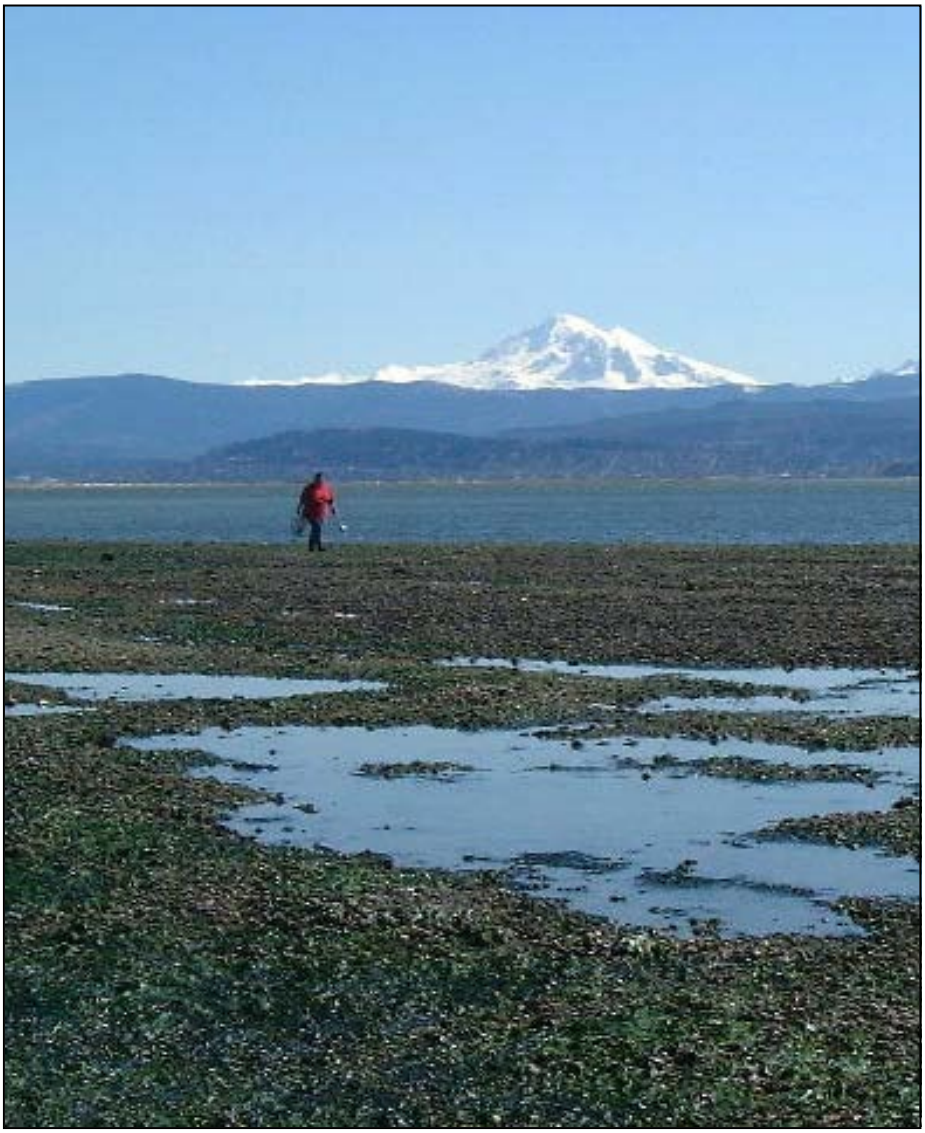
Status and Trends in Fecal Coliform Pollution in Shellfish Growing Areas of Puget Sound: Year 2011

June 2012



Washington State Department of Health

Office of Shellfish and Water Protection

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Web-Based Status and Trends Reports

The Washington State Department of Health periodically prepares status and trends reports for selected individual shellfish growing areas. These reports are prepared at the request of department staff and local authorities to support remedial programs. The reader may view the most recent reports by visiting: **http://www.doh.wa.gov/CommunityandEnvironment/Shellfish/ShellfishPublications.aspx** .
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For summaries of data and statistics, please contact:

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Background

The Washington State Department of Health Office of Shellfish and Water Protection collects and analyzes fecal coliform data to protect shellfish consumers from eating contaminated shellfish. The Department also uses the data to analyze status and trends in fecal pollution in shellfish growing areas of Puget Sound. To perform the analysis, the Department uses "estimated 90th percentiles," one of two statistics specified by the National Shellfish Sanitation Program (NSSP) for classification of shellfish growing areas (see Appendix A on page 8).

