample may exceed 406 organisms/100 ml. See Figure 6/Table 2 for map and site codes. Data: ODEQ 2006, 2007.

(RS), Stock Slough at mouth (StSM), Catching Slough at Lone Tree Bridge (CSLTB), and two South Slough sites, Hallmark Seafood on South Slough West Side (SSHSW) and Winchester Creek at Hinch Rd Bridge (SSWC)(Fig. 2, 5, 6). With the exception of 4 sites (SCM, WCM, CoTG, ShSM), those sites with high levels of *E. coli* bacteria in storm-related sampling also had high levels in TMDL sampling. Many of these sampling sites are higher in the watershed and more heavily influenced by land use and characterized by fresher water than lower estuary sites. In general, South Slough, Coos estuary, and sites in the lower

Box Plots (or Whisker and Box Plots)

Useful for graphing data that are highly variable, box plots help compare a range of data values (i.e., distribution) and identify outliers. Box plots also show median values in the data, which can be useful for interpreting highly variable results.

The "box" indicates the middle 50% of the data values; the full range of values from the rest of the data is indicated as "whiskers" that in normal box and whisker plots, or in Tukey-style box plots, are an additional 1.5 x the width of the box (i.e., 1.5 x the "interquartile" range).

In Tukey-style box plots outliers outside the range of the whiskers are also shown (represented by points outside the box and whisker plot).

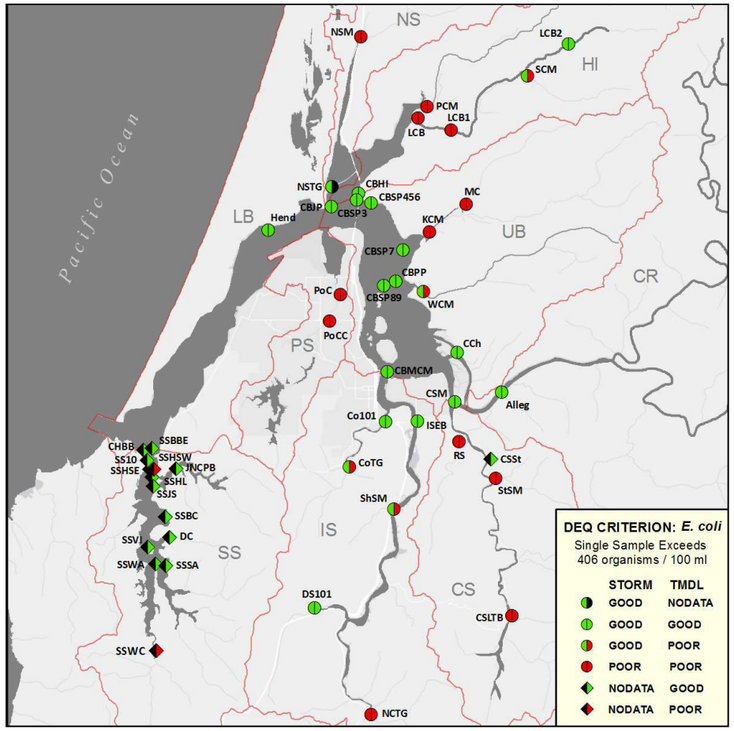


Figure 6. (left) Location and condition of Storm-Related and TMDL *E. coli* bacteria sampling sites.

Table 2. (below). Site codes and names for Storm-Related and TMDL bacteria sampling sites.

Site Codes	Site Name	Site Codes	Site Name
Alleg	Coos River at Allegany Road Bridge (Eastside)	**LCB2**	Larson Creek at second bridge upstream of dairy
CBHI	Coos Bay at entrance to Haynes Inlet at Marker #1	**MC**	Mettman Creek at mouth
CBJP	Coos Bay at Jordan Point	**NCTG**	Noble Creek at tide gate
CBMCM	Coos Bay Marshfield Channel Mouth	**NSM**	North Slough at mouth (Causeway Bridge)
CBPP	Coos Bay at Pierce Point Channel	**NSTG**	North Slough upstream of tide gate
CBSP3	Coos Bay at Silver Point 3	**PCM**	Palouse Creek at mouth
CBSP456	Coos Bay at Silver Point 4,5,6	**PoC**	Pony Creek south of North Bend High School
CBSP7	Coos Bay at Silver Point 7	**PoCC**	Pony Slough at Coca Cola bottling plant
CBSP89	Coos Bay at Silver Point 8,9	**RS**	Ross Slough at Ross Slough Road
CCh	Cooston Channel at south end	**SCM**	Sullivan Creek at Mouth
CHBB	Charleston Boat Basin at east end	**ShSM**	Shingle House Slough at mouth
Co101	Coalbank Slough at Hwy 101 (Coos Bay)	**SS10**	South Slough at Buoy #10 - Charleston Triangle
CoTG	Coalbank Slough at Tide gate	**SSBBE**	South Slough at entrance to Charleston Boat Basin
CSLTB	Catching Slough at Lone Tree Bridge	**SSBC**	South Slough In Brown's Cove
CSM	Catching Slough at Mouth	**SSHL**	South Slough at Hanson's Landing
CSSt	Catching Slough at dock downstream of Stock Slough	**SSHSE**	Hallmark Seafood on South Slough East Side
DC	Day Creek upstream of foot bridge	**SSHSW**	Hallmark Seafood on South Slough West Side
DS101	Davis Slough at Highway 101	**SSJS**	South Slough 50 yards west of Joe Ney Slough
Hend	Coos Bay at Marker #23 (Henderson Marsh)	**SSSA**	South Slough at head of Sengstacken Arm
ISEB	Isthmus Slough at Eastside Bridge	**SSVI**	South Slough at west side of Valino Island
JNCPB	Joe Ney Slough at Crown Point Bridge	**SSWA**	South Slough at head of Winchester Arm
KCM	Kentuck Creek at mouth (upstream of tide gate)	**SSWC**	Winchester Creek at Hinch Rd Bridge
LCB	Larson Creek at mouth	**StSM**	Stock Slough at mouth
LCB1	Larson Creek at first bridge upstream of mouth	**WCM**	Willanch Creek at mouth (tide gate)

