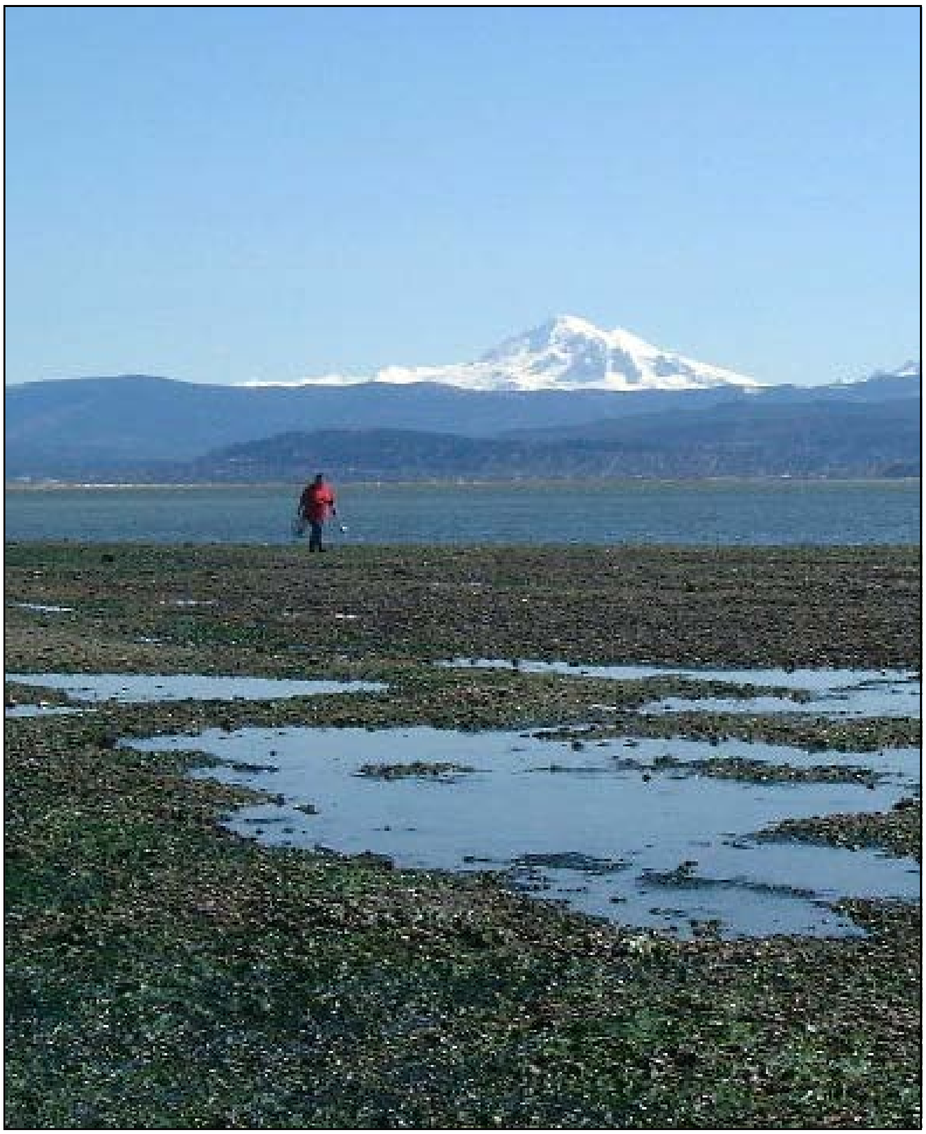
Status and Trends in Fecal Coliform Pollution in Shellfish Growing Areas of Puget Sound: Year 2010

December 2011



Washington State Department of Health
Office of Shellfish and Water Protection

PSAMP
Puget Sound Assessment and Monitoring Program

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Washington State Department of
Health
Office of Shellfish and Water Protection

DOH 332-101

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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/ehp/sf/sfpubs.htm.**

For summaries of data and statistics, please contact:

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Leslie Banigan and Mindy Fohn of the Kitsap County Health District helped compose sections for Dyes Inlet and Burley Lagoon.

Linda Hofstad of Thurston County Health Department helped compose sections for Henderson Inlet.

Christopher Krembs, PhD, Senior Oceanographer, Washington State Department of Ecology provided insight into the use of the Pacific Decadal Oscillation (PDO) index as a tool to assess climatic fluctuations.

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 15).

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.

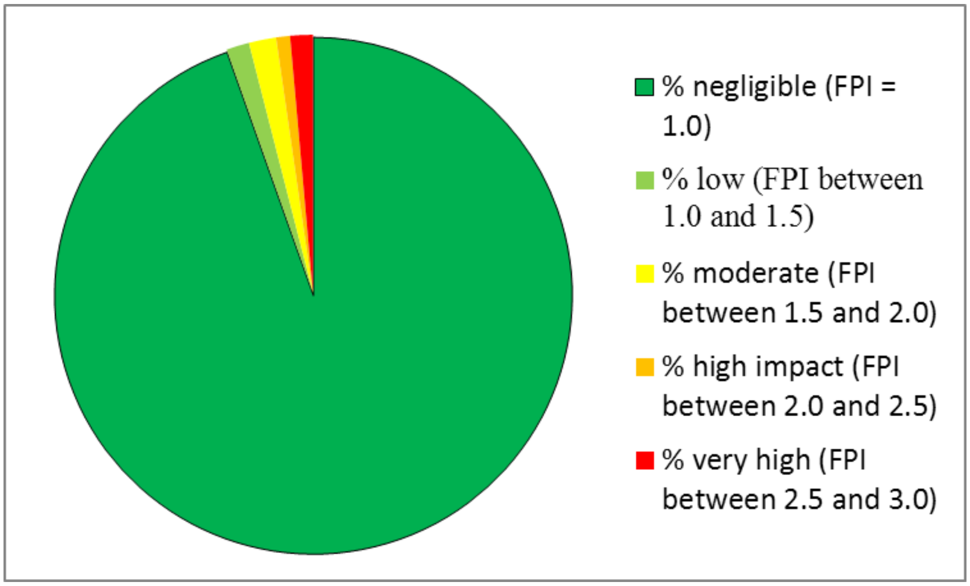
Nonpoint Fecal Pollution Sources and Remedial Action: In the early 1980s, nonpoint fecal pollution became the key factor in closure of shellfish beds. Intensive development of rural watersheds and the marine shoreline of Puget Sound have increased the risk of contamination of shellfish resources.

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 16) 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 2010.

