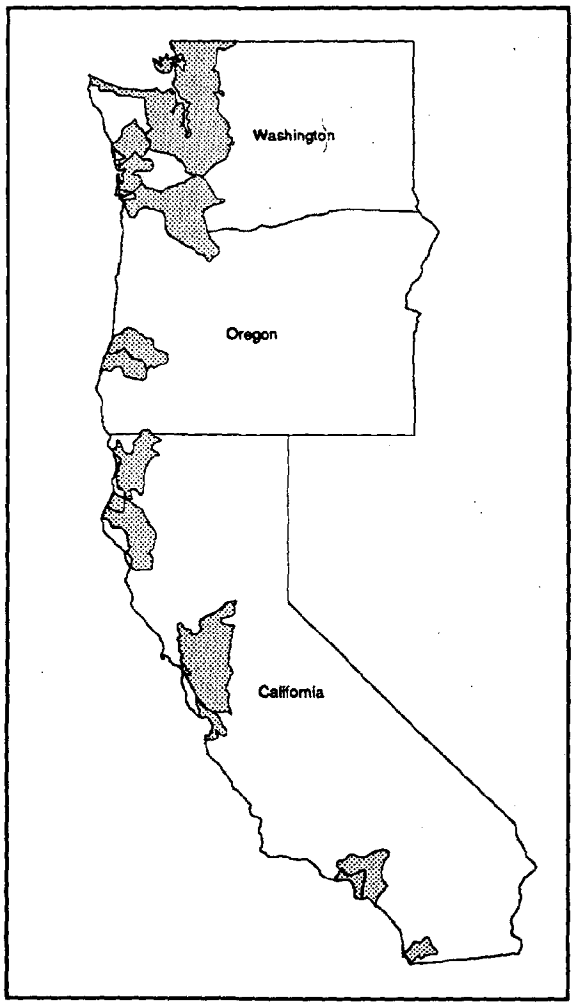
National Estuarine Inventory

The Quality of Shellfish Growing Waters on the West Coast of the United States



June 1990

U.S. Department of Commerce

National Oceanic and Atmospheric Administration

NOAA's National Estuarine Inventory

The National Estuarine Inventory (NEI) is a series of inter-related activities of the Strategic Assessment Branch of the Office of Oceanography and Marine Assessment (OMA), National Oceanic and Atmospheric Administration (NOAA), to develop a national estuarine data base and assessment capability. The NEI was initiated in June 1983 as part of NOAA's program of strategic assessments of the Nation's coastal and oceanic resources.

The NEI Data Atlas identifies 127 of the most important estuaries and subestuaries of the contiguous USA; presents information through maps and tables on physical and hydrologic characteristics of each estuary; and specifies a commonly derived spatial unit for all estuaries, the estuarine drainage area (EDA), for which data are compiled. These estuaries represent over 90 percent of the estuarine water surface area of the coastal United States. Subsequent volumes of the NEI present area estimates for 31 categories of land use, 1970 and 1980 population estimates by estuary, public recreation facilities in coastal areas, and coastal wetlands in the New England and Gulf of Mexico regions. These publications and others, produced by the Strategic Assessment Branch, are listed inside the back cover of this report.

The Shellfish Program

Developing information on the health of shellfishing waters is an important part of the NEI. Work on classified shellfish growing waters began with the 1985 National Shellfish Register of Classified Estuarine Waters (FDA and NOAA, 1985), a compilation of classification of shellfish growing waters by state. Data were later reorganized by estuary, for all NEI estuaries (Broutman and Leonard, 1986). Additional information on the administration of state shellfish programs, status of growing waters, trends in classification, and pollution sources were added to improve the utility of the data for assessing estuarine water quality. An assessment of shellfish waters in the Gulf of Mexico was completed in January 1988 (Broutman and Leonard, 1988), followed by an assessment of East Coast waters in March 1989 (Leonard, Broutman and Harkness, 1989).

Preparing for the 1990 Register

The Register is a compilation of the classified shellfish growing waters of 22 states produced by Federal agencies since 1966. The 1990 version will be expanded to include information collected for the Quality of Shellfish Growing waters projects: identification of classifications as of January 1, 1990; changes from the 1985 classifications and reasons for the changes, particularly those related to water quality; and the source of pollution affecting the limitation of harvest. The 1990 Register will be expanded to include Hawaii and Alaska. For the first time, classified areas, as delineated on NOS charts, will be digitized using NOAA's Geographic Information System (GEOCOAST). This system will store spatial data, calculate areas, print data onto nautical charts and calculate changes in classification between 1985 and 1990. The 1990 National Shellfish Register of Classified Estuarine Waters will be published in early 1991.

The Quality of Shellfish Growing Waters on the West Coast of the United States

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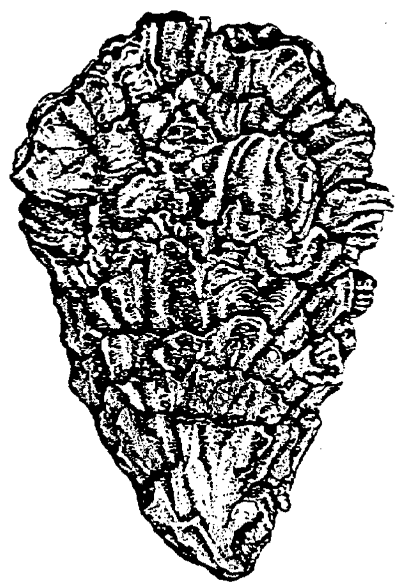

Crassostrea gigas

June 1990

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Findings

Estuarine waters are classified for the commercial harvest of oysters, clams and mussels based on the presence of actual or potential pollution sources and fecal coliform bacteria levels in surface waters. To protect the public health of shellfish consumers, harvest limitations are placed on waters that may be contaminated with bacterial or viral pathogens. State shellfish control agencies conduct sanitary surveys to identify these potential sources, sample ambient water quality, and conduct hydrologic studies. All west coast states also conduct monitoring to protect the consumer from paralytic shellfish poisoning (PSP.)

Molluscan Shellfish Landings

- In 1985, Willapa Bay and Puget Sound led oyster production at 2.5 million lbs. each. These major producers, along with Samish Bay at 298,000 lbs. and Grays Harbor at 662,000 lbs., gave Washington the lead in west coast oyster production at almost 6 million lbs. California was second with landings of 1.2 million lbs., mostly from Drakes and Humboldt Bays. Oregon produced 327,000 lbs., 82 percent of which were harvested from Tillamook Bay.

- In 1985, the most productive estuaries in clam landings were: Puget Sound, at almost 8 million lbs.; Willapa Bay, 136,000 lbs.; Nehalem Bay, 40,000 lbs.; Tillamook Bay, 34,000lbs.; and Coos Bay, 23,000 lbs.

Classified Shellfish Growing Waters

- On the West Coast of the United States, nearly 2.6 million acres of estuarine waters are considered shellfish growing waters under the National Shellfish Register inventory conducted in 1985. Over 75 percent of these waters are in Washington, 21 percent in California, and only 3 percent in Oregon.

- NOAA has aggregated west coast shellfish growing waters into 24 estuaries and 2 subestuaries based upon the National Estuarine Inventory (NEI). Over 2 million acres (81 percent) are considered nonproductive for shellfish and 163,000 acres (6 percent) unclassified, leaving only 326,000 acres, or 13 percent, both productive and classified.

- Of the NEI classified and productive estuarine waters, 31 percent are approved, 48 percent are prohibited, 20 percent conditionally approved, and less than one percent restricted.

- Washington has the highest percentage of approved waters (48 percent), followed by Oregon (33 percent), and California (2 percent).

- California has the highest percentage of prohibited waters (85 percent), followed by Oregon (33 percent), and Washington (27 percent).

- Oregon has the most conditionally-approved waters at 33 percent, followed by Washington (25 percent), and California (< one percent).

Trends in Classifications, 1971-1985

Trends in classifications were examined to determine if improving or declining water quality conditions were reflected in reclassification data.

- *California* reclassified 2 thousand acres, 93 percent of which were downgrades and 7 percent upgrades. All downgrades were due to increased monitoring efforts, while the upgrades were improvements in water quality.

- *Oregon* reclassified 19 thousand acres, 33 percent of which were downgrades as a result of increased monitoring, and 67 percent were upgrades, of which 25 percent were attributed to improvements in water quality.

- *Washington* showed a decline in water quality in over 62,000 acres. Almost all of the 20,000 acres upgraded in classification were surveyed in response to applications for shellfish leases. Until areas are surveyed, states are required by the NSSP guidelines to classify them prohibited.

Pollution Effects

- Industry is the major source of pollution in west coast estuaries, affecting 43 percent of estuarine waters and 22 percent of upstream waters. Industry also affects the largest estuaries: San Francisco Bay, Coos Bay, Puget Sound, and Skagit Bay.

- Sewage treatment plants, a major factor in the Northeast (80 percent), affect only 25 percent of West Coast estuarine waters and 50 percent of upstream waters.

- Nonpoint sources affect west coast estuaries, particularly urban runoff (33 percent), agricultural runoff (15 percent), boating activity (11 percent), and wildlife (11 percent.)

Introduction

The Quality of Shellfish Growing Waters on the West Coast of the United States is the third in a series of water quality reports produced by the Strategic Assessment Branch of NOAA to address the health of our Nation's shellfish waters. These reports serve as a resource for federal and state agencies, researchers, the shellfish industry, and private interests in the evaluation of their policies and programs.

Approximately 326,000 acres of estuarine waters on the West Coast of the United States are classified for the commercial harvest of oysters, clams, and mussels, based on public health concerns. These molluscan shellfish are filter feeders, capable of pumping large volumes of water through their systems and accumulating particles or pollutants present in water. Bacterial or viral pathogens may accumulate in shellfish tissue and digestive systems and may be passed to humans who consume partially cooked or raw shellfish. To protect public health, harvest for human consumption is not allowed in waters that are near potential pollution sources or contain high levels of coliform bacteria. While all coliform bacteria are not harmful, they are measured in water to indicate possible presence of pathogenic bacteria and viruses of sewage origin.

This report presents recently compiled information on the quality of shellfish growing waters in west coast estuaries. Section I provides background information on the National Shellfish Sanitation Program, pathogen-related illnesses, and marine biotoxins. Regional descriptions focus on three large and potentially productive estuaries: San Francisco Bay, Puget Sound, and Willapa Bay. Historic landings of clams and oysters are traced by estuary and the practice of shellfish culture is discussed. State shellfish programs are compared in terms of budget and sampling stations.

Section II examines the status of classified shellfish growing waters. It reveals that of the productive estuarine waters, 31 percent are approved, 48 percent are prohibited and 20 percent are conditionally approved. Changes in classification are noted and trends established where possible. In most cases, changes are related to administrative actions such as increased monitoring, rather than changes in water quality.

Section III identifies the sources of pollution affecting classified waters in California, Oregon and Washington. Overall, pollutants discharged from industries have been identified as the most significant factor in restricting shellfish harvests in developed estuaries, while nonpoint runoff, agricultural runoff, and wildlife are the causative factors in less developed estuaries.

In the Discussion, three case studies show the correlation between the degradation of water quality, as exhibited by downgrades in classification, and a decline in shellfish landings. A description of successful attempts to protect and restore the quality of shellfish growing waters by public agencies and the shellfish industry is discussed. The report ends with a review of planned and ongoing research to resolve the public health debate.

"Threats to the continued viability of molluscan shellfish resources are a matter of mounting concern among the public, various Federal, state and local agencies, and the shellfish industry." (David R. Zoellner, NMFS, 1977.)

"The oyster industry in the lower Chesapeake Bay, like many areas of the country , is dead." (Dr. William Hargis before the Interstate Seafood Seminar, 1989.)

Ostrea lurida

Public Health

By the early twentieth century, illnesses associated with the consumption of raw oysters, clams, and mussels were a major concern to public health officials. In 1924, following an outbreak of typhoid fever traced to oysters contaminated by sewage, public health authorities requested action by the Surgeon General of the U.S. Public Health Service (PHS). A conference of public health officials, meeting in February 1925, formulated a program of public health controls including the issuance of "certificates" (permits to operate) to shellfish shippers. This program, the National Shellfish Sanitation Program (NSSP), was developed and is still administered as a cooperative effort between states, industry, and the Federal government through the Interstate Shellfish Sanitation Conference. Under the NSSP, the Food and Drug Administration (FDA) of the PHS appraises each state's shellfish program to determine if their procedures are consistent with the current Manual of Operations (Interstate Shellfish Sanitation Conference, 1989).

The NSSP is based on the assumption that a relationship exists between sewage pollution of shellfish growing areas and human disease. Pathogens are transmitted through a fecal-oral route and may enter the waters through direct discharges of untreated or poorly treated human wastes or through nonpoint runoff from streets, lawns, or disturbed soils. Bivalve molluscs, such as oysters, clams and mussels are filter feeders, straining food and particulate matter that is carried to their location by currents. This water transport brings with it plankton, decomposed particulate matter, and other microorganisms. Because they filter large volumes of water relative to their size, molluscan shellfish may concentrate pollutants and pathogens.

Pathogen-Related Illness. Currently, the clinically significant enteric diseases associated with consumption of shellfish from sewage-contaminated waters are hepatitis A, Norwalk virus, and nonspecific gastroenteritis. Nationwide, reported incidence of these viral diseases have increased in recent years, while bacterial illnesses have declined (Richards, 1986). Since 1954, there have been no reported outbreaks of typhoid fever, a bacterial illness and the predominant shellfish-borne disease of the early twentieth century. A recent report by the U.S. Government Accounting Office (1988) concluded that illnesses associated with the consumption of shellfish or finfish accounted for only five percent of all food-borne illnesses. Even so, shellfish, mostly of East Coast origin, have been implicated in more than 900 cases of hepatitis and over 2,000 cases of gastroenteritis since 1961 (Richards, 1986).

Marine Biotoxins. In addition to sewage-related diseases, West Coast waters are affected by planktonic blooms that produce marine biotoxins. The neurotoxic substance produced, saxitoxin, is accumulated in the shellfish and passed on to warm blooded animals, including humans, causing paralytic shellfish poisoning (PSP). PSP was first documented by Captain George Vancouver during exploration of the British Columbia coast in 1793. The dinoflagellate associated with PSP incidents occurring from California to Alaska is *Gonyaulaux cantenella.* The toxin affects the nervous system, ranging from a slight numbness in the area of the mouth to muscular paralysis and possible death within 3 to 12 hours after consuming the shellfish.

The impact of PSP on the Pacific states' oyster industry has been dramatic. For example, in 1980 the oyster industry in California was affected by a PSP outbreak centered in Tomales Bay and Drakes Estero, with 61 cases attributed to commercially-harvested oysters. The most severe impact was the disruption of the market. The cost of confiscated destroyed product and loss of harvest time was added to market losses to give a total estimated loss of $630,456 to west coast growers during one toxic bloom. (Conte 1984).

All West Coast states have developed management plans to control the monitoring and closure of growing waters during toxic blooms. These management plans are separate from those developed to control harvest of sewage-contaminated shellfish. Under the NSSP, state shellfish control agencies regularly collect and assay samples of shellfish from growing areas where the "blooms", sometimes referred to as "red tides", are likely to occur. These toxicity management programs focus on the ability to detect toxic blooms in a body of water. All west coast states now deploy mussels at critical sites (mussel monitoring stations), which are sampled on a schedule based upon historic blooms. If the paralytic shellfish poison content reaches 80 micrograms per 100 grams of the edible portions of raw shellfish meat, the area is closed to harvest and the public advised against harvest and consumption of shellfish from those areas.

PSP management plans include the testing and recall of commercial product affected by *Gonyalaux cantanella.* In 1988, the Washington Department of Health and Human Services was faced with a major recall of product from eight states due to high toxin levels extending from south of the Tacoma Narrows Bridge to Dopplemeyer and Hartstene Points, the first time that a bloom had occurred in south Puget Sound. The ban affected sport and commercial fishermen and included all clams, mussels, oysters, and scallops. (Sunday Oregonian, October 9, 1988).

The majority reported PSP cases have been from recreational harvest of clams and mussels. In response, California, with more than 509 cases and 32 deaths through 1980, imposes an annual quarantine on sports harvest from May to October 31. Although there is no annual quarantine, Oregon samples at 17 sites from April through December. Washington began testing for saxitoxin in the 1930's and, since 1942, has imposed a quarantine on the sports harvesting of clams and mussels on all marine beaches.

British Columbia (BC) has had a long history of *Gonyalaux cantanella;* 113 illnesses from 1793 to 1987 (10 from commercial harvest of clams) and 6 deaths. The BC Department of Fisheries and Oceans runs an average of 1600 samples per year. The toxin levels vary greatly in intensity and geographic area.

Alaska has experienced the most PSP-related deaths from the recreational harvest of clams, 160 cases with 103 deaths through 1980. As a result, the state initiated a year-round sports-harvest quarantine. This management program, initiated in 1974, involves the biweekly bioassay of razor clam samples at 25 stations. Commercial shellfish are not affected by annual quarantines. However, each batch harvested must be tested to ensure that levels are below 80 micrograms. This causes major delays in the shipment and marketing of commercially-harvested shellfish. The expansion of the Alaska shellfish industry is restricted by the widespread incidence of PSP and the difficulty of monitoring remote areas.

The National Shellfish Sanitation Program

The NSSP is conducted by the Interstate Shellfish Sanitation Conference (ISSC) to ensure the safety of shellfish for human consumption by preventing harvest from waters that may contain pathogenic organisms or other contaminants. Under NSSP guidelines, waters are classified for harvest based on the presence of actual or potential pollution sources and levels of coliform bacteria levels in surface waters. Waters are classified by states into one of four categories: approved; conditionally-approved; restricted; or prohibited.

Table 1. Definition of classifications.

Classification	Description
Approved	Waters may be harvested for the direct marketing of shellfish at all times.
Conditionally Approved	Waters do not meet the criteria for approved waters at all times, but may be harvested when criteria are met.
Restricted	Shellfish may be harvested from restricted waters if subjected to a suitable purification process.
Prohibited	Harvest for human consumption cannot occur at any time.

For this report, the term "harvest-limited" refers to conditionally approved, restricted or prohibited waters. A closure area is an area in which some restriction on harvest has been placed, e.g. harvest limited area.

Waters are classified by each state based upon sanitary surveys that: (1) identify actual or potential pollution sources that may affect shellfish growing waters -- a "shoreline survey"; (2) evaluate hydrologic and meteorological conditions affecting pollutant transport; and (3) sample waters for bacteriological quality.

The NSSP standard for approved waters is either a median or geometric mean total coliform bacteria con-

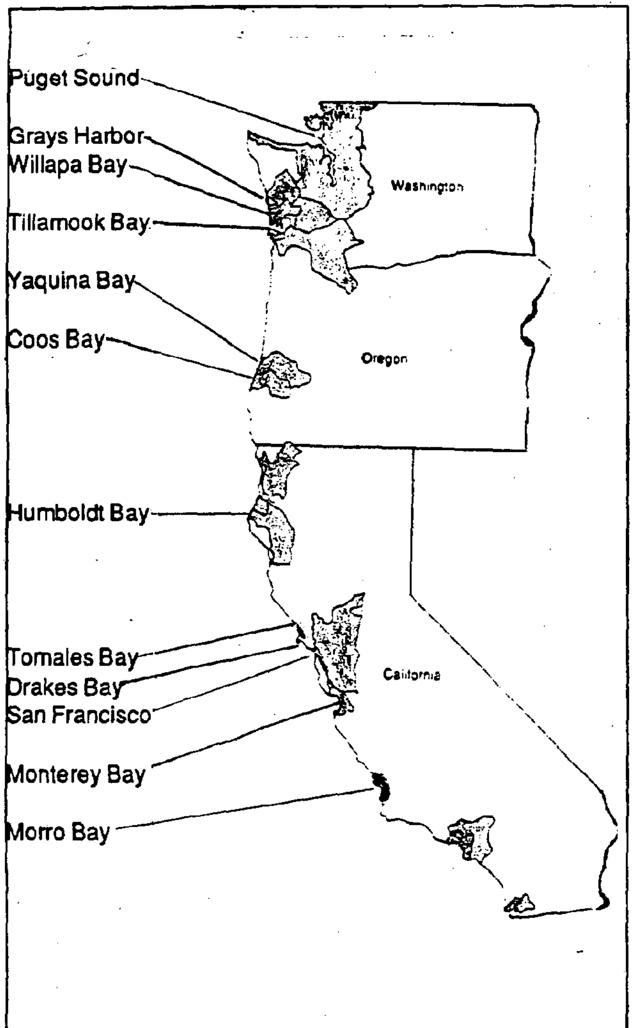


Figure 1. Productive West Coast estuaries.

concentration of less than 70 MPN (most probable number) per 100 ml, with no more than 10 percent of the samples exceeding 230 MPN per 100 ml, or a fecal coliform standard of 14 MPN per 100ml, with no more than 10 percent of the sample exceeding 43 MPN per 100ml (Interstate Shellfish Sanitation Conference, 1989).

These coliform standards are used routinely to ascertain the possible presence of enteric pathogens. However, evidence suggests that these standards may not be reliable as indicators of viral pathogens because enteric viruses are more resistant than coliforms to temperature and chlorination, and may accumulate and depurate at different rates. Although state health departments concur that guidelines restricting the levels of enteric virus contamination in shellfish would reduce the incidence of shellfish-borne disease, the research on more effective indicators has not yet been conducted.

