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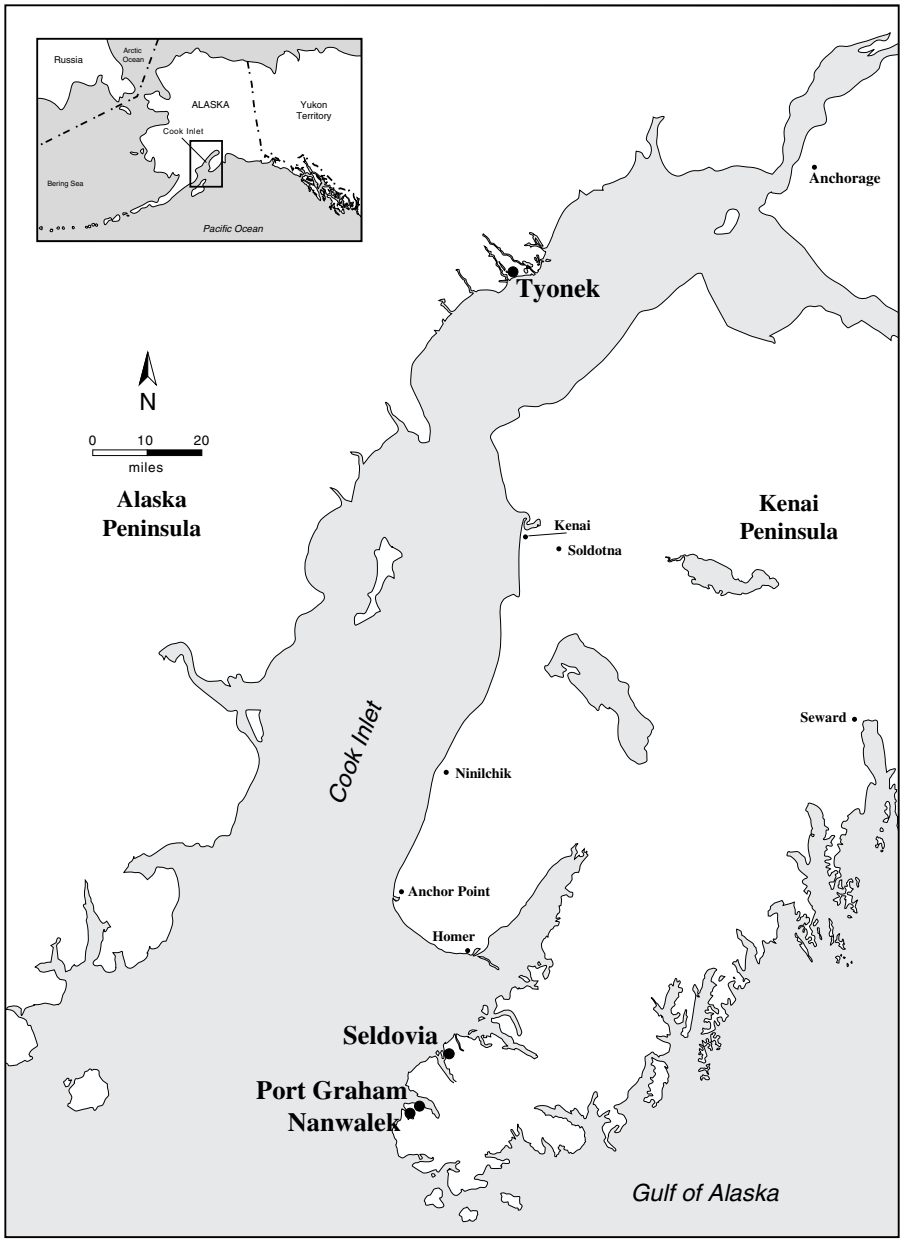
Office of Environmental Assessment

December 2003

Survey of Chemical Contaminants in Fish, Invertebrates and Plants Collected in the Vicinity of Tyonek, Seldovia, Port Graham and Nanwalek - Cook Inlet, AK



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Survey of Chemical Contaminants in Seafoods Collected in the Vicinity of Tyonek, Seldovia, Port Graham and Nanwalek in Cook Inlet, Alaska

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Prepared by

US Environmental Protection Agency
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This study was conducted by the U.S. Environmental Protection Agency (USEPA), Office of Water's Office of Science and Technology (OW-OST), through an InterAgency Agreement with the Department of Interior, Minerals Management Service (IAG No. DW14937850-01-0, May 1, 1997). The USEPA Work Assignment Manger for this study was Mr. Jeffrey Bigler. Sample collection for the study was conducted by Arthur D. Little, Inc. Representatives from the villages of Nanwalek, Port Graham, Seldovia, and Tyonek assisted in the study design and field collection activities. Laboratory oversight was provided by Ecology & Environment, Inc. Data QA review was provided by DynCorp. A draft risk assessment was prepared by EVS Environment Consultants (EVS) under contract to Tetra Tech, Inc. The EVS Project Manager for that project was Dr. Steve Ellis.

This study was designed and conducted because local Tribal residents in Kachemak Bay and Cook Inlet contested renewal of the oil and gas industry's NPDES discharge permit. The NPDES discharge permit allows the oil and gas industry in Cook Inlet a waiver to the national zero discharge law on the assumption that discharges have no adverse effect on traditionally harvested foods. The Kachmemak Bay and Cook Inlet Tribes worked very hard to get the attention of OW-OST, to make the study happen and to ensure that it was as meaningful as possible.

The current report which presents a summary of the data was prepared by Dr. Roseanne Lorenzana, D.V.M., Ph.D., EPA Region 10, Office of Environmental Assessment. Dr. Patricia Cirone provided editorial review.

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LIST OF ACRONYMS

ADFG	Alaska Department of Fish and Game
ADL	Arthur D. Little, Inc., Cambridge, Massachusetts
Axys	Axys Analytical Services, Inc.
DMA	dimethlyarsinic acid
EPA	US Environmental Protection Agency
OST	US Environmental Protection Agency, Office of Water, Office of Science and Technology
PAH	polycyclic aromatic hydrocarbon
PCBs	polychlorinated biphenyl
QA/QC	quality assurance and quality control
QAPP	quality assurance project plan
QL	quantification limit
USEPA	US Environmental Protection Agency

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EXECUTIVE SUMMARY

These data were collected by EPA Office of Water (OW), Office of Science and Technology with assistance from Port Graham and Nanwalek Tribal residents and professional staff. Field sampling was conducted between June 5 and July 24, 1997. This report is a summary of the data, only. For chemical concentrations which were detected, the average, maximum and minimum values are presented. The individual data on an accompanying compact disk (Appendix C).

A total of 81 tissue samples comprised of seven fish species, eight invertebrates and three plant species were sampled and analyzed for concentrations of 161 chemicals These results provide a good survey data set for environmental chemicals present in uncooked, whole body tissues samples of these Cook Inlet biota. There were detections of global contaminants: mercury, organochlorine pesticides, and PCB congeners. On the other hand, there was minimal detection of another ubiquitous contaminant group, dioxins and furans. In the 81 tissue samples analyzed for dioxin and furan congeners, only one type of dioxin, OCDD, was detected in one duplicate chinook salmon sample (13 ppt). Detectable concentrations of dioxins and furans were not found in other Cook Inlet tissue samples. The detection of many individual PAH compounds in the Cook Inlet tissue samples may have resulted from the use of very sensitive methods. Approximately one-half of the 104 individual PAHs were detected in fish, invertebrate and plant samples. Chinook tissue samples had the highest total average PAH concentration (253 ppb).

The biota species which were sampled, the size of the biota and the harvest locations were intended to represent those traditionally used by members of the four Alaskan tribal villages of Tyonek, Seldovia, Port Graham and Nanwalek. However, all possible harvest sites were not evaluated. And, not all fish, invertebrate and plant species consumed in a traditional diet were included in this survey. It is unlikely that this one-time sampling is representative of contaminant concentrations in these species over the entire lifetime of a human who consumes these species.

Whole-body samples such as these are representative of exposures to the biota, itself, or predators that consume the whole body. Combining several individuals into a single sample (composite sample) precluded the availability of chemical concentration data for individual fish, invertebrate or plant samples. These data contain no definitive information to distinguish wild versus hatchery or pen-raised fish.

The sensitivity of the analytical methods used in this study should be carefully considered when using these data. In some cases, the methods were more sensitive than data sets for other comparable fish samples (e.g. polycyclic aromatic hydrocarbons). But, there were also cases in which the methods were less sensitive than other data sets (e.g. dioxins and furans). Information on the sensitivity of method is provided in Appendix C.

Comparisons were made with market basket food contaminant data published elsewhere and with Columbia River (Washington, Oregon USA) fish contaminant data. With few exceptions, contaminant concentrations in Cook Inlet area species were similar or lower.

1.0 INTRODUCTION

In 1997, the US Environmental Protection Agency (USEPA) collected chemical contaminants in subsistence seafoods collected in the vicinity of four Alaskan tribal villages located along Cook Inlet, Alaska (Figure 1). There were tribal concerns regarding NPDES waste water discharge permit renewals for oil and gas industrial activities in Cook Inlet. Tribes in the four Alaskan tribal villages of Tyonek, Seldovia, Port Graham and Nanwalek were concerned about potential contaminants in their traditional foods. A copy of the tribal letter is provided in Appendix A.

Cook Inlet is a large tidal estuary in southeast Alaska that connects to the Gulf of Alaska. The inlet is approximately 280 km (174 mi) long and 20 to 90 km (12 to 56 mi) wide. Cook Inlet can be divided into three regions with distinct hydrodynamic characteristics: the head, consisting of the Knik and Turnagain Arms; upper Cook Inlet, extending from the West Forelands to Point Woronzof; and lower Cook Inlet, extending from West Forelands to the Gulf of Alaska (ADL 1998). The village of Tyonek is located along the northwest shore of upper Cook Inlet. The other three villages, Seldovia, Port Graham, and Nanwalek, are located along the southwest portion of the Kenai Peninsula in lower Cook Inlet (Figure 1). Coastal oil and gas activities within Cook Inlet are confined to the upper portions of the inlet, where a total of 15 multiwell platforms are located (Figure 1).

Thirteen of these platforms were productive as of March 1996. Together they produced 37,400 barrels of oil per day and 385,000,000 cubic feet of gas per day (USEPA 1996). Of the 13 active platforms, 5 separate and treat production fluids (oil, gas, and water) at the platform and discharge produced water directly to receiving waters within Cook Inlet. The remaining 8 platforms pipe the production fluids to three shore-based facilities— Granite Point, Trading Bay, and East Foreland—for separation and treatment. Produced water from the three shore-based facilities is discharged to Cook Inlet following treatment. Two of the facilities, Trading Bay and East Foreland, discharge the treated produced water directly from the facility, while the third facility, Granite Point, sends its treated produced water back to a platform for discharge (USEPA 1996). These three facilities treat and discharge 96 percent of the produced water generated from all platforms in Cook Inlet (USEPA 1996).

Approximate distances from the village to the shore-based facilities or production platforms range from 8 to 44 km (5 to 27 mi). The village of Tyonek is located closest to the oil and gas operations in Cook Inlet. Seldovia is 188 km (117 mi) from the closest platform. Nanwalek and Port Graham are the farthest from oil and gas operations at approximately 206 km (128 mi) from the nearest platform (Figure 1).

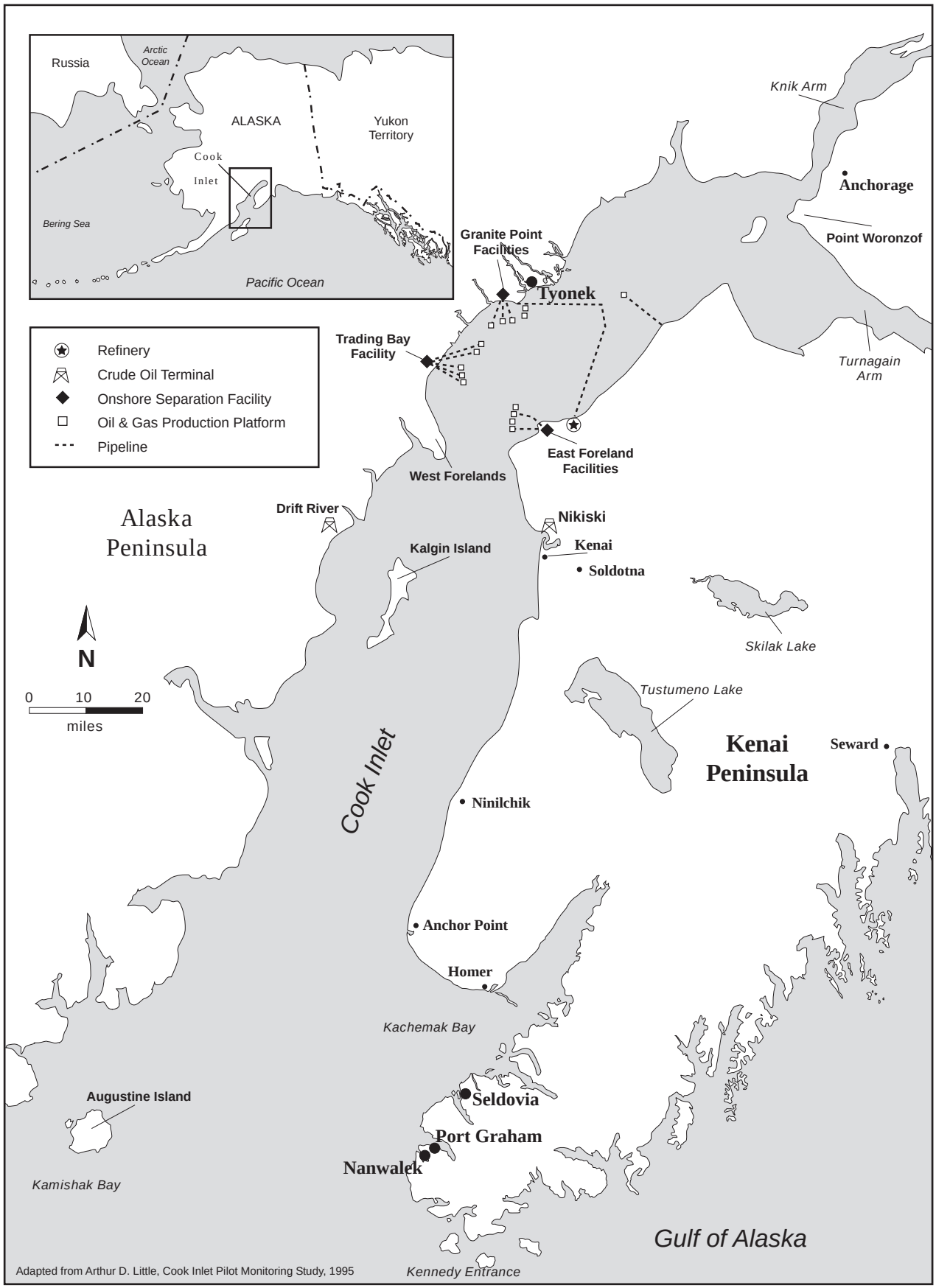

Figure 1. Four Native Alaskan villages and oil platforms in Cook Inlet

The aim of this study was to collect samples of fish, invertebrates, and marine plants commonly harvested by members of four Alaskan tribal villages and analyze for a large suite of chemicals to provide a recent data set. These data were collected by contractors for the EPA Office of Water (OW), Office of Science and Technology with assistance provided by the participating Tribes. Included in Appendices F through L are the Quality Assurance Project Plans, audit reports, data review narratives, sample identification information, sampling station locations and photographs of sampled species.

