#10

303

Report:

SEAFOOD CATCH AND CONSUMPTION IN URBAN BAYS OF PUGET SOUND

WASHINGTON STATE DEPARTMENT OF SOCIAL & HEALTH SERVICES

DIVISION OF HEALTH

Recreational and Subsistence Catch and Consumption of Seafood from Three Urban Industrial Bays of Puget Sound: Port Gardner, Elliot Bay and Sinclair Inlet

by

Mary McCallum

January 1985

Project Director
Lucy Harter

Principal Investigator
Floyd Frost

Washington State
Division of Health
Epidemiology Section

CONTENTS

FIGURES

TABLES

APPENDICES

PUGET SOUND FISH CATCH & CONSUMPTION SURVEY
FINAL REPORT

INTRODUCTION

Studies begun in 1978 by the National Oceanic and Atmospheric Administration (NOAA) examined chemical pollutants in the sediments, fish and invertebrates of urban and non-urban embayments of Puget Sound. The studies were undertaken to determine if sediment and marine life from urban bays had higher levels of pollutants (e.g. metals, pesticides and industrial organic compounds) than non-urban bays (Malins, 1982). Other studies examined fish and invertebrates (clams, crabs, worms, etc.) for the presence of pathological abnormalities, such as tumors and liver lesions.

The NOAA studies detected low levels of various chemical pollutants throughout Puget Sound. They found higher pollutant levels in the urban embayments, most notably Seattle's Elliot Bay and Tacoma's Commencement Bay. Also bottom fish taken from polluted urban bays had a higher prevalence of tumors and lesions.

The sediment and tissue pathology findings raised questions about the human health effects of consuming seafood taken from contaminated bays. Although the concentrations of pollutants were low in edible tissues, if people ate large quantities of bottom dwelling fish (e.g. English and rock sole), then a theoretical excess risk of cancer may occur.

To ascertain the number of individuals who have repeated, long-term exposure to fish and shellfish taken from contaminated urban bays, the Washington State Division of Health (DOH), with the assistance of the Washington Department of Ecology (WDOE) and the U.S. Environmental Protection Agency (EPA), conducted a survey of fish and shellfish collectors in urban bays. Specifically the study collected information on the species consumed, the amount consumed, the frequency of fish or shellfish consumption and the location of collection. Of particular concern was whether Southeast Asian immigrants or other low income groups were frequent users of urban fishing sites and whether they consumed the more contaminated species (e.g. sole) or the more contaminated parts (e.g. fish liver, crab hepatopancreas).

METHODS

Three major urban bays in Puget Sound were selected for the DOH catch and consumption survey: Port Gardner (Everett), Elliot Bay (Seattle), and Sinclair Inlet (Bremerton and Port Orchard) (Figure 1). Criteria for selection included both evidence of significant contaminant levels in the sediments and evidence of human fishing, crabbing or clamming activity. Although Commencement Bay (Tacoma) satisfied these criteria, it was not included because in 1983 the Tacoma Pierce County Health Department had conducted a similar catch and consumption survey of Commencement Bay. Bellingham Bay was initially included in the survey, but observed fishing activity was not high enough to warrant continued coverage.

Other potentially contaminated bays in Puget Sound were surveyed on a one-time basis. The general type and amount of seafood gathering activity was assessed from on-site observations and conversations with anglers, marina owners, Washington Department of Fisheries surveyors, etc. These areas included Port Angeles, Port Townsend, Anacortes, Dugalla Bay and Holmes Harbor on Whidbey Island, Eagle Harbor on Bainbridge Island, Liberty Bay (Poulsbo), Shelton, Aberdeen and Hoquiam, and Olympia.

The specific shore-based fishing, crabbing or clamming sites within each of the three major areas selected for continued survey coverage were identified by the Washington Department of Fisheries personnel (Marine Recreational Fishing Statistical Survey) and from preliminary field investigations of the DOH surveyor (Figure 2). Boat fishing was not included in the DOH survey due to resource limitations and to the fact that most boat anglers fish outside of urban embayments.

On-site interviews were conducted from July 1983 through June 1984. During the initial weeks of the survey, an attempt was made to cover each survey area on different days of the week, and at different hours of the day. After the times, days and sites of high use were confirmed, survey effort was adjusted accordingly. The survey schedule was also modified throughout the year to reflect seasonal changes in fishing, crabbing or clamming effort. In general, each major survey area was surveyed each month on 3-4 weekend days in the morning (6 a.m.- noon), afternoon (noon - 6 p.m.), and evening (6 p.m. - midnight); and 1-2 weekdays in the morning and evening. Fishing activity during the time period from midnight to 6 a.m. was not sufficient to justify coverage. Tides (except for clamming) and weather were disregarded in scheduling.

At each site a non-selective attempt was made to interview all anglers, crabbers or clamdiggers present by starting at one end of the pier or beach and working down to the other end. Only those people seeking bottomfish, crabs or clams were fully interviewed. Each angler was initially asked if he/she were fishing for bottomfish or salmon. If an angler indicated that he/she were fishing for salmon only and never fished for bottomfish, this was noted on the interview form and no further questions asked. Also, although squid fishing is an intense activity during the winter at some sites, people obviously jigging for squid were not interviewed. Salmon and squid are highly migratory and not expected to be contaminated by toxic contaminants obtained from urban bays. If a person had been interviewed on a previous day by the DOH surveyor, only their catch and time of arrival and departure were recorded. Children under the age of 12 were usually not interviewed if it was apparent they were not serious anglers.

The one-page interview form (Appendix IV) included questions intended to provide three types of information: demographics (age, sex, race, residence), catch and consumption (species caught, size of catch, if eaten, parts eaten, cooking methods) and fishing frequency.

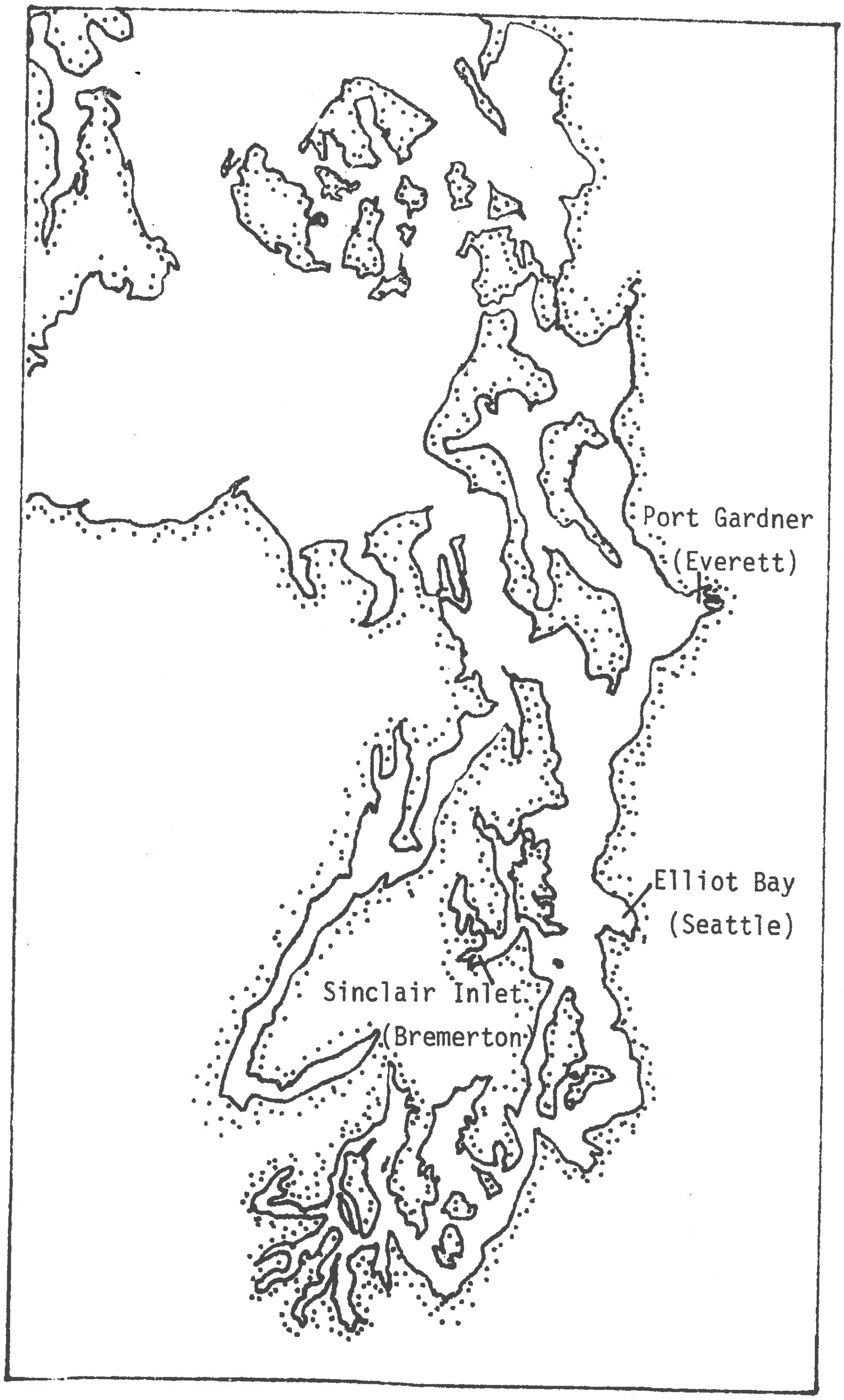


Figure 1. Location of survey areas.

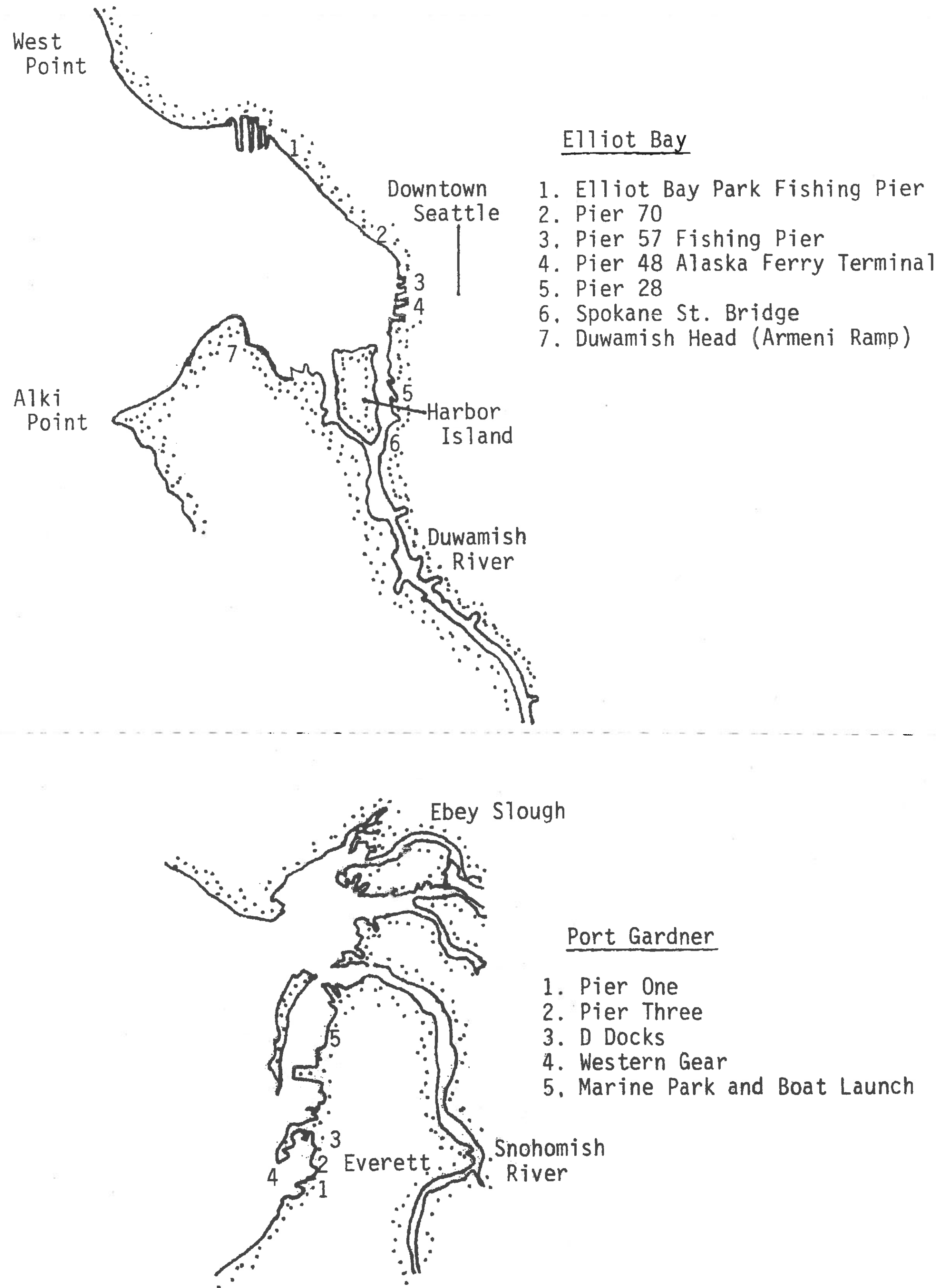
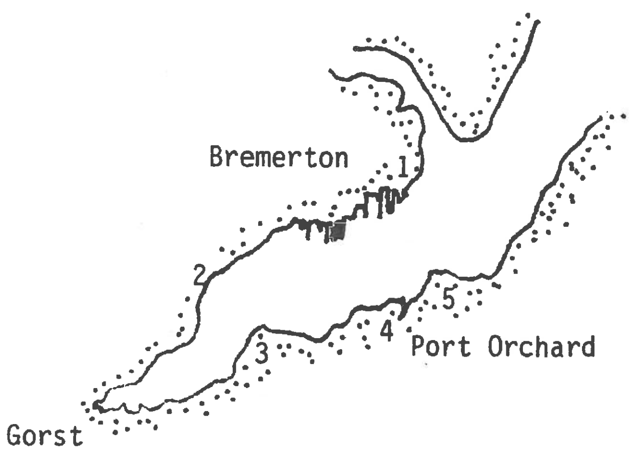


Figure 2. Survey sites (piers, docks, bridges, beaches etc.) within each survey area.