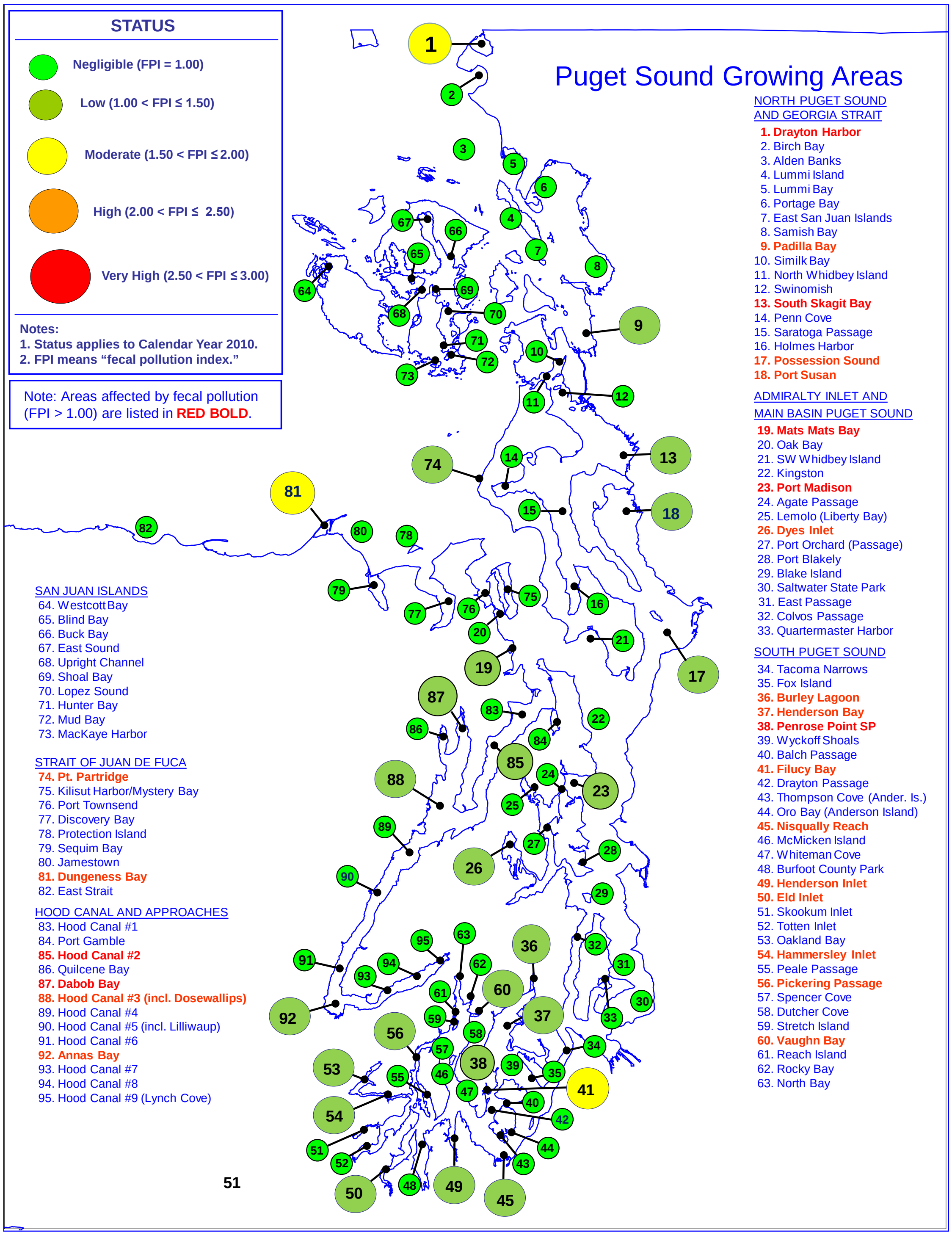
Fecal Pollution Impact Puget Sound-Wide. Figure 1 show proportions of FPIs in 2010 from all 1465 sampling stations throughout Puget Sound. There are five impact categories (defined in figure legend). Nearly 95% of stations (1387) showed negligible impact. 1.4 % of stations had very high impact. The remaining categories ranged from 0.9 to 1.7%.

Figure 1 shows the proportion of sampling stations throughout Puget Sound that fell into five categories of fecal pollution impact in 2010.



Fecal Pollution Impact among Growing Areas in Puget Sound. An annual FPI for 2010 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. Drayton Harbor (Area 1 on Figure 2) and Filucy Bay (Area 41 on Figure 2) appear to be the shellfish growing areas most affected by fecal pollution in 2010.

Figure 2 shows fecal pollution impact among 95 shellfish growing areas of Puget Sound during Calendar Year 2010.



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

Figure 3 ranks 25 Puget Sound shellfish growing areas affected by fecal pollution according to fecal pollution index in 2010.

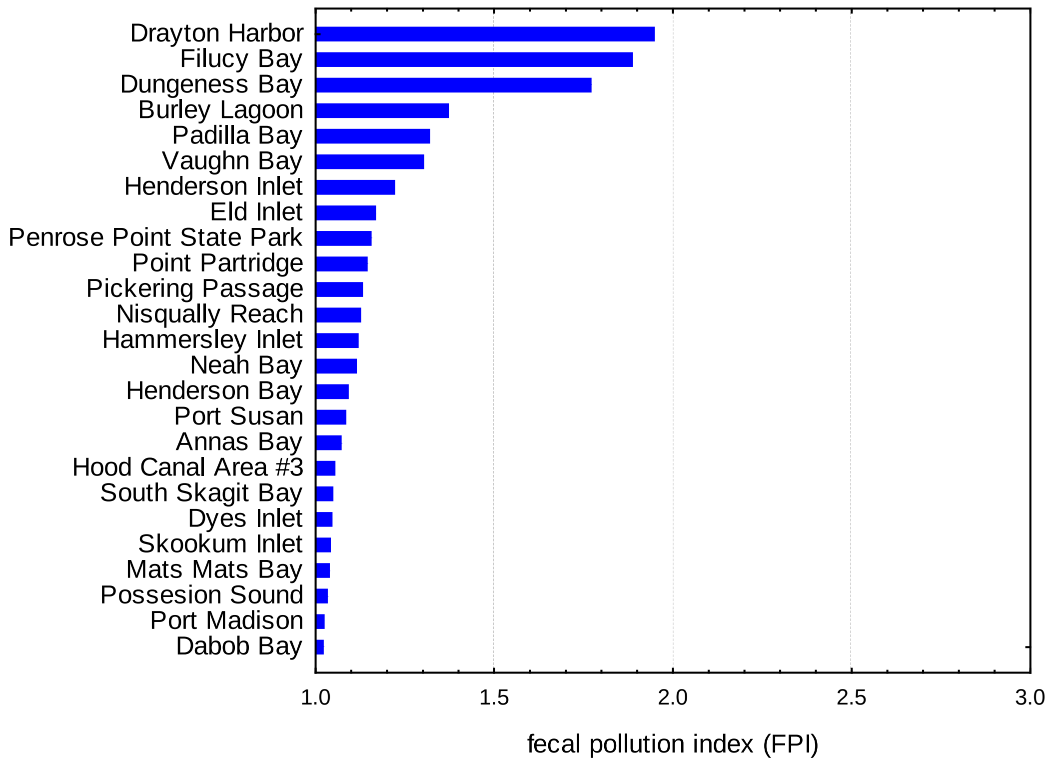


Table 1 summarizes the how changes in fecal pollution have affected growing areas between 2009 and 2010 (numbers indicate location of areas on Figure 2).

