Status and Trends of Fecal Coliform Bacteria in Shellfish Growing Areas in Puget Sound and the Straits of Georgia and Juan de Fuca

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Background

Department of Health Mandate
The Washington State Department of Health (Health) classifies more than 100 commercial shellfish growing areas in Puget Sound and the straits of Georgia and Juan de Fuca. Health monitors fecal coliform levels in these growing areas to protect shellfish consumers from contaminated shellfish. Health is also a partner in the Puget Sound Ambient Monitoring Program (PSAMP). PSAMP is a multi-agency monitoring program coordinated by the Puget Sound Water Quality Action Team. Data gathered to classify and manage shellfish beds are also used to address PSAMP goals. This report addresses two PSAMP-related questions:

1. Has fecal coliform pollution changed in shellfish growing areas of Puget Sound during the last decade?
2. Are changes (if they have occurred) related to pollution control, addition of new sources, or the interaction of both factors?

Development and Fecal Pollution Sources
Prior to the 1970s, the major threat to shellfish beds was wastewater discharged through pipes (point sources). This threat diminished after legally mandated wastewater treatment facilities were built. Since the early 1980s, nonpoint sources have become an increasingly important factor in closure of shellfish beds. Nonpoint sources include failed individual on-site sewage systems, unmanaged runoff from farms, stormwater, sewage from boats, marinas, wildlife, etc. Rapid migration of people into Puget Sound during the last two decades and the growing "suburbanization" of rural watersheds have increased the risk of pollution impacts on shellfish habitat.

Remedial Action
During the past decade, governments and citizens have dedicated time and treasure to control nonpoint pollution. Remedial action has included (to greater or lesser degrees): watershed planning; agricultural best management practices; repair of failed individual on-site sewage systems; upgrading of municipal sewage facilities; construction of stormwater treatment facilities; and installation of pump out-dumpout waste stations at marinas and marine parks.

Classification of Shellfish Growing Waters
The Department of Health applies two components to classify a shellfish growing area:

- **Shoreline survey:** all significant point and nonpoint pollution sources along shorelines and in upland drainages are located and evaluated.
- **Water quality sampling:** Stations within the proposed growing area are selected and routinely sampled until a minimum of 30 results per station is available. Two statistics (geometric means and 90th percentiles) are calculated from the results. These are compared to water quality criteria set by the National Shellfish Sanitation Program (NSSP).

The NSSP **Water Quality Criteria** are applied according to type of pollution sources present:

1. The **geometric mean** is not to exceed 14 most probable number (MPN) of fecal coliforms per 100 milliliters of water (applied when point and/or nonpoint sources are present).
2. The **90th percentile** is not to exceed 43 MPN per 100 milliliters of water (applied to areas where only nonpoint sources are present); OR 10% of results are not to exceed 43 fecal coliforms per 100 milliliters (applied in Conditionally Approved areas and those receiving point-source discharges).

Both water quality criteria **must be met** to meet NSSP requirements. An area cannot be approved for harvest if it fails the shoreline survey despite acceptable water quality. If water quality criteria are met **and** significant pollutant sources are absent, the area is classified as **Approved**. If pollution events are episodic and predictable (rain-related runoff, etc.), the area can be **Conditionally Approved**. An area subjected to limited, unpredictable pollution is classified **Restricted**. Areas chronically affected by pollution episodes that are both excessive and unpredictable are classified **Prohibited**. After classification, monitoring continues and shoreline surveys are periodically conducted to detect change.

"Early Warning" Program

Each year Health reviews data from growing areas throughout Washington State. Health issues an "Early Warning" report if one or more stations in a growing area are "Threatened":

- A growing area is Threatened if the 90th percentiles equals or exceeds 30 MPN per 100ml or about 70 percent of the NSSP limit of 43 MPN per 100ml).

The 90th percentile (rather than the geometric mean) is the Threatened statistic because experience has shown that 90th percentiles respond more quickly to change than geometric means. A list of Threatened growing areas is sent to shellfish growers, tribes, and local and state agencies.

Although analyses for Early Warning and PSAMP are similar, they were designed independently to achieve different goals. The PSAMP analysis detects long-term change. The Early Warning analysis detects recent degradation of water quality, so that pollution sources, if present, might be located and repaired to prevent possible downgrades.

Methods

Field and Laboratory Protocols

Health uses a systematic random sampling (SRS) strategy (U.S. FDA 1997) when sampling fixed stations in shellfish growing areas. Under this strategy, each growing area is sampled at reasonably fixed intervals without regard to environmental factors.