Sinclair Inlet

1. 1st St. Dock
2. Highway between Gorst and Navy Base
3. Pt. Ross
4. Port Orchard Pier
5. Annapolis Pier

RESULTS

<u>Elliot Bay</u> (Seattle)

From July 1983 through June 1984, 702* interviews of shore-based anglers and crabbers were conducted in Elliot Bay. Approximately 5 percent of the likely fishing hours were surveyed based on an 18-hour fishing day. Demographics, catch, frequency of use and consumption habits of the interviewed population are presented in Table 1. Twenty-five people refused to be interviewed. Language was of some problem with 94 of the interviews.

Fishing is the main activity in Elliot Bay (92% or 644 of the 702 interviews). Seven percent (48 of the interviews) indicated both crabbing and fishing, and one percent (10 interviews) indicated crabbing only. No clamming activity was observed within the survey area of Elliot Bay; however, it is known that regular clamming activity takes place south of Alki Beach.

Seventy-two percent of the anglers (496 interviews) were seeking bottomfish. Seventeen percent (121 interviews) said they were fishing specifically for cod, and seven percent (45 interviews) were fishing specifically for perch. Approximately one percent (8 interviews) said they were fishing specifically for rockfish or flatfish.

Sablefish were the most commonly caught fish in Elliot Bay and accounted for 62 percent of the total fish catch by weight. The average sablefish weighed 0.9 pounds. Walleye pollock and Pacific cod comprised another 21 percent of the fish catch. Pollock weighed an average of 0.8 pounds. Pacific cod were usually the largest fish caught and weighed an average of 1.3 pounds. Rockfish, perch and flatfish accounted for only 14 percent of the total fish catch by weight in Elliot Bay.

Sablefish were distinctly seasonal. Eighty-one percent were caught during the winter months (December through February). Pollock were caught mainly in the fall and winter months. Pacific cod were caught throughout the year. All three species were more often caught at night.

Red rock crab was the only species of crab taken by crabbers in Elliot Bay. The average size was 4 inches across the back.

The fish catch rate was 0.5 fish per angler hour. The fish catch distribution shows that most anglers were not successful, while a minority caught most of the fish. Seventy percent of the anglers had caught no fish at the time of the interview, 12 percent had caught one fish, and 18 percent had caught two or more fish. The average angler had been fishing 1.5 hours prior to the interview.

---

*Exclusive of people previously interviewed on other days and people fishing for salmon only.

The crab catch rate was 0.6 crab per crabber hour. Sixty percent of the crabbers had no crab at the time of the interview. The average crabber had been crabbing 1.2 hours prior to the interview.

Over one third (36% or 254 interviews) of the anglers or crabbers were new to the activity and were out for the first, second or third time. Sixteen percent (111 interviews) said they fished or crabbed one to four times per month, and 25 percent (174 interviews) said they fished one to four times per week.

Fifty percent (349 interviews) were Caucasian, 29 percent (203 interviews) were Asian and 18 percent (128 interviews) were Black. Most of the Asians were from Korea (62 interviews), the Philippines (35 interviews) or Vietnam (36 interviews). Most of the interviews were male (86% or 601 interviews). Seventy-four percent (511 interviews) were distributed between the ages of 19 and 49. The vast majority were local residents. Seventy-five percent (527 interviews) indicated they lived in Seattle, and another 10 percent (72 interviews) lived in King County.

Ninety-one percent of the anglers and 100 percent of the crabbers intended to eat their catch.

Of the total responses to the question on what parts of the fish are consumed, 31 percent (156 responses) indicated eating the skin in addition to the muscle, and four percent (22 responses) indicated eating the head or eyes. Less than one percent (5 responses) indicated eating the internal organs of fish, although a language barrier occasionally confused the questioning.

Of the total responses to the question on what parts of the crab are consumed, four percent (1 response) indicated eating the hepatopancreas in addition to the muscle.

Frying was the most popular method of preparing fish (66% or 447 of the responses). Baking was the second most common method (17% or 117 of the responses). Other various methods of preparing fish were occasionally mentioned such as steaming, boiling, barbecuing, broiling and smoking. Only one response indicated eating raw fish.

Crab were usually boiled (72% or 21 of the responses) or steamed (14% or 4 of the responses). Another 14 percent of the responses indicated frying crab.

Table 1. Demographics, catch and consumption of anglers and crabbers in Elliot Bay (Seattle).

*No. of unique interviews	702
No. of repeat interviews	198
Agree	96% (677)
Disagree	4% (25)
Language barrier	13% (94)
**Complete trip interviews	15% (106)
Incomplete trip interviews	85% (596)

Race

Caucasian	50% (349)
Black	18% (128)
Asian	29% (203)
Other or unknown	3% (22)

Country of Origin

United States	66% (464)
Philippines	5% (35)
Cambodia	2% (14)
Laos	1% (9)
Vietnam	5% (36)
Japan	1% (4)
Thailand	<1% (2)
Korea	9% (62)
China	1% (6)
Other	2% (15)
Unknown	8% (55)

Age

12-18	9% (61)
19-29	31% (214)
30-39	22% (152)
40-49	21% (145)
50-59	8% (58)
60-69	7% (49)
70+	2% (16)

Residence

Seattle	75% (527)
King County	10% (72)
Other county in state	4% (26)
Other state	3% (20)
Other country	1% (7)
Unknown	7% (50)

Sex

Male	86% (601)
Female	14% (101)

*Excludes people that fished only for salmon and people interviewed on a previous day.
**Person had finished fishing or crabbing for the day when interviewed.
(No.) - Number of unique interviews unless noted.

Table 1.(cont.)

Activity

Fishing	92%	(644)
Crabbing	1%	(10)
Fishing & crabbing..	7%	(48)

Frequency of fishing or crabbing

1st time	26%	(181)
2nd or 3rd time	10%	(73)
1-4 times/year	9%	(61)
5-11 times/year	3%	(21)
1-4 times/month	16%	(111)
1-4 times/week	25%	(174)
5-7 times/week	2%	(16)
No response	9%	(65)

*Target species of anglers (exc. salmon)

Bottomfish in general	72%	(496)
"Cod" (gadoids & sablefish)..	17%	(121)
Perch	7%	(45)
Flatfish	<1%	(4)
Rockfish	<1%	(4)
Salmon today. Bottomfish other days	3%	(21)

Table 1 (cont.)

Catch of anglers or crabbers interviewed (inc. repeat interviews)

	Numbers of fish caught						
Species	Mar-May Spring	June-Aug Summer	Sept-Nov Fall	Dec-Feb Winter	Total Number	Mean Weight (lbs)	% of Total Catch by Weight
Pacific cod	8	19	9	10	46	1.3	10%
Pacific Hake	0	4	9	1	14	0.7	2%
Tomcod	0	1	2	1	4	0.4	<1%
Pollock	0	3	36	38	77	0.8	11%
Sablefish	51	3	20	320	394	0.9	62%
Striped perch	5	0	0	13	18	0.7	2%
Pile perch	1	1	0	0	2	1.0	<1%
Rockfish .... (brown, quillback or copper)	1	20	3	1	25	0.6	3%
Rock sole	1	3	5	0	9	0.5	1%
English sole	0	3	2	0	5	0.7	1%
Other flatfish ...	2	49	6	2	59	0.6	6%
Other bottomfish							
Greenlings	0	0	0	0	0		
Sculpins	0	0	2	0	2	0.3	<1%
Sharks	0	0	3	1	4	1.5	1%
Shiner perch ...	0	26	73	14	113	0.04	1%
Mackerel	0	0	3	0	3	1.0	<1%
Wolf eels	0	0	0	0	0		
Dungeness crab ...	0	0	0	0	0		
Rock crab	19	16	16	0	51	4"	

Table 1.(cont.)

Parts Consumed (number of responses)

Fish			Crab		
muscle only	62-69%	(508)	muscle only	96%	(25)
skin	31%	(156)	hepatopancreas	4%	(1)
head	4%	(22)	entrails	0%	(0)
entrails	<1%	(5)			
broth	2%	(11)			

Preparation (number of responses)

Fish			Crab		
raw	<1%	(1)	raw	0%	(0)
fried	66%	(447)	boiled	72%	(21)
baked	17%	(117)	steamed	14%	(4)
broiled	5%	(31)	fried	14%	(4)
steamed	3%	(23)			
boiled	6%	(40)			
barbecued	2%	(11)			
smoked	1%	(9)			

Catch Rate

Fish	Crab
0.5 fish/angler hour	0.6 crab/crabber hour

Catch Frequency

Fish (exc. shiner perch)		Crab	
No. caught	% anglers	No. caught	% crabbers
0	70%	0	60%
1	12%	1	7%
2	6%	2	8%
more than 2	12%	more than 2	25%

Mean length of time angler at site prior to interview.....1.5 hours

Mean length of fishing trip....2.5 hours

Mean length of time crabber at site prior to interview.....1.2 hours

Mean length of crabbing trip...2.4 hours

Port Gardner (Everett)

From July 1983 through June 1984, 641* interviews of shore-based anglers and crabbers were conducted in Port Gardner. Approximately 8 percent of the likely fishing hours were surveyed based on a 12-hour fishing day (night fishing not allowed in Everett). Data on the demographics, catch, frequency of use and consumption habits is presented in Table 2. Only one person refused to be interviewed. One hundred fifty-one interviews were hampered to some degree by a language barrier.

Crabbing is the main activity in Port Gardner. Fifty-two percent of the interviews (335 interviews) were crabbing only, and another 25 percent (158 interviews) indicated both fishing and crabbing. Only 23 percent of the interviews (148 interviews) indicated fishing only. No clamming activity was observed in the Port Gardner area within the survey boundaries. Regular clamming activity does occur south of the survey area at Mukilteo.

Of the interviews seeking bottomfish, 52 percent (163 interviews) were fishing for bottomfish in general, four percent (14 interviews) said they were fishing specifically for cod, and 41 percent (129 interviews) were fishing for perch. Less than one percent (2 interviews) said they were fishing for flatfish or rockfish.

Dungeness crab was the most commonly caught seafood in Port Gardner. Red rock crab were also taken, but the larger Dungeness species was preferred. Dungeness crab averaged 6 inches across the back, and red rock crab averaged 4 inches. The crab catch was not noticeably seasonal.

Striped perch and pile perch were by far the most common species of fish caught by anglers in Port Gardner (79% of the fish catch by weight), and they were caught sporadically throughout the year. The average weight was 1.0 pounds for pile perch and 0.6 pounds for striped perch.

The crab catch rate was 0.6 crab per crab hour. At the time of the interview, 56 percent of the crabbers had zero crab, 17 percent had one crab and 27 percent had two or more crab. The average crabber had been crabbing 1.5 hours at the time of interview.

The fish catch rate was 0.3 fish per angler hour. Most of the anglers, 64 percent, had caught zero fish, and only 36 percent had caught one or more fish at the time of the interview. The average angler had been fishing 1.4 hours at the time of interview.

The responses to the question, "How often do you fish or crab here?", tended to cluster around two different frequencies. Almost half, 48 percent (313 interviews), said it was their first, second or third time. Most of the remaining interviews said they fished or crabbed one to four times per month (18% or 113 of the interviews), or one to four times per week (17% or 107 of the interviews).

*Exclusive of repeat interviews (people previously interviewed on other days) and people that fished only for salmon.

A high percentage of the people interviewed in Port Gardner (55% or 351 of the interviews) were Asian. Over 25 percent (175 interviews) of the total interviews were from Southeast Asia (Laos, Cambodia or Vietnam). Caucasians comprised 43 percent (277 interviews) of the interviewed population, and only one percent (5 interviews) were Black.

A high percentage, 29 percent (184 interviews), of the anglers and crabbers were female. The interviewed population was also relatively young. Sixty-three percent (404 interviews) were between the ages of 19 and 39.

Slightly more than half of the anglers and crabbers were local residents. Fifty-seven percent (367 interviews) lived in Everett or Snohomish County. A large number, 37 percent (239 interviews), drove to the area from Seattle or King County.