This report is a summary of the data, only. For chemical concentrations which were detected, the average, maximum and minimum values are presented with the expectation that these data may be used in future evaluations or other activities related to contaminants in Alaskan tribal traditional foods.

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2.0 MATERIALS and METHODS

The species analyzed include some of the resident and anadromous fish, marine invertebrates, and marine plants that are harvested by residents of the villages of Tyonek, Seldovia, Port Graham, and Nanwalek. Village representatives were consulted during the development of the study plan for advice regarding choice of species. Sampling sites were selected based on interviews with villagers. An area of collection was established for each village (Figure 2). The study plans developed by EPA are provided in Appendix F (ADL 1997). Listed in Table 1 are the number of samples and species that were collected within the study areas defined for each village. The study design shown in Table 1 differs slightly from the original study plan (Appendix F) and quality assurance project plan (QAPP; Appendix G). Modifications to the study design were primarily due to the inability to collect sufficient numbers of selected target species during field sampling. To characterize marine mammals, Beluga whales and harbor seals were supposed to be sampled. However, these samples were not collected because arrangements could not be made between the National Marine Fisheries Service and the village of Tyonek. Seals could not be sampled due to the lack of supervisory staff to oversee the sampling event (ADL 1998). By the time both issues had been resolved, the sampling period had passed (ADL 1998). A complete description of the field sampling efforts and the rationale for deviations from the original study plan are provided in Field Sampling Report for the Cook Inlet Contaminant Study (ADL 1998).

Field sampling was conducted between June 5 and July 24, 1997 (ADL 1998). Consistent with EPA guidance (USEPA 1995), samples were collected, prepared for shipment, and shipped to the designated laboratory. A detailed description of the actual field sampling activities is provided in the report titled Field Sampling Report for the Cook Inlet Contaminant Study (ADL 1998).

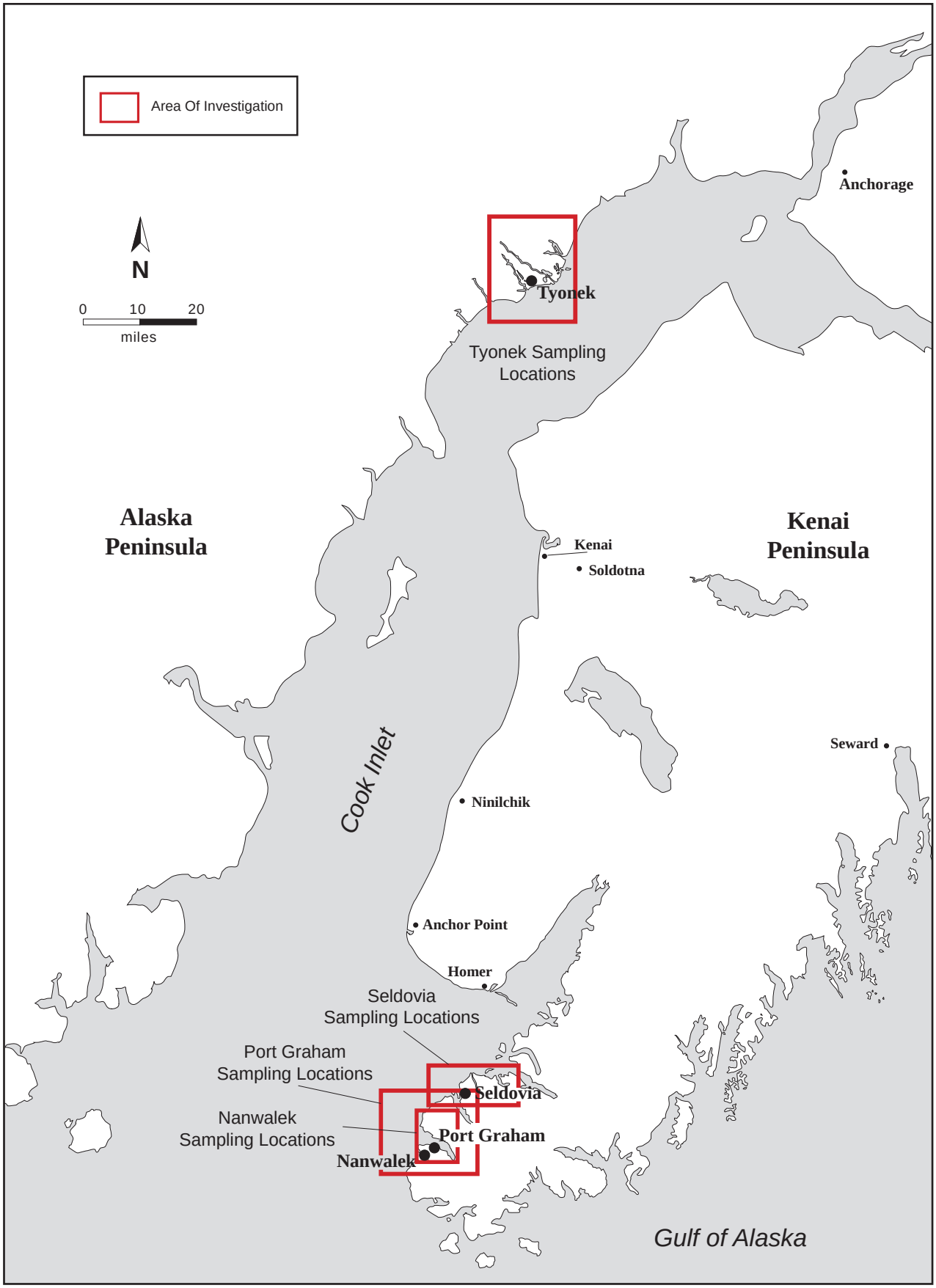

Figure 2. Areas of investigation

Table 1. Study Design

Village	Category	Species	Sample Type	Number of Composite Samples	Number of Individuals per Composite
Tyonek	Fish	Chinook salmon	Whole body	3	3, 4, 5
		Sockeye salmon	Whole body	3	5
Seldovia	Fish	Chinook salmon	Whole body	2	5
		Sockeye salmon	Whole body	3	5
		Halibut	Whole body	3	5
	Invertebrates	Blue mussel	Whole body	3	32, 35, 37
		Butter clam	Whole body	3	5
		Chiton	Whole body	3	>25
		Snail	Whole body	3	>50
Port Graham	Fish	Chinook salmon	Whole body	1	5
		Chum salmon	Whole body	2	2, 6
		Sea bass	Whole body	5	1, 2, 2, 5, 5
		Flounder	Whole body	3	2, 3, 10
	Invertebrates	Large clam	Whole body	3	5
		Steamer clam	Whole body	3	13, 15, 32
		Chiton	Whole body	3	30, 38, 45
		Octopus	Whole body	3	1
		Snail	Whole body	3	>50
	Plants	Goose tongue	Edible portion	3	~200–250
		Kelp	Edible portion	3	>50[a]
Nanwalek	Fish	Sockeye salmon	Whole body	3	5
		Cod	Whole body	3	5
		Halibut	Whole body	3	5
	Invertebrates	Mussel	Whole body	3	~50
		Chiton	Whole body	3	21, 21, 25
		Snail	Whole body	3	>50
	Plants	Goose tongue	Edible portion	3	~250
		Seaweed	Edible portion	3	~20

Source: ADL1998
a Also qualified as “a large section.”

Characteristics of the species collected during field sampling are listed in Table 2. Photographs were taken (see Appendix J) but samples were not identified by genus/species at the time of collection. Photographs were inadequate to later determine the genus/species of some of the categories named "mussel" and "large clam" at the time of collection. Therefore, the genus/species for "mussel" and "large clam" are shown on Table 2 as "not determined". The collection locations for all samples are provided in Appendices H and I.

The species collected at each location was based on consultations with the four villages. In Seldovia, the species collected were chinook salmon, sockeye salmon, halibut, butter clams, mussels, chitons, and snails. At Nanwalek, sockeye salmon, halibut, cod, mussel, snail, chiton, goose tongue, and seaweed were collected for analyses. At Port Graham, Chinook salmon, chum salmon, sea bass, flounder, chiton, octopus, snail, large clam, steamer clam, goose tongue, and kelp were collected. At Tyonek, chinook salmon and sockeye salmon were collected. No invertebrate or plant samples were collected in the vicinity of Tyonek (i.e., salmon were the primary traditional food in Tyonek) (ADL 1998).

Table 2. Characteristics of Species Sampled in the Study

Species	Taxon	Size Range Total Length (cm)	Sample Type
Fish			
Chinook salmon	*Oncorhynchus tshawytscha*	59.7–96.5	Whole body
Chum salmon	*Oncorhynchus keta*	57.2–73.7	Whole body
Sockeye salmon	*Oncorhynchus nerka*	40.6–76.2	Whole body
Sea bass	*Sebastes melanops*	30.5–58.4	Whole body
Cod	*Gadus macrocephalus*	58.4–81.3	Whole body
Flounder	*Lepidopsetta bilineata*	27.9–41.9	Whole body
Halibut	*Hippoglossus stenolepis*	67.3–101.6	Whole body
Invertebrates			
Blue mussel	*Mytilus* cf. *trossulus* sp.[c]	Not reported[d]	Whole body without shell
Mussel	Not determined[c]	Not reported[d]	Whole body without shell
Butter clam	*Saxidomus giganteus*[e]	Not reported[d]	Whole body without shell
Large clam	Not determined[a]	Not reported[d]	Whole body without shell
Steamer clam	*Protothaca staminea*[e]	Not reported[d]	Whole body without shell
Chiton	*Polyplacophora* sp.[c]	Not reported[d]	Whole body without shell[f]
Octopus	Octopodidae[c]	Not reported[d]	Whole body[f]
Snail	*Littorina* sp.	Not reported[d]	Whole body without shell[f]
Plants			
Goose tongue	*Plantago maritima*	Not reported[d]	Edible "tongue" portion
Kelp/bull kelp	*Nereocystis luetkeana*[g]	Not reported[d]	Edible bulb portion
Seaweed	*Porphyra* sp.[g]	Not reported[d]	Blades

a Brown pers. comm. 2000a.
b Brown pers. comm. 2000b.
c Brown pers. comm. 2000c.
d The field sampling records denote that individuals should be of similar size and of a size traditionally collected for subsistence (ADL 1998).
e Clam identifications were estimated (Brown pers. comm. 2000a).
f Chiton/snail radula and octopus beak were not removed.
g Taxa were identified at Port Graham, other locations were not determined (Brown pers. comm. 2000d).

Composite samples were analyzed. The number of individuals in a composite are shown in Table 1. With the exception of the marine plants, all analyses were performed on whole-body samples.

Table 3 lists all the analytes which were measured in this study. A subset of these analytes are associated with oil and gas operations, and these are shaded (USEPA 1996; see Appendix D). The main categories of chemicals were trace metals, polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides, polychlorinated biphenyls (PCBs), and dioxins/furans. Before undertaking the study, quality assurance project plans were developed for this project (Appendices F, G and H).

Table 3. Chemical Analytes

TRACE METALS

- Arsenic
  - Total Inorganic Arsenic
  - Arsenic III
  - Arsenic V
  - Dimethylarsinic Acid
  - Monomethylarsenic Acid
- Barium
- Cadmium
- Chromium
- Lead
- Total Mercury
  - Methylmercury
- Selenium

POLYCYCLIC AROMATIC HYDROCARBONS

- C1-Dibenzothiophenes
- C2-Dibenzothiophenes
- C1- Fluoranthene/pyrenes
- C2- Fluoranthene/pyrenes
- C3- Fluoranthene/pyrenes
- C4- Fluoranthene/pyrenes
- C1-Naphthalenes
  - 1-Methylnaphthalene
  - 2-Methylnaphthalene
- C2-Naphthalenes
  - 1,2-Dimethylnaphthalene
  - 1,3-Dimethylnaphthalene
  - 1,5-Dimethylnaphthalene
  - 1,7/1,6-Dimethylnaphthalene
  - 1-Ethylnaphthalene
  - 2,3/1,4-Dimethylnaphthalene
  - 2,6/2,7-Dimethylnaphthalene
  - 2-Ethylnaphthalene
- C3-Naphthalenes
  - 1,3,6-Trimethylnaphthalene
  - 1,3,7-Trimethylnaphthalene
  - 1,4,5/1,2,3-Trimethylnaphthalene
  - 1,4,6/1,3,5/2,3,6-Trimethylnaphthalene
  - 2,3,5/1,2,7/1,6,7/1,2,6-Trimethylnaphthalene
- C4-Naphthalenes
- C1-Phenanthrene/anthracene
  - 1-Methylphenanthrene
  - 2-Methylphenanthrene
  - 3-Methylphenanthrene
  - 2-Methylanthracene
  - 9/4-Methylphenanthrene
  - 1-Methylanthracene
- C2-Phenanthrene/anthracene
- C3-Phenanthrene/anthracene
- C4-Phenanthrene/anthracene
- 1-Methylchrysene
- 1,2,9-Tetrahydropicene
- 2,2,9-Tetrahydropicene
- 2,9-Dimethylpicene
- 3,3,7,12a-Tetramethylocta Hydrochrysene
- 3,4,7,12a-Tetramethylocta Hydrochrysene
- 3-Methylcholanthrene
- 4,5-Methylenephenanthrene
- 5,9-Dimethylchrysene
- 7-Methylbenzo(a)pyrene
- 9-Methylbenzofluoranthene
- Abietadienol
- Acenaphthene
- Acenaphthylene
- Acephenanthrylene
- Anthanthrene
- Anthracene
- Benz(a)anthracene
- Benzo(a)fluoranthene
- Benzo(a)fluorene/ 3-Methylfluoranthene
- Benzo(a)pyrene
- Benzo(b,j,k)fluoranthenes
- Benzo(b)chrysene
- Benzo(b)fluorene
- Benzo(b)naphtho(1,2-d) thiophene
- Benzo(b)naphtho(2,3-d) thiophene
- Benzo(b)naphtho(u,n,k)thiophene
- Benzo(c)phenanthrene
- Benzo(e)pyrene
- Benzo(g,h,i)fluoranthene
- Benzo(g,h,i)perylene
- Bisnorsimonellite
- Cadalene
- Carbazole
- Cholanthrene
- Chrysene/Triphenylene
- Coronene
- Cyclopenta(c,d)pyrene
- Dehydroabietane
- Dehydroabietanol-1
- Dehydroabietanol-2
- Dehydroabietin
- Dibenz(a,j)anthracene
- Dibenz(a,h)anthracene/ Dibenz(a,c)anthracene
- Dibenzo(2,3-a)pyrene
- Dibenzo(a,e)pyrene
- Dibenzo(b,k)fluoranthene/ Dibenzo(a,l)pyrene
- Dibenzo(e,l)pyrene
- Dibenzofuran
- Dibenzothiophene
- Fluoranthene
- Fluorene
- Ideno(7,1,2,3-c,d,e,f) chrysene
- Indeno(1,2,3-c,d)pyrene
- Naphthalene
- Naphtho(1,2-k)fluoranthene
- Naphtho(2,1-e)pyrene/ Benzo(b)perylene
- Naphtho(2,3-e)pyrene
- Norabietatetraene
- Pentaphene
- Perylene
- Phenanthrene
- Picene
- Pimanthrene
- Pyrene
- Retene
- Simonellite
- Tetrahydroretene
- Tetramethyloctahydro-chrysene- isomer