Added in 2010	*Areas Removed in 2010*
13. South Skagit Bay	53. Oakland Bay
19. Mats Mats Bay	63. North Bay
23. Port Madison	
38. Penrose Point State Park	
87. Dabob Bay	
Neah Bay (not shown on Figure 2)	

Neah Bay is newly ranked among impacted growing areas. South Skagit Bay returned to the ranking list after several years. On the other hand, several areas frequently listed in the late '90s, such as Hood Canal Area #9 (Lynch Cove) and Eld Inlet, have been off the list for several years.

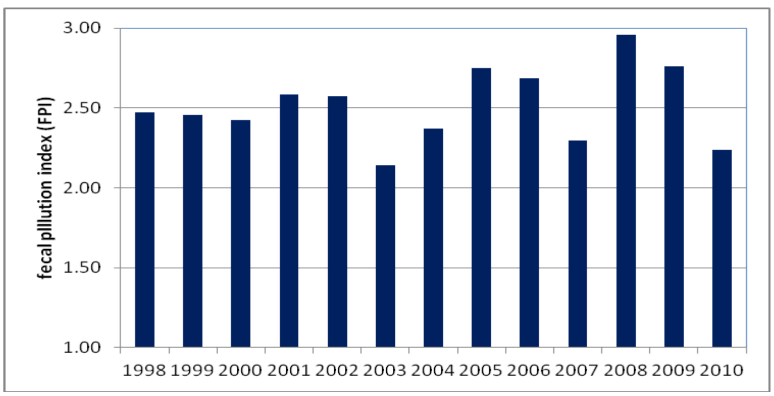
Fecal Pollution Trends in Puget Sound Shellfish Growing Areas 1998-2010

To examine how fecal pollution impact may vary among individual growing areas under a variety of conditions, 21 growing areas were selected for analysis of temporal trend. The first 16 areas are shown in the order of their 2010 fecal pollution ranking (Figure 3). The remaining five areas are included because they have been ranked in the past, but now have negligible pollution impact.

The 2010 "historical" FPIs shown on the graph for each of the 16 impacted areas shown below may differ somewhat from its FPI counterpart on Figure 3. This is because the annual FPIs in Figure 3 are calculated from statistics from all stations in the growing area, including new stations. On the other hand, "historical" FPIs are calculated with statistics only from stations that have a continuous sampling record (see Appendix B).

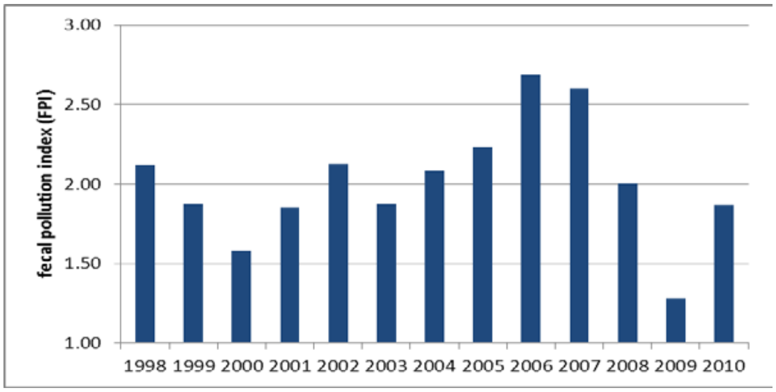
Note: Each growing area described below is referenced by number to its location in Figure 2 on Page 3.)

Drayton Harbor
(Area 1 in Figure 2)



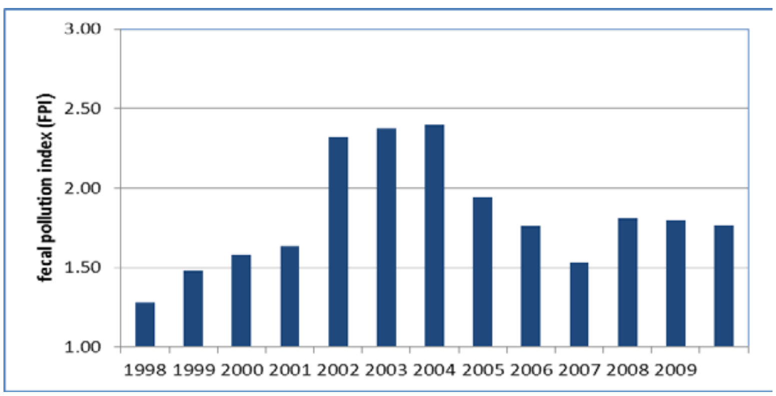
Potential fecal pollution sources addressed over the years include treated effluent from a wastewater treatment plant, fish processer waste, contaminated stormwater, boat waste from marinas, failed onsite sewage systems, and waste from farm animals. Wildlife has also been identified as a significant source of fecal pollution. Remedial action included repair of onsite sewage systems, best management practices installed on dairies and small farms, pump-outs installed at both local marinas, and partial repair of the Blaine sewer system. Fecal pollution remains sporadic (although it has dropped over the last three years).

Filucy Bay
(Area 41 in Figure 2)



Major potential pollution sources include boat waste from Longbranch Marina, failed onsite sewage systems along the marine shoreline, and animals pastured at bay's edge and along upland creeks. Some failed onsite sewage systems have been repaired, and some land owners have implemented agricultural pollution controls. Fecal pollution appears to have dropped since 2006. Fecal pollution in 209 was at its lowest since 2000. However, it jumped sharply in 2010.

Dungeness Bay
(Area 81 in Figure 2)

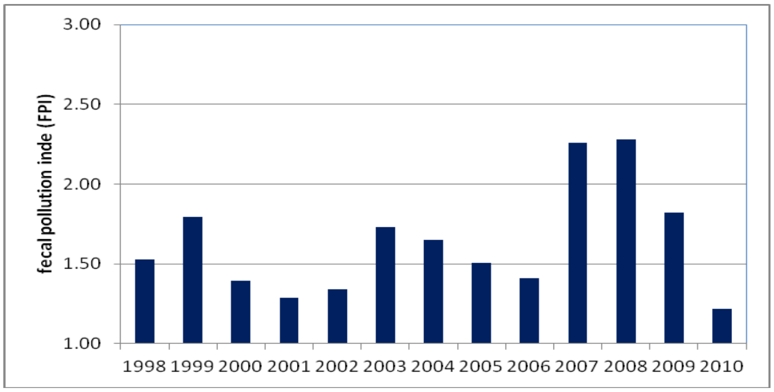


A major potential fecal pollution source is cow manure from pastures along the Dungeness River and associated drainages. Other suspected sources include onsite sewage systems along the marine shoreline, and wildlife (marine birds and harbor seals) on the Dungeness Spit. Since 2001, DOH has downgraded shellfish beds in Dungeness Bay several times. The Clallam Conservation District has carried out several projects with local landowners:

- Installed streamside buffers along Matriotti Creek by fencing and planting vegetation.
- Installed over five miles of underground piping to keep water off of pastures.