Regional Characteristics

In this report, the West Coast comprises 26 estuaries from San Diego Bay in southern California to Skagit Bay in northern Washington. San Francisco Bay, Puget Sound, and Willapa Bay are highlighted in this section since they are the largest and/or most productive West Coast estuaries. In addition, a brief discussion is presented on shellfish activities in Hawaii and Alaska.

Although there are extremely productive shellfish growing areas in some West Coast estuaries, the coast overall has fewer estuaries than either the East Coast or the Gulf of Mexico. The West Coast is characterized by uniformly uplifted, resistant rock except for parts of the Washington coast that have become coastal flats and islands due to erosion of sedimentary rock. Pacific shoreline mountain formations have restricted the area of low-lying coastal plain and rivers that flow toward the sea.

The large estuaries of San Francisco Bay and Puget Sound were formed when sections of the continent containing former river valleys sank below sea level because of active mountain building. In the case of Puget Sound, additional deepening and elongation occurred due to glacial activity, resulting in a narrow, deep fjord with several internal sills. Both estuaries tend to be dominated by tides rather than freshwater inflows. The mean tidal range varies from almost 11 feet in Washington to 3.7 feet in southern California. The influence of tides upon the estuarine circulation varies. For example, some large estuaries, such as Puget Sound and San Francisco Bay, have tide-dominated circulation, while the circulation patterns in the smaller estuaries are a function of river discharge. These smaller estuaries, such as Eel River, Columbia River, and Humboldt Bay, are heavily influenced by river discharge. The first two are not suitable for shellfish production. Humboldt Bay has 12,000 acres of prohibited waters and only 5,000 conditionally-approved productive acres. Riverine discharges bring nutrients into shellfish beds, but also carry fecal coliforms discharged from upstream point sources and nonpoint runoff.

Sediment loads into estuaries vary within the region.

Loads tend to be high around the San Diego Bay area, moderate throughout central California, and generally low from northern California through Washington, where extensive forest lands reduce sediment runoff. In areas of clear-cutting, the sediment loading is high until forest is re-established. Long-term precipitation is highly variable within the region, ranging from 128 inches in coastal northern Washington to about 8 inches in southern California. Runoff and freshwater inflow vary by season and location. Southern California experiences a dry season from May through October, when the flow of some coastal streams disappears. Further north, freshwater inflow becomes more dependable, with the highest occurring from December through April. The runoff during the rainy season closes some of the most productive areas in the Northwest. For example, the average freshwater flow to Tillamook Bay in December is almost 9,000 cubic feet per second (cfs).

San Francisco Bay is the second largest estuary in the United States, extending over 7,000 square miles. The watershed is a broad, semi-enclosed basin, supporting extensive tidal marshes, mudflats and a population of over five million. The freshwater inflow from the Sacramento and San Joaquin Rivers, the large ocean connection, and a myriad of discharges provide a unique physical environment. The system supports a large assortment of organisms, tolerant of fluctuating salinities, temperature, and turbidity. The estuary is often referred to as the River-Delta-Estuary-Sea system. The two rivers drain over 40 percent of the State. The annual inflow fluctuates in response to frequent and heavy winter storms followed by dry summers.

Shellfish were harvested on a large scale during the post-Gold Rush years until earlier in this century when the shellfish beds were fouled by human and industrial wastes. The eastern oyster, *Crassostrea virginica*, was introduced in 1870's and became the most important fishery in California by the 1890's. The oysters began to deteriorate in the early 1900's as a result of untreated human and industrial wastes discharged into the bay (Nichols, 1988). San Francisco Bay is a classic example of how the deterioration of a productive bay is heralded by the decline of the oyster industry (Fred Conte, personal communication).

The annual harvest of the eastern soft-shell clam, *Mya arenaria*, peaked in the late 1800s at 1-3 million lbs., declining to 300,00 lbs. between 1913 and 1935, and then dropping off rapidly. The decline is attributed to increasing labor costs of harvesting clams and the pollution or filling of clam beds. (Nichols, 1988). In 1932, the California State Board of Health established a permanent quarantine on clams in San Francisco Bay "by reason of sewage pollution ... and consequential danger of typhoid fever and gastroenteritis". The general quarantine was rescinded in 1953. The Japanese littleneck, *Tapes philippinarum*, was accidentally introduced in the 1930's and has thrived to become the focus of sport shellfish harvesting. Although there is a possibility of contamination from wastes, particularly from urban runoff, and despite no authorization, the sport harvesting of shellfish continues in San Francisco Bay.

Puget Sound. South Puget Sound extends from Tacoma Narrows south to the Nisqually Delta and is characterized by large tidal fluctuations which, in combination with shallow inlets, result in extensive tidelands and mudflats. Although these shorelands are not well suited for commercial development, they provide superior habitats for clams and oysters. Hood Canal is also an excellent area for the production of clams and oysters because waters are warmer than those of the rest of the Sound. The main channel of northern Puget Sound extends northwest to the Strait of Juan de Fuca. To the east of Whidbey Island lie several large bays where the water is shallow and productive for shellfish and other marine life. Outside of Puget Sound proper lie the San Juan Islands which have a few fairly shallow bays used for the production of oysters and mussels.

River systems in the northern half of the Puget lowland contribute 70 percent of the fresh water discharge and more than 69 percent of the sediment. Annual runoff varies from very low in the early fall, following the dry summer, to very high in the early winter months when there are frequent storms. Above average precipitation continues in the early spring and augments high river flows from melting mountrain snow. The annual range of precipitation within the Puget Sound basin is 16 to 96 inches, producing an average annual inflow of 45,000 cubic feet per second (cfs). These discharges provide the nutrients needed for shellfish production and carry contaminants from the land to the waters of the Sound. (Puget Sound Water Quality Authority, 1987.) During the rainy season, soils around the Sound can become saturated with water and their capacity to process wastes from septic systems and manure applications is reduced.

The Shellfish Protection Strategy, produced by Washington Department of Ecology in 1983, concludes that the most significant current problem for the Puget Sound shellfish industry is nonpoint contamination in rural areas. Until recent years, the major impact was development and the resultant discharges from sewage treatment plants. Historically, the best shellfish culture grounds have coincided with the least developed areas of the sound. For example, the rich tideflats of Southern Puget Sound, as well as Willapa Bay, have been the heart of the oyster business since the 1880's. The leading areas of clam production have been South Puget Sound and the Port Townsend/Discovery Bay area. However, recent shellfish closures have occurred near Olympia and Tacoma, in suburban areas adjacent to Minter Bay, Burley Lagoon, Henderson, and Eld Inlets. The closures are attributed to: nonpoint pollution, originating from an increase in the use of onsite waste disposal, often in poor soils; development near shorelines and creeks; and an increasing population of household pets. Commercial agriculture is also a significant nonpoint concern affecting areas such as Port Susan and Samish Bay .

Willapa Bay, formerly Shoalwater Bay, is located in southwest Washington and is separated from the sea by an 18-mile long spit, the Long Beach Peninsula. It has been described as the most productive bay on the Pacific coast (Hedgpeth 1981). At present, approximately 15,000 acres of bay are used for oyster production out of a potential 42,500 acres. According to The Fisheries Statistical Report, by the Washington Department of Fisheries, Willapa Bay leads Puget Sound and Grays Harbor in the production of Pacific oysters. It produced over two thirds of state landings in 1953 and approximately half in 1985. Washington State is responsible for 70 to 80 percent of the West Coast oyster harvest. (Figure 5 .)

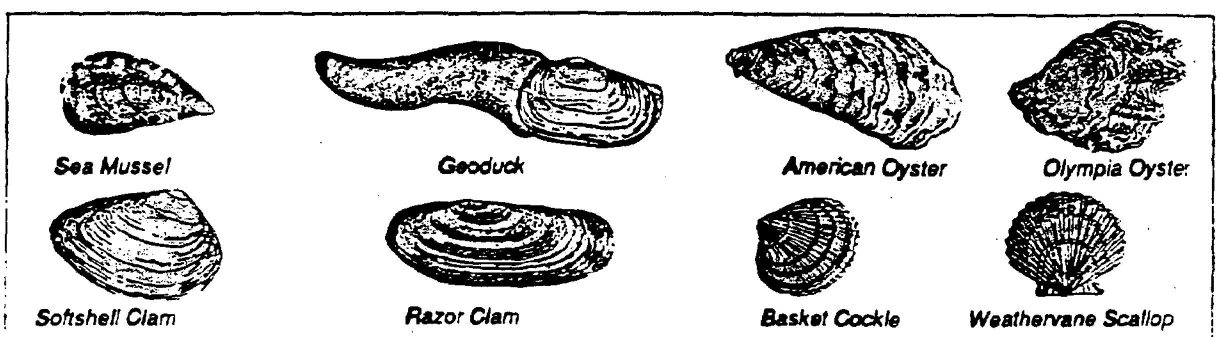
Most of Willapa Bay is extensive tidal flats. More than 50 percent of the total high tide surface area is exposed at low tide and much of the remainder is 1 to 6 feet below mean low tide. The bay is a complex estuary, fed by rivers which drain approximately 461,000 acres. Annual precipitation ranges from 65 to 100 inches, while mean annual runoff ranges from 31,000 cfs to 190,000 cfs. Willapa Bay has a mean tidal range of 6 to 8 feet. Approximately 45 percent of the bay water empties into the Pacific on each tidal cycle.

Oysters were Willapa Bay's first industry, beginning during the Gold Rush days with the extensive harvest of the native oyster, *Ostrea lurida*. The native oyster was soon overharvested. Current stocks in state oyster reserves are very small and there are no plans for commercial production. (Dennis Tufts, personal communication, August, 1989). The eastern oyster, *Crassostrea virginica*, was transplanted to Willapa Bay in 1894 but failed to spawn. In 1928, the Japanese or Pacific oyster, *Crassostrea gigas*, was introduced and has continued as the major species produced in Willapa Bay. Seed oysters were transported from Japan until local hatcheries were developed. These hatcheries have been extremely successful, producing enough seed for Willapa growers, and allowing them to sell the excess outside the state. Landings in 1986 were 429,000 *gallons of shucked product.

*Note: Landings of molluscan shellfish are reported differently from state to state. Most of this report compares landings in pounds as derived from bushels of shell products or gallons of shucked product.

The Japanese littleneck clam, *Tapes japonica,* grows naturally in Willapa Bay, and is harvested commercially by 3 farmers with annual landings of approximately

Figure 2. Representative harvested bivalves.



100,000 lbs.(Figure 4). There are some areas of the bay with excellent potential for expansion of production, Oysterville Flats, for example, but cultivation will require the investment by growers in gravel to provide suitable habitat (Dennis Tufts, personal communication. August 1989).

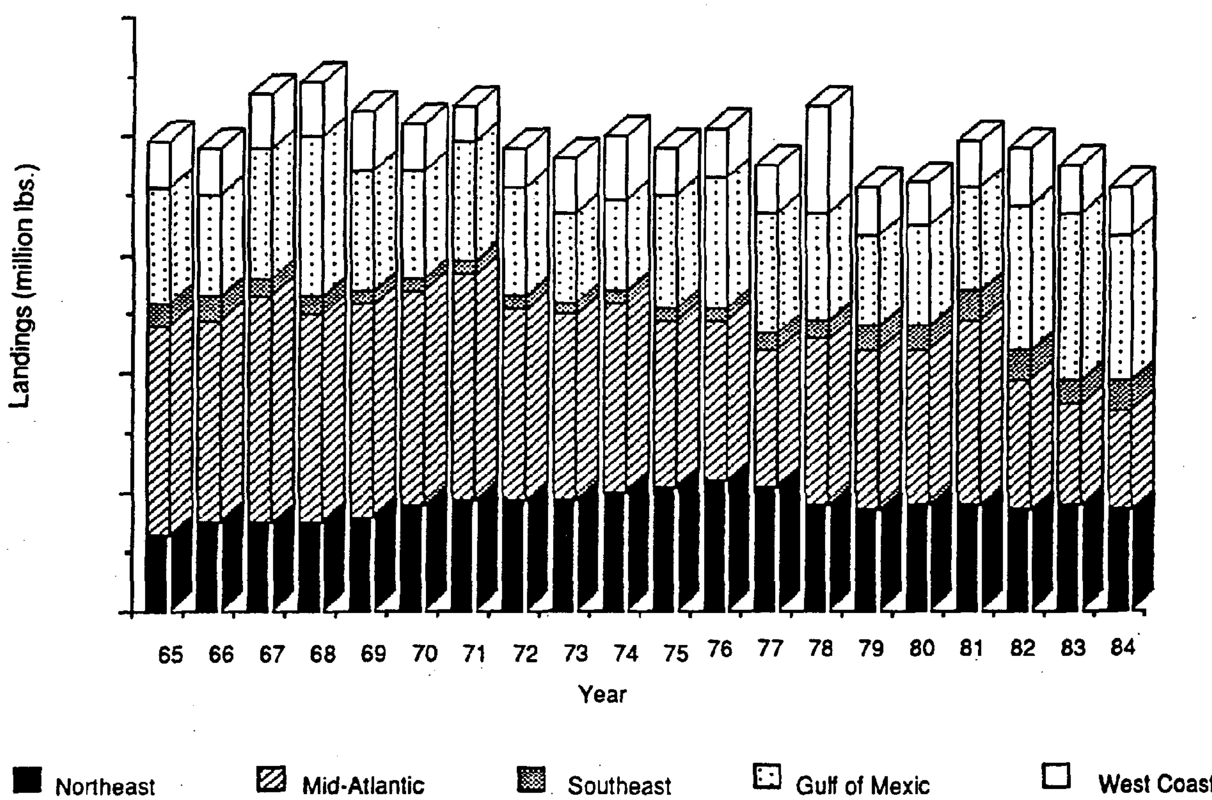
Molluscan Shellfish Aquaculture and Landings

During the Gold Rush years of the mid-nineteenth century, there was a high market demand and extensive harvesting of shellfish, particularly the oyster. In the 1850's, sailing schooners dredged Puget Sound and Yaquina Bay for oysters marketed in San Francisco. However, about 90 percent of the oysters delivered to San Francisco in the late 1800s were harvested from Shoalwater Bay, referred to now as Willapa (Barrett, 1963). California's oystermen began the culture of oysters around 1850 when juvenile oysters were transplanted from beds in Oregon to San Francisco Bay. In about 1869, the eastern seed oysters became the predominant specie, shipped by fast freight mainly from the New York and New Jersey estuaries and averaging about 100 carloads annually. These shipments ended in 1910 and the eastern oysters, remaining in San Francisco Bay, were transplanted to Humboldt Bay. During the period from 1888 to 1908, eastern oysters accounted for 85 percent of the oysters produced in California.

Beginning in 1890, the State of Washington encouraged private citizens to raise, or farm, shellfish by allowing the purchase of intertidal lands. The enabling legislation, referred to as the "Callow Act", restricted those purchases to tidelands supporting natural oyster beds. About 60 percent of the tidelands were purchased by private individuals before the legislature prohibited private sale of tidelands. Oregon and California also permitted purchase of intertidal lands, although never to the extent permitted in Washington. Currently, tidelands, subtidal bottom, water surface, and columns are leased for the culture of shellfish in California, Oregon, Washington, and Alaska.

Oysters. The first oyster to be farmed along the Pacific coast is the *Ostrea lurida*, referred to as the Olympia oyster. Most of the natural beds were exploited by the early 1900's. At the turn of the century, when many oyster harvesters switched to oyster farming, they started with the Olympia. The natural beds are usually located below low water level because the Olympia is easily

Figure 3 . US Landings of clams and oysters.



affected by temperature extremes. To raise this species, oystermen built parks, mostly in the intertidal zone in Totten Inlet (southern Puget Sound), where the oysters are always covered with water. The ground is levelled in terraces and surrounded by low dikes made of concrete or creosoted wood. Cultch (gravel and shell) is used to promote the settling of natural spat. The oysters are moved to sites where growth or fattening is encouraged. These culture methods are very expensive and the Olympia is very small, usually less than 2 inches in length. The oyster is shucked for cocktail use and is sold for $120-150 per gallon. In 1985, 2,000 lbs. were landed in Washington with an estimated value of $53,000. (WA Dept. Fisheries. 1986). Some Olympias also survive in Netarts and Yaquina bays in Oregon, contributing a few thousand gallons of shucked meats per year (Breese and Wick, 1974).

Near the turn of the century, the eastern oyster, *Crassostrea virginica*, was introduced into several growing areas in California, Oregon and Washington. The seed oysters had to be shipped from the East Coast as natural reproduction was poor in West Coast estuaries. Initially, the introduction of the eastern oyster created an important industry, particularly in San Francisco Bay, but high mortality rates and poor reproduction ended commercial production in 1939.

In 1905, Japanese oystermen from Samish Bay, Washington, imported mature Pacific oysters, *Crassostrea gigas*, from Japan and, by 1912, they were experiencing some initial success in natural spawning and growout. Oystermen also imported seed oysters from Japan beginning in 1919 They first produced Pacifics in Samish Bay, and by 1930 in Willapa Bay and Tillamook Bay, Oregon. In recent years hatcheries have been started in Washington, Oregon and California, producing both seed oysters and eyed larvae. The seed oysters are either attached (cultched) or not attached (cultchless) to mother shell. The cultchless is only used to grow single oysters for the half shell trade. The production by hatcheries of eyed larvae has benefitted the industry, because the larvae can be shipped inexpensively. The eyed larvae have a fairly high success rate for seed settlement on cultch in controlled temperatures and salinity-controlled tanks (Chew, 1983).

Pacific oyster culture expanded rapidly, reaching a peak in 1946 of 13 million lbs. in Washington alone, where production declined to 6 million lbs. in 1985. Washington produces about 80 percent of all West Coast oysters. Currently four types of Pacific oysters are commercially cultivated on the West Coast: Miyagi, commonly known as the Pacific oyster; Kumamoto; a hybrid, Miyagi-Kumamoto, referred to as Gigamoto; and a neutered Miyagi oyster. Methods of grow-out include on-bottom and off-bottom culture. Historically, growers spread the seed oysters on firm, first class, tidelands and allowed them to grow out there. Most first class tidelands are no longer available so growers can

Figure 4. West Coast clam landings/acre classified

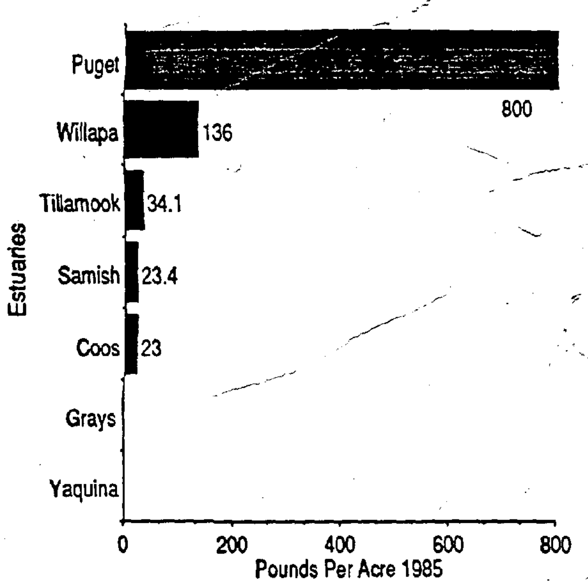
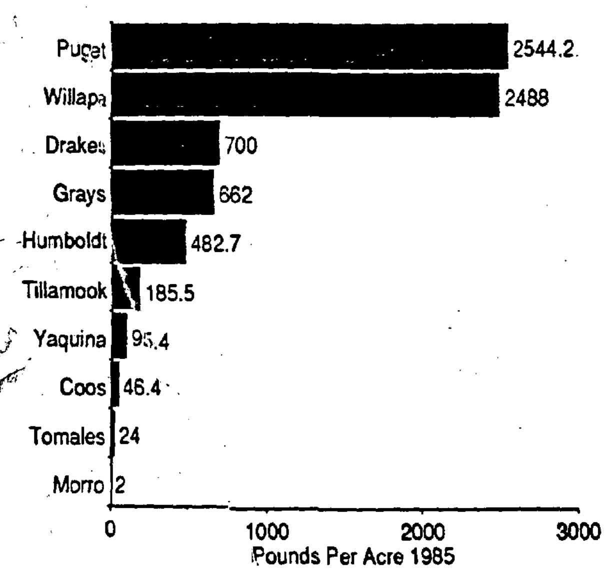