Ninety-nine percent of the crabbers intended to eat their catch and 91.5% of the anglers intended to eat their fish.

Of the total responses to the question on parts of the fish consumed, 22 percent (45 responses) indicated eating the skin in addition to the muscle, five percent (11 responses) indicated eating the head or eyes, eight percent (17 responses) consumed fish broth, i.e. fish soup. No one indicated eating fish entrails.

Of the total responses to the question on parts of crab consumed, 15 percent (65 responses) indicated eating the hepatopancreas and four percent (17 responses) indicated eating the entrails in addition to the muscle.

Frying was by far the most common method of preparing fish (72% or 193 of the responses). No one indicated preparing raw fish.

Crab were commonly boiled (68% or 341 of the responses) or steamed (28% or 140 of the responses).

Table 2. Demographics, catch and consumption of anglers and crabbers in Port Gardner (Everett).

*No. of unique interviews	641
No. of repeat interviews	151
Agree	99% (640)
Disagree	1% (1)
Language barrier	24% (151)
**Complete trip interviews	13% (82)
Incomplete trip interviews	87% (559)

Race

Caucasian	43% (277)
Black	1% (5)
Asian	55% (351)
Other or unknown	1% (8)

Country of Origin

United States	45% (287)
Philippines	17% (111)
Cambodia	6% (38)
Laos	15% (96)
Vietnam	6% (41)
Thailand	<1% (3)
Japan	1% (4)
Korea	2% (14)
China	2% (15)
Other	1% (6)
Unknown	4% (26)

Age

12-18	8% (52)
19-29	34% (220)
30-39	29% (184)
40-49	18% (113)
50-59	6% (36)
60-69	4% (28)
70+	1% (8)

Residence

Everett	38% (243)
Snohomish County	19% (124)
*Other county in state	40% (255)
Other state	2% (15)
Other country	<1% (2)
Unknown	<1% (2)

*Seattle and King County .. 37% (239)

Sex

Male	71% (457)
Female	29% (184)

*Excludes people that fished only for salmon and people interviewed on a previous day.
**Person had finished fishing or crabbing for the day when interviewed.
(No.) - Number of unique interviews unless noted.

Table 2.(cont.)

Activity

Fishing	23%	(148)
Crabbing	52%	(335)
Fishing & crabbing..	25%	(158)

Frequency of fishing or crabbing

1st time	38%	(247)
2nd or 3rd time	10%	(66)
1-4 times/year	10%	(63)
5-11 times/year	2%	(16)
1-4 times/month	18%	(113)
1-4 times/week	17%	(107)
5-7 times/week	1%	(5)
No response	4%	(24)

*Target species of anglers

Bottomfish in general	52%	(163)
"Cod" (gadoids & sablefish)..	4%	(14)
Perch	41%	(129)
Flatfish	<1%	(2)
Rockfish	0%	(0)
Salmon today. Bottomfish other days	1%	(4)

Table 2.(cont.)

Catch of anglers or crabbers interviewed (inc. repeat interviews)

	Numbers of fish caught						
Species	Mar-May Spring	June-Aug Summer	Sept-Nov Fall	Dec-Feb Winter	Total Number	Mean Weight (lbs)	% of Total Fish Catch By Weight
Pacific cod	0	1	1	0	2	1.0	2%
Pacific Hake	0	1	0	0	1	0.8	1%
Tomcod	0	0	10	0	10	0.4	4%
Pollock	0	0	0	0	0		0%
Sablefish	0	0	0	1	1	0.9	1%
Striped perch	22	6	3	37	68	0.6	42%
Pile perch	2	15	14	5	36	1.0	37%
Rockfish .... (brown, quillback or copper)	0	3	2	0	5	0.7	4%
Rock sole	1	0	1	0	2	0.4	1%
English sole	0	0	0	0	0		0
Other flatfish	0	1	0	0	1	0.6	1%
Other bottomfish							
Greenlings	0	0	0	0	0		0%
Sculpins	0	0	8	0	8	0.3	2%
Sharks	0	0	0	0	0		0%
Shiner perch	0	62	23	0	85	0.04	4%
Mackerel	0	0	0	0	0		0%
Wolf eels	0	0	1	0	1	1.3	1%
Dungeness crab	77	79	79	107	342	6"	
Rock crab	24	85	158	17	284	4"	

Table 2.(cont.)

Parts Consumed (number of responses)

Fish		Crab	
muscle only	65-78% (208)	muscle only	81-85% (423)
skin	22% (45)	hepatopancreas	15% (65)
head	5% (11)	entrails	4% (17)
entrails	0% (0)		
broth	8% (17)		

Preparation (number of responses)

Fish		Crab	
raw	0% (0)	raw	0% (0)
fried	72% (193)	boiled	68% (341)
baked	10% (27)	steamed	28% (140)
broiled	4% (11)	fried	4% (21)
steamed	2% (4)		
boiled	10% (27)		
barbecued	1% (3)		
smoked	1% (3)		

Catch Rate

Fish

0.3 fish/angler hour

Crab

0.6 crab/crabber hour

Catch Frequency

Fish (exc. shiner perch)

No.s caught	% anglers
0	64%
1	15%
2	9%
more than 2	12%

Mean length of time angler at site prior to interview.....1.4 hours

Mean length of fishing trip....2.6 hours

Crab

No.s caught	% crabbers
0	56%
1	17%
2	10%
more than 2	17%

Mean length of time crabber at site prior to interview.....1.5 hours

Mean length of crabbing trip...2.7 hours

Sinclair Inlet (Bremerton, Port Orchard)

From July 1983 through June 1984, 225* interviews of shore-based anglers and crabbers and 75 interviews of clamdiggers were conducted in Sinclair Inlet. Approximately 5 percent of the likely fishing hours were surveyed based on an 18-hour fishing day. Demographics, catch, frequency of use and consumption habits of the interviewed population are presented in Table 3 (anglers and crabbers) and Table 4 (clamdiggers). No one refused to be interviewed. Twenty-two angler/crabber interviews and six clamdigger interviews were incomplete because of a language barrier.

The majority of angler/crabbers interviewed in Sinclair Inlet were fishing only (72% or 163 interviews). Another 16 percent (35 interviews) were both fishing and crabbing, and 12 percent (27 interviews) were crabbing only.

Of the people fishing, 74 percent (151 interviews) were seeking bottomfish in general, and 12 percent (25 interviews) mentioned they were fishing specifically for cod. Seven percent (14 interviews) were fishing for perch. Only four percent (8 interviews) were fishing specifically for rockfish or flatfish.

Pacific cod and perch were the most commonly caught fish in Sinclair Inlet and comprised 48% and 30% of the total fish catch by weight respectively. Pacific cod averaged 1.8 pounds and perch averaged 0.9 pounds.

Red rock crab was the only species of crab caught in Sinclair Inlet. The average size was 5 inches across the back.

The common species of shellfish were abundant on the beaches such as butter clams, native littlenecks, Japanese littlenecks, cockles, horse clams and soft shell clams. About 50 percent of the clamdiggers kept all species indiscriminately, and the other 50 percent selected only the littlenecks or butter clams.

The fish catch rate was 0.3 fish per angler hour. Sixty-six percent of the anglers had zero fish at the time of the interview, 16 percent had one fish and 18 percent had two or more fish. The average angler had been fishing 1.7 hours at the time of interview.

The crab catch rate was 0.9 crab per crabber hour. Forty-seven percent had zero crab, 21 percent had one crab and 32 percent had two or more crab at the time of the interview. The average crabber had been crabbing 1.4 hours at the time of interview.

Almost half of the interviews were fishing or crabbing for the first, second or third time (47% or 105 interviews). Thirty-eight percent (85 interviews) said they fished anywhere from one to four times per month to one to four times per week.

*Exclusive of people interviewed on a previous day and people fishing only for salmon.

A large number of the clamdiggers were also clamming for the first time (31% or 23 interviews). Most of the rest indicated they either clammed one to four times per year (29% or 22 interviews) or one to four times per month (27% or 20 interviews).

Most anglers and crabbers were Caucasian (67% or 150 interviews) or Asian (28% or 62 interviews). Ten percent (22 interviews) were from Southeast Asia (Cambodia and Vietnam).

The majority of the clamdiggers were Asian (52% or 39 interviews). Twenty-seven percent of the clamdiggers (20 interviews) were Caucasian and 15 percent (11 interviews) were Native American. Almost two-thirds of the Asian clamdiggers were born in the Philippines or the United States.

Eighty percent of the anglers and crabbers (181 interviews) were male, and 69 percent (155 interviews) were between the ages of 19 and 39.

The clamdiggers, in contrast, were 56 percent male and 44 percent female, and were evenly distributed between the ages of 19 and 69.

The majority of the anglers and crabbers were local residents. Sixty-five percent (145 interviews) were from Bremerton or Port Orchard, and another six percent (14 interviews) lived in Kitsap County. A significant number drove from Tacoma or Pierce County (18% or 40 interviews).

Very few of the clamdiggers were local residents. Only 16 percent (12 interviews) lived in Bremerton, Port Orchard or Kitsap County. Sixty-one percent of the clamdiggers (46 interviews) lived in Tacoma or Pierce County.

~~Eighty-five percent of the anglers said they would eat their catch, and 100~~ percent of the crabbers and clamdiggers said they would eat their catch.

Of the total number of responses to the question on parts of the fish consumed, 23 percent (34 responses) indicated eating the skin in addition to the muscle. Only three percent (4 responses) indicated eating the head or eyes, and no one indicated eating the entrails.

Of the total responses to the parts of the crab consumed, 14 percent (6 responses) indicated eating the hepatopancreas in addition to the muscle, and no one indicated eating the entrails.

Clamdiggers were not very specific in response to the question on parts of the clam consumed, but, in general, the small clams such as littlenecks were eaten whole and the larger clams such as butter clams were cleaned (entrails removed).

Frying was the most popular method of cooking fish (66% or 142 of the responses). One family (less than 1% or 2 of the responses) prepared raw fish (sashimi).

Crab were almost always boiled (80% or 36 of the responses) or steamed (16% or 7 of the responses).

Clams were usually boiled or steamed (75% or 126 of the responses). A few people also commonly prepared marinated raw clams (11% or 18 of the responses).

Table 3. Demographics, catch and consumption of anglers and crabbers in Sinclair Inlet (Bremerton, Port Orchard).

*No. of unique interviews	225
No. of repeat interviews	59
Agree	100% (225)
Disagree	0% (0)
Language barrier	10% (22)
**Complete trip interviews	18% (41)
Incomplete trip interviews	82% (184)

Race

Caucasian	67% (150)
Black	6% (13)
Asian	27% (62)
Other or unknown	0% (0)

Country of Origin

United States	72% (163)
Philippines	14% (31)
Cambodia	7% (16)
Laos	0% (0)
Vietnam	3% (6)
Thailand	<1% (1)
Japan	<1% (1)
Korea	1% (3)
China	0% (0)
Other	0% (0)
Unknown	2% (4)

Age

12-18	12% (27)
19-29	43% (96)
30-39	26% (59)
40-49	14% (32)
50-59	2% (5)
60-69	2% (5)
70+	<1% (1)

Residence

Bremerton	41% (91)
Port Orchard	24% (54)
Kitsap County	6% (14)
*Other county in state	22% (50)
Other state	6% (14)
Other country	0% (0)
Unknown	2 (4)
*Pierce County	18% (40)

Sex

Male	80% (181)
Female	20% (44)

*Excludes people that fished only for salmon and people interviewed on a previous day.
**Person had finished fishing or crabbing for the day when interviewed.
(No.) - Number of unique interviews unless noted.

Table 3.(cont.)

Activity

Fishing	72%	(163)
Crabbing	12%	(27)
Fishing & crabbing..	16%	(35)

Frequency of fishing or crabbing

1st time	32%	(72)
2nd or 3rd time	15%	(33)
1-4 times/year	4%	(10)
5-11 times/year	2%	(4)
1-4 times/month	15%	(34)
1-4 times/week	23%	(51)
5-7 times/week	7%	(17)
No response	2%	(4)

*Target species of anglers (exc. salmon)

Bottomfish in general	74%	(151)
"Cod" (gadoids & sablefish)..	12%	(25)
Perch	7%	(14)
Flatfish	3%	(6)
Rockfish	1%	(2)
Salmon today. Bottomfish other days	3%	(5)

Catch of anglers or crabbers interviewed (inc. repeat interviews)

Species	Mar-May Spring	June-Aug Summer	Sept-Nov Fall	Dec-Feb Winter	Total Number	Mean Weight (lbs)	% of Total Fish Catch by Weight
	Numbers of fish caught						
Pacific cod	0	3	44	2	49	1.8	48%
Pacific Hake	0	0	0	0	0		0%
Tomcod	0	0	0	0	0		0%
Pollock	0	0	0	0	0		0%
Sablefish	0	0	0	0	0		0%
Striped perch	1	15	20	0	36	0.7	14%
Pile perch	0	10	15	0	25	1.2	16%
Rockfish .... (brown, quillback or copper)	0	5	1	0	6	1.5	5%
Rock sole	1	7	7	3	18	0.8	8%
English sole	0	0	0	0	0		0%
Other flatfish	2	3	3	1	9	1.1	5%
Other bottomfish							
Greenlings	1	1	3	0	5	0.9	2%
Sculpins	0	3	0	0	3	0.3	<1%
Sharks	0	1	0	0	1	1.5	1%
Shiner perch	0	7	0	0	7	0.04	<1%
Mackerel	0	0	0	0	0	0.04	0%
Wolf eels	0	0	0	0	0		0%
Dungeness crab	0	0	0	0	0		
Rock crab	0	38	42	16	96	5"	

Table 3.(cont.)

