

Bandon Marsh National Wildlife Refuge

evaluation of cleanup activities on an adjacent wood treatment facility

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EXECUTIVE SUMMARY

Bandon Marsh National Wildlife Refuge (NWR) is located in the Coquille River estuary, approximately one mile upstream from the mouth of the Coquille River in Bandon, Oregon. An abandoned wood treatment facility and associated dump site is located within 0.25 mile of the refuge. Concerns developed over the movement of contaminants from the dump onto the refuge due to chemical spills and poor wood treatment procedures that occurred during plant operations. This study was undertaken to determine if contaminants associated with the wood treatment facility and the dump site were entering Bandon Marsh NWR, and to assess the potential hazard to fish and wildlife using the area.

Several matrices were evaluated for contamination. Surface water and sediment samples were collected from six sites; clam tissue was collected from four sites. Two sampling sites on the refuge and furthest from the dump on the refuge were used as reference sites. Chemical analyses included scans for trace elements, organochlorine pesticides, total and congener-specific polychlorinated biphenyls, dioxins and furans, polyaromatic and aliphatic hydrocarbons, total petroleum hydrocarbons, and pentachlorophenol. Criteria for both freshwater and marine systems were used to interpret water concentrations because the study area is estuarine. Criteria for both soil and sediment were used to interpret sediment concentrations due to the lack of available sediment guidelines for comparison.

Elevated concentrations of several trace elements were observed in water, sediment, and tissue samples. Cadmium, chromium, iron, lead, and nickel concentrations in water samples exceeded Federal and State freshwater or marine chronic criteria for the protection of aquatic life. Trace element concentrations in the intermediate sediment sample were generally greater than those in sediments associated with the refuge or dump. Sediment concentrations of arsenic, chromium, and nickel concentrations in the intermediate sample exceeded most guidelines. Barium concentrations in one dump sediment sample slightly exceeded Environmental Protection Agency (EPA) guidelines. Copper and iron concentrations were elevated relative to sediment criteria used by the Ontario Ministry of the Environment. The distribution of trace elements in water and sediment samples suggests that there are localized areas in which contaminants may pose a threat to fish and wildlife, though the dump does not appear to be the source. Sixteen trace elements were detected in clam tissue samples, however, few guidelines were available to assist in the interpretation of these residue levels. Chromium levels exceeded Eisler's (1986a) recommended criteria for the protection of predators, but were well below the U.S. Food and Drug Administration's (1993c) Level of Concern for humans consuming molluscan bivalves.

In general, water and sediment organochlorine (OC) pesticide concentrations did not appear to be at levels harmful to aquatic resources, yet the presence of these compounds in water indicated a relatively recent exposure. Three OC pesticides were detected in water samples from the dump and two compounds were detected in water from the intermediate sample; all other samples, including all refuge samples, were below detection limits in both the water and sediment matrices. Fifteen OC pesticides were detected in tissues from the dump location and one compound was detected in the intermediate sample; no OC pesticides were detected in clam tissue from the refuge samples. Tissue concentrations of heptachlor epoxide and total DDT (sum of the concentrations of p,p'-DDT, p,p'-DDE, and p,p'-DDD and their ortho-para isomers) in dump samples exceeded their respective criteria and may represent a hazard to fish and wildlife using the area. The presence and distribution of organochlorine pesticides in water and tissue samples indicated the dump was the probable contaminant source.

Although concentrations of total polychlorinated biphenyls (PCBs) in sediments were negligible, total PCB residues in water and tissue samples were well above available guidelines. Bioaccumulation of total PCBs in animal tissue could present a serious threat to fish and wildlife resources. Total PCB concentrations were found in tissue from all sampling locations, with

dump samples being 5 to 8 times higher than those from the refuge. This contamination pattern suggests a potential movement from the dump location.

Individual PCB congeners were detected in water and tissue samples, and in one sediment sample, in a pattern indicating that the dump location may be the origin of the PCB congeners in the area. Detection limits used in the analysis of congener-specific PCBs in water were above recommended guidelines for freshwater and marine systems. Thus, the detection of any congener-specific PCBs in water samples suggests a potential hazard to aquatic organisms. Tissue concentrations did not appear elevated, but the toxicity of most individual PCBs analyzed in this investigation is not known.