Figure 5. West Coast oyster landings/acre classified

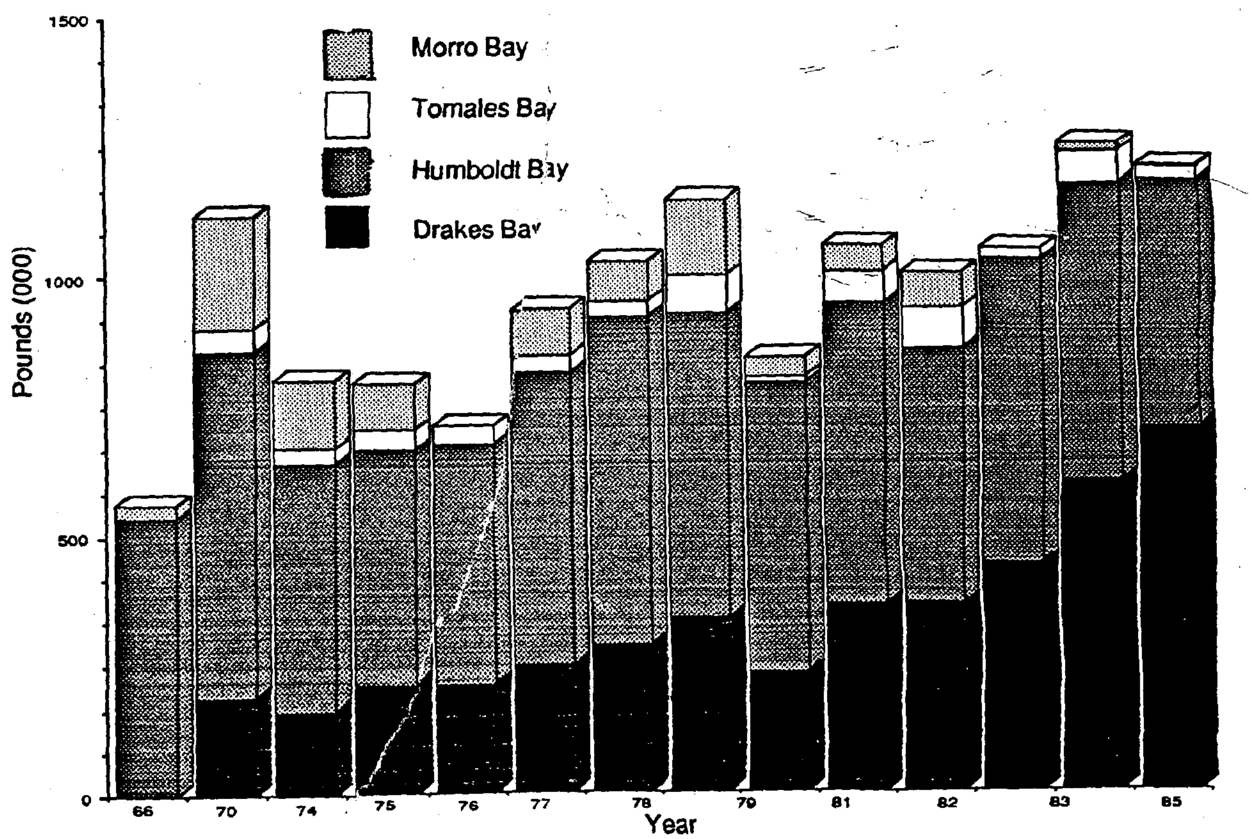


only lease second or third class tidelands with soft or muddy bottom. On the less desirable tidelands and intertidal plots, off-bottom methods are employed: longline, rack, raft, stake, rack and bag culture, and suspended culture. In longline culture, the mother shell, with spat attached, is strung on rope or wire suspended above the bottoms. These lines are then anchored on hard bottoms, hung on racks or suspended on stakes. Stake culture involves attaching mother shell to stakes driven into the bottom. Rack and bag culture is used to grow out single oysters for the half shell trade. Oysters are grown in mesh bags clipped to rebar racks. In floating culture, grow-out trays or cages are stacked on the floor of a sink float or suspended in the water columns. Japanese lantern nets, suspended from the dock or float with a rope bridle, are employed on San Juan Island. In recent years, oyster farming has become subjected to increased regulation, shoreline development permits, health certification, site lease agreements, and navigable water permits. The off-bottom and floating culture methods have received criticism as a threat to navigation and aesthetic values. Although it is is considered a water-dependent use, objections from shoreline developers and residents may restrict future development of aquaculture.

Clams. Many species of clams grow in West Coast estuaries, nine of which are harvested commercially. Although the Pacific coast clam fishery represents only one percent of the total U.S. catch, it is an important part of the heritage of coastal communities and a factor in the economy of rural communities (Schink, McGraw, Chew, 1983). The 1985 Washington landings were 6 million lbs. of hardshell clams, 71,000 lbs. of razor clams, and 3 million lbs. of geoducks. Intertidal areas in Oregon and California produce small quantities of clams for commercial use. In Oregon, horseclams are harvested in Coos and Yaquina bays, and native littlenecks and butter clams in Tillamook Bay. In California, there have been very small numbers of butter and jackknife (*Tagelus californianus*) clams landed.

Clam farming on the Pacific coast is either intertidal or subtidal. Native littleneck, butter, *Manila and softshell* clams are harvested by hand digging from intertidal beds. Native littleneck and butter clams are also harvested from subtidal beds by hydraulic escalator har-

Figure 6. California oyster landings.



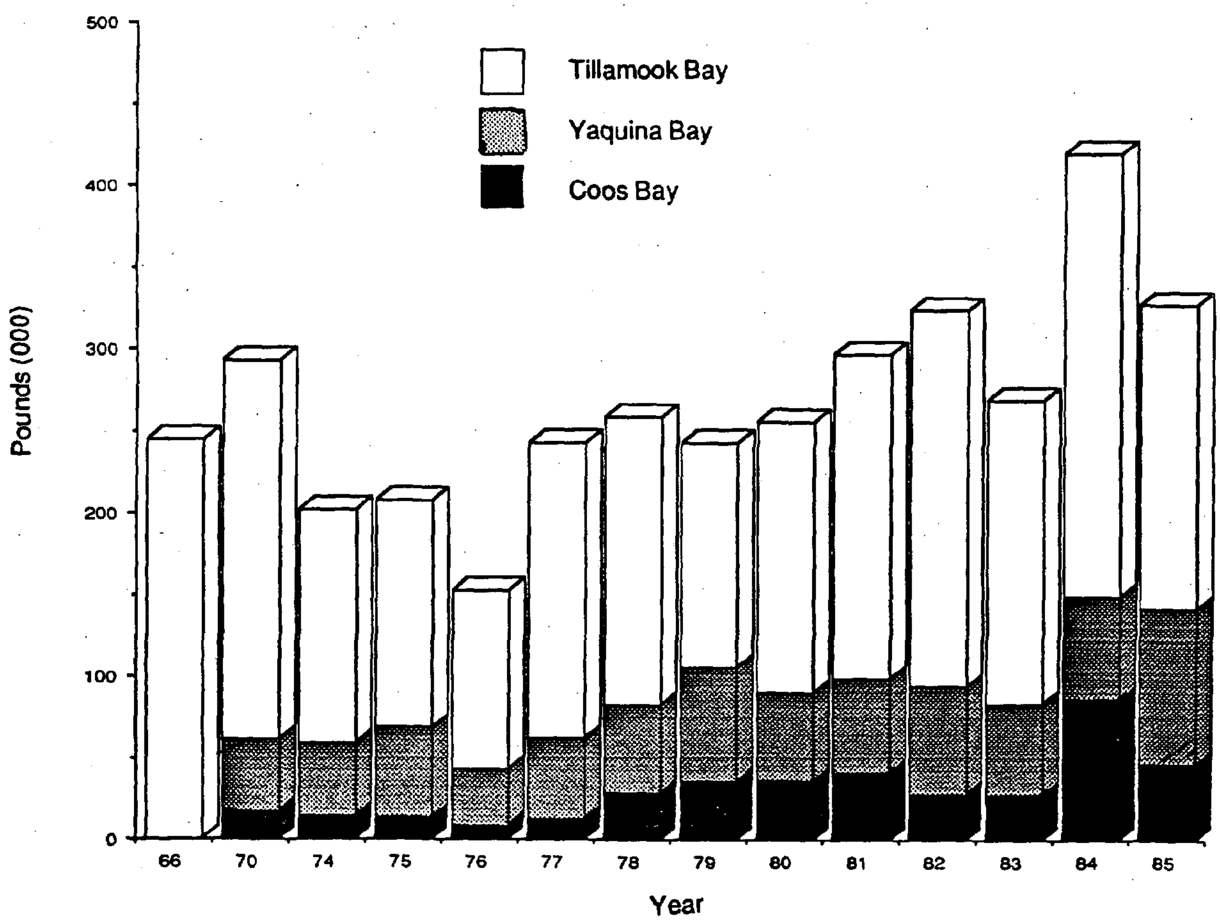
vestors. Geoducks and horse, or snow clams, are harvested from subtidal beds by scuba divers using suction devices.

Clam culture has developed less rapidly than oyster culture because of the large wild population, the difficulty of collecting clam seed from natural reproduction, the lack of commercial hatcheries, and extensive larval losses from predation. (Glude. 1989). The market exists for an expansion of clam culture on the West Coast. The clam species with the most potential for culture is the Manila. Recently, seed has been produced with ease in a number of hatcheries. Seed clams are planted under a protective plastic net cover, resulting in exclusion of predators, stabilization of beach substrate, and possible enhancement of natural settlement. Seed can also be produced successfully for Pacific geoduck and razor clams.

Mussels. Mussel culture began in the 13th century in Europe and has been successfully practiced in Spain, France, England and the Netherlands. The industry in the U.S. is just beginning to emerge in response to increased market demands. Landings of the blue mussel, *Mytilus edulis*, from five commercial growers in Washington, went from zero in 1971 to 297,000 lbs. in 1985. (WA Dept. Fisheries. 1986).

California mussel landings were approximately 104,000 lbs. in 1985. Oregon's landings, mostly the California mussel, *Mytilus californianus* , were 61,000 lbs. in 1980. The resurgence of the East Coast mussel industry, the research and application of improved culture methods and economic success of some growers in Washington and California, have stimulated the expansion of mussel aquaculture on the West Coast. One of the most successful operations occurs on oil platforms in the Santa Barbara Channel. The platforms attract mussels, but their accumulated weight is a hazard. The nuisance mussels are now harvested from the platforms and marketed, currently averaging twenty tons a month for ten months of the year. These cultivated mussels have been given a clean bill of health from California Health Services and the new

Figure 7 . Oregon oyster landings.



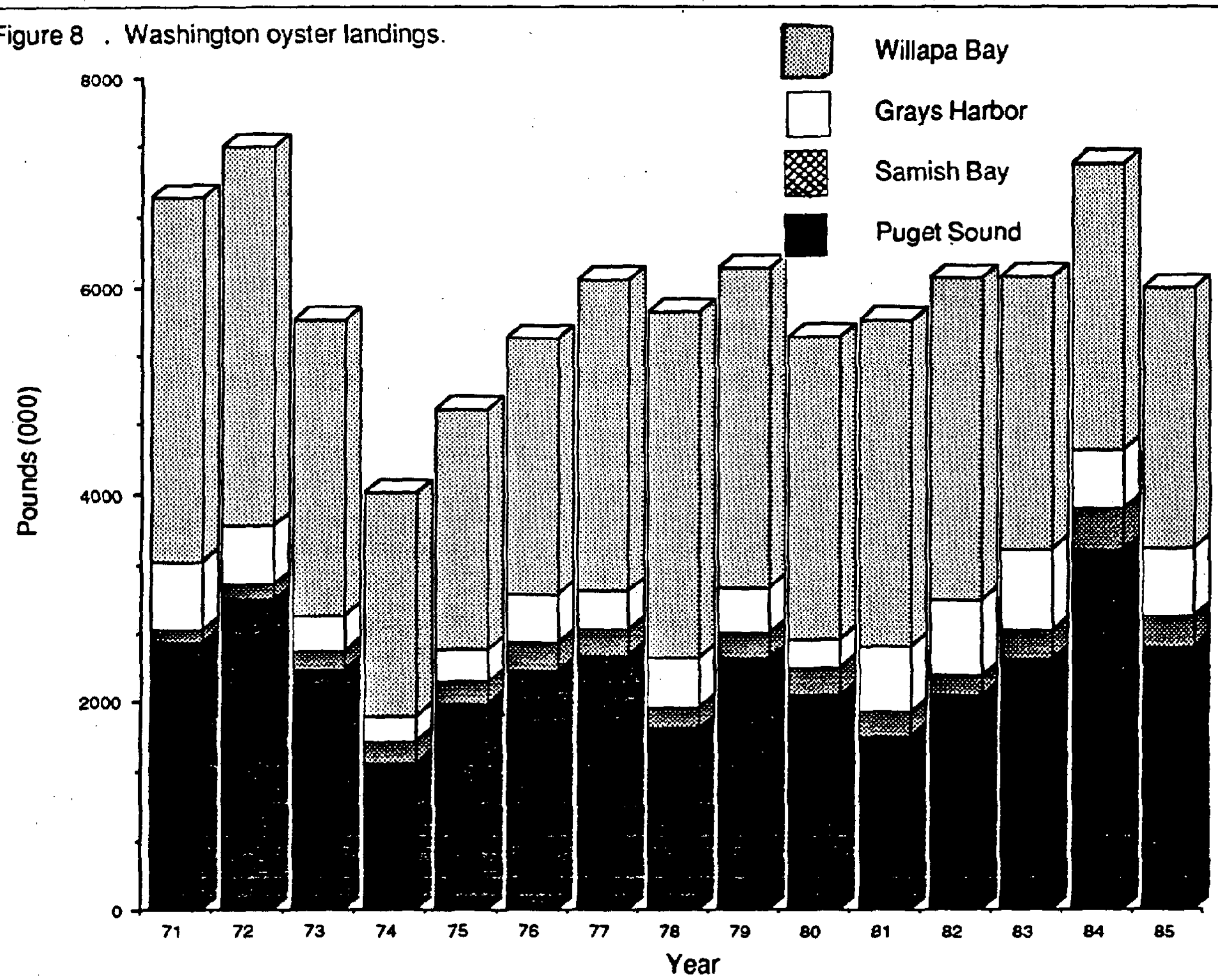
business has been expanded to include oysters, scallops and clams, cultivated on the platforms (Robert Meek, personal communication).

Scallops. There are four species of scallops found in Puget Sound; the weathervane or giant Pacific scallop (*Patinopecten caurinus*), the spiny and pink scallops (*Chlamys hastata hericia* and *C. rubida*) and the purple-hinged rock scallop, *Crassodoma giganteous* (*Hinnites)* Except for the rock scallop, which is attached to the bottom, these species are bottom dwelling but capable of free swimming. Harvest is by divers using hand tools. Washington harvest of scallops totalled 51,000 lbs. in 1985, with an increase to 307,000 in 1988. The scallop has not been a major concern of shellfish sanitarians because most harvest has been in deeper oceanic waters and only the adductor muscle has been consumed, usually cooked. Recently there has been an increase in the consumption of the whole scallop, served with roe attached in its shell, raising the issue of whether the scallop should be managed under the NSSP.

The potential for scallop culture has been investigated on the West Coast using the weathervane and rock scallop. Although the larvae of the Atlantic sea scallop have been reared in the laboratory, there is little interest in rearing this species due to abundant East Coast stocks and lower market prices. A species with excellent potential for culture on the West Coast is the Japanese scallop, *Patinopecten yessoensis*. (Mike Kaill, personal communication). The Japanese have been raising this species successfully, using onion bag or nets, suspended off bottom. The pelagic larvae attach to the strands of the bag or net and, after some initial growth, are then transplanted to suspended trays or cages for growout.

Mussels and scallops, like oysters and clams, can become highly toxic after ingesting large quantities of *Gonyalaux*. Recent outbreaks of "red tide" in Puget Sound have stopped the harvest of mussels and scallops for extended periods of time, and associated bad

Figure 8 . Washington oyster landings.



publicity has dampened the market. If some of the impediments to mussel and scallop culture can be removed there is considerable potential for the industry.

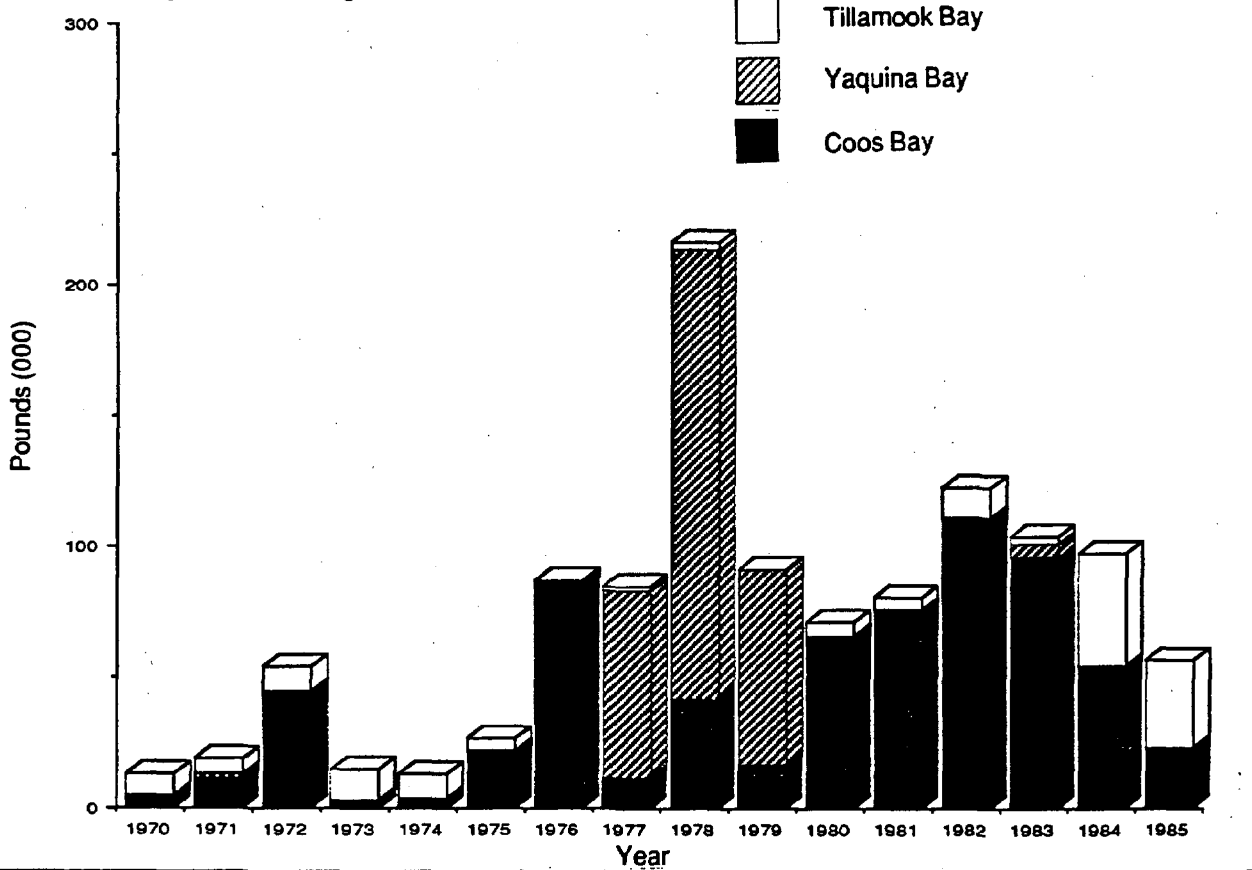
Administration of State Shellfish Programs

California. State regulatory agencies on the West Coast act in response to industry's applications to culture or grow molluscan shellfish. In California, a grower must apply to the California Department of Fish and Game for an aquaculture registration or a Tidal Invertebrate Permit. If shellfish are to be cultivated on state tidal or submerged lands, an aquaculture lease must be obtained from the Fish and Game Commission. If shellfish are to be cultured on tidelands granted to harbor or port districts, the leases must be obtained directly from the agency holding the grant. The prospective grower must also obtain a Growing-Area Certificate from the California Department of Health Services. The state will then conduct a sanitary survey and classify the shellfish growing waters.

Between the 1985 Register and this publication, the West Coast states have made substantial changes in their shellfish programs. California has added 4 additional staff members with expertise in sanitary engineering, biological and environmental sciences, and microbiology. Memoranda of Understanding have been developed with California Fish and Game and water resources control boards and new state shellfish regulations have been adopted. Sanitary surveys have been completed for Morro Bay, Aqua Hedionda, and Humboldt Bay and a new and expanded Paralytic Shellfish Poisoning monitoring program has been developed and implemented.

In Oregon, the commercial cultivation of oysters is under the jurisdiction of the State Department of Agriculture. However, the Oregon Fish and Wildlife Commission has jurisdiction over the native oysters. Oyster growers may apply for a plat and if the area is available and approved as suitable for oyster cultivation, the grower must then apply for a certificate of shellfish sanitation from the Health Division of the Department of Human Resources. As in California, the State then classifies the growing area based on a sanitary survey. These certificates must be issued for each area of

Figure 9. Oregon clam landings.



operation and renewed with requisite fees annually.