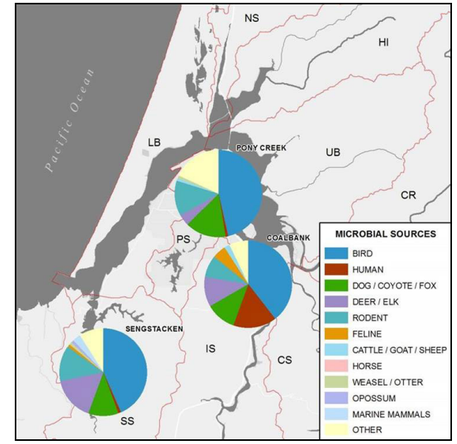


Figure 7. *E. coli* microbial source tracking results shown as a percentage of bacterial samples collected in Pony Creek, Coalbank Slough, and Sengstacken arm of South Slough. Data: Souder 2003.

watershed show much lower bacteria concentrations compared to smaller sloughs and upper watershed creek sites (Figures 2-6). Mean and median *E. coli* levels fell below 215 MPN/100 mL for Coos Bay lower watershed and main estuary sites and South Slough with the exception of one site, Hallmark Seafood on South Slough West Side (SSHSW)(Fig. 2, 5).

Overall, highest total coliform and fecal coliform mean values occurred at Ross Slough (RS) and Stock Slough (StSM)(Fig. 3, 4 TMDL); and Hallmark Seafood on South Slough West Side (SSHSW)(Fig. 5). In addition, Coalbank Slough at tide gate (CoTG), North Slough at mouth (NSM), Kentuck Creek at mouth (KCM), Larson Creek at first bridge upstream of mouth (LCB1), Mettman Creek at mouth (MC) and Willanch Creek at mouth (WCM) all had high levels of total coliforms for TMDL data (Fig. 3). Some of the lowest fecal coliform levels were at South Slough sites (<60 CFU/100 mL), with the exception of Day Creek (DC)(mean = 208 CFU/100 mL), Winchester Creek Bridge (SSWC)(mean = 236 CFU/100 mL), and Hallmark Seafood (SSHSW)(mean = 48,517 CFU/100 mL)(Fig. 5).

<u>What does CFU/100 mL and MPN/100 mL mean?</u>

CFU stands for 'Colony Forming Units' and refers to the number of viable bacterial cells in a sample per unit of volume (i.e., only live cells). For example: 50 CFU/100 mL means 50 Colony Forming Units per 100 mL of sample.

MPN stands for 'Most Probable Number' and refers to a method that uses dilution cultures and a probability calculation to determine the approximate number of viable cells in a given volume of sample; this measurement is useful when samples contain too few organisms for agar plates to be used or when organisms will not grow on agar.

Bacteria units – including CFU, counts, organisms, and MPN – are considered equivalent measures of bacteria concentration.

Sources: APHA 1998, USEPA 2001

<u>Bacteria Sources</u>

A joint study conducted by the Coos Watershed Association (CoosWA), SSNERR, and

Statistic	Pony Creek			Coalbank Slough			Sengstaken Arm		
	TC	FC	EC	TC	FC	EC	TC	FC	EC
Arithmetic Mean	5,089	246	182	3,130	349	237	342	36	26
Standard Deviation	6,709	129	103	3,498	292	204	318	31	21
Geometric Mean*	2,297	206	139	2,105	215	138	149	14	19
Est. 90th Percentile*	4,910	230	182	2,790	379	280	972	49	25
* Calculated according to procedures in *Guidance Document A.7. – Estimating the Ninetieth Percentile.*									

Table 3. Summary statistics from the traditional public health bacteria indicators at the three *E. coli* DNA sample locations. TC = Total coliform; FC = Fecal coliform; EC = *E. coli*. TC and EC units are MPN/100 mLs; FC units are CFU/100 mLs. Arithmetic Mean is the average. From: Souder 2003.

Marshfield High School investigated bacteria concentrations and sources in three locations in the Coos estuary: Pony Creek, Coalbank Slough, and the Sengstacken arm of South Slough (Figure 7)(Souder 2003). Investigators used DNA-based microbial source tracking methods to compare total coliforms, fecal coliforms, and *E. coli* concentrations in estuary water samples from July 2000 to June 2002.

