NOAA Technical Memorandum NOS OMA 42

A REVIEW AND SUMMARY OF TRACE CONTAMINANT DATA FOR COASTAL AND ESTUARINE OREGON

Seattle, Washington
March 1989

noaa NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

NATIONAL OCEAN SERVICE

Office of Oceanography and Marine Assessment
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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OMA implements NOAA responsibilities under Title II of the Marine Protection, Research, and Sanctuaries Act of 1972; Section 6 of the National Ocean Pollution Planning Act of 1978; and other Federal laws. It has three major line organizations: The Physical Oceanography Division, the Ocean Assessments Division, and the Ocean Systems Division.

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Seattle, Washington
March 1989

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NOTICE

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1. INTRODUCTION

1.1 Scope and Limitations

The Pacific Office of the Coastal and Estuarine Assessment Branch (CEAB) is within one of the three branches of the Ocean Assessments Division of the National Oceanic and Atmospheric Administration (NOAA). One mission of CEAB is to evaluate spatial and temporal patterns of marine environmental quality. This technical memorandum was initiated, in support of this mission, to present information on marine environmental quality in Oregon.

Marine environmental quality, as used in this report, has been given a particular working definition: only contamination or degradation of the coastal marine ecosystem by trace organics and trace metals was considered. These parameters present clear implications regarding the degree of impact upon the environment by human activities. Conventional oceanographic parameters--dissolved oxygen, temperature, pH, etc.--were not analyzed as indicators of marine environmental quality. Distinguishing natural cycles from anthropogenic impacts for conventional parameters was deemed beyond the scope of this project. The emphasis of this review was to identify areas indicative of higher degrees of contamination, primarily relative to ***statewide*** levels, and secondarily, relative to regional or coastal conditions.

The main purpose of this report was to draw together in one place, for the first time, all available information on trace contaminant levels in sediment, water, and biota from Oregon in the hope that sufficient data could be gathered to identify statistically significant geographic and temporal trends within the state. A secondary purpose was to begin the process of answering the question "Of what biological importance are these observed levels of contamination?" Some indication as to the relative ecological importance or impact of contamination is desired. Because essentially no information on pathological manifestations of pollution stress in Oregon was encountered, this latter goal was addressed by comparison between observed contaminant levels in Oregon and appropriate Food and Drug Administration (FDA) or Environmental Protection Agency (EPA) criteria, and by comparison with levels observed in areas of known contamination or with results of laboratory bioassay studies.

In addition to ambient environmental measures of chemical concentrations, a more direct measure of pollution was briefly reviewed: A survey of coastal point-source dischargers was made when the project was initiated to identify the scale and nature of anthropogenic inputs to the marine environment within Oregon.

In the preparation of this report, federal, state, and local agencies were surveyed as potential data sources. Also, extensive searches were made of computerized abstracts, published reports, and articles. It was found that the scope of marine environmental monitoring data in Oregon has been limited to essentially five categories:

- Investigations of a suite of chlorinated pesticides,
- Surveys of dichloro-diphenyltrichloroethane (DDT), its metabolic congeners, and polychlorinated biphenyls (PCBs).
- Investigations into the levels of aromatic hydrocarbons in bivalves.
- Analyses of trace metals.
- Studies of radionuclides.

The scope of this report was limited to the first four categories. Radionuclides are largely a matter of historical interest in Oregon. At one time, gradients in radioisotopes could be observed in coastal organisms past the Oregon-California border, and out to sea as far as 200 miles. After shutdown of reactors at Hanford in 1971, levels of radioisotopes, even in the Columbia River region, have generally dropped to background concentrations (Holton, personal communication). These elements may still be important as tracers and indicators of ocean processes.

1.2 Methodology

Although extensive searches were made to retrieve all possible contaminant data for Oregon, it is not be expected that *all* such data has been found. This database does represent the vast majority of such environmental contaminant data. Computer searches for data references were conducted on the Dialog system through National Technical Information Service, Pollution Abstracts, Oceanic Abstracts, Aquatic Sciences and Fisheries Abstracts, and the National Environmental Data Referral Service. Theses at Oregon State University College of Oceanography were also reviewed. Numerous office contacts were made with state and federal agencies, private companies, and investigators who had previously performed research in Oregon. Some data sets obtained have never been published or reported elsewhere.

No attempt has been made at data verification with original laboratories or principle investigators (with a few exceptions). Data was accepted as printed in journals, reports, etc. Whenever possible, raw data (*i.e.*, individual samples) were used in preference to summarized data. All biotic concentrations in this report are given on a wet weight (ww) basis, unless otherwise stated. All sediment concentrations are given on a dry weight (dw) basis. All statistical analyses in this report were conducted using MINITAB or STAT-PAK. Unless stated otherwise, all conclusions from statistical tests are based on a significance level (α) of 0.05 or better.

1.3 Environmental Setting of Oregon Estuaries

This report deals with the contamination of the near-shore oceanic environment, and the estuarine embayments of Oregon. For several reasons, however, the main focus of pollution assessments has frequently been on the estuarine zone. This is not only where most of man's wastes are directly discharged to the marine environment, but also the zone in which a great many of these wastes are deposited due to geophysical processes. Estuaries are biologically important zones as well. They are capable of high nutrient storage and can support great densities of biomass. They normally have a great diversity of species linked through an intricate network of predator-prey relationships. Estuaries also serve as nurseries or spawning grounds for several species of fish and shellfish, many of which are commercially harvested. These factors (plus a myriad of others) designate estuaries as critical habitats worthy of protection. It is no surprise then that the bulk of trace contaminant investigations in Oregon have been in estuaries.

There are 17 estuaries in Oregon (Figure 1.1). A characterization of size and activities for some is presented in Table 1.1. Three estuaries stand out as having major population centers with some degree of industrialization: Tillamook, Yaquina, and Coos bays. The majority of trace contaminant analyses in Oregon come from these three estuaries plus the Columbia River estuary (which lies partially in Washington State). Maps of these four areas may be found in Figures 1.2 and 1.3.

Coos Bay is the largest Oregon estuary. It is an important industrial bay with log storage, pulp manufacturing, lumber shipment, fish processing, marinas, and other industrial uses. These activities are spread out over the various sloughs and along North Bend, the main population center. In addition to two commercial oyster beds, there is heavy recreational use of clam beds in Coos Bay.

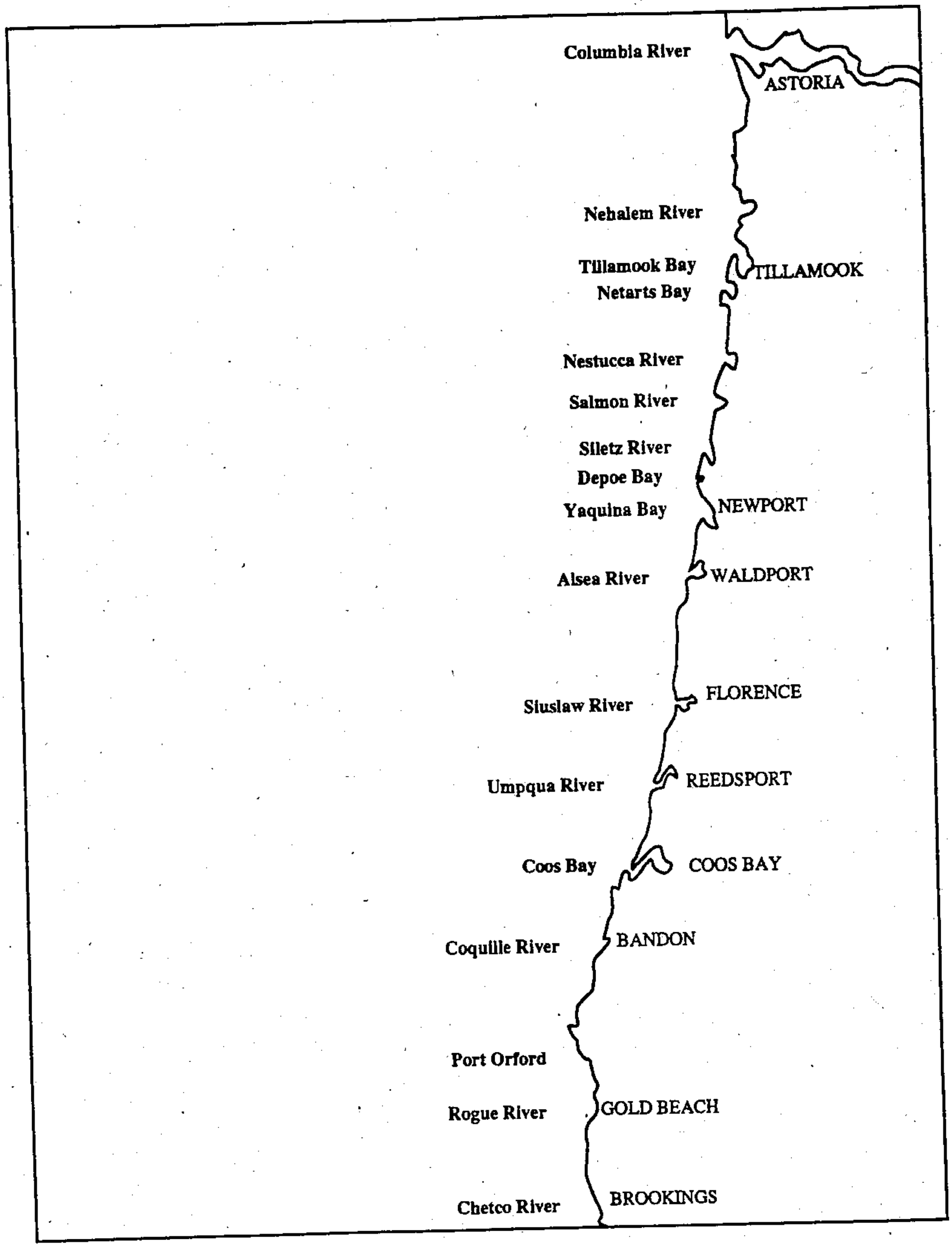

Figure 1.1. Oregon estuaries and their adjacent cities.

Table 1.1. Characteristics of Oregon estuaries.

Location	Estuarine[a,b] Surface Area (acres)	Drainage[b] Basin Area (sq mile)	Fresh Water[b] Input (x100acrefeet)	Adjacent[c] Human Population	Relative[d] Degree of Industry	Pulp[e] Mill/ Logs	Seafood Processors	Shipping	Sewage Inputs	Shellfish Growing Approval
Columbia River	93,782	258,000	92,575	1 million	*****	+	+	+	+	na
Nehalem Bay	2,309	847	2,700	1,188	*		+			20% closed
										80% open
Tillamook Bay	8,289	540	2,203	n.a.		**	+	+	+	60% closed
										40% conditional
Netarts Bay	2,325	15	2	930						100% open
Nestucca Bay	1,000	322	1,600	695	*				+	
Salmon River Estuary	204	75	450	65						
Siletz Bay	1,187	373	1,800	1,203	*				+	
Yaquina Bay	3,910	253	780	8,381	***	+	+	+	+	50% closed
										50% conditional
Alsea Bay	2,146	474	1,500	900	*	+			+	
Umpqua River	6,830	4,560	6,700	5,269	**	+	+	+	+	
Coos Bay	12,380	605	2,200	32,092	****	+	+	+	+	70% closed
Coquille River Estuary	771	1,058	2,400	9,180	*		+		+	

[a] Excludes marshes and narrow riverine sections of estuaries.
[b] Oregon Department of Fish & Wildlife, 1979.
[c] Population is an estimate of riverine and/or estuarine population from DSL Tideland maps, UAACE Environmental Impact Statements, and Oregon Department of Fish and Wildlife surveys.
[d] Level of indusry as rated by Oregon State Sea Grant undated; 1 is low and 5 is high.
[e] + indicates presence of activity.

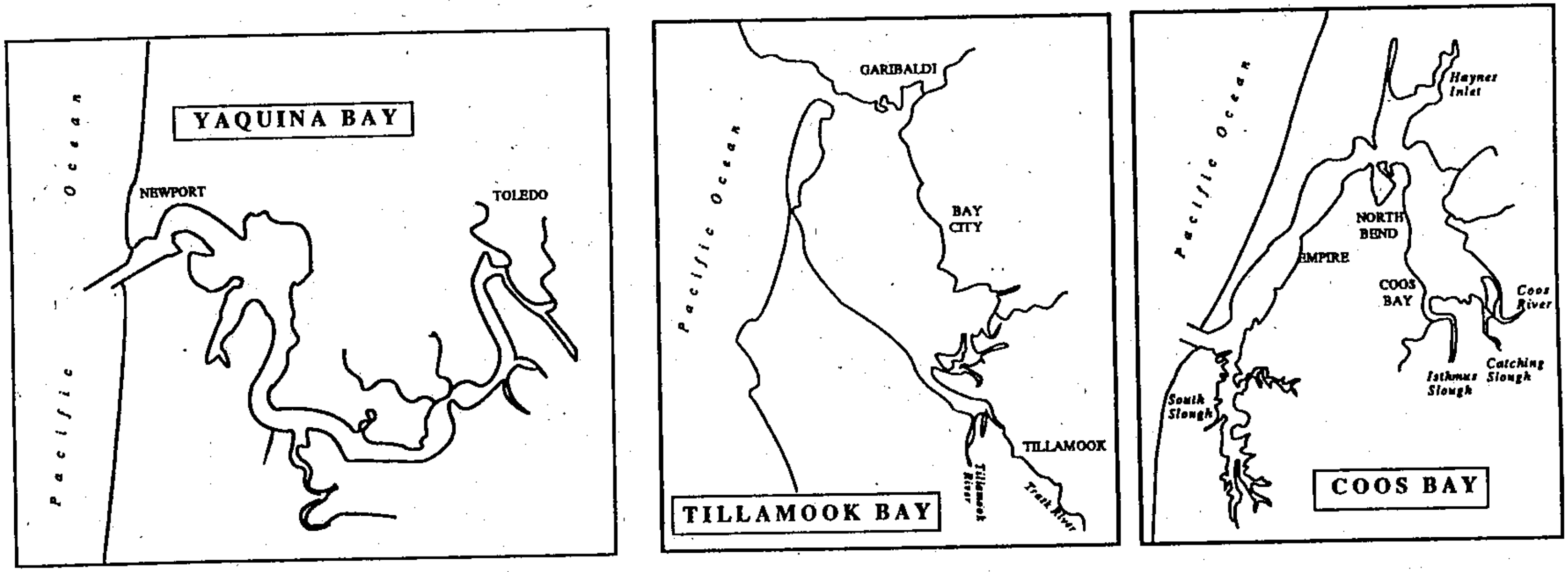

Figure 1.2. Three major coastal Oregon estuaries.

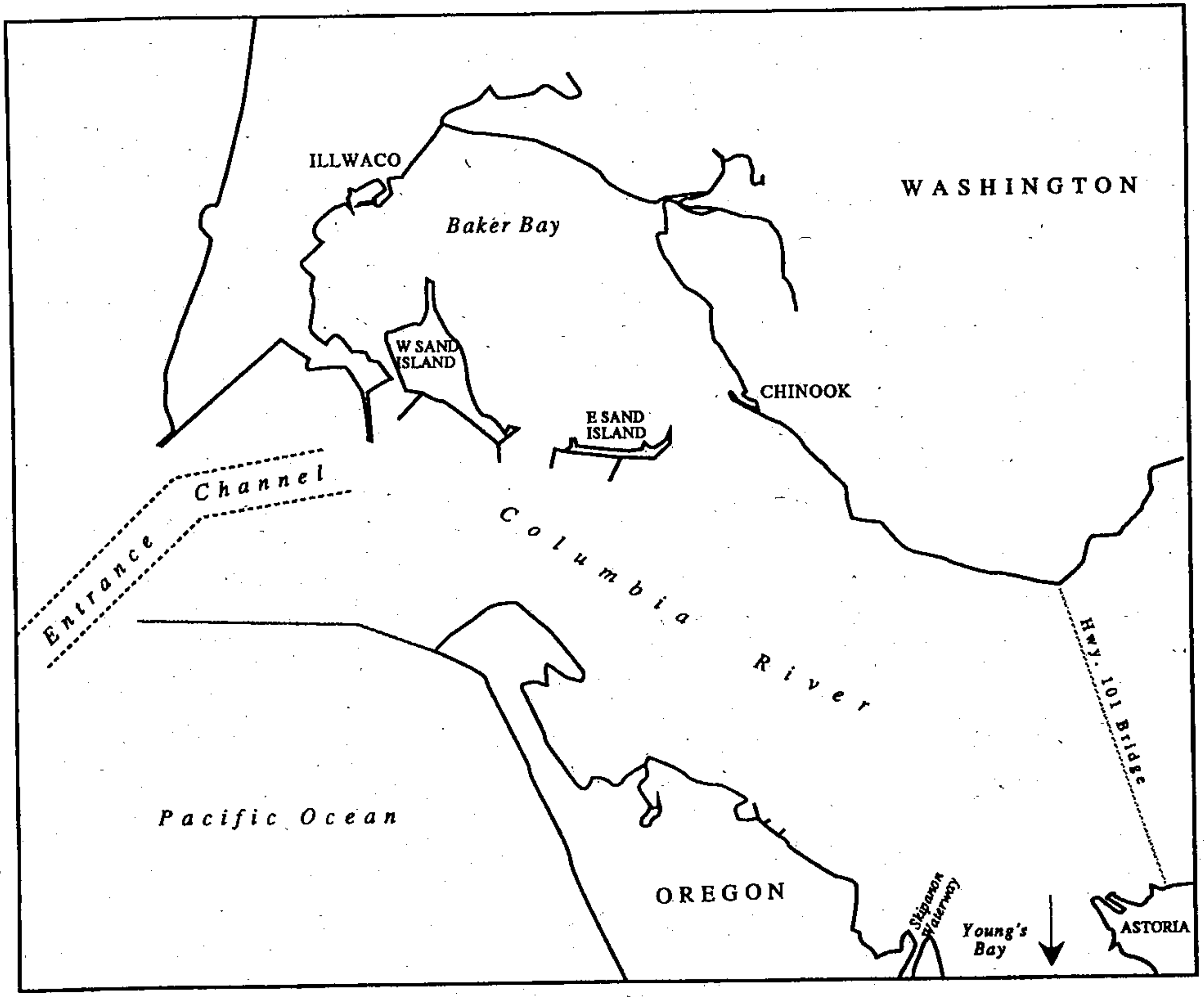

Figure 1.3. Major features of the Columbia River Estuary.

Tillamook Bay is the second largest Oregon estuary. Major industries in Tillamook include timber and agricultural products, fish and seafood processing, and tourism. There are three commercial oyster companies plus moderate recreational clamming.

Yaquina Bay is an important industrial, commercial, and natural resource bay. Fish processing, log storage, pulp manufacturing, lumber shipment, and moderate industrial processes all occur in Yaquina Bay. Most of this activity occurs in the lower reaches of the bay, with agricultural operations up-bay.

The Columbia is the largest river on the Pacific Coast and forms the boundary between Washington and Oregon, with the majority of its estuary coming under Oregon domain (approximately three-fourths). There is heavy commercial shipping traffic of pulp, paper, and wood products, foodstuffs, petroleum products, and a wide variety of other goods through the estuary. There are major boat basins in Ilwaco, Chinook, and Skipanon Waterway, plus commercial piers in Astoria. The estuary is also a major recreational and commercial salmon fishing area. Adjacent marshlands provide valuable habitat for waterfowl.

1.4 Environmental Setting of Coastal Oregon

Three principal features of physical coastal oceanography applicable to Oregon will be briefly considered--oceanic surface currents, upwelling, and the Columbia River Plume. These are large-scale phenomena which have great impact on ecosystem dynamics, as well as pollutant transport. For more detailed discussions, the reader is referred to Hickey (1979) for surface circulation, EPA (1971) for upwelling, and Barnes *et al.* (1972) for the Columbia River Plume. The following information has been summarized from these sources.

1.4.1 Surface Circulation

Patterns in large-scale circulation off Oregon are dominated by seasonal cycles of trade winds in the northeast Pacific. Ocean currents (and upwelling) characteristic of Oregon are driven by these trade winds, yet are highly coherent with sea level. There are two large-scale surface currents off Oregon: the California Current, a permanent feature and the Davidson Current, a seasonal flow.

The California Current is a broad, slow, shallow current flowing southward and seaward of the shelf. California Current water originates from the West Wind Drift and is basically subartic. Definition of the current varies, but it is generally considered to be a diffuse, offshore band ranging from 200 to 500 kilometers (km) off Oregon with an average alongshore speed of 0.2 knots in summer. The current is maintained, though diminished in extent during winter, and is bracketed by northward flow on its seaward boundary and a seasonal northward flow (the Davidson Current) on its landward boundary.

The Davidson Current is a seasonal, northward surface current flowing alongshore and inside of the California Current (*i.e.*, along the slope) with a minimum width of 50 miles, and is a countercurrent to the California Current. The driving force of the Current is local wind stress resulting from the south-southeasterly trades during winter. It has been hypothesized that the flow is a surface expression of the California Undercurrent. Its maximum speed varies from 0.5 to 0.9 knots, depending on the strength of winter winds. The Current begins to develop off the Oregon-Washington coast in September, and is well established by January. It wanes again in spring, disappearing by May.

1.4.2 Upwelling

During the summer season, when trade winds are consistently from the north-northwest, there is considerable transport of surface water offshore (to a depth of 10 to 20 meters) by Eckman dynamics. "Replacement" water for this transport is a subsurface counterflow of deep water that moves onshore, then up into the surface layer. This cycling of water results in the upwelling characteristic of the Oregon coast. The signature of this upwelled water mass is high nutrient content, low temperature, low dissolved oxygen, and high salinity.

Off Oregon, upwelling is of sufficient scale to bring the seasonal pychnocline to the surface, forming a surface front from about 10 to 20 km offshore. Waterborne pollutants, floating or particulate, may be concentrated along these fronts.

1.4.3 Columbia River Plume

In the coastal region of Washington and Oregon, the Columbia River is a major influence on the physical oceanography of the continental shelf. In late summer, the Columbia accounts for more than 90 percent of the freshwater drainage entering the seas between San Francisco Bay and the Strait of Juan de Fuca; in winter, this decreases to slightly over 60 percent. Because of the enormous drainage basin, over 670,000 km^2, and the inland nature of this basin, cycles of the Columbia River Plume are not synchronous with those of other coastal rivers. Most coastal systems experience their peak flow in fall or winter. The Columbia's peak discharge of 21,000 $meter^3$ per second, the result of interior snowmelt, is attained by May or June.

The Columbia River Plume maintains its identity for hundreds of kilometers as it moves under the influence of local winds and oceanic currents. The scale of dominance of the Plume in the north Pacific may be seen in surface salinities during summer (Figure 1.4B). Dissolved and suspended contaminants associated with the Columbia River may be expected to follow the general direction of the Plume, though not necessarily for the full distance the Plume is detectable.

The Plume shifts from north to south seasonally, as may be seen in Figure 1.4A-D, according to the influence of the Davidson and California Currents. During winter, the Plume hugs the Washington coast to as far north as the Strait of Juan de Fuca. In summer, it drifts to the southwest. The vertical extent of the influence also shifts seasonally. Depending on river flow, the Plume extends down 40 to 60 meters.

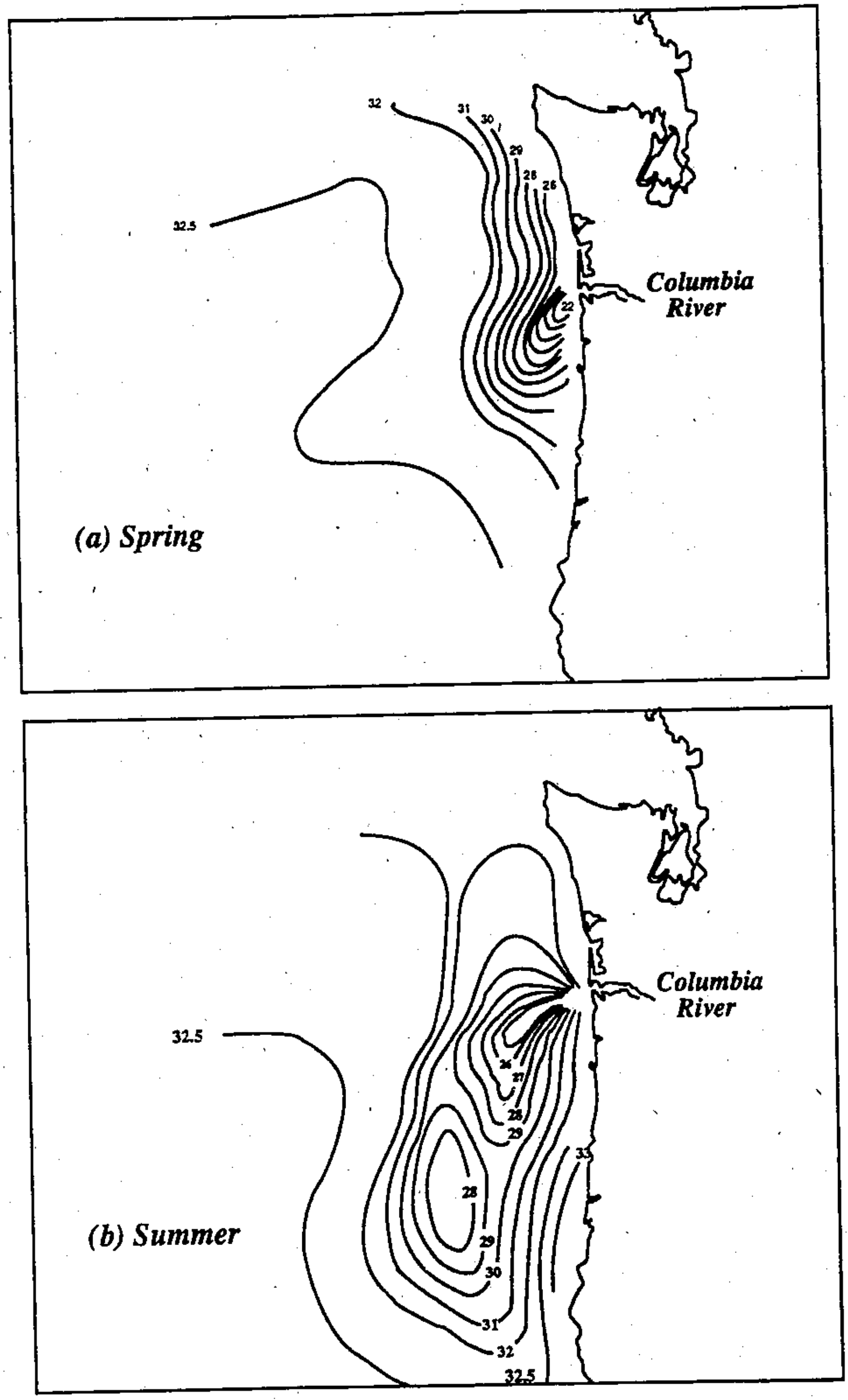

Figure 1.4. Mean surface salinity contours in the Columbia River plume region, by season (Barnes et al., 1972).

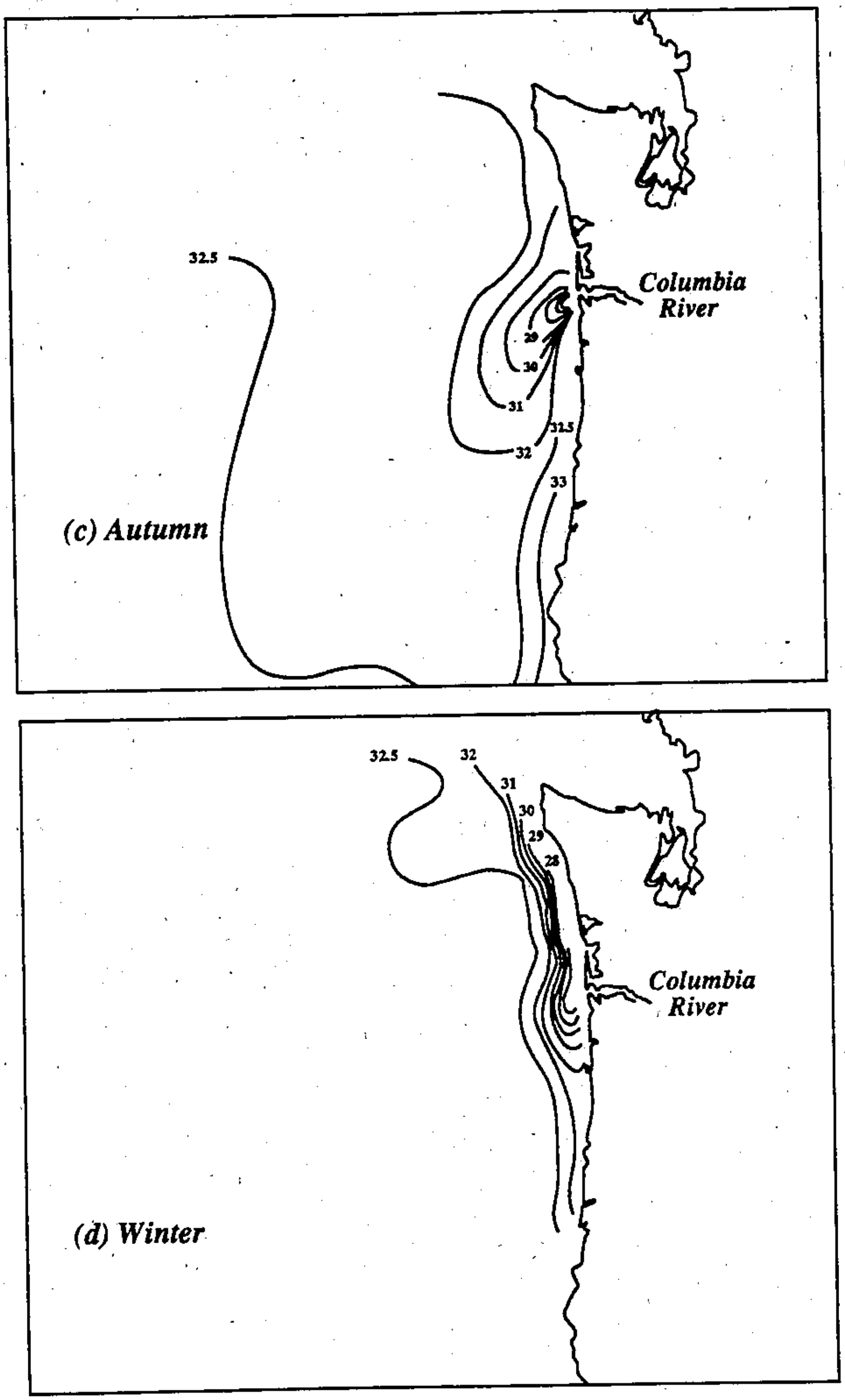

Figure 1.4 cont. Mean surface salinity contours in the Columbia River plume region, by season (Barnes et al., 1972).

2. POINT-SOURCE DISCHARGES

The EPA maintains a file of point-source dischargers of pollutants as one requirement of the Congressional mandate to control these sources. Dischargers are required to obtain permits in order to release their effluents. It is this permit system, the National Pollution Discharge Elimination System (NPDES), which allows a partial inventory of what is being released to the environment. Major dischargers are generally required to monitor their effluent on some regular basis to insure their permit regulations are not violated. An example of the information available in NPDES permittee reports held by EPA is shown in Figure 2.1.

The EPA uses a rating system based on effluent composition, volume, and quality of receiving water to determine whether a source is "major" or not. In Oregon, "major" dischargers are considered to be those which discharge more than 1 million gallons per day (MGD); those having certain "water-based quality" (mainly the presence and level of chlorine residuals or nitrogenous by-products); and permittees whose effluents are known to contain highly toxic components, regardless of volume.

2.1 Conventional Pollutants From Coastal Dischargers

NPDES lists 276 point source dischargers as being "coastal" dischargers. Actually, these discharges may be direct to the ocean or estuaries or to coastal streams and rivers. Of the 276, only the following 14 dischargers are considered "major" with truly oceanic ones denoted by an asterisk:

City of Ashland	discharging	to	Rogue River
City of Coos Bay (Plants 1 and 2)	"	"	Coos Bay *
Georgia Pacific (Toledo)	"	"	Pacific Ocean *
City of Grants Pass	"	"	Rogue River
Henna Nickel Smelting Co.(Riddle)	"	"	Crawford Creek
International Paper Co.(Gardiner)	"	"	Pacific Ocean *
City of Medford	"	"	Rogue River
City of North Bend	"	"	Coos Bay *
North Roseburg Sanitary District	"	"	S. Umpqua River
City of Roseburg	"	"	S. Umpqua River
Tillamook County Creamery	"	"	Wilson River *
City of Tillamook	"	"	Trask River *
Weyerhaeuser (North Bend)	"	"	Pacific Ocean *

All of these dischargers are required to measure biological oxygen demand (BOD), pH, and suspended solids (Table 2.1). Other parameters may be included as appropriate. For instance, large sewage treatment plants measure coliform and chlorine residuals; the Toledo Georgia-Pacific pulp and paper plant and the Tillamook County Creamery are required to monitor cooling water temperature; and the Hanna Nickel Smelter is required to measure suspended solids, pH, chromium (Cr), and manganese (Mn).