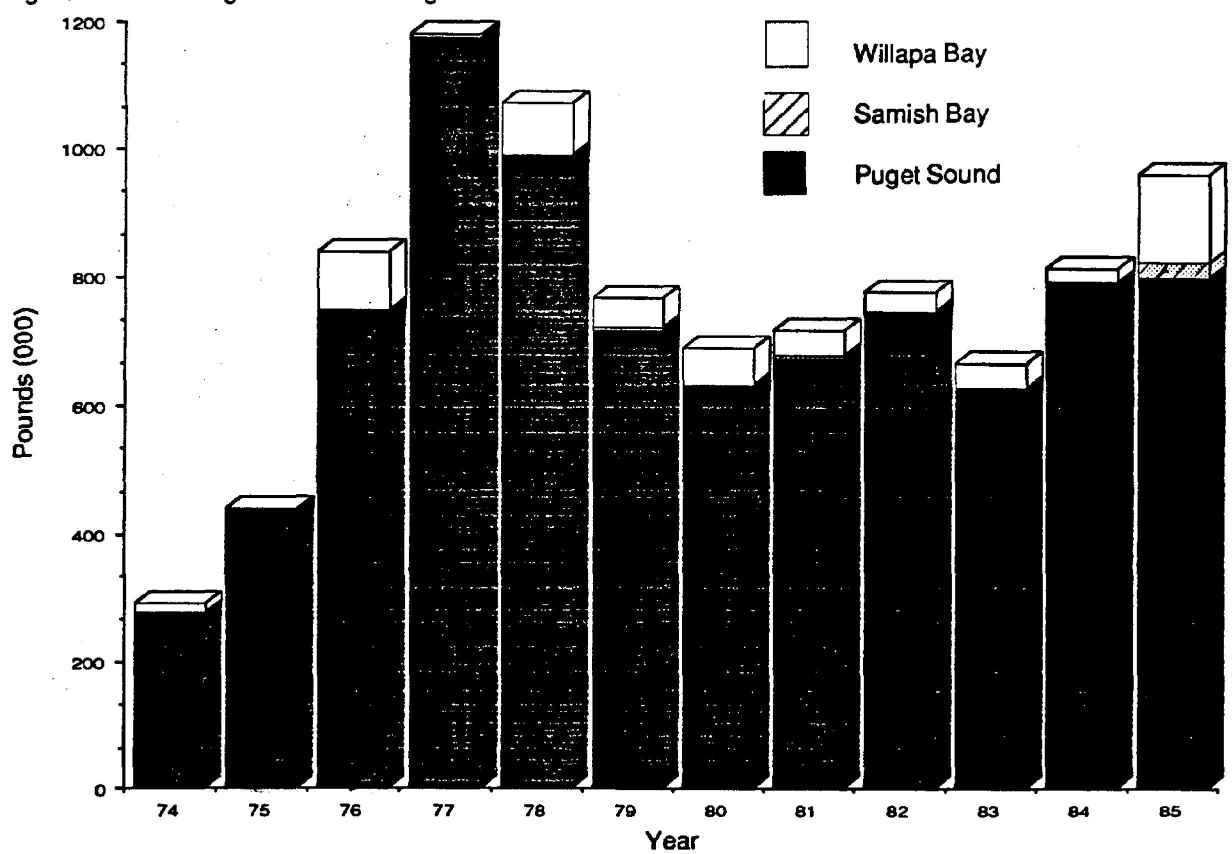
Since 1985, the Oregon Health Department has increased its staff and is contracting with six county health departments to augment sampling and shoreline survey work. Bacteriological and PSP sampling has been increased and shellfish management plans have been developed for Netarts, Tillamook, Yaquina and Coos bays, Joe Ney, and South Sloughs. Oregon has increased its monthly ambient water sampling to 8 bays with intensive wet weather sampling in conditionally managed areas, and accelerated oyster meat samples and plant inspections. Oregon Health works closely with the Department of Environmental Quality to increase sampling coverage and correct septic failures and other water quality problems.

In Washington, lands are held and managed as a public trust by the Division of Land Management of the Department of Natural Resources. Tidelands and shorelands are designated as first class or second class and are leased with preference to water-dependent uses, including aquaculture. Waste discharges into state waters are regulated by the Department of Ecology and the Department of Health. The latter classifies shellfish growing waters, monitors the shellfish beds and processing plants, and samples for PSP.

Washington has expanded their shellfish program within both the Health Department(DOH) and Department of Fisheries (DOF), with additional assistance from programs developed under the Puget Sound Water Quality Management Plan. The Washington Department of Ecology (DOE) has provided funding for twelve "early action" watersheds, six of which are addressed in Section III of this report on pollution (T. Determan, personal communication). DOE also operates a marine ambient monitoring system coordinated with the Puget Sound Ambient Monitoring Program. Citizen monitoring programs have been organized for Eld and Henderson Inlets and Hood Canal. Special projects on water quality impacts from marinas have been conducted by DOH, culminating in a marina management plan for Washington.

In recent years, the tribal governments in Washington have begun to exercise local governmental power in such activities as resource use enhancement, taxing, and their unique powers to undertake profit-making

Figure 10. Washington Clam Landings



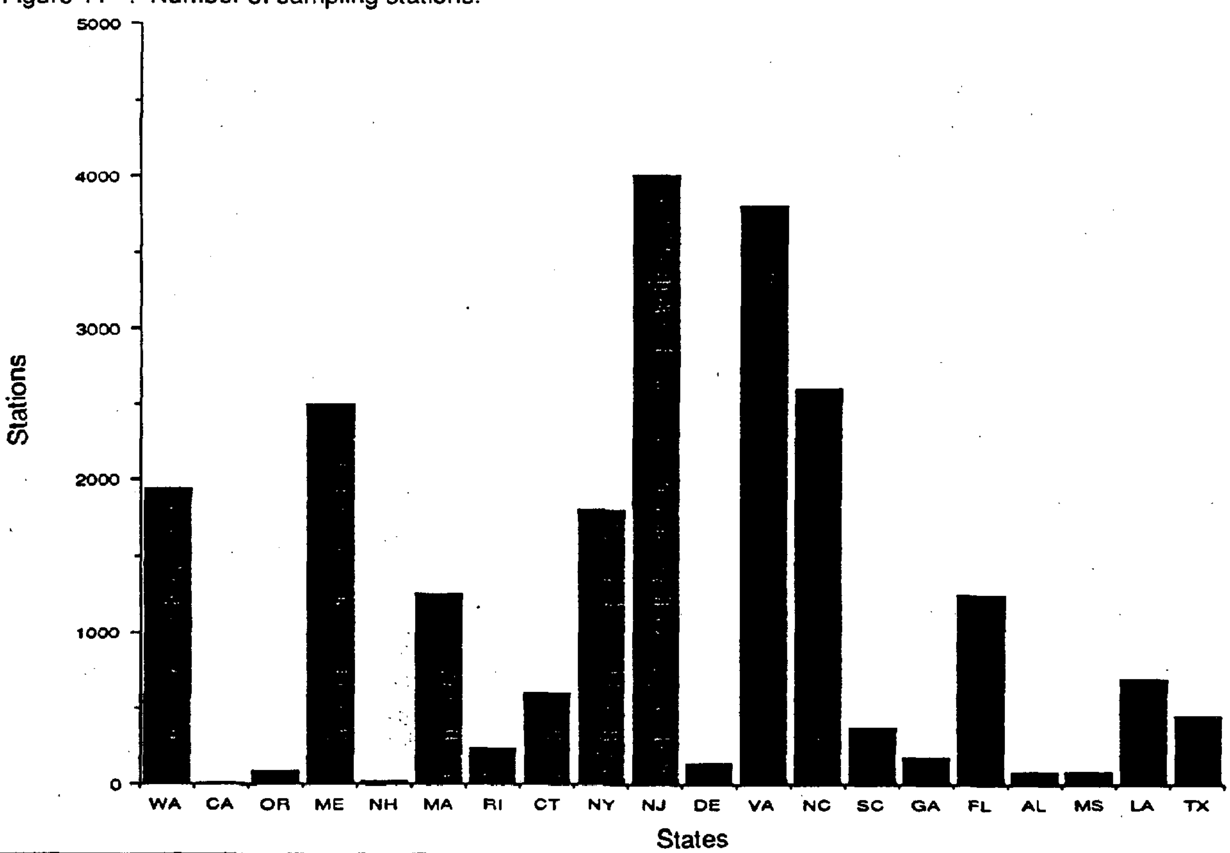
businesses. The question of ownership and control of the shellfish resource has not been resolved and may, like many other tribal issues, be decided in the courts. Meanwhile, Washington DOH and DOF are working closely with the Pacific Northwest Indians Commission to develop written agreements on health and certification issues related to the harvest of shellfish. DOH is looking for alternative certification processes to resolve problems such as the harvesting of shellfish from prohibited areas for subsistence or ceremonial purposes but which are then sold in markets.

Hawaii. Although Hawaii is considered a producing state, there were no harvesting areas classified as approved in 1985. A clam resource exists in Pearl Harbor, but the area is classified prohibited because of high fecal levels, toxics, organic compounds, and heavy metals. In Kaneohe Bay, clams were harvested until sewage and urban runoff closed the bay to all shellfish harvest. Construction of an ocean outfall for the disposal of regional sewage effluent has cleaned up the bay. However, by the 1970's the clam resource had declined, and current nutrient levels are too low to support commercial clam production. (David Zieman, personal communication, January 1989). Approval of a recent application for certification by the Hawaii Department of Health would allow production of hardshell clams, *Mercenaria mercenaria*, in the 19 acre Nomilu Fish Pond on the Island of Kauai.

Many new innovations in shellfish culture are taking place on Oahu and the Island of Hawaii. In 1978, the state aquaculture plan projected a $35-45 million industry within 10 years. Although it has not reached the projected goal, the industry grosses $5.4 million annually and markets more than 20 species, among them clams, oysters, abalone and sea urchins.

Located at Keahole Point, near Kona on the big island of Hawaii, Hawaii Ocean Science and Technology Park (HOST) offers long-term leases for aquaculture development. Nutrient-rich, deep ocean water is pumped ashore at 45 degrees F in a temperate climate with plenty of sunshine. These are excellent conditions in which to raise numerous species of ocean plants and animals. One of the success stories at Keahole Point is the Ocean Farms operation which is moving rapidly ahead in the production of kelp, salmon, abalone and sea urchins. Oysters are raised in the

Figure 11 . Number of sampling stations.



large ponds, with kelp and salmon; an example of polyculture.

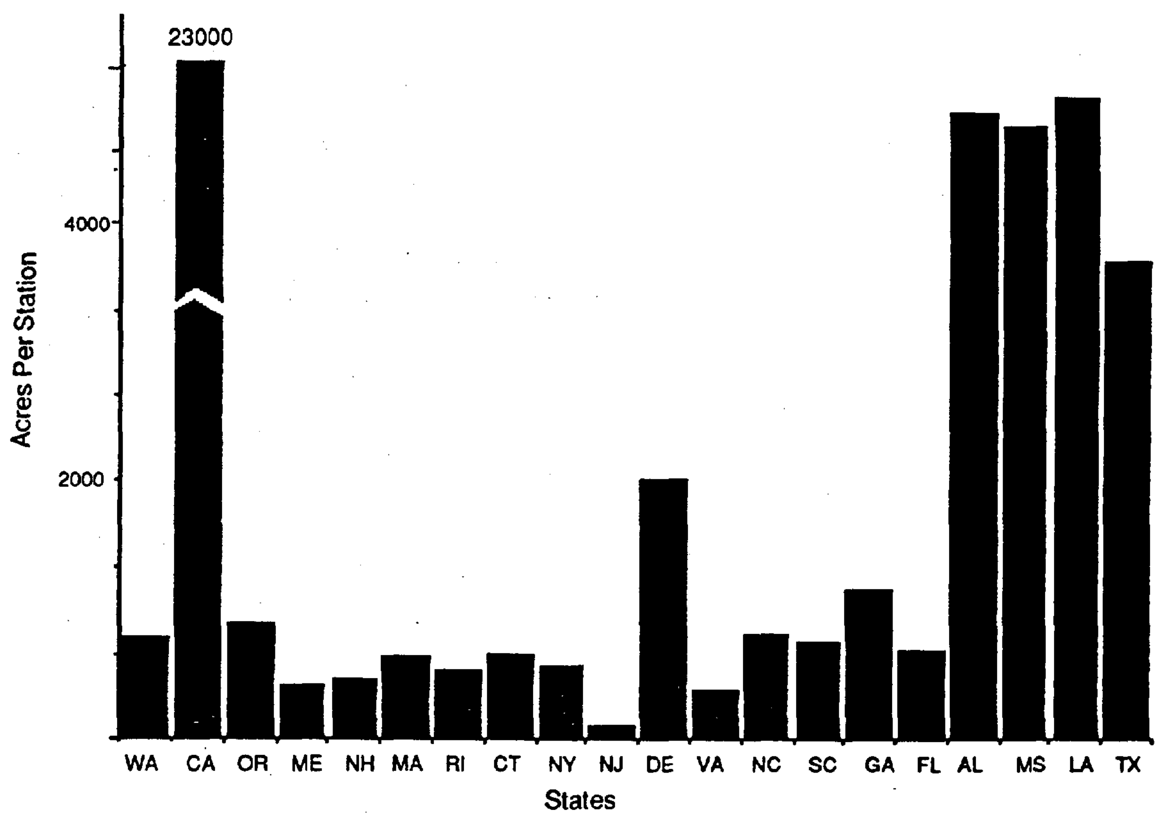
Alaska. In the early 1900's, Alaska was a major producer of razor clams, reaching a production peak of approximately 6 millions lbs. in 1916 and declining to a minimal bait clam industry in 1961. The decline in production was due to stock depletion, heavy winter storms and unfavorable market conditions. Canned Alaska razor clams, produced at relatively high harvest costs, could not compete with the East Coast industry.

Alaska has had a particularly difficult time maintaining the approved status under the NSSP because of the lack of resources needed to carry out program requirements and the extensive geographic areas which must be surveyed. FDA withdrew their approval of the Alaska program in 1954. The intrastate market was limited, and all product shipped out of state was restricted for use as crab bait. In 1975, Alaska received its NSSP program approval and the industry began to rebuild. As of October, 1988, 30 areas had been surveyed, covering 110 harvestors and approximately 150,000 acres.

Alaska is producing razor clams, littlenecks, geoducks, oysters, and mussels. Commercial harvest in Alaska is still inhibited by paralytic shellfish poisoning, high labor costs, small local markets, and high transportation costs for out-of-state markets. The Alaska Department of Environmental Conservation (1989) projects an increase in molluscan shellfish landings from 175,000 lbs. in 1989 to 1.2 million lbs. in 1992, an increase in value from $327,000 to over $2 million. This expansion of the shellfish industry will require a commitment from the state in terms of resources to survey, sample, and manage the shellfish sanitation aspects, as well as an expansion of shellfish research and resource management. *The 1990 National Shellfish Register* will include Alaska, mapping and measuring all shellfish growing areas and assessing potential pollution impacts.

In British Columbia (BC), two ministries are concerned with shellfish culture: the Ministry of Forests & Lands, which allocates aquatic Crown land for aquaculture; and the lead agency, the Ministry of Agriculture & Fisheries, which has overall control of the shellfish industry, providing financial and marketing services, controlling licensing and inspection of fish buyers and processors, and establishing fish production and quality standards. The

Figure 12 . Acres per sampling station.



Federal Department of Fisheries and Oceans enforces regulations of both the Fisheries Act and the Fisheries Inspection Act and exercises paralytic shellfish poison control. Shellfish production is profitable; landings in 1985 were 3420 tons, at a value of $2.5 million (Canadian).

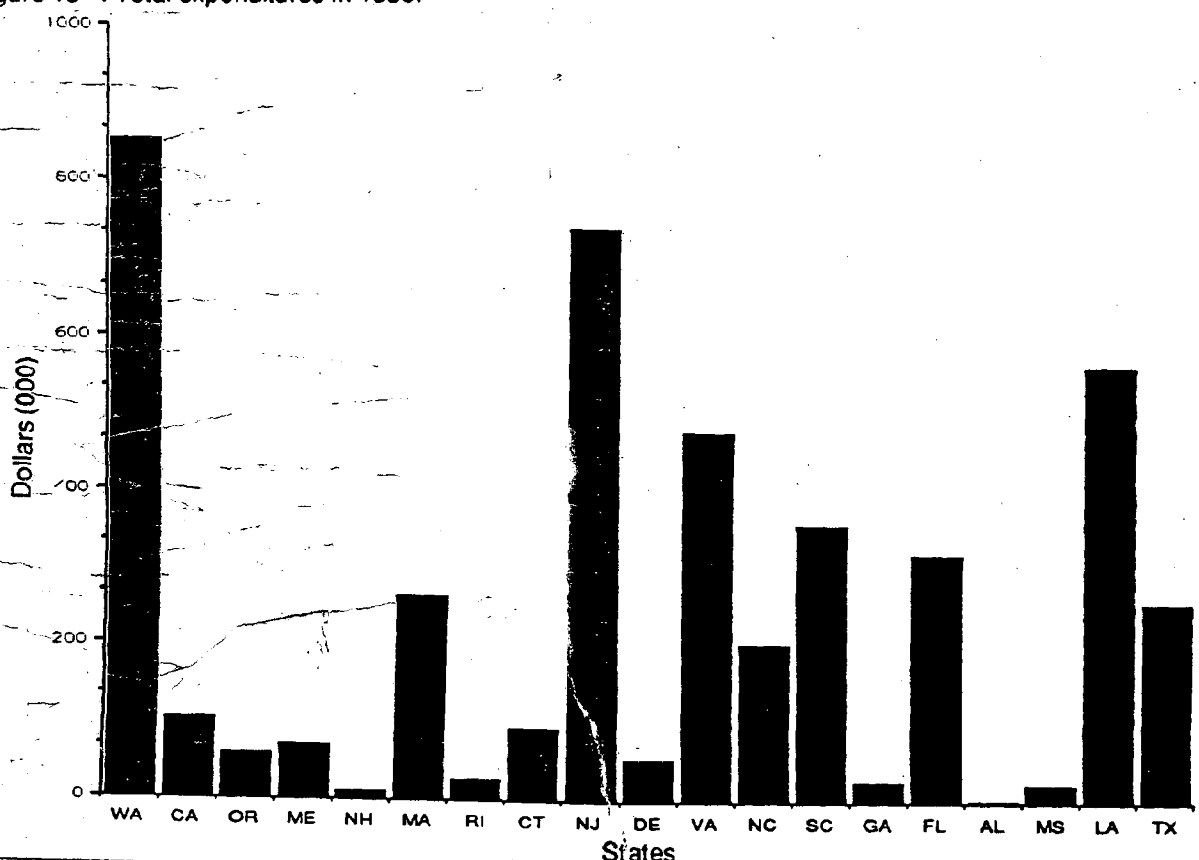
Pollution is the most serious of current problems facing the Canadian shellfish industry today (Quayle 1989). In the Canadian Maritime provinces of Nova Scotia, New Brunswick and Prince Edward Island, there are about 150 shellfish growing areas which are unproductive because of pollution. In British Columbia, sewage pollution has closed or limited a significant proportion of oyster producing grounds. Industrial pollution is also a problem in shellfish growing areas, primarily waste liquor from pulp mills and log booming operations. In 1985, 135,000 acres were closed to harvest in southern BC because of domestic and industrial pollution. All waters in northern BC are closed to harvest because of PSP (Canada Department of Fisheries and Oceans, 1985).

State Budgets and Sampling Programs. The level of financial and personnel resources allocated to the shellfish control agency has a major impact on the classification of shellfish growing waters. A questionnaire was used to collect information on the administration of state programs, including staffing and budgets. Over a million dollars were spent by West Coast states in 1985 to survey and classify waters (Figure 13.). Oregon spent more than 84 cents per acre, and Washington and California spent 42 and 19 cents per acre, respectively.

Sampling requirements vary from state to state, depending upon physical characteristics of the estuaries (eg. miles of shoreline), and how waters are classified; conditionally approved waters generally require the most budget and staff resources. Water samples are taken near the surface and often include other parameters such as salinity and temperature. Weather conditions are noted since samples should reflect water quality during major pollution events such as heavy rainfall or high river stage. The ability of the states to predict environmental thresholds is related to the comprehensiveness and timeliness of their data collection efforts.