Dioxins and furans, polyaromatic and aliphatic hydrocarbons, and pentachlorophenol were not found at levels indicating potential hazards to aquatic organisms in any sample matrix. Total petroleum hydrocarbon (TPH) concentrations in water samples were also below guidelines (Woodward *et al.* 1981, Woodward and Riley 1983) and pose no apparent threat to fish and wildlife. TPH concentrations in sediments and tissues were elevated relative to available criteria, particularly in the dump and intermediate samples, respectively. However, these TPH values appear to be primarily biogenic in origin.

Results from this investigation indicate that total PCBs and some OC pesticides are moving from the dump to adjacent areas. Confirmation sampling, further characterization of the former Moore Mill dump site, and remediation activities are necessary to adequately protect aquatic life from impacts associated with these contaminants in the water. Acquisition of the tidelands south of the existing refuge boundary for incorporation into the refuge should continue to be postponed until the source of the contamination can be determined and remediated.

BACKGROUND

Bandon Marsh National Wildlife Refuge (NWR) is located in Coos County, Oregon along the west bank of the Coquille River, approximately one mile upstream from the mouth of the river (Figure 1). It is one of the largest of the few remaining salt marsh ecosystems along the Oregon Coast and provides important marsh and estuarine habitat for migrating shorebirds, waterfowl, and anadromous fish. Portions of the refuge are also used by the endangered peregrine falcon (*Falco peregrinus*) and California brown pelican (*Pelecanus occidentalis*), and the threatened bald eagle (*Haliaeetus leucocephalus*).

An abandoned wood treatment facility and associated dump site, formerly owned by Moore Mill and Lumber Company (Moore Lumber), is located within 0.25 mile of the southern boundary of the refuge (Figure 1). The mill began operation in 1909 and disposed of wastes at the dump site until its closure in 1986. The dump site, located just south of the refuge on former mudflats in the Coquille River estuary, covers approximately 10 to 15 acres with an average depth of 8 to 10 feet. The base and slope of the dump site, on the north and west sides, are inundated by tidal flows on a daily basis. A freshwater stream with tidal influence is located along the east side of the fill. The dump contains phenol and other wood preservative products, treated wood, fill materials, and miscellaneous debris. Chemical spills and poor wood treatment procedures, such as preserving wood directly over the estuary, were noted during the mill's operation (Ecology and Environment, Inc. 1988).

In 1985, the Oregon Department of Environmental Quality (ODEQ) collected soil and water samples at the mill and found elevated concentrations of several phenol compounds at various locations on the property (Ecology and Environment, Inc. 1988). Tetrachlorophenol (TCP) was detected in both soil and wood waste samples at concentrations up to 1,720 mg/kg and 1,100 mg/kg, respectively. Pentachlorophenols (PCP) were also found in soil and waste samples, at concentrations of 700 mg/kg and 680 mg/kg, respectively (Ecology and Environment, Inc. 1988). Because of such elevated contaminant levels, ODEQ recommended that additional sampling and monitoring be conducted on the site.

Moore Lumber closed the sawmill in 1986, citing economic reasons. Although an environmental assessment was recommended by ODEQ in 1985, a revised assessment proposal by Riedel Environmental Services, Inc. (Riedel), submitted by Moore Lumber, was not accepted until early 1986. At the time of closure, no assessment activities had been initiated. In August of 1987, a fire destroyed the sawmill, consuming all wood products present in the building. Following the fire, Ecology and Environment, Inc., Technical Assistance Team (TAT), sent by the U.S. Environmental Protection Agency Superfund Response and Investigations Section, and Riedel (contracted by Moore Lumber) conducted independent site assessments at the former Moore Lumber facilities. Riedel began field work in August 1987, as outlined in a modified sampling program designed by ODEQ. Riedel installed three shallow monitoring wells (one designated as background) to assess the seasonal impact of contaminants on subsurface water. Phenols were detected at two monitoring wells and concentrations (126-128 mg/L and 18-20 mg/L) were elevated relative to the background well (below laboratory detection limits; Ecology and Environment, Inc. 1988). Limited water and sediment surveys were also conducted, in cooperation with ODEQ, to replicate ODEQ's 1985 sampling. In October 1987, Ecology and Environment's TAT performed their site assessment. Results of water and sediment samples indicated that phenolic compounds were moving into the estuary (Ecology and Environment, Inc. 1988). Dioxin and furan compounds were also detected on the premises (Ecology and Environment, Inc. 1988). Although both groups found decreased levels of phenolic compounds relative to the 1985 sampling, certain areas of the property still contained measurable or elevated concentrations of contaminants (Ecology and Environment, Inc. 1988). The Ecology and Environment TAT determined that the site did not warrant emergency removal actions under