Reports from EPA's NPDES system do not indicate that any major dischargers had violations of the maximum allowable concentrations or discharge rates in their permits during a 1 year period (June 1982 to 1983). However, according to permittee reports, it was not uncommon for discharge rates to be exceeded, most often during winter months. Allowances are made by Oregon State Department of Environmental Quality (DEQ) which administers the NPDES program according to permit type and circumstances. For instance, exceeding a daily limit is allowed if discharges are compensated such that the monthly limit is not exceeded. DEQ makes spot inspections and checks of dischargers approximately once a year to determine whether the monitoring information provided by permittees is reasonable.

EPA REGION X
POINT SOURCE SYSTEM
PERMIT CONDITIONS AND DMR DATA REPORT
(REPORT#9)
REPORT COVERS: 820701 TO 830731

3-OCT-83
PAGE 2

PORTLAND, CITY OF - COLUMBIA B

OR0026905
PORTLAND CITY OF
——> PIPE=001

DIST: 05
COLUMBIA RIVER
M
SIC : 4952

INITIAL LIMITS :
INTERIM LIMITS: 740705 - 790531
FINAL LIMITS: 800205 - 840531

REPORT DATE	LIMIT SP	CON	PCODE	PARAMETER NAME	UNITS	PERMIT CONDITIONS MINIMUM	AVERAGE	MAXIMUM	FREQ	TYPE	ACTUAL REPORTED MINIMUM	AVERAGE	MAXIMUM	FREQ	TYPE
820701	F	56	00310	BOD	MG/L		30		01/01	24		26	44	05/07	24
	F	56	00310	BOD	LBS/DAY		25000	50000	01/01	24		26	22605	05/07	24
	F	56	00400	PH	STD	6.0		9.0	01/01	24	6.7		7.0	01/01	GR
	F	56	00530	SUSPENDED SOLIDS	MG/L		30	45	01/01	24		30	40	05/07	24
	F	56	00530	SUSPENDED SOLIDS	LBS/DAY		25000	50000	01/01	24		15237	21210	05/07	24
	F	56	31616	FECAL COLIFORM	#/100ML		200	400	01/07	GR		10	400	02/07	GR
	F	56	50050	FLOW	MGD		100		01/01			60.9	74.8	01/01	RC
	F	56	50060	CHLORINE RESIDUAL	MG/L				01/01	CN	.2	1.4	2.9	01/01	GR
820801	F	56	00310	BOD	MG/L		30	45	01/01	24		15	38	05/07	24
	F	56	00310	BOD	LBS/DAY		25000	50000	01/01	24		8156	25871	05/07	24
	F	56	00400	PH	STD	6.0		9.0	01/01	24	6.4		7.0	05/07	GR
	F	56	00530	SUSPENDED SOLIDS	MG/L		30	45	01/01	24		13050	28222	05/07	24
	F	56	00530	SUSPENDED SOLIDS	LBS/DAY		39	45	01/01	24		24	36	05/07	24
	F	56	31616	FECAL COLIFORM	#/100ML		200	400	01/07	GR		41	200000	01/01	GR
	F	56	50050	FLOW	MGD		100		01/01			65.2	94.8	01/01	RC
	F	56	50060	CHLORINE RESIDUAL	MG/L				01/01	CN	.1	1.3	2.6	05/07	GR
820901	F	56	00310	BOD	MG/L		30	45	01/01	24		12	42	01/01	24
	F	56	00310	BOD	LBS/DAY		25000	50000	01/01	24		8177	60879	01/01	24
	F	56	00400	PH	STD	6.0		9.0	01/01	24	6.4		6.9	05/07	GR
	F	56	00530	SUSPENDED SOLIDS	MG/L		30	45	01/01	24		22	38	05/07	24
	F	56	00530	SUSPENDED SOLIDS	LBS/DAY		25000	50000	01/01	24		12678	21012	05/07	24
	F	56	31616	FECAL COLIFORM	#/100ML		200	400	01/07	GR		1	4	02/07	GR
	F	56	50050	FLOW	MGD		100		01/01			69.1	173.8	01/01	RC
	F	56	50060	CHLORINE RESIDUAL	MG/L				01/01	CN	.1	1.1	2.8	05/07	GR
821001	F	56	00310	BOD	MG/L		30		01/01	24		18	60	01/01	24
	F	56	00310	BOD	LBS/DAY		25000	50000	01/01	24		12827	68004	01/01	24
	F	56	00400	PH	STD	6.0		9.0	01/01	24	6.0		6.9	05/07	GR
	F	56	00530	SUSPENDED SOLIDS	MG/L		30	45	01/01	24		25	64	05/07	24
	F	56	00530	SUSPENDED SOLIDS	LBS/DAY		25000	50000	01/01	24		16525	54660	05/07	24
	F	56	31616	FECAL COLIFORM	#/100ML		200	400	01/07	GR		1	100	03/07	GR
	F	56	50050	FLOW	MGD		100		01/01			70.0	135.9	01/01	RC
	F	56	50060	CHLORINE RESIDUAL	MG/L				01/01	CN	.6	1.2	2.2	05/07	GR

Figure 2.1 Sample NPDES permit data report.

Table 2.1. BOD and suspended solids discharges
(Permittee NPDES data from June, 1982 through June, 1983).

Location	BOD (lbs. per day)	Suspended Solids (lbs. per day)
Coastal Dischargers		
Coos Bay	1,026	1,158
Tillamook Bay	119	326
Umpqua River	3,868	3,483
Pacific Ocean at Yaquina Bay	8,100	14,613
Pacific Ocean at Coos Bay	1,054	2,069
Columbia River Discharges (Washington and Oregon)		
Tualatin River (n=2)	448	500
Willamette River (n=11)	11,043	41,716
Portland and (n=5) upriver	34,915	50,458
Below Portland (n=9)	7,324	97,414
Total Riverine (n=27)	103,730	190,088

2.2 Conventional Pollutants From Columbia River Dischargers

The NPDES lists 656 dischargers to the Columbia River, and major tributaries which merge with the Columbia along the Washington and Oregon borders. These dischargers may be 100 miles removed from the Columbia, as in the case of permittees along the Willamette River. Of these 656, there are only 27 "major" dischargers to the Columbia River below Bonneville Dam or to tributaries within 20 miles of their confluence with the Columbia. Table 2.1 also provides summary data for these major dischargers. Sewage treatment plants and pulp or paper mills account for 70 percent of these "major" dischargers.

The annual, cumulative discharge of suspended solids from these permittees was approximately 0.035 million tons per year. After settling, the total is estimated to be 0.017 million tons per year at Vancouver (CREST, 1977). This can be compared to the total suspended solid flux for the Columbia River, estimated at 10.5 million tons per year at Portland (CREST, 1977). The load at Astoria is approximately 40 percent of this figure. (The Columbia estuary experiences complex, cyclic variations in suspended solid fluxes, both seaward and landward, according to river flow and tidal regime). Clearly, the anthropogenic flux of solids to the Columbia system is trivial in relation to the total riverine load. However, this is not to imply that the chemical composition or effect of some of these inputs may be trivial. Also, there is the potential for decreased natural suspended solids loadings as water level management of the Columbia has increased, thus increasing the relative portion due to dischargers.

2.3 Trace Contaminant Discharges

In addition to measures of conventional pollutants, NPDES reports from major dischargers do provide some limited trace contaminant loading data for inorganic and bulk organic compounds. In the Columbia (Oregon and Washington), they indicate a total oil and grease input of approximately 150 pounds per day; less than 1 pound per day of phenols; and 2 pounds per day of cyanide.

DEQ has made estimates for the statewide metals loadings from major dischargers throughout Oregon (Table 2.2). Nearly all of these sources discharge to the Willamette River system, which carries slightly more than 70 percent of the entire state metals load. Zinc (Zn) constitutes 70 percent of this total Willamette metals burden (Dunnette, 1983). These Willamette dischargers may be over 100 miles away from the confluence with the Columbia River, which again is many miles away from the estuary.

One final note concerning trace metal discharges: only five metals are estimated to have statewide anthropogenic mobilization rates equal to or greater than natural levels–cadmium (Cd), copper (Cu), mercury (Hg), lead (Pb), and Zn (Dunnette, 1983). Riverine loads of other trace metal compounds are assumed to be principally the result of natural weathering processes, though they may be augmented by anthropogenic sources as well (Dunnette, 1983).

2.4 Effluent Bioassays

DEQ tested the toxicity of effluent from selected major dischargers during 1981 and 1982. A static renewal, 96-hour, acute bioassay procedure was used. Steelhead trout in 20 liter aquaria at 13°C were the test organisms. Renewal of test water was made at 24-hour intervals.

The metallic composition of effluents and results of these bioassays are presented in Table 2.3. Nearly half of the dischargers' effluents possessed no observable acute toxic impacts. The only metals present above detection limits were moderately elevated levels of Cu and Zn in two effluents. Direct correlations between metallic composition and LC_{50}s are not high because of mitigating factors such as pH, hardness, or carbon content (Dunnette, 1983).

2.5 Spills

DEQ has reported summary information concerning chemical spills throughout Oregon for the last decade (Table 2.4). The number of marine spills cannot be separated from the regional totals; presently, the majority of spills occur in freshwater or on land. Nevertheless, there is potential for future marine spills and there have been significant spills in recent years- the Mobile Oil spill in the Columbia River (March 1984) and the Blue Magpie at Yaquina Bay (November 1983).

The data show an increase in the incidence of hazardous chemical spill events and spills requiring DEQ field response. This is due partly to increased reporting of such incidents, and partly due to increased transportation of hazardous wastes through the state (Sutherland, personal communication). In 1986, one third of all spills statewide were the result of transportation accidents. Of these spills, 83 percent occurred on highways and involved cargo and fuel equally. Only 3 percent of the transportation spills were from ships. Of all spills statewide in 1986, two-thirds were of gasoline or petroleum products, while a variety of chemical spills comprised the remainder. PCBs represented 6 percent of all spills, or nearly 20 percent of the chemical spills. While this may seem high, public awareness and concern may lead to higher reporting rates for this class of compounds (Sutherland, personal communication).

Table 2.2. Trace metal loadings for "major" Oregon industries (Dunnette, 1983) (units in pounds per day).

COMPANY	LOCATION	STREAM	As	Cd	Cu	Cr	Pb	Hg	Zn
Borden Chemical[a]	Springfield	Willamette							0.03
Champion Building[b]	Dee	Hood	0.01	0.020	0.25		0.17	0.002	0.64
Crown Zellerbach[b]	Wauna	Columbia	0.01		0.04	0.17			0.08
Crown Zellerbach[b]	West Linn	Willamette			0.90				5.00
Halsey Pulp	Halsey	Willamette	0.44		3.00			0.20	9.00
Hanna Nickel[a]	Riddle	Cow Creek	0.05			0.15	0.08		
Oregon Metalurgical[b]	Albany	Oak Creek			0.18				0.29
Owens-Corning[b]	St.Helens	Columbia	0.01		0.12	0.04	0.12	0.005	0.77
Pennwalt[b]	Portland	Willamette	0.08			10.40	6.90	0.03	11.7
Portland Willamette	Portland	Columbia			0.01				
Publishers Paper[b]	Newberg	Willamette			4.09				17.97
Publishers Paper[b]	Oregon City	Willamette			5.86				13.64
Reynolds Metals	Troutdale	Columbia		0.090					
Wacker[a]	Portland	Willamette				0.04			
Weyerhauser[b]	Springfield	Willamette			0.51				16.00
TOTALS			0.60	0.11	14.96	10.44	7.27	0.237	75.12

[a] Based on NPDES monitoring data during summer 1981 (3-4 grab samples).

[b] Based on consolidated permit data (generally a single 24-hour composite).

Table 2.3. Industrial effluent toxicity bioassay results (Dunnette, 1983).

	Characteristics of Wastewater[a]														Toxicity Bioassay Results (96 hour)
	As	Cd	Cr	Cu	Pb	Hg	Zn	Hardness	Alka-linity	Conduc-tivity	pH	TOC	TKN	Flow mgd	
Teledyne Wah Chang	bd	bd	3	7	11	bd	30	2,720	22	7,300	7.2	10	7.2	2.5	None
Publishers, Newberg	bd	bd	5	27	10	bd	100	350	68	989	6.9	340	14.0	11.4	19%
Publishers, Oregon City	bd	bd	5	27	10	bd	100	318	77	913	7.0		9.2	9.0	23%
Crown Z, West Linn	bd	bd	2	3	bd	bd	30	67	37	228	6.8		3.0	7.0	90%
Tektronix			100	1,500			100	–	219	2,620	8.4			1.2	65%
Oregon Metallurgical	bd	bd	bd	7	bd	bd	bd	1,740	469	7,310	7.7	100	bd	1.0	46%
Weyerhaeuser Springfield	bd	bd	5	2	bd	bd	20	82	60	973	7.1		4.8	10.0	None
Hanna Nickel	bd	bd	36	4	bd	bd	bd	155	152	305	8.2			None	
None															
Boise Cascade, Salem									39	1,054	6.6			18.2	None
Pennwalt									2	441	6.2			37	47%
American Can, Halsey	bd	bd	5	bd	bd	bd	20	171	152	2,300	6.6		4.2	14.5	None
American Can									60	2,080	7.0				17-42
Detection limits		5	1	2	2	10	0.05								

[a] parts per billion (ppb): As, Cd, Cr, Cu, Pb, Hg, Zn, and parts per million (ppm): Hardness, Alkalinity, total organic carbon (TOC), total Kjeldahl nitrogen (TKN)

Table 2.4. Number of spills for DEQ's three coastal regions, 1976-1986 (DEQ, 1987).

Region	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986
Northwest Region											
Petroleum/Sewage	133	150	163	181	130	97	84	131	118	97	76
Chemical/Hazardous	*	*	*	*	*	22	39	47	31	53	65
DEQ Field Response	13	22	37	44	43	30	39	65	48	*	27
Willamette Valley Region											
Petroleum/Sewage	32	44	29	39	30	21	39	59	60	52	100
Chemical/Hazardous	*	*	*	*	*	6	12	22	18	24	43
DEQ Field Response	25	32	20	33	22	18	40	48	40	*	39
Southwest Region											
Petroleum/Sewage	17	16	19	11	22	33	26	59	77	50	62
Chemical/Hazardous	*	*	*	*	*	7	5	9	19	20	14
DEQ Field Response	12	6	13	6	19	33	20	31	75	*	53
TOTAL						186	205	299	323	296	360

* Information for these years is not available.

Summary

- Of the "major" dischargers in Oregon (those with greater than 1 MGD or having certain "water-based" quality), 70 percent are either sewage treatment plants or pulp and paper mills.

- The NPDES permitting system lists seven major marine dischargers along the Oregon Coast, discharging a total of 21,620 pounds per day of suspended solids and 14,170 pounds per day BOD, during 1982 and 1983.

- NPDES lists 27 major dischargers within the Columbia River region (below Bonneville Dam or in tributaries within 20 miles of confluence from either the Washington or Oregon side) with a 1982-83 yearly average discharge of 190,000 pounds per day suspended solids, 104,000 pounds per day of BOD, 190 pounds per day of oil and grease, 2 pounds per day of cyanide, and less than 1 pound per day of phenols. This solids load is minimal, by weight comparison, to the total suspended solids load of the Columbia River.

- Although dischargers exceed their short-term permitted rates on occasion (usually during winter months), as a whole they are averaging within 60 to 80 percent of their cumulative, annual permitted discharges.

3. CHLORINATED HYDROCARBONS

Although studies of chlorinated hydrocarbons in Oregon's marine environment are scarce and focus almost exclusively on pesticides, they are in general agreement as to which of these compounds have commonly been observed. While other compounds have been detected on occasion (see Table 3.12), DDT and its metabolites, PCBs, chlordane, and dieldrin are the chlorinated pesticides most often detected in Oregon samples. However, there are several classes of significant environmental pollutants which have not been investigated at all within Oregon. The following section will discuss chlorinated pesticides **except** DDT and its metabolites. Due to the greater sampling effort expended on DDT and PCBs, a separate discussion of these compounds will follow in Section 3.2.

3.1 Chlorinated Pesticides (Excluding DDT)

3.1.1 Sediment and water concentrations

Only four reports detailing pollutant levels in sediments or water were encountered in published journals or reports. Three of these reports addressed levels in sediments or water, and the other dealt specifically with Columbia River water.

The United States Geological Survey (USGS), in cooperation with the United States Army Corps of Engineers (COE), conducted a survey of chlorinated hydrocarbons and selected metals in filtered water and sediments of Tillamook, Coos, Yaquina, Umpqua, and Columbia river estuaries in 1980, plus the Rogue and Chetco rivers in 1982 (Fuhrer and Rinella, 1983; Fuhrer, 1984). The 1982 sampling also reinvestigated metals at some Columbia River sites. The analysis methods of Goerlitz and Brown (1972) were used for 1980 organics samples and of Wershaw (1983) for the latter ones, along with a quality assurance program of replicates, blind samples, and standard addition samples. As these two methodologies are essentially the same (Schroeder, personal communication), the two sampling events will be considered synoptic. The compounds tested for and the appropriate detection limits are presented in Table 3.1.

Chlorinated pesticides were above detection limits in sediments at four of the seven estuaries--the Columbia River Estuary, Yaquina Bay, and the Rogue and Chetco rivers (Figure 3.1). Dieldrin and chlordane were most common. In Yaquina Bay, only dieldrin at 0.5 parts per billion (ppb) was found in sediment; at the other sites, a suite of three to five compounds were detected. Also at Yaquina Bay, 2,4-DP[1] at 0.01 ppb was detected in filtered water near the entrance jetty. This was the only water sample to contain any compounds above detection limits. The occurrence of aldrin in the Columbia River sediment is suggestive of recent inputs, since this pesticide readily hydrolyzes to dieldrin (Callahan *et al.*, 1979).

The COE has also conducted sediment and water sampling in Coos Bay and at proposed disposal sites off the entrance jetty from 1979 through 1981 (Sollitt *et al.*, 1984). Analyses were conducted according to EPA methodologies. Aldrin and dieldrin values were the only pesticide data provided in published reports.

Samples of sediments offshore from Coos Bay (n=25) before disposal did not indicate any aldrin residues above the detection limits of 0.02 ppb, however it was detected in all but one water column sample (n=17 of 18) at a mean concentration of 2 parts per trillion (pptr). Also, dieldrin was found in about half the water samples (n=8 of 18) at a mean level of 3 pptr. It may be that aldrin in the sediments had been converted to dieldrin, which was not reported for the sediment samples, or that recovery was too low to detect this pesticide. Given that both these

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[1] a herbicide comprised of 4-(2,4-dichlorophenoxy)butanoic acid.

Table 3.1. Compounds, detection limits, and occurrence of organics analyzed by USGS/COE (Fuhrer and Rinella, 1983).

	Compound	Detection Limits	Occurrence
Sediment: (dry wt)	Aldrin	0.1 ppb	+
	Chlordane	" "	+
	Dieldrin	" "	+
	DDT	" "	+
	Endosulfan	" "	
	Endrin	" "	
	Heptachlor	" "	+
	Heptachlor epoxide	" "	
	Lindane	" "	+
	Methoxychlor	" "	+
	Mirex	" "	
	PCBs	1 ppb	+
	PCN	" "	
	Perthane	" "	
	Silvex	" "	
	Toxaphene	" "	
	2,4-D	" "	
	2,4,5-T	" "	
	2,4-DP	" "	
Native Water:	Aldrin	0.01 ppb	
	Ametryne	0.1 ppb	
	Atraone	" "	
	Atrazine	" "	
	Chlordane	" "	
	Dieldrin	0.01 ppb	
	DDT	" "	
	Endosulfan	" "	
	Endrin	" "	
	Heptachlor	" "	
	Heptachlor epoxide	" "	
	Lindane	" "	
	Methoxychlor	" "	
	Mirex	" "	
	Polychlorinated Naphthalenes	0.1 ppb	
	Perthane	" "	
	Phenol (total)	1 ppb	+
	Prometone	0.1 ppb	
	Prometryne	" "	
	Propazine	" "	
	Silvex	0.01 ppb	
	Simazine	0.1 ppb	
	Simetone	0.01 ppb	
	Toxaphene	1 ppb	
	2.4-D	0.01 ppb	
	2,4,5-T	" "	
	2,4-DP	" "	+

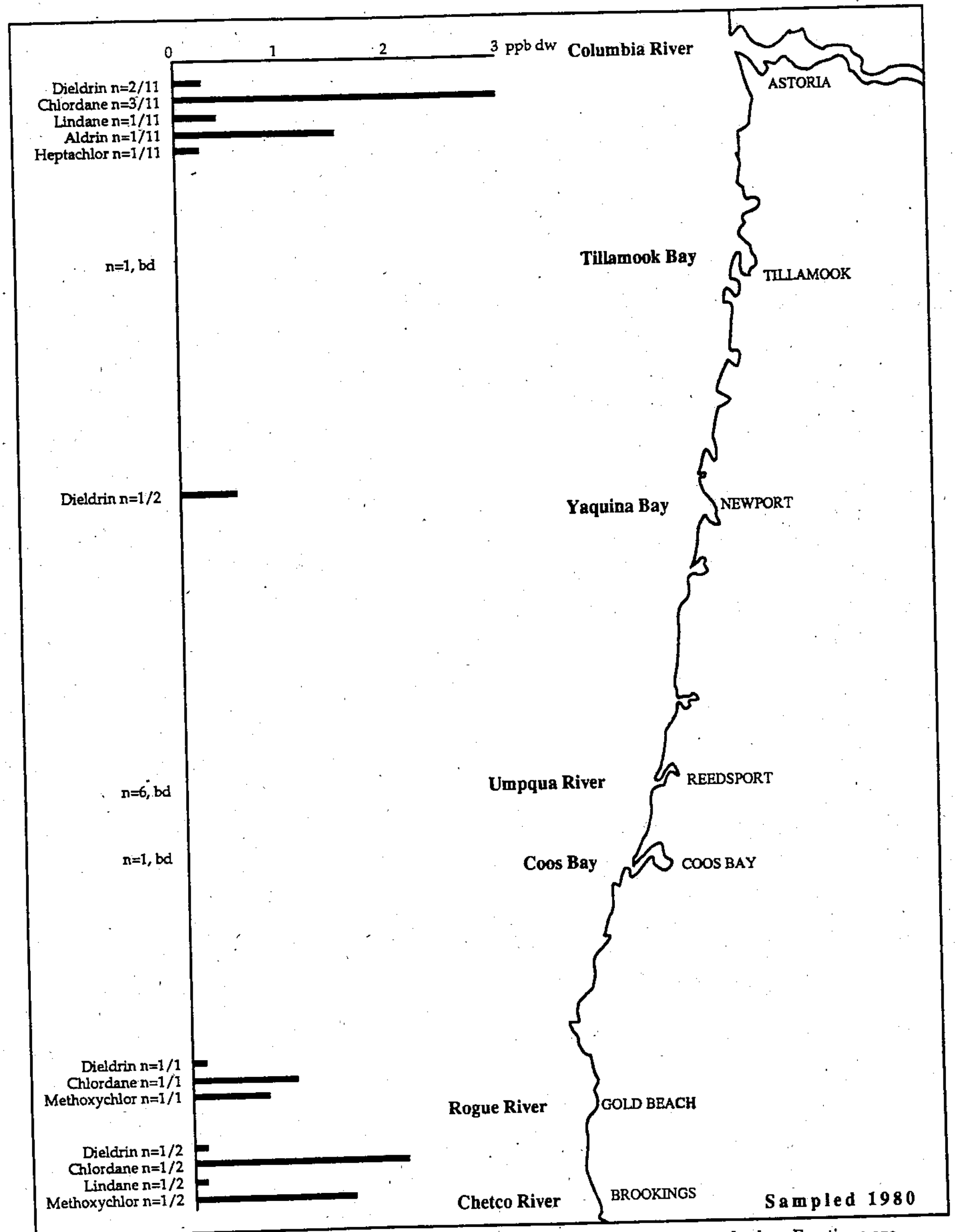

Figure 3.1. Sediment pesticides in coastal estuaries, mean of positive samples in ppb, dw. Fractions are number of positive samples over number of total samples. (Fuhrer & Rinella, 1983; Fuhrer, 1984).

compounds were detected in water, and the fact that no quality assurance procedures were reported, the absence of aldrin in sediment may indicate that these data should be considered suspect.

Within Coos Bay, sediment core samples were taken from the center of the dredged navigation channel and adjacent to the channel in a transect upriver from Empire to Isthmus Slough. No surface fractions were analyzed, but aldrin was indicated in the 20-60 centimeter deep fraction at 1 ppb (n=2 of 3) at North Bend and Isthmus Slough.

Manigold and Schulze (1969) tested Columbia River water at The Dalles monthly for various pesticides during 1966 through 1968. Although The Dalles is above the Bonneville Dam, and therefore totally freshwater, this study can provide some historical indication of contaminant inputs to the Columbia River estuary. In half of the 19 samples taken, Manigold and Schulze were not able to detect any chlorinated pesticides above their detection limits of 0.01 ppb. Only four pesticides (besides DDT) were detected in the 19 samples: dieldrin at 0.01 ppb; silvex at 0.03 ppb; 2,4-D[1] at 0.02 and 0.03 ppb; and heptachlor at 0.01 ppb three times and 0.02 ppb once. Concentrations of 2,4,5-T[2], lindane, heptachlor epoxide, and endrin were below detection limits of 0.01 ppb at all times.

3.1.2 Biotic concentrations

Ten studies citing tissue levels of pesticides (excluding DDT) in organisms in Oregon were encountered. These studies dealt mainly with fish and bivalves, but also covered pelagic crustaceans, seabirds, and mammals.

One synoptic survey of pesticides in marine species was conducted by Claeys *et al.* (1975) off the Washington-Oregon coast. Claeys *et al.* analyzed various fish and invertebrates from coastal Washington and Oregon in 1971 (60 to 180 miles offshore); estuarine fish taken from Coos Bay and the Columbia rivers in 1972-73; South Rogue River steelhead in 1970; and molluscs collected from Tillamook, Coos, Yaquina, Umpqua, and the Columbia River estuaries during 1972. Liquid-gas chromatography techniques were employed to detect PCBs, DDT, benzene hexachloride (BHC), chlordane, mirex, toxaphene in one elutriate column; and dieldrin, endrin, heptachlor epoxide, and methoxychlor in a second column. Base hydrolysis was used to confirm DDT compounds. Sulfuric and nitration tests were used to confirm the presence of toxaphene and chlordane. Quality assurance consisted mainly of analyses of spiked samples.

In Claeys' *et al.* molluscan samples, dieldrin was found in all three species tested from the Columbia River estuary--bay mussels, Asiatic clams, and freshwater clams--but never exceeded 4 ppb. In other samples, poor lipid separation hampered dieldrin quantification, yet it was indicated in many of the coastal pink shrimp and euphausiid samples and in nearly all flatfish samples. When dieldrin was indicated (Figure 3.2), levels were estimated at 0.2 to 5 ppb in the euphausiid samples. Microcoulometric detection positively confirmed dieldrin in these latter samples. Dieldrin was also confirmed in South Rogue River steelhead at 21 ppb and in four species of fish from the Columbia River Estuary (90 to 1,160 ppb). The steelhead samples also contained 6 ppb endosulfan and chlordane each, and were the only samples found to contain these two compounds.

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[1] a systemic herbicide comprised of 2,4-dichlorophenoxyacetic acid

[2] a herbicide comprised of 2,4,5-trichlorophenoxyacetic acid

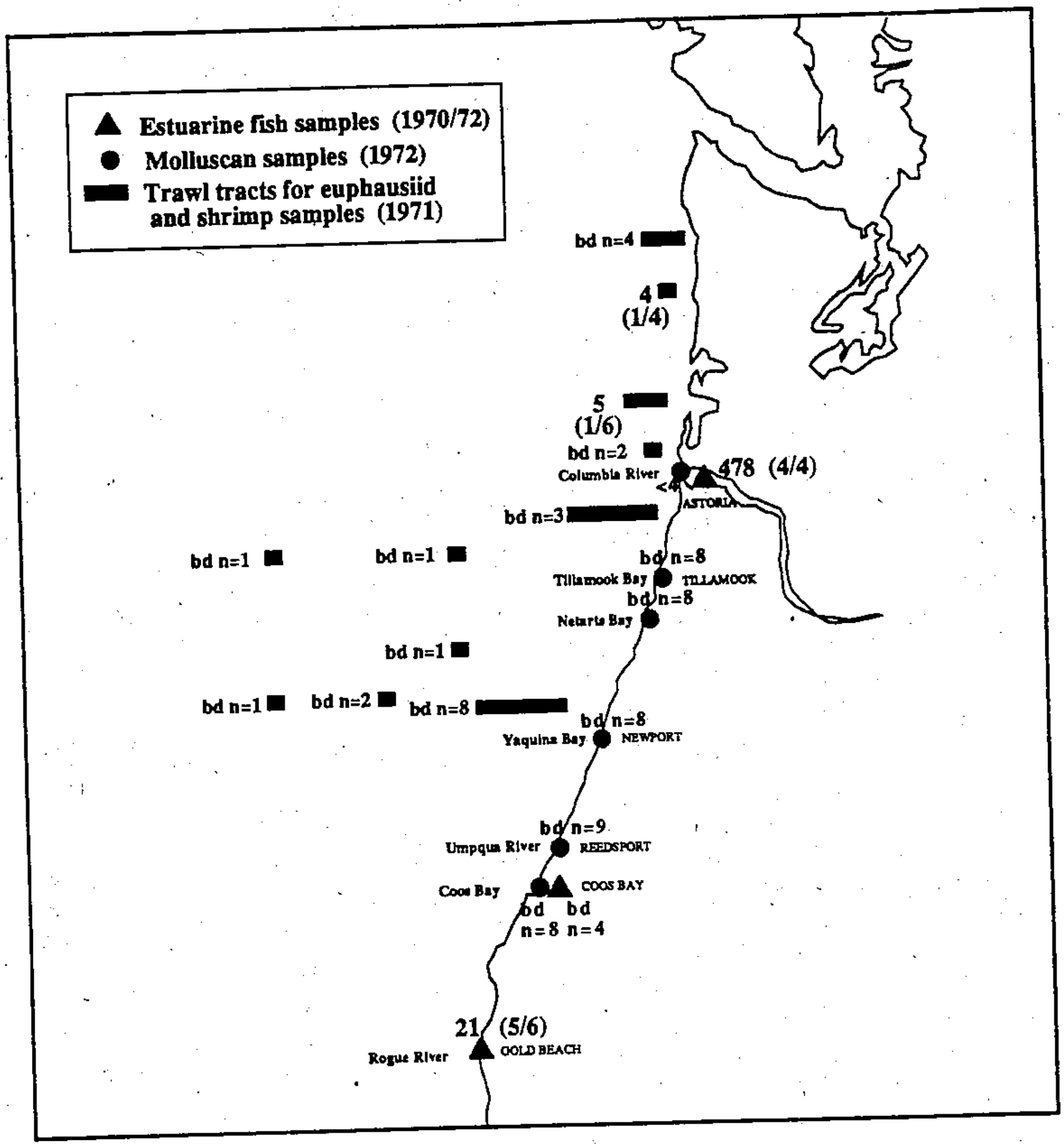

Figure 3.2. Mean dieldrin concentrations in positive samples of estuarine fish and molluscs, and offshore euphausiids and shrimp, in ppb ww. Fractions are number of positive samples over number of total samples (Claeys et al., 1975).

Oregon DEQ has conducted analyses for selected priority pollutants in fish or shellfish throughout the state. Samples were collected by DEQ personnel but analyzed by independent laboratories. Although the vast majority of the sampling sites are freshwater, there are data available from estuarine stations in the Coos Bay system (Table 3.2). Of the 12 pesticides analyzed in Coos Bay tissue samples (besides DDT), only alpha-BHC was above detection limits ranging from 1 to 12 ppb. BHC was found in Upper Coos Bay oysters at 2 to 12 ppb (n=2 of 7), and in South Slough samples at 2, 3, and 4 ppb (n=3 of 4). In addition to this Coos Bay sampling, DEQ has detected aldrin at 25 and 6 ppb in livers of Rogue River steelhead and suckers, respectively, sampled in 1981. No pesticides were detected in the two samples of oysters from Tillamook Bay.

Duke and Wilson (1971) analyzed two samples from Oregon as part of a synoptic survey of pesticides in livers of Northeastern Pacific fish. Chinook salmon from the mouth of the Columbia and hake from 12 miles off Coos Bay were collected in April and May, 1970. With packed column gas chromatography-electron capture (GC-EC) methods at 10 ppb detection limits, no BHC, heptachlor, heptachlor epoxide, aldrin, dieldrin, endrin, toxaphene, methoxychlor, or chlordane were found in these two samples.