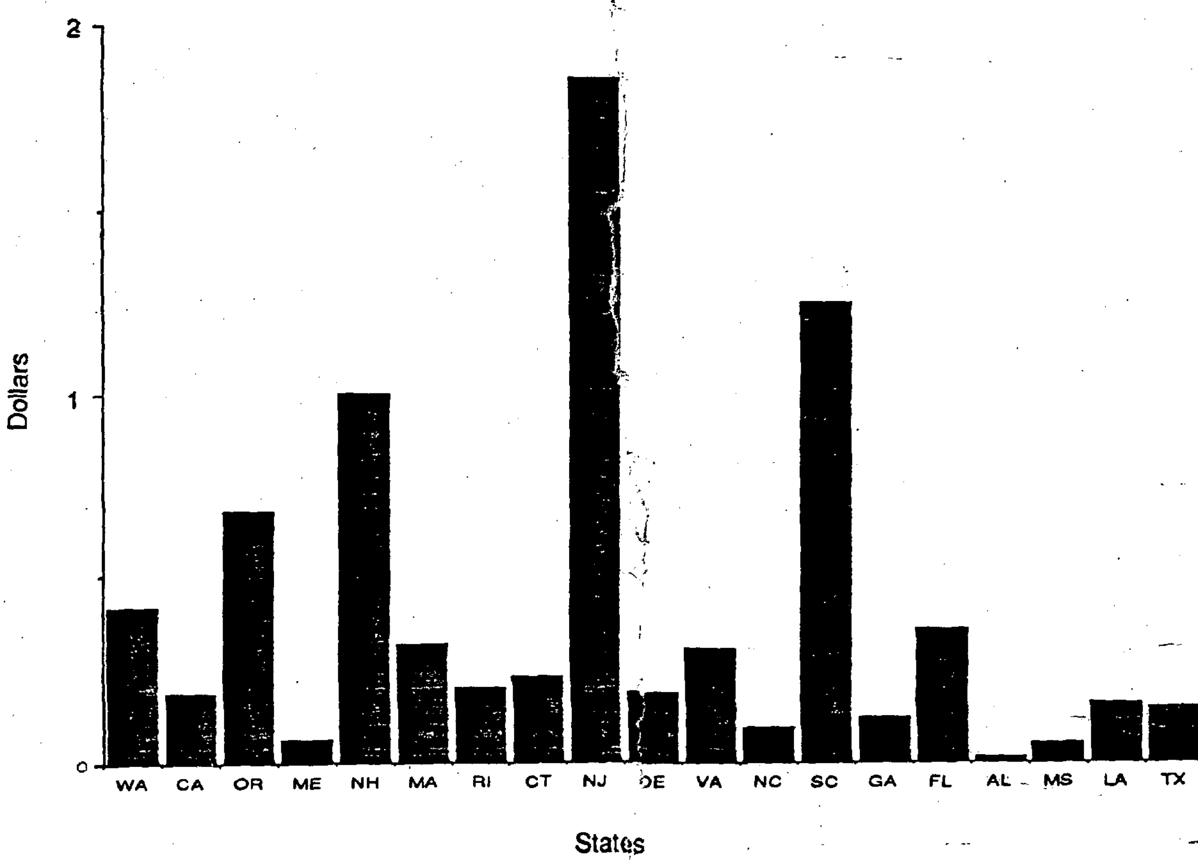
West Coast waters are monitored for fecal coliforms at over 2500 sampling stations located near potential sources of pollution and productive harvesting sites (Figure

Figure 13 . Total expenditures in 1985.



11). In 1985, California sampled at 23 stations (23000 acres per station), Oregon at 91 (901 acres per station), and Washington at approximately 2000 (948 acres per station) (Figures 11 and 12). The NSSP guidelines suggest that a minimum of five water samples be taken annually. In most cases, the states far exceed this requirement, with monthly sampling the norm.

Figure14 . Expenditures per acre in 1985.



Section II. Classification of Shellfish Growing Waters

This section examines the status of classified shellfishing waters as of 1985 and trends in classification between 1971 and 1985. Classification data were derived from charts of the 1985 and 1971 versions of the National Shellfish Register of Classified Estuarine Waters. Data were clarified through interviews with state agency personnel and reference to written materials.

1985 Classifications

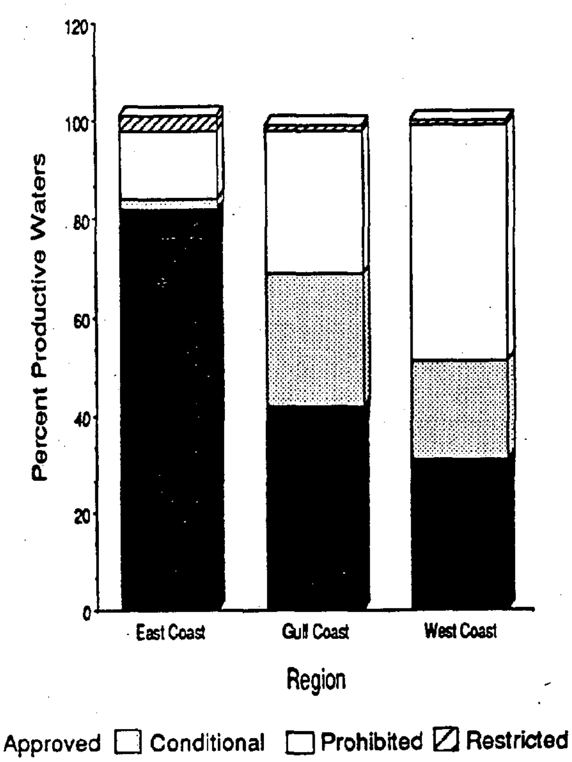
The majority of shellfish waters classified by California, Oregon, and Washington are owned or leased for bottom or suspended culture of molluscan shellfish, particularly oysters. Some clam harvest and limited mussel and scallop harvest takes place in public waters. Over 102,000 acres (31 percent) of West Coast classified shellfishing waters were approved for harvest in 1985 (Table 2). Much of this approved area is found in Willapa Bay (27,000 acres), Puget Sound (34,000 acres), and the Puget Sound subestuaries of Skagit Bay (17,000 acres) and Hood Canal (8,000 acres). Fifteen estuaries in the region had no approved waters. Most of these are nonproductive estuaries such as the Eel, Klamath, and Rogue rivers which are small river systems with little potential for shellfish culture. Of the three states, Washington had the most approved waters, 85 percent of the total West Coast classified waters.

A comparison of the West Coast to other regions of the country is shown in Figure 15 . In 1985, 42 percent of the classified waters were approved in the Gulf of Mexico, while 82 percent of East Coast waters were approved (Leonard et al,1988 and Broutman et al, 1987). The large disparity shown between West Coast and East Coast percentages can be explained by the inclusion of large areas of nonproductive waters in the East Coast totals. Large areas of open water in Long Island Sound, Chesapeake Bay and Pamlico Sounds account for nearly 50 percent of the approved waters on the East Coast. Although these highly saline waters meet the standards for approved waters, they are not productive because many molluscan shellfish prefer moderate salinities. Large open water systems are not found along the Gulf coast and, on the West Coast, nonproductive open waters (mostly in Puget Sound) are not classified. This makes meaningful comparison between the regions difficult.

Prohibited Waters. West Coast waters that were not approved were primarily prohibited, comprising 47 percent of total classified areas. Some of these prohibited waters are in highly productive estuaries, for example: Morro Bay, 58 percent; Humboldt Bay, 55 percent; Yaquina Bay, 44 percent; and Tillamook Bay, 36 percent. According to the NSSP, waters which do not have current sanitary surveys must be classified prohibited. This is the case for much of the West Coast prohibited acreage.

Restricted Waters. Only 1,587 acres, or less than one percent of West Coast waters, were classified as restricted in 1985 and were located in Monterey Bay, Tomales Bay and Elkhorn Slough. These areas are designated for harvest of shellfish for depuration, also known as controlled purification. Depuration allows shellfish harvested from waters with a limited degree of pollution to be marketed after sufficient processing in a series of tanks supplied with bacteria-free water.

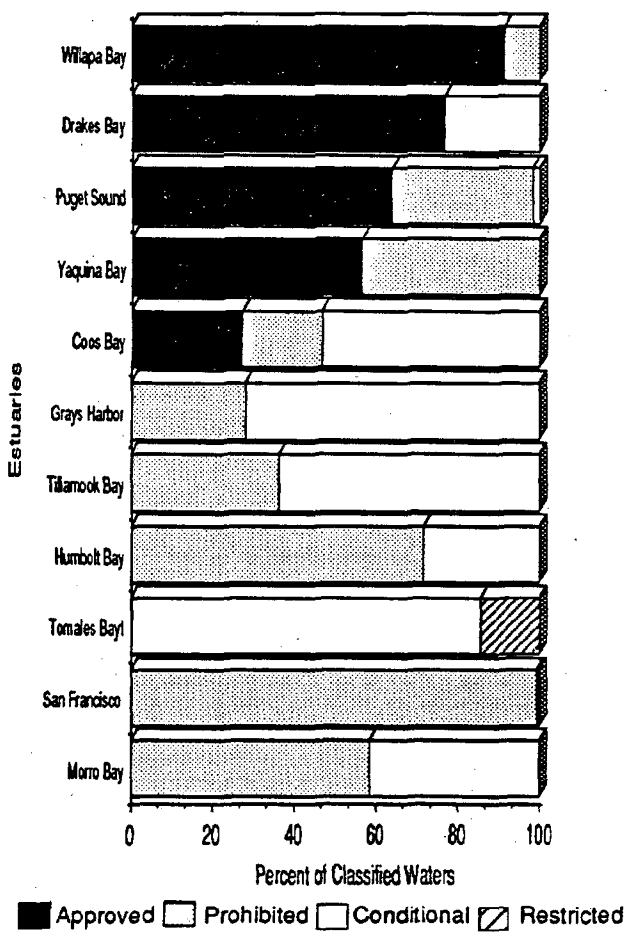
Figure 15. Classification by region.



Conditionally Approved Waters. More than 21 percent of West Coast waters were conditionally approved in comparison to 27 percent of Gulf waters and two percent of East Coast waters. Heavy rainfall events have an immediate effect as the runoff from urban areas, agricultural lands, woodlands, and marshes flows into estuarine waters. Elevated fecal coliform levels are associated with freshwater inflows, regardless of the land use of the surrounding area.

Use of the conditionally approved classification requires the development of a management plan that clearly defines the conditions under which the waters will be opened and closed. States limit the use of the conditionally approved classification to areas with significant shellfish resources because they are able to justify additional efforts required to develop a management plan and increase monitoring. Often the most productive estuaries are those classified conditionally-approved as the runoff and freshwater inflow bring with them the nutrients necessary for shellfish production.

Figure16. Classification of productive estuaries.



State Classifications

California. California classifications were altered for this report to reflect more accurately 1985 classifications. In Humboldt Bay, 5,000 acres, designated for recreational harvest by the California Fish and Game Department, were listed as unclassified.

The California Department of Health Services also requested that NOAA reevaluate classifications in San Francisco Bay. In 1985, the National Shellfish Register listed 250,000 acres prohibited based upon the lack of sanitary surveys. During the 1989 field work, NOAA worked closely with California Department of Health Services to delineate areas that should be prohibited because of nonpoint runoff, industry and boats, (80,000 acres). Although water quality in San Francisco Bay has improved because of improvements in industrial and domestic waste treatment facilities (Luoma and Cloern, 1980), according to several sources there is still a substantial problem from increased urban runoff and sewage overflows (Nichols, 1988), and increased BOD, nutrients and heavy metals related to a decrease in freshwater input (Russell et al, 1980). Almost 51,000 acres are considered nonproductive. For the remainder of the Bay, 156,000 acres, will remain "unclassified" until lease applications are received and/or sanitary surveys performed. Additional resources will be required to complete a comprehensive sanitary survey of the total San Francisco Bay-Delta-Estuary system.

Only 108,000 acres (21 percent) of California waters are classified. Approximately 2,000 acres are classified approved, all located in Drake's Bay. California's 161,000 acres of unclassified waters represent 48 percent of all West Coast waters. The majority of classified waters, 85 percent, were prohibited. San Francisco Bay had 80,000 of these acres or, 85 percent of the total prohibited, followed by Humboldt Bay with 12,000 acres. In 1985, conditional areas in California totalled 12,000 acres, located in productive Humboldt, Tomales, Drakes and Morro bays.

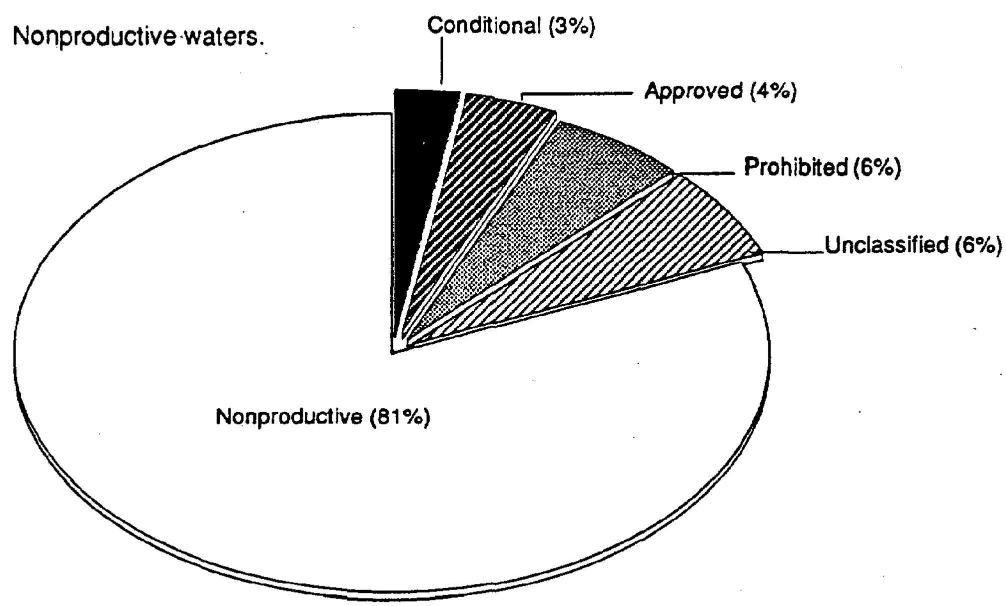
Oregon. Nonproductive waters comprised 53 percent of Oregon's waters, with 3 percent unclassified and the remainder, 78,000 acres (44 percent), classified. Of these classified waters, 33 percent were approved, mainly Netarts Bay (100 percent), Nehalam Bay (88 percent) and Winchester and Yaquina bays, each at 56 percent approved.

Table 2. Classification by estuary (acres)*

Estuary	Approved	Prohibited	Conditional	Restricted	NS/NP	Unclassified
San Diego Bay	0	0	0	0	11573	0
San Pedro Bay	0	0	0	0	15484	0
Santa Monica Bay	0	0	0	0	247	0
Morro Bay	0	1273	905	0	0	0
Monterey Bay	0	109	0	703	133914	0
San Francisco Bay	0	79688	593	0	50558	155875
Drakes Bay	2017	0	611	0	29205	0
Tomales Bay	0	0	5259	884	9197	0
Eel River	0	0	0	0	2998	0
Humboldt Bay	0	11814	4669	0	0	5102
Klamath River	0	0	0	0	804	0
Rogue River	0	0	0	0	536	0
Coos Bay	3049	2144	5935	0	0	0
Winchester Bay	3229	2574	0	0	0	0
Siuslaw River	0	1501	0	0	0	0
Alsea Bay	0	0	0	0	0	2345
Yaquina Bay	2113	1629	0	0	0	0
Siletz Bay	821	383	0	0	0	0
Netarts Bay	2406	0	0	0	0	0
Tillamook Bay*	0	3209	5666	0	0	0
Nehalem Bay	1654	236	0	0	0	0
Columbia River	0	0	0	0	74189	0
Willapa Bay	27402	2552	0	0	0	0
Grays Harbor	0	16761	43085	0	0	0
Puget Sound	34283	22835	1143	0	1528868	0
Hood Canal	8399	204	0	0	100250	0
Skagit Bay	16978	6568	439	0	132218	0
TOTAL	102351	153478	68307	1587		
Percent of Total Classified	31	47	21	0		

* Values represent classified waters. Classified waters represent 13% (325,723 acres) of all West Coast waters. Non-shellfish/ nonproductive waters represent 81% (209,004 acres) of all West Coast waters. Unclassified waters represent 6% (163,323 acres) of all West Coast waters.

Figure 17 . Nonproductive waters.



Over 33 percent of Oregon's shellfish waters were classified prohibited in 1985. Unfortunately, this classification applied to potentially productive oyster areas in Yaquina, Coos and Tillamook Bays. The classifications in Oregon were split evenly in 1985, with conditional areas also equivalent to 33 percent. Only Tillamook and Coos bays had areas classified as conditionally approved.

Washington. Large acreages in Puget Sound are considered nonproductive due to the depths, currents and unsuitable substrate. Nonproductive waters totalled almost 2 million acres or 91 percent of Washington's waters. The remaining 180,000 acres, was 48 percent approved, mainly in the extremely productive estuary of Willapa Bay (91 percent). Prohibited areas totalled 27 percent, mainly in Grays Harbor, Port Susan, and some developing areas of south Puget Sound. Grays Harbor contributed 43,000 acres (96 percent) to the state conditional total of 45,000 acres.

Trends in Classification, 1971-1985

Evaluating trends in water quality based upon changes in shellfish classification is difficult because classifications are changed for reasons other than water quality. New applications for aquaculture leases open up areas for classification and management by the atate. Waters that were not previously surveyed are opened after completion of a sanitary survey, or waters monitored under favorable conditions, are closed after sampling under worst case conditions.

Trends were evaluated by examining differences between 1971 and 1985 charts from the *National Shellfish Register* series. State shellfish managers were asked to provide reasons for changes in classificaton and to distinguish changes that resulted from alterations in water quality from those that were primarily administrative. A summary of upgrades and downgrades are shown by state in Figure 18, with those related to water quality compared to administrative changes.

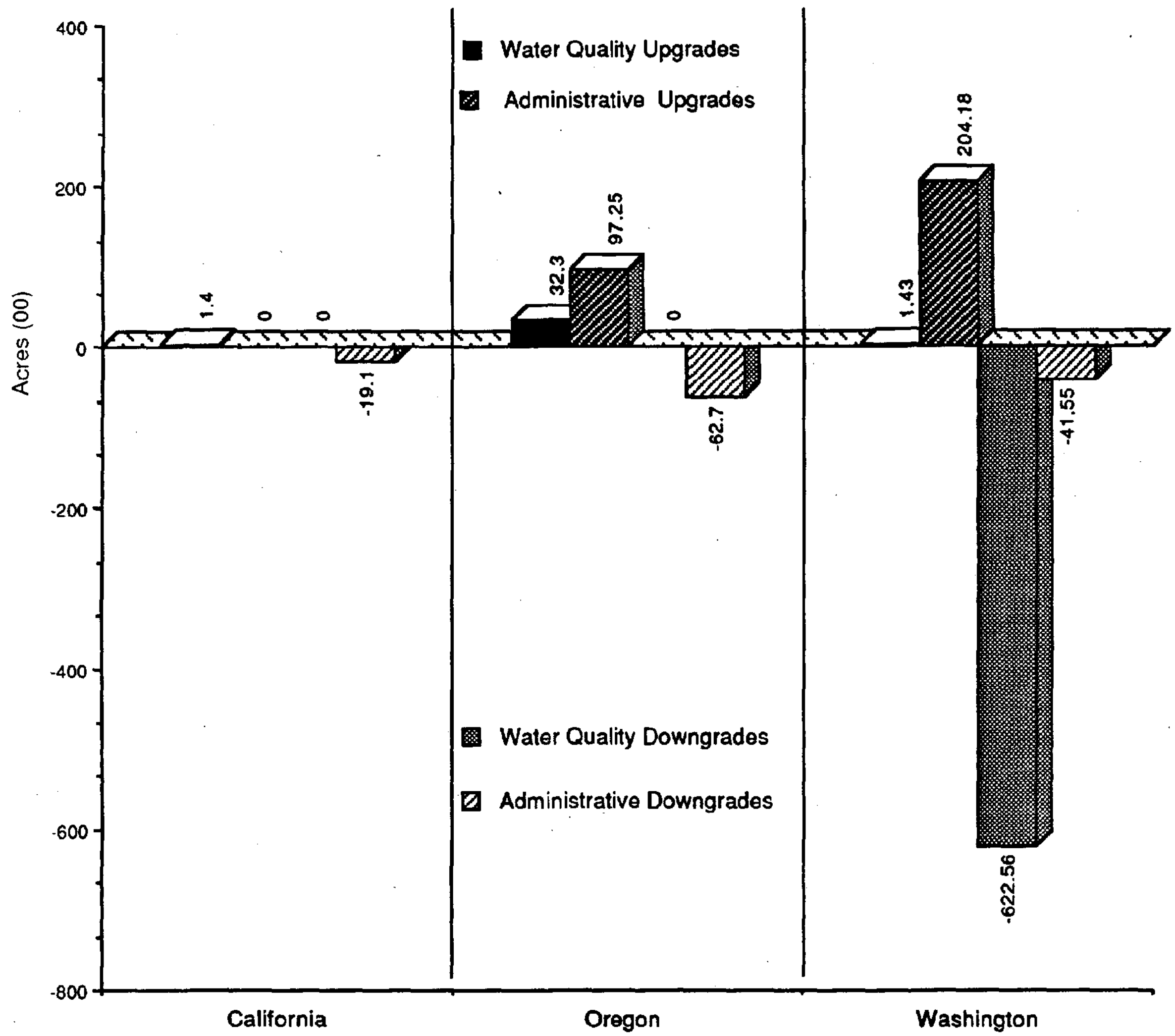
All California upgrades were water quality related. In Elkhorn Slough, 139 acres were reclassified from prohibited to restricted because of improvements in sewage treatment and the sewering of Moss Landing. This upgrade in classification has allowed two growers to raise oysters and mussels in Elkhorn Slough. All downgrades in California were administrative, a result of increased monitoring activities.

Conditions in Oregon were similar to California from 1971 to 1985. All downgrades and 75 percent of the upgrades in classification were a result of additional areas surveyed or improved monitoring. Only one area, 3,000 acres in the Umpqua River section of Winchester Bay, was upgraded from prohibited to approved because of improvements in sewage treatment.

Washington's trends can be assessed by using information from the Shellfish Protection Strategy, which traces classifications as far back as the 1950s (Washington Department of Ecology, 1984). The publication also attributed changes to specific sources of pollution. Results indicated that 99 percent of the upgrades in Washington were administrative; areas that were surveyed and classified approved. However, over 62,000 acres were downgraded because of pollution, totalling 92 percent of all downgrades. Although, historically the most significant impact on shellfish growing waters has been urban growth and resultant discharges from sewage treatment plants, the DOE report suggested a major threat to the traditional shellfish culture areas is nonpoint contamination in rural areas. Appendix B has a listing of the water quality changes on the West Coast and the pollution sources affecting the downgraded areas.