Table 3. Chemical Analytes

Organochlorine Pesticides	Polycyhlorinated Biphenyls	Dioxins/Furans
DDD	Aroclors	2,3,7,8-TCDD
2,4'-DDD	PCB 1016	1,2,3,7,8-PeCDD
4,4'-DDD	PCB 1221	1,2,3,4,7,8-HxCDD
DDE	PCB 1232	1,2,3,6,7,8-HxCDD
2,4'-DDE	PCB 1242	1,2,3,7,8,9-HxCDD
4,4'-DDE	PCB 1248	1,2,3,4,6,7,8-HpCDD
DDT	PCB 1254	OCDD
2,4'-DDT	PCB 1260	2,3,7,8-TCDF
4,4'-DDT		1,2,3,7,8-PeCDF
DDT/DDD/DDE (Total)	Congeners	2,3,4,7,8-PeCDF
	3,3',4,4'-TCB (77)	1,2,3,4,7,8-HxCDF
Chlordane (Sum)	2,3,3',4,4'-PeCB (105)	1,2,3,6,7,8-HxCDF
Alpha-chlordane	2,3,4,4',5-PeCB (114)	1,2,3,7,8,9-HxCDF
Gamma-chlordane	2,3',4,4',5-PeCB (118)	2,3,4,6,7,8-HxCDF
Oxychlordane	2',3,4,4',5-PeCB (123)	1,2,3,4,6,7,8-HpCDF
Cis-nonachlor	3,3',4,4',5-PeCB (126)	1,2,3,4,7,8,9-HpCDF
Trans-nonachlor	2,3,3',4,4',5-HxCB (156)	OCDF
Dieldrin	2,3,3',4,4',5'-HxCB (157)	
Endosulfan (Total)	2,3',4,4',5,5'-HxCB (167)	
Endosulfan I	3,3',4,4',5,5'-HxCB (169)	
Endosulfan II	2,2',3,3',4,4',5-HpCB (170)	
Endrin	2,2',3,4,4',5,5'-HpCB (180)	
Gamma-BHC	2,3,3',4,4',5,5'-HpCB (189)	
Heptachlor Epoxide		
Hexachlorobenzene		
Mirex		
Pentachloroanisol		
Toxaphene		

NOTE: Shading - Analytes previously associated with oil and gas exploration operations (USEPA 1996, Appendix D).

Samples of fish, invertebrate, and plant species were collected by staff from Arthur D. Little (ADL), Inc., the Alaska Department of Fish and Game (ADFG), and village residents, in general accordance with the QAPP (Appendices F and G) and EPA (1995). The following is a brief summary of procedures used for the collection of all samples. The collection area, sampling station, and sample replicate were identified with a unique sample identification number. Samples were collected by hand, wearing gloves. The use of tools for collection was minimized to avoid potential sample contamination. Samples were rinsed with sea water after collection. Samples were placed in appropriate labeled containers. Invertebrates (except octopus) and plants were placed in glass containers; chinook salmon, halibut, and octopus were placed in polyethylene bags; all other fish were wrapped in precleaned aluminum foil and placed in polyethylene bags (ADL 1998). The samples were packed into coolers for shipment to the processing laboratory. All coolers were packed with dry ice to maintain a temperature below -4°C until receipt at the laboratory. Field record forms were completed for each location where individual and composite samples were collected. Chain-of-custody forms were used to document the transfer of all samples from field

collection to receipt at the processing laboratory. Photographs were taken to document sample collection procedures at each village. Field record forms, chain-of-custody forms, photographs, sample collection locations, sample identification numbers, and compositing information are provided in ADL (1998). Appendix H summarizes sample ID, location, type, and descriptions. Maps of sampling locations near each village are included in Appendix I.

Although the fish samples were intended to represent the size range and species regularly consumed, this goal was not achieved. The composite samples included some individual fish that were smaller than intended. This deviation was due to the unavailability of fish in the size range specified in the study design (ADL 1998).

Fish were collected by hook and line (sea bass, cod, halibut, sockeye salmon, and flounder) and gill nets (chinook, sockeye, and chum salmon). Where possible, three stations within each collection area were sampled (Appendices I and J). This objective was not achieved for chinook salmon from Seldovia and Port Graham, where difficulties in collecting sufficient numbers of fish resulted in only two and one composite sample(s) being collected, respectively (see Table 1). For similar reasons, only two composite samples of chum salmon were collected at Port Graham. For sea bass collected from Port Graham, one fish was analyzed as an individual in addition to the three composite samples. Photographs of samples collected for analysis are presented in Appendix J. The size range of individual fish within each composite is shown in Table 4. The Composite ID letter-plus-number codes shown in Table 4 can be used to identify data in Appendix C (compact disk containing electronic spreadsheet of data for each sample).

Table 4. Fish Composite Samples Collected

Species	Composite ID	No. of Fish per Composite	Village	Size Range (cm)	Comments
Chinook salmon	TY-KS-01	5	Tyonek	59.7–96.5[a]	
Chinook salmon	TY-KS-02	3	Tyonek	63.5–68.6	
Sockeye salmon	TY-RS-01	5	Tyonek	43.2–53.3[a]	
Sockeye salmon	TY-RS-02	5	Tyonek	40.6–53.3	
Sockeye salmon	TY-RS-03	5	Tyonek	43.2–50.8	
Chinook salmon	SE-KS-04	5	Seldovia	68.6–91.4	
Chinook salmon	SE-KS-05	5	Seldovia	74.9–94.0	
Sockeye salmon	SE-RS-05	5	Seldovia	57.2–76.2	
Sockeye salmon	SE-RS-06	5	Seldovia	55.9–61.0	
Sockeye salmon	SE-RS-07	5	Seldovia	54.6–68.6	
Halibut	SE-HA-01	5	Seldovia	69.9–83.8	
Halibut	SE-HA-02	5	Seldovia	67.3–96.5[a]	
Halibut	SE-HA-03	5	Seldovia	72.4–86.4	
Chinook salmon	PG-KS-01	5	Port Graham	71.1–91.4	
Chum salmon	PG-DS-02	6	Port Graham	68.6–73.7	
Chum salmon	PG-DS-01,02	2	Port Graham	57.2–71.1	Samples collected from one site, PG-DS-02
Sea bass	PG-SB-01	5	Port Graham	35.6–50.2[a]	
Sea bass	PG-SB-02	5	Port Graham	35.6–52.1[a]	

Species	Composite ID	No. of Fish per Composite	Village	Size Range (cm)	Comments
Sea bass	PG-SB-03, 02B,04	1 or 2	Port Graham	30.5–58.4[a]	Samples collected from three locations
Flounder	PG-FL-01	5	Port Graham	27.9–41.9[a]	
Flounder	PG-FL-02,03	5	Port Graham	30.5–34.3	Samples collected from two locations
Sockeye salmon	NA-RS-01	5	Nanwalek	67.3–72.4	
Sockeye salmon	NA-RS-02	5	Nanwalek	63.5–73.7	
Sockeye salmon	NA-RS-03	5	Nanwalek	61.0–76.2	
Cod	NA-CD-01	5		58.4–71.1	
Cod	NA-CD-02	5	Nanwalek	58.4–78.7[a]	
Cod	NA-CD-03	5	Nanwalek	73.7–81.3	
Halibut	NA-HB-01	5	Nanwalek	69.9–102.0[a]	
Halibut	NA-HB-02	5	Nanwalek	76.2–89.0	
Halibut	NA-HB-03	5	Nanwalek	71.1–83.8	

a Minimum individual size is less than 75 percent maximum individual size.

The size range of collected invertebrates was consistent with the design. Sampling sites were selected based on interviews with villagers. Three composite samples were collected for each species (see Table 1). The number of individuals in composite samples and weight information is provided in Table 5. The Composite ID alphanumeric codes shown in Table 5 can be used to identify data in Appendix C (compact disk containing electronic spreadsheet of data for each sample). Mussels, snails, and octopi were collected by hand. Butter clams and large clams were hand-collected from holes dug with a shovel. Steamer clams were collected by digging with a shovel and rake. Chiton were hand-collected using a stainless steel blade to pry the organisms off the rocks.

Table 5. Invertebrate Composite Samples Collected

Species	Composite ID	No. of Individuals per Composite	Village	Wet Weight(g)
Butter clam	SE-BC-01-01	5	Seldovia	–[a]
Butter clam	SE-BC-01-02	5	Seldovia	–[a]
Butter clam	SE-BC-01-03	5	Seldovia	–[a]
Blue mussel	SE-MU-01-01	35	Seldovia	–[a]
Blue mussel	SE-MU-01-02	37	Seldovia	–[a]
Blue mussel	SE-MU-01-03	32	Seldovia	–[a]
Snail	SE-SN-01-01	>50	Seldovia	–[a]
Snail	SE-SN-01-02	>50	Seldovia	–[a]
Snail	SE-SN-01-03	>50	Seldovia	–[a]
Chiton	SE-CH-01-01	>25	Seldovia	350[b]
Chiton	SE-CH-01-02	>25	Seldovia	345[b]
Chiton	SE-CH-01-03	>25	Seldovia	362[b]
Large clam	PG-LC-01-01	5	Port Graham	–[a]

SPECIES	COMPOSITE ID	NO. OF INDIVIDUALS PER COMPOSITE	VILLAGE	WET WEIGHT(g)
Large clam	PG-LC-01-02	5	Port Graham	–[a]
Large clam	PG-LC-01-03	5	Port Graham	–[a]
Steamer clam	PG-CL-01-01	32	Port Graham	–[a]
Steamer clam	PG-CL-02-01	15	Port Graham	–[a]
Steamer clam	PG-CL-03-01	13	Port Graham	–[a]
Octopus	PG-OT-01-01	1	Port Graham	4,700
Octopus	PG-OT-01-02	1	Port Graham	6,000
Octopus	PG-OT-02-01	1	Port Graham	1,200
Snail	PG-SN-01-01	>50	Port Graham	–[a]
Snail	PG-SN-02-01	>50	Port Graham	–[a]
Snail	PG-SN-02-02	>50	Port Graham	–[a]
Chiton	PG-CH-01-01	38	Port Graham	–[a]
Chiton	PG-CH-01-02	45	Port Graham	–[a]
Chiton	PG-CH-02-03	30	Port Graham	–[a]
Mussel	NA-MS-01-01	~50	Nanwalek	–[a]
Mussel	NA-MS-02-01	~50	Nanwalek	–[a]
Mussel	NA-MS-03-01	~50	Nanwalek	–[a]
Snail	NA-SN-01-01	>50	Nanwalek	–[a]
Snail	NA-SN-02-01	>50	Nanwalek	–[a]
Snail	NA-SN-03-01	>50	Nanwalek	–[a]
Chiton	NA-CH-01-01	25	Nanwalek	–[a]
Chiton	NA-CH-02-01	21	Nanwalek	–[a]
Chiton	NA-CH-03-01	21	Nanwalek	–[a]

a Not reported. Field sampling records denote that individuals should be of similar size and of a size traditionally collected for subsistence (ADL 1998).

b Weight of sample after shucking. Individual chiton lengths ranged from 4 to 8 cm.

All plants were collected by hand and three composite samples were collected for each species. Composite goose tongue samples were composed of the edible tongue portion of the plant from approximately 200 to 250 individuals. Kelp samples were only collected in the vicinity of Port Graham; the three composite samples consisted of the edible bulb portion from approximately 50 plants (ADL 1998). Seaweed samples were only collected in the vicinity of the village of Nanwalek; the three composite samples each consisted of the blades from approximately 20 plants.

The following provides a brief discussion of the laboratory procedures for sample receipt, processing, distribution, chemical analysis, and QA/QC processes. Sample processing and distribution was conducted by Axys Analytical Services, Inc. in Sydney, British Columbia, Canada. Coolers containing samples were received at Axys from June 27 through September 4, 1997. All samples were received frozen and in good condition (Ecology and Environment, Inc., 1998). Samples were stored in freezers at -20°C until all details on sample preparation and subsequent analysis were approved by the Office of Water, Office of Science and Technology and the sample

control center, operated by DynCorp in Alexandria, Virginia (Ecology and Environment, Inc., 1998).

Sample homogenization and compositing was initiated on February 25, 1998. Composite samples of whole fish, invertebrates, and marine plants were homogenized. Before homogenization, shells were removed from invertebrates by hand; gloves were worn and solvent-rinsed shucking tools were used. Composite samples of octopi were not analyzed; each whole-body octopus was homogenized individually. Three types of blenders were available for use in homogenization—a Virtis mixer, Oster blender, and commercial meat grinder. The type of blender used depended on the amount and type of tissue in the sample. Samples were hand mixed between each pass through the blender. Homogenization equipment was cleaned thoroughly after each composite sample was prepared. Equipment was cleaned with soap and water, then rinsed with acetone, hexane, and dichloromethane, then with a 5 percent nitric acid solution, and lastly with deionized water.

Composite samples were assigned EPA sample numbers. Aliquots of material were placed into appropriate containers for future analysis and frozen at -20°C. Sample aliquots and blanks were shipped frozen to Pacific Analytical, Inc., in Carlsbad, California, and Battelle Marine Sciences in Sequim, Washington; or were retained at Axys for subsequent chemical analysis.

On March 2, 1998, Ecology and Environment, Inc., staff from Lancaster, New York, conducted an audit of the sample preparation and compositing samples by Axys. The results of this audit are provided (see Appendix K). It was concluded from the audit that the processing and homogenization of samples were being conducted in accordance with the standard operating procedures designated in the QAPP (see Appendix G).

The analytical methods used for the analysis of samples are listed in Table 6. All analytical methods are established EPA methods. Some methods were modified for the analyses of tissues (rather than water) or to include analytes not listed for that method. An example of the latter is the use of Method 1638 for the analyses of chromium and barium.

To provide data regarding the toxic chemical species of mercury and arsenic, methylmercury, trivalent arsenic, pentavalent arsenic, dimethylarsinic acid and monomethylarsenic acid were included in the analytes.

Table 6. Chemical analysis methods used for the Cook Inlet Contaminant Study

ANALYTE	METHOD
Dioxins/furans	USEPA Method 1613, Revision B
Polychlorinated biphenyls	USEPA Method 1656 (Aroclors) USEPA Method 1668 (congeners)
Polycyclic aromatic hydrocarbons	USEPA Method SW846, modified methods 8270C-SIM and 3630
Organochlorine pesticides	USEPA Method 1656
Trace Metals:	

ANALYTE	METHOD
Total mercury	USEPA Method 1631
Methylmercury	USEPA Method 1630
Selenium	USEPA Method 1638
Cadmium	USEPA Method 1638
Chromium	USEPA Method 1638
Barium	USEPA Method 1638
Lead	USEPA Method 1638
Total Arsenic	USEPA Method 1638
Arsenic III	USEPA Method 1632, revision A
Arsenic V	USEPA Method 1632, revision A
Monomethylarsenic acid	USEPA Method 1632, revision A
Dimethylarsinic acid	USEPA Method 1632, revision A

The performance of all analyses were consistent with quality control elements described in the versions of EPA 600 and 1600 series methods current in 1998. The QA/QC review of the data was performed by DynCorp of Alexandria, Virginia. All data were acceptable according to the data review guidelines for the various methods (specified in Appendix L).