Overall, Pony Creek had the highest average total coliform (5,089 MPN/100 mL), while Coalbank Slough had the highest average concentrations of fecal coliform and *E. coli* (349 CFU/100 mL and 237 MPN/100 mL respectively)(Table 3). Sengstacken arm consistently had lowest bacteria levels of all three sites.

Microbial source tracking results found that the most common source of bacteria at all three sites was from birds (avian sources) – responsible for 46% of all bacteria at Pony Creek, 39% at Coalbank Slough and 43% at Sengstacken arm (Figure 7).

Pony Creek also had high concentrations of bacteria from canines (15% dogs, coyotes, foxes) and rodents (13%) while Coalbank Slough had high concentrations from humans (16%), canines (11%), and deer/elk (11%), and Sengstacken from deer/elk (16%), rodents (16%), and canines (11%)(Figure 7).

Bacteria in Shellfish Growing Areas

Oregon Department of Agriculture (ODA) samples for fecal coliforms at several sites near commercial shellfish cultivation areas in the Coos estuary (including the Upper Bay, Lower Bay, North Slough, Haynes Inlet, and South Slough subsystems)(Figure 8) once per month on average. During shellfish harvest, the fecal coliform samples must meet ODEQ bacteria criteria for marine and estuarine shellfish growing waters; they cannot have a median concentration higher than 14 organisms per 100 mL, and no more than 10% of samples may exceed 43 organisms per 100 mL. Data summarized below are from 1999-2014.

Overall, median bacteria concentrations were relatively low and met regulatory standards. In Coos Bay (all non-South Slough sampling sites), the average concentration of fecal coliform bacteria at all sites was between 3 and 14 organisms/100 mL. The median concentra-

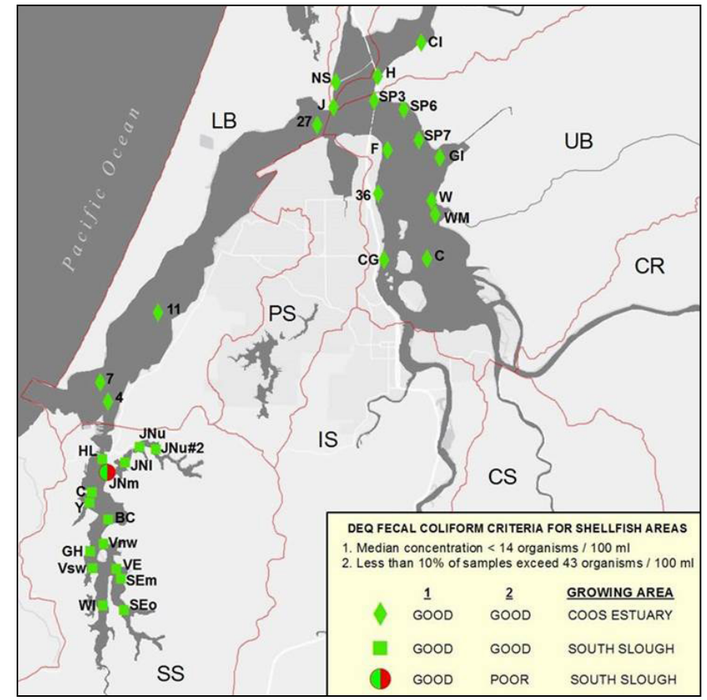


Figure 8. ODA Fecal Colifrm sampling sites in Coos Bay and South Slough. Green symbols indicate sites that met ODEQ standards shellfish growing waters; Red symbols indicate sites that did not meet the standards.

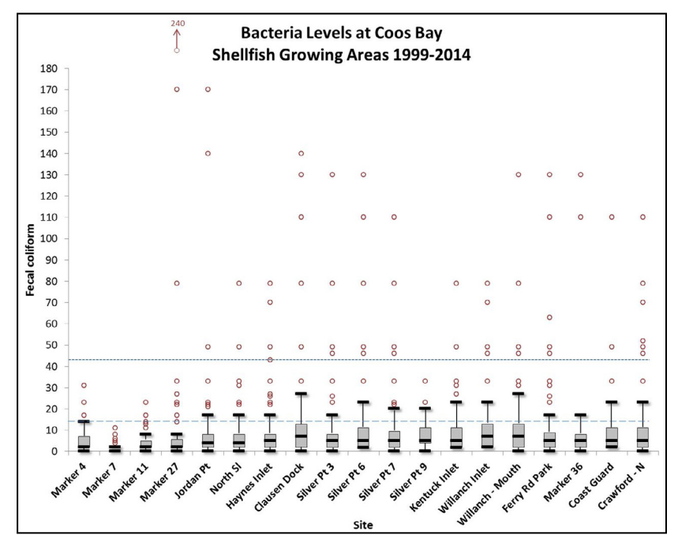


Figure 9. Tukey-style box plots of fecal coliform concentrations from ODA Coos Bay shellfish growing sampling sites from 1999-2014. Shaded gray box represents middle 50% of the data. Central black line (within gray box) indicates median value. Upper and lower black bars bound 99.3% of normal distribution data. Outliers outside this coverage are shown as open red circles. One outlier was outside the scale of this figure; value is indicated above arrow at the top. Short blue dashed line indicate ODEQ standard: 10% of samples may not exceed 43 organisms/10mL. Long blue dash line indicate ODEQ standard of median 14 organisms/100mL. Data: ODA 2014