In the National Pesticide Monitoring Program (NPMP) of whole juvenile estuarine fish, two composite samples of 25 yearlings each were collected at least semiannually from Columbia River, Umpqua, Coos Bay, Tillamook Bay, and Yaquina Bay estuaries during 1973 to 1975 (Butler and Schutzmann, 1978). Samples were collected by personnel at the Oregon State University Marine Science Center and sent to EPA's Gulf Breeze lab for analysis. Three different packed columns with EC detectors, plus one more with a flame photometric detector, were used to analyze for a number of chlorinated and organophosphate pesticides (Table 3.3). (See Table 3.7 for species and numbers sampled.) None of the organophosphates or organochlorine pesticides were encountered above their detection limits in fish from any of the sites.

Table 3.2. Coos Bay pesticide sampling efforts by DEQ (DEQ, 1987).

Pollutant	Isthmus Striped Bass	Catching Slough Striped Bass	South Slough Pacific Oyster	Stanwood Pacific Oyster	Empire Horse Clam	Tillamook Bay Oyster
Aldrin	1979	1981	1979-81	1980-82	1981	1984
Chlordane	1979	1981	1979-81	1980-82	1981	1984
Dieldrin	1979	1981	1979-81	1980-84	1981	1984
DDT	1979	1981	1979-81	1980-82	1981	1984
Endrin	1979	1981	1979-81	1980-82		1984
HCB	1979	1981	1979-81	1980-82	1981	1984
Heptachlor		1981	1980-81	1980-84	1981	
Lindane	1979	1981	1979-81	1980-84	1981	1984
α BHC	1979	1981	1979-81	1980-84	1981	1984
β BHC			1982	1982-84	-	1984
Methoxychlor	1979		1979	1980		
Nonachlor	1979		1979	1980	1980	
PCBs	1979	1981	1979-81	1982-84		1984

Table 3.3. Compounds and detection limits for estuarine fish 1972-76 (Butler and Schutzmann, 1978).

Compound	Detection Limit
Organochlorines	
Aldrin	10 ppb ww
Chlordane	10 "
Dieldrin	10 "
Endosulfan	20 "
Heptachlor	10 "
Lindane	10 "
Methoxychlor	30 "
Mirex	50 "
Toxaphene	50 "
Trifluralin	10 "
Organophosphates	
Azinphosmethyl	10 "
Carbophenotion	50 "
DEF	50 "
Demeton	10 "
Diazinon	10 "
Ethion	30 "
Malathion	10 "
Parathion	10 "
Phorate	10 "

In a joint NOAA/EPA study, Butler (1976) investigated pesticides in liver and muscle tissue of fish collected from the Columbia River in October and December, 1976 and from Coos Bay during May through June, 1977. The same methods as above were employed with blind internal standards as one quality assurance check. None of the pesticides were found above the detection limits.

In July 1982, in response to an unpermitted application of sevin in Tillamook Bay, laboratory analyses were conducted by the Oregon State Department of Agriculture on samples of oysters obtained from four commercial growers in the Tillamook Bay area. The samples were tested for sevin and its hydrolytic metabolite, 1-naphthol. Although there were reports of invertebrate mortalities directly after chemical spraying, neither compound could be detected in oyster tissues above the detection limit of 40 ppb.

The only data on contaminant levels in Oregon seabirds encountered were those from the United States Fish and Wildlife Service. Henny *et al.* (1982), collected single eggs from 62 nests of ten seabird species (plus one snowy plover) from Oregon in 1979 (Figure 3.3). These eggs were analyzed for organochlorines by gas-liquid chromatography with EC detectors. For verification, five samples were confirmed with a gas-liquid chromatograph mass spectrometer (MS). Spiked samples were analyzed for quality assurance. The lower limit of pesticide detection was 0.01 ppb.

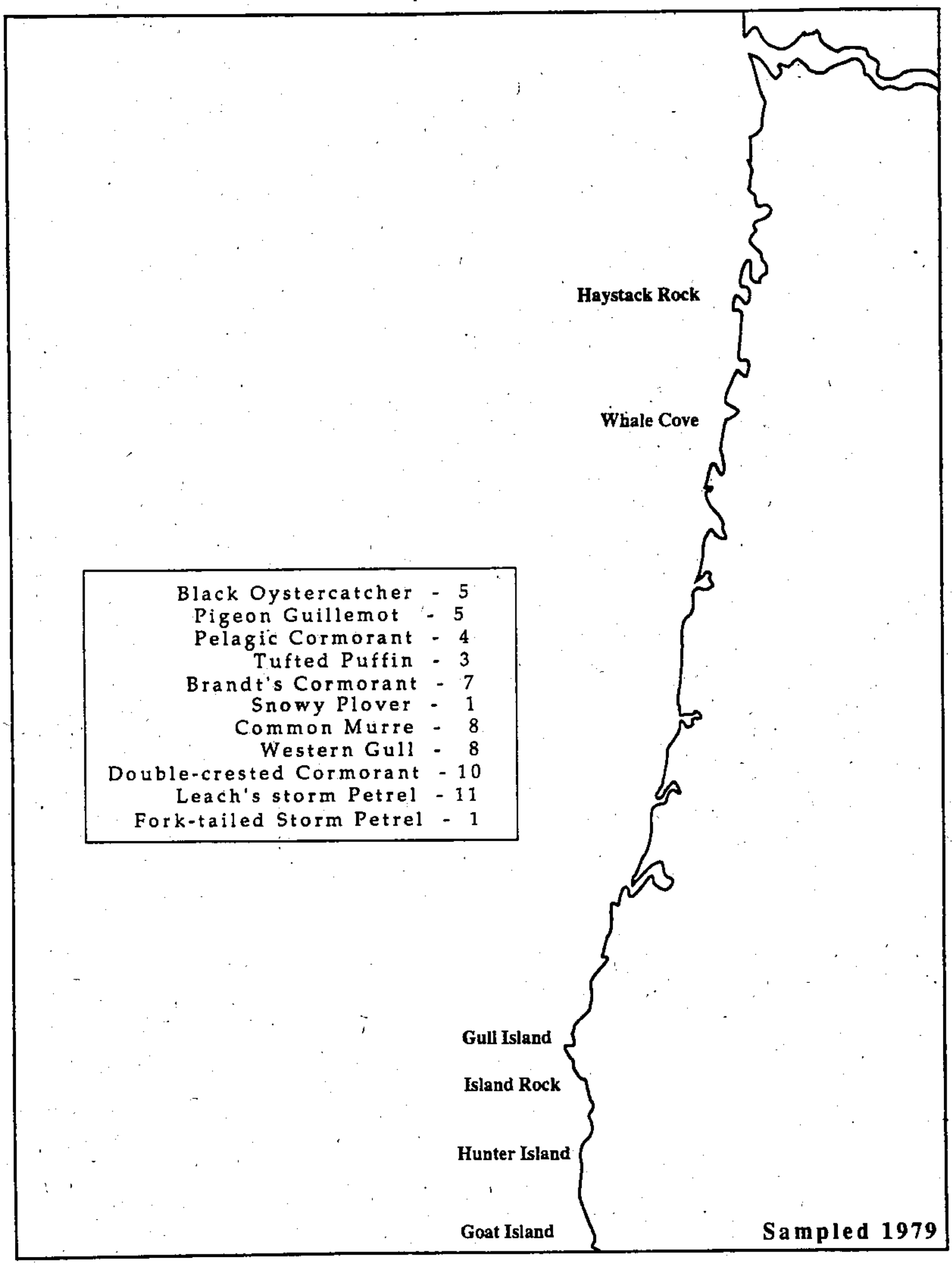

Figure 3.3. Sampling locations, species, and number of eggs collected for contaminant analyses (Henny et al., 1982).

Only five compounds besides DDT and PCBs were detected in the eggs; chlordane, dieldrin, heptachlor epoxide, nonachlor, and toxaphene (Table 3.4). Except for toxaphene, which reached a maximum of 0.67 ppm, none of these compounds occurred above 0.25 ppm. The three most contaminated species were the double-crested cormorant, Leach's storm petrel, and fork-tailed storm petrel. The eggs of these species had the highest total concentrations of organochlorines, as well as the widest variety of compounds.

Varoujean (1979) lists 46 colonies for 13 species of breeding seabirds inhabiting Oregon. Henny's sampling of ten species therefore covers most species found in Oregon. Due to low sample size, his data may not be representative of organochlorine levels in certain species. Also, because of migratory habits, birds are integrative indicators of large regions, rather than specific sites. So although these samples were collected in Oregon, the source of contaminants in parent individuals, which are transferred to their eggs, may be from other areas.

Henny *et al.* (1980) also investigated organochlorine residues in liver and leg muscle tissue from mink (n=59) and river otter (n=20) obtained from trappers in selected regions of Oregon (Figure 3.4). Residues were quantified by GC-EC, with six samples confirmed by GC-MS. The detection limit for pesticides was 0.1 ppm. As part of the study, levels in fingerling salmonids and sculpins were also determined. Analytical techniques similar to those used for the mammal samples were employed by an independent laboratory for the fish analyses.

Although these mammals are basically aquatic, they do venture into estuarine or marine environments, particularly along the coast, and therefore are still useful as indicator organisms (Maser *et al.*, 1981). The primary food of both species are fish, aquatic crustaceans, and amphibians (Toweill, 1974; Bailey, 1936). Because of their diet and aquatic lifestyle, they provide some measure of the potential for biomagnification of contaminants present in inflow to estuaries, and indicate which areas may have significant influxes of contaminants.

Table 3.4. Concentrations of pesticides in breeding seabird eggs along the Oregon coast, in ppm ww (Henny *et al.*, 1982).

Species (no. examined)	Pesticide (no. exceeding detection)	Concentration (ppm)
Black Oystercatcher (5)	none	
Pigeon Guillemot (5)	none	
Pelagic Cormorant (4)	Heptachlor epoxide (1)	0.09
	trans-nonachlor (2)	0.09 & 0.18
Tufted Puffin (3)	none	
Brandt's Cormorant (7)	trans-nonachlor (3)	0.15, 0.17, 0.20
Snowy Plover (1)	none	
Common Murre (8)	none	
Western Gull (8)	Dieldrin (1)	0.36
Double-crested Cormorant (10)	Dieldrin (2)	0.09 & 0.19
	oxychlordane (2)	0.12 & 0.16
	cis-nonachlor (1)	0.09
Leach's Storm Petrel (11)	trans-nonachlor (5)	0.09 to 0.12
	Toxaphene (9)	0.22 to 0.45
Fork-tailed Storm Petrel (1)	oxychlordane	0.22
	trans-nonachlor	0.16
	Toxaphene	0.67

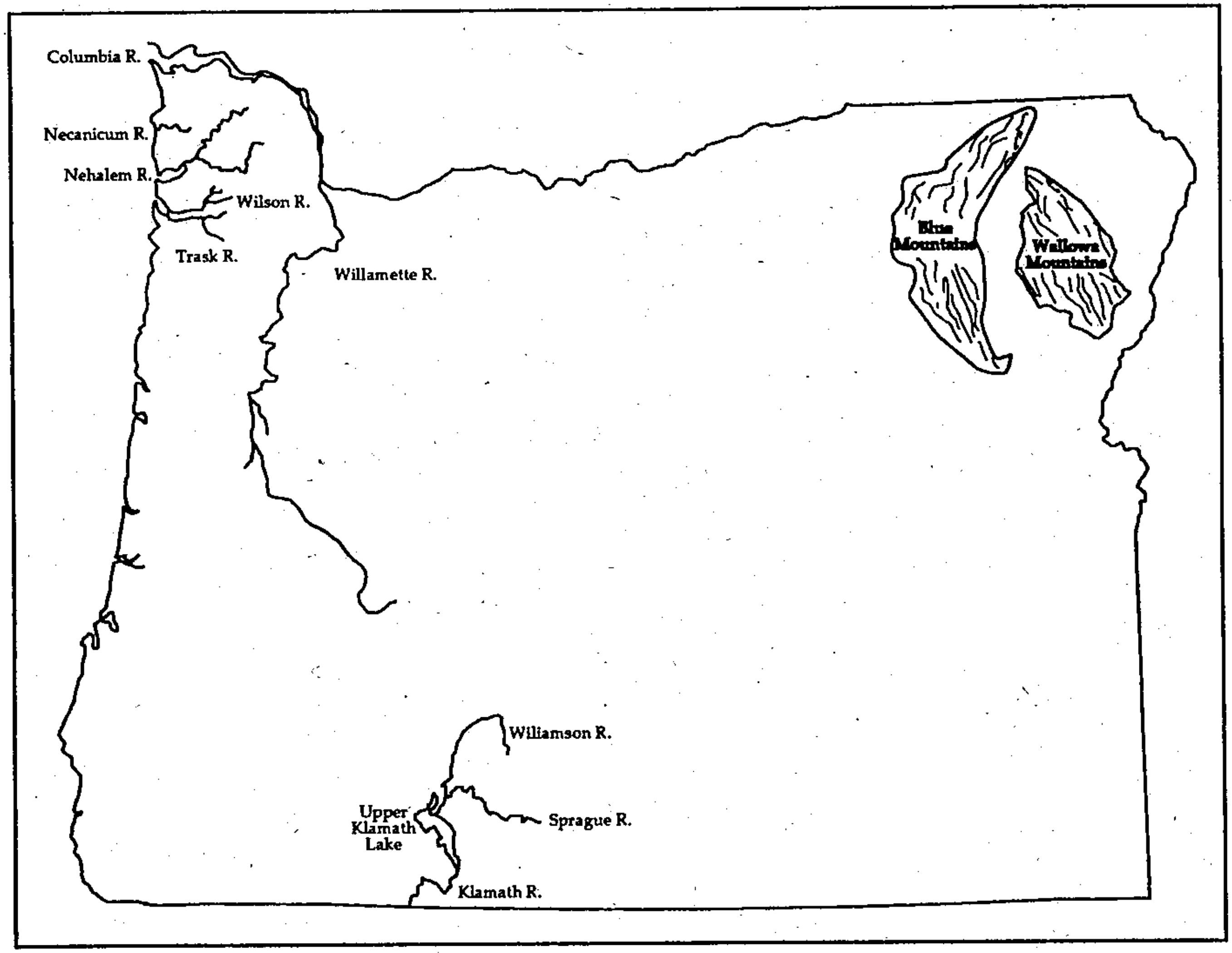

Figure 3.4. Sampling areas for contaminants in mink and otter (Henny et al., 1980).

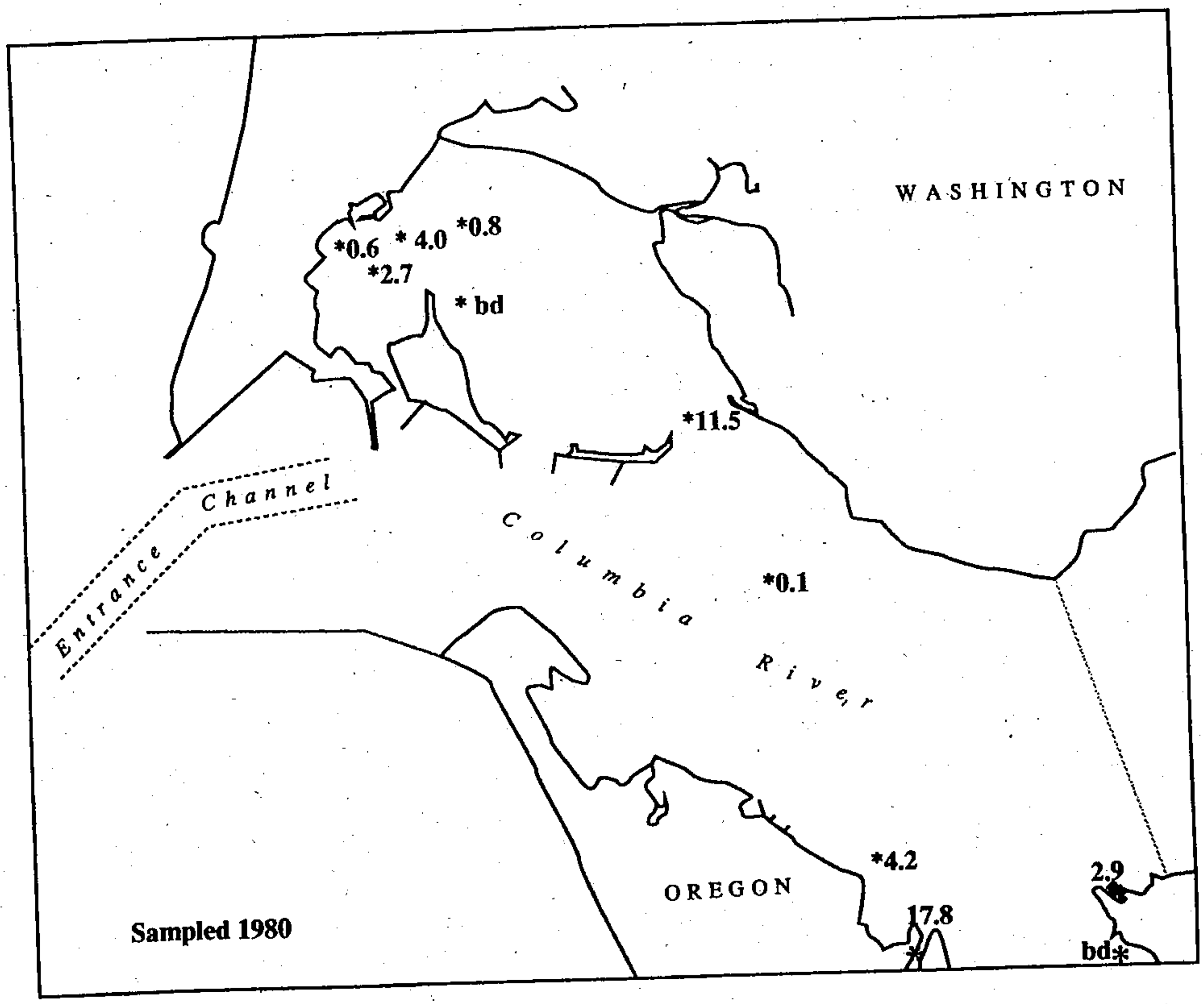

Figure 3.5a. Sediment tDDT concentrations in the Columbia River Estuary, in ppm dw (Fuhrer & Rinella, 1983).

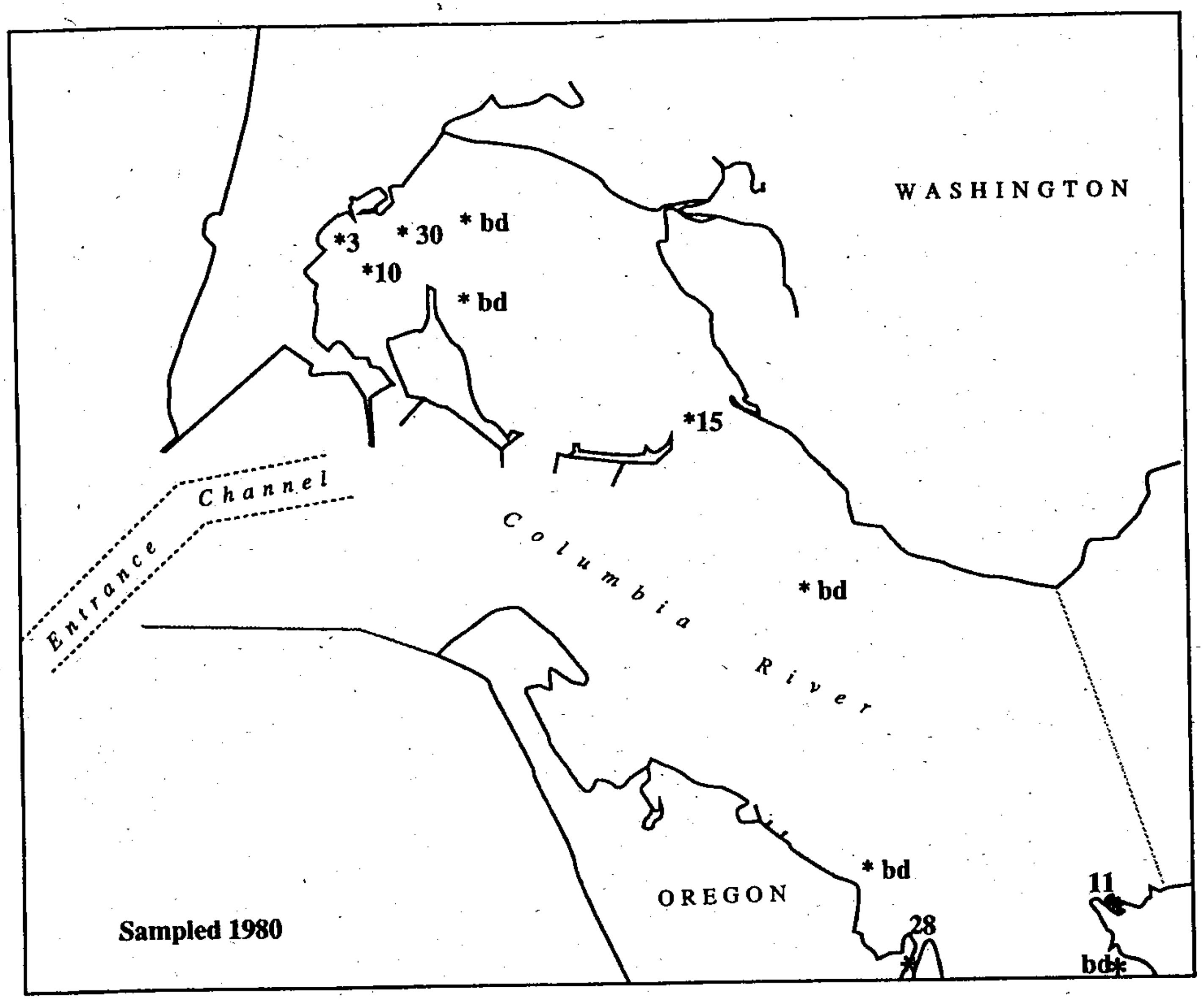

Figure 3.5b. Sediment tPCB concentrations in the Columbia River Estuary, in ppm dw (Fuhrer & Rinella, 1983).

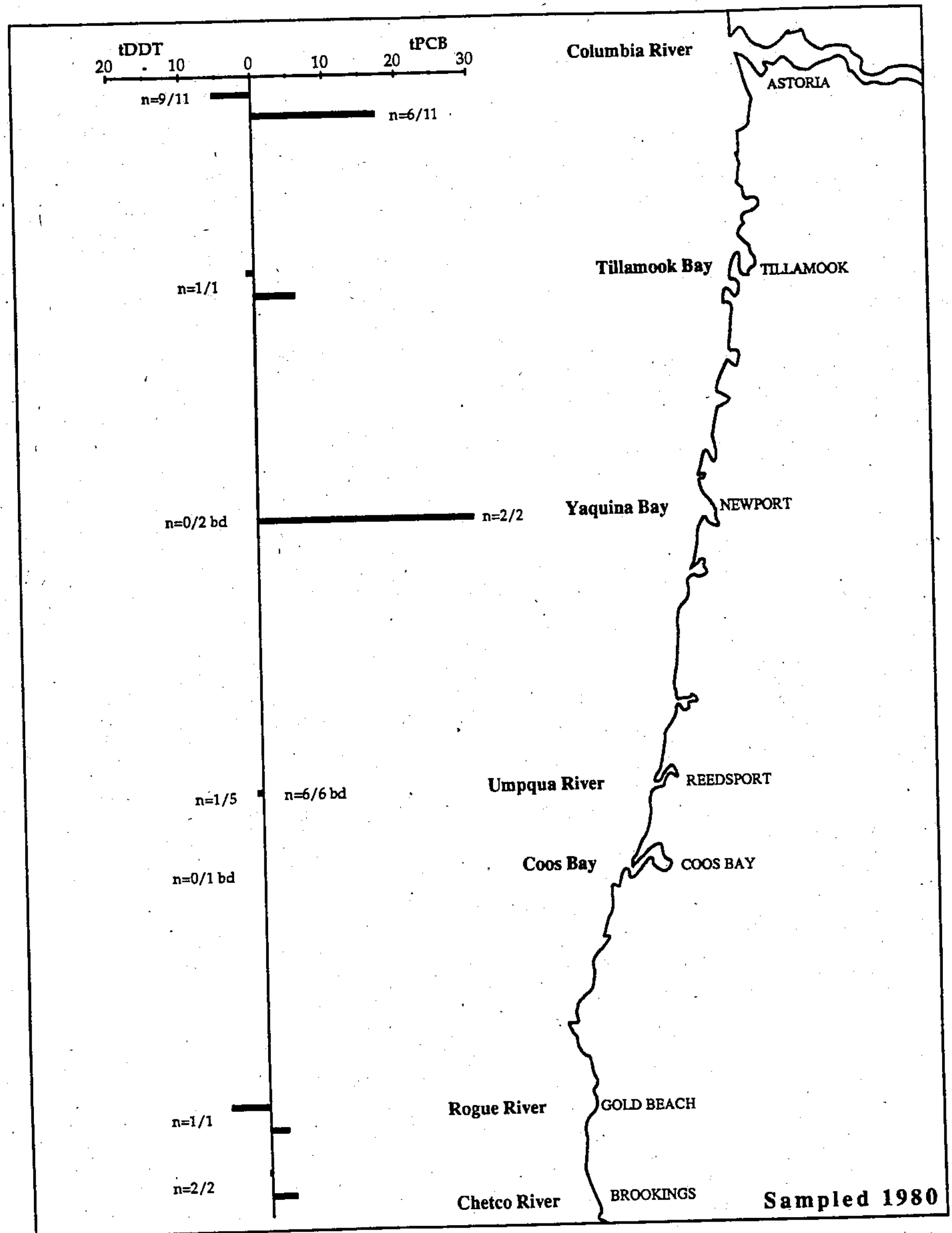

Figure 3.6. tDDT and PCBs in estuarine sediments, mean of positive samples in ppb dw. Fractions are number of positive samples over number of total samples (Fuhrer and Rinella, 1983; Fuhrer, 1984)

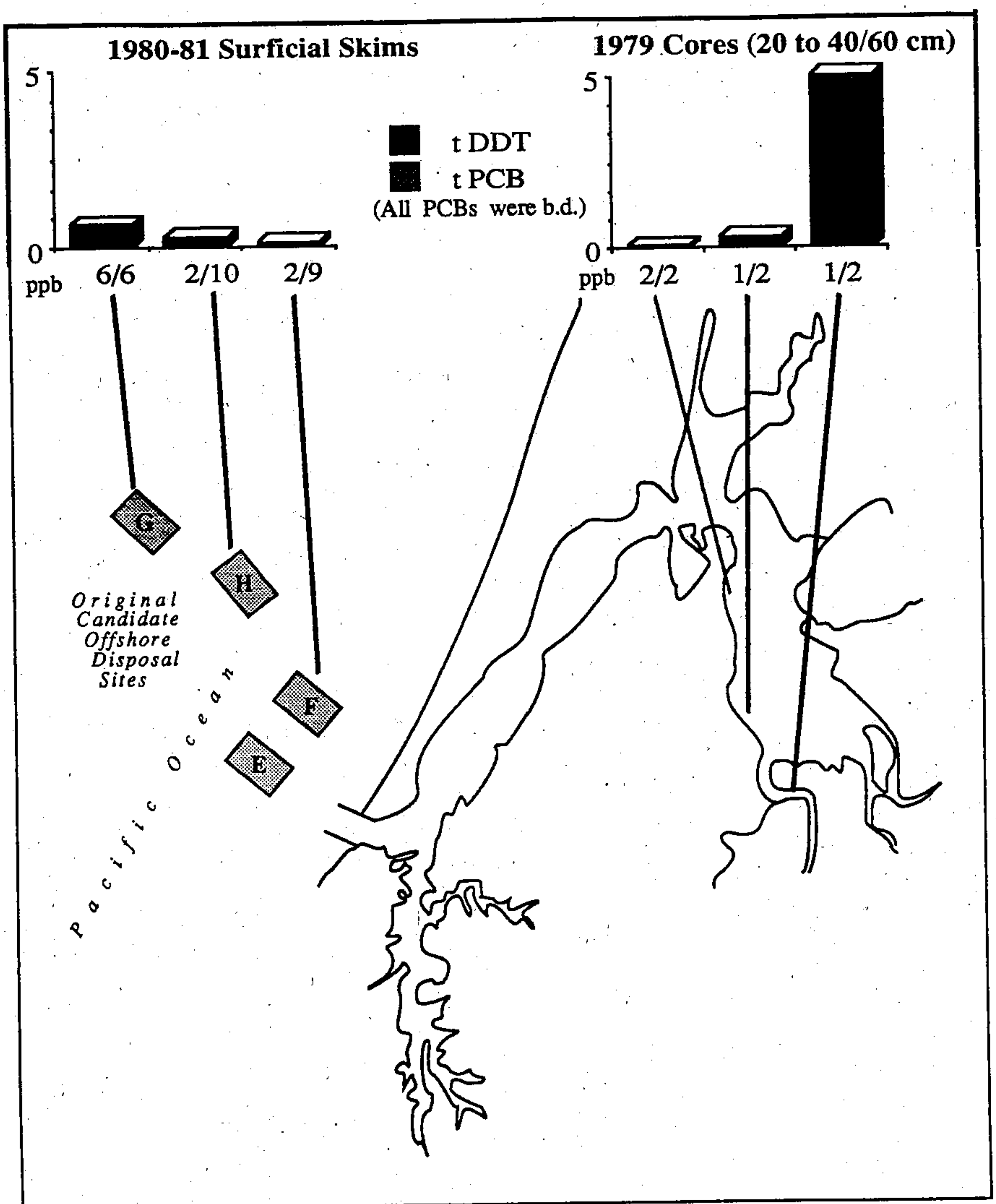

Figure 3.7. Coos Bay sediment t DDT and PCB, in ppm dw. Fractions are number of positive samples over number of total samples (Sollitt et al., 1984).

Using single subsets of the data, some indications are evident nonetheless. A logarithmic decrease in DDT was observed, even in the 20- to 40- or 60-centimeter deep core segments, with distance from Isthmus Slough. DDT levels in the core from the head of the slough were an order of magnitude higher than offshore surficial sediments. Also, DDT trends in offshore samples were related directly to sediment grain size; higher levels of DDT were found with the finer material at site "G" (Sollitt *et al.*, 1984). Though the DDT and PCB data are of marginal value (for the purpose as used here), similar trends were observed for other parameters in the study as well.

3.2.2 Biotic concentrations

Several studies of DDT or PCBs in biota were available. These reports ranged from small research projects to large regional synoptic surveys, plus one routine monitoring program.

Stout and Beezhold (1981) conducted synoptic sampling for DDT and PCB in groundfish along the west coast in the early 1970s (Table 3.5). Although only a few samples were taken from Oregon, their work reveals general trends for the northeast Pacific and helps put Oregon levels in perspective. Their analysis methods evolved during the course of the study. For a few of the early samples, the method of Horowitz (1970) was employed: the sample size was adjusted to limit the oil content to 2 percent, then water was added to adjust the total sample size. In earlier samples, DDT and PCBs were not separated. Samples, blanks, and extracts were quantified by GC-EC. Later samples were corrected using a method described by Stout (1980). Unfortunately, this change in methodology precludes making any conclusions about temporal variations. (In the text, the year of sample collection is shown in brackets with the particular species' concentrations.)

Stout and Beezhold (1981) detected neither DDT or PCBs in samples of Oregon pink shrimp from Tillamook Head, Tillamook Bay, or Columbia River Estuary [1972, n=50 each], with detection limits of 0.01 ppm for DDT and 0.05 ppm for PCBs. The highest residue encountered along the West Coast, 0.43 ppm PCBs, occurred in Elliott Bay, Washington [1976].

Stout and Beezhold (1981) sampled nine species of fish in Oregon, four of which were sole (n=10 each). With only two exceptions, all fish samples were from the Columbia River region. English sole contained 1.21 milligram (mg) ΣDDT per kg lipid. Sand sole had 1.60 mg ΣDDT per kg lipid. Rex and Dover sole levels were below detection. Hake from the same area contained 1.92 mg ΣDDT per kg lipid [1970 for all flatfish and hake]. These samples were not analyzed for PCBs. Further upstream, adult chinook and coho were analyzed [1973, n=2]. Chinook had 2.29 and 2.20 mg ΣDDT per kg lipid and mg PCB per kg lipid, respectively, while coho has less than 0.44 mg ΣDDT per kg lipid and 0.98 mg PCB per kg lipid PCB. The other two marine samples from Oregon were boccacio collected approximately 20 nautical miles off Yaquina Head [1975]. They had a mean ΣDDT concentration of 9.75 mg per kg lipid, and a mean PCB concentration of 7.37 mg per kg lipid.

Stout and Beezhold's 1981 fish data for DDE and ΣDDT are presented in Figure 3.8 (on a wet weight basis). The plots cover data from the Washington Coast to Baja California. Although Columbia River levels appear slightly higher than those from either Washington or Northern California, these differences are not statistically significant (Student's t-test). The power of this test, however, was hampered by small sample size.