Summary statistics for the analytical results are compiled in Appendix B. For each analyte in each species, the summary statistics include the maximum and minimum detected concentrations, the arithmetic average of the detected concentrations, and the number of detections.

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3.0 RESULTS

3.1 Overview

A total of 81 samples consisting of fish, invertebrates and plants were collected. Samples were analyzed for 161 chemicals in five chemical groups (metals, PAHs, pesticides, PCBs, and dioxins/furans). Approximately one-half (85) of these analytes were not detected in any sample (Table 7). And, approximately one-half (76) of these chemical were detected (Table 8). The numbers of detected chemicals by sample type and chemical group are shown (Table 9).

Mean contaminant concentrations are provided in Appendix B. The entire data set is provided on a compact disk which accompanies this report (Appendix C). The results of the quality assurance review are provided in Appendix L.

Table 7. List of chemicals not detected in any tissue sample

PAHs	1,2,9-Tetrahydropicene	**PAHs, cont.**	Dibenzo(el)pyrene
	1,2-Dimethylnaphthalene		Indeno(7,1,2,3-c,d,e,f)chrysene
	1,3,7-Trimethylnaphthalene		Indeno(1,2,3-c,d)pyrene
	1,4,5/1,2,3-Trimethylnaphthalene		Naphtho(1,2-k)fluoranthene
	1,5-Dimethylnaphthalene		Naphtho(2,1-e)pyrene/Benzo(b)perylene
	1-Ethylnaphthalene		Naphtho(2,3-e)pyrene
	1-Methylchrysene		Norabietatetraene
	2,2,9-Tetrahydropicene		Pentaphene
	2,3,5/1,2,7/1,6,7/1,2,6-Trimethylnaphthalene		Perylene
	2,9-Dimethylpicene		Picene
	2-Ethylnaphthalene		Retene
	2-Methylanthracene		Tetramethyloctahydrochrysene
	3-Methylcholanthrene		
	3,3,7,12A-Tetramethyloctahydrochrysene	**Pesticides**	Toxaphene
	4,5-Methylenephenanthrene		
	5,9-Dimethylchrysene	**PCB Aroclors**	PCB 1016
	7-Methylbenzo(a)pyrene		PCB 1221
	9-Methylbenzofluoranthene		PCB 1232
	Acephenanthrylene		PCB 1242
	Anthanthrene		PCB 1248
	Anthracene		PCB 1254
	Benzo(a)fluoranthene		
	Benzo(a)fluorene/3-Methylfluoranthene	**PCB Congeners**	2,3,4,4',5-PeCB (114)
	Benzo(a)pyrene		3,3',4,4',5-PeCB (126)
	Benzo(b,j,k)fluoranthenes		2,3,3',4,4',5'-HxCB (157)
	Benzo(b)chrysene		3,3',4,4',5,5'-HxCB (169)
	Benzo(b)naphtho(1,2-d)thiophene		2,3,3',4,4',5,5'-HpCB (189)
	Benzo(b)naphtho(2,3-d)thiophene		
	Benzo(b)naphtho(u,n,k)thiophene	**Dioxins**	2,3,7,8-TCDD
	Benzo(c)phenanthrene		1,2,3,7,8-PeCDD
	Benzo(e)pyrene		1,2,3,4,7,8-HxCDD
	Benzo(g,h,i)fluoranthene		1,2,3,6,7,8-HxCDD
	Benzo(g,h,i)perylene		1,2,3,7,8,9-HxCDD
	Bisnorsimonellite		1,2,3,4,6,7,8-HpCDD
	C3-Fluoranthene/pyrenes		
	Cholanthrene	**Furans**	2,3,7,8-TCDF
	Chrysene/triphenylene		1,2,3,7,8-PeCDF
	Coronene		2,3,4,7,8-PeCDF
	Dehydroabietanol-1		1,2,3,4,7,8-HxCDF
	Dehydroabietanol-2		1,2,3,6,7,8-HxCDF
	Dibenz(a,j)anthracene		1,2,3,7,8,9-HxCDF
	Dibenz(a,h)anthracene/Dibenz(a,c)anthracene		2,3,4,6,7,8-HxCDF
	Dibenzo(2,3-a)pyrene		1,2,3,4,6,7,8-HpCDF
	Dibenzo(a,e)pyrene		1,2,3,4,7,8,9-HpCDF
	Dibenzo(b,k)fluoranthene/Dibenzo(a,l)pyrene		OCDF

Note: PAH - polycyclic aromatic hydrocarbon
PCB - polychlorinated biphenyl
Shading - Analytes previously associated with oil and gas exploration operations (USEPA 1996, Appendix D).

Table 8. Numbers of detected chemicals in the Cook Inlet Contaminant Study

Chemical Group	Total Number of Chemicals Measured	Number Detected
Trace metals	7	7
Polycyclic aromatic hydrocarbons	104	47
Pesticides	13	12
Polychlorinated biphenyls:		
Aroclors	7	1
Congeners	13	8
Dioxins/furans	17	1
Total	161	76

Table 9. Number of samples in which chemical was detected

	Total Number of Samples	Number of Samples in which Chemical was Detected					
		Metals	PAHs	Pesticides	PCB Aroclors	PCB Congeners	Dioxins/ Furans
Fish[a]	33	33	33	33	5	33	1
Shellfish[b]	15	15	10	1	0	1	0
Other Invertebrates[c]	21	21	19	8	0	8	0
Plants[d]	12	12	9	1	0	0	0

[a] Chinook salmon, chum salmon, sockeye salmon, sea bass, cod, flounder, halibut.
[b] Blue mussel, mussel, butter clam, large clam, steamer clam.
[c] Chiton, octopus, snail.
[d] Goose tongue, kelp, seaweed.

3.2 Trace Metals

3.2.1 Fish

Arsenic (total), barium, cadmium, chromium, lead, methymercury and selenium were analyzed. In addition, analyses of arsenical species included trivalent arsenic (As3+), dimethylarsinic acid and monomethylarsenic. The total average concentration of metals ranged from 1.4 ppm to 5.8 ppm. The highest total concentrations were in cod tissue samples (average 5.8 ppm, Figure 3)

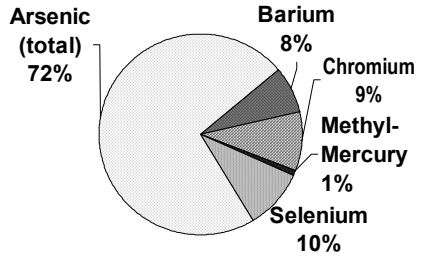


Figure 3. Cod Samples - Percent Metal Concentrations (total 5.8 ppm)

Arsenic (total) is shown because concentrations were detected in all fish species. In contrast, inorganic arsenic concentrations did not have a consistent pattern.

The lowest total concentrations were in chinook tissue samples (average 1.4 ppm, Figure 4).

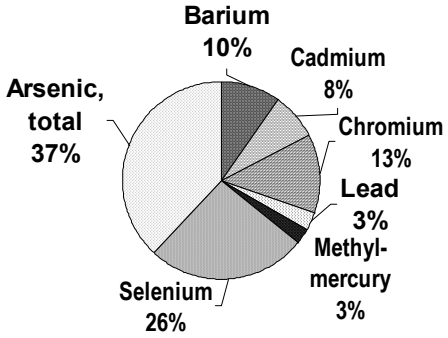


Figure 4. Chinook Samples - Percent Metal Concentrations (total 1.4 ppm)

Arsenic (total), barium, chromium, methylmercury and selenium were detected in all seven species of fish. Lead was only detected in chinook and flounder (average 4.2 ppm in both). In chum salmon, barium accounted for the greatest percentage (Figure 5).

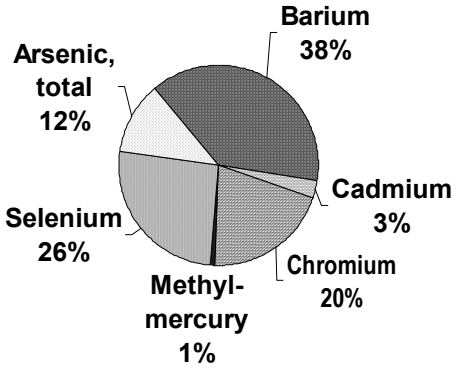


Figure 5. Chum Salmon Samples - Percent Metal Concentrations (total 2 ppm)

In sockeye salmon, chromium accounted for the greatest percentage (Figure 6). The highest concentrations of chromium were found in sockeye salmon tissue samples (maximum = 11.7 ppb, average = 1.9 ppm).

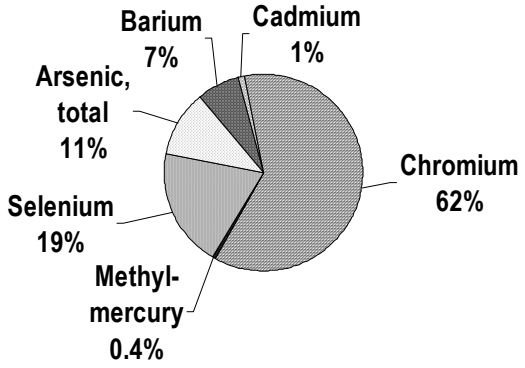


Figure 6. Sockeye Salmon Samples - Percent Metal Concentration (total 3.2 ppm)

Arsenic (total) average concentrations ranged from 0.24 to 4.2 ppm. The highest average arsenic (total) concentrations were detected in cod tissue samples. The lowest average arsenic (total) concentrations were detected in chum salmon. Except in chum and sockeye salmon, arsenic (total) accounted for the greatest percentage of the metals concentrations (Figures 3 through 9). Inorganic arsenical species were detected in four fish species. Trivalent arsenic and monomethylarsenic cocentrations were detected only in flounder tissue samples (average 0.012 and 0.013 ppm, respectively). Dimethylarsinic acid concentrations were detected in tissue samples of cod, halibut and sea bass (range of averages 0.024 to 0.055 ppm).

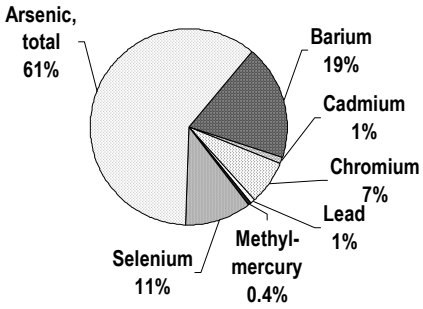


Figure 7. Flounder Samples - Percent Metal Concentrations (4.8 ppm)

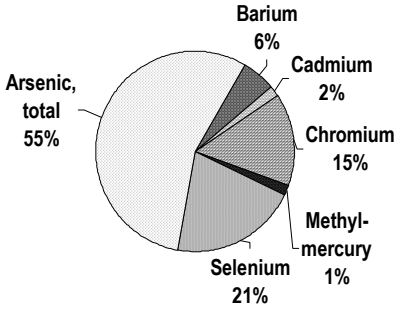


Figure 8. Halibut Samples - Percent Metal Concentrations (2.3 ppm)

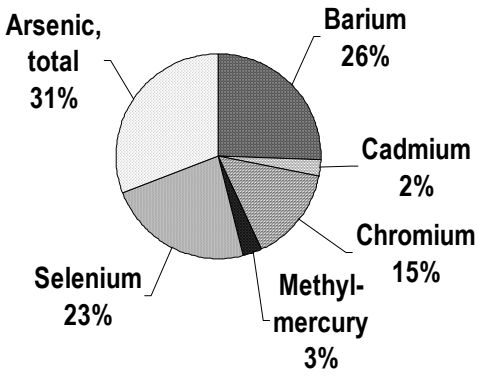


Figure 9. Sea Bass Samples - Percent Metal Concentrations (2.6 ppm)

Cadmium was detected in all fish tissue samples, except cod tissue samples (range of averages 37 to 109 ppb) (Figure 10).

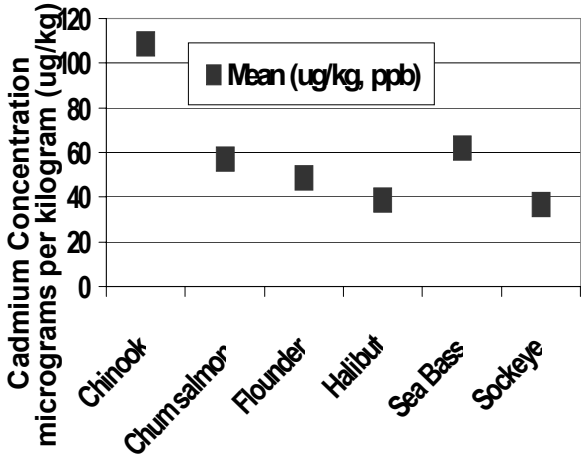


Figure 10. Cadmium Concentration in Cook Inlet Fish Tissue Samples (mean micrograms per kilogram, ug/kg, ppb).

Average concentrations of methylmercury ranged from 15 to 75 ppb (note ppb, not ppm, Figure 11). The highest average methylmercury concentrations were in sea bass. The lowest average methylmercury concentrations were in sockeye salmon.

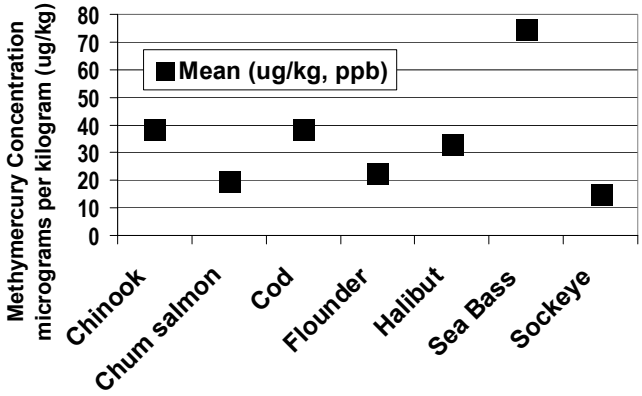


Figure 11. Methylmercury Concentration in Cook Inlet Fish Tissue Samples (mean micrograms per kilogram, ug/kg, ppb).

Selenium was detected in all fish tissue samples. The highest mean tissue concentration was measured in sockeye salmon tissue samples (621 ppb). However, the highest maximum concentration was measured in flounder tissue samples (1580 ppb).

3.2.2 Invertebrates

Arsenic (total), barium, cadmium, chromium and selenium were detected in all 8 invertebrate tissue samples. Lead was detected in all tissue samples, except steamer clams. The average concentrations of total metals in invertebrates ranged from 0.3 to 8.4 ppm (Table 10). The highest total average concentrations were found in snail tissue samples. The lowest total average concentrations were found in mussel tissue samples. In most cases, total arsenic contributed the greatest percentage (range of averages 40% to 81%). However, in snail tissue samples cadmium contributed the greatest percentage (54%, Table 10 and Figure 12). Individual metal concentrations detected in each species are provided in Appendix B.