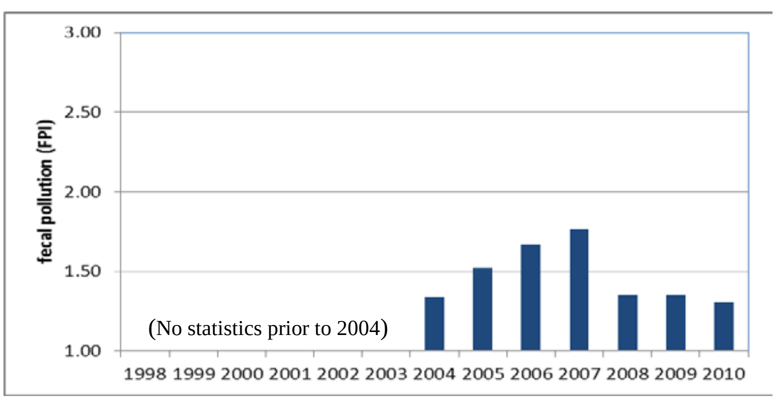
Fecal pollution has declined substantially since 2004, but has not returned to 1998 levels.

Burley Lagoon
(Area 36 in Figure 2)



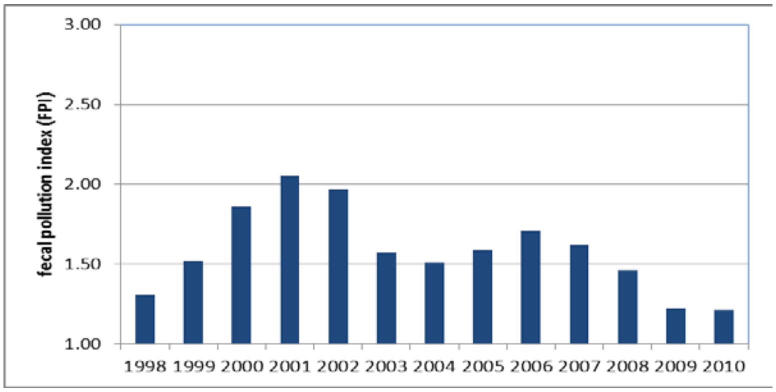
The Department first downgraded Burley Lagoon to Restricted in the mid-1980s. Over the years, remedial action has included: collection and export of sewage from Purdy Village, finding and repairing of failed on-site sewage systems, and improving pasture and livestock management. Despite several upgrades over the years, DOH also downgraded Burley Lagoon several times as new sources emerged. Local staff has always responded to meet the challenge. In 2008 Kitsap County Health designated Burley Lagoon as a Marine Recovery Area, enabling the Health District to receive funding from DOH to review records and field-check high-risk systems along Burley Creek. Several failed onsite sewage systems were discovered and fixed. Recently, Pierce County received a Centennial Clean Water Funds (CCWF) grant. The grant will enable both Pierce and Kitsap jurisdictions to continue their nonpoint pollution work through 2011. Recent remedial efforts may be a factor in the drop in fecal pollution since 2008. The FPI for 2010 is the lowest it has ever been since 1998.

Vaughn Bay
(Area in Figure 2)



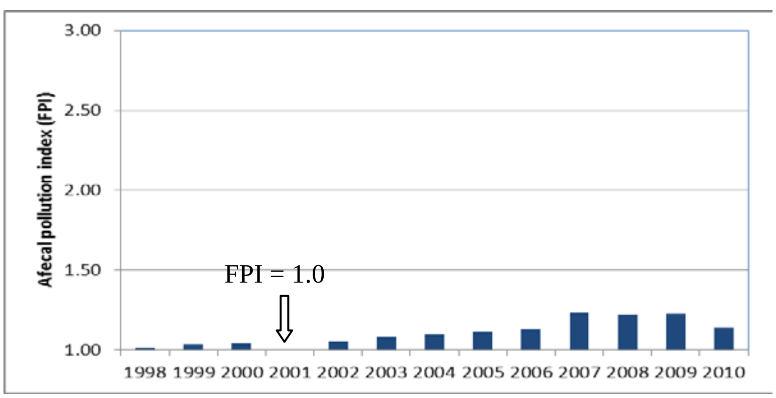
In 2008 DOH opened part of Vaughn Bay for the first time since the 1970s. The opening followed analysis of fecal pollution statistics, pollution source investigations, and action by Tacoma-Pierce County Health Department and Pierce County Public Works and Facilities. Water quality improved through 2010. In April 2011, the Approved area was expanded.

Henderson Inlet
(Area 49 in Figure 2)



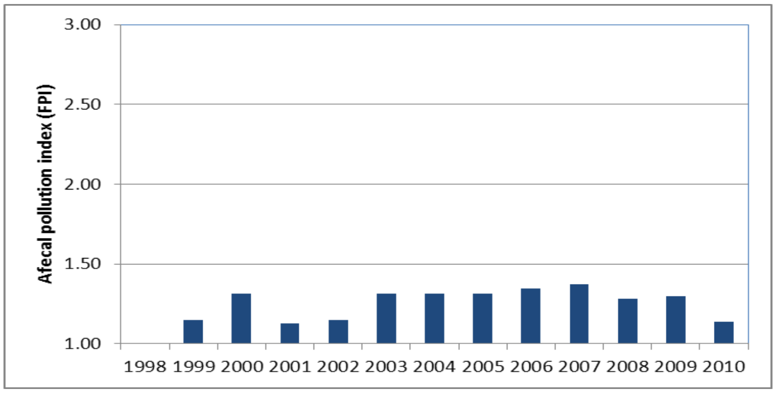
Major potential pollution sources include poor pastures, failed onsite sewage systems, and stormwater from Lacey and East Olympia. The County and the Conservation District have carried out outreach and remedial programs for over a decade. Thurston County created a shellfish protection district for Henderson Inlet. A new operation and maintenance program will assure routine maintenance of more than 6,000 onsite sewage systems. Over 1,800 homeowners are now trained to monitor their own systems. The Health Department also provides financial aid to low -income, elderly, or disabled residents for repair and maintenance of their systems through the Small Works Septic Grant Program. Fecal pollution dropped in 2001-2002. Fecal pollution impact in 2010 was the lowest since 1998. Henderson inlet was upgraded in 2010.