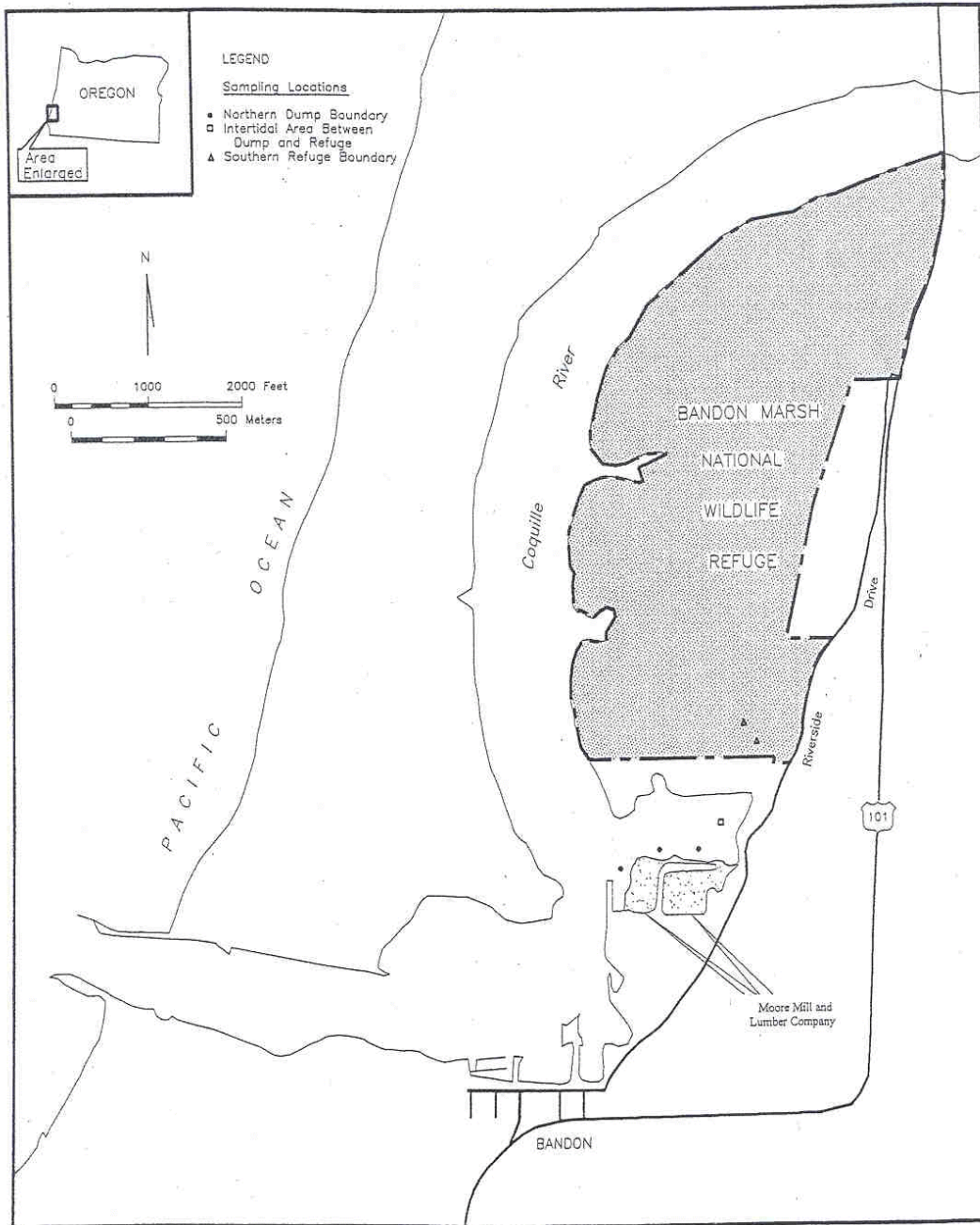


Figure 1: Sampling locations for the FWS cleanup evaluation of Moore Mill and Lumber Company in Bandon, Coos County, Oregon.