Table 10.
Total metal concentrations in invertebrate and plant tissue samples (average milligrams per kilogram, mg/kg, ppm).

Sample	Total Metal (mg/kg)	Highest Concentration	Percent of Total
Blue mussel	2.5	Arsenic, total	49%
Butter clam	7.5	Arsenic, total	53%
Large clam	5.5	Arsenic, total	58%
Mussel	2.0	Arsenic, total	48%
Steamer clam	3.3	Arsenic, total	73%
Goose Tongue	0.3	Chromium	46%
Kelp	3.6	Arsenic, total	71%
Seaweed	3.6	Arsenic, total	81%
Chiton	4.2	Arsenic, total	40%
Octopus	5.0	Arsenic, total	59%
Snail	8.4	Cadmium	54%

Arsenic (total) concentrations are comprised of many different arsenical species. In this study, four arsenical species were analyzed (dimethylarsinic acid, monomethylarsenic, trivalent inorganic arsenic and pentavalent inorganic arsenic). In the invertebrate tissue samples, these four arsenical species accounted for a small portion of the total arsenic concentration. This is illustrated by blue mussel sample results which were typical of the invertebrate results (Figure 13).

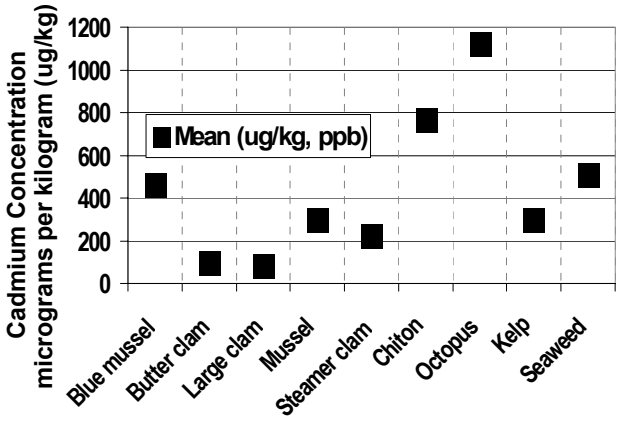


Figure 12.
Cadmium Concentrations in Cook Inlet Invertebrate Tissue Samples (mean micrograms per kilogram, ug/kg, ppb). Not shown: Snail, mean concentration 4493 ppb.

Arsenic (total) average concentrations ranged from 0.013 to 3.9 ppm. The highest arsenic (total) average concentrations were detected in butter clam tissue samples. The lowest arsenic (total) average concentrations were detected in mussel tissue samples. Trivalent arsenic was detected in tissue samples from blue mussels, butter clam, large clam, steamer clam and snail (range of averages 0.005 to 0.053 ppb). Snail tissue samples had the highest trivalent arsenic concentrations. Dimethylarsinic acid concentrations were detected in all invertebrate tissue samples (range of averages 0.031 to 0.208 ppm). Monomethylarsenic concentrations were not detected in any tissue samples.

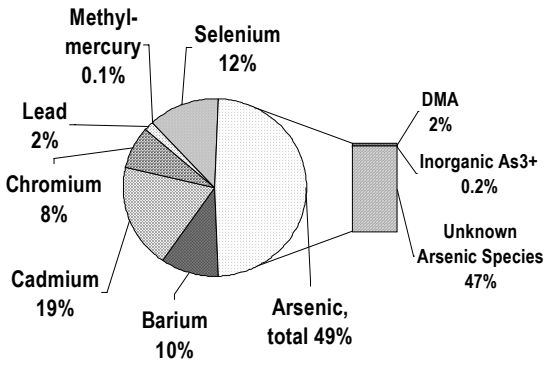


Figure 13. **Blue Mussel Samples - Percent Metal Concentrations (2.5 ppm)**

Chromium was detected in all invertebrate tissue samples. The highest mean tissue concentrations were measured in butter clams (2.0 ppm) and large clam (1.0 ppm). Mean tissue concentrations in these two species were approximately 10 times higher than other invertebrate tissue samples, which ranged from approximately 0.128 to 0.612 ppm.

Methylmercury average concentrations were detected in all invertebrate tissue samples (Figure 14). Average methylmercury concentrations ranged from 1.8 to 7.9 ppb (note ppb, not ppm). The highest average methylmercury concentrations were detected in octopus tissue samples. The lowest average methylmercury concentrations were detected in chiton tissue samples.

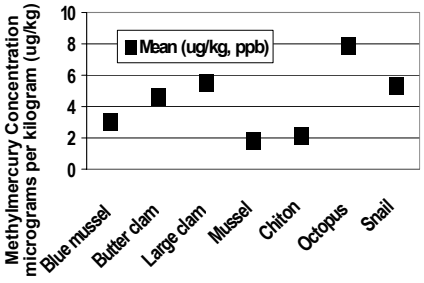


Figure 14. **Methylmercury Concentration in Cook Inlet Invertebrate Tissue Samples (mean micrograms per kilogram, ug/kg, ppb).**

3.2.3 Plants

Metals were detected in the three plant species analyzed. Barium was detected in goose tongue and kelp tissue samples (averages 112 and 363 ppb, respectively). Cadmium concentrations were detected in kelp and seaweed (averages 301 and 510 ppb, respectively). Mean chromium concentrations detected in the three plant species ranged from 128 to 232 ppb. Lead concentrations were detected in goose tongue and kelp (averages 26 and 25 ppb, respectively). Mean selenium concentrations detected in kelp were 135 ppb.

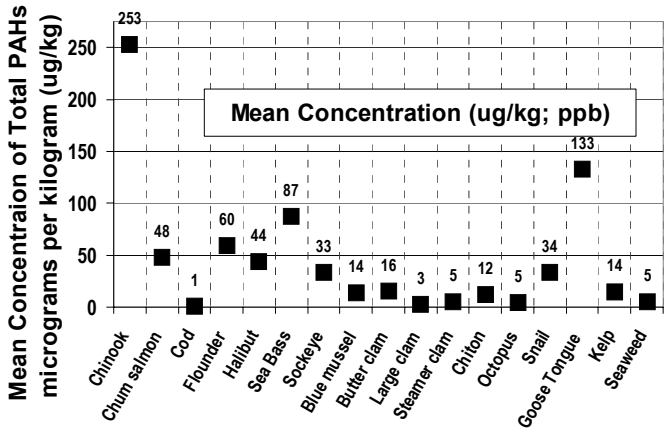
Total arsenic was present in the greatest percentage of the total metals in kelp and seaweed (Table 10). Chromium was the greatest percentage of total metals in goose tongue (Table 10).

3.3 Polycyclic Aromatic Hydrocarbons (PAHs)

3.3.1 Fish

The 81 tissue samples consisting of fish, invertebrates and plants were analyzed for 104 PAHs (Table 3). Approximately one-half of these PAHs were detected in the Cook Inlet tissue samples. PAHs were detected in all fish tissue samples (Figure 15).

Figure 15.
Total Polycyclic Aromatic Hydrocarbon Concentrations in Cook Inlet Tissue Samples
(micrograms per kilogram, ug/kg, ppb)



In fish tissue samples, total PAHs average concentrations ranged from 1 to 253 ppb. The highest average concentrations were detected in chinook tissue samples. The lowest average concentrations were detected in cod tissue samples.

Acenaphthylene, carbazole, dibenzofuran, fluoranthene, and phenanthrene were only detected in chinook salmon. The mean chinook tissue concentrations and detection frequencies for these chemicals are shown in Table 11.

Table 11. Polycyclic aromatic hydrocarbon compounds detected only in chinook salmon tissue samples

Chemical	Mean Chinook Salmon Concentration (µg/kg, ppb)	Detection Frequency
Acenaphthylene	1.2	2 of 6
Carbazole	1.3	2 of 6
Dibenzofuran	3.8	2 of 6
Fluoranthene	2.6	1 of 6
Phenanthrene	7.2	2 of 6

2-Methylnaphthalene was only detected in chinook salmon tissue samples. In these samples, this chemical was detected in two of the six tissue samples analyzed; the mean whole-body tissue concentration was 4.5 ppb.

Acenaphthene was not detected in sockeye salmon, cod, or flounder. Acenaphthene was detected infrequently in chinook salmon, chum salmon, sea bass, and halibut. The mean tissue concentrations in these tissue samples ranged from 0.82 ppb in chum salmon tissue samples to 8.95 ppb in chinook salmon tissue samples.

Benz(a)anthracene was only detected in one out of four sea bass tissue samples analyzed; the mean whole-body tissue concentration for these tissue samples was 1.0 ppb. This chemical was not detected in any other fish tissue sample.

Fluorene was detected infrequently in chinook salmon, sockeye salmon, and sea bass tissue samples. The mean tissue concentrations in these tissue samples ranged from 0.78 ppb in sea bass tissue samples to 3.85 ppb in chinook salmon. This chemical was not detected in chum salmon, cod, flounder, or halibut tissue samples.

Naphthalene was detected in two chinook salmon tissue samples, one sockeye salmon sample, and one halibut sample at mean tissue concentrations ranging from 2.3 to 3.45 ppb. This chemical was not detected in chum salmon, sea bass, cod, or flounder tissue samples.

Pyrene was detected in one sample of flounder (mean = 1.3 ppb).

3.3.2 Invertebrates

Except for mussel tissue samples, PAHs were detected in all invertebrate tissue samples (Figure 15). Total PAHs average concentrations ranged from 3 to 34 ppb. The highest average concentrations were detected in snail tissue samples. The lowest average concentrations were detected in large clam tissue samples.

2-Methylnaphthalene was only detected in snail tissue samples. In these samples, 2-methylnaphthalene was detected in two of the nine tissue samples analyzed; the mean whole-body tissue concentration was 1.5 ppb. Naphthalene was detected in blue mussel (mean = 2.5 ppb) and snail tissue samples (mean = 4.55 ppb). Acenaphthene, benz(a)anthracene, fluorene and pyrene were not detected in any of the invertebrate tissue samples.

3.3.3 Plants

PAHs were detected in all plant tissue samples (Figure 15). Total PAHs average concentrations ranged from 5 to 133 ppb. The highest average concentrations were detected in goose tongue tissue samples. Pyrene was detected in one sample of goose tongue (mean = 4.1 ppb). Acenaphthene, benz(a)anthracene, fluorene and naphthalene were not detected in any of the plant tissue samples.

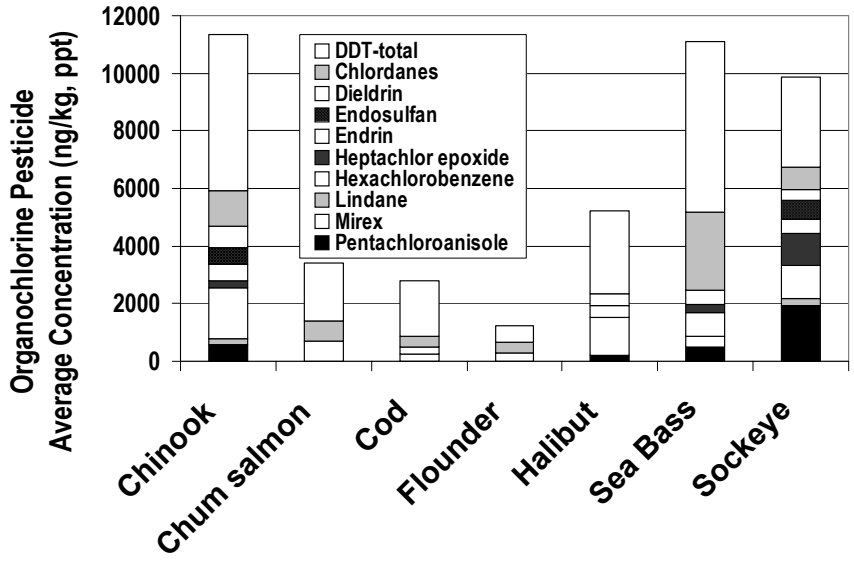
3.4 Pesticides

The 81 tissue samples consisting of fish, invertebrates and plants were analyzed for 13 organochlorine pesticides.

3.4.1 Fish

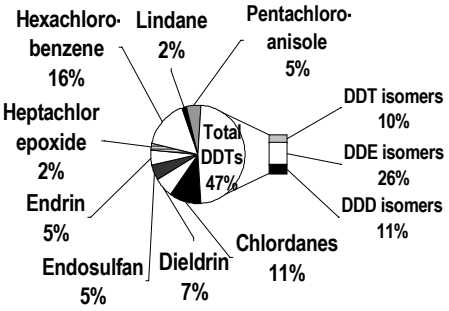
The occurrence of all pesticides detected in fish tissue samples is illustrated in Figure 16. Average concentrations were less than 12,000 ppt. The lowest average concentrations were detected in flounder tissue samples (1,243 ppt) and highest average concentrations were detected in chinook and sea bass tissue samples (11,324 and 11,090 ppt, respectively).

Figure 16.
Total Organochlorine Pesticides Concentrations
in Fish Tissues (average nanograms per kilogram, ng/kg, ppt)



Chinook and sockeye tissue samples contained the greatest number of organochlorine pesticides - 9 out of 13 - and had similar proportions of the nine detected pesticides (Figure 17).

Figure 17.
Organochlorine pesticide compounds in chinook tissue samples (total average 11,324 ppt)



The highest concentrations of several pesticides — hexachlorobenzene, endrin, and dieldrin — were measured in chinook salmon tissue samples. The highest concentrations of DDT compounds, chlordanes, heptachlor epoxide and mirex were detected in sea bass tissue samples. The highest concentrations of endosulfans, lindane and pentachloroanisole were detected in sockeye tissue samples.

The concentration of DDT compounds (DDT-total) was estimated as the sum of the isomers—2,4-DDD, 2,4-DDE, 2,4-DDT, 4,4-DDE, 4,4-DDD, and 4,4-DDT (Figure 18). DDT compounds were detected in all fish tissue samples, and represented the greatest organochlorine pesticide concentration (range of averages 588 to 5894 ppt). Highest average concentrations were detected in Sea Bass tissue samples (5894 ppt), and lowest average concentrations were detected in flounder tissue samples (588 ppt). DDE isomer concentrations were present in the greatest amount followed by DDT, then DDD concentrations.

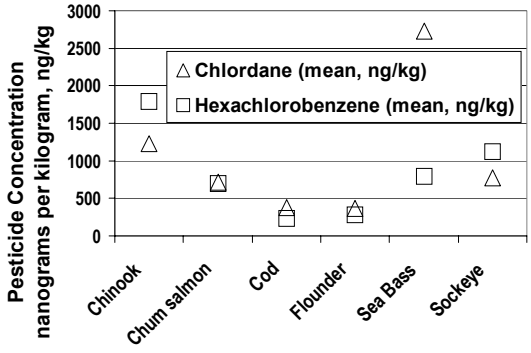


Figure 18. Total Chlordanes and Hexachlorobenzene Concentrations in Cook Inlet Fish Tissues (average nanograms per kilogram, ng/kg)

The concentration of total chlordanes was estimated as the sum of alpha-chlordane, cis-nonachlor, gamma-chlordane, oxychlordane and trans-nonachlor (Figure 19). Chlordane compounds were detected in all species, except halibut. Highest average concentrations were detect in sea bass tissue samples (2732 ppt), and the lowest average concentrations were detected in flounder tissue samples (372 ppt). Hexachlorobenzene was detected in all fish species (Figure 19). Highest average concentrations were detected in chinook tissue samples (1787 ppt), and lowest average concentrations were detected in cod tissue samples (237 ppt).