Parts Consumed (number of responses)

Fish

muscle only	72-77%	(148)
skin	23%	(34)
head	3%	(4)
entrails	0%	(0)
broth	3%	(4)

Crab

muscle only	86%	(42)
hepatopancreas	14%	(6)
entrails	0%	(0)

Preparation (number of responses)

Fish

raw	<1%	(2)
fried	66%	(142)
baked	16%	(34)
broiled	1%	(3)
steamed	6%	(12)
boiled	6%	(12)
barbecued	4%	(8)
smoked	<1%	(2)

Crab

raw	0%	(0)
boiled	80%	(36)
steamed	16%	(7)
fried	4%	(2)

Catch Rate

Fish

0.3 fish/angler hour

Crab

0.9 crab/crabber hour

Catch Frequency

Fish (exc. shiner perch)

No. caught	% anglers
0	66%
1	16%
2	5%
more than 2	13%

Mean length of time angler at site prior to interview.....1.7 hours

Mean length of fishing trip....2.6 hours

Crab

No.s caught	% crabbers
0	47%
1	21%
2	8%
more than 2	24%

Mean length of time crabber at site prior to interview.....1.4 hours

Mean length of crabbing trip...2.2 hours

Table 4. Demographics, catch and consumption for clamdiggers in Sinclair Inlet (Bremerton, Port Orchard).

No. of unique interviews	75
No. of repeat interviews	0
Agree	100% (75)
Disagree	0% (0)
Language barrier	8% (6)
Estimated shellfish harvest effort	4,300 user trips per season (Wash. Dept. of Fisheries data)

Race

Caucasian	27% (20)
Black	0% (0)
Asian	52% (39)
*Other or unknown	21% (16)

*Native American ... 15% (11)

Age

12-18	7% (5)
19-29	21% (16)
30-39	17% (13)
40-49	20% (15)
50-59	15% (11)
60-69	19% (14)
70+	1% (1)

Sex

Male	56% (42)
Female	44% (33)

Frequency

1st time	31% (23)
2nd or 3rd time	8% (6)
1-4 times/year	29% (22)
5-11 times/year	5% (4)
1-4 times/month	27% (20)
1-4 times/week	0% (0)
5-7 times week	0% (0)

Country of Origin

United States	52% (39)
Philippines	16% (12)
Cambodia	8% (6)
Laos	0% (0)
Vietnam	0% (0)
Thailand	0% (0)
Japan	8% (6)
Korea	3% (2)
China	0% (0)
Other	8% (6)
Unknown	5% (4)

Residence

Bremerton	4% (3)
Port Orchard	12% (9)
Kitsap County	0% (0)
*Other county in state	81% (61)
Other state	3% (2)
Other country	0% (0)

*Pierce County or Tacoma ... 61% (46)

Parts consumed

muscle only	58% (64)
entire	42% (46)

Intend to eat

yes	100% (75)
no	0% (0)

Preparation

raw	11% (18)
boiled	41% (69)
steamed	34% (57)
fried	15% (25)

Table 4 (cont)

Mean catch weight (primarily butter clams, littlenecks or both) of completed interviews (35)..	14 lbs wet weight in shell
Mean no. of people catch to be shared with...........................	7-8

SUMMARY OF FINDINGS

Most people were very cooperative and eager to answer questions. Only 26 out of more than 1500 interviews refused to be interviewed. Although the surveyor was aware that some people were initially uncomfortable or suspicious when approached by someone who appeared to be a "game warden," there were only one or two instances when an angler apparently left the site because of the surveyor's presence.

A language barrier was noted on the interview form if there was any difficulty in communication. In the majority of cases the problem was minor. With patience most questions could be understood and answered. Children in the group often spoke excellent English. Seldom did the surveyor encounter a complete language barrier. However, questions concerning the parts of the catch eaten, how it was prepared and how often the person fished, crabbed or clammed were consistently the most troublesome.

The most common species of fish caught by anglers were Pacific cod, sablefish, striped perch and pile perch. These species comprised 77% of the total fish catch by weight. Dungeness crab and red rock crab were the two most commonly caught species of crab. Butter clams and littleneck clams were the common species of clams taken in Sinclair Inlet.

The fish caught by urban anglers tended to be small, usually ranging from 1/2 to 1 1/2 pounds and seldom exceeding 3 pounds. Crab rarely exceeded 6 1/2 inches across the back. Both the crab catch rate and the fish catch rate were low. It was noted that the fish catch was highly variable and could change from hour to hour, day to day, week to week and season to season. Sometimes an angler would go home with a "bucket-full" of fish, but this was more the exception than the rule. The crab catch seemed to be more consistent and did not vary markedly throughout the year. The clam catch was mainly determined by how many the clamdigger chose to dig.

Frequency of fishing and crabbing tended to cluster around two frequencies. Roughly one-third to one-half of the interviewees were new to the activity and said it was their first, second or third time out. More than another third of the interviewees said they fished or crabbed from once per month to four times per week. Once per week was the most common response. Most clamdiggers clammed infrequently. Clamming activity tends to be a family activity and is mostly restricted to minus low tides in the summer months. Once or twice per month was probably the most often anyone dug clams in Sinclair Inlet.

A problem was noted with the question, "How often do you fish/crab/clam here?" Most people tended to respond on the basis of their activity in the recent past. If they had fished every day for the past week, they said they fished every day even though they had not fished before that week or would not fish again for the rest of the year. Also, people probably overestimated how often they actually fished, and responded on the basis of how often they would like to fish or the most often they ever fished. It was the surveyor's observation that seldom did anyone fish consistently year around. Fishing frequencies presented in this report may be inflated.

The most productive fishing took place in the winter, particularly at night. Elliot Bay had the most nighttime and wintertime fishing activity. More people fished in the summer, but the fishing was not as good. Summertime fishing activity was more recreational and family oriented in nature than wintertime fishing activity. Crabbing in Everett took place year around, but was more intense in the summer. Clamming in Sinclair Inlet was mainly a summer activity. In all seasons weekend activity was much greater than weekday. Rain did not seriously hamper fishing effort; however, a strong wind would usually curtail most activity. Most anglers preferred to fish the high tide or incoming tide, but availability of free time was a more important factor in determining when people fished.

Although most people intended to eat the fish they caught, quite a few (8.5% to 15%) said they would not for various reasons. Often people were just fishing for sport and did not like to eat fish or would prefer to give it away than bother to fix it. Although not a solicited response, many people mentioned they would not eat bottomfish, particularly flounder and sole, because of "pollution." This response was particularly common in areas such as Port Gardner and Elliot Bay where findings of diseased fish have been publicized. Misconceptions about contaminated fish were common. Most people thought that they would be "sick" immediately if they ate a contaminated fish. Many were certain they could tell a contaminated fish by looking for parasites, tumors, malformations, etc. Flatfish, which are commonly infested with the parasitic worm Philometra, were often discarded for this reason. People frequently confused paralytic shellfish poisoning (PSP) and toxic chemical contamination. Most people regarded reports of contaminated fish seriously.

The vast majority of people either fried, baked or steamed their fish. Crab and shellfish were almost always steamed or boiled. Asians cooked their fish, crab and shellfish in a much greater variety of ways then Caucasians, although frying was still a common method of cooking fish.

Everyone ate the muscle of fish, crab and shellfish. Some people said they ate fish skin, but the answer seemed to depend on the type of fish. Skin of salmon and trout was more acceptable than skin of bottomfish. Some people ate the head and eyes of fish, or used fish heads to make soup stock. It was not uncommon for Asians to eat the crab hepatopancreas ("crab butter") which is considered a delicacy in many Asian cultures. No one clearly ate the entrals, although language and cultural differences sometimes interfered with the interview. Conversations with Southeast Asian caseworkers at the Thurston County Refugee Center indicated that it was not customary to eat the internal organs of fish or crab in Southeast Asian cultures. Small clams such as littlenecks were eaten whole and larger clams such as butter clams were usually cleaned.

The Asian people interviewed represented a variety of Asian cultures and economic levels. A minority of the Asian people interviewed were recent Southeast Asian refugees, and only some appeared to be subsistence level. A particularly high percentage of Asians (over 50% of the interviews) fished or crabbed in the Port Gardner area. It was noted that some were local residents from Everett, but most drove from the Seattle or King County area. Everett is one of the nearest sites to Seattle with productive crabbing, especially for the larger Dungeness crab. Also, it was noted that most of the Asians clamming or fishing along the highway between Gorst and Bremerton drove from Tacoma or Pierce County.

The high percentage of females clamming in Sinclair Inlet and crabbing in Port Gardner can be attributed to the fact that crabbing and clamming tend to be family activities. It was not uncommon for large extended family groups to arrive at a site with a picnic lunch and spend the entire day on the piers or beaches.

The surveyor's impression was that most people were fishing, crabbing or clamming for recreation and relaxation foremost. Even fishing on cold, wet winter nights contained an element of sport. A small minority of the interviewees appeared to be fishing with the sole purpose of catching food. It is probable that low income people, particularly recent Southeast Asian immigrants, have few options in the use of their leisure time. Fishing and crabbing is inexpensive and a traditional part of many Asian cultures.

REVIEW OF SPECIES ECOLOGY AND LIFE HISTORIES

Over 165 species of fish and shellfish can be found in Puget Sound. Only a small fraction of these species are of interest to the recreational angler, crabber or clamdigger, and even a smaller fraction may be of concern for human exposure to industrial contaminants.

The following section contains an overview of the ecology and life histories of the major groups of Puget Sound bottomfish and shellfish that are of interest to the recreational consumer. The groups reviewed are the gadoids, sablefish, surf perch, flatfish, rockfish, crab and clams. The specific species listed are those most frequently caught and consumed by the shore-based urban anglers, crabbers and clamdiggers interviewed in this survey. Highly migratory species, such as salmon and squid, were excluded from the survey. These species are only briefly exposed to contaminated sediments and are not considered likely to be contaminated by most chemicals found in the sediments of urban bays.

In addition to information intended to familiarize the reader with the characteristics of the bottomfish and shellfish commonly caught in Puget Sound, available information on the migratory habits, amount of contact with the bottom sediments, average age and feeding habits, is included to suggest a species' tendency to accumulate contaminants on an ecological basis. Although evidence implies that these ecological factors may play a role in determining a species' level of contamination, it should be kept in mind that intrinsic factors such as a species' inability to metabolize certain chemicals, or the tendency for a particular chemical to biomagnify in the food chain, also have to be considered when speculating on contamination levels in the absence of actual tissue analyses.

Gadoids

Species: Pacific cod (*Gadus macrocephalus*), Pacific hake (*Merluccius productus*), walleye pollock (*Theragra chalcogramma*)

Common names used by survey's anglers: cod, true cod, tomcod, hake

Habitat: Schooling, midwater or bottom oriented. Adapted to a variety of bottom types ranging from smooth silt to rock. Shallow to deep water (5-50 fathoms).

Migratory behavior: Pacific cod, Pacific hake and walleye pollock show seasonal movements but the extent of these movements is unknown. These species may make feeding migrations to the surface at night.

Average size and age at maturity[1]: Pacific cod ......19-24 inches, 2-3 years
Pacific hake .....12-30 inches, 3 years
walleye pollock ..14-15 inches, 3 years

[1]Data from Pederson and DiDonato (1982). Average size and age in commercial and sport catch in Puget Sound.

Food: Variety of small fish and invertebrates such as marine worms, crabs, shrimp and herring.

Sablefish

Species: sablefish (Anoplopoma fimbria)

Common name used by survey's anglers: black cod

Habitat: Schooling, mid-water and often less bottom oriented than the gadoids.

Migratory behavior: Extensively migratory. Juveniles migrate out of Puget Sound at approximately 3 years of age.

Average size and age[1]: 12 inches, less than 3 years.

Food: Variety of smaller fish and invertebrates.

Flatfish

Species: rock sole (Lepidopsetta bilineata), English sole (Parophrys vetulus) starry flounder (Platichthys stellatus), sand sole (Psettichthys melanostictus)

Common names used by survey's anglers: sole, flounder, halibut

Habitat: Flat sand to mud bottoms. More common in shallow water. Usually lie in direct contact with the bottom and, at times, actually bury in the sediment with only the eyes protruding.

Migratory behavior: Tagging studies have shown that English sole are somewhat migratory but their range is limited. The possibility of discrete stocks in Saratoga Passage, Possession Sound, Port Madison and Shilshole Bay has been well documented. However, within these areas there is considerable movement from deep water spawning areas in the winter to shallow water in the spring.