"Although, historically the most significant impact on shellfish growing waters has been urban growth... a major threat to the traditional shellfish culture areas is nonpoint contamination...."

Fiaure 18. Trends in classification.



Note: Classification upgrades include waters that were reclassified between 1971 and 1985: 1) from prohibited to approved, conditionally approved, or restricted; or 2) from unclassified to approved. Classification downgrades include waters reclassified: 1) from approved to conditionally approved, restricted, or prohibited; or 2) from conditionally approved or restricted to prohibited; or 3) from approved to unclassified.

The water quality of the nation's estuaries is a growing concern, and is a major theme in the NEI. Shellfish can be useful indicators of water quality changes.

This section summarizes information collected on pollution sources affecting shellfishing waters. Pollution sources that contribute to the permanent or temporary closure of West Coast waters were identified for each harvest-limited area classified as prohibited, conditionally approved or restricted.

Concept of Contributing Source

Only those sources that are significant factors in classifying the area were identified. The effect of a pollution source on shellfish growing waters depends on several factors: the numbers of coliform bacteria discharged by the source to receiving waters, the volume of water into which the discharge occurs, and flushing ability related to tides and circulation. The effect of a source will depend on the size of the growing area and the presence of other sources. A marina, significant in a small remote area, might not be identified as a contributing source if located in a major urban area. In other situations, a pollution source may be identified in a shoreline survey although the actual contribution of fecal coliform bacteria is small. In the case of a sewage treatment plant (STP) buffer zone, the shellfish growing area may be closed as a safety zone because of the potential effect of plant failure, rather than the actual contribution of fecal coliform bacteria to the system.

To assess the overall effect of a pollution source, each source that is identified as a contributing factor for a classified area is weighted by the acreage of the area. Acreages identified for each source are then summed by estuary to determine total acreage affected by the source. The percent of estuary affected by each source is the ratio of the total affected acreage to the total harvest-limited area of the estuary.

Humbolt Bay provides an example of the concept of contributing source. One large prohibited shellfish growing area, adjacent to Arcata Marsh, accounted for 42 percent of the total harvest-limited area of Humboldt Bay. The Arcata Marsh area was affected by sewage treatment plants (STPs), agricultural runoff and wildlife; each affected the entire acreage area of 9,026 acres.

Septic systems were cited as a pollution source only in Central Arcata Bay, a total of 4,644 acres; a contributing factor in 22 percent of the harvest-limited area of Humboldt Bay. Agricultural runoff and wildlife contributed to fecal pollution in all 5 areas, making them a contributing factor in 100 percent of shellfishing growing areas.

Sources of pollution affecting harvest-limited waters are described by category (Table 3). Pollution sources that discharge directly to estuarine waters are distinguished from upstream sources that affect waters indirectly through tributaries. The area in which a pollution source is identified as a contributing cause is summarized by estuary in Figure 19 and Appendix C.

Upstream Sources of Pollution

Pollution sources that affect shellfish growing waters through river systems are identified in a separate upstream sources category. The upstream sources, identified in this study, have been derived from studies or inferred from land use. Rivers have a profound effect on classified waters. As a river enters a bay system, it transports fresh water and nutrients as well as pollutants from upstream sources. Thus, higher fecal coliform levels are often associated with riverine freshwater inputs. Early studies suggest that coliform die-off rates are higher in highly saline estuarine waters located offshore and at a distance from the confluence with river systems. However, more recent studies suggest that the organisms may actually go into a dormant stage during periods of high salinity (Office of Technology Assessment, 1987). As the river stage increases, the effects of the river extend further into the estuary. STPs (50 percent), industry (22 percent) and urban runoff (19 percent) were the major upstream contributors in West Coast estuaries.

Point Sources of Pollution

Sewage Treatment Plants. Sewage treatment plant failure is a common problem in the heavily populated Northeast and in the rapidly developing Southeast and Gulf areas. However, on the West Coast, sewage treatment facilities were a contributing factor in only 25 percent of West Coast shellfish growing areas and 50 percent of upstream waters. STPs had a major effect

Table 3. Description of Pollution Sources

Pollution Source	Description
Sewage Treatment Plants (STPs)	Discharges of inadequately treated effluent from older plants, malfunctioning disinfection systems, or from bypassing of raw sewage through an outfall pipe during overload periods. Buffer zones are established around outfalls to protect public health in case of emergencies.
Combined Sewer Overflows (CSOs)	During periods of heavy rainfall sanitary wastes are combined with stormwater runoff and discharged to the waterbody.
Industry	Fecal coliform from seafood processors, pulp and paper mills, dairies and cheese factories, shipyards or from human sewage discharged with industrial wastes. There may also be potential hazards from toxics or heavy metals.
Septic Systems	Nonpoint pollution from unsewered areas or from the leaching of faulty septic systems.
Urban/Rural Runoff	Storm sewers, drainage ditches, or overland runoff from urban areas containing fecal material from pets, birds, and rodents.
Agricultural Runoff	Runoff from agricultural fields, including feedlots.

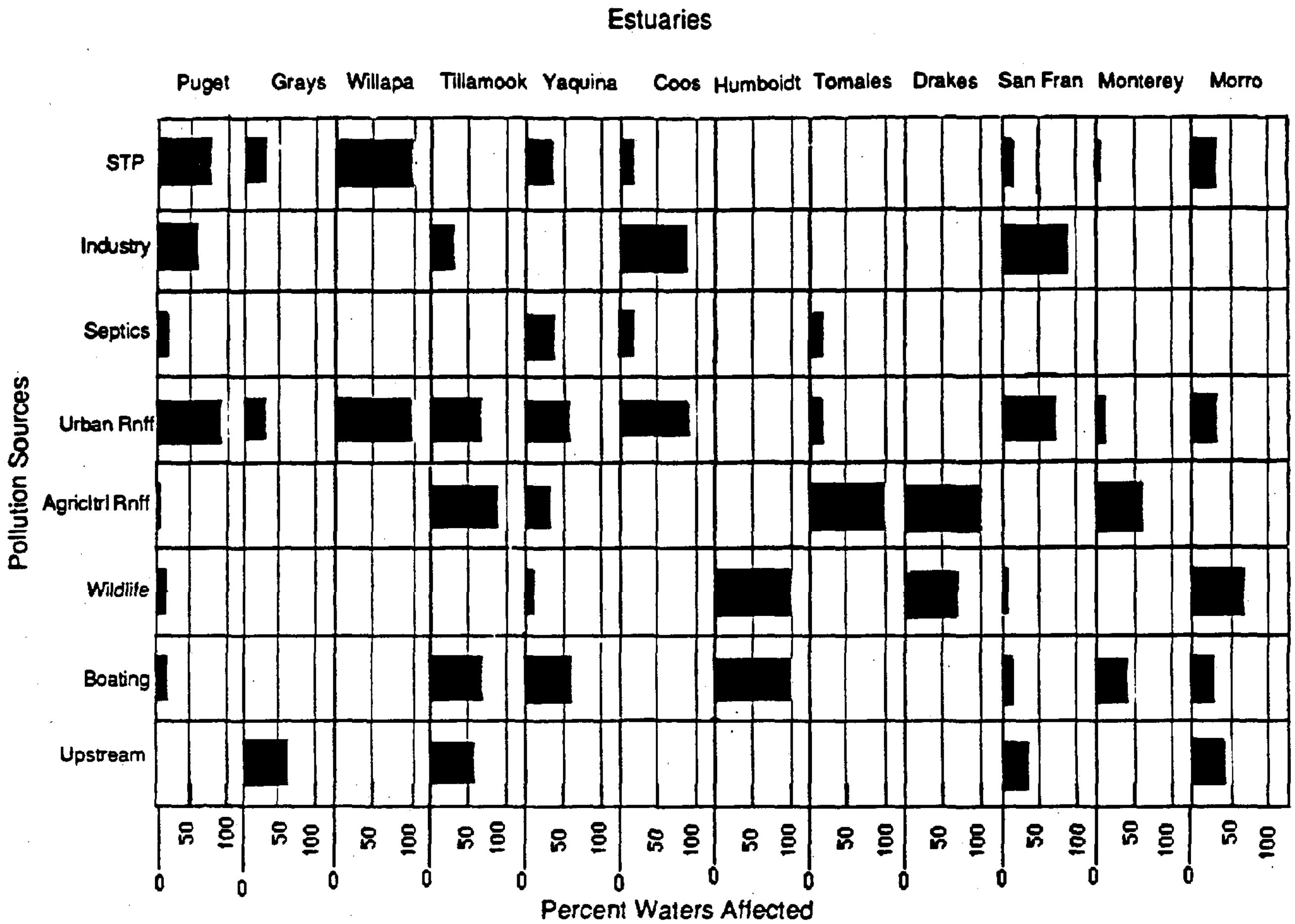
in Winchester Bay (95 percent), Puget Sound (78 percent), Skagit Bay (43 percent), and in the only prohibited area in Willapa Bay (2552 acres).

In the majority of West Coast estuaries, shellfish beds are located in relatively undeveloped areas or where sewage discharges have been diverted to the ocean. When functioning properly, sewage treatment plants do not contaminate shellfish growing waters. However, in order to protect public health, state shellfish control agencies classify the areas adjacent to the outfalls of treatment plants as "closed safety zones" or "buffer zones", to protect shellfish beds in the event of a system failure. The safety zones surrounding outfalls are sized according to loadings, hydrographic conditions, and emergency installations and procedures. In some instances, STPs release raw sewage during heavy rainfall events (bypasses). According to state health department officials, bypasses occurred in Humboldt and Yaquina bays in 1985.

Industry. Using the concept of the "contributing source" as described above, the major source of shellfish closures in West Coast estuaries was industry, affecting more than 98,000 acres or 43 percent of harvest-limited waters and 22 percent of upstream waters. This figure can be misleading because industry sources affected the largest estuaries; San Francisco Bay (72,000 acres), Coos Bay (7,000 acres), Puget Sound (12,000 acres), and Skagit Bay, a subestuary of Puget Sound (3,000 acres).

Industrial discharges are of concern to public health officials because of the potential presence of high fecal coliform levels and effects from toxics and heavy metals. Seafood processing plants located in coastal areas may have an impact on the level of fecal coliform bacteria in adjacent waters by discharging processing and sanitary wastes into sewage treatment facilities, or in some cases, directly into receiving waters. Discharges from pulp and paper processing facilties contain *Klebsiella,* a fecal coliform bacteria found in cellulose wastes and infrequently in human wastes. Runoff from shipbuilding facilities and repair yards contain significant levels of lead, tributyl tin and petroleum products affecting shellfish growing waters such as those in lower Coos Bay. Dairy and cheese factory wastes are extremely difficult to treat and contribute to elevated fecal coliform levels. The latter affected shellfish growing areas in Tillamook Bay.

Figure 19. Contributing pollution sources.



In San Francisco Bay, industrial and domestic waste discharges can be characterized by a high background level of continuously discharged pollutants, a significantly seasonally variable input of pollutants, and a series of unpredictable discharges, most of which result in localized releases of pollutants. Over 200 permits for industrial discharges have been issued for San Francisco Bay. For every toxic metal, there are several locations in the bay where concentrations approach or exceed the highest concentrations reported for similar species in world-wide surveys of contamination (Luoma and Cloern, 1982). Trends in concentrations of toxic trace organic compounds, for example polychlorinated biphenyls, appear similar to those for trace metals. Concentrations of petroleum hydrocarbons in mussels are 20 times higher than those on the North California coast and near the concentrations found in San Diego and Los Angeles harbors (Luoma and Cloern, 1982).

In Puget Sound, the most productive growing areas were not affected by industry. However, approximately 270 industrial dischargers have NPDES permits to release treated effluents directly to Puget Sound or its tributaries. Some of the industrial discharges contain complex mixtures of heavy metals, toxic chemicals or other harmful compounds.(Puget Sound Water Quality Management Plan, 1988). Primary industries in the Puget Sound area included chemicals and related products (2 companies), lumber and wood products (9 pulp and paper mills), petroleum refining (8 refineries), primary metals manufacturing (2 aluminum and steel processing plants), meat and seafood processing, and marine cargo and transportation facilities, such as aeronautics or shipbuilding.

Nonpoint Sources of Pollution

Septic systems. Septic systems that malfunction were identified as contributing sources to only 5 percent of harvest-limited shellfish growing waters. Septics are a major factor in smaller estuarine systems where the population is rural and communities are unsewered, for example, Winchester Bay, Siuslaw River, Nehalem Bay, and Hood Canal. The impact of faulty septic systems was less significant in Tomales, Yaquina and Skagit bays. Siting becomes an important issue in areas of bedrock and poor soil permeability where, subsurface leaching problems are difficult to identify and correct.

Urban runoff . Urban runoff from adjacent coastal areas was identified as the contributing cause in 33 percent of West Coast shellfish growing area closures. An additional 19 percent was identified as upstream inputs. In 13 of the 18 estuaries for which sources of pollution were identified, there are medium to high density developments in which runoff from impervious areas, such as streets and parking lots, storm sewers, ditches and lawns, carry pollutants to the estuarine system. A 1983 EPA report attributes high bacteria levels in urban runoff to heavy loads of animal wastes, particularly pets and rodents. The study found that during heavy rainfall, runoff exceeded recommended bacterial counts at virtually every one of 28 urban study sites. Fecal coliform counts in urban runoff are typically tens to hundreds of thousands per 100 ml during wet weather conditions, with the median for all sites being around 21,000/100 ml. The study also indicated that use of coliforms as an indicator of human health risk, when the sole source of contamination is urban runoff, warrants further investigation (EPA, 1983).

Agricultural Runoff. Runoff from cropland fertilized with manure or land used by grazing animals contributes fecal coliform bacteria to surface waters. Studies show that the fecal coliform count is five to 10 times higher from grazed land than from ungrazed areas and that there is significant bacterial contamination where high-density livestock activities are allowed adjacent to a stream (Milne, 1976). Faust and Goff (1978) estimate that the fecal coliform contribution of one livestock unit is equal to the contribution of 60-70 persons .

Although agricultural runoff limits harvest in only 15 percent of West Coast shellfish growing areas, plus an additional 2 percent from upstream impacts, it does affect all harvest-limited areas in Drakes, Tomales, and Humboldt bays — the most productive bays in California, and 91 percent in Tillamook Bay, the most productive system in Oregon. Tillamook Bay has developed a program using Best Management Practices (BMPs) as the tool to improve water quality.

In Washington, noncommercial "hobby farms" are a major threat to water quality (Wallace, 1987) (Saunders, 1984).

Wildlife . Wildlife has been identified as a probable source of fecal coliform bacteria in areas with minimal human populations. On the West Coast, 11 percent of harvest limited shellfish growing waters are affected by wildlife, with an additional 2 percent in upstream sources. In Humboldt and Siletz bays and Hood Canal, all harvest-limited waters are affected by wildlife sources. In addition, Morro Bay (67 percent and 42 percent upstream), Drakes Bay (72 percent), Winchester Bay (95 percent upstream) and Puget Sound (11 percent) suffer shellfishing restrictions because of wildlife populations.

In addition to the wildlife sources identified in coastal areas such as migratory birds, muskrats, deer and elk, many West Coast estuaries are affected by populations of harbor seals. Under the Marine Mammal Protection Act of 1972, harbor seals are protected and limitations imposed on state control of seal populations. Shellfish beds located near haulouts or nesting areas often exhibit high fecal coliform counts.

A recent study (Calambokidis et al, 1989) in northern Hood Canal identified increasing populations of harbor seals as the primary source of fecal coliform pollution in the productive shellfish growing areas. From 1,200 to 1,400 harbor seals were counted during aerial surveys of Hood Canal in September 1988 as compared to less than 1,000 in 1984. There was a clear correlation between seal populations and high fecal coliform levels at Dosewallips River Delta and Still Harbor. The report discussed potential health risk from harbor seals, and listed pathogenic bacteria as reported from marine mammals. The report recommends that more research be done to provide information on the health risk of transmission of disease from animals to humans.

Boating activity . Boating activity (including marinas and adjacent buffer zones) affected 10 percent of West Coast harvest-limited shellfishing waters, with substantial impacts in Nehalem Bay (100 percent), Yaquina Bay (60 percent), Tillamook Bay (73 percent), and more than 30 percent in Monterey and Morro bays. In the two largest estuaries, San Francisco Bay and Puget Sound, boating is a contributing source at 13 percent and 11 percent of harvest-limited waters, respectively. The significance of sewage discharge from boats has been controversial nationwide. Boaters generally argue that their discharges are insignificant while Federal and State regulators demand stronger controls. An environmental health survey by Washington Department of Health found that 34 percent of shoreline property owners acknowledged having sewage on their beaches which they attributed to boats, and 59 percent complained about litter and garbage floating ashore (DOH, 1989). Studies in the 1950s and 1960s showed that sampling stations in areas of heavy boat use had higher levels of fecal coliform than stations outside anchorage areas. However, where tidal exchanges were large, no detectable increases in pollution levels attributable to boats were apparent.

Boating and marinas were contributing factors in 11 percent of harvest-limited waters, from an estimated 160,000 registered boats in Puget Sound. Washington DOH produced a report in 1989 on five boating areas in Puget sound, reporting a close correlation between boating activity and fecal coliform levels. The study revealed that shellfish tissue was the most noticeable indicator of fecal pollution in waters subjected to pollution from boating activity. DOH concurred with other studies which consider the public health threat from fresh fecal matter discharged from boats to be a potentially greater public health threat than that of fecal matter discharged in municipal wastewater treatment effluent. The municipal sewage most likely has been comminuted, settled, skimmed, aerated, diluted, and disinfected prior to discharge as opposed to fresh feces discharged from boats.

To protect public health from the effect of boat wastes, the Interstate Shellfish Sanitation Conference (1985) developed a marina policy that requires states to establish buffer zones around marinas and canals. The area within the marina proper must be classified as prohibited or restricted. An additional closed area beyond the marina also may be required. Many shellfish producing states are developing techniques for closing areas based on dilution, dispersion, die-off or residence time, and hydrodynamics, as well as marina design, quality, and usage.

"Faust and Goff (1978) estimate that the fecal coliform contribution of one livestock unit is equal to the contribution of 60 to 70 persons."

Results of Water Quality Degradation

The West Coast shellfish industry is particularly vulnerable to alterations in water quality. The majority of shellfish production is from aquaculture which takes place on leased bottom or in leased water columns. Once a grower has obtained a lease and received a permit to operate, he/she is tied to the leased area. Suitable bottom is limited and there is considerable competition for leases. If a growing area is affected by a pollution incident or a general degradation of water quality, there is no exchange of bottom or water column to accommodate anticipated shellfish production. The following case studies show a direct correlation between the decline in water quality, as demonstrated by the reclassification of shellfish growing waters, and the decline in shellfish production.

Humboldt Bay. For many years the highest oyster production in California came from Humboldt Bay. Landings peaked at 1.5 million lbs. in 1962 and declined to 456,000 in 1988 (personal communication, L. LaBranche). A draft report from California Department of Health Services relates decreased shellfish production to stricter enforcement of water quality standards, including growing-area closures during and following periods of rainfall and emergency closures because of failures in wastewater treatment and collection systems. (California Department of Health Services, 1988).

In 1984, improvements were completed to the Elk River STP. Effluents were redirected to the ship channel near the entrance to Humboldt Bay and discharged only on the outgoing tide. A new $5.5 million treatment plant was completed for the City of Arcata in 1986. The Arcata STP uses an innovative series of tertiary treatment ponds through which disinfected secondary effluent flows prior to final discharge to North Humboldt Bay. Although the wastewater improvements virtually eliminated a wet-weather problem associated with the discharge of raw or partially treated sewage, Humboldt Bay still receives pollutants from other sources in the watershed. For example, increased seagull activity during the annual herring run elevates fecal coliform levels. A 1987 FDA study uncovered an additional source of human sewage contamination to Humboldt Bay. Thousands of sea gulls congregate on the bay flats at low tide to feed on herring eggs which are deposited on eel grass during the winter months. When the tides cover the eel grass the gulls move to the local solid waste landfill to feed on waste materials and to the Arcata STP where they were observed feeding on raw sewage entering the plant at primary clarifiers. The gulls then return to the bay flats at low tide, depositing fecal coliforms on the eel grass and oyster beds. The City of Arcata will exclude seagulls from the clarifiers and the landfill is being covered by soil. However, still to be managed are agricultural wastes which affect the shellfish beds during rainfall events.