Stout's measurements from sablefish [1971] were in slight contrast to other teleosts. Sablefish generally showed higher levels of ΣDDT than other groundfish species. For this reason, a special collection of sablefish was made (Table 3.6). This single species survey from Alaska to Baja California provides another reference for comparison of Oregon levels. A significant geographic gradient (by regression test) in levels of this collection was evident:

Table 3.5. tDDT and PCBs in Northern Pacific fish muscle, in ppm ww (Stout & Beezhold, 1981).

Species	Sampling Date	Sampling Location	Number of[a] Individuals	Lipid Content (%)	Mean fork length (cm)	Mean weight (g)	tDDT (wet weight basis)	PCB[b] (wet weight basis)
Albacore	9/70	Off Grays Harbor, WA	7	8	66	5,833	0.052	na
	8/73	Northern California	10[c]	6.8	61	4,849	0.017	bd
	6/73	33°00'N 135°00'W	10[c]	3.4	61	3,946	0.013	bd
Anchovy, northern	7/69	Camano Island, WA	19	13	15		0.050	na
	9/72	San Pedro Harbor, CA	25[d]	11.4	12	15	2.18	0.83
Bass, striped	6/73	Umpqua River, OR	10[c]	2.6	84	9,645	0.108	0.19
	6/73	Clarksberg, CA	10[c]	2.8	80	7,517	1.04	0.99
Bocaccio	6/75	44°42'N 124°24'W	10[c]	1.9	73	4,772	0.185	0.14
	4/74	34°06'N 119°24'W	10[c]	1.2	50	1,519	0.797	0.16
	5/70	Santa Monica Bay, CA	9[e]	1.4	31	282	11.6	na
	9/70	Santa Monica Bay, CA	4[e]	3.8	33	249	7.9	na
	9/70	Santa Monica Bay, CA	3[e]	3.0	44	643	28.9	na
Bonito, Pacific	3/71	Ventura, CA	10[c]	8.0	60	3,030	8.08	na
Cod, Pacific	9/70	Vancouver Island, B.C.	10	0.5	49	1,349	bd	na
Croaker, white	5/70	Oceanside, CA	16	0.7	23	161	0.641	na
Hake	9/70	Astoria, OR	10[d]	5.2	45		0.100	na
Halibut, Pacific	7/71	Kodiak, AK	10	2.8	132	42,350	0.008	0.05
	8/71	British Columbia	10	3.1	101	13,870	0.018	bd
	4/72	S. of Willapa Bay, WA	10	4.0	117	24,730	0.89	0.09
Herring, Pacific	12/68	Bellingham, WA	50[d]				0.097	na
Lingcod	7/73	41°20'N 124°10'W	10	1.2	78	5,821	0.088	bd
	4/4	35°35'N 125°16'W	10	0.9	69	3,741	0.999	0.20
Mackerel, jack	10/69	Long Beach, CA	13[e]		29	224	3.21	na
	7/73	Near LA Harbor, CA	10[c,e]	9.9	31	374	3.12	0.92
	12/69	Southern California	52[e]			106	0.510	na
	1/70	Southern California	25[c,e]	2.9			5.70	na
	6/73	Cortes Bank, CA	10[c,e]	4.7	24	163	0.077	bd
Rockfish, blue	5/70	Farnsworth Bank, CA	5	1.8	22	170	0.495	na
Rockfish, rosy	5/70	Farnsworth Bank, CA	16	0.7	16	87	0.283	na
Rockfish, unknown	1/70	Cortes Bank, CA	10	0.9	24	245	0.123	na
Rockfish, starry	5/70	Santa Monica Bay, CA	5	1.8	25			
	9/70	Santa Monica Bay, CA	2	2.1	22	148	76.3	na
	5/70	Farnsworth Bank, CA	3	0.9	19	104	0.283	na
Rockfish, vermillion	5/70	Santa Monica Bay, CA	10	2.2	31	533	16.0	na
	9/70	Santa Monica Bay, CA	2	3.5	24	297	46.5	na
	9/70	Santa Monica Bay, CA	1	4.2	34	621	69.1	na
Salmon, chinook	7/70	Manchester hatchery, WA	25[e]	3.4	11	16	0.118	na
	9/70	Manchester hatchery, WA	25[e]	2.4	13	34	0.115	na
	9/74	Westport, WA	1				0.075	0.24
	5/73	Columbia River, OR	2	11.8	74	10,669	0.270	0.26
	8/69	Jones Beach, OR	25[e]	fingerlings		0.134	na	
	8/74	Point Reyes, CA	2	6.8	4	953	0.091	0.09
Salmon, chum	6/73	Puget Sound, WA	2	7.4	56	2,156	0.006	bd
Salmon, coho	7/70	Manchester hatchery, WA	1[e]	8.2	43	1,150	0.144	na
	9/70	Manchester hatchery, WA	15[e]	2.9	23		0.098	na
	11/75	Auburn, WA	10	3.1	60	2,565	0.034	0.24
	5/73	Columbia River, OR	2	6.1	54	3,100	0.027	bd
	8/74	Point Reyes, CA	5	5.4	61	4,067	0.064	bd
Salmon, pink	6/73	Puget Sound, WA	2	9.6	55	2,270	0.009	bd
Salmon, sockeye	8/70	Seattle, WA	9	9.5			0.039	na
	6/73	Puget Sound, WA	2	9.4	56	2,384	0.007	bd
Saury, Pacific	8/70	Off Grays Harbor, WA	75[e]	6.3	50		0.030	na
	67	La Jolla, CA	30[d]				bd	na
Scorpionfish, California	7/70	Farnsworth Bank, CA	10	0.9		378	0.258	na
Sole, Dover	7/70	Astoria Canyon, OR	10	0.5	42	688	bd	na
	9/70	Astoria, OR	10	0.8	32		bd	na
	5/70	Santa Monica Bay, CA	3	3.6	24	141	13.3	na
Sole, English	76	Elliot Bay, WA	80[d]	4.0	26	141		1.71[f]
	9/70	Astoria, OR	10	1.9	29		0.023	na
	5/70	Point Loma, CA	14	0.8	22		0.781	na
Sole, rex	7/70	Astoria Canyon, OR	10	0.5	30	154	bd	na
	9/70	Astoria, OR	10	0:6	28		bd	na
Sole, sand	7/70	Astoria, OR	10	0.5	38	608	0.008	na
Treefish	5/70	Farnsworth Bank, CA	7	0.9	20	146	0.229	na

[a] Composite samples with stated number of individuals, except as noted.
[b] Aroclor 1254 used as standard; detection limit ranged from 0.04 to 0.09ppm.
[c] Analyzed individually, with the mean reported.
[d] Whole fish.
[e] Whole fish, less head, tail, and viscera.
[f] Aroclor 1254 and 1260.

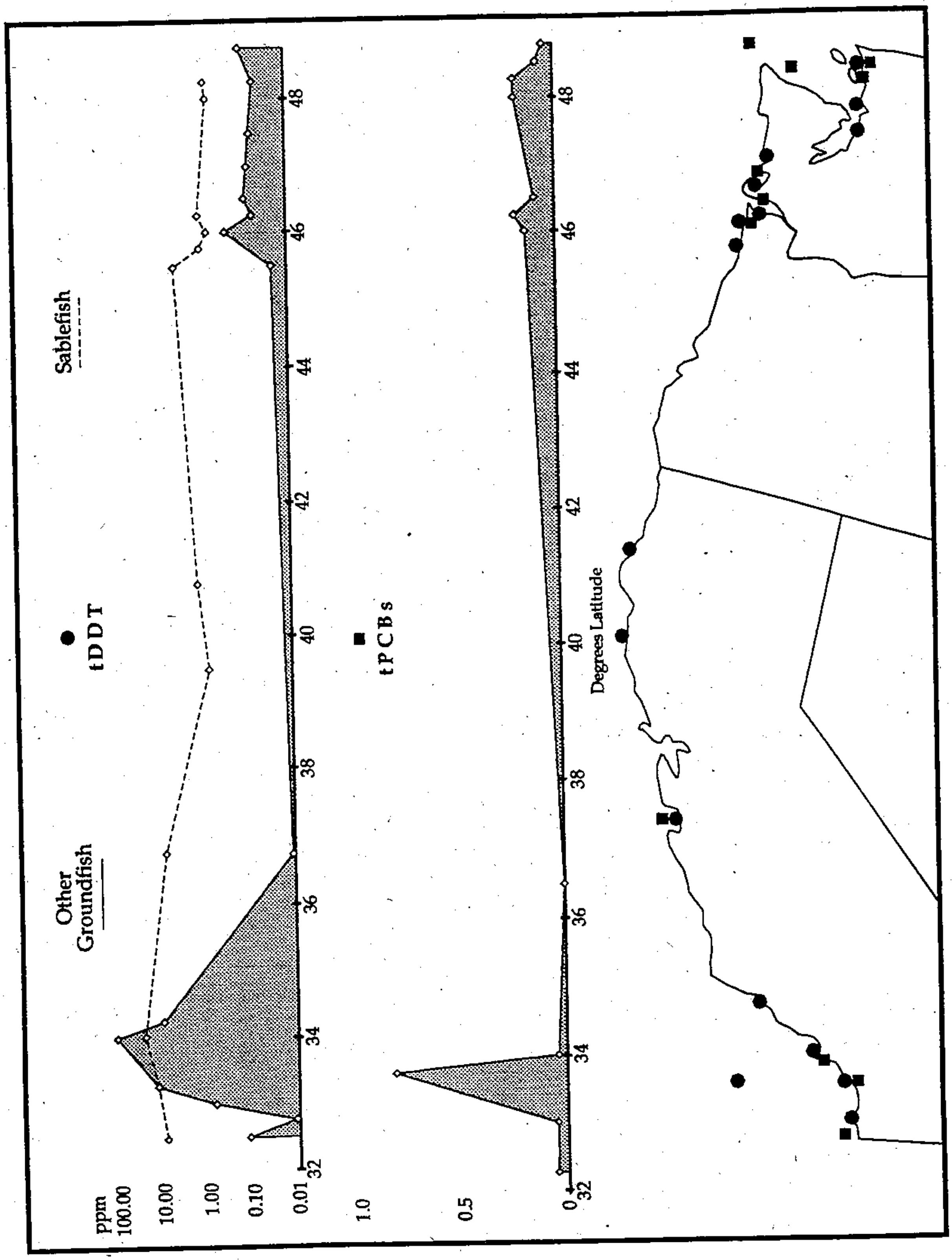

Figure 3.8. tDDT concentrations in groundfish and sablefish muscle, in ppm ww (Stout and Beezhold, 1981).

Table 3.6. Total DDT concentrations in sablefish muscle, in ppm ww (Stout and Beezhold, 1981).

Latitude (Approx)	Lipid Content (as %)	Fork Length (cm)	Weight grams	DDE ppm	ΣDDT ppm	Lipid DDE ppm	Lipid ΣDDT ppm	Ratio of DDE/ΣDDT	Region
60	.034	33	916	.01	.01	.294	.294	1	
58	.05	52	1375	.03	.03	.6	.6	1	
56	.188	42	2015	.133	.215	.707	1.144	.62	Alaska
56	.176	50	3610	.082	.142	.466	.807	.58	
54	.117	42	1917	.061	.107	.521	.915	.57	
48.35	.18	59	2485	.454	.621	2.522	3.45	.73	
48.13	.127	57	2658	.349	.539	2.748	4.244	.65	
46.33	.19	67	3086	.582	.834	3.063	4.389	.7	Wash.
46	.135	40	1881	.723	.937	5.356	6.941	.77	
46.02	.116	37	1522	.362	.489	3.121	4.216	.74	
46	.125	44	2311	.336	.465	2.688	3.72	.72	
46	.094	37	1160	2.63	2.92	27.979	31.064	.9	Oregon
45.9	.074	37	1280	.462	.578	6.243	7.811	.8	
40.83	.129	56	2335	1.5	1.88	11.628	14.574	.8	
40.83	.016	32	1270	.03	.03	1.875	1.875	1	
40.83	.062	32	849	.211	.257	3.403	4.145	.82	
39.42	.098	34	946	.505	.638	5.153	6.51	.79	
36.92	.152	40	1756	3.08	4.08	20.263	26.842	.75	
36.92	.16	50	4001	7.25	8.86	45.312	55.375	.82	Calif.
34	.06	48	831	19	23.4	316.667	390	.82	
32.43	.142	38	1366	5.77	7.5	40.634	52.817	.77	
32.43	.136	38	1352	7.13	9.33	52.426	68.603	.76	
32.43	.143	39	1406	5.7	7.57	38.86	52.937	.75	
32.42	.107	38	1517	4.79	5.99	44.766	55.981	.8	

concentrations increased three orders of magnitude from Alaska, southward to Los Angeles, then began to decline in Baja. This again, suggests Oregon levels are not at a "background" level. (As used here, "background" is used to imply an apparent or presumed baseline concentration, with respect to the West Coast, indicative of a global distribution mechanism.) In fact, individual fish from Oregon contained up to 13.4 ppm ΣDDT, well over the FDA action level of 5 ppm.

DDE was the principle component of ΣDDT in sablefish, as well as other groundfish. The mean ratio of lipid DDE to lipid ΣDDT was 78 percent and never fell below 57 percent. This ratio would indicate a fair amount of biotransformation of the parent DDT compound.

Sablefish prefer a soft bottom to rocky, and are a fairly demersal species (Dark, personal communication). Also, they generally remain in a limited area (30 miles) after migrating to 100 to 500 fathoms as adults. This migration to deeper water occurs at age 4 to 5, and appreciable growth stops afterward. Due to these factors, sablefish should be reasonable indicators of local, shelf conditions.

The exact reason for the greater accumulation of ΣDDT in sablefish than species of equally high lipid content (salmon, herring, saury, etc.) which live higher up in the water column is not known. Size of the sablefish, as represented by fork length and weight, does not significantly correlate with ΣDDT concentrations. It has been shown that fish tend to have greater ΣDDT or PCB levels the more they are associated with sediments (Matta *et al.*, 1986). DDT levels in sablefish may be associated with early life in contaminated embayments. However, a significant input of DDT to the deep ocean cannot be ruled out.

Duke and Wilson's (1971) composite liver samples of hake off Coos Bay (n=13) and Chinook salmon from the Columbia River (n=10) from 1970 contained 3.34 and 0.25 ppm ΣDDT respectively, 70 percent of which was DDE. Because these values are for livers, they cannot directly be compared to Stout's muscle data. However, they did indicate a comparable level of biodegradation to DDE.

In the NPMP sampling of whole juvenile estuarine fish, Butler and Schutzmann (1978) detected DDT only in Coos Bay and the Columbia River estuary, and PCBs only in the Columbia samples (Table 3.7). Levels were below detection in all samples from Tillamook Bay, Yaquina Bay, and the Umpqua River. In Coos Bay, one-fourth of the individual fish contained detectable amounts of ΣDDT, consisting entirely of DDE. In contrast, 80 percent of the Columbia River fish had quantifiable levels of ΣDDT, with all three congeners present.

In the joint NOAA/EPA program (Butler, 1976), fish muscle and livers from Coos Bay and Columbia estuary were sampled during 1976 and 1977 (Table 3.8). Due to poor fishing in Coos Bay, noncommercial species were substituted, and none are in common with the NPMP program or Duke and Wilson's earlier samples (1971). Again, only DDE was encountered (with one DDD exception) in about one-fourth the samples. Concentrations were similar to 1973-1975 NPMP whole fish samples, however, ΣDDT was found only in liver tissues in the 1976-1977 NOAA/EPA samples. Since livers generally accumulate organics to a greater degree than muscle tissue, equivalent concentrations between the NPMP and NOAA/EPA samplings may suggest either a temporal decrease or a species- specific difference. Liver levels also appear to be an order of magnitude lower in these later NOAA/EPA samples than those Duke and Wilson reported (1971). Again, this may represent a species difference, an actual temporal decrease, or, possibly, even a spatial difference due to different sampling designs.

In Butler's (1976) Columbia estuary samples, shad and starry flounder were the only two species in common between the NPMP samplings. DDT levels in these two species did seem to decline over the 5-year period. (Again, exact tests with both data sets are not possible due to differences in sample matrices.) Butler's data are also generally lower than Duke and Wilson's one composite salmon sample (1971). PCBs were below detection in Butler's later samples from the Columbia (Table 3.8), and therefore appear to be lower than the NPMP samples (based on the presumption of the propensity of liver to tissue accumulate higher levels of organics than muscle tissue). Again, firm conclusions regarding these perceived trends should not be made due to differences in sampling design.

Claeys *et al.* (1975) also collected fish from the Rogue River, Coos Bay, and the Columbia River and analyzed for all p,p' congeners of ΣDDT and the PCBs, Aroclor 1254 and 1260 (Figure 3.9). Samples of steelhead from 1970 (n=6 of 6) contained 97 ppb p,p'-DDE and no p-p'-DDD or p-p'-DDT. Only two of these samples were analyzed for PCBs and were found to contain 100 and 150 ppb Aroclor 1254, but no Aroclor 1260. Claeys *et al.* also found p-p'-DDE in starry flounder at 34 ppb sampled from the Columbia estuary in 1972, and in striped perch, sand sole, staghorn sculpins, and starry flounder at 3 to 7 ppb sampled from Coos Bay in 1973. These Coos Bay residues are lower than those reported by either the NPMP or NOAA/EPA programs. Although Claeys *et al.* quantified only the p-p' isomers, these compounds normally constitute the vast majority of ΣDDT. Also, their values were reported for muscle tissue, not livers. PCBs

Table 3.7. NPMP of whole, juvenile estuarine fish in ppb ww (Butler and Schutzmann, 1978).

Estuary / Species (number)[a]	1973 (number)	1973 DDE	1973 ΣDDT	1973 1254	1974 (number)	1974 DDE	1974 ΣDDT	1974 1254	1975 (number)	1975 DDE	1975 ΣDDT	1975 1254
Tillamook												
English sole	(0/2)				(0/2)				(0/2)			
Sand sole	(0/4)				(0/3)				n.a.			
Shiner perch	n.a.				(0/1)				(0/2)			
Buffalo sculpin	(0/6)				(0/4)				(0/2)			
Yaquina												
English sole	(0/6)				(0/4)				(0/2)			
Sand sole	(0/2)				n.a.				n.a.			
Shiner perch	(0/2)				(0/2)				(0/2)			
Speckled sanddab	n.a.				(0/2)				n.a.			
Buffalo sculpin	(0/6)				(0/4)				(0/2)			
Staghorn sculpin	(0/1)				n.a.				n.a.			
Umpqua												
English sole	(0/4)				n.a.				n.a.			
Sand sole	(0/3)				(0/2)				n.a.			
Shiner perch	n.a.				(0/2)				(0/2)			
Speckled sanddab	(0/2)				(0/2)				n.a.			
Starry flounder	(0/1)				n.a.				n.a.			
Pacific tomcod	n.a.				(0/2)				n.a.			
Pacific sandlance	n.a.				(0/2)				n.a.			
Pacific sculpin	(0/2)				n.a.				n.a.			
Coos												
English sole	(1/3)	15	15		(2/4)	12	12		(0/1)			
Sand sole	(1/3)	13	13		(0/2)				n.a.			
Speckled sanddab	(1/6)	13	13		(2/4)	14	14		(0/2)			
Pacific tomcod	(0/2)				n.a.				n.a.			
Pacific sandlance	n.a.				(1/2)	17	17		(0/2)			
Pacific sardine	(0/1)				n.a.				n.a.			
Columbia River												
English sole	(5/6)	18	22		(2/4)	16	16		(0/2)			
Sand sole	(2/3)	18	39		n.a.							
Shiner perch	(4/4)	40	79	78	(4/4)	30	47		(1/1)			274
Starry flounder	(6/6)	26	32	224	(3/4)	19	23		(0/2)			
Pacific tomcod	(1/2)	22	22		(1/1)	9	19		n.a.			
Pacific sculpin	n.a.				(2/4)	121	121	144	n.a.			
Pacific herring	n.a.				(2/2)	21	38		n.a.			
American shad	n.a.				(2/2)	106	203	244	(2/2)	12	12	283
Longfin smelt	n.a.				(1/1)	37	64	167	(3/3)	10	10	191

[a] the number of positive samples out of the total number of samples for the given year
n.a. indicates no samples collected for that year

Table 3.8. DDT and PCB Levels in Columbia River and Coos Bay fish from the joint NOAA/EPA program, in ppb ww (Butler, 1976).

No. of Species	Tissue Individuals[a]	Date	Type	DDE	DDD	DDT	tDDT	Aroclor 1232	Aroclor 1254	Aroclor 1260
Columbia River										
American shad	10 *	Oct 76	Muscle	bd	bd	bd	bd	bd	bd	bd
	1 *	"	Liver	17	"	"	17	"	"	"
	5	"	"	100	"	"	100	"	"	"
Redstripe	5	"	Muscle	bd	"	"	bd	"	"	"
surfperch	5	"	"	"	"	"	bd	"	"	"
	5	"	Liver	139	"	"	139	"	"	"
	5	"	"	28	"	"	28	"	"	"
Starry	10 *	"	Muscle	bd	"	"	bd	"	"	"
flounder	10 *	"	Liver	119	"	"	119	"	485	"
White	10 *	Dec 76	Muscle	10	23	"	17	"	bd	"
Sturgeon	10 *	"	Liver	87	55	"	117	"	627	"
Coos Bay										
Night smelt	5	Feb 77	Whole	bd	bd	bd	bd	"	"	"
	20	"	"	"	"	"	"	"	"	"
	20	"	"	"	"	"	"	"	"	"
Pile perch	5	May/Jun 77	Muscle	"	"	"	"	"	"	"
	5	"	"	"	"	"	"	"	"	"
	5	"	Liver	17	"	"	17	"	"	"
	5	"	"	16	"	"	16	"	"	"
Shiner perch	7	"	Whole	bd	"	"	bd	"	"	"
	7	"	"	"	"	"	"	"	"	"
Striped surf	5	"	Muscle	"	"	"	"	"	"	"
perch	5	"	"	"	"	"	"	"	"	"
	5	"	Liver	10	"	"	"	"	"	"
	5	"	"	15	19	"	22	"	"	"

[a] * indicates data are a mean of individual samples, otherwise, values are for composite samples

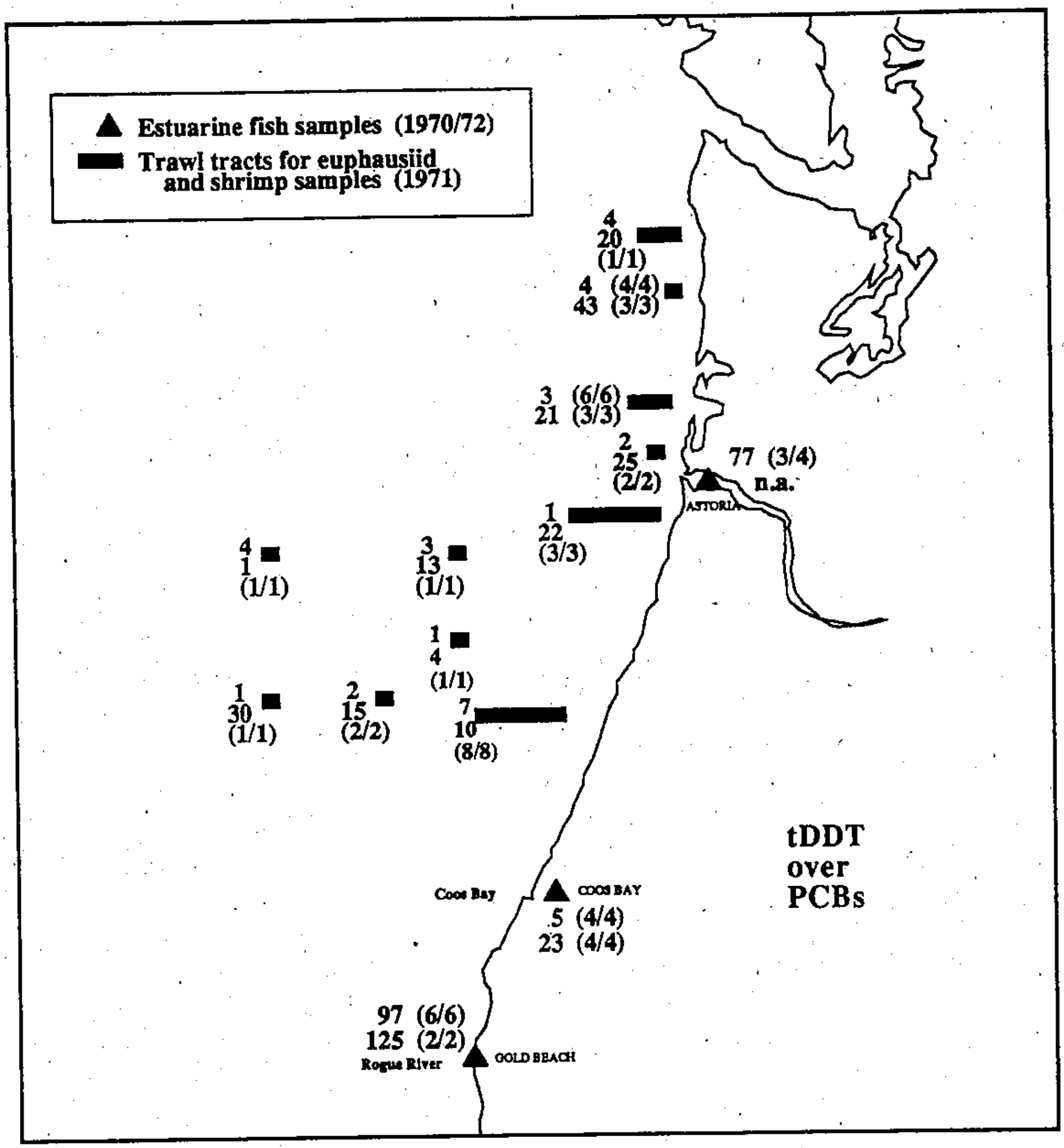

Figure 3.9. Mean tDDT & PCB concentrations in samples of fish and offshore euphausiids and shrimp in ppb ww.
Fractions are number of positive samples over number of total samples (Claeys et al., 1975).

were not analyzed in Columbia River bottom-fish samples, but were detected in the Coos Bay samples at 17 to 27 ppb. These values are also lower than the NPMP or NOAA/EPA data, yet are within an analytical error range that has been observed for PCB determinations.

Another synoptic collection, mainly of offshore invertebrates in 1971, was made by Claeys *et al.* (1975), and shows few geographic patterns off Oregon and Washington (Figure 3.9). DDE was frequently the only form of ΣDDT detected, averaging 2 ppb in euphausiids and pink shrimp (n=15 and 13 respectively), and 10 ppb in flatfish (n=16). Total DDT residues were 3 ppb for both euphausiids and pink shrimp, and 13 ppb in flatfish. Flatfish off Washington appeared to contain slightly more ΣDDT than those off Oregon, 15.6 ppb vs. 11.7 ppb, but this was not a significant difference (Student's t-test). This is a reversal of the pattern in fish observed by Stout and Beezhold (1981).

PCB levels were higher than those of ΣDDT in euphausiids, pink shrimp, and flatfish, averaging 9, 27, and 30 ppb, respectively. Considering that all three species have about 2 percent lipid content, the relationship between DDT and PCB levels among these three groups is of some interest. Feeding habits and vertical distribution may be possible explanatory factors (Stout and Beezhold 1981), but further investigation is required to determine the nature of this difference.

Claeys *et al.* (1975) also measured bivalve hydrocarbon levels quarterly during 1972 (Figure 3.10). Due to different estuarine regimes, Claeys was forced to collect different molluscan species from the Columbia River estuary than from Coos, Tillamook, Umpqua, or Yaquina estuaries which makes site comparisons subjective. However, the disparity between Columbia River concentrations and concentrations from other sites is probably not solely attributable to interspecies factors.

From the National Mussel Watch Program, Goldberg *et al.* (1978) have reported DDE and PCBs in Oregon mussels sampled during August 1976. A combination of GC and GC-MS analysis techniques were used by the laboratories involved in this program. Usually, samples were composites of at least 30 individuals. For comparative purposes, all of Goldberg's West Coast data are presented in Figure 3.11. Oregon concentrations are not significantly different from other coastal values, except those in the Southern California Bight.

In a later publication of the National Mussel Watch Program, Farrington *et al.* (1982) provided an update to the 1976 data. He reported data on a dry weight basis with no moisture or lipid values provided (Table 3.9). There were no discernible temporal trends, however sample sizes were too small for rigorous testing.

Table 3.9. Mean concentrations of DDE and PCBs in mussels, in ppm dw (Farrington *et al.*, 1982).

	DDE		PCBs		
	1976	1977	1976	1977	1978
Columbia River	2	5.2	42	26	22
Tillamook Bay	2-17(n=5)	8.6	9-25(n=5)	25	
Yaquina Head	5	4.3	20	21	
Coos Bay	2	2.7	19	13	
Gold Beach	8	4.7	24	10	

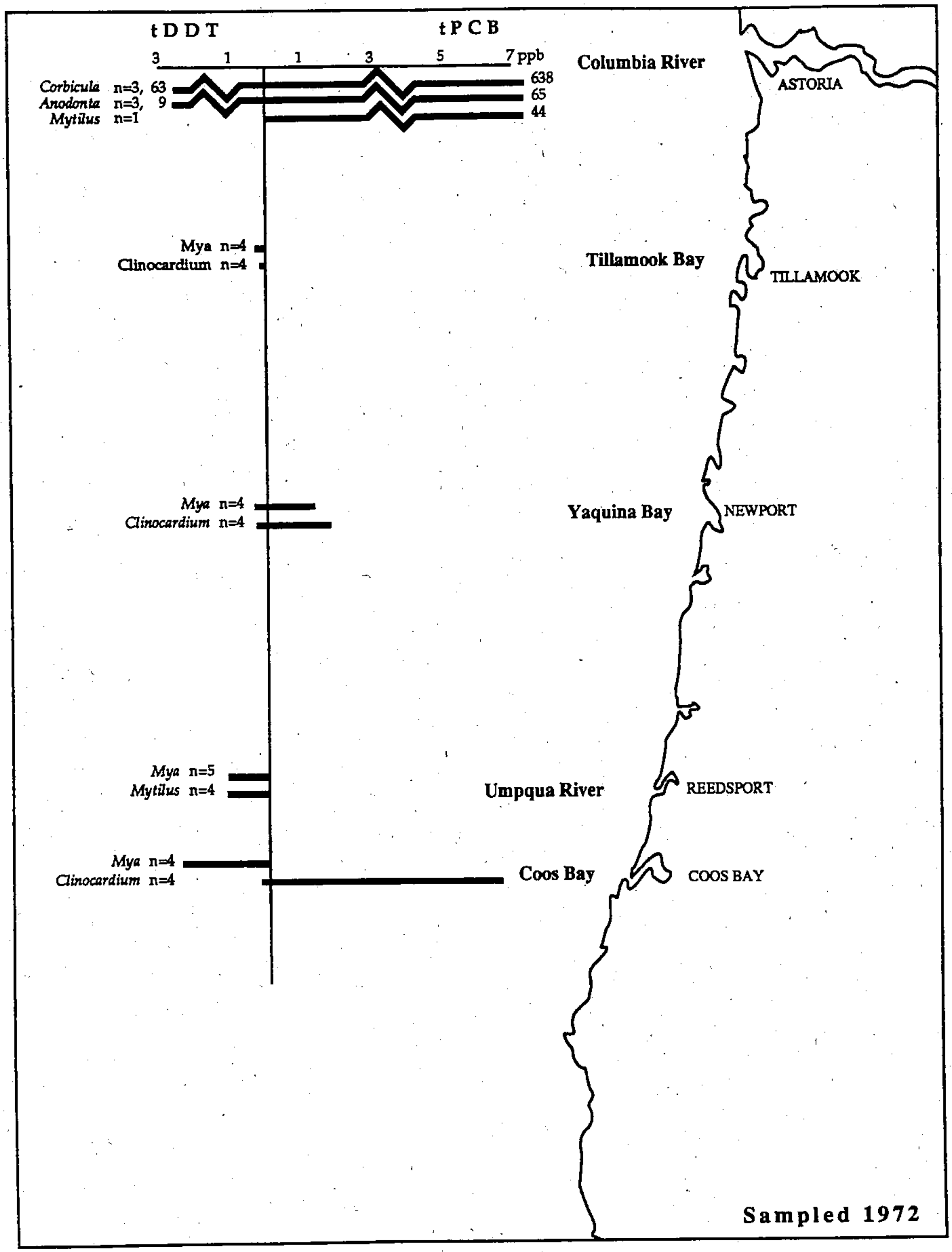

Figure 3.10. Mean molluscan tDDT and tPCB concentrations, in ppb ww (Claeys et al., 1975).