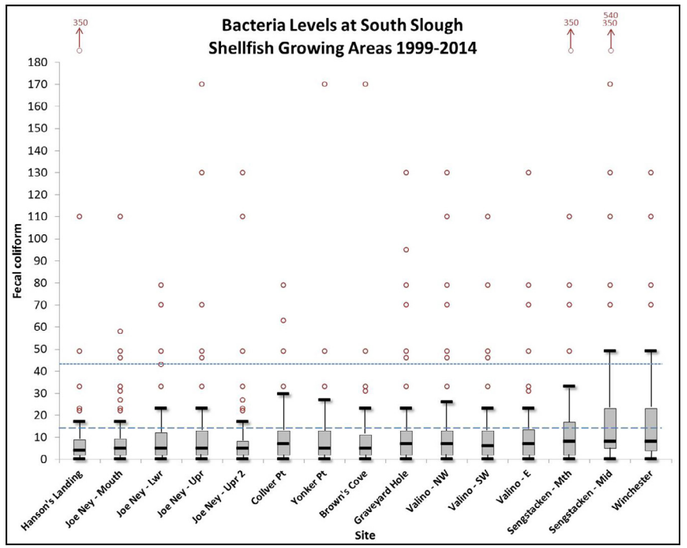


Figure 10. Tukey-style box plots of fecal coliform concentrations from ODA South Slough shellfish growing sampling sites from 1999-2014. Shaded gray box represents middle 50% of the data. Black line within gray box indicates median value. Upper and lower bars bound 99.3% of normal distribution data. Outliers outside this coverage are shown as open red circles. Several outliers were outside the scale of this figure and values are indicated above arrows at the top. Short blue dashed line indicate ODEQ standard: 10% of samples may not exceed 43 organisms/10mL. Long blue dash line indicate ODEQ standard of median 14 organisms/100mL. Data: ODA 2014

tions were between 2 and 7 organisms/100 mL (Figure 9). The percent of samples that were greater than 43 organisms/mL (all years combined) were low and ranged from 0-7%, at no time exceeding the criterion of greater than 10% of samples. Similarly, for South Slough, the average concentration of fecal coliform bacteria at all sites ranged from 5 to 21 organisms/100 mL (Figure 10). The median concentrations fell between 4 and 8 organisms/100 mL. The percent samples greater than 43 organism/mL were low and

A.

Median Monthly Fecal Coliform Values at ODA's Coos Bay Sampling Sites 1999-2014

	Marker 4	Marker 7	Marker 11	Marker 27	Jordan Pt	North Sl	Haynes Inlet	Clausen Dock	Silver Pt 3	Silver Pt 6	Silver Pt 7	Silver Pt 9	Kentuck Inlet	Willanch - Inlet	Willanch - mouth	Ferry Rd Park	Marker 36	Coast Guard	Crawford Pt
Jan	2	5	5	5	8	8	6	8	7	8	8	6.15	5	13	11	7.5	17	5.8	13
Feb	2	2	2	5	2	3.5	5	7	7	11	5	5	8	6.5	7.8	8	2	5	10.5
Mar	2	2	2	6.5	5	5	8	7	5	11	5	5	5	12	7	7.5	7	8	5
Apr	4.5	2	2	2	2	2	5	6.5	2	2	2	11	4.5	6.4	6.4	6	5	4.5	5.5
May	2	2	2	2	4.5	2	2	4.5	2	2	3.5	7.8	7	7.9	4	4	5	5	3
Jun	2	2	2	2	2	2	4	5	2	2	5	4.5	5	2	5	5	4	6	4.5
Jul	3.5	2	2	2	3.25	4	5	5	3	2	5	13.9	4.25	5	5	2	5	7	5
Aug	8	2	3	2	4.25	2	2	5	2	2	4.5	2	2	4.25	4	4.75	5	5	2
Sep	3	2	2	2	2	2	2	6	2	5	4.5	3.25	4.5	8	7	2	7	6.5	5
Oct	2	2	2	2	2	2	2	4.5	2	3.5	2	6	6	4.75	2	3.25	4.25	5	2
Nov	3.5	2	2	4.25	8	7	5	5	5	13	8	5	6.5	10	13	12	7	8	11
Dec	6	3.5	3.5	10.5	6	5	5	8	5	5	8	7	11	8	11	13	7.4	11	5

B.

Median Monthly Fecal Coliform Values at ODA's South Slough Sampling Sites 1999-2014