Morro Bay. Morro Bay, the leading producer of Pacific oysters in California in the early forties, has had difficulty supporting shellfish production because of consistently high fecal coliform levels from variable sources. Production decreased from 149,000 lbs. in 1979 to 17,500 lbs. in 1984, to a bare minimum of 2,000 lbs. in 1985. The bay, located on the California coast, halfway between San Francisco and Los Angeles, is a shallow estuary, approximately 1,220 acres in size, affected by a 75 square mile watershed. Principal tributaries are Los Osos Creek and Chorro Creek, the latter of which is a source of pollution to bay shellfish beds. In 1985, the population in the immediate communities was 25,000. One of the major sources of pollution was the City of Morro Bay wastewater treatment plant, which discharges effluent through a 170-foot long diffuser at 50 feet water depth, located 4,400 feet offshore of the Morro Bay entrance. The effluent is mixed primary and secondary effluent and was not chlorinated in 1985. The bay sampling program showed high fecal coliform levels at the station located just outside the breakwater to the channel possibly indicating that pollution was entering the bay from the ocean (California Dept. Health Services, 1985). Tributary stream sampling showed elevated levels in the station located just below cattle feed lots and below a marshland inhabited by large bird populations. Recreational boats totalled over 300 in 1985. Although pump-out facilities are provided and liveaboards prohibited, sampling indicated a probability of boats as a source of fecal coliform. Currently, corrections to pollution problems and new ownership of 760 acres of shellfish leases should restore Morro Bay to its former production levels (personal communication P. Wells, CA Health Services).

Tillamook Bay. The largest producer of oysters in Oregon, Tillamook Bay, has experienced a dramatic decline in landings from 588,000 lbs. in 1968 to less than 185,000 in 1985. Potential production of the bay is 2 million lbs. of oysters. (S. Hayes in Tillamook Headlight Herald 9/20/89). Water quality in the bay and tributaries has declined as well, with major increases in fecal coliform levels occurring during major rainfalls.

The Tillamook Bay drainage basin is located on the northern Oregon coast, approximately 48 miles south of the Columbia River. The watershed is 550 square miles with five major river subbasins draining 97 percent of forested land into Tillamook Bay. The lower portions of the subbasins are agricultural lands, a total of 23,540 acres, over half of which are used for dairy operations. Over 23,000 cows contribute 322,500 tons of manure annually. Conclusions in a Tillamook Bay bacterial study (OR Department of Environmental Quality, 1982) attribute most of the fecal coliform bacteria in the bay to the Tillamook, Trask and Wilson subbasins. Dairy operations, primarily manure storage and disposal in barnyards and on pastureland, were contaminating the surface waters of the drainage basin. Sewage treatment plants had the potential of elevating fecal coliform levels when malfunctions occur and some septic systems were identified as inadequate. Tillamook Soil and Water Conservation District, Oregon Departments of Environmental Quality (DEQ), and Health and Human Resources/Health Division, in cooperation with US Department of Agriculture, US Environmental Protection Agency and the US Food and Drug Administration, the dairy and oyster industries and local citizens developed an extensive nonpoint source pollution abatement plan with a goal of 70 percent reduction in fecal coliform bacteria entering the water courses. The USDA established a Rural Clean Water Program in Tillamook County in 1981 with projected expenditures in excess of 7 million dollars (Federal share of 5 million, and individual farmers, over 2 million). The project involves 109 dairy farms which are installing best management practices (BMPs),including animal waste management (liquid and dry storage, roofing, buried manure lines, curbing, diversions, and subsurface drainage ditches), grazing land protective systems, stream protection, fertilizer management and sediment retention, erosion or control. Results indicate 40-50 percent reduction in mean fecal coliform concentration, (North Carolina State University Agricultural Extension Service, 1989).

The situation has not eased for the oyster industry in Tillamook Bay. On September 6, 1989, the State Health Division once again closed Tillamook Bay to oyster harvest because of increased levels of fecal coliform. The DEQ cited The Tillamook County Creamery Association (TCCA) for continued violations of its waste discharge permit requirements. (Oregonian 9/15/89). The creamery association handles one million lbs. of milk per day producing 34 million lbs. of Tillamook cheese annually. The cheese factory attracts 800,000 tourists each year, producing more sewage than the municipal wastewater treatment plant. The DEQ fined the TCCA 14,400 dollars for repeatedly violating its wastewater discharge permit between February and September of 1989. The violations included high levels of fecal coliform and the exceeding of standards for total suspended solids and biochemical oxygen demand. The dairy was also cited because it did not reduce production while the treatment plant failed to meet standards. Instead, the creamery has increased production and the number of tourists visiting its facility. Although the Health Division opened the bay again on September 18, 1989, future oyster production may still be in jeopardy because 700,000 dollars in creamery improvements are behind schedule and still do not address the need to separate treatment for milk residues and restroom sewage (Oregonian, 10/6/89).

State Efforts to Improve Water Quality

West Coast state officials are concerned about water quality and are particularly responsive to the impact on the shellfish industry. Although state agencies are restricted in their efforts because of limited budgets and personnel resources, they have developed cooperative programs to solve water quality problems and upgrade classifications whenever possible. For example, Oregon Health Division receives assistance from the Department of Environmental Quality in sampling estuarine waters. Washington Department of Health receives funding and assistance from the Washington Department of Ecology (DOE).

Concerned with the possible degradation of water quality within Puget Sound's urban embayments, the Washington State Legislature appointed the Puget Sound Water Quality Authority in 1985 and issued a mandate to prepare and adopt a water quality plan for the sound. These activities are supported in part by an annual income of approximately $45 million from the state cigarette tax. The Puget Sound Water Quality Management Plan, adopted in 1986, established broad goals regarding shellfish: (1) to protect shellfish consumers from pathogens and other contaminants, including toxicants; (2) to maintain and enhance shellfish abundance; (3) reopen closed/correctable commercial shellfish beds; and (4) to control sources of pollution to prevent additional closures of commercial and recreational beds. DOE, in cooperation with the Department of Health and other state and local agencies will jointly develop a program to protect over 140 recreational shellfish beaches from pollution.

In order to achieve these goals the DOE has provided grants to local governments for commercial shellfish protection as part of the nonpoint program. Twelve watersheds were designated "early-action," six of which manage shellfish as an impacted beneficial use. A more detailed description of the six watershed management plans are contained in Appendix D.

Although Puget Sound Water Quality Authority, state and local governments, and the shellfish community are working very hard to correct pollution problems and sustain water quality in shellfish growing areas, there are nonpoint problems that are extremely difficult to identify and even more difficult to correct. In March, 1987, a major nonpoint source pollution conference was held at the University of Washington to address the water quality problems of Puget Sound. Speakers stressed the need to control urban and agricultural nonpoint sources of nutrients and toxics. The question to be addressed now is whether the education, monitoring, BMPs and other corrective measure are effective. NOAA will have another opportunity to assess the quality of shellfish growing waters to determine whether improvements have occurred in recent years. The *1990 National Shellfish Register of Classified Estuarine Waters* will assess the changes in the classifications of shellfish growing waters between 1985 and 1990 and identify the sources of pollution or improvements responsible for the changes.

Industry Efforts to Improve Water Quality

Santa Barbara Channel. The shellfish industry has also made a substantial investment in time and finances to stop the degradation of shellfish water quality. For example, Jeff Young, owner of Pacific Seafood Industries in California, had to delay production on his oyster leases while bringing pressure to bear on the California communities of Santa Barbara and Goleta to meet effluent standards and chlorinate effluent discharged through ocean outfalls. In 1985, with almost 500,000 dollars invested in his mariculture operation, Young was unable to sell his mature oysters to local restaurants because meats did not meet the bacteriological market standard. The levels were erratic and did not agree with ambient water quality standards which usually met the fecal coliform standard. Young suspected contamination from the Goleta outfall located 4.5 miles up the coast. Goleta Sanitary District was preparing to apply to US Environmental Protection Agency (EPA) to extend the federal waiver that allows reduced levels of treatment for California coastal outfall plants. The 6.8 million gallons of sewage per day received primary treatment and no chlorination. In 1986, EPA ordered the Goleta District to chlorinate and, in 1988, solid waste removal was increased from 65 to 84 percent. At the same time, the Regional Water Quality Control Board ordered Santa Barbara to chlorinate their city's effluent, a cost of $265,000 for the improved facility. Bacteria levels went down as soon as Goleta began chlorination (Santa Barbara Press, February 13, 1989). There are currently seven harvestors in the Santa Barbara channel, all looking forward to clean water and a healthy growth in the industry. Young has filed for damages from the Goleta Sanitary District and has begun work on a law degree which will allow him to work with others to clean up the marine environment (P. Wells, personal communication).

Willapa Bay. At a recent meeting in Bay City, oyster growers and county residents discussed with NOAA their concerns regarding the future of Willapa Bay. Described as the most productive estuary on the Pacific coast, with annual oyster landings of almost 500,000 gallons, the bay has stayed relatively clean for many years. Slow growth, coupled with the bay's excellent capacity to cleanse itself on each tide, has protected the waters until now. By the year 2000, over 75 percent of the US population will live within 50 miles of the coast. With a spectacular wide beach, excellent clamming, crabbing and fishing, and a superb climate from May to September, the watershed of Willapa Bay has great development potental. Add to the growth in residential and commercial development, an explosion in boating and other water recreation, and the estuary will experience a decline, first in water quality, then in species diversity and abundance.

The local officials and residents are exploring options to protect Willapa Bay, including nomination to the national system of estuarine reserves. The goals are to promote the long-term viability of the resources, promote and coordinate research on the bay ecosystems, manage natural resources and educate policy makers and local residents in the value and fragile nature of the bay resources. Another approach being evaluated is the formal development of a water quality protection district with designation of Willapa Bay as a "shellfish protection district." Enabling legislation was passed by the Washington Legislature in 1985.

Public Health Debate on Pollution Sources

West Coast shellfish regulators and industry debate the public health impact from animal-transmitted pathogens on the West Coast as well as other areas of the US. Industry, regulators and scientists concur that contamination of waters with human sewage is a major cause of shellfish-borne diseases. However, the public health significance of nonhuman sources of fecal pollution, for example, in agricultural runoff or from wildlife, is less certain. Enteric viruses, the major disease-causing agent when shellfish are harvested from sewage contaminated waters, are human specific and are not believed to be passed from animals to humans. In West Coast estuaries, over 64,000 harvest-limited acres were affected by animal-related closures, over 36,000 from agricultural runoff, and over 27,000 from wildlife. A total of 24,883 acres of shellfish growing areas were harvest-limited in areas where no human sources have been identified.

Scientists and regulators are pursuing research to provide answers regarding the public health significance of the coliform bacteria indicator. FDA, in cooperation with the Texas Department of Health, is measuring pathogens in growing areas in Texas affected by wildlife. A NOAA/EPA study (Dufour and White, 1985) is using epidemiological studies to examine relationships between indicators and disease at sites affected by potential point sources (STPs) of human pathogens.

In addition, the National Collaborative Shellfish Pollution Indicator Study is addressing the relationships between indicators and incidence of shellfish-borne disease. Field studies will evaluate proposed alternate indicators of fecal pollution and the health risks associated with consumption of shellfish from sites affected by human and animal sources. Validation of indicators in the environment and verification of the public health risk through epidemiological studies will provide a scientific basis to develop meaningful numerical standards for classifying shellfish growing waters.

Concluding Comments

Recently, marine resources throughout the West Coast begun to experience effects associated with development that have affected East Coast resources for almost a century. Rapid development of West Coast metropolitan areas and intense agriculture have placed increased environmental stress on many of the region's marine resources. Shellfish are one of the most sensitive indicators of such changing conditions. Healthy shellfish beds in West Coast states have now been compromised by pollution and the trend seems likely to continue. For example, at the turn of the century, San Francisco Bay was producing 2.7 million pounds of oysters and 1.3 million pounds of clams annually, while today the Bay shellfishery is negligible. As a consequence of these drastic declines in production, a concerted effort is now underway along the West Coast to assess and improve the condition of it's shellfish resources.

On the West Coast and throughout the country, consumers are losing confidence in the quality of shellfish products. A mandatory seafood inspection program now being considered by Congress is an indication of this concern. Several bills in both Houses emerged from a consumer advocate initiative. The common feature of all the bills is required inspection of all domestic and imported seafood at source, processing and market levels. However, the program does not address directly the maintenance and improvement of estuarine water quality, without which nationwide declines in the shellfish production are likely to continue. Overall, it does not seem that a high enough priority has not been placed on preserving the water quality of our productive shellfish estuaries. Once waters are closed to shellfish harvest, they soon become unavailable for recreation and the support of other recreational and commercial species.

The 1990 National Shellfish Register now underway by NOAA will quantify the changes in classification by acreage since 1985. It will also present information on the reasons for the changes and the pollution sources which may have contributed to these changes, and will help to determine the rate at which the shellfishery decline is occurring.

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Appendices

A. Personnal Communications

B. Waters Classified As A Result Of Water Quality Changes

C. Sources of Pollution In West Coast Shellfishing Waters

D. Puget Sound Watershed Management Plan

Appendix A. Personnal Communications

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Appendix B. Waters Reclassified as a Result of Water Quality

State	Estuary	Area Name	'71	'85	Losses	Gain	Reason
California	Monterey Bay	Elkhorn Slough	p	r		139	Upgrade Moss Lndg STP
Oregon	Winchester Bay	Umpqua R.	p	a		3229	Upgraded STP
Washington	Willapa Bay	Willapa B.	*	p	2552		STP, Raymond, S. Bend
	Grays Harbor	Grays Hbr.	a	p	2665		STPs, lumber mills
		North Bay	a	c	43085		Nonpoint runoff
	Puget Sound	Washington H	a	p	337		STP, urban runoff
		Burley Lgn.	*	p	480		Nonpoint rnff, wildlife
		Minter Crk.	u	p	93		Nonpoint runoff
		Dougall Pt.	u	p	194		STP
		Oakland Bay	*	c	1224		Shelton STP, lumber mll
		Dyes Inlet	*	p	836		Bremerton STP
		Sinclair Inlet	*	p	3233		Bremerton STP
		Budd Inlet	*	p	1081		STP, Deschutes River
		Liberty Bay	*	p	2417		Poulsbo, STP, marina
		Henderson	a	p	163		Urb Rnff,septics,wldlfe
		Eld Inlet.	a	c	459		Nonpoint Runoff
		Quilcene	a	p	50		Nonpoint Runoff
		Livingston B.	u	p	2550		Dairy rnff (river), STP
		Penn Cove	u	c	439		STP

* Decertified culture areas from Washington State Department of Ecology, 4/1984 Shellfish Protection Strategy.

Appendix B.1. Trends on the West Coast

State	Estuary	Area Name	Class'n 1971	Class'n 1985	Acres Changed losses	Acres Changed gains	Reason for Change
California							
	Monterey Bay	Elkhorn Slough	p	r		139	upgraded STP, Moss Landing sewered
	Tomales Bay	Tomales	a	ns/np			476 acres administrative
		Tomales (conditional)	a	c	13		Administrative
		Tomales (restricted)	a	r	987		Administrative
	Morro Bay	Morro Bay South	a	c	905		Administrative- better data
		Agua Hediondo	a	ns/np			289 acres approved for lease in 2/85
	California Totals	Total acres *reclassified*	**2044**		**1905**	**139**	
		percent of changes			93%	7%	
		Water Quality related Changes			0	139	
		Percent WQ Changes			0%	100%	
		Administrative or other Reasons			1905	0	
		Percent Administrative Changes			100%	0%	
Oregon	Coos Bay	Slough Entrance	p	a		1628	surveyed
		Coos Bay	p	c		5935	surveyed
	Winchester Bay	Umpqua R	p	a		3229	upgraded Stp
	Siletz Bay	Siletz Bay	ns/np	a			821
	Tillamook	Kilchis R to Tillamook R	a	p	13		Administrative
		Tillamook Bay	a	c	5666		increased monitoring
	Coquille River	Coquille R	p	a	355		surveyed
	Nehalem Bay	Wheeler	a	p	236		increased monitoring
	Yaquina Bay	Lower Yaquina R-Inset	p	a		172	Administrative
		Yaquina Bay	p	a		1990	Administrative
	Oregon Totals	*total acres affected*	19224		6270	12954	
		percent of changes			0.3262	0.673845194	
		Water Quality related Changes			0	3229	
		Percent WQ Changes			0	0.249266636	
		Administrative or other Reasons			6270	9725	
		Percent Administrative Changes			1	0.750733364	

State	Estuary	Area Name	Class'n 1971	Class'n 1985	Acres Changed losses	Acres Changed gains	Reason for Change
Washington							
	Willapa Bay	Willapa Bay	*	p	2552		Raymond, South Bend STPs
	Gray's Harbor	Grays Hbr	a	p	2665		STPs, mills
		North Bay	a	c	43085		nonpoint runoff
	Puget Sound	Olele Point	a	u	50		surveyed
		Brownsville Bay	u	a		30	
		Drayton Hbr	u	c	319		
		Westcott Bay	u	a		255	surveyed
		East Sound	u	a		140	surveyed
		Henry Island	u	a		149	surveyed
		Shoal Bay	u	a		276	surveyed
		Lummi Bay	u	a		2487	surveyed
		Washington Hbr	a	p	337		STP, urban runoff
		Burley Lagoon	*	p	480		nonpoint runoff/wildlife
		Henderson Inlet	*	p	163		urb runoff/septics/animals
		Minter Creek	u	p	93		nonpoint
		Fox Island	a	u	51		surveyed
		Filucy Bay	u	a		60	surveyed
		Nisquilly Reach	u	a		122	surveyed
		Lay Inlet	a	u	184		
		Allen Bank	u	a		153	surveyed
		Dolphin Point	u	a		306	surveyed
		Glen Acres	u	a		143	surveyed
		Lynch Cove	a	u	1673		
		N. of Reach Isl	a	u	102		
		Grapeview	a	u	153		
		Dougall Pt	u	p	194		STP
		McMichen	u	a		40	
		Wilson Pt	u	a		316	
		Quartermaster Hbr	a	u	235		
		Oakland Bay	*	c	1224		Shelton STP, mill
		Dyes Inlet	*	p	836		Bremerton STP
		Sinclair Inlet	*	p	3233		Bremerton STP
		Budd Inlet	*	p	1081		STP, Deschutes R
		Liberty Bay	*	p	2417		Poulsbo, STP, marina
		McLane	p	a		20	surveyed
		Henderson	a	p	163		nonpoint
		Lower Eld Inlet	a	c	459		nonpoint
			u	c	143		
		Eld Inlet	p	c		143	

State	Estuary	Area Name	Class'n 1971	Class'n 1985	Acres Changed losses	Acres Changed gains	Reason for Change
		Olele Pt	a	u	50		
	Hood Canal	Lone Rock	u	a		255	surveyed
		Misery Pt	u	a		40	surveyed
		Brownsville Bay	u	a		30	
		Duckabush	u	a		214	surveyed
		Sylopash Pt	u	a		612	surveyed
		Big Beef Hbr	u	a		408	
		Quilcene	a	p	50		nonpoint
		Mats Mats Bay	a	u	15		surveyed
		Colvos	a	u	204		surveyed
		Hood Canal	a	u	1673		
	Skagit Bay	North Port Susan	u	a		6120	
		Livingston Bay	u	p	2550		dairy runoff in Stillaguamish R, S
		Skagit Bay	u	a		8242	
		Penn Cove	u	c	439		STP
		San de Fuca	u	p	1020		
	Washington Totals	Total acres changed			67893	20561	88454
		percent of change			77%	23%	
		Water Quality Related		0%	0	143	1%
		Administrative or other		6%	4155	20418	99%

• Decertified Culture Areas from Washington State Dept. of Ecology, 4/1984. Shellfish Protection Strategy

Appendix C. Sources of Pollution Affecting West Coast Shellfish Growing Waters

State	Estuary	Chart	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	CSOs	Direct Dischg	Ind	Septics	Urban Runoff	Ag Runoff	Wildlife	Boating	Upstream STP	Industry	Ur Runoff	Ag Runoff	Wildlife
CA	Morro Bay	18703	North Morro Bay	709			709					709			709					
			Central Morro Bay		905									905					905	905
			South Morro Bay	564										564						
	Total Morro Bay			1?73	905	0	709					709		1469	709				905	905
	Percent of total						33					33		67	33				42	42
	Monterey Bay	18685	Santa Cruz Hrb	40			40					40			40					
			Santa Cruz	4			4					4			4					
			Elkhorn Slough			508							508							
			Moro Cojo Slough			34									34					
			Moss Landing Harbor			161									161					
			Monterey Hrb	65								65			65					
	Total Monterey Bay			109		703	44					109	508		304					
	Percent of total						5					13	63		37					
	San Francisco Bay	18649	Richardsonville Bay	3068											3068					
			Emeryville Bay	670			607					670			670					
			San Leandro Bay	831			831					831								
			Oakland Outer Harbor	627						627		627			627					
			Oakland Inner Harbor	3161			3161					3161			3161					
			Richmond Inner Harbor	1839			1839			1839				1839	1839					
			San Pablo Bay	4331						4331						4331				
			San Rafael Bay	314								314			314	314				
		18651	Coyote Point Harbor		593		593					593			593					
		18654	San Pablo Bay	64847						64847						64847				
	Total San Francisco Bay			79688	593		7031			71644		6196		1839	10272	69492				
	Percent of total			99	1		9			89		8		2	13	87				
	Drakes Bay		Schooner Bay		441								441	441						
			Home Bay		170								170							
	Total Drakes Bay				611								611	441						
	Percent of total												100	72						
	Tomales Bay		Tomales Bay		5259								5259							
			South Tomales Bay			884					884	884	884							
	Total Tomales Bay				5259	884					884	884	6143							
	Percent of total										14	14	100							
	Humboldt Bay	18622	Mad R Slough		25								25	25						
			Humbolt Bay	2788									2788	2788						
			Arcata Marsh	9026									9026	9026						
			Central Arcata Bay		4644								4644	4644						
	Total Humboldt Bay			11814	4669		0				0		16483	16483						
	Percent of total						0				0		100	100						
OR	Coos Bay	18587	N Slough & Haynes Inlt	682							682									
			Isthmus Slough	381								381								
			Coos Bay Channel	1081			1081			1081		1081								
			Coos Bay		5935					5935		5935								