Eld Inlet
(Area 50 in Figure 2)



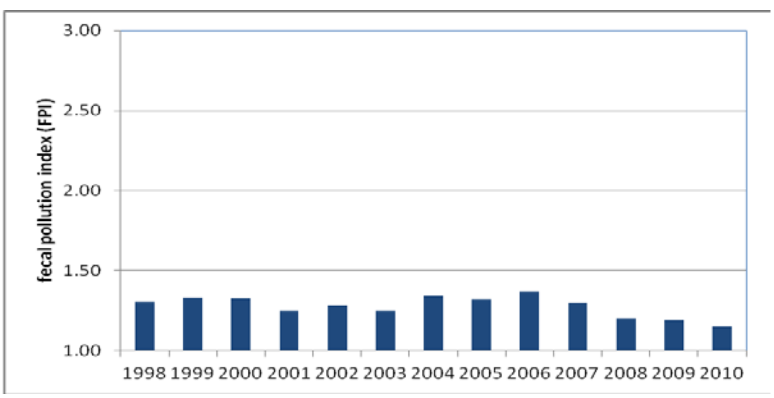
Major potential fecal pollution sources are onsite sewage systems (particularly along the marine shoreline) and waste from farm animals. Thurston County Health Department carried out an intensive onsite sewage program in 1991-1992, composed of a combination of intensive education and outreach, followed by rigorous sampling, inspections, hands-on technical help, and (when necessary) enforcement. As a result, many failed onsite sewage systems were located and repaired. In 1998 the Department upgraded most of Eld Inlet from Conditionally Approved to Approved. Although Eld Inlet remains Approved, fecal pollution steadily increased from 2002 through 2007. Since then, fecal pollution appears to have fallen slightly.

Pickering Passage
(Area 56 in Figure 2)



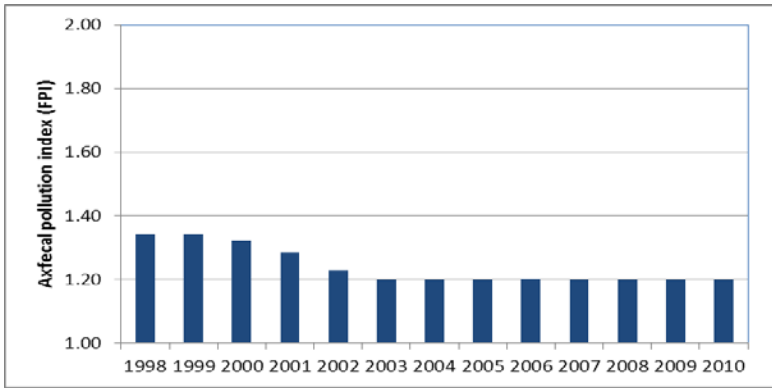
Fecal pollution rose in 2003 and remained relatively constant until 2007. DOH performed a sanitary survey in 2007. Potential sources included on-site sewage systems along the marine shoreline (no direct discharges were seen), 9 pasture sites (near McLane Cove), 3 small wastewater treatment plants, two yacht destinations, and 3 creeks. Confirmed pollution was associated with the agricultural sites. DOH downgraded McLane Cove, and placed closure zones around the treatment plants and the mouth of Jones Creek. In 2010 fecal pollution impact was the lowest it has been in nearly 10 years. DOH upgraded McLane Cove in 2011.

Nisqually Reach
(Area 45 in Figure 2)



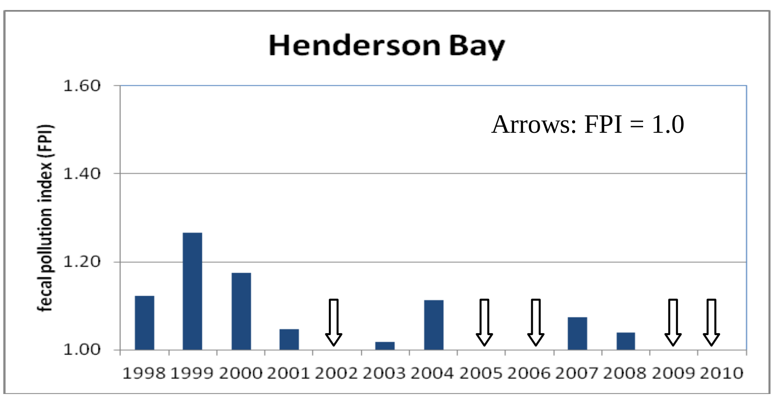
Major potential sources include onsite sewage systems along marine shorelines and upland drainages, extensive pasturage in lower Nisqually River and McAllister Creek drainages, storm water from residential developments, and wildlife at the Nisqually Nature Preserve and in upland areas. Thurston County Health has located numerous failed onsite sewage systems, and Thurston Conservation District has overseen installation of agricultural best management practices. DOH reclassified Nisqually Reach several times between 2000 and 2010. Although fecal pollution has decreased since 2006, the level of pollution appears to have been rather stable over the last decade.

Hammersley Inlet
(Area 54 in Figure 2)



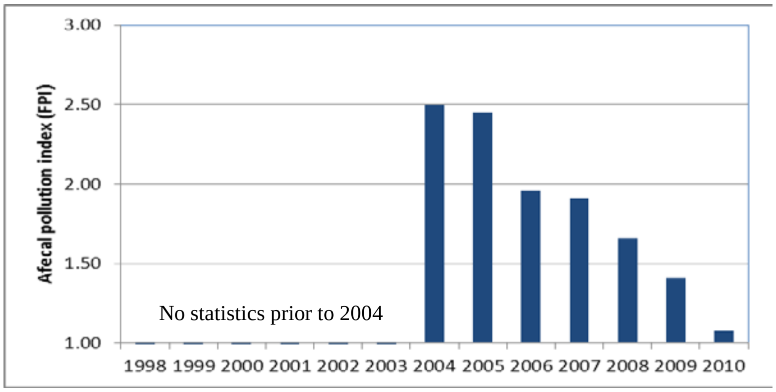
In DOH conducted a sanitary survey of Hammersley Inlet in April 2004. Numerous small seeps and drains lined the shoreline. Many older on-site sewage systems, some alterative systems, and several "high risk" discharges are located close to the shore. The survey also found an overgrazed pasture and a site used for disposal of dog waste. The Shelton Wastewater Treatment Plant (WWTP) discharge is at the west end of the growing area. The Department of Ecology conducted a hydrographic study of the Shelton WWTP in 2005. As a result of the study, DOH reduced the size of the Prohibited zone around the Shelton WWTP. DOH also classified most of Hammersley Inlet Approved. The most significant (and persistent) fecal pollution source remains Mill Creek, which drains a 19-square mile watershed. The mouth of Mill Creek is Unclassified.

Henderson Bay
(Area 37 in Figure 2



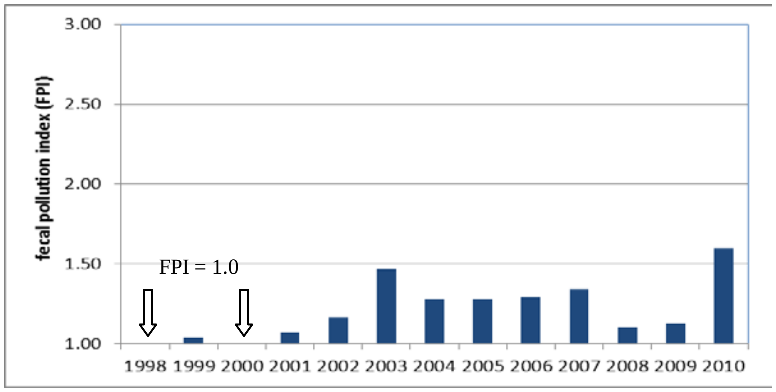
The Henderson Bay shoreline is almost exclusively residential. Onsite sewage systems serve the homes. The sources are failing onsite sewage systems and poor pasture management. The beach along the outer side of Purdy Spit is currently Prohibited due to failed onsite sewage systems near Wauna (at the southwest end of Purdy Spit). The systems have been repaired and an upgrade is underway. (Note: Minter Bay is not included in this analysis. The data record for sampling stations in Minter Bay is considerably shorter than for the rest of Henderson Bay.)