Surface samples for fecal coliform analysis are collected at each station according to APHA (1984). The samples are packed on ice and sent to the Health Public Health Laboratory in Seattle. Analyses are run within 30 hours of collection. Fecal coliforms are analyzed with the multiple tube fermentation (MPN) procedure using A-1 broth (described in Method 9221 E *in* APHA 1995). Surface measurements of salinity and temperature are recorded, together with tide and weather conditions.

Selection of Growing Areas for Analysis

Health uses two strategies for PSAMP:

- **Core** areas are evaluated annually. Core areas have been harvested for many years, and harvest is likely to occur for many more (barring pollution-related closures). They are affected by nonpoint pollution, but control programs are in place and show potential for success. Most Core areas have parts that are classified Conditionally Approved and are sampled 12 times a year.
- **Rotational** areas are examined every 3 years. Rotational areas include all Approved and Restricted areas. Approved areas are typically remote from pollution sources. Restricted areas have typically responded poorly to control programs. Thus, monthly sampling is fiscally unjustified. Rotational areas are generally sampled six times a year.

Rotational areas are divided among three regions. The north region includes north Puget Sound, the straits of Juan de Fuca and Georgia, and the San Juan Islands. The central region includes Main Basin Puget Sound and Hood Canal. The third region is South Puget Sound. This year's PSAMP analysis included all Core growing areas throughout Puget Sound, and Rotational areas in the central region

Calculations.
Health selected for PSAMP analysis individual stations in each growing area that were consistently sampled for the longest time. For each selected station, a geometric mean and a 90th percentile were calculated for the earliest date that had the required minimum of 30 prior results. These statistics were then calculated for each subsequent date forward through March 2000. In other words, the statistics are "moving statistics," progressing forward through time. As stated earlier, the 90th percentile was selected as the statistic to measure status and trends. Statistics were calculated with Excel 5.0 (Microsoft Corp.). The statistics were then exported to STATISTICA 5.1 (Statsoft, Inc., Tulsa, OK) for statistical and graphical analysis.

Status and Trends of Individual Stations within a Growing Area
Status was determined for the period from January 1999 through 2000. Ninetieth percentiles were first plotted against sampling date (Figure 1 shows Station 3 in Henderson Inlet). The 90th percentiles were then sorted into three groups (**GOOD**, **FAIR**, and **BAD**) as follows:

- **GOOD**: equal or less than the Threatened threshold of 30 MPN per 100ml. (See **"Early Warning" Program** above)
- **FAIR**: higher than 30 MPN per 100ml, but did not exceed the NSSP criterion of 43 MPN per 100ml.
- **BAD**: greater than the NSSP criterion.

Figure 1 shows that 5 of 15 90th percentiles (33%) were GOOD, 7 (47%) were FAIR, and 3 stations (20%) were BAD. The pie chart summarizes the status of the station, and can be visually compared against other stations in the growing area (see Figure 3 in **Results**).

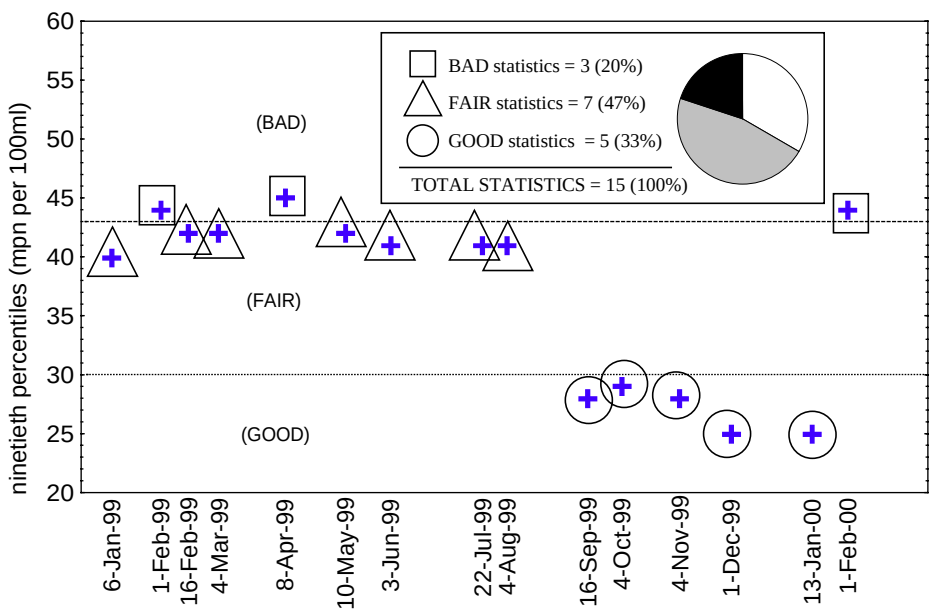

Figure 1. Method of determining station status using a plot of 90th percentiles versus date at station 3 in Henderson Inlet (Jan 1, 1999-March 2000).