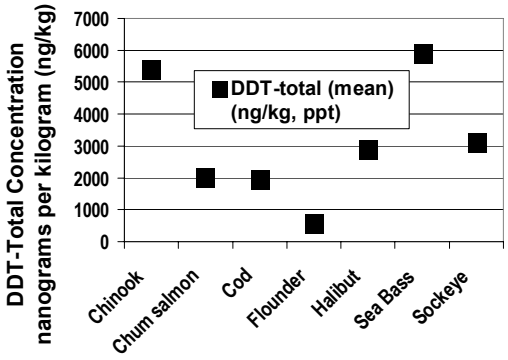


Figure 19. Average Concentrations of total DDTs in Cook Inlet Fish Tissue Samples (ng/kg, ppt)

Dieldrin was not detected in chum salmon or flounder tissue samples. Highest average concentrations were detected in chinook tissue samples (769 ppt), and lowest average concentrations were detected in cod tissue samples (237 ppt).

Endosulfans were detected only in chinook and sockeye salmon tissue samples (averages 544 and 664 ppt, respectively). Endrin was detected only in chinook, halibut and sockeye (range of averages 407 to 582 ppt). Heptachlor epoxide was detected only in chinook, sea bass and sockeye tissue samples. Average concentrations in chinook and sea bass tissue samples were 238 ppt and 310 ppt, respectively. While average concentrations in sockeye tissue samples were 174 ppt. Lindane was detected only in chinook and sockeye tissue samples (averages 185 and 275 ppt, respectively). Mirex was detected only in sea bass tissue samples (average 379 ppt). Pentachloroanisole was detected in chinook, halibut, sea bass and sockeye tissue samples. Highest

average concentrations were detected in sockeye tissue samples (1919 ppt), and lowest average concentrations were detected in halibut tissue samples (226 ppt).

3.4.2 Invertebrates

There were very few detections of organochlorine pesticides in invertebrates. The compounds for which there were no detections in any species included chlordane compounds, DDT compounds, dieldrin, endosulfans and mirex.

The organochlorine pesticide compounds which were detected included endrin (chiton, average 266 ppt), lindane (chiton and snail, average 175 and 155 ppt, respectively), heptachlor epoxide (chiton, average 207 ppt) and hexachlorobenzene (mussel and snail, average 301 and 624 ppt, respectively).

3.4.3 Plants

Of the three plant species tested in this study, only DDD was detected in one of the goose tongue samples (218 ppt).

3.5 Polychlorinated Biphenyls

The 81 tissue samples consisting of fish, invertebrates and plants were analyzed for seven commercial PCB mixtures (Aroclors) and thirteen individual coplanar PCB congeners. Aroclor 1260 was the only Aroclor detected and was found only in chinook salmon, chum salmon, and sea bass. Aroclor 1260 was detected in 5 of 81 tissue samples analyzed. Five of the 13 PCB congeners (114, 126, 157, 169, and 189) were not detected in any of the tissue samples analyzed.

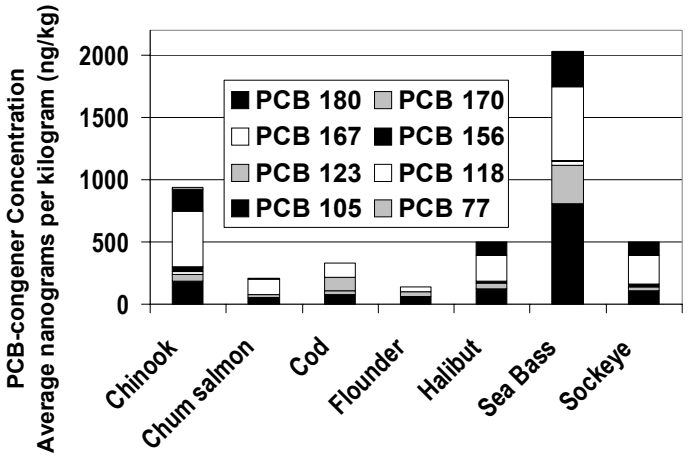


Figure 20. **PCB-Congener Concentrations in Cook Inlet Fish Tissue Samples (average nanograms per kilogram, ng/kg, ppt)**

Fish sample concentrations of the eight detected PCB congeners (77, 105, 118, 123, 156, 167, 170 and 180) are shown in Figure 20. The only congeners which were detected in all seven fish tissue samples included 118, 170 and 180. Except in flounder and sea bass, PCB congener 118 concentrations were present in the highest amount of all the congeners (range of averages 39 - 593 ppt). In flounder and sea bass, PCB congener 180 concentrations were present in the highest amount (range of averages 55 - 807 ppt). PCB congener 77 was present in the lowest concentrations (range of averages 3 - 9 ppt).

Chinook tissue samples contained concentrations of all the eight detected PCB congeners. Sea bass tissue samples contained the highest sum of averages of all PCB congeners (2,030 ppt). Flounder tissue samples contained the lowest sum of averages of all PCB congeners (135 ppt).

Butter clam, octopus and snail were the only invertebrate tissue samples with detected PCB congeners (Figure 21). PCB congener 77 was detected in one butter clam sample (9 ppt). PCB congeners 118 and 180 were detected in octopus tissue samples (averages ~ 24 ppt). PCB congeners 170 and 180 were detected in snail tissue samples (average 23 ppt and 57 ppt, respectively).

Only one PCB congener was detected in plant tissue samples. PCB congener 118 was detected in seaweed (average 45 ppt).

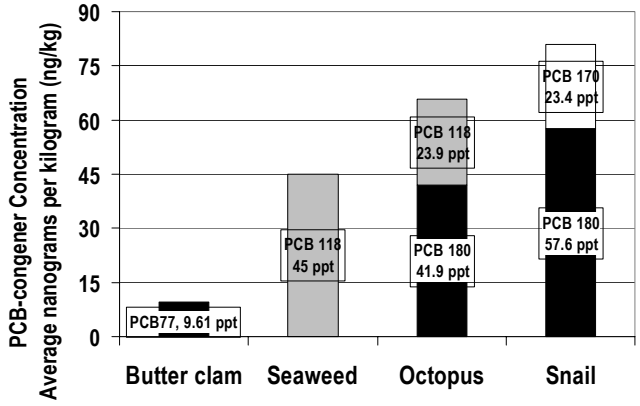


Figure 21. PCB-Congener Concentrations in Cook Inlet Invertebrate Tissue Samples (average nanograms per kilogram, ng/kg)

3.6 Dioxins and Furans

The 81 tissue samples consisting of fish, invertebrates and plants were analyzed for seven dioxin and ten furan congeners. Dioxins and furans were rarely detected in tissue samples. In the 81 tissue samples analyzed for dioxin and furan congeners, only one congener, OCDD, was detected in one duplicate chinook salmon sample (13 ppt). Detectable concentrations of dioxins and furans were not found in other Cook Inlet tissue samples.

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4.0 UNCERTAINTIES

4.1 Sampled Species

The extent to which concentrations in the samples analyzed in this study are representative of concentrations in other Cook Inlet biota consumed by Alaskan tribal villagers is unknown. Not all fish, invertebrate and plant species consumed in a traditional diet were included in this study.

The chinook captured in 1997 off the Seldovia breakwater and off the beach at Port Graham are most likely adult fish that have resulted from stocking of hatchery smolts in this area to enhance local fisheries (L. Pelts, ADFG, pers. comm., February 21, 2001). Data on fin tags, clips or other hatchery identification were not collected during sampling. Hence, these data contain no definitive information to distinguish wild versus hatchery or pen-raised fish.

4.2 Age and Size of Specimens

The size of the biota species sampled in this study was intended to be representative of the size of organisms traditionally harvested by Cook Inlet Alaskan tribal villagers for consumption. However, contaminant concentrations in specimens smaller or larger than the sizes analyzed in this study may vary. For example, in this study smaller sized halibut were sampled (see Table 2). Even though smaller size halibut are eaten, very large halibut which are likely older with higher contaminant burdens are also eaten. The size of an organism may be correlated with its age. Older specimens which have longer exposure durations may have higher tissue concentrations of chemicals that bioconcentrate over time (Gutenmann et al. 1992, USEPA 1995). Organic contaminants in fish have been shown to increase with age (Armstrong and Sloan 1980, Hansen et al. 1982). Fish length was positively correlated with total PCB concentrations in chinook salmon (Miller 1994) and with mercury concentrations in freshwater sportfish (Gilmour and Riedel 2000).

4.3 Timing of Sample Collections

The range of chemical concentrations in the sampled species over time periods that they are susceptible to harvest by Cook Inlet Alaskan tribal villagers has not been documented. The values presented in this report reflect chemical concentrations measured in whole body samples collected during the months of June and July 1997. The tissue concentrations measured in samples during this study may not be representative of tissue concentrations measured during other times of the year. It is unlikely that this one-time sampling is representative of contaminant concentrations in these species over the entire lifetime of a human who consumes these species.

4.4 Harvest Location

Harvest locations were intended to be representative of areas used by members of the four Alaskan tribal villages of Tyonek, Seldovia, Port Graham and Nanwalek. However, all possible harvest sites were not evaluated.

It was not determined whether harvest locations coincided with sediment depositional areas or locations where contaminant deposition could be linked with oil and gas operations in Cook Inlet. Additionally, no samples were collected from harvest sites known to be representative of background conditions; i.e. where Cook Inlet oil and gas operations would have no influence. Therefore, due to the sampling design confident conclusions linking identified contaminants to oil and gas operations can not be made.

4.5 Sample Type

The contaminant concentrations presented in this report are based on analyses of uncooked whole-body, unscaled fish samples. For the purposes of a contaminant survey, whole-body samples are representative of exposures to the fish or predators that consume the whole fish. However, chemical concentrations derived from a whole-body measurement may not be representative of exposures resulting from consumption of individual body parts.

Specimens were collected such that each fish in a composite sample was of similar size with the smallest length or weight no less than 75% of the largest (ADL 1997). Compositing of individual fish limits the information available for chemical concentrations in individual fish.

4.6 Chemical Analytes

One hundred sixty-one analytes were measured in fish, invertebrate, and plant tissues collected from Cook Inlet. While the chemicals analyzed in this study include ones that have often been detected in regional and national fish and shellfish monitoring programs (USEPA 1992, Tetra Tech 1996), a complete analysis of all possible chemical contaminants present in Cook Inlet sampled species was not conducted. Therefore, the potential presence of other contaminants, including those which could be associated with oil and gas operations in Cook Inlet, was not analyzed in this study and is unknown. However, many of the detected analytes have been previously reported in conjunction with oil and gas operations in Cook Inlet as indicated in Table 2-3.

4.7 Chemical Speciation of Inorganic Chemicals

Seven inorganic chemicals were measured (arsenic, barium, cadmium, chromium, lead, mercury, selenium). All of these have multiple chemical species (chemical forms). The hazard potential of the various chemical forms vary from practically nontoxic to very toxic. Except for arsenic, the various chemical forms were not separately measured. In the case of arsenic, several chemical forms of arsenic were measured. For this study, the potentially toxic forms which were measured included trivalent arsenic, pentavalent arsenic, dimethylarsinic acid or arsenosugars which can be metabolized to dimethylarsinic acid (Le et al. 1999). Dimethylarsinic acid has been classified by the EPA as a B2 carcinogen (USEPA 2001).

4.8 Concentrations Reported as Not Detected

In determining mean contaminant concentrations, only the detected values were used. However, the concentration in a sample reported as not detected can actually range from zero up to the reported detection limit.

Detection limits associated with the analytical methods used in this study should be carefully considered when using these data. In some cases, the detection limits were lower than limits in data sets for other comparable biota (e.g. polycyclic aromatic hydrocarbons). But, there were also cases in which detection limits were higher than limits in other data sets (e.g. dioxins and furans). The reported quantitation limits are provided (Appendix C).

4.9 Effects of Cooking and Preparation

Cooking can change chemical concentrations in fish through volatilization, loss of moisture, and changes in fat content (Skea et al. 1979). The concentrations of chemicals that tend to accumulate in fat tissue, such as PCBs, dioxins, and organochlorine pesticides tend to be lowered by cooking methods that reduce the fat content of the fish sample (Table 12). The cooking process can also increase the chemical concentrations in fish. Methylmercury binds strongly to proteins and therefore is found primarily in the muscle tissues of fish (Gutenmann and Lisk 1991). The weight reduction of a fish sample due to loss of moisture and fat content during cooking can increase the concentration of mercury in the fish tissue that is consumed (Table 12). The smoking of fish has also been shown to increase the concentration of PAHs in processed fish (Zabik et al. 1996).

The fish and invertebrate samples analyzed in this study were uncooked whole-body samples. The values shown in Table 13 illustrate that an analysis of an individual's exposure to chemicals in fish based on uncooked samples may be substantially different than their actual exposure to chemicals in cooked fish.

A wide variety of cooking methods were used in the studies which are summarized in Table 12. Cooking methods included smoking, broiling, deep frying, pan frying, baking, canning and boiling. This information is reviewed in the USEPA 2000 edition of "Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories", Volume 2, Appendix C (USEPA 2000). An important point which can be observed in the results shown in Table 12 is that, in general, for organic contaminants in fish cooking appears to result in a decrease of concentration. In contrast for mercury in fish tissue, cooking may result in an increase in concentration as confirmed by one study (Morgan et al. 1997).

Table 12. Change in the concentration of chemicals due to various cooking methods.