Average size and age at maturity[2]:

rock sole.........11-12 inches, 4 years
English sole .....10-12 inches, 3 years
starry flounder...12-14 inches, 3 years
sand sole ....12-13 inches, 2-3 years

Food: Small bottom dwelling organisms such as crabs, shrimp, worms, clam necks, brittle stars and small fish.

---

[1]Data from Bargmann (1982). The average size caught by recreational anglers from structures (excluding boats) in Puget Sound in 1981.

[2]Data from Pederson and DiDonato (1982). The average size and age in Puget Sound sport and commercial catch.

Surf Perch

Species: pile perch (*Rhaccochilus vacca*), striped perch (*Embiotoca lateralis*)

Common names used by survey's anglers: perch, rainbow perch, sea bass

Habitat: Usually shallow water (less than 10 fathoms) and associated with pilings, rocks or kelp beds.

Migratory behavior: The migratory range of surf perch is unknown. Schools of perch are reported to move into nearshore areas in the late spring and summer to spawn.

Average size and age at maturity[1]: pile perch........11 inches, 3 years
striped perch.....10 inches, 3-4 years

Rockfish

Species: copper rockfish (*Sebastes caurinus*), brown rockfish (*Sebastes auriculatus*), quillback rockfish (*Sebastes maliger*)

Common names used by survey's anglers: rock cod, cod

Habitat: Shallow water. Associated with kelp beds, pilings, rocks and other submerged structures.

Migratory behavior: Tagging studies on copper rockfish have shown little migration.

Average size and age at maturity[2]:
copper rockfish.....11 inches, 4 years
brown rockfish......11 inches, 6 years (female)
quillback rockfish.. 9 inches, 4 years (female)

Food: Smaller fish and invertebrates (shrimp, crabs and small clams).

Crab

Species: Dungeness crab (*Cancer magister*), red rock crab (*Cancer productus*)

Common names used by survey's crabbers: Same as species name

Habitat: Dungeness crab prefer a mud or sand bottom, particularly eelgrass beds, and are found at depths of 0-50 fathoms. Red rock crab utilize a wider variety of bottom types ranging from mud, sand or gravel bays to more rocky habitats. Red rock crab are more often found in the intertidal zone than Dungeness crab.

[1]Data from Pedersen and DiDonato (1982). Average size and age in commerical and sport catch in Puget Sound.
[2]Ibid.

Migratory behavior: Both Dungeness and red rock crab are mobile species, making onshore migrations in the spring and summer, and moving offshore in the winter. Puget Sound populations are thought to be less migratory than ocean coast populations.

Average size and age[1]: Dungeness crab.... 6-7 inches, 4 years
red rock crab .... 5 inches

Food: A wide variety of marine organisms including fish, clams, mussels, snails, worms, starfish, barnacles, shrimp and other crabs.

Clams

Species: Butter clams (Saxidomus giganteus), native littlenecks (Protothaca staminea), Manila clams or Japanese littlenecks (Venerupis japonica)

Common names used by survey's anglers: butter clams, littlenecks, steamers

Habitat: Prefer gravel beaches in protected waters. Not as common in mud or silt bays. Found from just beneath the surface to 14 inches within the sediment, and are abundant in the lower third of the intertidal zone. Large populations are also found subtidally.

Movement: Sedentary

Average size and age[2]: butter clams...................... 3 inches, 5-7 years
Manilas and native littlenecks.... 2 inches, 3-4 years

Food: Microscopic organisms (plankton) filtered from the surrounding water.

[1]Washington Dept. of Fisheries (1978) and Washington Dept. of Ecology (1981). Harvestable size and age in Puget Sound.
[2]Ibid.

References

Bargmann, G. 1980. Studies on Pacific cod in Agate Pass, Washington. Washington Dept. of Fisheries Progress Report No. 123.

Bargmann, G. 1982. Recreational angling from piers, docks and jetties in Puget Sound, Washington during 1981. Washington Dept. of Fisheries Tech. Report No. 73.

Day, D. 1976. Homing behavior and population stratification in central Puget Sound English sole. Journal of the Fisheries Research Board of Canada. Vol. 33, No. 2. pp. 278-282.

Gosho, M. 1976. Results of the tagging of Pacific cod (Gadus macrocephalus) in Washington waters. Washington Dept. of Fisheries Tech. Report No. 19.

Gowan, R. 1983. Population dynamics and exploitation rates of rockfish (Sebastes spp.) in central Puget Sound, Washington. Ph.D. Dissertation, University of Washington, Seattle.

Hart, J. 1973. Pacific fishes of Canada. Fisheries Research Board of Canada. Bulletin No. 180.

Holland, G. 1969. Age, Growth and mortality of races of English sole (Parophrys vetulus) in Puget Sound, Washington. Pacific Marine Fisheries Commission Bulletin 7. pp. 36-50.

Hueckel, G. 1980. Foraging on an artificial reef by three Puget Sound fish species. Washington Dept. of Fisheries Tech. Report No. 53.

Pasquale, N. 1964. Notable mgirations of sablefish tagged in Puget Sound. Washington Dept. of Fisheries. Fisheries Research Papers. Vol. 2, No. 3. p. 68.

Pedersen, M. and G. DiDonato. 1982. Groundfish management plan for Washington's inside waters. Washington Dept. of Fisheries Progress Report No. 170.

Pruter, A. 1959. Tagging experiments on sablefish at Holmes Harbor, Washington. Washington Dept. of Fisheries. Fisheries Research Papers. Vol. 2, No. 2. pp. 66-70.

Schadt, T. and M. Pedersen. 1979. A study of two populations of walleye pollock (Theragra chalcogrammus) in Puget Sound, Washington. Washington Dept. of Fisheries.

Washington Dept. of Ecology. 1981. Washington coastal areas of major biological significance.

Washington Dept. of Fisheries. 1978. Washington State shellfish.

CHEMICAL CONTAMINANTS IN PUGET SOUND SEAFOOD*

A discussion of chemical contaminants in Puget Sound and the impact on human health is exceedingly complex and difficult for a number of reasons. Hundreds of chemical contaminants have been identified in Puget Sound water, sediment and biota, with evidence for hundreds yet to be identified. These chemicals vary greatly in their chemical behavior and degree of toxicity.

Some contaminants, such as the pesticide DDT, are chemically stable and very persistent in the environment. Despite a ban on DDT manufacture and use since 1972, environmental levels remain high. Other chemical contaminants can be transformed via biological, chemical or other actions. In some cases, these new compounds may be equally or more toxic than the parent compound. Relatively non-toxic forms of inorganic mercury can be converted to the highly toxic organic form, methylmercury, by microorganisms in marine sediments. In other cases, the new compound formed may be less toxic, such as methylated arsenic.

Chemical contaminants also vary greatly in their tendency to accumulate in the biota. PCBs and mercury, for example, have a strong tendency to bioaccumulate and concentrations are actually magnified up the food chain. In other words, levels of PCBs and mercury tend to be higher in the predator than its prey.

Differences in contaminant levels in different organisms may also have an inherent physiological or biological basis. A number of factors, including a lack of metabolism, excretion or both processes in a particular species may regulate bioaccumulation. For example, clams, unlike fish lack the ability to sufficiently metabolize polynuclear aromatic hydrocarbons (PAHs or PNAs) and thus, accumulate higher levels of PAHs or PNAs than other marine organisms. In some organisms a "contaminant" may not be a contaminant at all, but an essential element for survival. Copper has been found in much higher concentrations in crab than in bottomfish in Puget Sound. This can be explained by the fact that crab have a copper-based pigment (hemocyanin) in the blood, unlike fish and humans which have the iron-based pigment hemoglobin.

---

*Man-made products or by-products of industrial processes that enter Puget Sound primarily through industrial atmospheric and wastewater discharge, municipal sewage discharge and non-point sources of pollution such as urban and agricultural surface runoff. This discussion does not include high biological oxygen demand (BOD) waste, bacterial contamination, oil spills or paralytic shellfish poisoning (PSP) which is a naturally occurring toxin produced by microorganisms in the water.

Other species differences in contamination levels may be more related to differences in ecology than physiology. Bottomfish in Puget Sound consistently show higher levels of contaminants than salmon. Bottomfish tend to live and feed near the bottom and are less migratory than salmon. Since bottomfish have more prolonged and intimate contact with potentially contaminated sediments, it is expected that bottomfish have higher concentrations of many chemical contaminants.

Within an organism, contaminants also occur at different concentrations in different tissues. Many chemical pollutants are fat soluble, so are usually found in higher concentrations in the fatty tissues such as the skin and soft organs. The liver, an organ which functions to remove toxins from the body, has much higher levels of contaminants than the muscle tissue. English sole examined in Commencement Bay and Elliot Bay had levels of PCBs 5 to 40 times higher in the liver than in the muscle (Malins, 1982).

In terms of human health, the effects of these chemical contaminants is even less understood. The concentrations of contaminants found in Puget Sound biota are much lower than the concentrations known to produce immediate toxic effects in humans. The concern for human health is primarily with the possible effects of long-term, low-level exposure to these chemical contaminants. In general, very little is known about the effects of low-level exposure to these chemicals, particularly to humans. Some chemical contaminants are known to be carcinogenic, mutagenic or teratogenic*, but at levels many times higher than detected in Puget Sound edible biota. Questions concerning the health effects of long-term, low level exposure to chemical contaminants are difficult to assess since cancer often takes 15 to 30 years to develop after initial exposure to a carcinogen. The Federal Food and Drug Adminstration (FDA) has been able to establish guidelines for only a handful of chemical contaminants in fish and shellfish (Appendix I). Also, the FDA guidelines are based on national average consumption rates of fish and shellfish and may not be realistic limits for coastal populations.

To help identify the most important chemical pollutants, the Environmental Protection Agency (EPA) has established a list of 129 priority pollutants (Appendix II) on the basis of toxicity, persistence in the environment, potential to bioaccumulate and amount of industrial production and discharge. Although a useful tool on a nation-wide level, the list may not reflect the importance of different chemical contaminants on a regional level. In the Northwest, the wood products industry has historically been a significant source of water pollution, whereas the steel industry has not been particularly important in comparison to the Midwest. As a result, many contaminants on the EPA priority list may not be of concern locally. Conversely, there may be contaminants of major concern in Puget Sound that are not on the EPA list.

---

*carcinogenic - causes cancer
mutagenic - causes genetic mutations
teratogenic - causes birth defects

An attempt to remedy this discrepancy has been made in the Puget Sound area (Konasewich, et al, 1982). All of the chemical contaminants detected in the Puget Sound marine environment have been ranked on the basis of their potential toxicity, presence and distribution in the water, sediment or biota. Class 1 contaminants are those judged to be "critical and of concern" in Puget Sound (Appendix III).

From a human health perspective, the direct concern is with the levels of chemical contaminants in the edible biota of Puget Sound. Although a large amount of data is available on the levels of chemical contaminants found in Puget Sound water, sediment and various plants and animals, very little data are currently available on the levels of contaminants in the muscle tissue of commonly consumed fish or shellfish in Puget Sound. The livers of English sole have been analyzed by numerous researchers. English sole is a common and widely distributed fish in Puget Sound, is relatively resident in a particular area or bay and lives and feeds in direct contact with the sediment. Since most chemical contaminants tend to settle in the sediments of industrial bays, English sole are one of the most likely fish to show any adverse effects of marine pollution. The liver is the tissue that has been most often analyzed for chemical contaminants because the liver is most likely to have the highest levels of contaminants. English sole are therefore useful indicators of marine pollution accumulating in the biota. Since few people consume English sole livers, the specific values for levels of contaminants in the liver are not directly useful for the assessment of human exposure to Puget Sound marine contaminants, although for some chemicals the levels in the muscle and liver may be correlated. The few studies that have included chemical analysis of muscle tissue in commonly consumed fish have often analyzed only one or two individuals of a particular species, and the results have varied too widely to be conclusive. Soft organ tissues of other marine organisms such as crab, clams and oysters are often consumed, but again, little data is available. In addition, no research has been done on cooked seafood in Puget Sound. Some contaminants may be relatively unchanged by various cooking processes, but others may be significantly lost or transformed.

The following section is an attempt to summarize the existing information on the levels and potential health impacts of chemical contaminants found in the muscle tissue of sport-caught seafood in urban bays of Puget Sound. Squid and salmon, although important sport species, have been omitted due to their highly migratory nature and lack of contact with potentially toxic sediments. A general summary of the major types of potentially toxic chemical contaminants found in Puget Sound is presented (Konasewich, et al, 1982. Class 1 contaminants). These include the inorganic trace metals, the pesticide DDT, polychlorinated biphenyls (PCBs), monocyclic aromatic hydrocarbons (MAHs), polynuclear aromatic hydrocarbons (PAHs), phthalate esters, halogenated aliphatic hydrocarbons (including CBDs) and polychlorinated dibenzofurans (PCDFs). Information on the contaminant's or group of contaminant's chemical properties, sources, mechanisms and potential for bioaccumulation and human toxicity is included. The trace metals, arsenic, cadmium, copper, lead, mercury, silver and selenium, are discussed individually because the levels found in the Puget

Sound marine environment and human toxicity have been researched extensively. The concentrations and health effects of PCBs and DDT are also comparatively well established. The concentrations and health impacts of the remaining groups of organic industrial pollutants is sketchy and incomplete. These contaminants are discussed by general group.