Temporal trends (significant changes in 90th percentiles over time) were determined at stations meeting two criteria. First, statistics needed to be available for a period of at least 3 years (i.e., March 1997 through March 2000). Second, 90th percentiles needed to be higher than 10 MPN per 100ml. Trends were tested with two nonparametric statistical tests: Spearman's *rho* and Kendall's *tau* (STATISTICA, Statsoft, Inc., Sokal and Rohlf 1969). The alternative hypothesis (a true trend existed) was accepted only if both tests rejected the null hypothesis (there is no significant trend). Trends are indicated with symbols for each station in a growing area (see Figure 3 in **Results**).

Status of Individual Growing Areas
The status of each growing area was determined using box plots of ranges of 90th percentiles for each station during the period from January 1999 through March 2000 (see Figure 2). Each station was categorized GOOD, FAIR, and BAD, as done previously. The number of stations in each category was then tallied. Figure 2 shows that 10 of 20 stations (50%) in Henderson Inlet were GOOD, 6 (30%) were FAIR, and 4 stations (20%) were BAD. The pie chart provides a visual summary of status with which Henderson Inlet (southern end of Puget Sound) can be compared with the 43 other growing areas analyzed this year (see Figure 4 in Results).

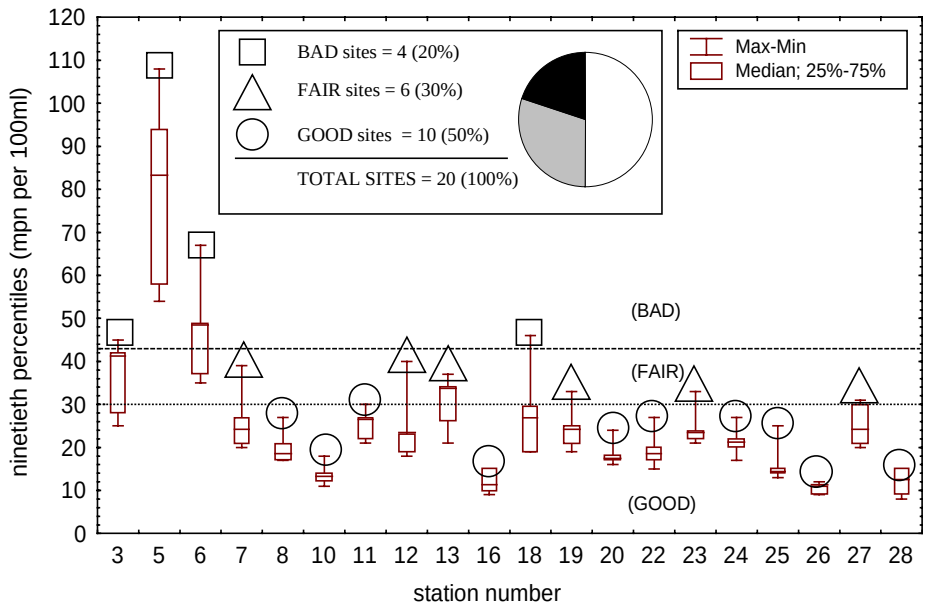

Figure 2. Method of determining growing area status using box plots of data pooled for each station in Henderson Inlet from January 1, 1999 through March 2000.

Ranking of Growing Areas
The rank of each growing area was determined by multiplying the percentage of stations in each category (**GOOD**, **FAIR**, and **BAD**) by a weighting factor (factor=1: **GOOD** percentages; factor=2 to **FAIR** percentages; and factor= 3 to **BAD** percentages). Division of the sum of the weighted percentages by 100 produced a "Fecal Impact Index". The impact index ranges from 1.00 (all stations in **GOOD** category) to 3.00 (all stations in BAD CATEGORY). A graphical summary of ranking of growing areas by fecal impact indices is in Figure 5 in **Results.**

Results

Status and Trends of Individual Stations within a Growing Area
Figure 3 summarizes status (January 1999-March 2000) and trends (entire period of record) for each station in Henderson Inlet. Eighteen of 20 stations showed significant increase in fecal pollution (black arrow pointing up) since early 1990. Two stations showed no significant change (gray diamond). Determan (in press) has a summary map for each of 26 growing areas impacted by fecal pollution.