	Hanson's Landing	Joe Ney Mouth	Joe Ney - Lwr	Joe Ney - Upr 1	Joe Ney - Upr 2	Collver Pt	Yonker Pt	Brown's Cove	Graveyard Hole	Valino - NW	Valino - SW	Valino - E	Sengstacken Mouth	Sengstacken - Mid	Winchester
Jan	5	8	5	6	2	8	3.5	7	5	13	7.9	5	5	9.5	5
Feb	2	2	5	5	2	5	5	2	5	5	6.5	3.5	5	2	3.5
Mar	2	5	4	2	2	5	2	2	2	5	4.5	5	6	8	8
Apr	5	5	4.5	2	4	7	7	2	7	5	4.5	7.5	8	5	5
May	6	5	6	4	5	8	6	5	2	8	2	5	5	17	8
Jun	4.5	7.15	5	5	5	11	5	8	7.9	19.5	3	6.5	8	8	11
Jul	2	8	7.5	10.5	8	10.5	6	8	8	6.5	13	11	17	17	22
Aug	2	5	4.75	4.5	5.9	5	13	8	7	13	13	10.5	6	9.5	6.5
Sep	4.5	5	4	5	7	8	5	5	5	5	5	5.5	8	10.5	8
Oct	2	6	7	10.5	8	8	8	11	13.5	9.5	7	5	13	8	5
Nov	5	5	11	6.8	5	4	3	2	8	8	5	8	5	12	8
Dec	7.8	8	8	11	12	9.5	7.5	6	13	6	7	8	10.5	13	6.5

Table 4. Median monthly fecal coliform at each ODA shellfish sampling site in A. Coos Bay and B. South Slough from 1999-2014. Beige bars indicate relative fecal coliform concentration. Red values indicate exceedance of ODEQ standard of median 14 organisms/100mL. Data: ODA 2014

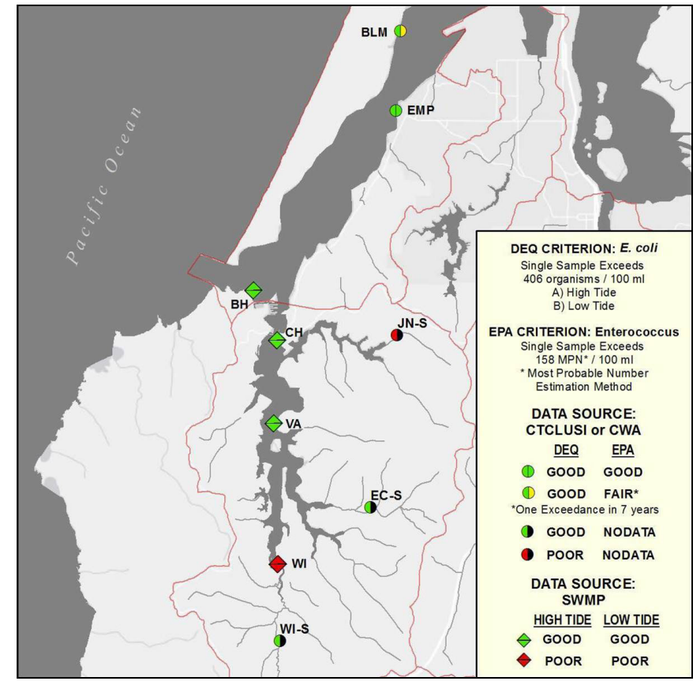


Figure 11. Bacteria concentrations at sites in the Lower Bay subsystem collected monthly by CTCLUSI (sites: BLM and EMP) and in South Slough by staff at SSNERR (sites: BH, CH, VA, WI). Three sites (JN-S, EC-S, WI-S) were stream sites sampled by CoosWA in 2010 as part of the State of the South Slough and Coastal Frontal Watersheds report. Sites were compared to ODEQ standards for *E. coli* or USEPA standards for *Enterococcus*. Site codes: BLM - BLM boat ramp, EMP: Empire Dock; BH: Boathouse, CH: Charleston, VA: Valino Island, WI: Winchester Creek; EC-S: Elliot Creek, JN-S: Joe Ney Slough; WI-S: Winchester Creek south.

ranged from 2-11%. The only site not meeting the percent samples standard when all years were combined was Sengstacken-Mid. Over the 15 year sampling period, bacteria concentrations remained relatively stable for all sites with linear regression slopes near zero (-0.0038 to 0.0056). Coos estuary sites with slightly positive slopes (bacteria levels slightly increasing) include Marker 7 and Willanch Inlet, and the majority of South Slough sites had slightly increasing slopes. The 16 remaining Coos Bay sites had slightly negative slopes, as did the following South Slough sites: Hanson's Landing, Valino SW, Valino NW, Joe Ney Mouth, Joe Ney Lwr, and Graveyard Hole.

When median monthly values were calculated for all years, no clear month or season emerged as having highest bacteria levels at all sites (Table 4). Higher winter month values occur at many Coos Bay sites (e.g., December and January at Marker 7 and Marker 11) while some of the highest medians overall were during summer months in South Slough (e.g., July at Sengstacken Mouth, Sengstacken Mid, and Winchester).

Lower Bay Bacteria Monitoring

CTCLUSI began monitoring bacteria concentrations in the Coos estuary in 2006 at their water quality monitoring site near the U.S. Bureau of Land Management (BLM) boat ramp on North Spit, followed by their Empire