Why Monitor Fecal Coliform Bacteria? Fecal coliforms are bacteria that live naturally in the intestines of warm-blooded animals, including humans. They generally do not make people sick. However, if high concentrations are in the water, it means that illness-causing pathogens might also be present. Shellfish take up the pathogens as they filter their food from the water and store them in their tissue. A shellfish consumer may become sick after eating the contaminated shellfish.

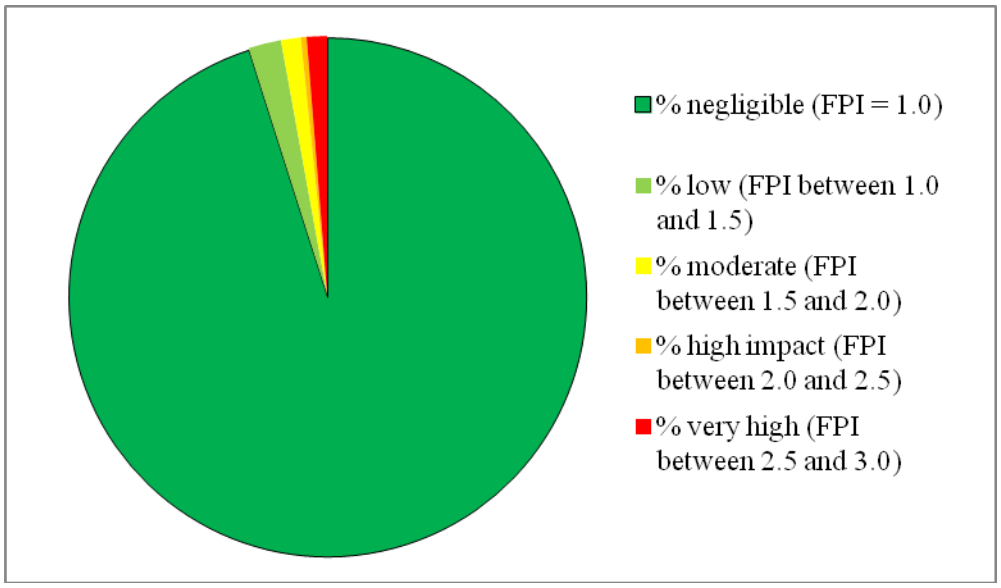
Nonpoint Fecal Pollution Sources and Remedial Action: In the early 1980s, nonpoint fecal pollution became the key factor in closure of shellfish beds. Intensive development of rural watersheds and the marine shoreline of Puget Sound have increased the risk of contamination of shellfish resources.

Measuring Status of Fecal Pollution with the Fecal Pollution Index (FPI). The Department developed a "fecal pollution index "(FPI) as a simple tool to quantify fecal pollution impact. Appendix B (page 10) describes the derivation and application of the FPI. The FPI is a unitless number that describes the degree of fecal pollution. The FPI ranges from FPI = 1.0 (100% of 90th percentiles are GOOD, i.e., negligible impact) to 3.0 (100% of 90th percentiles are BAD, maximum impact). The FPI may be applied at the level of the sampling station, the growing area, regions within Puget Sound or Puget Sound-wide.

Status of Fecal Pollution in Puget Sound in 2011.