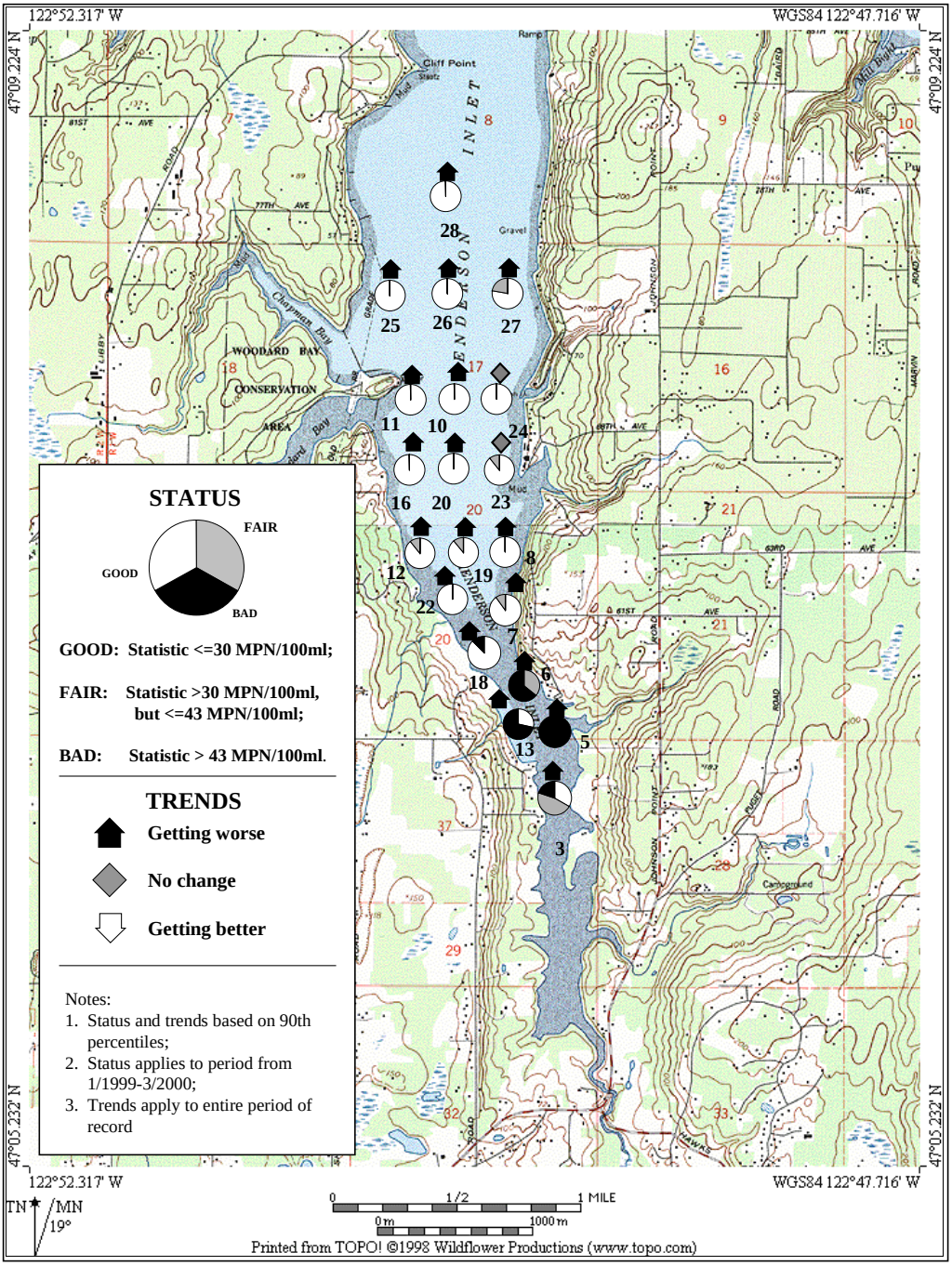

Figure 3. Status and trends in fecal pollution in Henderson Inlet through March 2000.