Port Susan
(Area 18 in Figure 2)



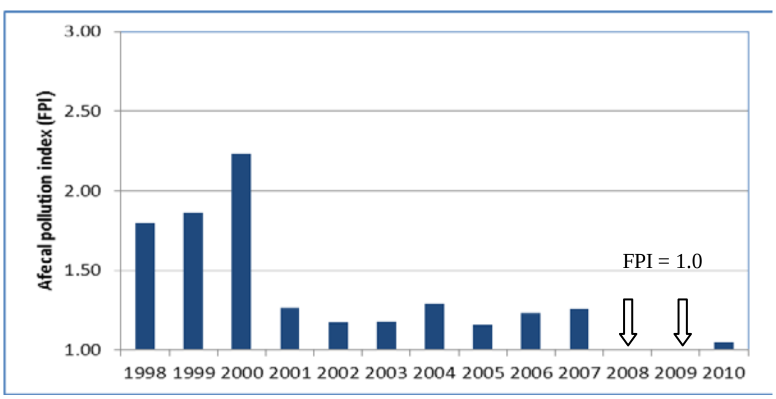
Harvest in Port Susan ended in 1987 due to unpredictable fecal pollution. DOH began routine sampling in 2002 after the Stillaguamish Tribe requested DOH to reevaluate its classification. DOH completed a major sanitary survey in 2009. In 2011, DOH classified an area in the middle of Port Susan as Approved. Most of the Stillaguamish River flow enters Port Susan near Hat Island. (The remainder flows into Skagit Bay). There are 12 dairies in the Port Susan Drainage. Onsite sewage systems serve the Warm Beach community on the East shore. Sewage Treatment camps serve the City of Stanwood, the Warm Beach Christian Camp and an industry (Twin City Foods). Nature Conservancy own 4,122 acres of estuary habitat in the Stillaguamish River delta.

Annas Bay
(Area 92 in Figure 2)



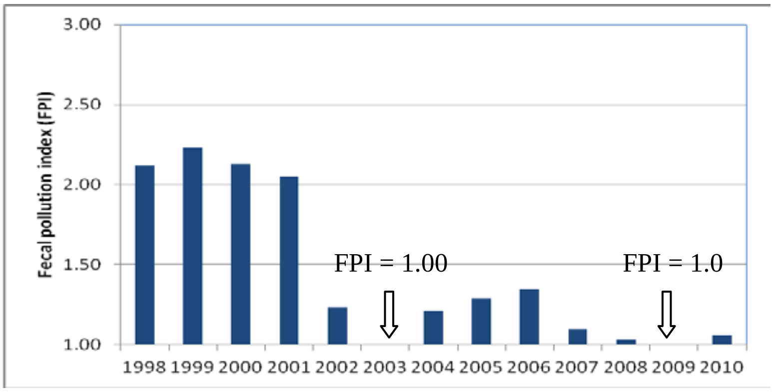
Major potential fecal pollution sources include animal waste from pastures along the lower Skokomish River. Other suspected sources are onsite sewage systems along the marine shoreline and harbor seals hauled out on the river delta. Since at least December 1995, DOH has closed Annas Bay to shellfish harvest during flooding of the Skokomish River. In 2005 DOH downgraded 300 acres of shellfish area near the mouth of the Skokomish River due to declining water quality. In 2006, the Mason County Commissioners approved the formation of a shellfish protect district. Fecal pollution has dropped since 2007 as a result of reduced fecal pollution from the Skokomish River. Reductions in fecal pollution loading were driven by a "Total Maximum Daily Loading" (TMDL) process carried out by the Dept. of Ecology. Fecal pollution impact in 2010 reached its highest level since 1998.

South Skagit Bay
(Area 13 in Figure 2)



The Skagit River greatly influences South Skagit Bay. Skagit River receives storm water and wastewater treatment discharge from Mt. Vernon, Sedro Woolley, and Burlington. Agriculture dominates land use in the river delta. In 2006, DOH upgraded parts of Skagit Bay after replacement and improved operation of the Stanwood Sewage Treatment Plant and improved water quality. DOH further expanded the growing area following a recent shoreline survey. Fecal pollution increased slightly in 2010.

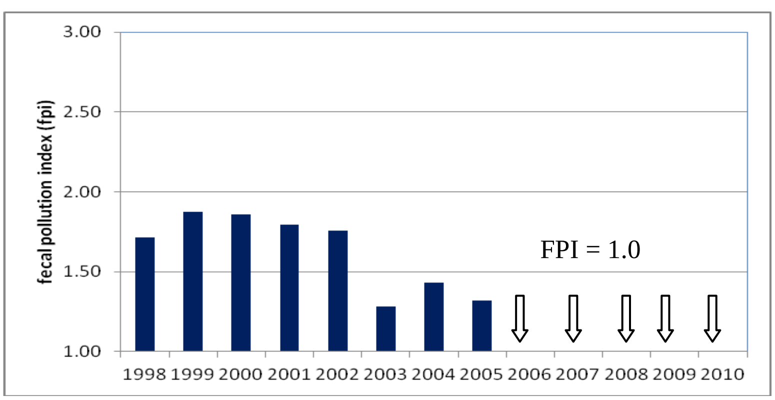
Dyes Inlet
(Area 26 in Figure 2)



The Dyes Inlet watershed supports diverse land uses: rural, suburban, high density residential and commercial. Potential fecal pollution sources include failed onsite sewage systems, waste from farm animals, combined stormwater-sewer overflows (CSOs), and contaminated stormwater runoff. Kitsap County and the City of Bremerton, guided by rigorous water quality monitoring and a U.S Navy water quality modeling study, found and fixed numerous fecal pollution sources. Intensive remedial action resulted in the partial reopening of Dyes Inlet after decades of closure. Recent projects include:

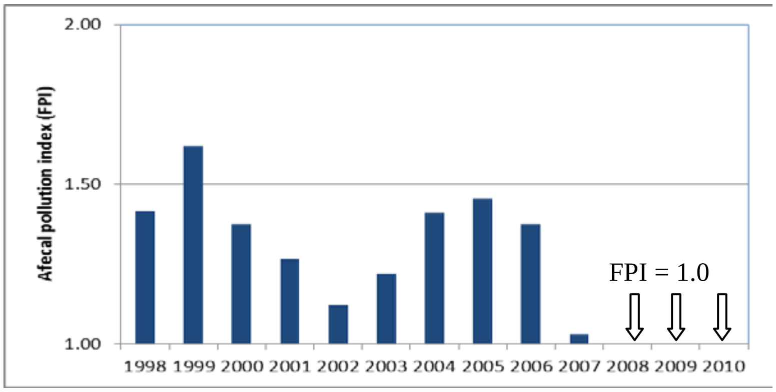
- reduction of untreated CSO discharge (City of Bremerton),
- inspection and repair of failed onsite sewage systems (Kitsap County Health District),
- improved manure management (local rural land owners and Kitsap Conservation District),
- stormwater system maintenance and source control (Kitsap County Public Works).