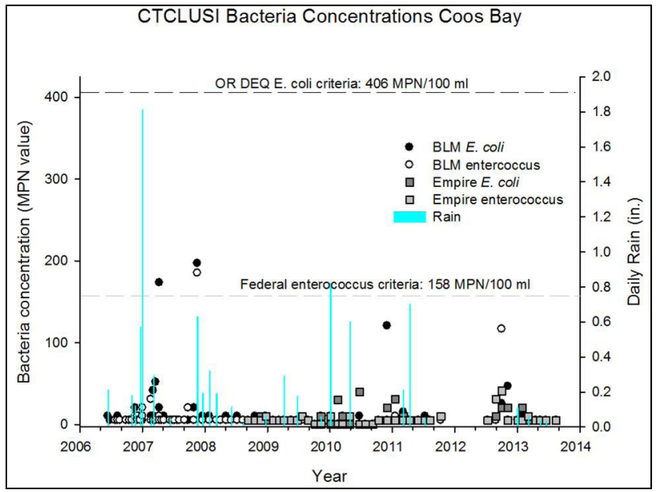


Figure 12. Monthly average *E. coli* and *Enterococcus* bacteria concentrations sampled at two sites in the Lower Bay subsystem by CTCLUSI. Gray dashed line is federal standard for *Enterococcus*; black dashed line is ODEQ *E. coli* standard for fresh and estuarine non-shellfish growing waters. Data: CTCLUSI 2007, 2008, 2009, 2010, 2011, 2012, 2013

Dock site in 2008 (Figure 11). Both *E. coli* and *Enterococcus* concentrations were monitored monthly. Data reported here were derived from their annual reports (CTCLUSI 2007, 2008, 2009, 2010, 2011, 2012, 2013).

Average monthly *E. coli* bacteria concentrations at the BLM station ranged from 5 to 25 MPN/100 mL and median values were 5 to 15.3 MPN/100 mL. Average monthly *Enterococcus* concentrations at the BLM station ranged from 1.1 to 32.9 MPN/100 mL while median values were 0 to 5 MPN/100 mL) (Figure 12).

At the Empire Dock station, average monthly *E. coli* levels ranged from 5 to 13.9 MPN/100 mL while median values were 5 (< 10) to 15 MPN/100 mL. Average monthly *Enterococcus* values ranged from 3.3 to 20.5 MPN/100 mL; median values were 0 to 18 MPN/100 mL (Figure 12).

Overall, both *E. coli* and *Enterococcus* levels were higher at the BLM station (average 13.8 and 9.0 MPN/100 mL respectively) than at Empire Dock (average 8.9 and 6.4 MPN/100 mL respectively).

There was no direct correlation between rainfall events and high levels of bacteria at either site, although some rain events were associated with slightly higher bacteria concentrations (Figure 12).

All samples at both stations fell well below ODEQ single sample standard; maximum *E. coli* bacteria concentrations at the BLM station were 197 MPN/100 mL and were 40 MPN/100 mL at Empire Docks (Figure 12).

The federal standard of no single sample exceeding 158 *Enterococcus* organisms/100 mL for Moderate Use Coastal Recreation

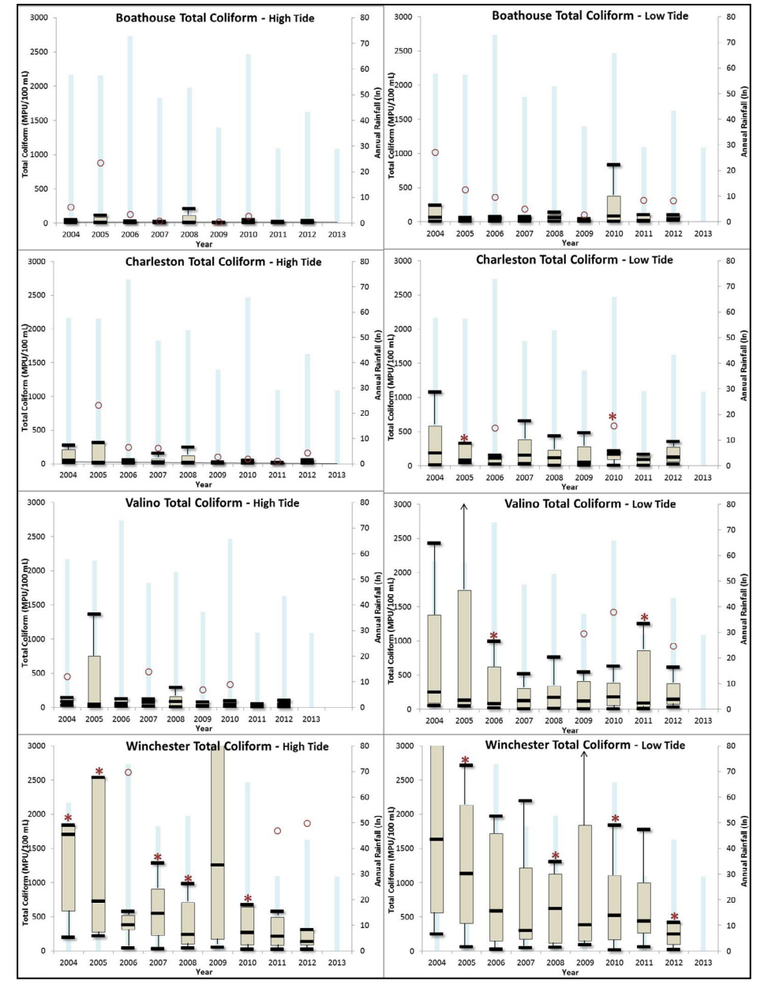


Figure 13. Tukey-style boxplots of average annual total coliform concentrations at high tide (left) and low tide (right) with daily rainfall at four South Slough sampling stations from 2004 to 2013. Shaded tan boxes represent middle 50% of the data. Black lines within tan boxes indicate median value. Upper and lower bars delineate normal distribution data. Outliers outside this coverage are shown as open red circles; red asterisks indicate outliers off the scale of the graphs. Rainfall is shown as blue bars behind the box plots. Bacteria data: SSNERR 2013; Precipitation data: NWS 2014

Waters was exceeded only once during the seven years of CTCLUSI sampling - at the BLM station in 2007 (184.9 MPN/100 mL). Generally concentrations were consistently low (e.g., the maximum level of *Enterococcus* at the Empire Dock station across all years was 41 MPN/100 mL).