CHEMICAL	CHANGE IN CONCENTRATION (%)	REFERENCE
PCBs	-74 to +4	1, 2, 3, 4, 5, 6, 7, 8, 9, 12
Dioxins/Furans	-80 to -33	10, 11
DDT, DDE, DDD	-75 to -2	3, 5, 6, 7, 8, 11, 12
Chlordane	-37 to -39	10, 12
Dieldrin	-21 to -53	8, 10, 12
Mercury	+10 to +100	13

1	Armbruster et al. (1987)	6	Smith et al. (1973)	11	Schecter et al. (1998)
2	Moya et al. (1998)	7	Wilson et al. (1998)	12	Zabik et al. (1996)
3	Puffer and Gossett (1983)	8	Zabik et al. (1979)	13	Morgan et al. (1997)
4	Salama et al. (1998)	9	Zabik et al. (1995)		
5	Skea et al. (1979)	10	Zabik and Zabik (1995)		

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5.0 DISCUSSION

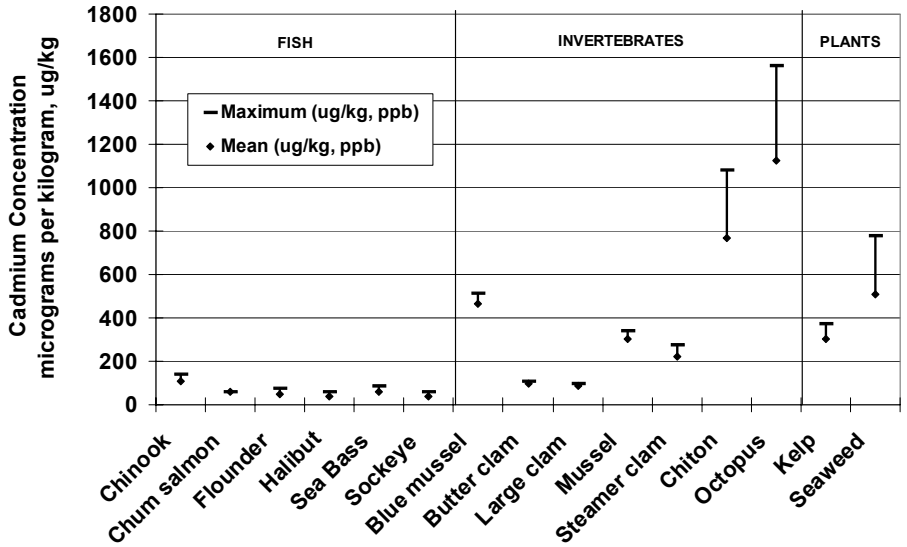
5.1 Comparisons of Cook Inlet Fish, Invertebrates and Plants

Average concentrations of total metals across all species ranged from 0.279 ppm to 8.4 ppm in goose tongue and snail tissue samples, respectively. Average concentrations of total arsenic in cod, flounder and halibut tissue samples were in the same range as the average concentrations in bivalve shellfish tissue samples. In contrast, total arsenic concentrations - both the average and the maximum concentrations - in salmon tissue samples (chinook, chum, and sockeye) were lower than total arsenic concentrations in all other species' tissue samples, except goose tongue. Concentrations of inorganic trivalent arsenic (As 3+) detected in flounder tissue samples were in the same range as As 3+ concentrations detected in blue mussel, butter clam, large clam and steamer clam tissue samples. In contrast, As 3+ concentrations detected in snail tissue samples were 2 to 10 times higher than concentrations detected in other samples. Dimethylarsinic acid (DMA) was detected more frequently in invertebrate and plant tissue samples than in fish tissue samples. Average DMA concentrations in fish were lower than all other samples, except blue mussel and octopus.

Barium was detected in all tissue samples except seaweed. It was detected in 69 of the 81 tissue samples analyzed. The range of mean tissue concentrations in fish (129 to 912 ppb), invertebrates (129 to 1063 ppb), and plant tissue samples (112 to 363 ppb) were similar.

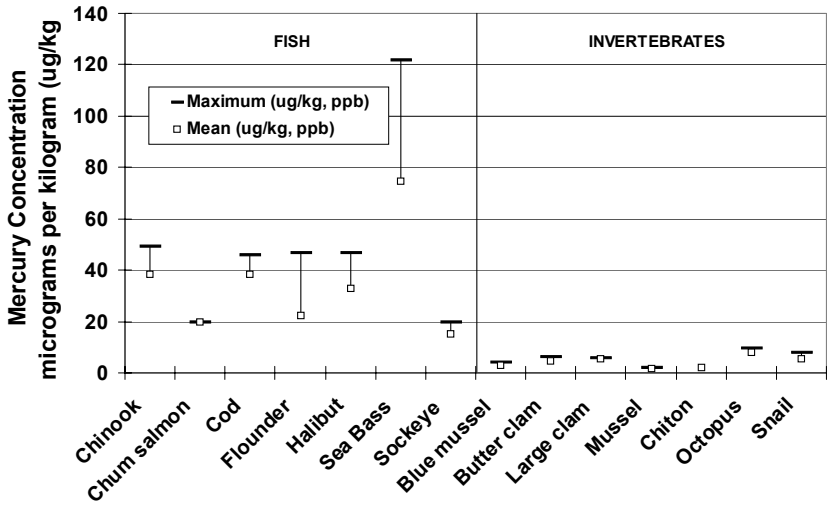
The range of average cadmium concentrations in fish tissue samples, 37 to 109 ppb, was lower than the range of average concentrations in invertebrate tissue samples, 100 to 1123 ppb (Figure 22). Average cadmium concentrations in snail tissue samples, 4493 ppb, were higher than all other samples (not shown in Figure 22).

Figure 22.
Cadmium Concentrations in Cook Inlet Fish, Invertebrate and Plant Tissue Samples (mean and maximum micrograms per kilogram, ug/kg, ppb).



Methylmercury concentrations in invertebrate tissue samples were approximately ten times lower than methylmercury concentrations detected in fish tissue samples (Figure 23).

Figure 23.
Methylmercury Concentrations in Cook Inlet Fish and Invertebrate Tissues Samples
(mean and maximum micrograms per kilogram, ug/kg, ppb).



Lead concentrations were detected more frequently in invertebrate tissue samples (range of averages 19 to 255 ppb) than in fish tissue samples (average 42 ppb). The range of mean selenium concentrations in fish (371 to 621 ppb) and invertebrate tissue samples (304 to 559 ppb) was similar.

The total concentration of polycyclic aromatic hydrocarbons (Total PAHs) varied considerably among the 81 tissue samples consisting of fish, invertebrates and plants (see also Appendix B). Goose tongue had the highest average concentrations (133 ppb), and cod tissue samples had the lowest concentrations (1 ppb).

Organochlorine pesticide detections occurred most often in the fish species. There were no detections of chlordane compounds, DDE, DDT, dieldrin, endosulfans or mirex in any of the invertebrate or plant tissue samples. DDD was the only pesticide detected in any of the plant tissue samples (goose tongue, 218 ppt).

While PCB congeners were detected in all of the fish tissue samples, no PCB congeners were detected in tissue samples of blue mussel, mussel, large clam, steamer clam, chiton, goose tongue, kelp, or seaweed.

5.2 Comparison With Regional and National Studies

Comparisons of inorganic arsenic, cadmium, chromium, lead, mercury, selenium, dieldrin, PAH, and PCB tissue concentrations measured in Cook Inlet tissues samples are made with similar data. Specifically, concentrations in Cook Inlet whole-body samples are compared with Columbia River whole-body sample results and FDA market basket sample results (USEPA, 2002; USFDA, 2000; USFDA 2003). Contaminant data from whole-body fish samples collected in 1996-9 from

the Columbia River provided the most comprehensive data set for comparisons to the whole-body samples collected in this study. These comparisons are intended to provide a general idea of how concentrations in Cook Inlet tissue samples compare with other locations. Statistical comparisons of the Cook Inlet data set with other data sets were not possible.

It should be noted that differences in analytical methods, analytical detection limits, the size of organisms analyzed, lipid content, and timing of sampling may all influence the conclusions discussed in this section. Some of the reasons that quantitative comparisons were not possible include: inability to determine whether variances in data sets were comparable, inability to determine if detection limits and analytical methods in data sets were comparable, inability to determine whether sampling designs were comparable (e.g. compositing, whole body, etc), and inability to determine whether species were comparable (e.g. could have been same species/genus but comparability of age, diet, habitat, etc could not be determined). Therefore, only qualitative comparisons were made.

The rational for comparison of Columbia River chinook and Cook Inlet chinook is discussed in this paragraph. Chinook salmon (*Oncorhynchus tshawytscha)* have two fundamental life histories referred to as "stream-type" and "ocean-type" life cycles. In North America, stream-type fish, which include the spring and summer races of chinook salmon, typically occur in northern latitudes and in the headwaters of more southern rivers. These fish usually spend one or more years rearing in fresh water before migrating to sea. Ocean-type fish, which includes the fall race, are typically found south of 56˚N on the Pacific Coast and usually migrate to the ocean in their first year of life (Healey 1991). Chinook salmon typically spend 3 to 4 years (range 2 to 8 years) feeding and growing in the ocean (Wydoski and Whitney 1979). Cook Inlet chinook salmon are 97 to 99 percent stream-type fish (Healey 1983). Both the Columiba River chinook and the chinook collected for this study, in Cook Inlet near Seldovia, Port Graham, and Tyonek, Alaska, are believed to be the stream-type race of chinook salmon.

5.2.1 Pesticides

Concentrations of organochlorine pesticides in Columbia River Spring and Fall chinook samples were 3 to 30 times higher as compared to concentrations in Cook Inlet finfish samples even though dieldrin and endrin were not analyzed in the Columbia River chinook samples (Figure 24). In Cook Inlet tissue samples, dieldrin and endrin concentrations accounted for ~5 to 15% of the total mass of organochlorine pesticides (Figure 16). Compared to FDA market basket samples, dieldrin concentrations in Cook Inlet samples were in the same general range of concentrations - except "salmon, baked" which was 2 to 20 times higher than any Cook Inlet sample (Figure 25).

Figure 24.
Organochlorine Pesticide Concentrations in Cook Inlet Fish Tissue Samples and Columbia River Chinook Tissue Samples (mean micrograms per kilogram, ug/kg, ppb)

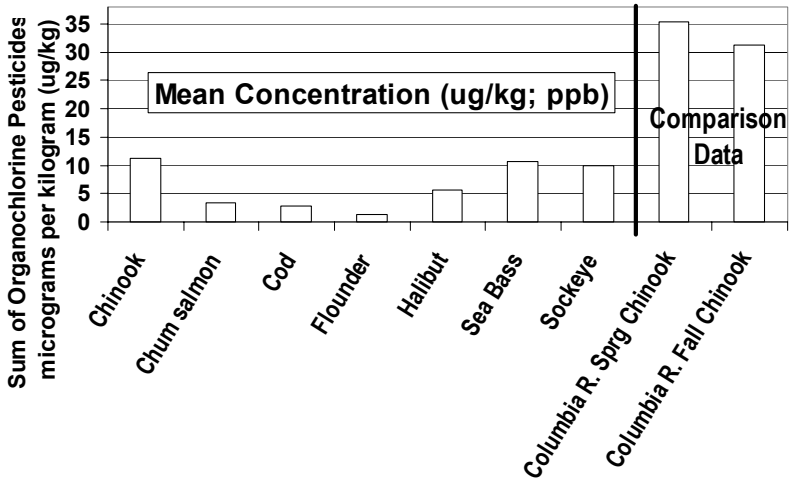
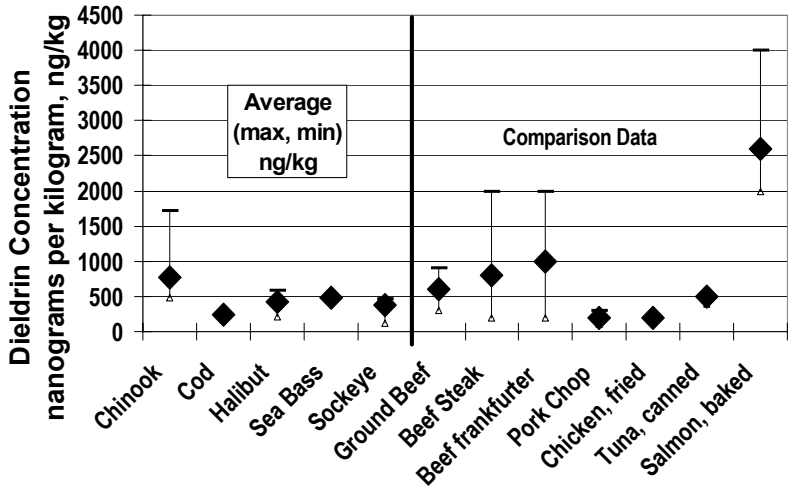
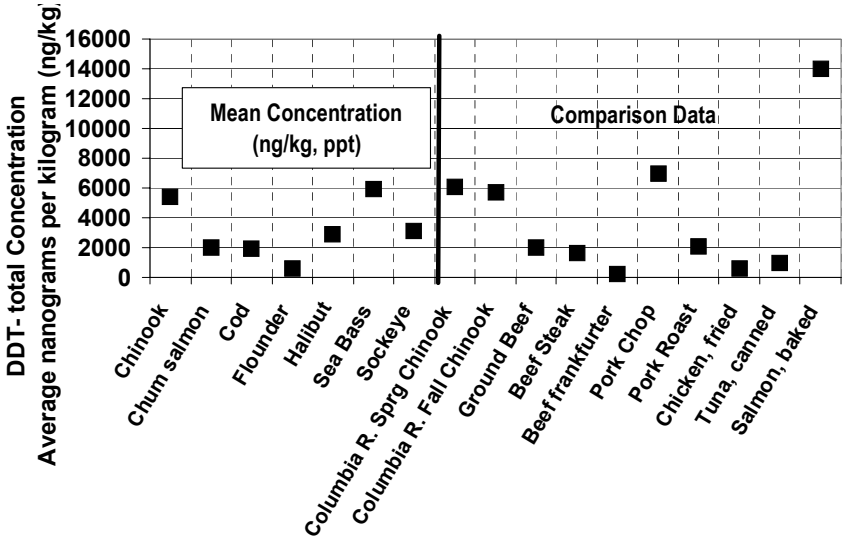


Figure 25.
Dieldrin Concentrations in Cook Inlet Fish Tissue Samples and FDA Market Basket Samples (average, maximum and minimum nanograms per kilogram, ng/kg, ppt)



Average concentrations of DDT compounds (DDT-total) in Cook Inlet chinook and sea bass tissue samples were in the range of average concentrations in Columbia River chinook tissue samples (Figure 26).

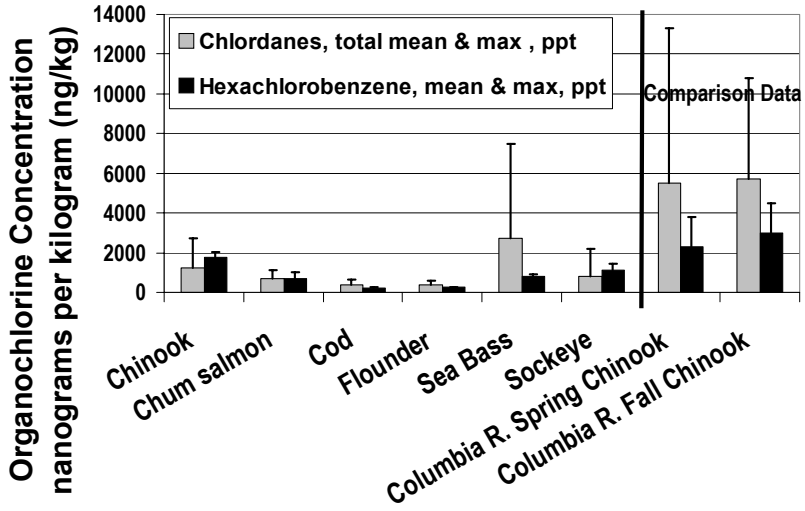
Figure 26.
DDT-total Concentrations in Cook Inlet Fish Tissue, Columbia River Chinook Tissue and FDA Market Basket Samples (average nanograms per kilogram, ng/kg, ppt)



DDT-total concentrations of other Cook Inlet fish samples were less than concentrations in Columbia River chinook tissue samples (Figure 26). DDT-total accounted for the greatest percentage of organochlorine pesticides in both Columbia River samples and Cook Inlet Samples. In Columbia River chinook samples, DDT-total represented 70% of the total organochlorine pesticides, and in the Cook Inlet samples DDT-total represented 30% to 70% (lowest: sockeye; highest: cod).