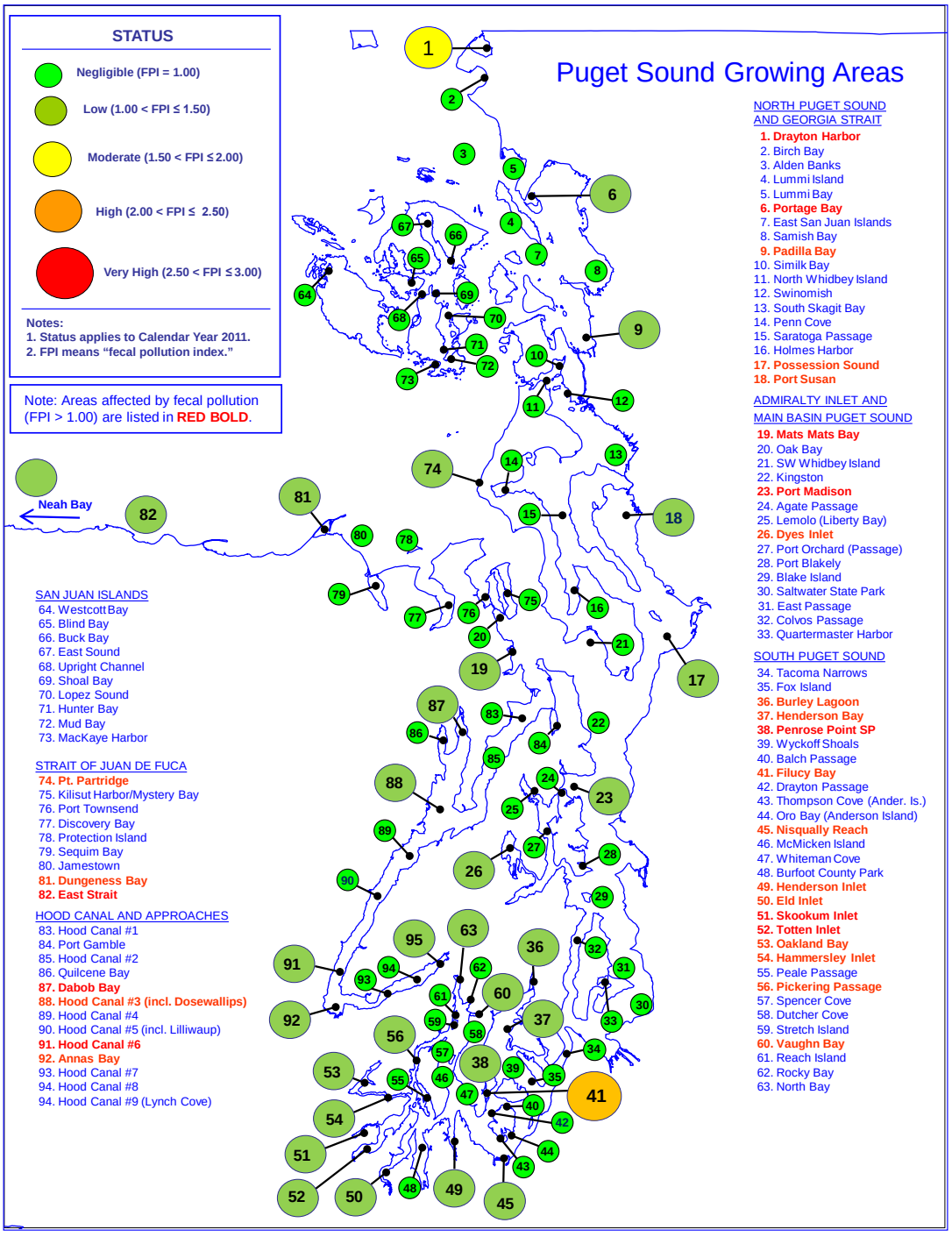
Fecal Pollution Impact Puget Sound-Wide. Figure 1 show proportions of FPIs from all 1459 sampling stations throughout Puget Sound. There are five impact categories (defined in figure legend). Sites with low fecal pollution impact increased from 1.4% of sites in 2010 to 2.1% of stations 2011. The remaining categories remained relatively unchanged.

Figure 1: The proportion of sampling stations throughout Puget Sound that fell into five categories of fecal pollution impact in 2011.



Fecal Pollution Impact among Growing Areas in Puget Sound. An annual FPI for 2011 was calculated for each of 95 shellfish growing areas in Puget Sound. The FPIs were used to categorize the fecal pollution impact of each area. Figure 2 (page 3) shows the distribution of fecal pollution impact among the growing areas. Filucy Bay and Drayton Harbor (Areas 1 and 42, respectively, on Figure 2) appear to be the shellfish growing areas most affected by fecal pollution in 2011.