South Slough Estuary Bacteria Monitoring

Staff at the SSNERR have conducted monthly bacteria concentration monitoring (total coliforms and *E. coli*) at four stations in the South Slough since 2004 as part of their long-term

System-Wide Monitoring Program (SWMP) (Figure 11). Reported here are data from 2004-2013.

Overall, the data were highly variable between sites, the most marine-dominated site (Boathouse) having lowest overall total coliform concentrations and lowest variability at both high and low tide. Bacteria concentrations increased up the estuary along the estuarine gradient peaking at the river-dominated Winchester station (Figure 13). All sites had higher total coliform levels and higher variability at low tide versus high tide.

Rainfall does not appear to have a strong relationship with bacteria levels; in fact, the years with the highest rainfall (2006 and 2010) had lower total coliform levels. Linear regressions of medians over the nine year period show a weak decreasing trend at all sites, all tides. Winchester station at low tide had the highest R^2 value at 0.61.

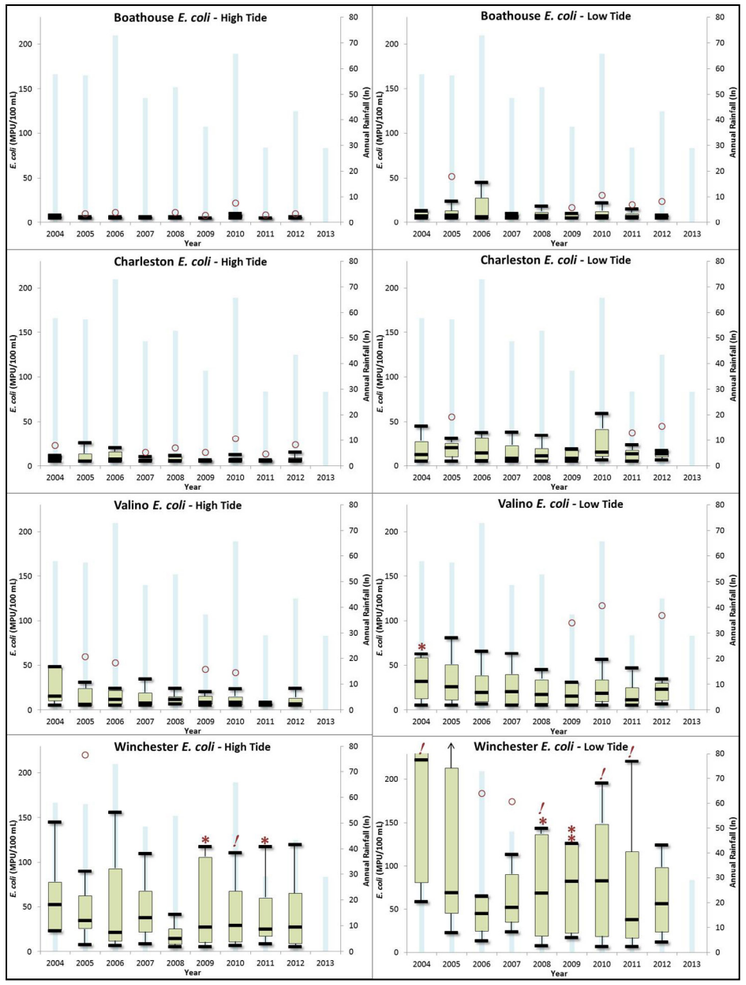


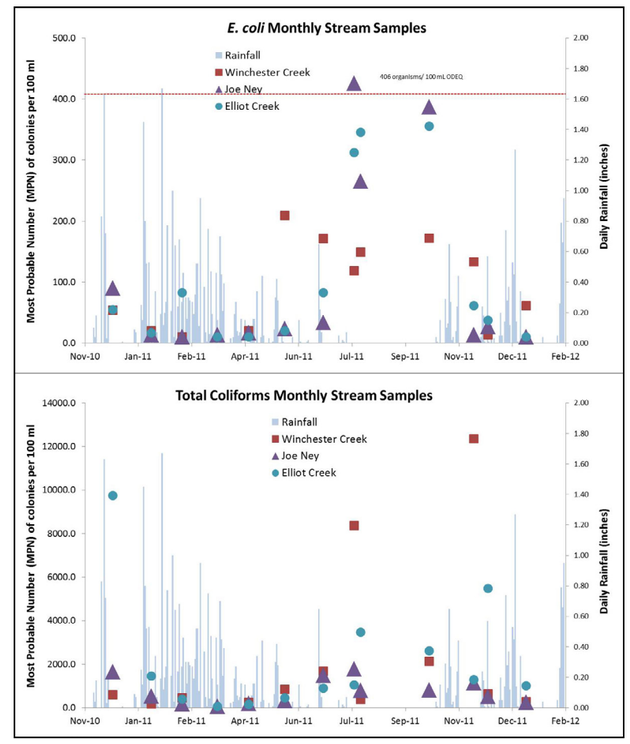
Figure 14. Tukey-style boxplots of average annual *E. coli* concentrations at high tide (left) and low tide (right) with daily rainfall at four South Slough sampling stations from 2004 to 2013. Shaded green boxes represent middle 50% of the data. Black line within green boxes indicates median values. Upper and lower bars delineate normal distribution data. Outliers outside this coverage are shown as open red circles; red asterisks indicate outliers off the scale of the figure; red exclamation points indicate outliers exceeding ODEQ's criterion of 406 organisms/100 mL. Rainfall is shown as blue bars behind the box plots. . Bacteria data: SSNERR 2013; Precipitation data: NWS 2014