The technological ability to detect many of these organic contaminants at very low levels has only recently been developed. As a result, there has been an influx of reports on these previously undetected organic contaminants (Malins, 1980, 1982. Gahler, 1982. DOE, 1982). Many of these compounds have been identified, but many have not. Most have been detected at very low levels, however, information on human toxicity, with a few exceptions, is virtually nonexistent.

Table 1 and 2 present the concentrations of PCBs, DDT and the metals, arsenic, cadmium, copper, lead, mercury, silver and selenium, found in muscle tissue of the species of seafood commonly caught and consumed in the urban areas covered in this survey (Everett Harbor, Elliot Bay, Sinclair Inlet). The chemical data have been gathered from several Puget Sound studies. For each study, average values for a particular bay or area and species were calculated. If data are available from more than one study, the highest average value was shown in the tables.

For many species chemical data do not presently exist. In other cases data are available from only one study which may have analyzed only a few samples. Values given simply represent the present state of knowledge and are not conclusive.

Table 3 list levels of the other organic contaminants which have been detected at quantifiable levels in fish muscle tissue in Puget Sound.

Arsenic

Arsenic is used in a wide variety of industrial products such as pesticides, wood preservatives and drugs. It is also a by-product of coal smelting. Most of the arsenic in the environment comes from natural sources. The weathering of rocks and soils releases arsenic which is ultimately deposited in Puget Sound by rivers and streams. The major industrial source of arsenic in Puget Sound is a copper smelter near Tacoma (ASARCO).

Arsenic is found in several different oxidation states and compounds, each with different properties and toxicities. Trivalent arsenic is more toxic than pentavalent arsenic. Arsenic can also be methylated by microorganisms in the sediment. Methylated arsenic is readily bioaccumulated, but is not significantly toxic. The arsine compounds are considered extremely toxic, but are also highly volatile.

Arsenic is not particularly water soluble and sediments are the primary sink for arsenic in the marine environment. Lower organisms, such as crustaceans and seaweeds, bioaccumulate arsenic more readily than fish. In fish, arsenic accumulation is primarily through water uptake, although uptake through food is of some importance.

Inhaled inorganic arsenic is a human carcinogen with a latent period of 10-30 years. Much of the arsenic absorbed from seafood is in protein-bound, non-toxic forms which are readily excreted, unchanged, by humans.

Cadmium

Cadmium is another metal which occurs naturally in the environment. Cadmium enters Puget Sound from natural river sources, and as by-products of ore smelting, electro-plating and the manufacture of paint, varnish, batteries, plastics, fungicides, fertilizers, tires and motor oil.

Cadmium is water soluble and easily transported throughout the marine environment. Cadmium is strongly bioaccumulated in the biota. Uptake is through water and elimination is slow. Methylated forms are not known to occur.

Cadmium has been classified as a suspect human carcinogen and definitely a human teratogen. The FDA guideline for edible fish and shellfish is *0.5 ppm.

*ppm = microgram/gram or milligram/kilogram

Copper

Copper is a metal which seems to be essential for some marine organisms, such as crab and seaweeds. Natural sources, such as rivers and erosion, contribute most of the copper to Puget Sound. Industrial sources are ore smelting, antifouling paints, municipal effluents and various other industrial discharges.

Copper is strongly adsorbed to the sediments and suspended particulate matter. Invertebrates bioaccumulate copper to a greater extent than fish. Copper is not biomagnified in the food chain. Food is the most important route of uptake for the biota, although uptake from water does occur.

Although copper is an essential element for some organisms, it is highly toxic at elevated levels. The toxic effects vary depending on the species' sensitivity and the chemical form of the copper contaminant. Human toxicity is not well established, but copper is not known to be a human carcinogen.

Lead

Lead has been found in relatively high concentrations in Puget Sound sediments compared to other metals. The highest levels have been reported in Seattle's Duwamish waterway and Tacoma's Sitcum waterway. Lead enters Puget Sound through natural erosion of geologic materials. Other sources are the use of leaded gasoline in automobiles, ore smelting, municipal sewage discharge, urban run-off and the manufacture of paint and batteries.

As with other metals, chemical speciation of lead determines toxicity and fate in the environment. Methylation by microorganisms is known to occur in freshwater sediments, but is questionable for marine sediments. Tetramethyl and tetraethyl lead are probably more toxic and more volatile than inorganic forms of lead. Sediments are the primary sink for lead in Puget Sound. Lead tends to accumulate to a greater extent in shellfish than in fish. Biomagnification through the food chain has not been demonstrated.

Data on toxicity of lead to saltwater organisms is very limited. In humans, lead has diverse biological effects. High doses interfere with blood synthesis, kidney function, reproduction and the nervous system. The chronic, low level effects of lead exposure in humans is not clear. Most lead is deposited in the bones, its concentration increasing with age. Lead compounds have teratogenic and carcinogenic effects in rats. The FDA administrative guideline for lead in fish and shellfish is 7 ppm.

Silver

Sources of silver in Puget Sound are both natural and industrial. Industrial sources include electro-plating, production of photographic materials, jewelry, mirrors, dental alloys and paints. The highest levels in Puget Sound biota have been found in Sinclair Inlet (Bremerton) and Case Inlet.

Silver occurs in different chemical forms which determine its potential to adversely affect living organisms. Silver is mostly bound to the sediments, but bioaccumulation is mainly from water intake and not through diet. Depuration (elimination) from the biota is slow.

Silver is highly toxic to marine organisms at low concentrations. Animal carcinogenicity is uncertain.

Selenium

Natural sources of selenium include volcanic activity, plants, animals and soils. The smelting of copper, lead and zinc is the major industrial source of selenium. Selenium is an essential trace element for many animals.

Chemical speciation of selenium is important in assessing toxicity and bioaccumulation. The selenite form of selenium is particularly prone to bioaccumulate. Diet is the primary source of selenium uptake in marine organisms. Bacteria also produce methylated forms of selenium in the sediments, although the toxicity of methylated forms is not known.

Selenium deficient diets produce various symptoms in rats, chickens, calves and pigs. However, high doses of selenium are toxic to animals. Selenium is teratogenic, although carcinogenicity has not been determined. There is evidence that selenium may detoxify the effects of other metals such as mercury and arsenic.

Mercury

Natural sources of mercury are volcanism and erosion of natural mercury deposits in rocks and soil. Historically, the major industrial sources of mercury in Puget Sound were a pulp and paper mill in Bellingham Bay and the Seattle METRO sewage plant prior to 1973. Other sources include a variety of manufacturing processes such as the production of vinyl chloride and fungicides used to treat grain.

Mercury occurs in many chemical forms, of which methylmercury is the most toxic. Mercury is primarily found in the sediments of Puget Sound, where microorganisms can convert inorganic forms to the more toxic methylmercury form. Mercury is bioaccumulated through food and water uptake, and biomagnified through the food chain. High concentrations of mercury are particularly found in long-lived predatory fish such as sharks and tuna.

Mercury is one of the most toxic metals, affecting the brain and nervous system in animals. The FDA guideline for edible fish is 1.0 ppm.

Dichloro-diphenyl-trichloroethane (DDT)

DDT is an insecticide. The manufacture and use of DDT, except in special situations, has been banned in the United States since 1972, but levels of DDT in the environment have remained elevated. The highest concentrations of DDT in Puget Sound have been found in Elliot Bay and Commencement Bay, but their exact source is unknown.

DDT and its metabolites, DDD and DDE, are very persistent, stable compounds in the environment. DDT is insoluble in water and has a strong tendency to accumulate in the sediments. DDT is accumulated in fish through water uptake and is stored in the fatty tissues. DDT is not biomagnified in the aquatic food chain.

DDT poses a greater risk to wildlife and the ecosystem than to human health. The most renowned toxic effect of DDT on wildlife is eggshell thinning in fish-eating birds such as cranes and herons. DDT has also produced malignant tumors in laboratory mice, but DDT is not considered to be a serious threat to human health based on epidemiological and occupational exposure studies. The FDA guideline for DDT in edible fish is 5 ppm.

Polychlorinated biphenyls (PCBs)

PCBs are very stable, man-made compounds which have been detected in the environment on a world-wide basis. Although no longer manufactured in the United States since 1976, the Monsanto Company, at one time, produced approximately 100 different PCBs compounds which differ in the percent of chlorine atoms and have different chemical properties. PCBs, because of their thermal stability, were manufactured as insulating fluids for transformers, heat exchangers and hydraulic systems. Leaks and spills from these sources contribute to environmental contamination.

Because of low water solubility, PCBs are bound to the sediments and are bioaccumulated in the fatty tissues of marine organisms. Uptake is through water in fish and invertebrates, but more through dietary sources in higher organisms such as mammals. PCBs are biomagnified through the food chain.

Studies on laboratory animals have demonstrated a wide variety of adverse effects from PCB exposure. There is particular concern for the effects of PCBs on fish eating birds and mammals in Puget Sound, such as the harbor seal and blue heron. Animal experiments and human epidemiological studies have concluded that PCBs or impurities in the PCB mixtures are carcinogenic. The FDA has set the maximum allowable concentration of PCBs in edible fish at 2 ppm.

Phthalate esters

Phthalate esters are primarily used in the production of polyvinyl chloride (PVC), and also in the production of paper.

Relatively little is known about the phthalate esters as pollutants. About five different phthalate ester compounds have been detected in Elliot Bay and Commencement Bay biota.

Phthalate esters adhere to the sediment and are lipophilic (fat soluble). Phthalate esters tend to accumulate in the biota, but depuration (elimination) is fairly rapid. Biomagnification does not occur. Microorganisms are able to degrade phthalate esters and fish are able to metabolize phthalate esters to apparently non-toxic compounds. The rates of these processes are largely unknown.

There is evidence that phthalate esters are toxic to marine organisms, particularly invertebrates. Phthalate esters have not been shown to be carcinogenic.

Polychlorinated dibenzofurans (PCDFs)

PCDFs are mainly by-products of the manufacture or burning of PCBs and pentachlorophenol. Pentachlorophenol is a wood preservative that is widely used in the wood industry in Puget Sound and is manufactured in Tacoma.

Little research has been done on PCDFs in Puget Sound. The highest levels have been found in Commencement Bay sediments.

PCDFs adhere to the sediments and are lipophilic. Based on their similarity in structure to better known compounds, it is surmised that PCDFs are not likely to be biodegraded by microorganisms, but bioaccumulation is expected. There is indication that higher organisms can depurate PCDFs rapidly.

PCDFs are highly toxic to birds and mammals. Little is known about toxicity to marine organisms or humans.

Halogenated aliphatic hydrocarbons

As a group, the halogenated aliphatics readily volatilize (evaporate) and are not considered major pollutants. Two groups of compounds within the halogenated aliphatics are considered to be significant pollutants in Puget Sound: the chlorinated butadienes (CBDs) and chlorinated ethylenes.

Of the chlorinated butadienes, hexachlorobutadiene (HCBD) has received particular attention in Puget Sound. Hexachlorobutadiene is a by-product of the production of other chemicals such as hexachlorobenzene and trichloroethylene, which are also contaminants of concern in Puget Sound. Elevated levels have been found in the sediments and biota of Commencement Bay. HCBD adheres to the sediment and tends to bioaccumulate. Little is known about biological uptake or biometabolism.

HCBD is carcinogenic in laboratory animals. Human carcinogenicity is not established.

The chlorinated ethylenes have been detected in the sediments and biota of Tacoma's Hylebos waterway. The compounds, di- and trichloroethylene are considered to be a particular concern in Puget Sound. Dichloroethylene is used in the production of plastic packaging (Saran wrap) and as a coating on the inside of storage tanks. Trichloroethylene is mainly used as a grease solvent in the metal industry, as a paint solvent and in the decaffeination of coffee. Chlorinated ethylenes can also be formed when organic compounds combine with the chlorine used to purify drinking water. Chlorinated ethylenes are water soluble, but little is known about biological uptake, accumulation or metabolism. Dichloroethylene is a potential carcinogen based on occupational exposure studies.

Monocyclic aromatic hydrocarbons (MAHs)

MAHs are cyclic (aromatic) compounds in structure, consisting of one ring as opposed to the straight chain or multi-ring structure of other organic compounds. Highest levels of MAHs have been found in Commencement Bay.

The non-chlorinated MAHs , such as benzene, toluene and phenol, are relatively volatile, susceptible to biodegradation and are not significantly bioaccumulated. The chlorinated MAHs , particularly hexachlorobenzene, are of particular concern as pollutants. Hexachlorobenzene is used as an agricultural fungicide and is also a by-product of the production of other chlorinated chemical compounds and chlorine gas. Hexachlorobenzene adsorbs to the sediments, has low solubility in water, an affinity for lipids and is resistant to microbial degradation. Hexachlorobenzene accumulates in the biota, but is probably not biomagnified. Uptake of hexachlorobenzene by marine organisms is through water rather than food.

Hexachlorobenzene is an animal carcinogen.