Figure 2: Fecal pollution impact among shellfish growing areas of Puget Sound during calendar year 2011.



Shellfish Growing Areas Ranked by Fecal Pollution Impact. In 2011, 29 of 95 shellfish growing areas were significantly affected by fecal pollution (up from 25 areas in 2010). Figure 3 ranks the 29 growing areas according to fecal pollution impact.

Figure 3: Ranking by FPI of 29 Puget Sound shellfish growing areas significantly affected by fecal pollution in 2011.

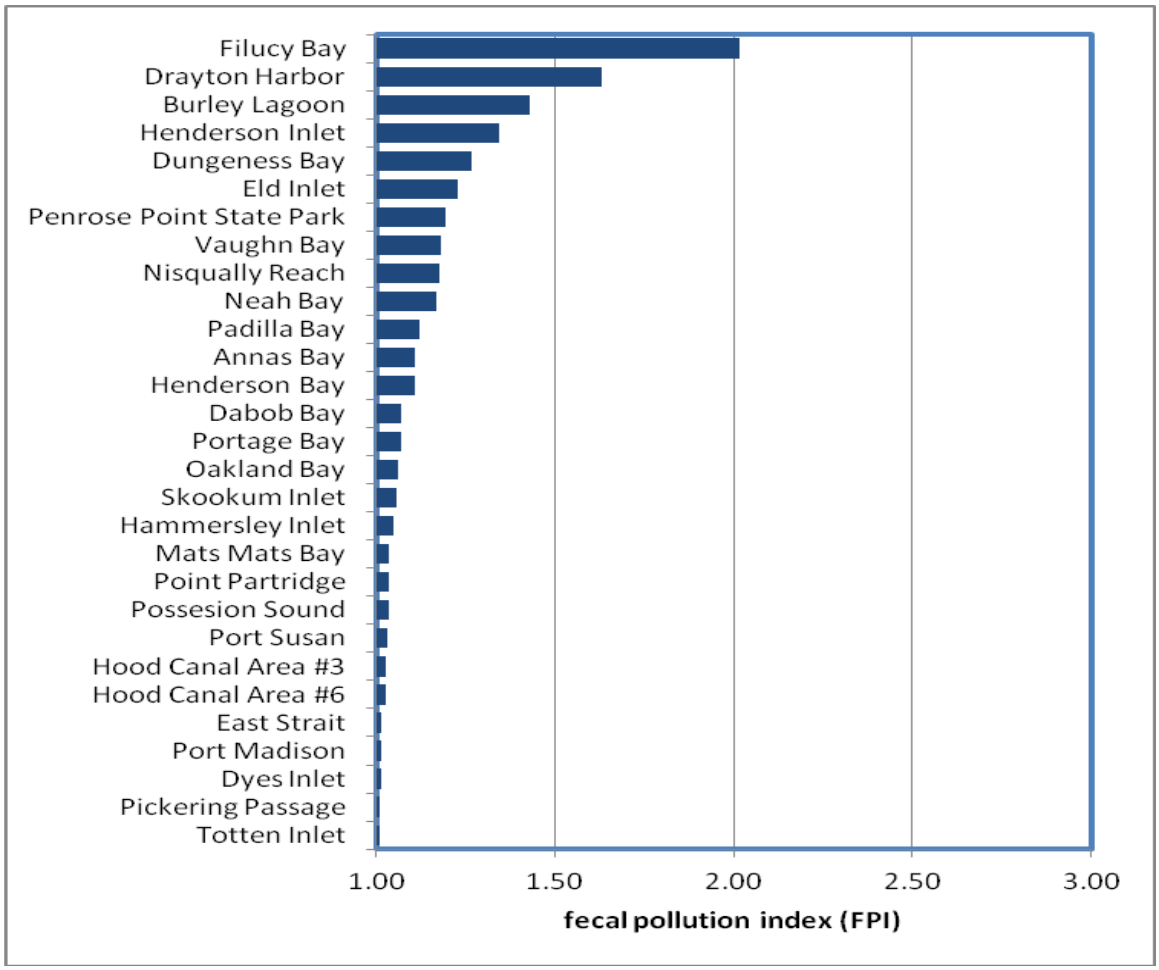


Table 1: Growing areas affected by changes in fecal pollution between 2010 and 2011 (numbers refer to locations on Figure 2).