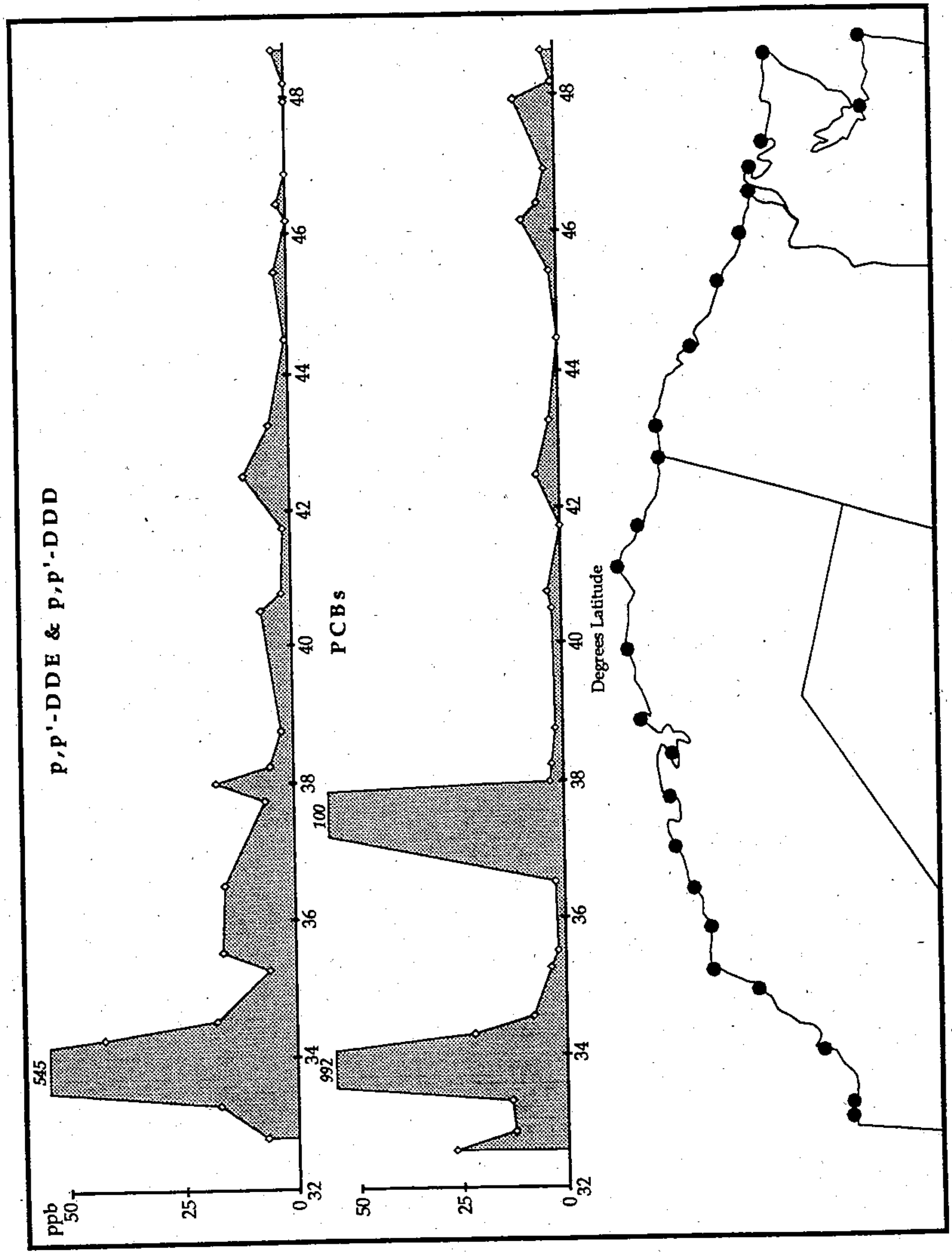

Figure 3.11. p,p'-DDE, p,p'-DDD, and PCB concentrations from EPA Mussel Watch Program, in ppb ww (Goldberg et al., 1978).

In their monitoring program, Oregon DEQ (1987) found ΣDDT and PCBs in Coos Bay oysters, but not in the one sample of horse clams (Figure 3.12). The ΣDDT residues were above detection limits of 0.01 ppm in the 1981 sampling at South Slough and three out of five samples from Haynes Inlet. Total residues never exceeded 50 ppb and appear to be declining with time at the Haynes Inlet site.

Oregon DEQ (1987) also sampled striped bass from Coos Bay on two occasions--whole fish in 1979 and livers in 1981. The one liver sample contained 20 ppb DDE. DEQ also found ΣDDT residues in a 1981 steelhead sample from the Rogue River at river mile 11. Liver tissue contained 36 ppb DDE. Suckers at the same site contained no DDT above detection in the livers. PCBs were below 10 ppb in both species from the Rogue.

Henny *et al.*'s (1982) investigation of breeding seabirds along the Oregon coast (see Figure 3.3 for species and sites) found DDE and PCBs to be ubiquitous, but at low levels in the eggs of the 11 species sampled. Eggs of seven species showed geometric mean concentrations of DDE that were less than 1 ppm, and mean PCBs in eight species were below 1 ppm. The double-crested cormorant, Leach's storm petrel, and the fork-tailed storm petrel were the only species with mean DDE or PCB concentrations over 1 ppm in their eggs (Table 3.10). Also, the petrel eggs were the only ones which contained other congeners of ΣDDT. Of 11 Leach's storm petrel eggs, 8 contained DDT ranging from 0.1 to 0.2 ppm. The sole fork-tailed storm petrel egg, in addition to the highest DDE, PCB, and toxaphene levels, had 0.67 ppm DDT and 0.26 DDD.

For comparison, a United States Fish and Wildlife Service report of eggs from Alaska may be examined (Ohlendorf *et al.*, 1978). Only one sample of eggs from the six species tested had a geometric mean above 1 ppm for either ΣDDT or PCB: the glaucous-wing gull collected from the Aleutian Islands with 3.29 ppm DDE and 3.41 ppm PCB concentrations. Otherwise, Oregon seabird eggs showed a threefold to fourfold increase in ΣDDT, PCBs, and other chlorinated pesticide levels, over those in Alaska. Due to small sample size in both studies, frequency of occurrence comparisons are not valid. Other studies, in the Farallon Islands, California (Coulter and Risebrough, 1973; Gress *et al.*, 1971), found levels in two marine bird species one full order of magnitude greater than those reported by Henny *et al.* (1982).

Table 3.10. Concentrations of DDE and PCBs in seabird eggs, in ppm ww (Henny *et al.*, 1982).

Species	Number of Samples	Mean DDE	Mean PCBs
Black Oyster Catcher	5	0.08	0.32
Pigeon Guillemot	5	0.26	0.33
Pelagic Cormorant	4	0.48	0.68
Tufted Puffin	3	0.62	0.51
Brandt's Cormorant	7	0.62	0.61
Snowy Plover	1	0.72	0.89
Common Murre	8	0.87	0.52
Western Gull	8	1.0	0.47
Double-Crested Cormorant	10	1.6	1.3
Leach's Storm Petrel	11	2.5	1.1
Fork-Tailed Storm Petrel	1	12.	5.1

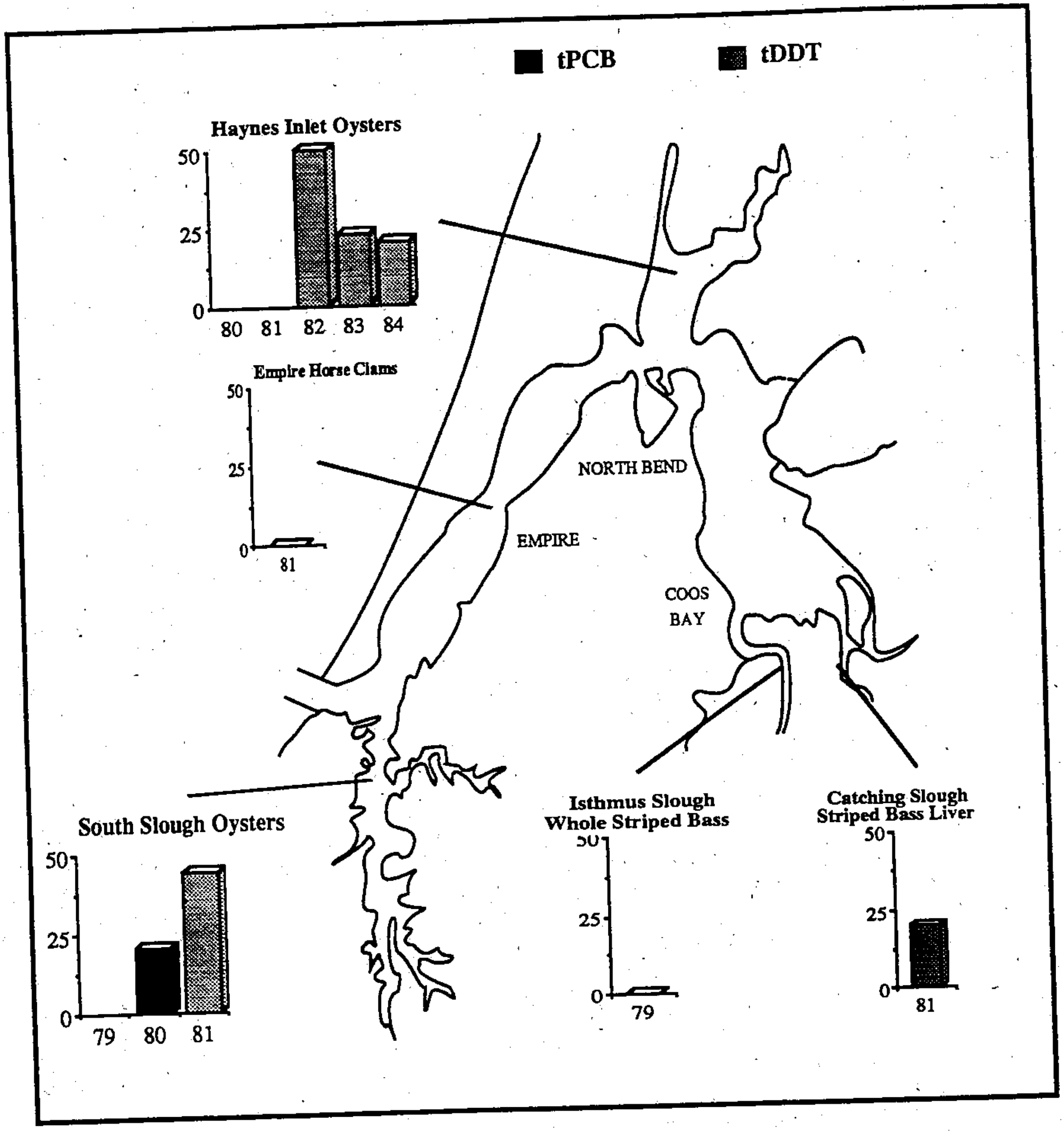

Figure 3.12 tDDT and tPCB concentrations in Coos Bay biota, 1979 to 1984 in ppb ww for tDDT and pptr ww for tPCB (DEQ, 1987).

Two studies were available which reported DDT and PCB values for marine mammals. In the first, Anas (1974) reported combined DDT and PCB levels in blubber of three harbor seals from the mouth of the Columbia River of 27.7, 80.4, and 139.9 ppm. Concentrations in samples from Alaska and California bracket these Columbia River values (Figure 3.13) Because Anas' sample sizes were extremely small, and because factors such as age and sex were not accounted for, care must be taken when comparing these values. All samples were taken during summer (June through August). As harbor seals do not migrate, they are thought to adequately reflect local contamination and potential bioconcentration.

Buhler *et al.* (1975) determined DDT and PCB levels in sick and healthy California sea lions collected along the Oregon coast in 1970-1973. Because these animals migrate along most of the West Coast, they are poor sentinel organisms of local conditions. Nevertheless, they can provide indications of the magnitude of bioconcentration possible for marine mammals in the coastal environment. Buhler *et al.* reported concentrations in various tissues and organs from healthy sea lions and sea lions infected with leptospirosis (Table 3.11). The impetus for their sampling was to understand the unusual strandings of numerous sick or dead sea lions along the Oregon Coast in 1970. This unusual condition may incorporate some bias in residue concentrations as indicators of [illegible] [illegible] [illegible] natural sea lion population.

3.3 Relevance of Chlorinated Hydrocarbon Levels Encountered

A summary of chlorinated hydrocarbon parameters from references used in Chapter 3 is presented in Table 3.12. If a specific compound was detected in biota, it is indicated by a 'B' in the table entry. An 'S' denotes the compound was detected in sediments, while an 'X' shows that the compound was not detected above the analytical limits. The chromatography techniques used by the principal investigators were roughly similar and, therefore, generally should have detected a similar suite of organochlorines. However, only those compounds which were ***specifically*** referred to in reports are reported in Table 3.12. Additional characteristics, including EPA criteria, for these compounds are given in Table 3.13.

Toxicity data of pesticides to marine species are rather scarce, and most data that are available are derived from acute bioassays. While acute bioassays are helpful for ranking compounds by relative toxicity, chronic tests are more appropriate for evaluating their potential damage to marine organisms. For example, an organism may be able to survive an acute dosage of a given concentration, yet reproduction, mobility, reaction times, *etc.* may be affected at that same concentration and the organism (and presumably the population) would have a diminished ecological viability. Depending on the extent of that impact, the population may be severely threatened.

Results from acute, aqueous bioassays, for two compounds detected in Oregon native water (Aldrin and Dieldrin), are presented in Table 3.14. These data, from numerous studies, were accessed through Chemical Information System (CIS), a computerized data base. These results suggest that levels of aldrin and dieldrin in Oregon water, though above EPA criteria (Table 3.13), were not likely to be high to ***acutely*** impact organisms, Levels may have been high enough, however, to cause some chronic stress to infaunal crustaceans (especially shrimp).

Due to insufficient data on water concentrations in Oregon, only very limited conclusions can be drawn from the information in Table 3.14. Furthermore, values of sediment concentrations, though more commonly available, can provide only approximate indications of the exposure and toxicity of a compound to infauna. Better methods to determine the potential impact of compounds need to be applied before a clear picture of risks to biota can be drawn. Likewise, occurrence of parent compounds in tissues should not be the sole parameter for indicating the degree of contamination of biota; lack of detection of parent compounds in tissues does not necessarily indicate pristine conditions. Metabolites which may be more abundant, more persistent, and more toxic than parent compounds need to be analyzed as well.

Another way to evaluate sediment contamination is by comparison with criteria for sediment levels of contaminants (Table 3.15). Though formal criteria have not been adopted nationwide, some interim guidelines do exist, and agencies are conducting research toward establishing official sediment quality criteria. Two major approaches to sediment quality criteria are currently being pursued by regulatory agencies-- equilibrium partitioning (EP) and apparent effects thresholds (AET). Equilibrium partitioning utilizes the physical properties of a chemical (*e.g.*, log K_{OW} and log K_{OC}) to predict the sediment concentration of a contaminant which results in an equilibrium concentration in interstitial water equal to the EPA's 24 hour, water quality criteria for that contaminant. The AET method relates concentrations of a contaminant with measures of biological effects (amphipod, oyster larvae, and microtox bioassays and benthic community impacts). The threshold is the ***maximum*** concentration associated with a station having no observable biological impacts. Presently, AETs are based on a limited database of stations from Puget Sound: as the database expands, AET values can only increase. Since AETs are arrived at for single contaminants, they disregard any cumulative, synergistic, or antagonistic interactions. Also, AETs derived from Puget Sound data have yet to be validated for other areas.

Table 3.12. Summary of chlorinated hydrocarbon references reviewed.

Reference	Matrix	Analysis Methods	PCB Reference Compounds	No. of Samples in Oregon
Anas '74	Harbor Seals	Electron Capture GC	Aroclor 1254	3
Buhler *et al.* '75	California Sea Lions	"	Aroclor 1254 and 1260	21
Butler & Schutzman '78	Fish	Electron Capture & Flame photometric GC	?	179
Butler '76	Fish	"	?	119
Claeys *et al.* '75	Pelagic Crustaceans, Bivalves, Fish	Electron Capture and Micro coulometric Detector GC	Aroclor 1254	19 Crust. 45 Bivalves 20 Fish
DEQ '87	Oysters & Fish	GC	Aroclor 1242, 1254, and 1260	14
Duke & Wilson '71	Fish	Electron Capture GC	?	2
Goldberg *et al.* '78	Mussels	GC	?	9
Farrington *et al.* '82	Mussels	GC	?	10
Fuhrer & Rinella '83	Sediment & Water	Electron Capture GC with Hydrolysis confirmation	Multiple Aroclors Base Models	11 Water 20 Sediment
Henny, *et al.* '82	Sea Birds	Electron Capture GC	?	63
Henny, *et al.* '80	Mink & River Otters	Electron Capture GC	?	59 Mink 20 Otter
Manigold & Schulze '69	Water	GC	?	19
Pearcy & Claeys '72	Albacore Tuna	Electron Capture & Micro-coulometric Detector GC	Multiple Aroclors	11
Sollitt *et al.* '84	Sediment & Water	EPA Methodology	?	111 sediment 24 water
Stout & Beezhold '81	Shrimp & Fish	Electron Capture GC	Aroclor 1254	3 Shrimp 13 Fish

Table 3.12 (continued)

Aldrin	BHC	Chlordane	DDT	Dieldrin	Endrin	Heptachlor	Hept. epoxide	Lindane	Methoxychlor	Mirex	PCBs	Silvex	Toxaphene	OTHERS [a]
x	x	x	B	x	x	x	x		x		B		x	
			B								B			
x		x	B	x		x		x	x	x	B		x	Endosulfan, Organophosphates
x		x	B	x		x		x	x	x	B		x	"
	x	B	B	B	x		x		x	x	x		x	Endosulfan (B)
x	B	x	B	x	x	x		x	x		B			HCB, Nonachlor
x	x	x	B	B	x	x	x		x		B		x	
			B								B			URC
			B								B			
S		S	S	S	x	S	x	S	S	x	S	x	x	Perthane(W); PCN; Endosulfan; 2,4-D; 2,4-DP(W); & 2,4,5 T
x			x	W	x	x	x	x			x	x	x	
		B	B	B	x		B	B		x	x	x	B	HCB, Nonachlor (B)
		B	B	x	x		x	x		x	x	x	x	HCB, Nonachlor (B)
		B									B			
		S									S			Chloro insecticides
		B									B			

[a] B- detected in biota; S- detected in sediment; W- detected in water; x - not detected.

Table 3.13. Biotoxicity and criteria data for selected contaminants (+ indicates postive response; n.a. indicates not available or applicable).

Pollutant	Aquatic[a] Toxicity	Bioaccumulation[a] potential (log P)	Metabolic[a] Degradation	Carcino-[b] genic	EPA[b] Aqueous Criteria 4-day avg (ppb)	EPA Priority[b] Pollutant Concen.	Maximum[c] Oregon Water Concen. (ppb)	Maximum[c] Oregon Sediment (ppb dw)
Aldrin	High	na	Fast	+	1.3(acute)	+	0.01	1.5
Dieldrin	High	na	Slow	+	0.0019	+	0.006	0.5
Aldrin/ Dieldrin (combined)	High	na	na	+	0.0069	na	0.02	2.0
BHC	Low	3.81	Fast	-	0.34[d]	+		
Chlordane	High	2.78	na	+	0.004	+	bd	2
Endosulfan	High	3.55	na	-	0.0087	+		
DDTs	Varies	5-6	Medium	+	0.001	+	bd	17.8
PCBs	Varies	4-6	Varied	+	0.03	+	bd	34

a Callahan *et al.*, 1979.

b EPA criteria, except as noted, are 4-day conventrations not to be exceeded once every three years for the protection of marine organisms from chronic impacts. From EPA, 1986.

c Fuhrer & Rinella, 1983; Fuhrer, 1984; or Sollitt, *et al.*, 1984.

d Insufficient data for criteria; value is Lowest Observable Effect Level for acute impacts.

Table 3.14. Acute, aqueous toxicities of aldrin and dieldrin (CIS, 1983).

Conc. (ppb)	Expos. (hrs.)	Effect	Species	Test Environment
<u>Aldrin</u> - Oregon Water[a]: 0.01 ppb				
10	96	Sublethal	Oyster	
25	Acute	EC_{50}	Eastern oyster	Flow-through
8	"	LC_{50}	Sand shrimp	Static
9	"	"	Gross shrimp	"
0.7	96	"	Korean shrimp	"
3	96	"	Korean shrimp	Flow through
0.3	1 day	EC_{50}	Pink shrimp	Static
33	Acute	LC_{50}	Hermit crab	Static
23	2 days	EC_{50}	Blue Crab (juvenile)	
5	Acute	LC_{50}	American eel	Static
8	"	"	Mummichog	"
4	"	"	Mummichog	"
17	"	"	Striped killifish	"
13	"	"	Atlantic silverside	"
39.8	"	"	3spine stickleback	"
274	"	"	3spine stickleback	"
7.2	"	"	Striped bass	Flow through
7.44	"	"	Shiner perch	Static
2.2	"	"	Shiner perch	Flow through
2	"	"	Dwarf perch	Flow through
12	"	"	Bluehead	Static
100	"	"	Striped mullet	Static
2	2 days	"	Striped mullet	
2.8	2 days	"	White mullet	
38	Acute	"	Northern puffer	Static
<u>Dieldrin</u>	Oregon Water[a]: 0.006 ppb			
50	5	LC_{100}	Mullet	
12	168	LC_{100}	Sailfin Molly	
595	5	TL_m	Shrimp larvae	
25	48	"	Brown shrimp	
50	48	"	White shrimp	
1172	24	"	Brine shrimp	Rock salt

[a] Maximum from Fuhrer and Rinella, 1983; Fuhrer, 1984; or Sollitt *et al.*, 1984

The data in Table 3.15 indicate that sediment DDT concentrations reported for some Oregon samples have exceeded both the EP and AET criteria recommended to EPA; total PCBs have exceeded the USGS Alert level; and aqueous dieldrin levels have exceeded the criteria for interstitial water as adopted by Region VI of the EPA. Maximum levels reported for Oregon samples for the other pesticides, and PCBs, listed in Table 3.15 are within one order of magnitude of the EP sediment criteria recommended to EPA. Given that these criteria are based on *acute* impacts, it is not unlikely that on occasion, infauna in and around the sites where these sediment samples were collected have been stressed by some chronic impacts.

Table 3.15. Various sediment quality criteria, along with maximum sediment concentrations for Oregon.

Contaminant	Maximum Oregon[a] Contaminant Level in Sediment (ppb dw)	Sediment Criteria EP Approach (ppb dw)	Sediment Criteria AET[b] Approach (ppb dw)	USGS[c] Alert Level (ppb)	EPA Region VI[c] Interstitial Water Criteria (ppb)
Aldrin (0.01 in water)	1.5	6.3	-	20	3
Dieldrin (0.006 in water)	0.5	1.1	-	20	0.0019
DDT	17.8	2.4	3.9	20	0.001
Lindane	0.4	3.2	-	20	-
Heptachlor	0.2	2.	-	20	0.0053
PCBs	34.	120	130	20	0.014

[a] Maximum values reported by Fuhrer and Rinella, 1984.
[b] Value is the lowest criteria given for the four measures of biological impacts (Tetra Tech, 1986).
[c] Cited in Pavlou and Weston, 1983.

Summary

- In relation to national levels, chlorinated pesticide levels were generally low (or below detection) throughout the state. However, there were certain locations, relative to statewide values, at which significantly higher sediment concentrations could be observed.

- The chlorinated pesticide compounds most commonly reported for Oregon samples (given the analysis techniques used and their detection limits) were DDT, PCBs, dieldrin, and chlordane.

- While sediment concentrations of most pesticides and PCBs were low in comparison to national levels, comparison with various sediment quality criteria indicate they may have been sufficiently high enough in certain areas to cause chronic stress to infauna, particularly crustaceans.

- Based on limited sampling, coastal DDT and PCB levels in biota off Oregon appear not to have been significantly different from those off Washington. Furthermore, offshore levels did not appear to be significantly influenced by the Columbia River. The Columbia River estuary, however, was the embayment with the widest variety and highest levels of chlorinated compounds within Oregon.

- Pesticide levels in Oregon were not representative of "background" or "baseline" levels; lower levels of contaminants have been reported from other regions of the West Coast.

- There are some indications that levels of chlorinated pesticides in Oregon are declining, however, the scarcity of data within the state does not permit conclusive analysis.

4. POLYNUCLEAR AROMATIC HYDROCARBONS

Polynuclear aromatic hydrocarbons (PAHs) are a class of compounds composed of two or more benzene rings. As a group, they are ubiquitous in nature (Youngblood and Blumer, 1975). However, as by-products of combustion and constituents of petroleum products (plus other sources), levels of specific PAHs have greatly increased since the Industrial Revolution (Hites *et al.*, 1977). PAHs enter the marine environment primarily via atmospheric fallout, in runoff, sewage effluents, industrial discharges, and spillage of petroleum products. Sediments are the main repository of PAHs, since sorption is pronounced in seawater (Callahan *et al.*, 1979). They are moderately lipophilic and can accumulate in biota (Roubal and Atlas, 1978), where they are metabolized to varying degrees by different species (Varanasi *et al.*, 1985).

Concern about PAHs is based on the fact that many of these compounds are extremely carcinogenic and/or toxic (especially those with a "bay" region to the molecular structure). Of EPA's 129 Priority Pollutants, greater than 10 percent are PAHs (16). These compounds have been purported in various studies to be the most likely causative agents (over PCBs, metals, etc.) for tumors observed in feral fish (Varanasi *et al.*, 1985).

4.1 Sediment and Water Concentrations

No studies reporting levels of anthropogenic PAHs in sediments, water, or suspended solids were available for review.

4.2 Biotic Concentrations

Data regarding levels of PAHs in marine organisms in Oregon were available from only one investigator, Dr Michael Mix of Oregon State University (Mix, 1979; Mix, 1982; Mix *et al.*, 1982). He determined tissue levels of individual PAHs during 1978 to 1980 in soft-shell clams and gaper clams from Coos Bay and in mussels and oysters from Yaquina Bay. He also conducted spot sampling of mussels, soft-shell clams, and oysters in Tillamook Bay in 1979 (Figure 4.1). Mix also investigated depuration rates, tissue storage sites, seasonality of PAH levels, and cellular proliferative disorders.

4.2.1 Site specific levels of PAH and site comparisons

A description of Mix's sampling scheme and ranges of levels encountered is presented in Table 4.1. Mix sampled bivalves from relatively non-industrialized areas in Tillamook Bay (T1M, TSS, TBC): at a pristine site (Y14C), a slightly industrialized site (Y1M), and one heavily developed site (Y2M) in Yaquina Bay; and at three sites ranging from pristine (C3S) to heavily industrialized (CSS) in Coos Bay. Four methods were used to identify individual PAHs. Mix used liquid chromatography with a variable wavelength ultraviolet detector and a variable wavelength fluorescence detector in series. Individual PAHs were quantified by use of an internal data system (of the high-pressure liquid chromatography [HPLC]). Concentration factors were calculated during a calibration run, then applied to sample peaks nearest the retention time of the calibration peaks. Concentrations for all PAHs were corrected using benzo(a)pyrene (B(a)P) recovery factors determined through ^{3}H liquid scintillation.

Mix did find significant differences between these estuaries, and also between sites within Coos and Yaquina Bays themselves (Table 4.2). The overriding factor for these differences appeared to be the degree of industrialization, *i.e.*, proximity to probable sources. Concentrations did not follow simple downstream gradients.

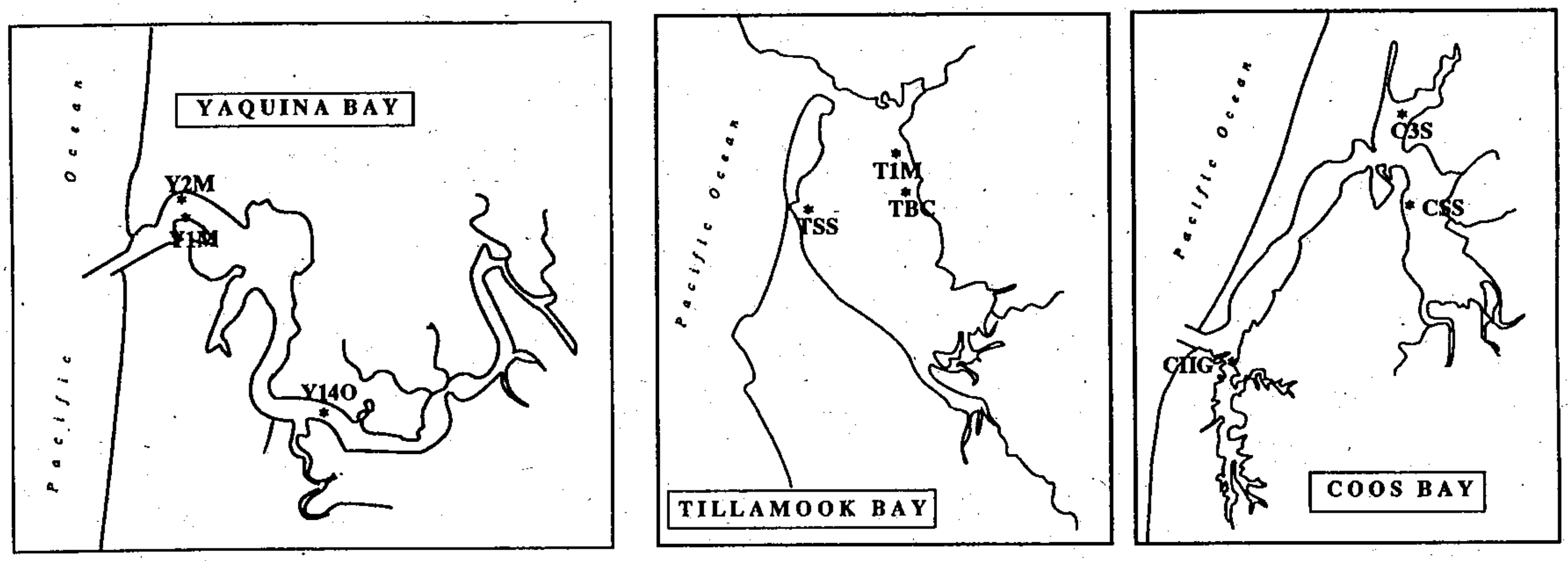

Figure 4.1. Sampling sites for PAH analyses (Mix, 1982).

Table 4.1. Sampling design for PAHs and ranges of concentrations encountered (Mix, 1982).

Site	Station	Species	Period of Sampling	Purpose (number of sampling dates)	PAH (ppb wet wt)	Degree of Industrialization
Tillamook	T1M	bay mussel	Twice 1979	PAH (2)	40-60	Relatively pristine
	TBC	oyster	Thrice 1979	PAH (3)	35-45	Relatively pristine
	TSS	soft-shell clam	Quarterly 1979	PAH (4)	30-60	Relatively pristine
Yaquina	Y14C	oyster	Quarterly 1976-80	PAH(14)	30-45	Relatively pristine;
	Y1M	bay mussel	Bimonthly 1978-80	PAH (17)	140-440	Light; shipping docks
				Histology (6)	0-2%	
	Y2M	bay mussel	Bimonthly 1978-80	PAH (12)	675-1325	Heavy; marinas, fish processing, recreational developments
				Histology (5)	4-12.2%	
Coos Bay	C3S	soft-shell clam	Bimonthly 1978-80	PAH (6)	70-90	Relatively pristine; near highway
				Histology (4)	0%	
	CSS	soft-shell clam	Bimonthly 1978-79	PAH (6+7)	480-650	Heavy; shipping docks, wood products industry, and marinas
				Histology (4)	0%	
	C11G	gaper clam	Bimonthly 1978-80	PAH (10)	30-110	Light; near marinas & fish processing plants

Table 4.2. Mean PAH concentrations of Oregon bivalves, ppb ww (See Table 4.1 for sampling dates) (Mix, 1982).