State	Estuary	Chart	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	CSOs	Direct Dischg	Ind	Septics	Urban Runoff	Ag Runoff	Wildlife	Boating	Upstream STP	Industry	Ur Runoff	Ag Runoff	Wildlife
	Total Coos Bay			2144	5935		1081			7016	682	7397								
	Percent of Total						13			87	8	92								
	Winchester Bay	18584	Winchester Bay	120							120				120					
			Upper Umpqua R	2451			2451				2451	2451							2451	2451
	Total Winchester Bay			2571			2451				2571	2451			120				2451	2451
	Percent of total						95				100	95			5				95	95
	Siuslaw R	18583	Siuslaw R	1501							1501	1501								
	Percent of total										100	100								
	Yaquina Bay	18581	West Yaquina Bay	971								971			971					
			Upper Yaquina R-Inset	506			506				506		506							
			Yaquina	152							152			152						
	Total Yaquina Bay			1629			506				658	971	506	152	971					
	Percent of total						31				40	60	31	9	60					
	Siletz Bay	18520	Siletz River	110									110	110						
			Schooner Creek	273										273						
	Total Siletz Bay			383									110	383						
	Percent of total												29	100						
	Tillamook Bay	18558	Miami Cove	779			779		779			779			779					
			Kilchis R to Tillamook	2430			2430						2430							
			Tillamook Bay		5666		5666					5666	5666		5666		5666			
	Total Tillamook Bay			3209	5666				779			6445	8096		6445		5668			
	Percent of total								9			73	91		73		64			
	Nehalem Bay		Wheeler	236			236				236		236		236					
	Percent of total						100				100		100		100					
	Willapa Bay	18504	Willapa Bay pro.	2552			2552					2552								
	Percent of total						100					100								
WA	Grays Harbor	18502	Grays Harbor	16761			16761					16761								
			North Bay		43085											43085	43085	43085		
	Total Grays Harbor			16761	43085		16761					16761				43085	43085	43085		
	Percent of Total						28					28				72	72	72		
	Puget Sound	18441	Elliot Bay	1907			1907			1907		1907								
			Liberty Bay	2417			2417							2417						
			Scandia		224		224							224						
		18400	Bellingham Bay	1723			1723					1723								
			Draton Hrb		319							319								
			Lummi Indian Reserval	51			51													
		18465	Washington Hrb	337			337					337								
			Port Angeles	2275			2275					2275			2275					
		18448	Burley Lagoon	480								480		480						
			Miller Creek	93							93	93		93						
			Sinclair Inlet	3233			3233			3233		3233								
			Ostrich Bay	836								836								
			Elliot Bay	1196			1196			1196		1196								
			Olympia	1081			1081			1081		1081			1081					

State	Estuary	Chart	Area	Classification (acres) Prohibited	Conditional	Restricted	Pollution Sources (acres) STP	CSOs	Direct Dischg	Ind	Septics	Urban Runoff	Ag Runoff	Wildlife	Boating	Upstream STP	Industry	Ur Runoff	Ag Runoff	Wildlife
			Commencement Bay	5579			5579			5579		5579								
			Glen Cove	46							46	46								
			Dougall Point	194			194													
			Henderson	163							163	163	163							
			Lower Eld Inlet		602						602		602							
			Oakland Bay	1224			1224	1224		1224		1224								
	Hood Canal	18441	Little Quilcene River	204							204			204						
	Skagit Bay	18441	Livingston Bay	2550							2550	2550								
			Everett	2999			2999			2999		2999								
			San de Fuca	1020							1020	1020								
			Penn Cove		439						439	439								
	Total Puget Sound			29608	1584		24440	1224		17219	5117	27500	765	3418	3356					
	Percent of total						78	4		55	16	88	2	11	11					
	Total Hood Canal			*204*							*204*			*204*						
	Percent of total										*100*			*100*						
	Total Skagit Bay			*6569*	*439*		*2999*			*2999*	*4009*	*7008*								
	Percent of total						*43*			*43*	*57*	*100*								
	Total West Coast			153478	68307	1587	55575	1224	779	95879	11413	73476	33222	24185	22177		48751	43085	3356	3356
	Percent of total						25	1	0	43	5	33	15	11	10		22	19	2	2

Discovery Bay, Port Townsend, Mats Mats Bay, Ludlow Bay and Jackson Cove systems, Jefferson County. The county wide water quality monitoring program in Eastern Jefferson County began in January 1988-February 1989 by establishing baseline fecal coliform data for the five bays and their fresh water sources (Rubida, 1989). A total of 493 freshwater and 301 marine water samples were analyzed in the county's laboratory for fecal coliform levels. Elevated levels were observed in stream reaches that passed through agricultural areas. Some land owners have agreed to mitigate or correct the bacterial pollution problem through the use of BMPs. In Discovery Bay all creeks showed increases in fecal coliform densities during wet weather, attributed to agricultural activity. In Port Townsend Bay there are two point discharges; Port Townsend Paper Company discharging industrial and sewage effluent and the wastewater treatment plant at the Indian Island Naval Base. Cattle seem to be a major contributor to fecal coliform levels. Local watershed residents have devised the following strategy for improvement: sediment catch basins, controlled dredging of the creek corridor and enhancement projects. Mats Mats Bay meets all standards while Ludlow Bay suffers from heavy seasonal boating traffic (Washington DOH has developed a marina management strategy to address the discharge of wastes from boats.). Jackson Cove had excellent water quality, the lowest levels of fecal coliform of all bays tested.

Burley Lagoon-Minter Bay system, Bremerton-Kitsap County. Since 1980, six commercial oyster growing areas in Puget Sound have been closed because of bacterial contamination. Two of these are Burley Lagoon and Minter Bay. An intensive survey of these areas was performed during 1983-85 (Determan et al, 1985). The study recommended more stringent requirements for septic systems, particularly in marginal areas. At least 40 failing septic systems had been identified in the survey. Erosion and sediment controls were recommended to reduce fecal coliform loading from agricultural activities. A followup study was conducted in 1987 showing an average decrease in the fecal coliform levels in Burley Lagoon streams of 52 percent (Struck, 1988). The remedial action assessment showed 49 systems corrected out of a total of 49 failing. The report identified reasons for failures as inadequate siting, overloading and exceeding useful life (totaling 33 percent), construction error (33 percent), graywater discharges (20 percent) and poor maintenance practices (14 percent). Several BMPs were implemented ranging from fisheries enhancement and stream bank revegetation to rip-rap erosion control. In spite of all efforts to improve water quality, commercial oyster beds in Burley Lagoon and Minter Bay remain uncertified as fecal coliform levels are still unacceptable. Stations with highest levels of contamination correspond to areas with highest livestock density. Struck recommends annual sanitary surveys to identify septic failures, but suggests that unless small noncommercial farms are addressed as a major problem, water quality necessary for oyster production will not be achieved.

Henderson Eld and Totten Inlet, Thurston County. The 1984 Water Quality Study identified three primary sources of fecal coliform contamination to Henderson Inlet; urban stormwater runoff, pasture runoff and inadequate shoreline on-site sewage systems in order of impact (Taylor, 1984). The report concluded that the bacterial loading contributed by failing on-site sewage systems was only 13.9 percent under worst possible conditions. The second most important contributor to fecal contamination was "hobby farms," which usually lack proper fencing from streams, adequate storage and removal of manure, and stream bank destruction. Poor pasture management was cited, particularly the crowding of large animals which total over one thousand, depositing over 25,000 pounds of manure per day. Stormwater runoff was the major contributor of fecal contamination. Table 23 of the report presents a comparison of bacterial loadings from various sources showing that a single urban stormwater outfall, under ambient conditions, contributes a significantly larger bacterial loading on a daily basis than all failing septic systems together.

A 1986 report on Totten Inlet found that the water quality in Totten Inlet was relatively high, but expressed concern about increasing development and the large number of marginally operated or seasonally inadequate sewage disposal systems (Taylor, 1986). The report recommends the following approaches to future water quality management: (1) formal development and designation of a "Totten Inlet Basin Water Quality Protection District," (2) development of a special zoning ordinance to prevent growth that would exceed Totten watershed's carrying capacity, (3) adoption of basin-wide BMPs, (4) continued monitoring and (5) the development of a public awareness and education program. During the 1986 sanitary survey, 78 failing septic systems were identified, accounting for 22 percent of all sewage disposal systems in the watershed. A followup report covering a twelve month monitoring study of the water quality of Henderson, Eld and Totten Inlets concluded that water quality in Henderson Inlet was declining, attributed to stormwater, agricultural waste and failing on-site sewage systems (Harrison, 1988). In Eld Inlet water quality has improved, affected by minor stormwater runoff and failing systems. Totten Inlet is the cleanest system, but this report also recommends a protective strategy in order to maintain water quality. The watershed planning is ongoing for Totten/Little Skookum watershed, including monitoring, correction and education and conducted by Thurston County Health Department in cooperation with local citizens.

Sequim Bay, Clallam County. During 1986-87 Clallam County Department of Community Development conducted a project to determine the nonpoint pollution impacts of the watersheds draining into Sequim Bay (Brastad et al, 1987). Identified as the major contributor of bacterial contamination were large agricultural activities, both beef and dairy cattle operations. Irrigation ditches were also identified with a septic system failure of less than five percent. Recommendations included the goal of open status for all shellfish beds within 5 years with no seasonal closures. Water quality research and comparison studies were recommended along with monitoring, education. This advisory group also recommended monitoring for pesticides and herbicides and tax incentive programs including reduced fees for upgrading septic systems.

Quilcene/Dabob Bays, Jefferson County. In 1984 Kirk Cook of Washington DOH conducted a sanitary survey of Quilcene Bay which identified a large percentage of residences whose drainfields were extremely close to the bay. Seasonal failures due to high water tables and impermeable soil conditions caused bacteriological contamination, particularly during flooding. Tributary diking has raised the base level of rivers, resulting in the raising the groundwater level. Cook recommended continued closure of shellfish growing waters at the head of Quilcene Bay.

In response to the identified water quality problems, Jefferson County conducted a 13-month intensive analysis in the watersheds of Quilcene and Dabob bays. The study supported previous investigations, identifying failing septic systems, poor animal keeping practices and, possibly, a large population of marine mammals as contributors to fecal contamination. Malfunctioning septic systems were corrected using no-cost technical assistance for septic system design along with a loan program for low to moderate income households. Recommendations also included educational programs, monitoring programs and studies on the harbor seal population. The citizen's advisory committee also suggested that DOH and FDA begin using an indicator organism that is more closely correlated to the presence of a public health hazard. It was felt that use of the fecal coliform indicator discriminates against rural areas because domestic animals, wood wastes and seals contribute to high concentrations of fecal coliforms, yet may not contribute to a correspondingly high health hazard (Welch and Banks, 1987).

Lower Hood Canal, Mason County. In 1987, Mason County completed a study of lower Hood Canal, including all tributaries and marine waters from Skokomish River to Lynch Cove. Lynch Cove was found to have the most significant water quality problems, resulting from homes and farms on Union River and malfunctioning sewage systems of several commercial establishments. The report recommended that Lynch Cover be decertified and the public beach at Belfair State Park be posted. This report also raised the issue of the effectiveness of sewage systems placed in fill behind bulkheads.

In addition to the watershed studies funded by the Puget Sound Water Quality a review was made of additional Puget Sound reports addressing the water quality of shellfish growing areas.

Oakland Bay. A 1987 Mason County report prompted the revision of shellfish harvesting classifications due to high bacterial concentrations. (Michaud, 1987) Because of excessive coliform levels, commercial shellfish harvesting was restricted to relaying during the rainy season, decreasing the levels of harvesting. There were six certified commercial shellfish harvestors operating in Oakland Bay, accounting for 42 percent of the state's 1986 hardshell clam production. The pollution sources identified were stormwater discharges from the City of Shelton, industrial effluent and two creeks. This report also questioned fecal coliform indicator, partially because of the fact the the fecal coliform group includes Klebsiella which, although associated with human pathogens, is also found in industrial wastes, soil, water and vegetation.

A 1989 report, produced by Brown and Caldwell, consulting engineers, summarized sampling efforts to date, examined potential sources of bacterial contamination, and evaluated the contribution of various land uses to nonpoint source pollution in the watershed. Sampling results identified the most contaminated creeks as Uncle John's, Shelton, Goldsborough and Campbell. Mentioned as pollution sources to Goldsborough and upper Shelton creeks are urban runoff, surcharging sewers, sewer lines in poor condition, combined storm and sanitary lines. Deer and livestock affected Campbell Creek and significant contamination from horses and cattle affect Uncle John's Creek. Additionally the ITT laboratory discharge and Simpson stormwater discharge have a negative impact on Oakland Bay water quality.

Dosewallips River Delta. Under the Puget Sound Water Quality Management Plan, DOH conducted a restoration study of the Dosewallips river delta following a reclassification from approved to restricted of the southern section of the area, across from Sylopash Point. Clearly identified as the source of fecal coliform pollution were a herd of approximately 300 harbor seals. A sanitary survey was unable to identify other sources and the high fecal levels were recorded only in tributaries which served as haul-out sites by the seal herd. As mentioned in Section III of this report harbor seals are protected under the Marine Mammal Protection Act, restricting the kinds of corrective measures open to the state and county.

To further complicate the problems at Dosewallips, members of the Skokomish and Port Gamble Klallam tribes harvested, for commercial use, hardshell clams and oysters from within the park boundaries. DOH is reluctant to permit relay of shellfish from this restricted area to an approved growing area for purification. Under the NSSP, "an area may be classified as restricted when a sanitary survey indicates a limited degree of pollution— levels of fecal pollution or poisonous or deleterious substances are low enough that relaying or purifying —will make the shellfish safe to market." (FDA, NSSP Manual of Operations, Part 1, Sanitation of Shellfish Growing Areas). Section D of the manual provides guidelines for relaying; requirements that control the movement and harvesting of the shellfish and testing of the meats to ensure that the bacteriological quality is the same as identical species already in the approved or conditionally-approved areas.

Two additional areas of Puget Sound have had studies completed to address the quality of shellfish growing waters.

Samish River. A 1987 report by the Skagit County Conservation District concluded that from upstream to downstream sampling stations there is a 24-fold increase in fecal coliform levels. Increases overall closely correlated with rainfall events. The Samish River watershed contains 24 dairy farms, averaging 179 acres and over 8,000 animals producing over 34 million gallons of manure annually. Fifty percent of the dairies had long-term storage of manure. The others spread manure during winter months leading to field runoff and poor stream water quality. Discharge from milking centers also contributes to the waste problems. Over 20 percent of the farms allowed animals direct access to the waterways. As in other farming areas of the west coast, farmers are cooperating by applying BMPs to their farm operations

San Juan County. There are four active shellfish culture areas that were included in a recent water quality study: Shoal, Westcott, Ship and Open bays (Arnold, 1985). All bays tested met fecal coliform standards. Important to note is the fact that no samples were taken during heavy rainfall events. During the NOAA field work, we visited San Juan Islands to speak with local shellfish operators. Our impression is that water quality in both Westcott and Ship bays is threatened by increasing shoreline development and extensive boating activity.

On Shoal Bay, a one-half acre longline mussel operation is located as well as marina activities and residential development (60 percent of land area.)

Ship Bay attracts many shorebirds during the annual herring run. The beach is used for recreation and commercial oyster and clam culture. Two tideland plots, totalling 13 acres, are seeded, using stake culture and hand harvested. Although there are 2 sewer outfalls and a storm water collection system, the only problem mentioned in Arnold's report was pastureland.

There is a commercial oyster and clam culture operation on the southeast side of the Westcott Bay including an onshore hatchery, oyster spawning racks on the beach and a grow-out area of 3 to 8 acres. Oyster are suspended in lantern nets for grow-out while clams are seeded and hand-harvested on the beach. A nearby resort is served by a private sewer system. Shoreline residents and those on small feeder streams rely on septic systems, some of which malfunction as soils are seasonally wet and poorly drained. The existing problems coupled with pressure for additional shoreline development could have a negative impact on water quality.

Open Bay is used to store oysters from Westcott Bay during warm months of April to September. The cool waters of Open Bay retard oyster spawning allowing top quality production year-round. Lack of land access prevents extensive development although both Open and Nelson bays are popular summer anchorage areas for pleasure boats. The report found very low levels of fecal coliforms at Open Bay.

Approved Waters	Waters from which shellfish may be harvested for direct marketing.
Coliform Bacteria	A group of bacteria present in sewage that are used to indicate possible presence of enteric pathogens of sewage origin. Fecal coliform bacteria are a subset of the total coliform bacteria group and more specifically indicate presence of fecal material.
Conditionally Approved Waters	Waters that meet approved classification standards under predictable conditions. These waters are opened to harvest when water quality standards are met and are closed at all other times.
Depuration	A controlled purification process in which shellfish from restricted areas are placed in tanks through which bacteria-free water is circulated, usually for 48 hours before shellfish are removed for marketing.
Enteric pathogens	Human intestinal bacteria or viruses that cause gastroenteritis or hepatitis.
Harvest-limited Waters	Waters that are classified as prohibited, conditionally approved, or restricted.
National Shellfish Sanitation Program	A cooperative program of the U.S. Food and Drug Administration, shellfish-producing states, and the shellfish industry to control harvest and distribution of molluscan shellfish for human consumption.
Prohibited Waters	Waters from which shellfish may not be harvested for direct marketing. Until 1986, relaying was allowed in prohibited waters.
Relay	The transfer of shellfish from restricted (or prohibited until 1986) waters to approved waters for natural cleansing , usually for a minimum of 14 days before shellfish are harvested.
Restricted Waters	Waters from which harvest may occur only if shellfish are relayed or depurated before direct marketing.
Sanitary Survey	The evaluation of all factors determining the classification of waters, including actual and potential pollution sources, hydrographic and meterorologic conitions, and coliform bacteria sampling results.
Shellfish	Edible species of oysters, clams, and mussels.
Shellfish Culture	The planting, cultivation and harvest of shellfish.
Shellfish Growing Waters	Waters that are classified for the commercial harvest of shellfish.

Relevant Publications by NOAA

1. Data Atlas Vol. 1 - Physical and Hydrologic Characteristics; Nov. 1985.

2. 1985 National Shellfish Register of Classified Estuarine Waters; Dec. 1985.

3. An Inventory of Coastal Wetlands of the U.S.A.; Jan. 1986.

4. Coastal Wetlands: Establishing a National Data Base; Nov. 1986.

5. The National Coastal Pollutant Discharge Inventory - Estimates for Long Island Sound; Dec. 1986.

6. National Estuarine Inventory: Classified Shellfish Growing Waters by Estuary; Dec. 1986.

7. Data Atlas, Vol. 2 - Land Use Characteristics; Jan. 1987.

8. Land Use and the Nation's Estuaries; Mar. 1987.

9. The Quality of Shellfish Growing Waters in the Gulf of Mexico; Jan. 1988.

10. Shoreline Modification, Dredged Channels, and Dredged Material Disposal Areas in the Nation's Estuaries; Feb. 1988.

11. How Representative are the Estuaries Nominated for EPA's National Estuary Program?; Mar. 1988.

12. Estuarine Living Marine Resources Project - Washington State Component; May 1988.

13. The National Coastal Pollutant Discharge Inventory - Estimates for San Francisco Bay; Jun. 1988.

14. The National Coastal Pollutant Discharge Inventory - Estimates for Santa Monica Bay, San Pedro Bay, and San Diego Bay; Jul. 1988.

15. Strategic Assessment of Near Coastal Waters (Northeast Case Study) - Susceptibility and Status of Northeastern Estuaries to Nutrient Discharges; Jul. 1988.

16. The National Coastal Pollutant Discharge Inventory - Estimates for Columbia River; Aug. 1988.

17. The National Coastal Pollutant Discharge Inventory - Estimates for Puget Sound; Aug. 1988.

18. The Distribution and Areal Extent of Coastal Wetlands in Estuaries of the Gulf of Mexico; Nov. 1988.

19. (NEI: Supplement 1) Physical and Hydrologic Characteristics - The Oregon Estuaries; Nov. 1988.

20. Data Atlas, Vol. 4 - Public Recreation Facilities in Coastal Areas; Dec. 1988.

21. Data Atlas, Vol. 3 - Coastal Wetlands: New England Region; Jan. 1989.

22. The National Coastal Pollutant Discharge Inventory - Agricultural Pesticide Use in Estuarine Drainage Areas: A Preliminary Summary for Selected Pesticides; Jan. 1989.

23. (NEI Supplement 2) Characterization of Salinity and Temperature for Mobile Bay; Mar. 1989.

24. (NEI Supplement 3) Physical and Hydrologic Characteristics - The Mississippi Delta System Estuaries; Mar. 1989.

25. The Quality of Shellfish Growing Waters on the East Coast of the United States; Mar. 1989.

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