Areas Added in 2011	*Areas Removed in 2011*
6. Portage Bay	13. South Skagit Bay
52. Totten Inlet	
53. Oakland Bay	
82. East Strait	
91. Hood Canal Area #6	

Fecal Pollution Trend among 38 Shellfish Growing Areas Significantly Affected by Fecal Pollution in Puget Sound (2000-2011)

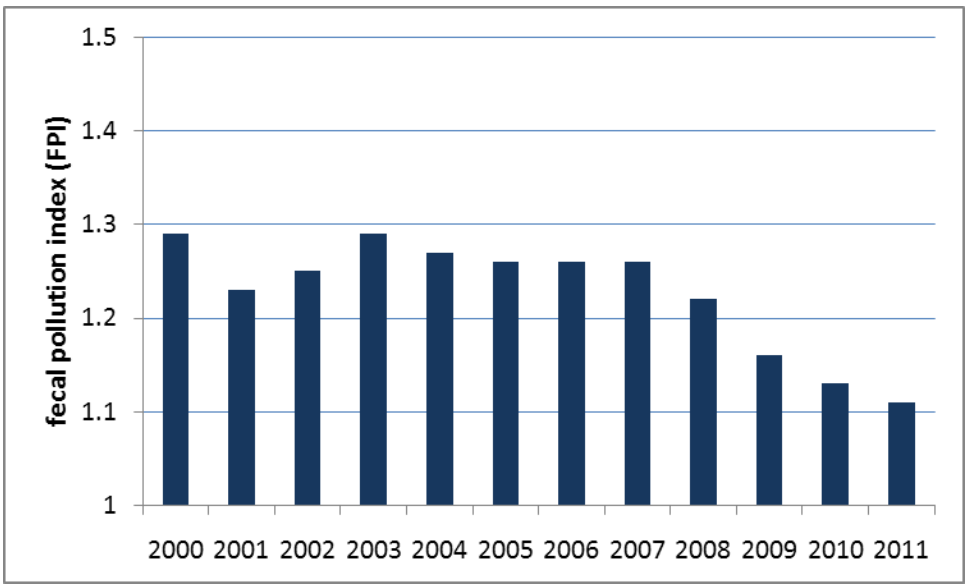
In order to analyze how fecal pollution has changed in Puget Sound during the past 12 years, DOH analyzed statistics from 38 shellfish growing areas that have experienced significant fecal pollution (i.e., annual FPI greater than 1.0) at some time from 2000 through 2011(Table 2). A "historical" annual fecal pollution index was calculated from estimated 90th percentiles pooled from over 500 "historical" stations in the 38 growing areas during each year during the period. "Historical" stations have a complete and uninterrupted set of NSSP (National Shellfish Sanitation Program) statistics (geometric means and 90th percentiles) for the entire period. Stations that were either added or dropped during the interim were eliminated from the calculation of the "historical" FPIs. See Appendix B (page 10) to see how the FPI is calculated.

Table 2: List of 38 shellfish growing areas used to evaluate trends in fecal pollution impact 2000-2011 (numbers refer to locations on Figure 2).

Map Refer.	Growing Area	Map Refer.	Growing Area
1	Drayton Harbor	56	Pickering Passage
2	Birch Bay	62	Rocky Bay
6	Portage Bay	63	North Bay
8	Samish Bay	66	Buck Bay
13	South Skagit Bay	67	East Sound
26	Dyes Inlet	73	MacKaye Harbor
31	East Passage	76	Port Townsend
33	Quartermaster Harbor	77	Discovery Bay
36	Burley Lagoon	81	Dungeness Bay
37	Henderson Bay	82	East Strait
41	Filucy Bay	83	Hood Canal Area #1
42	Drayton Passage	84	Port Gamble
44	Oro Bay	85	Hood Canal Area #2
45	Nisqually Reach	88	Hood Canal Area #3
49	Henderson Inlet	90	Hood Canal Area #5
50	Eld Inlet	91	Hood Canal Area #6
51	Skookum Inlet	92	Annas Bay
53	Oakland Bay	94	Hood Canal Area #8
54	Hammersley Inlet	95	Hood Canal Area #9

Figure 4 assesses trend in fecal pollution among the 38 areas for the entire period. A simple runs test for trends (Sokal and Rohlf 1969) suggests that fecal pollution has been reduced significantly over the last decade (t_s = -2.73, p = 0.05).