Portage Bay
(Area 6 in Figure 2)



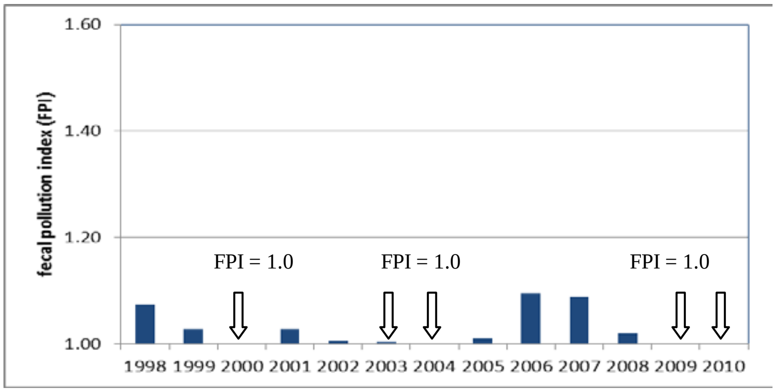
Major potential fecal pollution sources include runoff from dairies along the lower Nooksack River and overflow from a sewer line along the Portage Channel shoreline. An intensive dairy waste control program was conducted in 2000, and several sewage systems have been upgraded. Since 2005, fecal pollution has been negligible (FPI=1.0). However, slightly rising statistics in late 2010 are a concern.

Samish Bay
(Area 8 in Figure 2)



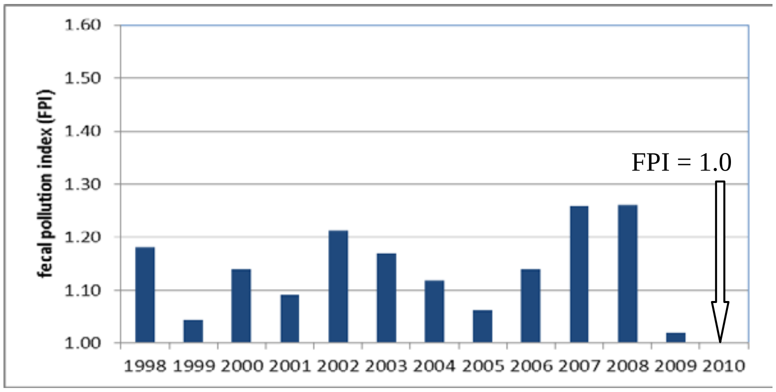
Major potential sources include poor waste management from farm animals, failed onsite sewage systems in the watershed, treated effluent from a "Large Onsite Sewage System (LOSS) at Edison, and wild birds (in pastures and nearshore marine waters). A downgrade in 1995 triggered remedial action (surveys and repair of onsite sewage systems, construction of a LOSS and collection in Edison, community education, etc.). Most of Samish Bay is now Approved. The area near the mouth of Edison Slough and the Samish River remains Prohibited. In 2010, fecal pollution in Samish Bay was negligible (FPI = 1.0). However, Samish Bay is subject to emergency closures during storm-generated high flow from the Samish River. DOH, local agencies, and shellfish growers participate in storm-event monitoring in the Samish watershed and marine waters. The Skagit County Commissioners provided funds to search for pollution sources. Meanwhile, outreach programs provide local landowners information and motivation to prevent runoff of pollution into creeks and drainages.

Oakland Bay
(Area 53 in Figure 2)



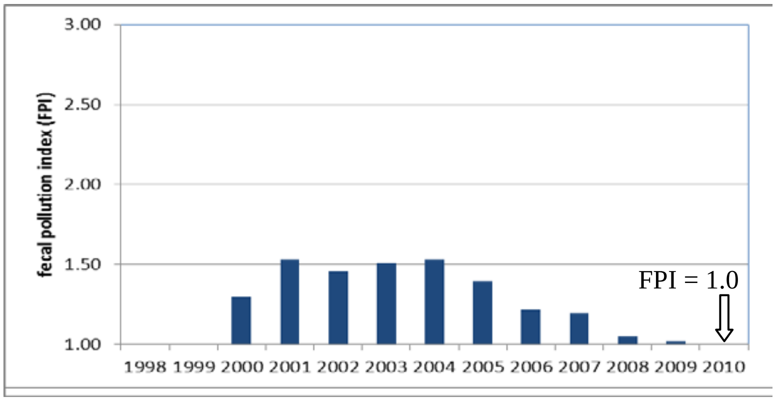
DOH closed Oakland Bay to shellfish harvest in 1987 due to overflowing sewage from the Shelton sewer system. Since then, Shelton has repaired or replaced much of its system. DOH upgraded parts of Oakland Bay in 1989 due to reduced fecal pollution. Other major potential fecal pollution sources include failed onsite sewage systems, waste from farm animals, and boat waste from the Shelton Yacht Club (a pumpout is installed). In 2006 DOH downgraded parts of Oakland Bay after newly sampled areas revealed significant fecal pollution. Mason County declared Oakland Bay a shellfish protection district. Many stakeholders are actively involved in the process. The County Health Department is carrying out remedial action, and the Squaxin Tribe is conducting special studies. Oakland Bay was partially upgraded in 2010.

North Bay
(Area 63 in Figure 2)



In 1991, DOH downgraded shellfish grounds near Allyn due to numerous failed onsite sewage systems along the shoreline. The systems were given temporary repairs in 1992, and much of the area was reopened to harvest. In 2001, Mason County installed a community-sized sewer collection system and wastewater treatment plant as a permanent solution to the problems with onsite sewage systems. By late 2002, DOH upgraded much of North Bay. Other potential fecal pollution sources include stormwater, boat sewage, pet waste, and wild bird populations. The Port of Allyn supplies a boat pumpout on the dock. Fecal pollution in North Bay has been somewhat cyclic over the past decade. In 2010 fecal pollution dropped to its lowest level since 1999. DOH has adjusted the classification of North Bay several times between 2005 and 2010.