Similar findings were seen with *E. coli* data, with Boathouse station having the lowest levels and least variability while Winchester station had the highest (Figure 14). The Winchester station exceeded ODEQ's *E. coli* criterion (no single sample > 406 organisms/100 mL) on four occasions at low tide and once at high tide; it was the only station to do so. Higher *E. coli* concentrations and higher variability were found at low tide over high tide.

Again, there was no clear relationship between *E. coli* levels and annual rainfall, and linear regressions of *E. coli* medians had a weak decreasing trend at all sites, all tides. Valino at low tide showed the strongest correlation with an R^2 value of 0.42.

<u>Bacteria Concentration in South Slough Streams</u>

Stream bacteria concentrations at three streams collected by Cornu et al. (2012) are presented as the average MPN/100 mL of



Figures 15 (top) and 16 (bottom). Average monthly *E. coli* bacteria concentrations (top) and average monthly total coliform concentrations (bottom) with daily rainfall in South Slough streams. Only Winchester Creek, Elliot Creek and Joe Ney are discussed in this report – other streams are outside project boundaries. Dashed red line indicates the ODEQ standard for a single *E. coli* sample. Adapted from: Cornu et al. 2012

three replicate samples per month. They observed a general pattern of higher *E. coli* counts during the summer season (May-Oct) (Figure 15). Overall, most of the *E. coli* data fell below the single sample standard set by ODEQ for recreational freshwater and estuarine waters in non-shellfish growing areas, with Joe Ney being the single exception (425 MPN/100mLs)(Figure 14). Joe Ney had the highest *E. coli* maximums, followed by Elliot Creek.

Counts for total coliforms followed the same general pattern as the *E. coli* bacteria with higher counts occurring in summer months (Figure 16). Winchester Creek had the highest total coliform maximum, again followed by Elliot Creek.

Why is it happening?

Higher bacteria counts are common (if not expected) during times of higher stream flows and rainfall because increased runoff delivers more nutrients and bacteria to the estuary. While results from the above studies include sites where bacteria counts increased during high flows and precipitation events, not all sites followed this pattern (e.g., see South Slough Estuary Bacteria Monitoring section).

Higher summer counts possibly result from a combination of higher summertime water temperatures (which can increase bacteria counts) and summertime wildlife activity (typically more active than in other times of the year)(Tiefenthaler et al. 2008).

A more important factor to consider is the difference in landscape settings of the different water bodies.
Souder (2003) investigated bacteria sources in three water bodies in our project area that were representative of developed, rural residential, and undeveloped regions. He found multiple sources of bacteria contamination common to all three sample locations, but in different proportions, including wildlife (e.g., waterfowl), canines (e.g. domestic dogs), humans (e.g., septic failures), and livestock (e.g., cattle). Differences in sources at each of the sites was most likely linked to their associated land uses.

Pony Creek was characterized as an urban stream that receives input from three small tributary streams near residential and commercial areas. In addition, two sewage pump stations and numerous stormwater outfalls are located near Pony Creek. Pony Creek easily had the highest bacteria levels overall of the three sites, probably due to greater impervious surfaces leading to higher surface water runoff into the creek during the rainy season. Other studies have found fecal coliform concentrations increase with development and associated stormwater runoff (directly related to amount of impervious surfaces), which is the leading cause of nonpoint source bacteria pollution (Blair 2011).

In contrast, Coalbank Slough was characterized as a typical rural residential area. Livestock farms (horse, cattle) as well as hobby farms with cattle, horses, llamas, turkeys, sheep, and goats dominate the land use. The residential area ranges from ½ to 40 acres, all parcels of which are on septic systems or cesspools. In upper parts of the watershed, the land is forested and typical wildlife includes elk, deer, beaver, and bear.

Similar rural residential areas of the estuary discussed in other studies above consistently had high bacteria levels (e.g., Ross Slough and Stock Slough from the TMDL/storm bacteria section above), and are similarly likely tied to land use (e.g., agriculture or septic failure).

In contrast, in all studies South Slough sites had generally low bacteria levels. Souder (2003) described South Slough as relatively pristine with little residential or rural development surrounded by relatively undisturbed marshes and second-growth upland forests (which are industrially harvested in the upper portions of the watershed).

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