Figure 4: Trend in fecal pollution impact among 38 growing areas significantly affected by fecal pollution 2000-2011.



Status and Trend Summaries for Selected Shellfish Growing areas in Puget Sound

Many of the 38 shellfish growing areas listed in Table 2 have experienced several decades of remedial action history. Over the years, the Washington State Department of Health has prepared several status and trends reports for individual shellfish growing areas. These reports are prepared at the request of department staff, local authorities and stakeholders or consultants. The purpose of the reports is to assess progress being made in local remedial action programs. This year,(to be filled in later) reports were prepared. They have been posted to the "Publications" web site of Washington Department of Health Office of Shellfish and Water Protection. See **http://www.doh.wa.gov/CommunityandEnvironment/Shellfish/ShellfishPublications.aspx** .

Appendix A. Sampling, Analytical, and Calculation Methods

Systematic Random Sampling (SRS). The Washington State Department of Health uses a systematic random sampling (SRS) method mandated by the National Shellfish Sanitation Program (NSSP) to sample stations in shellfish growing areas. Under SRS, The Department samples each area at roughly even intervals over time. Conditionally Approved areas are generally sampled 12 times a year. Approved and Restricted areas are sampled 6 times a year. SRS avoids targeting specific environmental factors, such as season, weather, tide, etc. SRS also requires a substantial data set (30 results) to calculate statistics to classify growing areas. As a result, the data represents a wide range of environmental conditions encountered in the growing area. SRS ensures that unbiased, representative data are available for classification.

Field Sampling. Stations are located using a Global Positioning System (GPS) unit. At each station, the sampler collects water samples several inches below the surface (APHA 1999) using a sampling wand, and places the sample on ice. The sampler also measures surface salinity and temperature. The boat operator records all data. The samples are sent to the Department's Public Health Laboratory at Shoreline for analysis.

Laboratory Methods. Fecal coliform bacteria are analyzed as soon as possible, but no later than 30 hours after sampling (PSEP 1996). The Department uses a multiple tube fermentation procedure with A-1 broth (Method 9221 E *in* APHA 1999). The multiple tube fermentation procedure does not count individual fecal coliform bacteria present in a sample. Instead the method gives a statistical estimate or "most probable number" (MPN) of the number of fecal coliform organisms present.

NSSP Growing Area Criteria. The Department classifies shellfish beds according to degree of risk to human health from fecal pollution. The Department applies the following NSSP criteria:

1. The concentration of fecal coliform bacteria cannot exceed a **geometric mean** of 14 organisms per 100 milliliters (ml) in water (applied in all cases).
2. The **estimated 90th percentile** cannot exceed 43 organisms per 100 ml of water (applied to areas where only nonpoint sources are present).

NSSP specifies that a minimum of 30 prior results are needed to calculate the statistics.

Calculations and Statistical Methods. The Department calculates NSSP statistics mainly for classifying growing areas (Appendix C, page 11). NSSP statistics are also used for the early warning analysis (Appendix D, page 12), and status and trend analysis.

For status and trends, statistics were calculated for the earliest sampling date possessing the required minimum 30 results, and for each subsequent sampling date through the end of 2010. Excel 2007 (Microsoft, Inc.) was used to calculate statistics, which were then exported to STATISTICA 6.1 (Statsoft, Inc., Tulsa, OK) for graphics and statistical analysis. Spearman's Rho, a nonparametric test for correlation, was used to test for significant temporal trend.

Appendix B. Calculation of the Fecal Pollution Index (FPI)

The fecal pollution index (FPI) is a single number that describes the annual status of fecal pollution. An FPI can be calculated for any level of resolution: sampling station, growing area, region, or all of Puget Sound.

Note: to demonstrate how the FPI is calculated, we will use an example obtained from the 2008 analysis from Dungeness Bay (see No. 81 on Figure 2).