Hood Canal #9 (Lynch Cove)
(Area 95 in Figure 2)



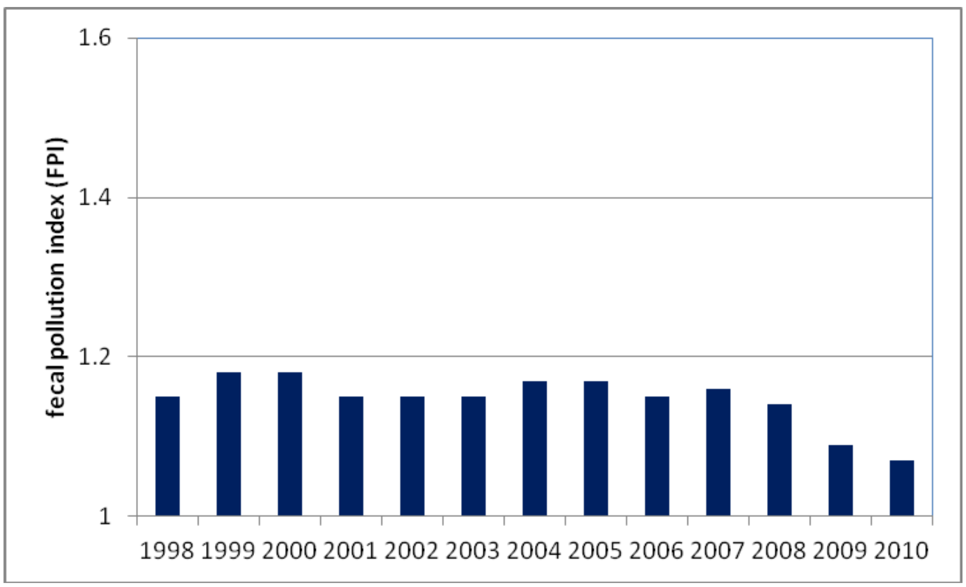
Major potential fecal pollution sources include onsite sewage systems in Belfair, along both the Lynch Cove shoreline and the banks of the Union River and other creeks. Other probable sources are animal waste from pastures along the Union River. In 1993 DOH downgraded all of Lynch Cove to Prohibited. Mason County conducted several focused onsite sewage control programs since 1996. These efforts produced several incremental upgrades of the shellfish growing area. The shoreline from Belfair State Park northeast to Belfair remains Prohibited. However, the western part of the State Park tideland is Approved. Fecal pollution has dropped progressively since 2004. A regional wastewater treatment plant is proposed for the near future.

Overall Fecal Pollution Trend in Puget Sound (1998-2010)

Figure 4 shows a "historical" annual fecal pollution index for all of Puget Sound for each year 1998-2010. Each annual FPI was calculated from estimated 90th percentiles pooled from more than 1400 stations in all 95 growing areas in Puget Sound for every year. Three general inferences can be drawn from Figure 5:

1. During the past decade, fecal pollution impact Puget Sound-wide has been low overall.
2. Annual FPIs from the early part of the decade suggested the possibility of a cyclic pattern.
3. Fecal pollution impact Puget Sound-wide appears to have steadily declined in recent years. Also fecal pollution impact in 2010 was lower than any year since 1998. However, these conclusions must be tentative. They currently lack statistical certainty.

Figure 4 shows trend in fecal pollution impact integrated over all of Puget Sound 1998-2010.



Individual 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/ehp/sf/sfpubs.htm.**

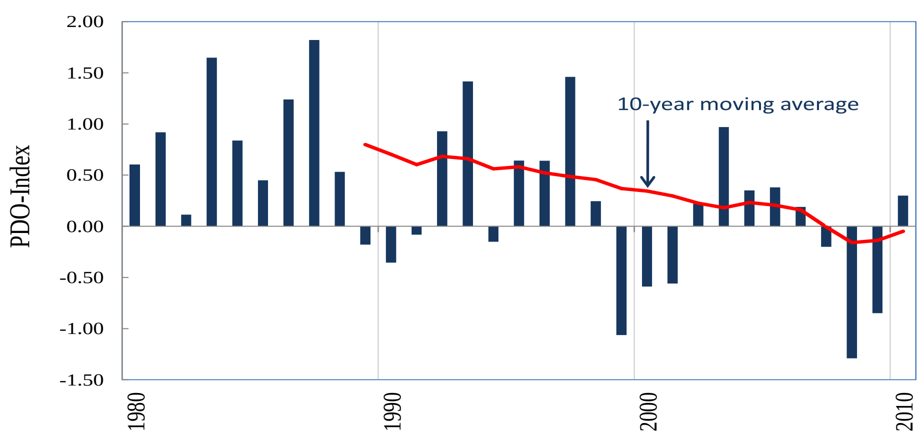
Interaction Between Remedial Action and Rainfall Fluctuations.

Over the last two decades, upland remedial action has been used to reduce fecal pollution in a number of shellfish growing areas (see pages 6-13). However some areas have shown reduction without much remediation. Indeed, during the last two years, fecal pollution has affected fewer growing areas than any time in the last decade. The question arises: are either rainfall fluctuations or remedial action the important factor in reducing runoff-related nonpoint fecal pollution?

Long-term Rainfall Fluctuation. The "Pacific (inter) Decadal Oscillation" (PDO) is a pattern of climatic fluctuation that has been described in the North Pacific Ocean. A PDO-Index has been derived, in part, from sea surface temperature data. Mantua, et al (1997) used the PDO-Index to identify several climate reversals in the North Pacific during the previous century: mostly positive PDO from 1925 through 1946, negative PDO between 1947 and 1976, and positive PDO from 1977 through 1997. During periods of positive PDO, the climate in Washington and Canada tends toward lighter than normal rainfall. Flows from three major Pacific Northwest rivers (Skeena, Fraser, and Columbia) are also markedly lower.

DOH obtained a table of monthly PDO-Index values from the Joint Institute for the Study of the Atmosphere and Oceans (JISAO), University of Washington (http://jisao.washington.edu/pdo/PDO.latest). The monthly values were averaged to produce annual PDO-Indices (Christopher Krembs, personal communication). Figure 5 shows annual average PDO-Indices from 1980 through 2010. The 10-year moving average is used to illustrate significant changes (Krembs, personal communication). The post-1977 positive PDO signature noted by Mantua, et al (1997) is evident. However, the moving average suggests that a negative signature may be developing. The shift could lead to heavier, more frequent rainfall and increased runoff. If this occurs, pressure on pollution control programs will likely intensify.

Figure 5 shows the annual average PDO-Indices from 1980 through 2010 superimposed by a plot of the 10-year moving average. The plot suggests a trend toward reduced indices (i.e., increased rainfall and storm runoff).



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 (geometric means and estimated 90th percentiles) mainly for classifying growing areas (Appendix C, page 18). NSSP statistics are also used for the early warning analysis (Appendix D, page 19), 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 ≤ 30 mpn/100ml)
- "FAIR" (30 mpn/100ml < 90th percentiles ≤ 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.

(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

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

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 15). The Department calculates a geometric mean and an estimated 90^{th} percentile from a minimum of 30 results. These are compared to the NSSP water quality criteria. Both the geometric mean and estimated 90^{th} 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 2010 may be found on the Internet: (**http://www.doh.wa.gov/ehp/sf/growreports.htm#alphalist**).

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