Status of Individual Growing Areas

Figure 4 compares the relative status of 43 growing areas evaluated for PSAMP. Figure 4 suggests the least impact from fecal pollution occurred in Hood Canal and most stations in Main Basin Puget Sound. The greatest impact seems to have occurred in Drayton Harbor (Georgia Strait), south Skagit Bay (Saratoga Passage near Whidbey Island), Dyes Inlet (near Bremerton), and Filucy Bay (south Puget Sound).

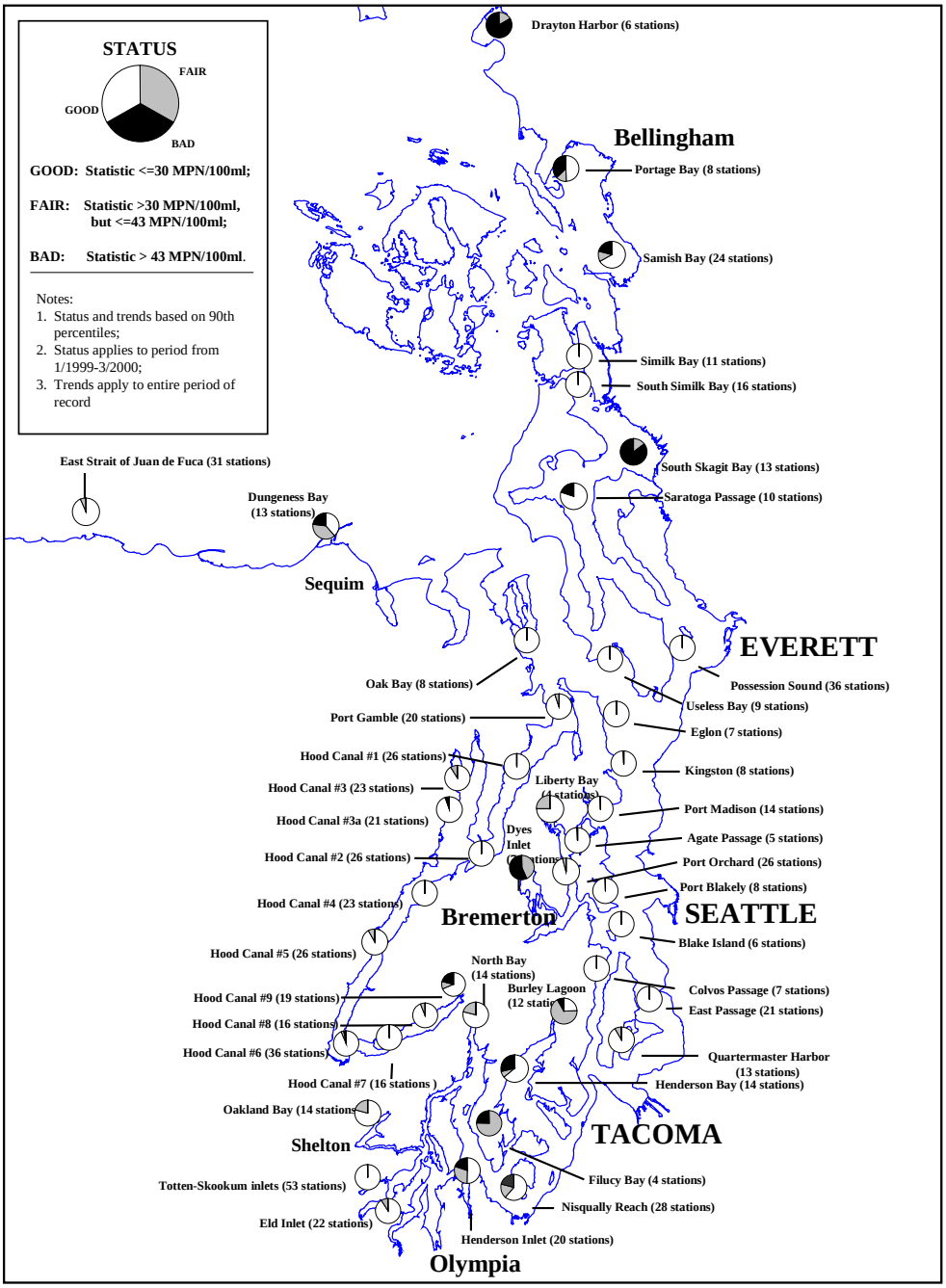

Figure 4. Status of fecal pollution in selected shellfish growing areas throughout Puget Sound and the Strait of Juan de Fuca January 1999 through March 2000.