Polynuclear aromatic hydrocarbons (PAHs or PNAs)

PAHs are cyclic compounds similar to MAHs, but PAHs consist of more than one ring (2-6). PAHs are ubiquitous in the environment. The combustion of coal, oil, wood, gas and other organic compounds produces PAHs. Petroleum products, such as creosote and road tar, contribute PAHs directly to the environment through leaching and runoff. Humans are continually exposed to PAHs found in cigarette smoke, auto exhaust, smoked fish, broiled hamburgers and alcoholic beverages. In Puget Sound, the highest levels of PAHs have been found in Elliot Bay, Commencement Bay and Eagle Harbor (Bainbridge Island).

PAHs are relatively insoluble in water, adhere to the sediments and accumulate in the biota. PAHs are also biodegraded by microorganisms and rapidly metabolized by fish and most invertebrates. The breakdown products (metabolites) may have equal or greater potential as carcinogens than the parent compound. Bivalves (clams) and crabs accumulate PAHs more than fish. This difference is attributed to a less active, or more selective, metabolic system in bivalves. Little is known about biological uptake mechanisms. The heavier weight, 4-6 ring PAH compounds, such as benzo(a)anthracene, benzo(a)pyrene and flouranthenes, the chlorinated and bromonaphthalenes are considered to be of particular concern as pollutants. These PAH compounds tend to be more toxic and more persistent in the sediments and biota than other PAHs.

Many PAHs are recognized as potent carcinogens.

Table 5. Metal Concentrations (ppm, wet weight) in Muscle Tissue of Commonly Caught Bottomfish and Shellfish in Puget Sound

	# Fish	Arsenic	Cadmium	Copper	Lead	Mercury	Selenium	Silver
USFDA Guidelines			0.5ppm		7.0ppm	1.0ppm		
Cod 2**								
Pacific cod	(3)	2.5	0	0.4	0.4	0.06	0	0
Pacific hake	(10)	0.6	0	0.4	0.4	0.06	0	0
Walleye pollock	(15)	1.7	0	0.7	0.5	0.08	0	0
Tomcod	(3)	0.7	0	0.5	0.5	0	0	0
Sablefish								
Perch[4,5]								
Striped perch	(3)	0.2	0.03	2.2	1.5			<0.03
Pile perch	(?)	0.8	0.1	3.7	<2.0			
Rockfish[4,5]								
Copper rockfish	(5)	1.1	0.08	3.4	2.5			<0.03
Brown rockfish								
Quillback rockfish								
Flatfish[2,6]								
Rock sole	(4-6)	0.7	0.03	0.8	0.8	0.05		0.004
English sole	(4-16)	3.4	0.04	0.7	1.3	0.30	0	0.007
Crab[2]								
Dungeness crab	(4)	4.3	0	13.9	0.8	0.08	0.19	0.3
Red rock crab								
Clams[1]								
Butter clams	(120)	2.2	0.24	3.8	1.2	0.02	0.04	
Littleneck clams	(240)	1.3	0.51	1.4	1.4	0.01	<0.63	
Manila clams	(240)	0.9	0.43	1.8	1.5	0.02	0.14	

*FDA guidelines based on national average intake of fish and shellfish

*Source of chemical data (page 49). If data are available from more than one study or from more than one bay within a study, the highest average concentration is shown

Table 6 PCB and DDT Concentrations (ppm, wet weight) in Muscle Tissue of Commonly Caught Bottomfish and Shellfish in Puget Sound

	# fish	PCBs	DDT, DDE, DDD
*USFDA Guidelines		2.0 ppm	5.0 ppm
Cod[2]**			
Pacific cod	(3-9)	0.04	0.007
Pacific hake	(10)	0.07	0.007
Walleye pollock	(15)	0.08	0.015
Tomcod	(3)	0.03	0.002
Sablefish			
Perch			
Striped perch			
Pile perch			
Rockfish			
Copper rockfish			
Brown rockfish			
Quillback rockfish			
Flatfish[2,3,6]			
Rock sole	(4-6)	0.07	0.005
English sole	(4-16)	1.03	0.013
Crab[2]			
Dungeness crab	(4)	0.06	0.004
Red rock crab			
Clams[1]			
Butter clams			
Littleneck clams			
Manila clams	(240)	0.055	

*FDA guidelines based on national average intake of fish and shellfish.
**Source of chemical data (page 49). If data is available from more than one study or from more than one bay or area within a study, the higest average concentration is shown.

Sources of Chemical Data (footnotes from Tables 5,6)

1. Cummins, et al. 1976. Chemical and biological survey of Liberty Bay, Washington. EPA 190/9-76-029. U.S. Environmental Protection Agency.

2. Gahler, et al. 1982. Chemical contaminants in edible, non-salmonid fish and crabs from Commencement Bay, Washington. EPA-910/9-82-093. U.S. Environmental Protection Agency.

3. Malins, et al. 1982. Chemical contaminants and abnormalities in fish and vertebrates from Puget Sound. NOAA Tech. Memo. OMPA-19. National Oceanic and Atmospheric Administration.

4. Washington State Dept. of Ecology. 1979. Memorandum dated April 19, 1979 from Greg Cloud to Rick Pierce. ASARCO Class II survey, September, 1978.

5. Washington State Dept. of Ecology. 1981. Memorandum dated December 7, 1981 from Marc Heffner to Rick Pierce. ASARCO Class II survey, February, 1981.

6. Washington State Dept. of Ecology. 1982. Memorandum dated November 10, 1982 from Dick Cunningham to Dr. Claris Hyatt. Assessment of toxic pollutants in English sole and rock sole: Everett Harbor and Port Gardner, Oct., 1982.

Other Reference

Konasewich, et al. 1982. Effects, pathways, processes, and transformation of Puget Sound contaminants of concern. NOAA Tech. Memo. OMPA-20. National Oceanic and Atmospheric Administration.

Table 7

Other Organic Contaminants
Quantified in Fish Muscle Tissue
in
Puget Sound

	**fish muscle ppm wet weight
Polynuclear Aromatic Hydrocarbons (PAHs)	
flourene	0.002
*naphthalene	0.510
*tetrachloroethylene	0.033
*trichloroethylene	0.043
Monocyclic Aromatic Hydrocarbons (MAHs)	
*hexachlorobenzene	0.048
phenol	0.082
ethylbenzene	0.01
toluene	0.02
Phthalate Esters	
*bis(2-ethylhexyl)phthalate	0.140
*diethyl phthalate	0.056
*di-n-butyl phthalate	0.384
*butyl benzyl phthalate	0.220
*dimethyl phthalate	0.008
Halogenated Aliphatic Hydrocarbons	
1,1,1 trichloroethane	0.04
*1.2 trans-dichloroethylene	0.01
methylene chloride	0.32
Nitrosamines	
n-nitrosodiphenylamine	0.064

*Class 1 contaminants (Konasewich, et al. 1982) "critical and of concern"

**Average of samples with quantifiable values. Many samples had conc. of contaminants that were too low to quantify or that were not detectable.

NOTE: Many other organic contaminants have been detected in the sediments or fish liver tissue in Puget Sound, and at higher levels. This table only lists those chemicals (other than PCBs, DDT and trace metals) found in fish muscle tissue at quantifiable levels.

Table 7 continued

Sources of Chemical Data:

Gahler, 1982. EPA. Commencement Bay, Discovery Bay
fish analyzed - bottom, off-bottom, and
mixed fish.

DOE, 1982. Everett Harbor, Gedney(Hat) Island
fish analyzed - english sole and rock sole

SUMMARY AND CONCLUSIONS

The Puget Sound Catch and Consumption Survey was undertaken to estimate the number of people fishing in or near the more heavily polluted urban bays of Puget Sound. The survey was motivated by National Marine Fisheries Service studies which showed an excess of liver abnormalities among English sole caught close to urban areas.

The health significance of the tissue pathology findings is unclear. Chemical analyses of some resident (non-migratory) fish species showed higher contaminant levels in fish caught near urban bays than in fish taken from relatively less polluted bays. Although none of the chemical levels violated standards set by either the U.S. Food and Drug Administration or the U.S. Department of Agriculture, for many chemicals no relevant standards could be found. Also, if people were continuously exposed to elevated levels of toxic chemicals, the total dose may exceed safe levels even though the contaminant concentration remained below the Federal standards. In particular, concerns were voiced that many people fished daily and that the catch accounted for a substantial portion of their total diet. There were special concerns for immigrants, who may be forced to rely on fishing for sustenance due to economic hardships and who may have no alternative but to fish close to the urban areas where they reside. These people, if they behave as assumed above, could have an excess theoretical risk of health effects if they consumed primarily the more heavily contaminated bottomfish.

Three urban bays were chosen to be surveyed. These included Seattle's Elliot Bay, Everett's Port Gardner Bay and Sinclair Inlet, near Bremerton and Port Orchard. Tacoma's Commencement Bay had been previously surveyed by the Pierce County Health Department. Several other bays were temporarily surveyed, including Bellingham Bay, Liberty Bay, Eagle Harbor, Dugalla Bay, Holmes Harbor and harbors adjacent at Olympia, Aberdeen, Hoquiam, Shelton, Port Angles and Port Townsend. In none of these areas was there sufficient fishing to justify survey coverage.

A total of 1568 interviews were completed (702 in Elliot Bay, 641 in Port Gardner Bay and 225 in Sinclair Inlet). Twenty-six percent were repeat interviews of anglers previously surveyed. Only 49% of the anglers were Caucasian while 39% were Asian. Eleven percent of the anglers were from either Vietnam or Laos. Port Gardner Bay had the largest number of Southeast Asian anglers. Twenty-six percent of the interviewees were females.

Although the species composition of fish caught varied from bay to bay, the primary species caught include Dungeness and rock crab, pile perch, striped perch, Pacific cod, walleye pollock, and sablefish. English sole, the fish showing the high prevalence of liver abnormalities, accounted for only .25% of the fish and crab caught (5 fish out of 1927 fish and crab examined). Considering all sole and other flatfish as a group, only 103 were caught by the anglers surveyed. This accounted for 5% of the total catch (fish and crab combined) and less than 5% of the total edible tissue.

In response to what parts of the fish were consumed, the majority (74%) of anglers replied that they ate only the muscle tissue. Twenty percent reported eating the skin and 6% ate other parts. Less than 1% reported eating the internal organs. All but 3 anglers reporting eating cooked fish, with the vast majority frying their catch. No one reported eating uncooked crab.

One quarter of the anglers accounted for all of fish caught. Forty percent of the anglers had at least one crab. An even smaller percentage of anglers accounted for most of the fish and crab catch. Only 12% of the anglers had more than two fish and less than 25% had more than two crab.

Repeat interview data suggest that anglers who fish the most often also catch the most fish per trip. These anglers concentrate primarily on the larger migratory fish (e.g. cod and sablefish). The theoretically more contaminated and less abundant flatfish are taken by the less experienced, occasional fisherman. Thus the concerns about repeated and excessive consumption of bottomfish by a small number of anglers seems to be unjustified.

Clamming is a seasonal activity limited by the availability of low tides during daylight hours. Better tides during daylight occur primarily in the summer months. These factors and the shortage of good clamming beaches near urban areas limit exposure potential.

Recommendations

This study did not detect a population of anglers with excessive exposure to contaminated bottomfish. Both Asian and Caucasian anglers concentrated on the same species. There is no evidence that the more contaminated internal organs are consumed by a significant number of people.

Several unanswered question remain. All chemical analysis has examined raw rather than cooked tissue. Since virtually no anglers consume raw fish and since cooking can dramatically change (reduce) the concentration of many organic contaminants, the analysis of raw fish can potentially bias the estimated health risks.

Analysis has also given priority to the determination of chemical levels in the fish entrails. Survey results indicate that few anglers consume the entrails. Perhaps more emphasis should be placed on chemical contaminants associated with the fish head and the skin since these parts are often consumed.

Both EPA and NOAA analyses have focussed on English sole. Although this species may be a useful indicator of environmental damage, it is not a good indicator of human health risk. English sole accounts for much less than 1% of all fish consumed. More emphasis should be placed on examining the fish, crab and clam species which are commonly consumed. Special emphasis should be given to examining chemical contaminants of the commonly consumed Dungeness and rock crab. Both these species are intimately exposed to sediment contamination. Crabs lack the necessary enzymes to metabolize or excrete many contaminants and may therefore concentrate the contaminants in their edible tissue.

Appendix I

U.S.F.D.A. - "Administrative Guidelines" (Action Levels)*: Edible tissue, concentrations in ppm, wet-weight basis.

Substance	"Administrative Guidelines" Fish	Shellfish	Notes
Total PCBs	2.0		This value is in Federal Register as a regulation.
Total Heptachlor and Heptachlor epoxide	0.3	0.3	Concentration of individual compounds must be ≥ 0.02 ppm to be included in total.
Endrin	0.3	0.3	
Aldrin	0.3	0.3	
Dieldrin	0.3	0.3	
Total Toxaphene	5.0		Includes all isomers of toxaphene.
Mirex	0.1		
Chlordecone (Kepone)	0.3	0.3	Shellfish value includes only crabs and oysters.
Total Chlordane	0.3		Includes cis and trans chlordane; cis and trans nonachlor; oxychlordane (octachlorepoxide); α, β, and γ chlordene and chlordene. Concentrations of individual compounds must be ≥ 0.02 ppm to be included in total.
DDT and analogues	5.0		Includes DDT, DDE, & DDD (TDE). Individual compounds must be ≥ 0.2 ppm to be included in total.
Total BHC	0.1	0.1	α, γ, and Δ forms must be ≥ 0.02 ppm, β form ≥ 0.04 ppm to be included in total.
Mercury	1.0		
Cadmium	(0.5)	(0.5)	This is an "unofficial guideline" adopted from other types of food.
Lead	(7.0)	(7.0)	This is an "unofficial guideline" adopted from other types of food.