To begin, we calculate the estimated 90th percentiles for each station and sampling date in 2008 according to NSSP methods (Appendix A, Sampling, Analytical, and Calculation Methods, previous page).

After the 90th percentiles are calculated, we follow the steps described below (cross-referenced with color coded text in Table D-1, next page).

Step 1. NUMBERS. Sort the estimated 90th percentiles from each station into categories:

- "GOOD" (90th percentiles $\leq$ 30 mpn/100ml)
- "FAIR" (30 mpn/100ml < 90th percentiles $\leq$ 43 mpn/100ml)
- "BAD" (90th percentiles > 43 mpn/100ml)

Table D-1 shows that Station 113 had **four** GOOD 90th percentiles, **four** FAIR 90th percentiles, and **four** BAD 90th percentiles during 2008 (in columns b-d in Table D-1).

Step 2. FRACTIONS. For each station, divide the number of estimated 90th percentiles in each category by the total 90th percentiles in all categories (column e). For Station 113, **four** GOOD 90th percentiles (column b) ÷ **12** total 90th percentiles = **0.33** (in column f).

Step 3. WEIGHTED FRACTIONS. Now, "weight" each fraction by multiplying it by a weighting factor:

- "GOOD" fractions × 1.00
- "FAIR" fractions × 2.00
- "BAD fractions" × 3.00

For example, for Station 113: the weighted FAIR fraction (**0.33,** column g) × 2.00 = **0.67** (column j).

Step 4. FPI. Finally, add the weighted fractions. The sum is the fecal pollution index for each station. The FPI for Station 113 (column l): (**0.33** + **0.67** + **1.00**) = **2.00**. The FPI ranges from 1.00 (100% of 90th percentiles are GOOD) to 3.00 (100% of 90th percentiles are BAD).

Growing Area and Puget Sound FPI. To calculate the annual FPI for Dungeness Bay in 2008, sum the numbers within each category for *all* stations (TOTAL DB line in Table D-1) and repeat the steps described above. Similarly, an FPI for all of Puget Sound can be calculated (TOTAL PS, Table D-1). The annual FPI for Dungeness Bay in 2008 was **1.57** in 2008. The FPI for all of

Puget Sound in 2008 was **1.16**. We can use the annual FPIs for growing areas to compare fecal pollution impact among growing areas in any given year (Figure 3 on page 4).

Temporal Trend Using FPI. The method is modified slightly to calculate annual "historical" FPIs for tracking change over time. "Historical" means that we use only 90th percentiles from stations with a continuous sampling history. We eliminate 90th percentiles from stations that were either dropped or added over time. Following the initial edit, we calculate an annual FPI for each year (1998 through 2008). Bar graphs of "historical" FPIs show change in fecal pollution over time. Figure 5 (page 14) shows temporal trend over all of Puget Sound. Temporal trend for growing areas affected by fecal pollution (FPI<1.0) is shown in each individual growing area report contained between page 6 and page 13.

Table D-1: FPI calculations for Dungeness Bay and Puget Sound in 2008.

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
	NUMBERS				FRACTIONS			WEIGHTED FRACTIONS			
STATION	GOOD	FAIR	BAD	TOTAL	GOOD	FAIR	BAD	GOOD	FAIR	BAD	FPI
103	11	0	0	11	1.00	0.00	0.00	1.00	0.00	0.00	1.00
104	0	0	12	12	0.00	0.00	1.00	0.00	0.00	3.00	3.00
105	6	6	0	12	0.50	0.50	0.00	0.50	1.00	0.00	1.50
106	0	12	0	12	0.00	1.00	0.00	0.00	2.00	0.00	2.00
107	11	1	0	12	0.92	0.08	0.00	0.92	0.17	0.00	1.08
108	8	4	0	12	0.67	0.33	0.00	0.67	0.67	0.00	1.33
109	11	1	0	12	0.92	0.08	0.00	0.92	0.17	0.00	1.08
110	7	6	0	13	0.54	0.46	0.00	0.54	0.92	0.00	1.46
111	0	8	4	12	0.00	0.67	0.33	0.00	1.33	1.00	2.33
112	11	0	0	11	1.00	0.00	0.00	1.00	0.00	0.00	1.00
113	4	4	4	12	0.33	0.33	0.33	0.33	0.67	1.00	2.00
114	12	0	0	12	1.00	0.00	0.00	1.00	0.00	0.00	1.00
115	12	0	0	12	1.00	0.00	0.00	1.00	0.00	0.00	1.00
TOTAL DB	81	42	20	143	0.57	0.29	0.14	0.57	0.59	0.42	1.57
TOTAL PS	7962	436	506	8897	0.89	0.05	0.06	0.89	0.10	0.17	1.16