In both Columbia River and Cook Inlet samples, chlordane compounds (sum of alpha-, gamma-, cis-nonachlor and trans-nonachlor) and hexachlorobenzene were the other major contributors to the total concentration of organochlorine pesticides (Figure 27). Average concentrations of chlordane compounds in all Cook Inlet finfish samples were lower compared to Columbia River chinook results. The approximate average for both Columbia River Spring and Fall chinook was 5.5 ppb. The highest average concentration of chlordane compounds in Cook Inlet fish samples was found in sea bass samples (2.5 ppb). Among the Cook Inlet samples, a single composite sea bass sample had the highest maximum concentration of chlordanes (7.5 ppb). The maximum concentrations of chlordane compounds in Columbia River Spring and Fall chinook were approximately 13.3 ppb and 10.8 ppb, respectively. Except for Cook Inlet chinook and sockeye samples, both the average and maximum hexachlorobenzene concentrations were less than the average concentrations in Columbia River Spring and Fall chinook (Figure 27). For Cook Inlet chinook and sockeye samples, the maximum concentrations of hexachlorobenzene exceeded Columbia R. Spring chinook average concentrations (Figure 27).

Figure 27.
Chlordanes (total) and Hexachlorobenzene Concentrations in Cook Inlet Fish Tissue Samples and Columbia River Chinook Tissue Samples (average and maximum nanograms per kilogram, ng/kg, ppt)



5.2.2 PAHs

Comparison of total PAH concentrations between Cook Inlet samples and Columbia River samples was not possible due to significant differences in the analytical methods used to extract and detect the individual PAH compounds. An enhanced method was utilized for the the Cook Inlet samples, hence many individual PAH compounds were detected. The individual PAH compounds, acenaphthene and 2-methylnaphthalene, were detected in both Cook Inlet chinook samples and Columbia River Spring chinook samples. Comparisons of concentrations of these two individual PAH compounds are shown in Figure 28. Average concentrations of both individual PAH compounds were higher in Columbia River Spring chinook samples as compared to Cook Inlet chinook samples.

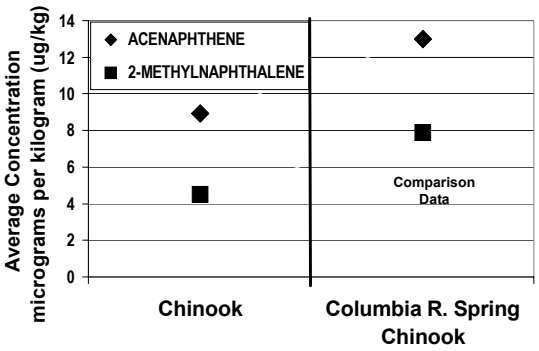
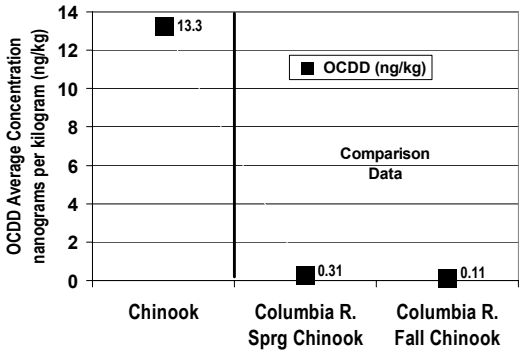


Figure 28.
Polycyclic Aromatic Hydrocarbon Compound Concentrations in Cook Inlet Chinook Tissue Samples and Columbia River Spring Chinook Tissue Samples (micrograms per kilogram, ug/kg, ppb)

5.2.3 Dioxins and Furans

In the Columbia River composite Spring and Fall chinook samples, basin wide average concentrations of the sum of chlorinated dioxins and furans were approximately 2 ng/kg. In Columbia River Spring chinook samples, 17 different dioxin or furan congeners were detected. While in Columbia River Fall chinook samples, 9 different dioxin or furan congeners were detected. However, the analytical detection limits in methods used for the Cook Inlet tissue samples were higher than the analytical detection limits in methods used for the Columbia River tissue samples. For example, for 2,3,7,8-TCDD the Cook Inlet study detection limits were 70 times higher than limits in the Columbia River Study.

Figure 29.
OCDD Concentrations in Cook Inlet Chinook and Columbia River Chinook Tissue Samples (average nanograms per kilogram, ng/kg, ppt)



OCDD concentrations were detected in one of six Cook Inlet chinook composite samples. In the Columbia River samples, OCDD was detected in 21 of 24 Spring chinook samples and 3 of 15 Fall chinook samples. OCDD average concentrations in the Cook Inlet chinook sample were approximately 40 times higher than basin wide average concentrations detected in Columbia River Spring or Fall chinook samples (Figure 29).

5.2.4 Mercury

Methylmercury concentrations were not measured in Columbia River tissue samples or FDA market basket samples. However, a common assumption is that virtually 100% of the mercury present is in the form of methylmercury. The following discussion compares methylmercury concentrations in Cook Inlet tissue samples and total mercury concentrations in other samples.

Except for Cook Inlet chinook and sea bass samples, average mercury concentrations were lower than average concentrations in Columbia River Spring and Fall chinook as well as the FDA market basket samples of canned tuna and baked salmon (Figure 30). The average mercury

concentration of Cook Inlet chinook samples was slightly higher than the FDA market basket baked salmon sample; however, both the average and maximum mercury concentrations were lower than concentrations in Columbia River Spring and Fall chinook and FDA market basket canned tuna samples. In Cook Inlet sea bass samples, the average mercury concentration was similar to average concentrations in Columbia River Spring and Fall chinook. In contrast, Cook Inlet sea bass mercury concentrations were higher than FDA market basket baked salmon samples and less than FDA market basket canned tuna samples (Figure 30).

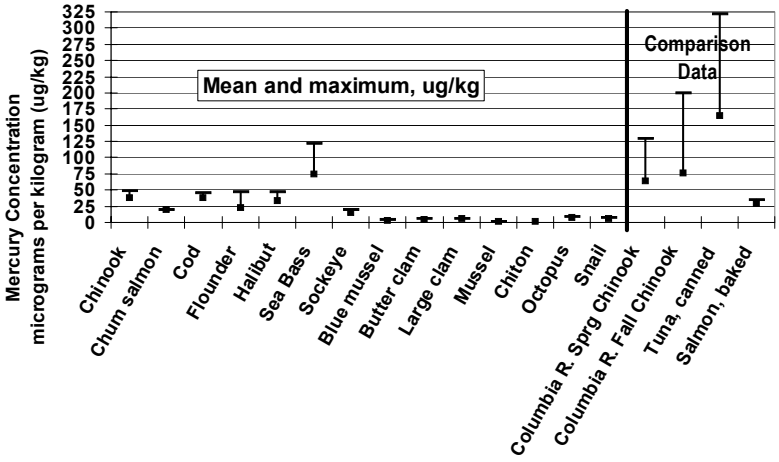


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Figure 30. Mercury Concentrations in Cook Inlet Tissue Samples, Columbia River Chinook Tissue Samples and FDA Market Basket Samples (mean and maximum micrograms per kilogram, ug/kg, ppb)

5.2.5 Cadmium

Except for Cook Inlet chinook samples, cadmium concentrations in Cook Inlet fish tissue samples were less than cadmium concentrations in Cook Inlet invertebrate and plant tissue samples (Figure 31). Average cadmium concentrations in Cook Inlet chinook tissues samples, were approximately the same as average cadmium concentrations in Cook Inlet butter clam and large clam samples.

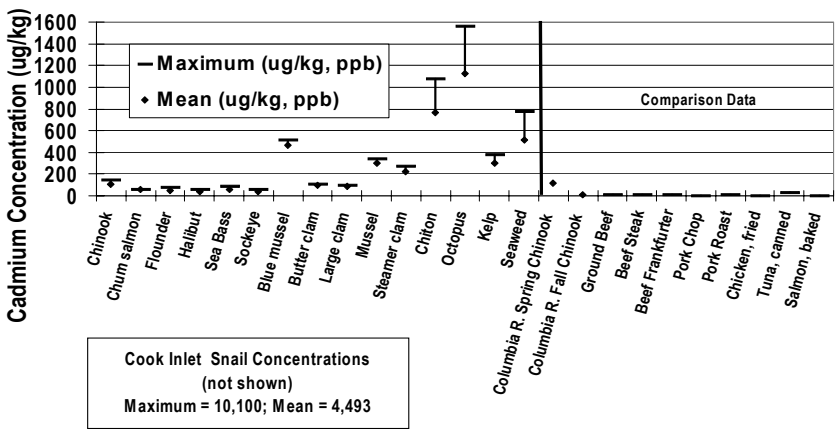

Figure 31. Cadmium Concentrations in Cook Inlet Tissue Samples, Columbia River Chinook Tissue Samples and FDA Market Basket Samples (mean and maximum micrograms per kilogram, ug/kg, ppb)

Average and maximum cadmium concentrations in Cook Inlet snail tissues samples greatly exceeded all other samples' tissue concentrations (4,493 and 10,100 ug/kg, respectively). Cook Inlet octopus tissue samples had the next highest cadmium concentrations. Average cadmium concentrations in Columbia River Spring chinook samples were slightly higher than Cook Inlet chinook samples.

Only maximum concentrations were available for FDA market basket samples (Figure 31). Cadmium concentrations in all the Cook Inlet samples were higher than the maximum concentrations in FDA market basket samples.

A report by the Agency for Toxic Substances and Disease Registry states, "Cadmium has been detected in nearly all samples of food analyzed with sufficiently sensitive methods." and "Shellfish, liver and kidney meats have higher concentrations than other fish or meat (up to 1 ppm). Particularly high concentrations of cadmium of 2-30 mg/kg (ppm) have been found in edible meat of marine shellfish" (ATSDR, 1999). In this study, mean cadmium concentrations in tissue samples were less then 30 ppm, the high end of the ATSDR range.

5.3 Nutritional Comparisons

The nutritional composition of Cook Inlet tissues sample in this study was not measured. The values shown in Table 13 were obtained from the literature (USDA 2003). In Table 13, the nutrient composition of the tissue types collected in this study are compared with commercial protein foods (chicken, hamburger, pork, lamb) or green vegetables (broccoli, celery). Based on the published values, the fish and invertebrate tissue are assumed to be lower in saturated fat, higher in Vitamin A and selenium, and provide more energy from protein than from fat as compared to the chicken, hamburger, pork and lamb shown in the table. Seaweeds are higher in protein, energy, calcium and iron than broccoli or celery.

Table 13. Nutrient Composition of Foods (per 100 grams)

Food Item	kcal	protein (g)	fat (g)	fatty acids, saturated (g)	Carbohydrate (g)	Moisture (g)	Ash (g)	Calcium (mg)	Iron (mg)	Selenium (ug)	Vit A (RE)	Thiamin (mg)	Riboflavin (mg)	Niacin (mg)	Ascorbic acid (mg)
Chinook Salmon, raw	180	20	10.4	2.5	0	73.2	1.4	22	0.7	37	136	0	0.1	7.8	4
Chum Salmon, raw	120	20	3.8	0.8	0	75.4	1.2	11	0.6	37	30	0.1	0.2	7	0
Sockeye Salmon, raw	168	21.3	8.6	1.5	0	70.2	1.2	6	0.5	34	58	0.2	0.2	5.8	0
Sea Bass, raw	94	18.8	1.6	0.4	0	79.3	1.2	9	0.4	37	57	0	0.1	3.2	0
Cod, raw	82	17.9	0.6	0.1	0	81.3	1.2	7	0.3	37	8	0	0	2	2.9
Flounder, raw	91	18.8	1.2	0.3	0	79.1	1.2	18	0.4	33	10	0.1	0.1	2.9	1.7
Halibut, raw	110	20.8	2.3	0.3	0	77.9	1.4	47	0.8	37	47	0.1	0.1	5.9	0
Mussel, raw	86	11.9	2.2	0.4	0	80.6	1.6	26	3.9	45	48	0.2	0.2	1.6	8
Clam, raw	74	12.8	0.9	0.1	0	81.8	1.9	46	14	24	90	0.1	0.2	1.8	13
Chiton, raw	83	17.1	1.6	--	0	78.6	3.7	121	16		495	0.1	0.3	4.2	0
Octopus, raw	57	11.9	0.6	--	0.9	84.4	2.2	24	5.3		0	0	0	2.1	0
Kelp, ribbon, dried	323	19.9	0.6		60	7.2	13	190	11		2	0.1	1	6.9	4.8
Kelp, raw	43	1.7	0.6		9.6	81.6	6.6	168	2.9		12	0.1	0.2	0.5	3
Porphyra seaweed, dried	43	24.4	1.4		48	10	16	230	2.9		113	--	--	--	--
Broccoli, raw	28	2.9	0.35		5.2	90.7	0.9	48	0.9	3	154	0.1	0.1	0.6	93
Celery, raw	16	0.75	0.14		3.7	94.6	0.8	40	0.4	0.9	13	0.1	0.1	0.3	7
Chicken, meat & skin, raw	215	18.6	15.1	4.3	0	65.9	0.8	11	0.9	14	41	0.1	0.1	6.8	1.6
Hamburger, fast food, plain	305	13.7	13.1	4.6	34	37.6	1.7	70	2.7	24	0	0.4	0.3	4.1	0
Hamburger, patty, sndwch	311	16.5	16.7	6.1	23	42.1	1.5	54	2.6	20	0	0.2	0.2	4.6	0
Pork, retail cuts, raw	143	21.1	5.9	2	0	72.3	1	16	0.9	32	2	1	0.3	4.8	0.7
Lamb, ground, raw	282	16.6	23.4	10	0	59.5	0.9	16	1.6	19	0	0.1	0.2	5.9	0

5.5 Conclusions

Seven fish species, eight invertebrates and three plant species were sampled and analyzed for concentrations of 161 chemicals. These results provide a good survey data set for environmental chemicals present in uncooked, whole body samples of these Cook Inlet biota. There were detections of global contaminants: mercury, organochlorine pesticides, and PCB congeners. There was minimal detection of another ubiquitous contaminant group, dioxins and furans. The minimal detection of dioxins and furans may be an artifact of the analytical detection limits associated with the methods used in this study. The detection of many individual PAH compounds in the Cook Inlet tissue samples may have resulted from the use of enhanced analytical methodology. Approximately one-half of the 104 PAHs were detected in fish, invertebrate and plant samples. Chinook tissue samples had the highest total average PAH concentration (253 ppb). This gives the appearance of relatively high total PAH concentrations. However, this is an uncertain finding which would benefit from additional verification.

Although the EPA has no current plans for additional studies, these results can contribute important information to the design of future investigations undertaken by others. Since most trace metals naturally occur in biota and many organic chemicals are worldwide contaminants, it will be important for future study designs to carefully consider the comparison or control data set that will be needed.

In addition, this report provides the individual data on an accompanying compact disk (Appendix C). With these data, other queries can be made. For example, segregating data and calculating descriptive statistics (e.g. mean concentrations) by location (e.g. beach collection sites) or by group characteristics (e.g. hatchery salmon and wild salmon) may provide another view of the results. The evaluation of polycyclic aromatic hydrocarbon patterns may also provide additional insight. The availability of these data is a significant product of this study (Appendix C).

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