PAH	Y1M (mussel)	Y2M (mussel)	Y140 (oyster)	C3S (clam)	CSS (clam)	C11G (gaper clam)	T1M (mussel)	TSS (clam)	TBC (oyster)
3 Ring									
PHEN	113.4	216.3	6.2	12.2	154.8	16.4	14.0	11.4	8.0
4 Ring									
FLOUR	49.5	179.9	5.8	10.5	110.7	10.0	9.5	7.9	9.0
PYR	24.7	109.3	3.7	6.3	61.6	6.3	7.4	5.6	3.7
BCP	27.8	94.1	4.3	3.1	55.3	6.0	4.8	2.6	4.5
TRI	28.0	105.5	2.5	7.9	43.3	5.4	3.3	4.7	4.6
BAA	30.0	94.2	5.2	2.9	41.7	7.7	2.5	1.9	2.4
CHRY	na	86.2	3.8	7.6	27.2	5.5	3.8	1.3	3.8
5 Ring									
BJF	na	na	na	na	na	na	na	na	na
BBF	2.5	8.0	1.2	1.5	12.1	2.4	1.2	1.0	1.1
BKF	2.5	17.4	1.2	2.6	9.6	1.6	0.8	0.1	2.7
BEP	na	na	na	na	na	na	na	na	na
B(a)P	1.3	26.2	1.4	3.5	8.7	1.1	0.3	0.5	1.1
DBAHA	2.1	9.6	0.4	4.7	6.9	0.9	0.3	0.7	0.8
6 Ring									
BGHIP	0.4	8.1	0.3	5.4	4.2	0.4	0.2	0.9	1.1
IP	0.3	5.7	0.3	5.9	3.9	0.3	0.2	0.1	0.7
7 Ring									
COR	0.7	4.6	0.4	1.3	2.7	0.3	0.2	0.0	0.6
TOTAL	283	986	37.8	76.3	551.1	67.5	48.6	39.9	41.3

PHEN - phenanthrene
FLOUR - flouranthene
PYR - pyrene
BCP - benzo(c)phenanthrene
TRI - triphenylene
IP - indeno(1,2,3-c,d)pyrene
BAA - benzo(a)anthracene
CHRY - chrysene
BJF - benzo(j)flouranthrene
BBF - benzo(b)flouranthrene
BKF - benzo(k)flouranthrene
COR - coronene
BEP - benzo(e)pyrene
DBACA - dibenz(a,c)anthracene
B(a)P - benzo(a)pyrene
DBAHA - dibenz(a,h)anthracene
BGHIP - benzo(g,h,i)pyrylene

4.2.1.1 Tillamook Bay

In Tillamook Bay, the least developed of all three bays, levels in oyster, mussels, and soft-shell clams did not differ among each other (Boniferroni t-test), even though collection sites were separated by several kilometers downstream. Average ΣPAH concentrations of all species was 42 ppb. Due to the relatively pristine environment of Tillamook Bay, this level will be used as a "background" concentration for Oregon.

4.2.1.2 Yaquina Bay

Concentrations in oysters from Yaquina Bay (mean ΣPAH=37.8 ppb) were similar to those found in all three species from Tillamook Bay (Boniferroni t-test), indicating a general parity with "background." Levels in Yaquina mussels, however, were considerably higher than either Tillamook mussels or oysters (Student's t-test). Yaquina mussels were sampled from two different sites located 7 to 8 km downstream of the oyster site in a much more developed setting. Of these sites, Y2M, (mean ΣPAH=986.2 ppb) was the more heavily industrialized, and had three to four times higher concentrations of all individual PAHs than the other site, Y1M, located just across the bay (mean ΣPAH=283.6 ppb). Degree of industrialization was the explanation presented for this difference between species, as well as the difference between the two mussel sites (Mix, 1982). This conclusion was further supported by the following points: variations in levels at Y2M did not correlate with temperature and/or salinity patterns; there were no increases in either gonad weight or B(a)P contributed to the gonad during times of high PAHs; and there were no seasonal patterns in oysters or Y1M mussels, as was found in Y2M mussels (Mix, 1982). It was concluded that gametogenesis was not responsible for the seasonal variations, but rather inputs of PAHs increased during winter and early spring and thus accounted for the seasonality of ΣPAH concentrations at Y2M. One notable trend was that levels at Y1M decreased through time (regression test). This was the only site which had a clear temporal increase or decrease.

4.2.1.3 Coos Bay

In Coos Bay, both soft-shell clam sites had significantly higher ΣPAH levels than all species from Tillamook Bay (Boniferroni t-test) indicating greater than "background" levels, and were significantly different from each other (Student's t-test). The CSS site was located along North Bend (mean ΣPAH=351 ppb), with C3S further north, on the far side of the main channel (mean ΣPAH=76 ppb). The difference in total levels was due to concentrations of three and four ring PAHs. Levels of individual five, six, or seven ring PAHs were not significantly different between the two sites (Students t-test). Mix's depuration tests indicate that lower ring compounds are purged very quickly, relative to the five, six, or seven ring compounds, and high values of lower ring compounds would therefore represent recent exposure. The difference between these two sites would then suggest a source in close proximity to North Bend.

Gaper clams, sampled from the South Slough area, had a mean ΣPAH concentration of 67.5 ppb. (This was the only site where gaper clams were sampled). This was comparable to levels in all three species from Tillamook Bay (Boniferroni test) and also soft-shell clams from C3S. It was, however, significantly less than levels in soft-shell clams from North Bend (Student's t-test). Due to species differences, no implication should be assigned to these similarities or differences.

Gaper clams showed no seasonal patterns, but ΣPAH concentrations were bimodal--37 to 51 ppb, and 104 to 110 ppb--between sampling events. The difference was attributable to variations in individual three and four ring PAH concentrations. This would be indicative of exposure incidents just prior to sampling in the South Slough. These higher level events occurred in four of the ten samples.

4.3 Relevance of PAH Levels Encountered

One statement can be made concerning PAH levels in Oregon, in comparison to data from the Puget Sound region (Riley *et al.*, 1981). The data of Riley *et al.* encompass a range of sites, from "clean" to Superfund sites. Riley *et al.* measured more compounds than Mix (27 versus 17) (Table 4.1), and reported their data in dry weight concentrations. However, the range of values between both studies is quite similar, and data for individual PAHs are generally similar as well. (A complete comparison is not possible since only summary data were presented for Puget Sound.) For example, Riley presented the following: 940 ppb in clams from the Duwamish and Hylebos waterways, 260 ppb in clams from Elliott and Commencement bays, and 30 ppb in clams from Case Inlet and Port Madison. Clearly, levels of PAHs in Oregon are not representative of "background" conditions, and actually indicate a fair degree of contamination.

4.3.1 EPA criteria and guidelines

Few specific PAH criteria for the protection of aquatic or marine life exist, due to lack of sufficient information. For the protection of human health from the potential carcinogenic effects due to exposure of PAHs through ingestion of contaminated water and aquatic organisms (*i.e.*, zero cancer rate), a zero level ambient criterion (*i.e.*, no PAHs) is recommended, based on threshold assumptions for these chemicals (EPA, 1980).

The data were encountered for PAH concentrations in Oregon marine waters. EPA has developed a model for estimating concentration limits, based upon assumptions of acceptable cancer risk, uptake of PAHs from marine waters by seafood species, and lifetime consumption of seafood (EPA, 1986). A limiting concentration of 0.311 µg/L is indicated if the human diet contains no other source of PAH.

A method of assessing seafood consumption risks has been developed for EPA (Tetra Tech, 1986, 1988). this risk assessment method uses a predictive model, with certain assumptions, to scientifically estimate the probability of incurring an adverse health effect from exposure to a toxicant. These standard assumptions are for 70 kg person with a lifespan of 70 years eating one-third pound of seafood each meal during a low average of 34 or high average of 52 meals per year, and utilize the EPA multi-stage cancer models.

4.3.2 Toxicity

Because only body burdens, and not aqueous concentrations, were measured by Mix, comparisons with laboratory acute or chronic bioassays to infer toxicity of Oregon levels are not possible. Mix did investigate the correlation between PAH levels and cellular pathology however. These results are discussed in the "Biological Measures" section.

4.4 Relationships Among PAH Concentrations

Mix found that there were generally no significant differences in tissue levels between specific PAHs of three or four rings, or among those compounds of five, six, or seven rings (Mix, 1982). Furthermore, there was an empirical relationship between an individual PAH tissue concentration and its solubility: smaller, more water-soluble PAHs were found in tissues at one or two orders of magnitude above the larger, lipid-soluble ones. In depuration experiments with soft-shell clams, Mix found that these smaller three and four ring PAHs were significantly reduced within 24 hours, but levels of the larger PAHs did not change significantly.

Using multiple regression and correlation, Mix concluded that a single PAH could not be used to predict ΣPAH concentrations, but a suite of PAHs, appropriate for a specific site, could be used (Mix, 1982). At two contaminated sites Mix was able to account for 99 percent of variance in ΣPAHs, using levels of only two or three individual PAHs. At one "pristine" site, however, levels for seven compounds were needed to make predictions at the same accuracy. An initial survey of a site would be necessary to determine what particular suite of individual PAHs should be measured as predictors. For all his sites in Oregon, Mix found that B(a)P was not a significant predictor, representing only 1 to 29 percent of the total PAH. In the past, B(a)P has been a common parameter to singularly describe the degree of contamination by total PAHs.

Summary

- No systematic sampling of sediment or water in Oregon has been conducted to determine levels of PAHs.

- Levels of PAHs in Oregon bivalves have been measured in Tillamook, Coos, and Yaquina bays. Concentrations ranged from 30 to 1,325 ppb. This is comparable to the range of concentrations encountered in Puget Sound,

- Bivalves in Tillamook Bay had the lowest concentrations. "Pristine" areas of Yaquina and Coos bays had similar levels. Sites with higher concentrations, in both Yaquina and Coos bays, were in close proximity to population centers.

- The highest values encountered occurred at a site next to Newport, Yaquina Bay. There was a cyclic variation in ΣPAH levels at this site, with high values in winter. This cycle did not correlate with any reproductive cycles, salinity, temperature, or ΣPAH concentrations at other sites. It was therefore postulated that inputs at this site were cyclic.

- Concentrations of ΣPAH in South Slough (Coos Bay) were bimodal. The difference between modes was due mainly to higher levels of individual three and four ring PAHs. The incidences of higher levels of ΣPAH were not cyclic, but were apparently due to exposure to increased levels shortly preceding sampling.

- As a sole-source, dietary exposure, Oregon bivalves from any of the sites studied have high enough ΣPAH levels to pose a significant cancer threat (given the assumptions of the EPA cancer model). While a dietary exposure solely of bivalves is unlikely, high consumption of bivalves from specific sites should be discouraged.

5. MISCELLANEOUS HYDROCARBONS

Only two, systematic studies explicitly describing occurrences of any classes of organic hydrocarbon compounds, other than pesticides, PCBs, or PAHs were encountered. The first, a published study by the USGS/COE, reported aqueous levels of phenolics (Fuhrer, 1984). The second data set, that of bulk oil and grease determinations from Coos Bay (Sollitt *et al.*, 1984), are presented to highlight spatial patterns for that area. Finally, a third, unpublished data set on sediment phthalate concentrations in Yaquina Bay, was provided by EPA (Schultz, 1984).

5.1 Phenolics

In the earlier USGS/COE study (Fuhrer and Rinella, 1983), bulk phenolics were detected in water samples from every site except Yaquina Bay (see Figure 3.1 for sampling sites); concentrations ranged from below detection (1 ppb) to 9 ppb. Values at the higher end of the range were found in the Columbia River region; lowest values were encountered in Tillamook Bay; and levels were below detection in the one Yaquina Bay sample. Concentrations in elutriates were consistently higher at all sites; the maximum value reported was 420 ppb.

A gross, colorimetric methodology was used for the 1980 samples. Phenolics were re-investigated in the Columbia, Rogue, and Chetco rivers using GC-MS techniques in order to more thoroughly understand their occurrence (Fuhrer, 1984). General findings from the 1982 sampling were that the phenolics encountered were generally of natural origin (Fuhrer, personal communication). No pentachlorophenol, one of the most toxic of the chlorophenolics, was detected (Fuhrer, 1984). Aqueous dichlorophenol in the Columbia and Rogue rivers, at approximately 2 ppb, was the only chloro-phenolic compound detected.

5.2 Oil and Grease

One bulk-measurement parameter employed in the COE Coos Bay disposal investigations was bulk sediment oil and grease (Sollitt *et al.*, 1984). Data are presented from this one data set to highlight the spatial and temporal trends at Coos Bay (Figure 5.1).

Oil and grease were detectable in all samples from the 3-mile stretch of channel along North Bend and Coos Bay, ranging from 410 to 2,200 ppm. The highest concentrations occurred at the head of Isthmus Slough. In contrast, levels of oil and grease were detectable only in half the samples from one of three candidate offshore disposal sites at 185 ppm, and only once each at the other two sites.

Post-disposal sampling indicates mean concentrations of 354 and 240 ppm within the disposal area, 1 and 1½ years after disposal. These levels of oil and grease are significantly elevated over the site 'H' reference (Student's t-test). This same basic trend was also observed for volatile solids and cadmium.

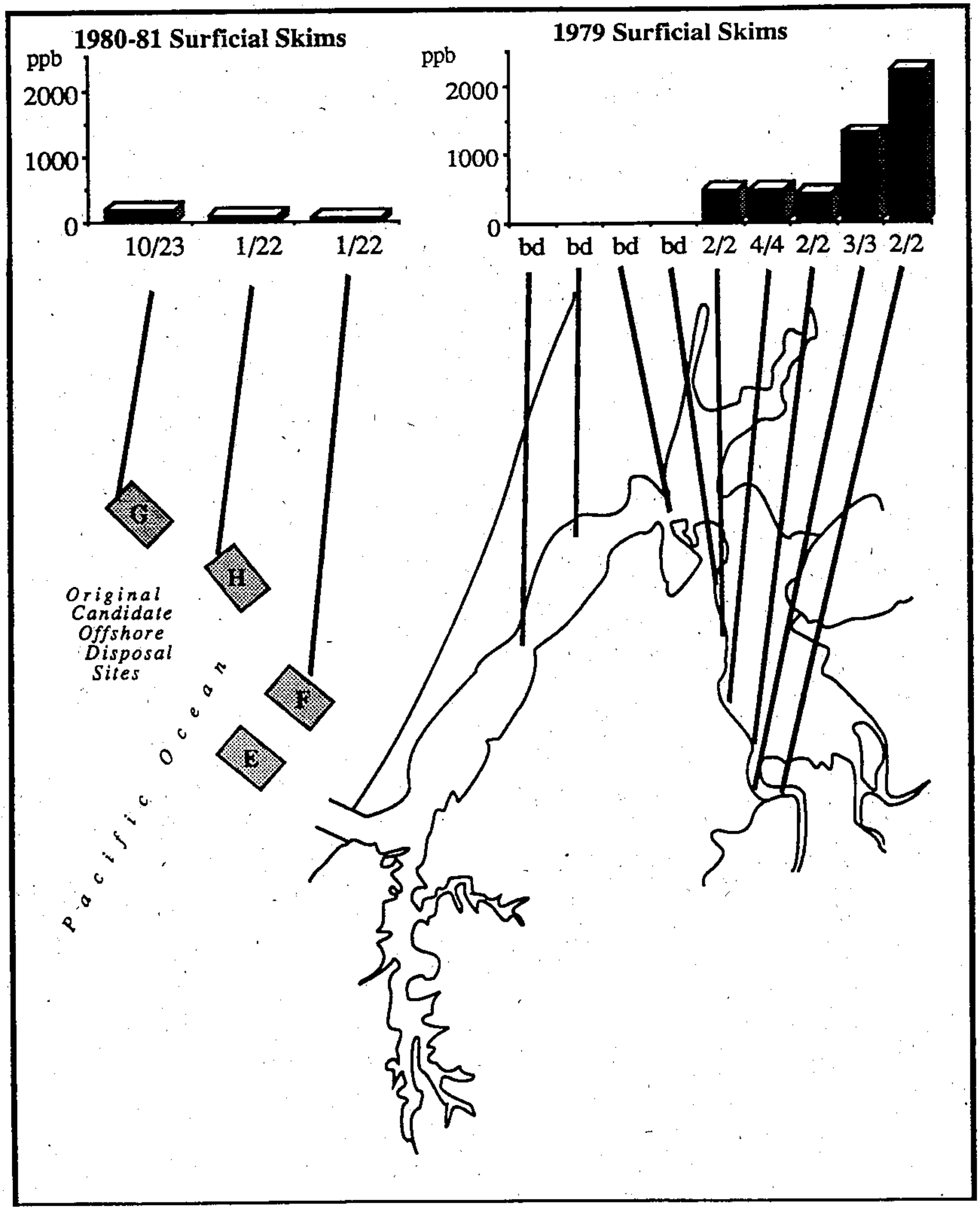

Figure 5.1. Coos Bay sediment oil and grease concentrations in ppb dw. Fractions are number of positive samples over number of total samples (Sollitt et al., 1984).

5.3 Phthalate Esters

There was only one unpublished data set available detailing sediment concentrations of phthalate esters in Oregon. In conjunction with sediment toxicity bioassays, Richard Swartz of EPA has analyzed sediment from a site in Yaquina Bay directly opposite Newport. Preliminary data indicated the absence of Aroclor 1254, HCB, and phenols above detection limits. Yet phthalate ester compounds were detected at the following levels (corrected for procedural blank):

diethyl phthalate	(DEP) -	1.6 ppb
dibutyl "	(DBP) -	9.7 "
butylbenzyl "	(BBP) -	0.9 "
diethyl hexyl "	(DEHP) -	31.3 "
dioctyl "	(DOP) -	6.0 "

The value for DOP is questionable; this sample may have been contaminated in the lab, (Schultz, personal communication). DEHP was the most predominant phthalate, which has also been found to be the most predominant phthalate compound in Puget Sound (Seattle METRO, 1984). Several PAHs and p,p'-DDE were also detected in these samples.

All of these data are preliminary and have not been peer reviewed as yet. Also, concentrations in procedural blanks were quite high in comparison to environmental samples. However, there is the indication that sediment at that site has been contaminated, to some degree, with a variety of chemicals including phthalate esters. It should also be pointed out that in spite of the presence of phthalates, a population of amphipods do exist at this site.

Phthalate esters have not been classified as carcinogens, yet Rubin *et al.* (1979) reported that dimethyl phthalates (DMP) and DEP produced positive *in vitro* mutagenic responses. Acute toxicity levels of phthalate esters are reasonably high, however, their sublethal effects are of much greater concern. EC-50 concentrations for a dinoflagellate range from 3.4 to 200 ppb for DBP; 3,000 to 6,100 ppb for DEP; and 54,000 to 96,000 ppb for DMP (Wilson *et al.*, 1978). Growth of brook trout is reduced significantly at 300 ppb DBP, but not at 90 ppb (McKim, 1974).

Considering that the Yaquina Bay site is 96 percent sand, it is expected that it would exhibit very low concentrations of most any organics. Nevertheless, phthalates were detected, and at levels that may approach significant chronic sublethal exposures. Given the sandy composition at this one site versus the rest of the bay, it is not unreasonable to expect that higher levels might be found in the finer grain portions of the bay. The occurrence of phthalates deserves further monitoring attention.

Summary

- Only one systematic sampling for specific hydrocarbons in Oregon sediments or biota, other than pesticides, PCBs, or PAHs was encountered--the synoptic survey of the USGS/COE (Fuhrer, 1984) which included phenolics for the limited sampling during the second year.

- Aqueous levels of "phenol" were common in samples from all sites, ranging from 1 to 9 ppb. Dichlorophenol was the only chlorinated phenolic compound detected in five samples analyzed by mass spectrometry.

- Sediment levels of phthalate esters from one site in Yaquina Bay indicate that there may be a significant, chronic exposure to infauna by some of these compounds.

- Oil and grease analyses from Coos Bay indicate that sediments from Isthmus Slough to North Bend are significantly contaminated (over offshore reference sites), and that this contamination persists for at least $1^{1}/_{2}$ years following disposal offshore.

- The need for more broad-scan analyses of samples from Oregon is indicated to document the nature and degree of contamination by assorted hydrocarbons.

6. TRACE METALS

Trace metals are ubiquitous constituents in the environment. They are natural components of soils and sediment and occur in soluble forms as well. Many trace metals are essential nutrients for flora and fauna. However, as their nomenclature implies, they normally occur at low levels in natural matrices, *e.g.*, ppb and less in water. At higher concentrations, many are toxic to organisms. Moreover, some of these metals--such as Cd, Hg, and Pb--have never been shown to be requisite nutrients, yet because of their chemical and steric nature, these toxic trace metals may be assimilated by organisms along with essential nutrients.

The identification of trace metal contamination in coastal marine environments is difficult. Assessing background levels is often a tenuous process. Natural inputs may be on the same order of magnitude as anthropogenic sources, or even greater. Also, concentrations of particular elements may vary widely according to the geologic nature of and degree of influence by adjacent watersheds.

Direct input of trace metals from outfalls, dumping, or runoff is the route of primary concern in the coastal region (Burns, personal communication). However, one characteristic of trace metals allows assessment of man's additive impact: because of high affinities for particulate phases, physical transport of certain metals in the coastal zone is on the order of a few kilometers (Burns, personal communication). Relative comparisons may then be made between stations, within a locale, with only moderate regard to absolute elevation above natural background levels.

In this report six metals of concern were chosen--Cd, Cr, Cu, Hg, Pb, and Zn. These metals were chosen on the basis of their toxicity, availability of data, and anthropogenic mobilization rates within Oregon. Some data on As and silver (Ag) have also been included. Data generated as portions of radiochemistry studies were generally not reviewed or included.

There are differences among analytical methods and data reporting for trace metals in sediment or water (, "total recoverable" vs. "total digestible"). Freshwater data from Oregon suggest that several sediment metal concentrations may be an order of magnitude greater when reported as "total digestible" than "total recoverable" (Dunnette, 1983).

6.1 Sediment and Water Concentrations

Six studies of trace metal concentrations in either water or sediment were reviewed. Only one study, the USGS/COE survey (Fuhrer and Rinella, 1983; Fuhrer, 1984), provides statewide data. Other more area-intensive studies provide checks and references for the USGS data.

Fuhrer and Rinella reported aqueous dissolved and "total recoverable" sediment concentrations. Data from this study for the Columbia River Estuary are presented in Figures 6.1A-F, and for six coastal estuaries in Figures 6.2A and B.

With respect to known contaminated sites, the sediment data of Fuhrer and Rinella show Oregon to have comparatively low trace metal levels. However, there were certain instances of high values, relative to state- wide levels. Portions of the Columbia River Estuary--Baker Bay, Astoria docks, and Skipanon channel--had elevated concentrations of Cd, Cr, Cu, Hg, Pg, and/or Zn. Baker Bay is a depositional zone of fine sediments, with marinas at either end. Both Astoria docks and Skipanon channel are sites of light to moderate industrial shipping traffic.

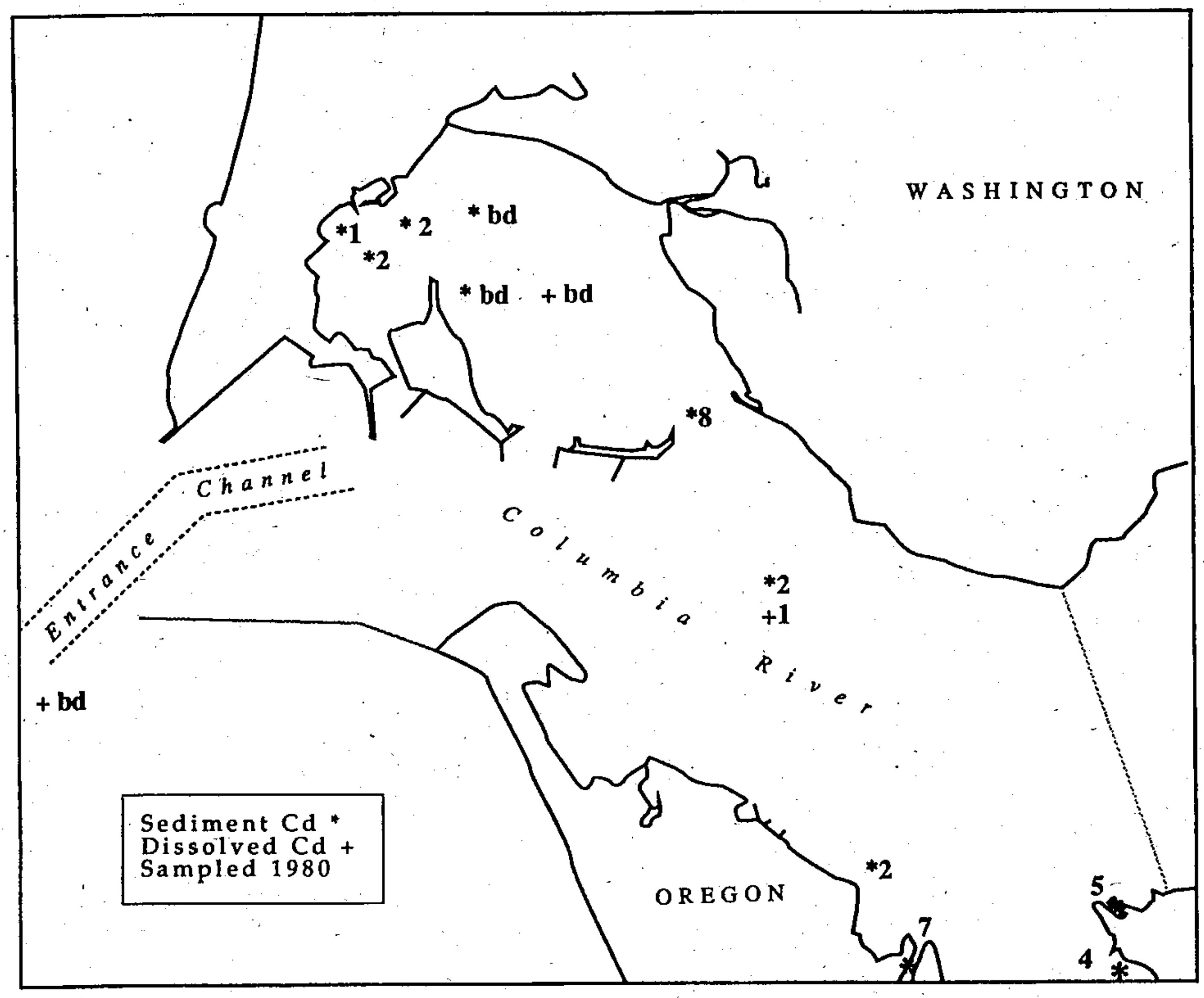

Figure 6.1a. Sediment Cd concentrations in ppm dw (asterisks) and dissolved Cd concentrations in ppb (crosses) in the Columbia River Estuary (Fuhrer and Rinella, 1982).

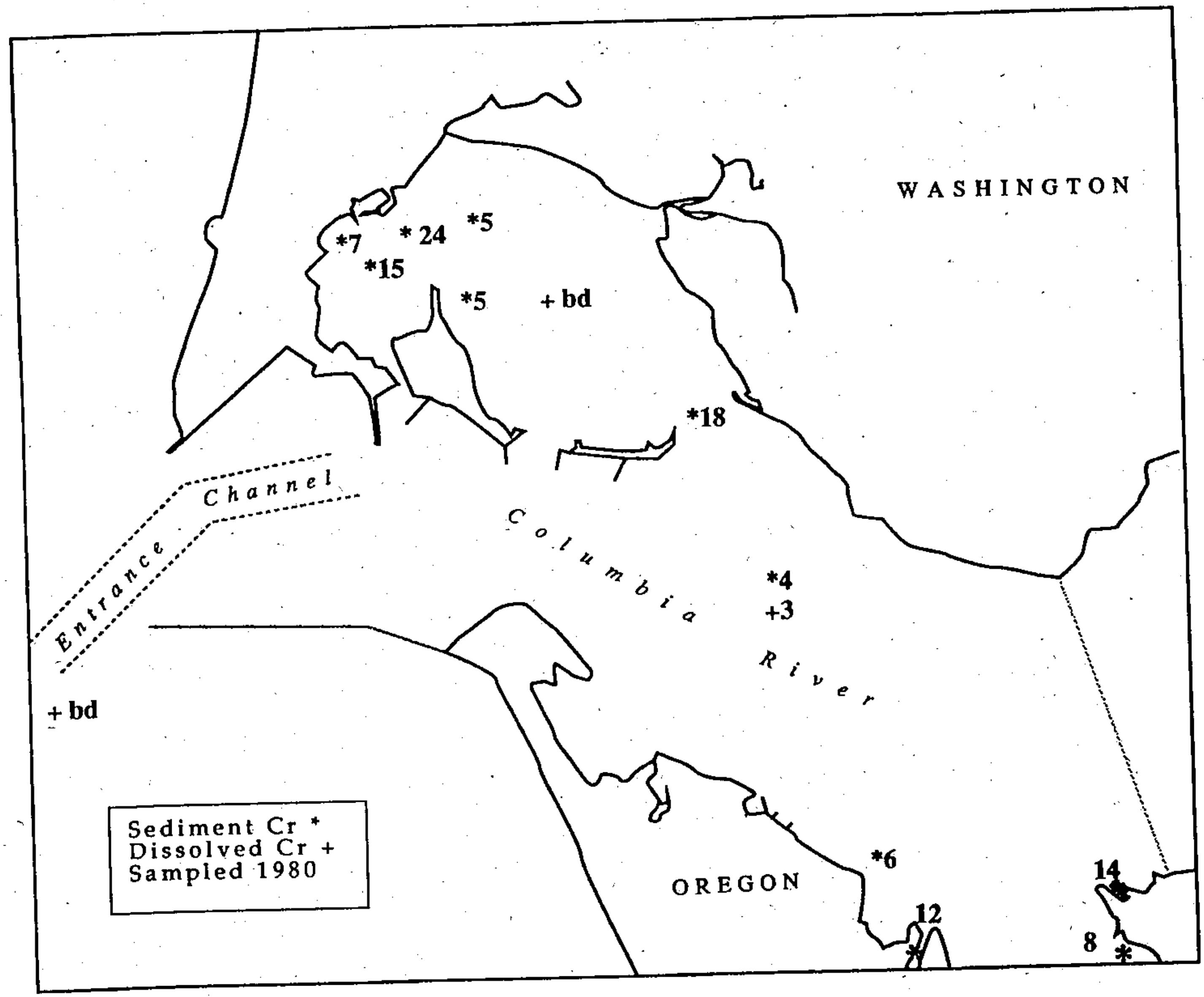

Figure 6.1b. Sediment Cr concentrations in ppm dw (asterisks) and dissolved Cr concentrations in ppb (crosses) in the Columbia River Estuary (Fuhrer and Rinella, 1982).

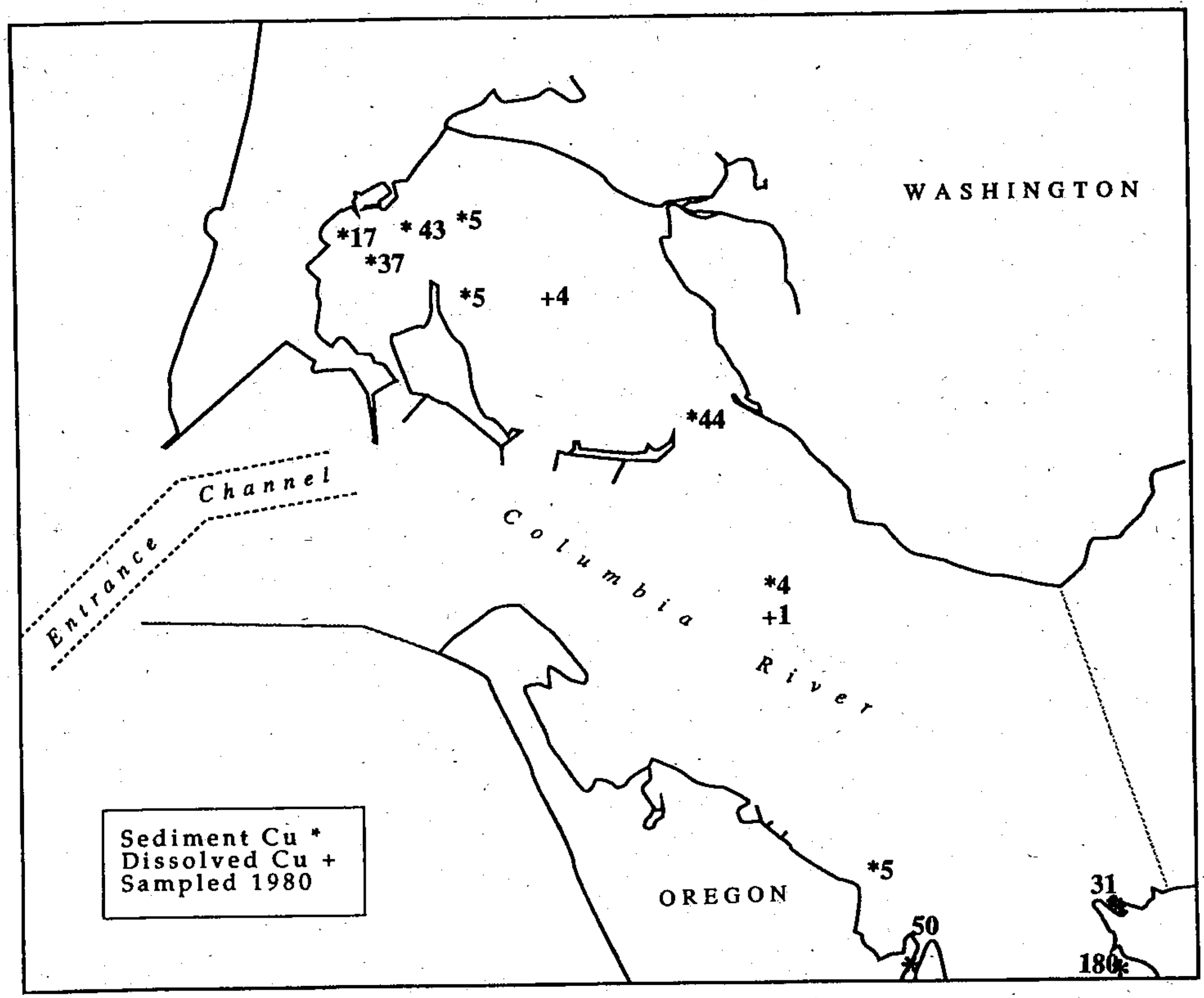

Figure 6.1c. Sediment Cu concentrations in ppm dw (asterisks) and dissolved Cu concentrations in ppb (crosses) in the Columbia River Estuary (Fuhrer and Rinella, 1982)..