Appendix C. Shellfish Growing Area Classification

The Washington State Department of Health applies guidelines set by the National Shellfish Sanitation Program (NSSP). All or part of each harvest area is classified into four categories:

- An area is classified **Approved** for unlimited harvest if NSSP water quality criteria are met and not subject to pollutant sources that threaten public health.
- An area is classified **Conditionally Approved** if NSSP water quality criteria are met, except during pollution events that are e*pisodic* and *predictable*, such as rain-related runoff. Harvest from a Conditionally Approved area requires a "Conditionally Approved Area Management Plan" (or CAAMP).
- An area is classified **Restricted** if it is subject to limited pollution. Shellfish from Restricted areas cannot be harvested directly. They may be "relayed" under strict supervision to clean waters for natural cleansing.
- If an area receives pollution that is *chronically excessive* and/or *unpredictable*, it is classified **Prohibited** (P). Shellfish from Prohibited areas cannot be harvested for human consumption.

To classify a growing area, the Department evaluates two questions in turn:

Question 1: Does an area comply with Approved classification? The Department collects water samples in a shellfish growing area according to NSSP procedures (Appendix A, page 8). The Department calculates a geometric mean and an estimated 90th percentile from a minimum of 30 results. These are compared to the NSSP water quality criteria. Both the geometric mean and estimated 90th percentile must meet the NSSP criteria.

The Department also surveys the upland watershed and marine shoreline to find and assess pollution sources. The Department cannot approve an area if the shoreline survey reveals pollution sources that threaten public health, even if the water quality meets the NSSP criteria. If statistics from all stations meet the NSSP criteria **and** the shoreline survey does not reveal significant fecal pollution sources, the Department classifies the area Approved.

Question 2. If not suitable for Approved classification, can a growing area be classified Conditionally Approved? If the area cannot be classified Approved, the Department carries out additional processing of the data to see if it can be classified Conditionally Approved. (The procedures are detailed. A full description is beyond the scope of this report.) The most common Conditionally Approved classification is based on rainfall. The Department defines a 24-hour rainfall limit, which is placed into a "Conditionally Approved Area Management Plan" (CAAMP) for the area. Other conditionally approved closures include closures based on boat moorage, wastewater treatment malfunction, and flooding.

The Department periodically updates data analysis and conducts a new shoreline survey. The Department continues fecal pollution monitoring under systematic random sampling (SRS) to ensure representative, unbiased data are continually collected. Thus, DOH samples ing is carried out even when daily rainfall exceeds the level specified for harvest in the CAAMP.

Appendix D. The Early Warning System

Each year, the Department issues an "Early Warning" report to government and private interests if a sampling station in any growing area violates the following guidelines:

- **Threatened With a Downgrade**: The estimated 90th percentile at one or more stations equals or exceeds 30 fecal coliform organisms (as MPN) per 100 ml of water.
- **Identified Concerns**: The estimated 90th percentile at one or more stations equals or exceeds 20 fecal coliform organisms (as MPN) per 100 ml of water.

The early warning provides an opportunity for local government and other local interests to begin investigations and remedial action before water quality deteriorates to the point that the Department must downgrade the growing area.

Although analyses for status and trends and Early Warning are similar, they were designed independently to meet different goals. The Early Warning analysis detects recent degradation of water quality to help prevent future downgrades. The status and trends analysis tracks long-term change.

An "Early Warning System" report for each shellfish growing area listed in 2011 may be found on the Internet:
(http://www.doh.wa.gov/CommunityandEnvironment/Shellfish/GrowingAreas/AnnualReports/AlphabeticalList.aspx#ews).

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