Ranking of Growing Areas

Seventeen of 43 growing areas evaluated this year had impact indices OF 1.00 (all stations GOOD). These included 4 of 9 areas in Hood Canal and 9 of 13 areas in the Main Basin. Impact indices for the remaining 26 growing areas are shown in Figure 5. The most contaminated areas were South Skagit Bay (Index = 2.85), Drayton Harbor (Index = 2.83). Chico Bay in Dyes Inlet (Index = 2.57), and Filucy Bay in south Puget Sound (Index = 2.25). Likely pollution sources in all areas include failing on-site sewage systems and pasture drainage from upland watersheds. Sources in Drayton Harbor, Henderson Inlet, and Oakland Bay include contaminated urban stormwater among assorted nonpoint sources. Drayton Harbor may also receive fecal wastes from boats. Major fecal pollution into Portage Bay appears to be drainage from livestock operations along the Nooksack River.

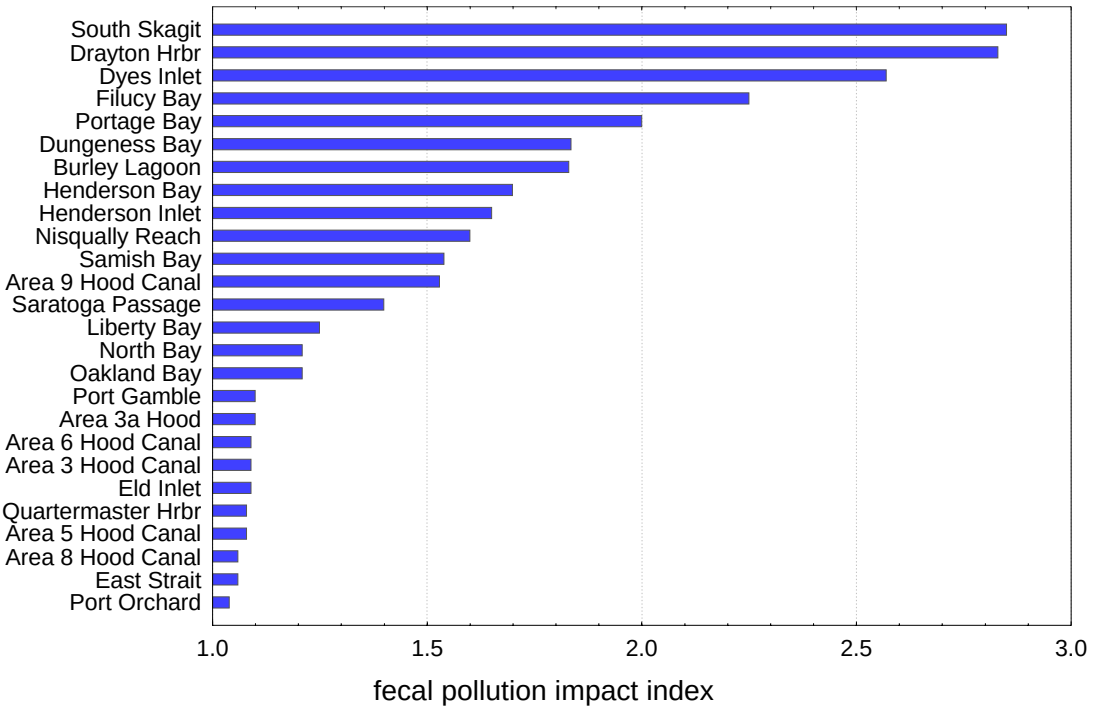

Figure 5. Shellfish growing areas ranked by fecal impact index (January 1999 through March 2000).

Summary

Status was determined for 702 stations in 43 growing areas examined this year. There were 593 GOOD stations (84.5 %), 58 FAIR stations (8.3 %), and 52 BAD stations (7.3 %). Temporal trends were determined on 225 stations in 26 shellfish growing areas. Fecal pollution increased significantly over time at 103 stations (46%) Fecal pollution decreased at 61 stations (27%). Fecal pollution was stable at another 27% of stations. Twenty-six of 43 growing areas were ranked according to fecal pollution impact. The greatest impact occurred at south Skagit Bay and Drayton Harbor.

References

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