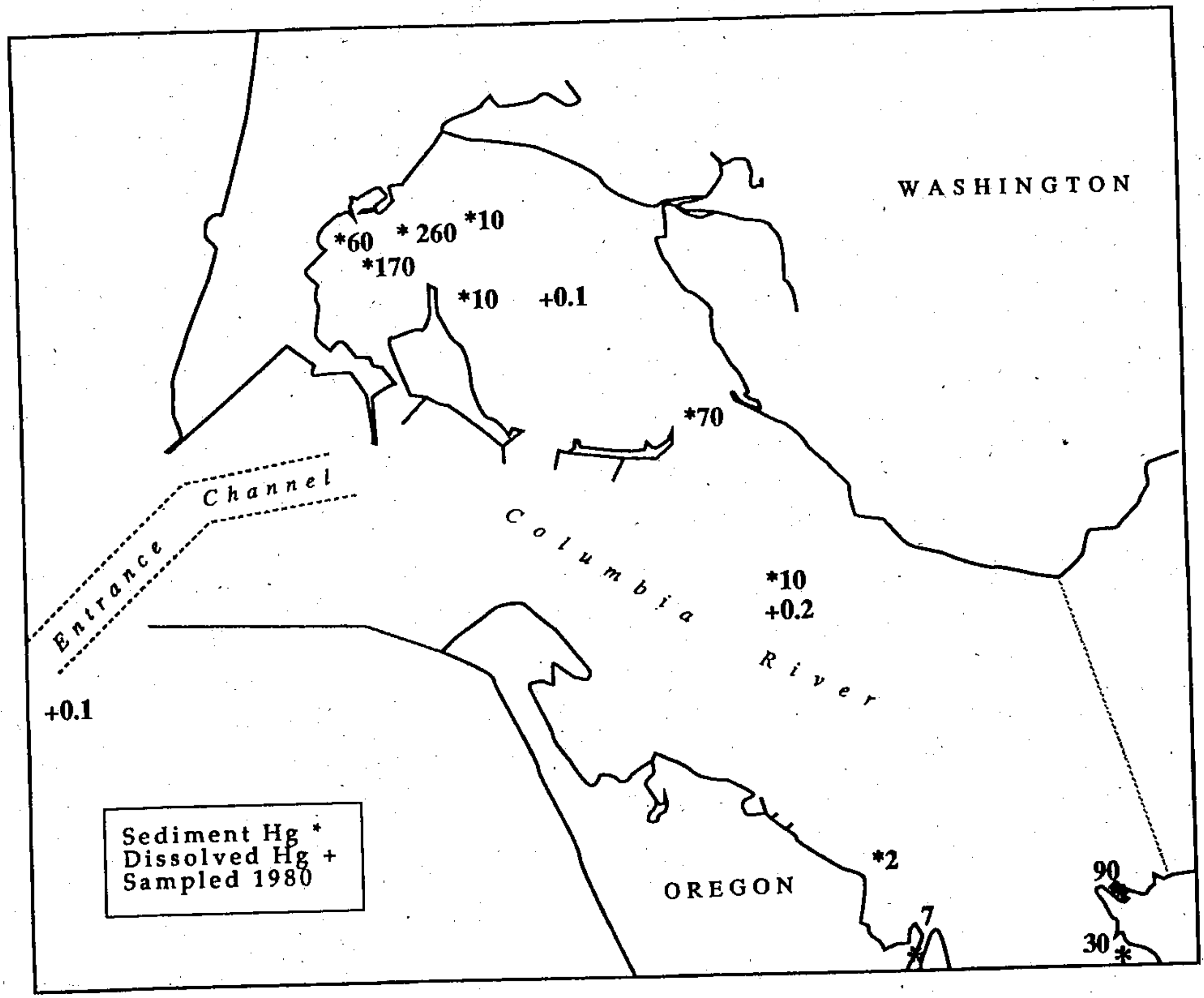

Figure 6.1d. Sediment Hg concentrations in ppb dw (asterisks) and dissolved Hg concentrations in ppb (crosses) in the Columbia River Estuary (Fuhrer and Rinella, 1982).

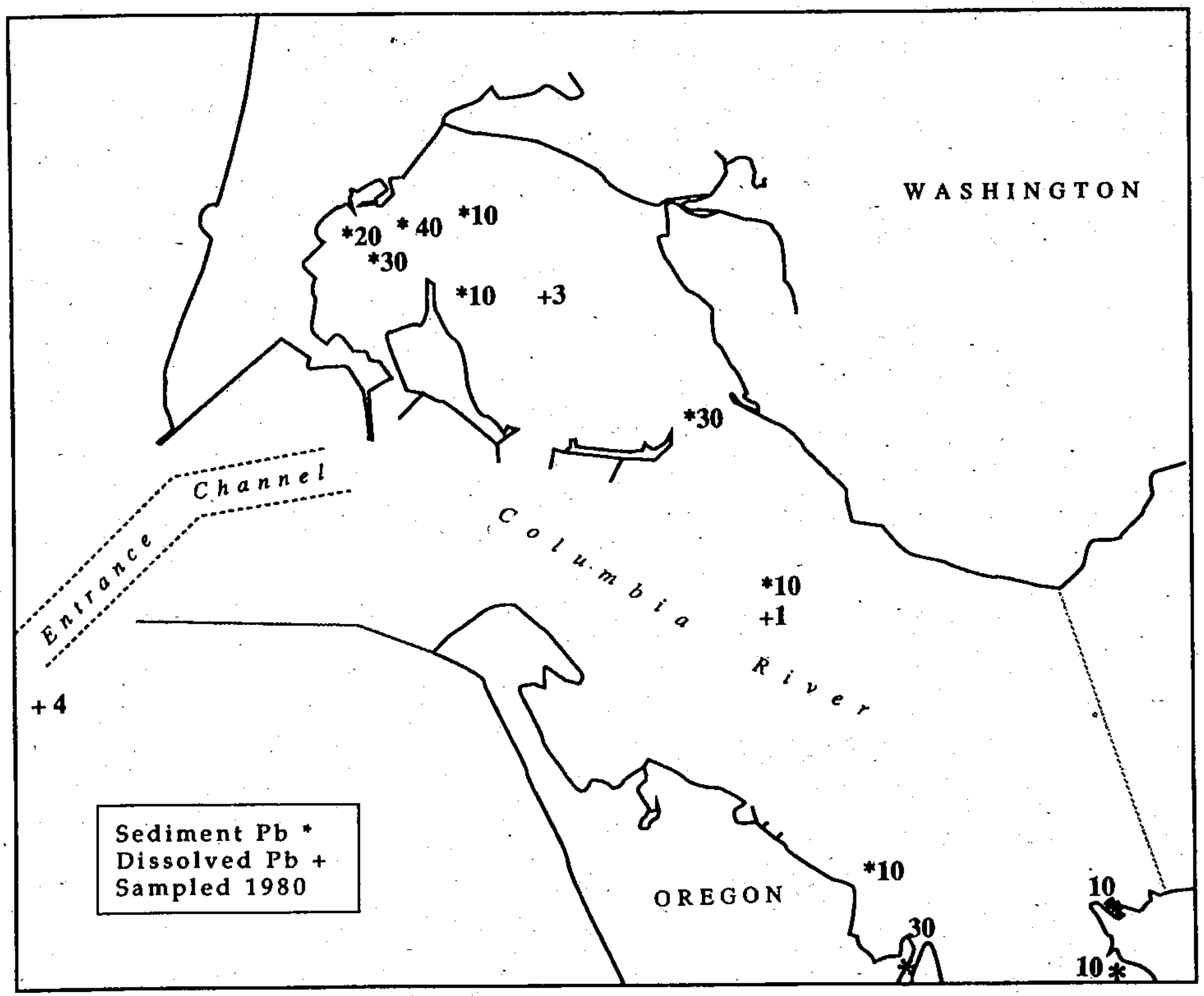

Figure 6.1e. Sediment Pb concentrations in ppm dw (asterisks) and dissolved Pb concentrations in ppb (crosses) in the Columbia River Estuary (Fuhrer and Rinella, 1982).

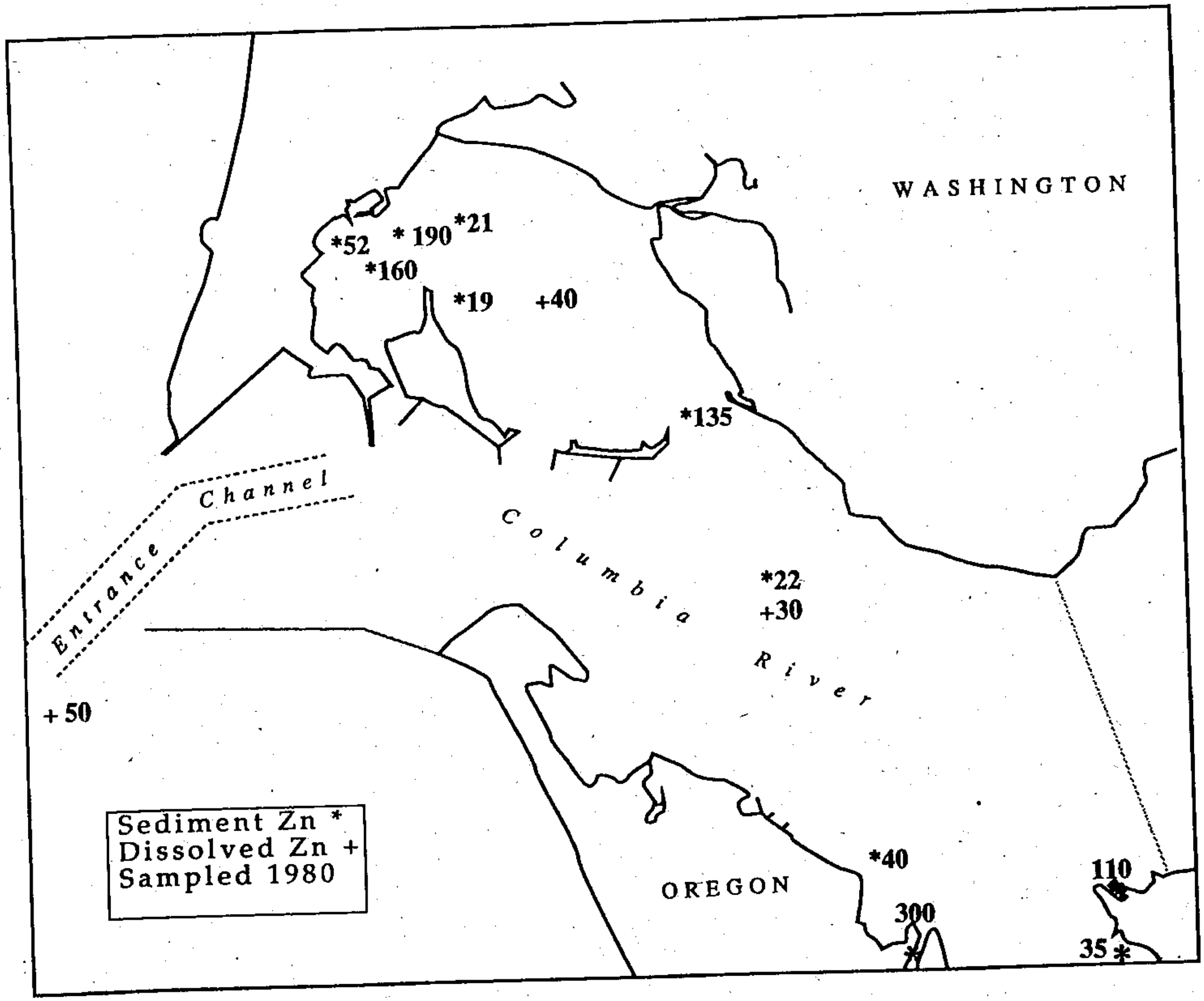

Figure 6.1f. Sediment Zn concentrations in ppm dw (asterisks), and dissolved Zn concentrations in ppb (crosses), in the Columbia River Estuary (Fuhrer and Rinella, 1982).

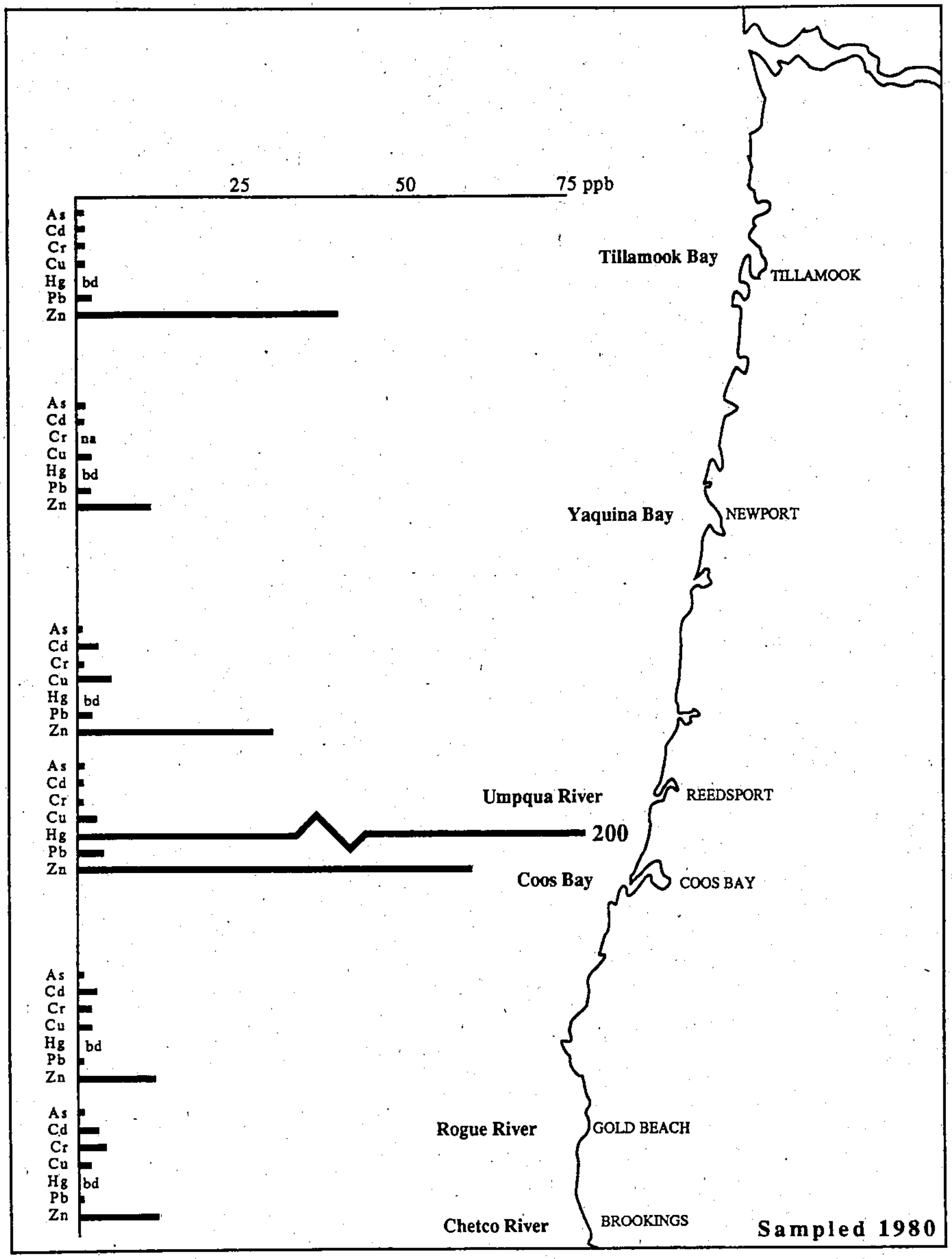

Figure 6.2a. Mean dissolved trace metal concentrations in coastal estuaries, in ppb (Fuhrer and Rinella, 1983; Fuhrer, 1984).

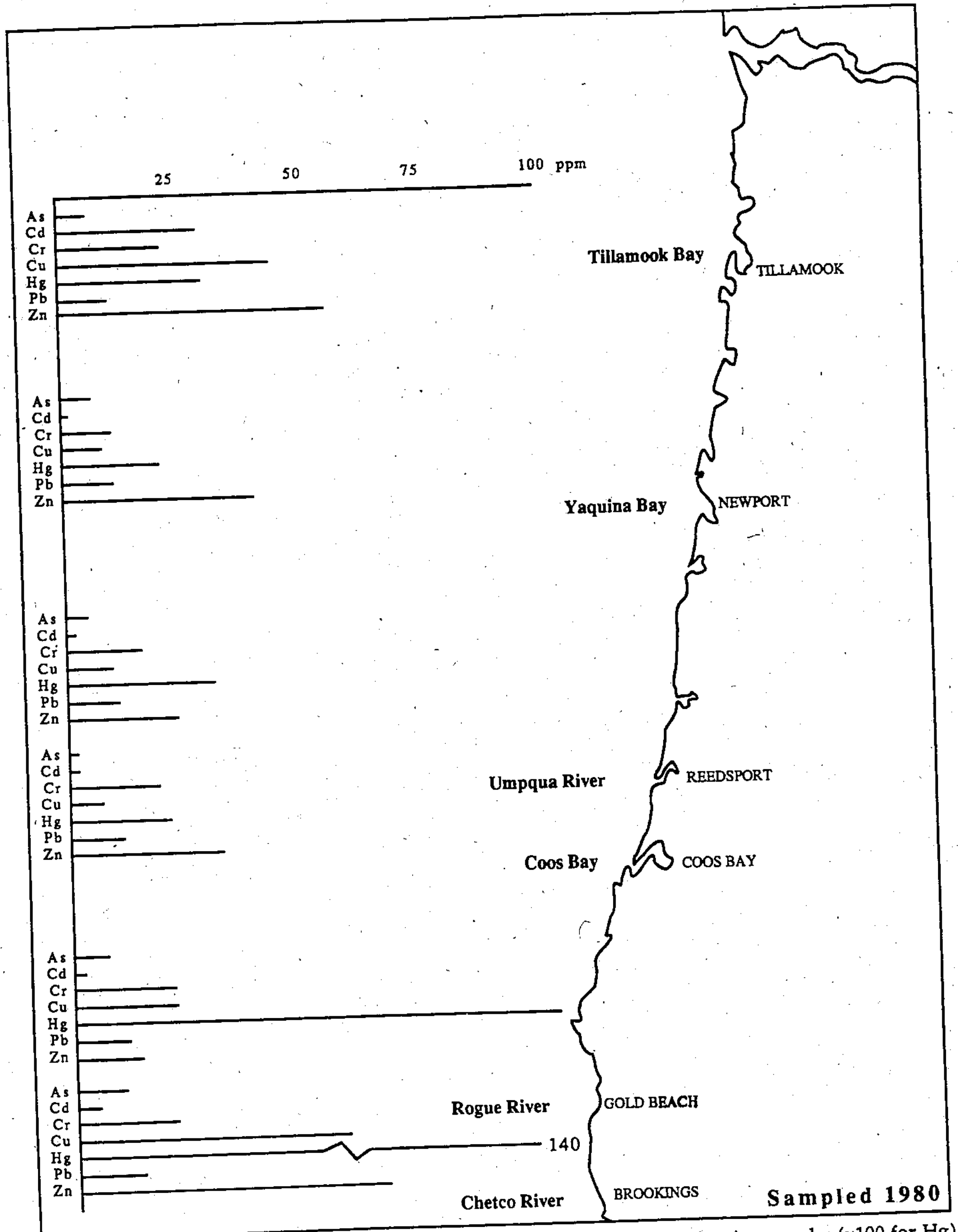

Figure 6.2b. Mean sediment trace metal concentrations in coastal estuaries, in ppm dw (x100 for Hg) (Fuhrer and Rinella, 1983; Fuhrer, 1984).

At both the Ilwaco and Chinook sites, concentrations of sediment metals increased from the mud flats into the dredged channels. This could be the result of greater deposition of fine sediments (which are expected to be more contaminated) in the channel due to decreased current velocity. Alternately, this distribution pattern may indicate the marinas are "point sources." Concentrations of DDT and PCBs also followed this same pattern.

Sediments in Depot Slough (Yaquina Bay), adjacent to a wood processing plant, produced the highest Zn , iron (Fe), beryllium (Be), As, and Pb concentrations of the entire study. In field logbooks, this site was characterized by very fine, black, oily sediments. Duplicate samples were re-run to confirm the high values. Tillamook Bay also had elevated levels of sediment Cd, Cr, Cu, and Zn relative to the other coastal estuaries.

Portland General Electric (PGE) has been required to monitor Zn and hexavalent Cr near its Rainier plant (Columbia River mile 72.4). During 1974-78, concentrations of dissolved hexavalent chromium were not above detection limits of 0.01 ppb at any time (PGE, 1983). Levels of dissolved Zn averaged 12, 11.4, and 11.35 ppb at river miles 73.7, 72.4, 72.0, respectively. The Columbia River at these stations is entirely freshwater and, therefore, these data cannot be compared to estuarine values. Levels were seasonally cyclic, with high values during spring and/or summer. This coincides with the peak flow periods of the Columbia, and the period when scouring of sediments is greatest. No significant elevation of either of these metals due to power plant operations was reported.

The South Slough Sanctuary area of Coos Bay was the subject of an intensive year-long study in 1979-1980 (Munson, 1983). Samples were collected quarterly at 7 to 13 different sites and analyzed by the Oregon DEQ laboratory in Portland. Detection limits were too high to make the dissolved metals data of any interpretive use (*i.e.*, always below detection). The sediment data from this study are generally lower than those reported by Fuhrer and Rinella (1983). Values for Hg were comparable; but Cu, Zn, and Pb concentrations were one-half to one-fourth the levels Fuhrer and Rinella reported for their site at the mouth of the Coos River, and Cd values were even less–about one-tenth. These data may suggest a comparatively greater flux of trace elements from the Coos River than the South Slough drainage basin. However, it is not possible to determine whether the differences observed are the result of spatial phenomena, physio-chemical phenomena (*e.g.*, flocculation), or due to methodology differences.

The COE has also investigated sediment trace metals within Coos Bay and at candidate offshore disposal sites (Sollitt *et al.*, 1984). Levels of As, Cd, Cu, Fe, Mn, Pb, and Hg were quantified at a number of stations within the bay during 1979-80 (see Figure 5.1 for station locations). Their data generally indicate higher levels than Fuhrer and Rinella's site at the mouth of the Coos River. They also indicate concentrations of all metals increase as one approaches Isthmus Slough. Sampling at offshore sites in 1981 confirms that the estuarine values are significantly higher for Cd, Cu, Pb, and Zn than these offshore reference sites (As and Hg were not measured).

One last reference reviewed was another COE study concerned with dredging activities in the Columbia River Estuary (Holton *et al.*, 1977). This study reported low dissolved trace metal values near the entrance, generally one order of magnitude lower than other reports for surface waters. However, this difference is within the range of variation possible due to differing methodologies. Additionally, this station experiences cycles between oceanic and riverine influence. Therefore, no firm conclusions should be drawn.

6.2 Biotic Concentrations

Eight references providing data on molluscan metals concentrations were reviewed. These studies encompassed different time periods, different geographic scales, and sampled different molluscan species. Therefore, they cannot collectively support decisive conclusions. Table 6.1 alludes to the data gaps in terms of time, species, metals, and locations. Overall, the data indicate Oregon bivalves have roughly average concentrations of trace heavy metals, as compared to other West Coast values (Goldberg *et al.*, 1978; FDA, 1983), with the exception of Pb. Levels of Pb appear to be lower than either the West Coast or national average.

Ten references were reviewed for trace metal levels in fish. These references often dealt with a single metal and/or single species. All but one describe conditions of the early 1970s. Although there were differences in the scale of the studies, most had been large-scale synoptic surveys using commercial landings as sample sources and therefore cannot provide accurate sample locations. There were also differences in the analytical methodology used by the various investigators. Hg analysis techniques were similar, but techniques for quantification of lead or cadmium varied considerably. Summary data for some of these studies are presented in Table 6.2.

Hall *et al.* (1976 a & b) investigated Hg contamination of sablefish and Pacific halibut along the west coast and Alaska (Figures 6.3 and 6.4). Flameless atomic absorbtion spectrometry (AAS) was used to quantify levels in muscle tissue. Statistical analysis of the sablefish data (regression or analysis of variance (ANOVA)), clearly shows latitudinal increases in mercury. After normalizing for age and size, there is still an order of magnitude increase in concentrations from Alaska to Los Angeles. Levels from the Columbia River region were higher than either northern or central California and therefore did not represent "background" conditions.

Hall *et al.*'s halibut samples also indicated a Hg increase with a shift to southern latitudes, yet sampling stopped in Oregon, making coastwide comparisons impossible.

Interpretation of these latitudinal trends needs careful consideration. There are numerous factors which could lead to this pattern, not the least of which is a concurrent temperature gradient. There were also significant differences in the age-size structure of sablefish, with a largest shift occurring in central California. It may also be that fish in southern California are a genetically separate stock (Dark, personal communication). Nevertheless, the trend is clear.

Childs and Gaffke (1973 and 1974) quantified Pb, Cd, and Hg levels of selected groundfish along the northern, central, and southern ranges of the Oregon coast. Flameless AAS was used for quantitation of the three metals in epiaxial muscle tissue. Although a higher mean was observed for both Cd and Pb in northern Oregon fish over fish from the southern Oregon coast region--0.061 versus 0.012 for Cd and 0.010 versus 0.07 for Pb--this difference was significant only at $p=.22$ and $p=.36$, respectively. One other observation was the lower variation in levels of southern fish. (Without data from individual samples, this difference cannot be statistically tested.)

Coastal hake along the West Coast were analyzed for Cd and Zn during 1969-1972 (Cutshall *et al.*, 1977). No significant spatial patterns were reported. Off Oregon, Zn levels in muscle tissue averaged 4,000 ppb while Cd was 26 ppb.

Table 6.1. Molluscan trace metal concentrations, in ppm ww.

Location	Year	As	Ag	Cd	Cr	Cu	Hg	Pb	Zn
Soft-shell clam (Caldwell & Buhler, 1983)									
Tillamook	1972			0.028		2.13	0.026		9.5
Coos Bay	1972			0.015		2.29	0.039		13.7
Yaquina Bay	1972			0.032		2.73	0.02		11.7
Umpqua River	1972			0.011		2.48	0.016		11.5
Basket cockles (Caldwell & Buhler, 1983)									
Tillamook	1972			0.02		1.85	0.022		10.5
Coos Bay	1972			0.008		1.24	0.02		10.5
Yaquina Bay	1972			0.039		0.9	0.018		10.7
Gaper clams (DEQ, 1987)									
Coos Bay	1981	6.2		0.08	0.5	4.68	bd	0.22	
Bay mussels (Caldwell & Buhler, 1983)									
Umpqua River	1972			0.262			0.015		11.8
Bay mussels (Goldberg *et al.*, 1976)									
Tillamook	1976		0.06	0.51		1.22		0.47	19.5
Bay mussels (La Touche *et al.*, 1981 & 1982)									
Tillamook	1979			12.2		11.2			130
Tillamook	1980	11.7		8.5		9.2			145
Tillamook	1981	13		5.7		7.2			137
California mussels (Goldberg *et al.*, 1976)									
Columbia River	1976		nd	0.46		1.9		1.1	33
Yaquina Head	1976		0.05	1.8		0.8		0.58	10.8
Coos Bay	1976		0.03	1.46		1.04		0.38	18
Gold Beach	1976		0.08	0.98		2.1		0.48	17.5
Pacific oysters (FDA, 1983)									
Tillamook	1974	0.1		0.76	0.24	12	0.05	0.64	52
Tillamook	1975	0.05		0.98	0.2	20	0.05	0.04	93
Yaquina Bay	1976	0.07		1	0.31	20	0.05	0.04	223
Pacific oysters (DEQ, 1987)									
South Slough	1980	3.5		0.8	1.1	12.8	0.14	0.18	
South Slough	1981	3.9		0.6	0.8	6.9	0.05	bd	
Upper Coos	1980	1.1		0.5	0.8	16.9	bd	0.22	
Upper Coos	1981	1.7		0.5	1.2	17	0.04	0.18	

Table 6.2. Trace metals in Oregon coastal groundfish muscle tissue, in ppb ww.

Species	Region[a]	Cd	Hg[b]	Pb[b]	Zn
Sablefish	N				
	C		(40)		
	S				4390
Hake	N	23-34			3,900-4,400
	C	24-32	(102)	(380)	3,700-4,100
	S	28-34		44	3,800-4,300
Sole	N	7-26	76-122	33-229	3,480
	C		94-102		3,340
	S	12-14	60-193	44-130	4,210
Starry Flounder	N		266		
	C		194		
	S	8		48	
Lingcod	N	224	403	70	4,420
	C		274		4,620
	S	9	400	36	4,510
Orange Rockfish	N	88			
	C				
	S	14			
<u>Statewide</u>					
Halibut			(450)		
Canary Rockfish				(197)	
Yellowtail Rockfish			(371)		
Rougheye Rockfish			(80)		
Flag Rockfish			(136)		
Thornyhead					(9180)
Arrowtooth Flounder			(154)		(9,750)
Slender Sole					(9,850)
Dover Sole					(8,000)
Eulachon					(10,490)
Spiny Dogfish			(602)		
Raja					(7,090)
Pandalus					(15,500)
Euphausiid					(13,500)

[a] N - Northern Oregon C - Central Oregon S - Southern Oregon

[b] Values in parenthesis are statewide means
(Childs and Gaffke, 1973 & 1974; Hall *et al.*, 1976a & b; Vanderploeg, 1979; Zook *et al.*, 1976; Cutshall *et al.*, 1977)

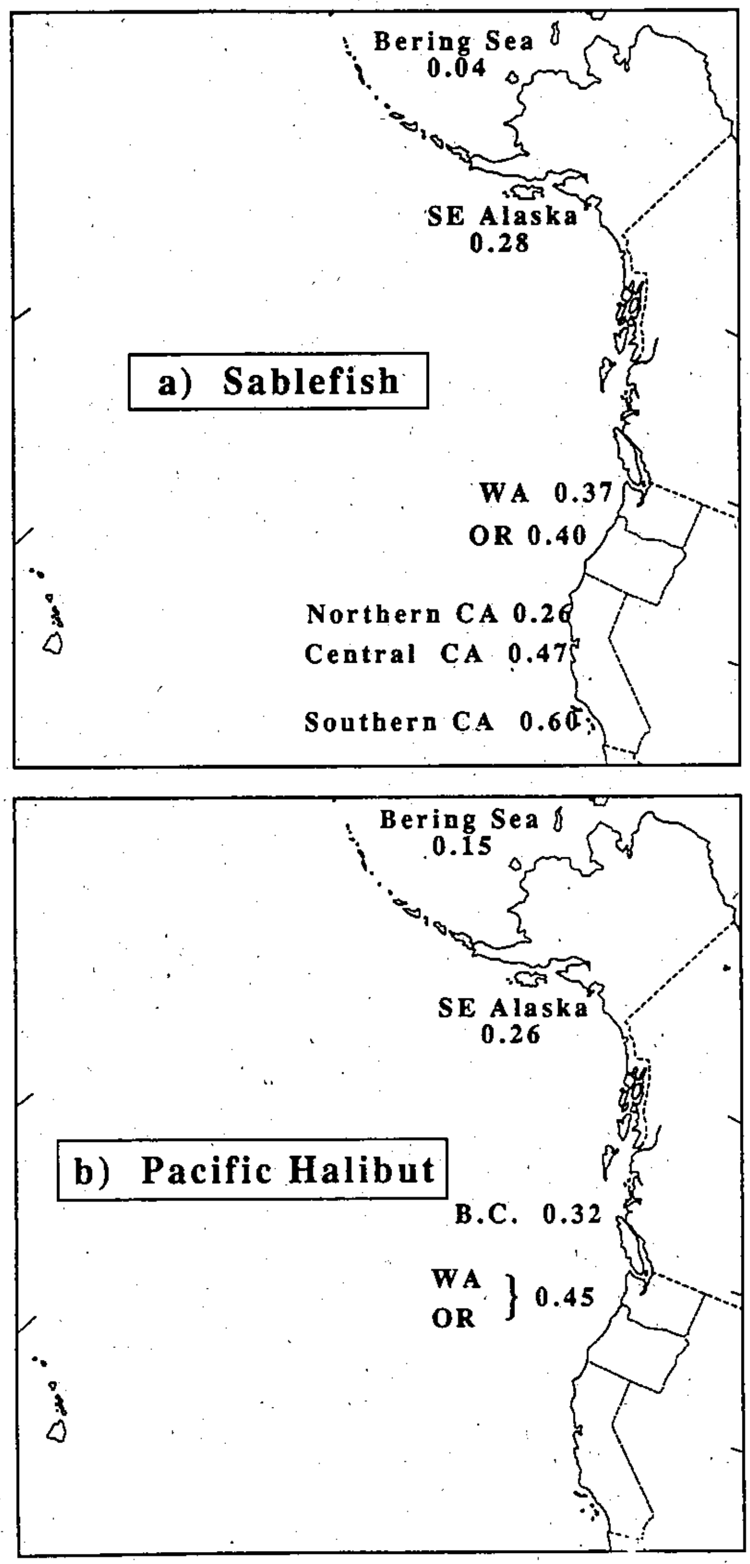

Figure 6.3. Mercury concentrations in (a) sablefish and (b) Pacific halibut muscle tissue in ppm ww (Hall et al., 1976).