*Unless otherwise noted, these are concentrations which, when exceeded, trigger FDA to consider action to remove commercial foods from distribution. They are administrative and (unless noted) not coded into law.

( ) = "Unofficial guideline."

Appendix II

List of USEPA priority pollutants.

COMPOUND NAME

1. *acenaphthene
2. *acrolein
3. *acrylonitrile
4. *benzene
5. *benzidine
6. *carbon tetrachloride (tetrachloromethane)

*chlorinated benzenes (other than dichlorobenzenes)

7. chlorobenzene
8. 1,2,4-trichlorobenzene
9. hexachlorobenzene

*chlorinated ethanes (including 1,2-dichloroethane, 1,1,1-trichloroethane and hexachloroethane)

10. 1,2-dichloroethane
11. 1,1,1-trichloroethane
12. hexachloroethane
13. 1,1-dichloroethane
14. 1,1,2-trichloroethane
15. 1,1,2,2-tetrachloroethane
16. chloroethane

*chloroalkyl ethers (chloromethyl, chloroethyl and mixed ethers)

17. bis(chloromethyl) ether
18. bis(2-chloroethyl) ether
19. 2-chloroethyl vinyl ether (mixed)

*chlorinated naphthalene

20. 2-chloronaphthalene

*chlorinated phenols (other than those listed elsewhere; includes trichlorophenols and chlorinated cresols)

21. 2,4,6-trichlorophenol
22. parachlorometa cresol
23. *chloroform (trichloromethane)
24. *2-chlorophenol

*dichlorobenzenes

25. 1,2-dichlorobenzene
26. 1,3-dichlorobenzene
27. 1,4-dichlorobenzene

*dichlorobenzidine

28. 3,3'-dichlorobenzidine

*dichloroethylenes (1,1-dichloroethylene and 1,2-dichloroethylene)

29. 1,1-dichloroethylene
30. 1,2-trans-dichloroethylene
31. *2,4-dichlorophenol

*dichloropropane and dichloropropene

32. 1,2-dichloropropane
33. 1,2-dichloropropylene (1,3-dichloropropene)
34. *2,4-dimethylphenol

*dinitrotoluene

35. 2,4-dinitrotoluene
36. 2,6-dinitrotoluene
37. *1,2-diphenylhydrazine
38. *ethylbenzene
39. *fluoranthene

*haloethers (other than those listed elsewhere)

40. 4-chlorophenyl phenyl ether
41. 4-bromophenyl phenyl ether
42. bis(2-chloroisopropyl) ether
43. bis(2-chloroethoxy) methane

*halomethanes (other than those listed elsewhere)

44. methylene chloride (dichloromethane)
45. methyl chloride (chloromethane)
46. methyl bromide (bromomethane)
47. bromoform (tribromomethane)
48. dichlorobromomethane
49. trichlorofluoromethane
50. dichlorodifluoromethane
51. chlorodibromomethane
52. *hexachlorobutadiene
53. *hexachlorocyclopentadiene
54. *isophorone
55. *naphthalene
56. *nitrobenzene

*nitrophenols (including 2,4-dinitrophenol and dinitrocresol)

57. 2-nitrophenol
58. 4-nitrophenol
59. *2,4-dinitrophenol
60. 4,6-dinitro-o-cresol

*nitrosamines

61. N-nitrosodimethylamine
62. N-nitrosodiphenylamine
63. N-nitrosodi-n-propylamine
64. *pentachlorophenol
65. *phenol

*phthalate esters

66. bis(2-ethylhexyl) phthalate
67. butyl benzyl phthalate
68. di-n-butyl phthalate
69. di-n-octyl phthalate
70. diethyl phthalate
71. dimethyl phthalate

*polynuclear aromatic hydrocarbons

72. benzo(a)anthracene (1,2-benzanthracene)
73. benzo(a)pyrene (3,4-benzopyrene)
74. 3,4-benzofluoranthene
75. benzo(k)fluoranthane (11,12-benzofluoranthene)
76. chrysene
77. acenaphthylene
78. anthracene
79. benzo(ghi)perylene (1,12-benzoperylene)
80. fluorene
81. phenanthrene
82. dibenzo(a,h)anthracene (1,2,5,6-dibenzanthracene)
83. indeno (1,2,3-cd)pyrene (2,3-o-phenylenepyrene)
84. pyrene
85. *tetrachloroethylene
86. *toluene
87. *trichloroethylene
88. *vinyl chloride (chloroethylene)

pesticides and metabolites

89. *aldrin
90. *dieldrin
91. *chlordane (technical mixture & metabolites)

*DDT and metabolites

92. 4,4'-DDT
93. 4,4'-DDE (p,p'-DDX)
94. 4,4'-DDD (p,p'-TDE)

*endosulfan and metabolites

95. a-endosulfan-Alpha
96. b-endosulfan-Beta
97. endosulfan sulfate

*endrin and metabolites

98. endrin
99. endrin aldehyde

*heptachlor and metabolites

100. heptachlor
101. heptachlor epoxide

*hexachlorocyclohexane (all isomers)

102. a-BHC-Alpha
103. b-BHC-Beta
104. r-BHC (lindane)-Gamma
105. g-BHC-Delta

*polychlorinated biphenyls (PCB's)

106. PCB-1242 (Arochlor 1242)
107. PCB-1254 (Arochlor 1254)
108. PCB-1221 (Arochlor 1221)
109. PCB-1232 (Arochlor 1232)
110. PCB-1248 (Arochlor 1248)
111. PCB-1260 (Arochlor 1260)
112. PCB-1016 (Arochlor 1016)
113. *toxaphene
114. *antimony (total)
115. *arsenic (total)
116. *asbestos (fibrous)
117. *beryllium (total)
118. *cadmium (total)
119. *chromium (total)
120. *copper (total)
121. *cyanide (total)
122. *lead (total)
123. *mercury (total)
124. *nickel (total)
125. *selenium (total)
126. *silver (total)
127. *thallium (total)
128. *zinc (total)
129. **2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD)

*Specific compounds and chemical classes as listed in the consent degree.

**This compound was specifically listed in the consent degree. Because of the extreme toxicity (TCDD), EPA recommends that laboratories not acquire analytical standard for this compound.

Appendix III

[1]Class 1 Contaminants

Chemicals Chosen to be of Concern in Puget Sound

1. DDT
   DDD
   DDE

2. Polychlorinated Biphenyls:
   - Chlorobiphenyl
   - Dichlorobiphenyl
   - Trichlorobiphenyl
   - Tetrachlorobiphenyl
   - Pentachlorobiphenyl
   - Hexachlorobiphenyl
   - Heptachlorobiphenyl
   - Octachlorobiphenyl
   - Nonachlorobiphenyl

3. Polychlorinated Dibenzofurans

4. Hexachlorobenzene (including other chlorinated benzenes)

5. Hexachlorobutadiene
   Pentachlorobutadiene
   Tetrachlorobutadiene
   Trichlorobutadiene

6. Dichloroethylene
   Trichloroethylene

7. Bis (2-ethylhexyl) phthalate
   Butylbenzyl phthalate
   Di-n-butyl phthalate
   Diethyl phthalate
   Dimethyl phthalate
   Di-n-octyl phthalate

8. Naphthalene
   - 1 methyl naphthalene
   - 2 methyl naphthalene
   - 1,3-dimethyl naphthalene
   - 2,3-dimethyl naphthalene
   - 2,6-dimethyl naphthalene
   - 2,3,5-trimethyl naphthalene
   - 2,3,6-trimethyl naphthalene
   - phenyl naphthalene

9. Benzo(a)Anthracene
   Dibenzanthracene
   Methyl (benzo(a)anthracene)

10. Fluoranthene
    - Benzo(b)fluoranthene
    - Benzo(g,h,i)fluoranthene
    - Benzo(i)fluoranthene
    - Methyl fluoranthene
    - Benzo(k)fluoranthene

11. Chlorinated naphthalene
12. Other halogenated polyaromatic hydrocarbons
13. Arsenic
14. Cadmium
15. Copper
16. Lead
17. Mercury
18. Selenium
19. Silver

[1]Konasewich, et al. 1982. Effects, pathways, processes, and transformation of Puget Sound contaminants of concern. NOAA Tech. Memo. OMPA-20. NOAA. U.S. Dept. of Commerce

Appendix IV

PUGET SOUND FISHERMAN AND SHELLFISH COLLECTOR SURVEY

Date:__/__/__ Time:__:__am/pm Surveyor: . . . .(_) Interview #____

Site: . . . .(_) Mode: 1. Dock 2. Beach 3. Bridge 4. . . . . (_)

Activity: 1. Fishing 2. Clamming 3. Crabbing 4. . . . . (_)

Race: . . . . (_) Sex: 1. Male 2. Female (_) Age: (__)

Interview Status: 1. Agree 2. Disagree 3. Language barrier 4. Previous interview (_)

Group type: 1. Alone 2. Family 3. Friends 4. Both (_) Size of group (__) Person #____

- -

What are you trying for? . . . .(_,_,_,_)

May I examine your catch? 1. Nothing caught 2. Yes 3. No 4. Not available (_)

Species	No.	Length or Total weight	Will eat?	Parts consumed*	Preparation method**
. . . .(_)	(_)	__________	. . . .(_)	. . . .(_)	. . . .(_)
. . . .(_)	(_)	__________	. . . .(_)	. . . .(_)	. . . .(_)
. . . .(_)	(_)	__________	. . . .(_)	. . . .(_)	. . . .(_)
. . . .(_)	(_)	__________	. . . .(_)	. . . .(_)	. . . .(_)
. . . .(_)	(_)	__________	. . . .(_)	. . . .(_)	. . . .(_)
. . . .(_)	(_)	__________	. . . .(_)	. . . .(_)	. . . .(_)
. . . .(_)	(_)	__________	. . . .(_)	. . . .(_)	. . . .(_)

- -

* 1. Entire 2. Muscle 3. Skin 4. Entrals 5. Broth 6. Other
** 1. Raw 2. Boiled 3. Baked 4. Fried 6. Other

- -

How often do you fish here? (___per week) (___per month) (___per year) (___1st X) (___2nd X)

When did you last use this area? (___days) How long were you out? (____hrs, ____min)

When did you last catch and eat something from this area? (____days)

	Species	No.	Species	No.	Species	No.
What did you get?	. . . .	(_)(_)	. . . .	(_)(_)	. . . .	(_)(_)

- -

How many people in your household eat seafood? (___)

City of residence: . . . . (___) Zip Code (_______)

How did you get here? 1. Car 2. City bus 3. Walked 4. Bicycle 5. . . . .(_)

Where were you born? . . . or. . . What is your native language? . . . .(_)

What time did you arrive? ___:___am/pm When will you leave? ___:___am/pm total hrs (__)

Appendix V. List of common and scientific names mentioned in the report.

COMMON NAME	SCIENTIFIC NAME
Gadoids	
Pacific cod	*Gadus macrocephalus*
Walleye pollock	*Theragra chalcogramma*
Pacific hake	*Merluccius productus*
Tomcod	*Microgadus proximus*
Sablefish	
Sablefish	*Anoplopoma fimbria*
Perch	
Striped perch	*Embiotoca lateralis*
Pile perch	*Rhacochilus vacca*
Shiner perch	*Cymatogaster aggregata*
Rockfish	
Brown rockfish	*Sebastes auriculatus*
Copper rockfish	*Sebastes caurinus*
Quillback rockfish	*Sebastes maliger*
Flatfish	
Rock sole	*Lepidopsetta bilineata*
English sole	*Parophrys vetulus*
Sand sole	*Psettichthys melanostictus*
Starry flounder	*Platichthys stellatus*
C-O sole	*Pleuronichthys coenosus*
Greenlings	
Kelp greenling	*Hexagrammes decagrammus*
Whitespotted greenling	*Hexagrammes stelleri*

Appendix V. (cont.)

COMMON NAME	SCIENTIFIC NAME
Sculpins	
Staghorn sculpin	*Leptocottus armatus*
Misc. bottomfish	
Spiny dogfish	*Squalus acanthius*
Wolf eel	*Anarrhichthys ocellatus*
Pacific mackeral	*Scomber japonicus*
Crab	
Dungeness crab	*Cancer magister*
Red rock crab	*Cancer productus*
Hardshell clams	
Butter clam	*Saxidomus giganteus*
Native littleneck	*Protothaca staminea*
Japanese littleneck	*Venerupis japonica*
Soft shell clam	*Mya arenaria*
Cockle	*Clinocardium nuttallii*
Horse clam	*Tresus nuttallii*, *Tresus capax*