Only one data set providing recent values of trace metals in fish was found, that of Oregon DEQ (1987). Although their monitoring program focuses almost entirely on the freshwater environment, samples from the Coos Bay area were collected over a 2-year span. The State also sampled the Rogue River on one occasion. Table 6.3 presents their data. Although Hg values in both Coos Bay samples are significantly higher than the one Rogue River sample (Student's t test), different species preclude making any firm conclusions.

One final study of trace elements encountered was a national survey of commercial fishes conducted by the National Marine Fisheries Service (NMFS) (Hall *et al.*, 1978; Zook *et al.*, 1976). The samples were accumulated over time, but generally were collected during the early 1970s, and have been summarized into means for 1° blocks of latitude and longitude. The species sampled within these blocks (and the number of individuals in composite samples) varied considerably. Also, the analytical methodology for particular metals in this survey--though state of the art at the time--may by questionable now. Means and standard deviations for some of the metals in this survey are presented in Table 6.4.

One observation from this data is that, along just the Oregon Coast, concentrations in six of nine metals (Hg, Pb, Cd, Cu, Zn, and V) generally decreased toward southern latitude . This is similar to the trends for Hg, Pb, and Cd in samples off Oregon reported by Childs and Gaffke (1973 & 1974). These trends are not significant when tested individually (p not less than 0.2), but may be significant as a whole when tested by multivariate analysis of variance (MANOVA) or multivariate regression.

One report on trace element concentrations in marine mammals was encountered. Buhler *et al.* (1975) examined Cd and Hg levels in sick sea lions (infected with leptospirosis) found beached along the Oregon coast in 1970. This sampling was followed with collections of healthy and sick animals in 1970, 1971, and 1973. In healthy individuals, Buhler found mean liver Hg levels of 74.1 ppm in 1971 (n=5), and 95.7 ppm in 1973 (n=3). Concentrations in the liver of sick animals collected in 1970 with a mean of 170 ppm Hg were significantly higher than healthy specimens (Student's t-test). Although sick animals had higher levels of hepatic Hg, levels in their kidneys were appreciably lower than those observed in healthy individuals.

These are some of the highest hepatic Hg values reported for marine mammals. Heppleston and French (1973) reported maximums of 182 ppm in grey seals, as opposed to Buhler's maximum of 229 ppm. De Long *et al.* (1973) encountered only 36 to 64 ppm Hg in sea lions sampled from Southern California in 1971. However, the role of Hg as a contributing factor in the illness of beached animals (or *vice versa*) in Oregon cannot be implied from this data.

Levels of Cd were similar among healthy and sick animals, with one exception--elevated levels in the cerebrum of sick specimens. Levels ranged from 0.032 ppm in cerebrum or cerebellum, to 12.0 ppm in kidney tissue. These are within an expected range of values. Anas (1974) reported 15.6 ppm Cd in kidneys of fur seals, and Heppleston and French (1973) found 22 ppm in kidneys of grey seals.

6.3 Relevance of Trace Metal Levels Encountered

A summary of trace metal data in the references for Chapter 6 is presented in Table 6.5. The significance of levels of metals reported by the investigators named will be inferred by two means: first, a comparison with the appropriate federal criteria or regulations; and second, a comparison with available data on the biological impact of metals.

Predictions of biological impacts based on trace metal contamination must be interpreted with caution. The complexity of trace metal chemistry in water is so great, and the nature of coastal environs so variable, that predicting fate and effects solely upon aqueous trace metal

Table 6.3. Trace metals in Coos Bay and Rogue River fish muscle, in ppm ww (DEQ, 1987).

Date	Location	As	Cd	Cr	Cu	Hg	Pb
12/79	Isthmus Striped bass	bd	bd	0.61	0.35	0.44	na
2/81	Catching Slough Striped bass	bd	0.05	bd	0.28	0.54	bd
02/81	Rogue River sucker	bd	0.06	bd	0.25	0.08	bd
Detection Limits		0.15	0.04	0.15	-	0.02	0.15

Table 6.4. Summary data of NMFS survey of trace metals in Oregon groundfish muscle tissue, in ppb ww (Hall *et al.*, 1978).

Latitude	Hg	Pb	Cd	As	Ag	Cr	Cu	Zn	V
Mean Concentrations									
47°-46°	270	440	144	4800	57.1	203	1241	9964	281
46°-45°	226	416	137	5946	3.5	362	594	6037	240
45°-44°	135	505	112	7233	61.6	278	483	5799	211
44°-43°	159	385	79	5270	44.9	166	505	4786	155
Standard Deviations about the Mean									
47°-46°	290	125	253	2602	43.0	89	1963	14139	167
46°-45°	198	185	170	4303	32.1	242	1261	7904	43
45°-44°	92	207	55	6238	71.0	141	479	3210	187
44°-43°	90	270	52	3795	36.8	78	572	2981	170

levels is very tenuous. Trace metals occur in numerous chemical forms, some of which are organic, others inorganic. Either of these classes may be soluble or insoluble. Not all chemical forms of metals are available to biota as well. The bioavailability (environmental route) and toxicity of a metal depends not only on the chemical form, but on the total ambient conditions (pH, dissolved oxygen,, temperature, redox, etc.). For example, Cu toxicity to rainbow trout can be radically reduced by inclusion of sewage effluent in the bioassay test chamber (Brown *et al.*, 1974). In this case, sewage effluent reduced the effective free Cu by complexation with dissolved organics.

Estimates of how much "total recoverable" metals are actually available to biota vary greatly. This is to be expected, given the complexity of metals chemistry. Morel and Morgan (1972) developed a computer model to illustrate the impact of other dissolved substances on trace elements and their bioavailability. Their purpose was not predictive, but rather illustrative! Their model calculated the following differences between the free, potentially toxic, bioavailable metal concentrations and the total recoverable metal concentration as determined in the laboratory:

"Bioavailable"	Cd - 3	orders of magnitude smaller than "total"
"	Cr - 9	" " " " " "
"	Cu - 5	" " " " " "
"	Hg -14	" " " " " "
"	Pb - 2	" " " " " "
"	Zn - 3	" " " " " "

There are also analytical problems associated with dissolved metals determinations which make predictions difficult. Several trace elements are rapidly sorbed to particulates. There may be a three to five order of magnitude difference between aqueous and sediment concentrations of trace elements. In relatively pristine waters, this property results in a majority of dissolved water samples having concentrations less than detection limits of common analytical methods. Also, the spatial and temporal variations in dissolved metals are much greater than sediment metals, thus requiring more detailed sampling to adequately describe an area.

The following, prepared by NOAA/Pacific Marine Environmental Laboratory (Feely and Curl, 1979), are stated to be conservative estimates of dissolved trace element levels in "clean, coastal oceanic water" (ppb):

Cd - 0.004	Pb - 0.005
Hg - 0.001	Cu - 0.08
Cr - 0.1	Zn - 0.01

Their estimates are conservative and are much lower than values previously presented by other investigators. They are at most two to three orders of magnitude lower than concentrations observed in Oregon.

6.3.1 EPA and FDA criteria

In comparing levels of aqueous metals in Oregon samples against the EPA criteria for maximum, 24-hour average aqueous concentration for the protection of aquatic life (Table 6.6), three metals were found to occasionally exceed the criteria--Cu, Hg, and Zn. Only Hg was consistently greater (up to one order of magnitude greater) in samples from both the Columbia River estuary and Coos Bay than EPA criteria.

Table 6.5. Summary of trace metal references reviewed.

Principal Investigator	Matrix	As	Cd	Cr	Cu	Hg	Pb	Zn	Fe	Mn	Ni	OTHERS
Buhler *et al.*, '75	Sea Lion		+			+						
Caldwell &	Bivalves, &		+		+	+		+	+	+		
Buhler, '83	Crab		+		+	+		+	+	+		
Childs & Gaffke '73	Groundfish					+						
" '74	"			+			+					
Cutshall *et al.*,'77	Hake		+					+				
DEQ, '87	Fish & Shellfish	+	+	+	+	+	+					
FDA, '83	Oyster	+	+	+	+	+	+	+		+		
Fuhrer & Rinella, '83	Water	+	+	+	+	+	+	+	+	+	+	Cyanide Be Ba
& Fuhrer '84												
Goldberg *et al.*, '78	Mussels		+		+		+	+	+		+	Sn Al Ag
Hall *et al.*, '76	Halibut					+						
" '76	Sablefish					+						
Holton *et al.*, '77	Sediment/water		+		+	+	+	+	+	+	+	
Johnson & Cutshall, '74	Sediment/water		+	+	+		+	+	+		+	K Cs Co U Th Eu F
La Touche *et al.*, '8	Mussels											V
" '81	"		+		+			+		+	+	V
" '82	"	+	+		+			+		+		
Munson, '83	Sediment/water		+	+	+		+	+	+		+	
Pearcy & Claeys, '72	Tuna							+				
PGE, '83	Water			+				+				B Ca
Sollitt *et al.*, '84	Sediment/water	+	+	+	+	+	+	+	+	+		
Vanderploeg, '79	Sole							+				
Zook *et al.*, '76	Fish	+	+	+	+	+	+	+		+	+	Sn Sb Mo Se Ag

Another way to evaluate contamination by trace metals is by comparison with proposed criteria for sediments (Table 6.7). Though formal criteria have not been adopted nationwide, some interim guidelines do exist. One of the major approaches to sediment quality criteria currently being pursued by regulatory agencies is that of apparent effects thresholds (AET). The AET method relates concentrations of a contaminant with measures of biological effects (amphipod, oyster larvae, and microtox bioassays and benthic community impacts). The threshold is the ***maximum*** concentration associated with a station having no observable biological impacts. Presently, AETs are based on a very limited database of stations; as the database expands, AET values can only increase. Also, since AETs are arrived at for single contaminants they disregard any cumulative, synergistic, or antagonistic interactions. Other guideline limits for sediment contaminants have been adopted by the USGS and different EPA regional offices (see Table 6.7).

Comparison of the sediment data for Oregon (Fuhrer and Rinella, 1983, and Fuhrer, 1984) with the various guidelines listed in Table 6.7 would indicate that most sites sampled have been impacted by trace metals. One or more of the criteria were exceeded in Oregon samples for every trace metal listed except Hg; and samples from all sites, except the Umpqua River, contained reported levels which exceeded at least one of the limits. The "cleanest" sites by comparison to these limits were the Umpqua River and Coos Bay. Yet if one considers that AETs are arrived at primarily for ***acute*** impacts (*i.e.*, bioassays) and allows for one order of magnitude lower levels for chronic impacts, levels of Cd, Cr, Hg, and Zn observed at these two sites would be of concern.

Criteria for trace metals allowed in fishery products for human consumption in the US have been developed only for Hg. This FDA Hg limit of 0.5 ppm was exceeded by Pacific halibut (36 percent of fish sampled), sablefish (29 percent), and spiny dogfish during the early 1970s (Hall *et al.*, 1976a & b; Childs and Gaffke, 1973). During the same period, Caldwell and Buhler did not encounter any edible mollusc samples which exceeded the FDA limit. Later sampling, during the NMFS trace element survey (Hall *et al.*, 1978), again indicated the only species to exceed this limit were halibut, sablefish, and dogfish.

Criteria for levels of other trace elements in shellfish and fish products which are regarded as safe levels for human consumption have been developed in several other countries (Nauen, 1983). These criteria generally are 1 ppm ww for Cd, 10 ppm ww for Cu, and 50 ppm ww for Zn (median values). Mean levels of trace elements reported by various authors have exceeded these limits on occasion in shellfish sampled during the early 1980s (see Table 6.1), but not by any means reported for samples of fish (see Tables 6.2-6.4).

6.3.2 Toxicity Information

There have been numerous aqueous bioassays of various trace metal compounds to determine their toxicity. Even though most of these deal with freshwater organisms, there are sufficient references for saltwater organisms to estimate acute toxicity threats. Table 6.6 also presents results from numerous different bioassays. Table entries are doses acutely lethal to 50 percent of the population (except as noted). Caution must be taken when making inter-specific comparisons; these bioassays are a mix of different methods (static and flow-through), for different periods of time, with different compounds, upon different species. Therefore, conclusions to be derived from this table should only be qualitative. There are reasonable indications from this information that suggest:

Table 6.6. Acute toxicity bioassay results as LC50s and EC50s, in ppb, along with EPA Water Quality Criteria (CIS, 1983) (* denotes an EC_{50} concentration.)

	As	Cd	Cr	Cu	Hg[c]	Pb	Zn
EPA Water Quality Criteria[a]	13[d]	9.3	50	2.9	0.025	5.6	58
Maximum Oregon[b] Aqueous Concentration	1	3.0	5	9	0.2	4	61
<u>Bioassay Results</u>							
Phytoplankton		160*		5*	0.6*	2,500	50
Diatom		175*		50*	0.4*	5*	50*
Alga	577*		1000*	50*	26	150	100*
Copepod	508	90		9	50	668	290
Colonial Hydroid		3*	10*				
Polychaete	14,500	200		40		1,000	900
Isopod		10,000					10,000
Mud Snail	2,000*	10,500		100*			7,400
Oyster	7,500	3,800		46	50*	2,450	75
Hard Clam						780	166
Bay Scallop	3,490	78*		5			
Mya		150		35		8,800	3,100
Grass Shrimp		50					
Mysid Shrimp		11		141		2,960	498
Panaeus Shrimp	24,700	720					
Blue Crab		50					
Fiddler Crabs		1*			100*		
Hermit Crabs		70					200
Herring		560*	33				
Striped Bass		5*					
Spot		200					
Cunner		50*					
Mummichog		7,800	44,000	500*		100*	43,000
Atlantic Silversides	16,033	160	14,300	136			2,730
Winter Flounder		5*		129			4,920
Chum Salmon	8,330						
Pink Salmon	3,787						

[a] From EPA, 1986.
[b] From Fuhrer and Rinella, 1983 or Fuhrer, 1984.
[c] Bioassay results are for tests which include only methyl or ethyl compounds.
[d] EPA criteria are 4-day concentrations not to be exceeded once every three years for the protection of marine organisms from chronic impacts.
Insufficient data for As criteria; value is Lowest Observable Effect Level for acute impacts.

Table 6.7. Various proposed or interim sediment quality criteria, along with maximum sediment concentrations for Oregon, in ppm dw.

Criteria[a]	Cd	Cr	Cu	Hg	Pb	Zn
Maximum Oregon[b] Sediment Conc.	29	30	180	0.26	40	300
AET Sediment Quality Criteria	5.8	27	310	0.41	300	260
USGS Alert Level	0	200	2000	20	50	5000
EPA Region V Guideline for Pollutional Classification of Sediment	6	25	25	1.	40	90
EPA Region VI Proposed Guidelines for Sediment Disposal	2	100	50	1.	50	75
Ontario Ministry for Environment Dredge Spoil Guidelines	1	25	25	0.3	50	100

[a] AET value is the lowest criteria given for the four measures of biological impacts (Tetra Tech, 1986). Other criteria are from Pavlou and Weston, 1983.

[b] Maximum values reported by Fuhrer and Rinella, 1984 and Fuhrer, 1984.

- Levels of As and total Cr in Oregon pose no apparent acute toxic threat to biota.
- Levels of Zn, Hg, and Pb may have been sufficiently high enough at one time to stress phytoplankton in Coos Bay and the Columbia River estuary.
- Levels of Cu in Coos Bay, Columbia River, and Umpqua River Estuaries may have been high enough to cause significant stress (reduction in photosynthesis) to phytoplankton, and impact other planktonic organisms as well.
- Levels of Cd in Coos Bay and the Columbia River estuary may have been sufficiently high to stress a variety of organisms.

Further monitoring is needed to confirm the temporal occurrence of these "high" aqueous levels of trace elements and investigate potential impacts. More intensive monitoring would answer whether the levels described in reports are indicative of normal, long-term conditions, or represent incidents of low probability. Given the high variance associated with metals data, it is not appropriate to draw firm conclusions from the scant information currently available.

Summary

- At least one of the various guidelines proposed for sediment quality criteria were exceeded by all siz metals reviewed-- Cd, Cr, Cu, Hg, Pb, and Zn.
- There were two particular locations with elevated levels of trace metals in sediments, relative to statewide values--the Columbia River estuary, and Depot Slough in Yaquina Bay.
- Levels of aqueous trace elements had a fairly uniform geographic distribution. Maxima generally occurred in either Yaquina Bay or the Columbia River estuary.
- Concentrations of aqueous Zn, Hg, Cu, and Pb may have been sufficiently high enough to stress phytoplankton at several locations.
- Levels of Cd may have been high enough in several areas to stress a variety of organisms, including some species of fish.
- During the 1970s, FDA limits on Hg content of seafood were exceeded in Oregon in halibut, sablefish, and dogfish muscle tissue.

7. BIOLOGICAL MEASURES OF POLLUTANT STRESS

The scarcity of dose-effect data for marine organisms makes it difficult to assess the biological implications of observed levels of chemicals in sediments and water, or of residues in marine animal tissues. There is a need to apply biological measures to determine sublethal pollution effects. An increasing number of pathological manifestations are being correlated with stress from pollution. Some approaches are long-standing and better developed than others, while some are not yet refined enough for use in pilot monitoring programs. Unfortunately, the bulk of this type of work has been conducted in regions known to be heavily polluted. Only four reports dealing with biological measures of pollutant stress or impact were encountered for Oregon.

7.1 Eggshell Thinning In Oregon Seabirds

Henny *et al.* (1982) collected eggs of several marine birds from the Oregon coast for pesticide analysis (see Figure 3.3 for sampling design). They also measured eggshell thickness of the samples to compare against pre-1947 museum samples. Of those species sampled in sufficient number to derive statistical trends, only the common murre and western gull showed significant thinning (ANOVA and Student's t-test). Eggs of both species had experienced about 5 percent thinning. Additionally, there were indications that significant recovery from eggshell thinning had been made by black oystercatchers and double-crested cormorants from the 1950s. Otherwise, those seabirds Henny examined showed no significant changes in shell thickness.

7.2 Molluscan Cellular Proliferative Disorders

In his study of PAH levels in mussels, Mix (1979, 1982) also performed histological examinations for the presence of abnormal cells in mussels from Yaquina Bay during the fall and winter of 1979-80; clams from Coos Bay during a 4-quarter period during 1978-79; and mussels from Tillamook Bay from February to May, 1980.

Cellular proliferative disorders were present in a significant number of mussels at YM2 (mean=9.8 percent), but rarely occurred at YM1 (mean=0.4 percent) during a 4-year period from 1976-80 (Mix, 1979; Mix, 1982). Occurrence of the disorder also followed the seasonal trends of PAH concentrations. No clams from Coos Bay or mussels from Tillamook Bay were found with disorders. The correlation between the degree of PAH contamination and cellular disorders is obvious; however, no cause-effect relationship was established. Although there have been numerous reports of abnormal cells in molluscs from contaminated environs, there has been no published report of cancer induction in bivalves exposed to, or injected with, PAH (Couch *et al.*, 1979). Indeed, the capability of these species to alter or metabolize PAH compounds is subject to debate (Stegeman and Teal, 1973; Anderson, 1978).

7.3 Sediment Toxicity Bioassays

EPA has conducted sediment toxicity bioassays at several sites on the west coast using phoxocephalid amphipods as test organisms (Swartz, 1982). The primary response criteria after a 10-day exposure is survival. One site in Yaquina Bay, in the channel directly opposite Newport, has been used numerous times as a control site for different studies, as well as a source of amphipods. Throughout these studies, the average mean survival rate for amphipods at this Yaquina site has increased from 95 to 97 percent. (Swartz, 1982). This increase is not thought to reflect any improvement in environmental conditions, but rather a refinement in testing methodologies (Swartz, personal communication). Mean survival from the Yaquina site has never dropped below 89 percent. In comparison, mean survival from a highly contaminated site, such as Hylebos Waterway near Tacoma, can be less than 50 percent (Long, personal communication).

The end point of survival in the amphipod bioassay is a function of several parameters which include the toxicity of any natural and/or anthropogenic compounds which may be present in the test sediment. There are purely physical differences between sediments which need to be considered. For example, variations in grain size can significantly and directly impact survival. Findings of low survival do not necessarily indicate contamination. However, the consistently high survival rate of Yaquina Bay indicates the biological viability of this site. (It should be noted that the Yaquina Bay site is 96 percent sand, therefore, it is not expected to contain high concentrations of toxic, organic chemicals.)

7.4 Oyster Deformities

Commercial growers in Coos Bay have noticed diminished growth and abnormalities in oysters for numerous years (Wolniakowski *et al.*, 1987). Recent sampling has confirmed the occurrence of abnormalities characteristic of organotin poisoning, such as balling and thickened, chambered shells (Young, personal communication; Cardwell, 1987). In one sampling, these disorders occurred at a 100 percent incidence, (Wolniakowski *et al.*, 1987). Organotin levels in this latter study were found to average 98 ppb in oyster tissue and 10.4 pptr in water, well above the levels at which effects have been observed elsewhere (Wolniakowski *et al.*, 1987).

Summary

- Analysis of egg shell thickness indicated that at least the western gull and common murre have experienced significant thinning (approximately 5 percent) in Oregon since the 1950s. Conversely, the black oystercatcher and double-crested cormorants have shown signs of significant recovery from eggshell thinning.

- Cellular proliferative disorders were observed in mussels from Yaquina Bay, and were correlated with seasonal maxima in PAH residues. Moreover, incidences were greater at the more industrialized site (mean of 9.8 percent) than at the other site at which the disorders were observed (mean of 0.4 percent).

- Disorders and poor growth in oysters from Coos Bay have been observed by commercial growers for several years, and were recently confirmed by several investigators. The observed conditions, balling and thickened shells with chambering, are characteristic of organotin poisoning. Sampling in late 1986 confirmed that organotin levels in oyster tissue and water are high enough to affect oyster growth.

8. RECOMMENDATIONS

Sampling of Oregon's estuarine and marine environment for xenobiotic contaminants, especially during recent years, has been relatively scarce. However, based on this scant data base, indications are that Oregon's coastal environment is not pristine or at "background" conditions. In fact, there may be significant exposures of marine biota to certain chemicals in the more populated or industrialized embayments. For example, very recent sampling in Coos Bay has encountered oysters with shell deformities which are characteristic of organotin poisoning (Young, personal communication); PAH levels in bivalves found by Mix (see Chapter 4) are comparable to the range in residues found in bivalves from reference sites to the most contaminated sites in Puget Sound; levels of at least one phthalate ester in Yaquina Bay sediments have been high enough to probably be a significant, chronic exposure.

Based on preliminary indications such as those above, and the assumption of limited resources for the completion of any assessment survey, the following recommendations are made:

1. Coordination among current monitoring programs should be maximized for the development of comparable data, and to a lesser extent, for more efficient geographic coverage. Federal programs (*e.g.*, USGS, EPA, NOAA) should also be included in this effort with state programs. Applicable sampling design parameters, especially station location and sample matrix, should be discussed and to the greatest extent possible, be mutually agreed upon. Consistency among different programs would maximize intercomparison of data and thus the informational content therein. Laboratory intercalibration among programs monitoring similar matrices should also be encouraged.

2. Intense synoptic surveys of Columbia River estuary, Coos, Yaquina, and Tillamook bays should be conducted to determine and identify the magnitude of contamination by xenobiotics. High density sampling of an embayment for analysis by inexpensive, bulk chemical parameters should be conducted. Measurements of oil and grease, total extractables, spectrophotometry analyses, *et cetera*, which are relatively inexpensive would allow for a high density, preliminary sweep of a system to identify "hot spots." However, it is requisite that sampling density be high enough to identify "hot spots" within a bay. Annual sampling, with a rotation between embayments, would allow limited resources to be concentrated and thus enable a greater density of sampling in any one bay. Results from this screening may be used for the selection of aliquots from stored, preserved samples for further, detailed chemical analyses, and/or to aid in site selection for any potential, subsequent sampling. Due to their accumulative nature, surficial sediment and/or microlayer sampling is recommended. Sediment is integrative over a long-term temporal scale, whereas the microlayer is indicative of recent inputs (*e.g.*, within hours). There is also a trade-off in the logistics required to collect these two matrices which must be considered in any decision. Ancillary, normalizing parameters (*e.g.*, such as grain size and TOC for sediment contaminants) should be included in any program.

3. Follow-up, detailed chemical analyses to quantify specific chemical compounds, should be conducted on preserved, stored aliquots (collected under 2 above) which were found to have high residue levels by bulk chemical analyses. However, it is likely that further field sampling in the vicinity

of identified "hot spots" would be required. The eventual aim of detailed chemical analyses is the identification of probable sources via "fingerprinting," and the development of control strategies. Chemical parameters should include selected trace metals (see Chapter 6), aromatics, phthalate esters (at least in Yaquina Bay), and selected pesticides. (Selection of pesticides could be based on Oregon usage patterns as well as predicted environmental behavior based on their physical properties.)

4. Intense synoptic surveys of Columbia River estuary, Coos, Yaquina, and Tillamook bays should be conducted to determine the magnitude of toxicity due to unknown mixtures of compounds which may be present in situ (*i.e.*, bioassays). Bioassays which measure both lethal and sublethal end points indicate whether the constituents present in environmental samples are capable of affecting biological systems under worst-case laboratory conditions. A suite of bioassays using different species and different end points (*i.e.*, impaired reproduction, lethality, mutagenesis, *et cetera*) should be employed. Depending on resources available and perceived priorities, this survey of toxicity could be conducted as an additional, inexpensive screening tool to aid in site location for detailed chemical monitoring (as in 3 above), or, as a follow- up tool to determine if observed concentrations of residues appear to be exerting significant biological impact.

Effort should be devoted to identifying co-occurrences, which can imply relationships between biological impacts (*i.e.*, bioassay results) and bulk chemistry, so as to provide indications of possible casual agents. These relationships could be used to help plan or direct any source-control efforts. They could also eventually lead to the development of sediment and/or water quality criteria.

5. Based on residue levels observed in existing data and recent observations of biological impacts, plus the cumulative level of the monitoring effort currently expended in Coos Bay (state and federal), priority should first be placed on assessing contamination throughout the Coos Bay system.

These recommendations are primarily for the identification of geographic trends in contaminants: documenting temporal trends, once "hot spots" have been identified, would obviously require further sampling, of possibly a different nature. These recommendations are also primarily from a source control perspective. A program emphasizing human health risks, for example, would necessitate a different design.

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APPENDIX A

LIST OF SCIENTIFIC NAMES FOR FISH AND SHELLFISH SPECIES SAMPLED IN OREGON

Albacore tuna	*Thunus alalunga*
American shad	*Alosa sapidissima*
Arrowtooth flounder	*Atheresthes stomias*
Asiatic clam	*Corbicula* spp.
Basket cockle	*Clinicardium nuttalli*
Bay mussel	*Mytilus edulis*
Boccacio	*Sebastes paucispinis*
Buffalo sculpin	*Enophrys bison*
Canary rockfish	*Sebastes pinniger*
Chinook salmon	*Oncorynchus tshawytscha*
Coho salmon	*Oncorynchus kisutch*
Cutthroat trout	*Salmo clarki*
Dover sole	*Microstomus pacificus*
English sole	*Parophrys vetulus*
Flag rockfish	*Sebastes rubrivinctus*
Freshwater clam	*Anodonta* spp.
Gaper clam	*Tresus capax*
Hake	*Merluccius productus*
Horse clam	see gaper clam
Lingcod	*Ophiodon elongatus*
Longfin smelt	*Spirinchus thaleichthys*
Night smelt	*Spirinchus starksi*
Orange rockfish	see canary rockfish
Oregon pink shrimp	*Pandalus jordani*
Pacific halibut	*Hippoglossus stenolepis*
Pacific herring	*Clupea harengus pallasi*
Pacific sandlance	*Ammodytes hexapterus*
Pacific sardine	*Sardinops sagax*
Pacific sculpin	unknown
Pacific tomcod	*Microgadus proximus*
Pile perch	*Rhacochilus vacca*
Redstripe surfperch	*Amphistichus koelzi*
Rex sole	*Glyptocephalus zachirus*
Rougheye rockfish	*Sebastes aleutianus*
Sablefish	*Anoplopoma fimbria*
Shiner perch	*Cymatogaster aggregata*
Slender sole	*Lyopsetta exilis*
Speckled sanddab	*Citharichthys stigmaeus*
Spiny dogfish	*Squalus acanthias*
Staghorn sculpin	*Leptocottus armatus*
Starry flounder	*Platichthys stellatus*
Steelhead	*Salmo gairdneri*
Striped bass	*Morone saxatilus*
Striped surfperch	unknown
Soft-shell clam	*Mya arenaria*
Suckers	*Catostomus* spp.
Thornyhead	*Sebastolobus* spp.
White sturgeon	*Acipenser transmontanus*
Yellowtail rockfish	*Sebastes flavidus*

APPENDIX B

ABBREVIATIONS, ACRONYMS, AND CONVENTIONS

2,4-D	2,4-dichlorophenoxy acetic acid
2,4-DP	2,4-dichlorophenoxy butanoic acid
2,4,5-T	2,4,5-trichlorophenoxy acetic acid
AAS	atomic absorbtion spectrometry
Ag	silver
Al	aluminum
ANOVA	analysis of variance
As	arsenic
B	boron
BAA	benzo(a)anthracene
B(a)P	benzo(a)pyrene
BBF	benzo(b)flouranthrene
BBP	butylbenzyl phthalate
bd	below detection
Be	beryllium
BEP	benzo(e)pyrene
BGHIP	benzo(g,h,i)pyrylene
BHC	benzohexachloride
BJF	benzo(j)flouranthrene
BKK	benzo(k)flouranthrene
BOD	biological oxygen demand
C	Celsius
Ca	calcium
Cd	cadmium
CEAB	Coastal and Estuarine Assessment Branch
CHRY	chrysene
CIS	Chemical Information System
Co	cobalt
COE	Corps of Engineers
COR	coronene
Cr	chromium
Cs	cesium
Cu	copper
DBACA	dibenz(a,c)anthracene
DBAHA	dibenz(a,h)anthracene
DBP	dibutyl phthalate
DDT	dichloro-diphenyltrichloroethane
DEHP	diethyl hexyl phthalate
DEP	diethyl phthalate
DEQ	Department of Environmental Quality
DMP	dimethyl phthalate
DOP	dioctyl phthalate
dw	dry weight

EC	electron capture
EC_{50}	effective concentration; level which adversely impacts 50% of the test organisms
EPA	Environmental Protection Agency
Eu	europium
F	flourine
FDA	Food and Drug Administration
FDA action levels	Unless otherwise noted, these are concentrations which, when exceeded, trigger FDA to consider action to remove c ommercial foods from distribution. They are administrative and (unless noted) not coded into law.
Fe	iron
FLOUR	flouranthene
GC	gas chromatography
GC-EC	gas chromatography-electron capture
GC-MS	gas chromatography-mass spectroscopy
geometric mean	the nth root of the product of the n data, also may be computed as the antilogarithm of the arithmetic mean of the logarithms of the data
gmd	grams per day
HCB	hexachlorobenzene
Hg	mercury
HPLC	high pressure liquid chromatography
IP	indeno(1,2,3-c,d)pyrene
K	potassium
kg	kilogram
kgd	kilograms per day
km	kilometers
LC_{50}	concentration lethal to 50% of the test organisms
LC_{100}	concentration lethal to 100% of the test organisms
lbs	pounds
MANOVA	multivariate analysis of variance
matrix	the principle media of a sample, *e.g.*, the exact tissue or sediment phase
mg	milligrams
MGD	millions of gallons per day
Mn	manganese
Mo	molybdenum
n=2 of 4 or n=2/4	the number of positive samples (*i.e.*, those above detection) out of the number of total samples
na	not applicable/not available
Ni	nickel
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPMP	National Pesticide Monitoring Program

PAH	polycyclic aromatic hydrocarbons
Pb	lead
PCBs	polychlorinated biphenyls
PHEN	phenanthrene
PGE	Portland General Electric
positive sample	a sample whose residue concentration is above the analytical detection limit
ppb	parts per billion
ppm	parts per million
pptr	parts per trillion
PYR	pyrene
Sb	antimony
Se	selenium
Sn	tin
t-	total
Th	thorium
TKN	total Kjeldahl nitrogen
TLm	mediun total lethal dose
TOC	total organic carbon
TRI	triphenylene
UAACE	
URC	unresolved complex
USGS	United States Geological Survey
V	vanadium
ww	wet weight
Zn	zinc