Superfund, but they expressed concern over the uncontrolled nature of the site (Oregon Department of Environmental Quality 1990). The TAT also noted that phenolic compounds were migrating into the estuary primarily from either surface runoff or infiltration via subsurface pathways (Ecology and the Environment, Inc. 1988). Consequently, there was concern that waste products at the dump site could pose a threat to the refuge and to natural resources in the area.

In 1990, chemical drums were found by U.S. Fish and Wildlife Service (Service) personnel on top of the dump. One of these drums was labeled contains chlorinated hydrocarbons . Water on top of the dump was discolored and draining off the dump onto the surrounding mudflat. Numerous areas of standing water on the mudflat around the dump were discolored and the discolorations appeared to be associated with the water flows draining off the dump site.

Due to these observations and knowledge of past practices, the potential for contaminants draining off the dump and onto the refuge was suspected. The purpose of this investigation was to determine if monitoring and cleanup activities following the facility's closure were adequate to protect fish and wildlife and whether additional cleanup actions are needed.

METHODS

Sample Collection

Evaluation of cleanup activities at Moore Lumber was assessed by collecting samples between the refuge and dump site for chemical analyses of trace elements, organochlorine pesticides, total and congener-specific polychlorinated biphenyls, dioxins and furans, polyaromatic and aliphatic hydrocarbons, total petroleum hydrocarbons, and pentachlorophenol (Table 1). Water, sediment, and tissue (softshell clam, *Mya arenaria*) were collected on August 17 and 18, 1993. Water and sediment samples were collected from six sites: three sites on the northern boundary of the dump adjacent to the refuge (dump samples), one site between the dump and the refuge (intermediate sample), and two sites on the southern refuge boundary adjacent to the dump (refuge samples; Figure 1).

At each site, three to four liters of water were collected in chemically-cleaned, one-liter bottles and mixed in a stainless steel pail. One liter of water from the pail was collected in a glass bottle and acidified to $\text{pH} < 2$ with ultra pure concentrated nitric acid; another liter of water was collected for analysis of organic contaminants. All water samples were transported on Blue Ice® to the Oregon State Office and stored at 4°C prior to shipment to an analytical facility.

Sediment samples were collected from each site using a stainless steel spoon and mixed in a stainless steel pan. Composited sediment was spooned into chemically-cleaned sample jars and placed in a cooler with Blue Ice®. Samples were then transferred to the Oregon State Office and stored at -20°C prior to shipment to an analytical facility.

One composite sample of invertebrate tissue containing 3 to 6 clams was collected from each of four sites: adjacent to the dump, between the dump and the refuge, and from two locations at the refuge boundary (Figure 1). Clams were collected by hand. Clam tissue was removed from the shell and placed in chemically-cleaned glass specimen jars, transported on dry ice to the Oregon State Office, and stored at -20°C prior to shipment to an analytical facility.

Sample collection techniques, and sample handling, storage, and shipment procedures followed Quality Assurance/Quality Control (QA/QC) guidelines documented in Standard Operating Procedures (SOPs) developed at the Oregon State Office and QA/QC procedures documented in the Service's Biomonitoring Operations Manual (Rope and Breckenridge 1993).

Table 1. Chemical analyses performed on water, sediment, and tissue samples.

Analytes	Matrix		
	Water	Sediment	Tissue
Trace Elements	x	x	x
Organochlorine Pesticides and Total Polychlorinated Biphenyls	x	x	x
Congener-Specific Polychlorinated Biphenyls	x	x	x
Dioxins and Furans			x
Polyaromatic Hydrocarbons	x	x	x
Aliphatic Hydrocarbons	x	x	
Total Petroleum Hydrocarbons	x	x	x
Pentachlorophenol	x	x	

Sediment and invertebrate tissue samples were shipped on dry ice and water samples were shipped with Blue Ice® by overnight carrier to the Research Triangle Institute (RTI), and to the Geochemical and Environmental Research Group (GERG) of Texas A&M University. RTI conducted trace element analysis on water, sediment, and tissue samples. GERG conducted all other analyses (Table 1).

Sample Analysis

Water and sediment samples were analyzed for trace elements, organochlorine pesticides and total polychlorinated biphenyls (PCBs), congener-specific PCBs, polyaromatic hydrocarbons (PAHs), aliphatic hydrocarbons, total petroleum hydrocarbons (TPHs), and pentachlorophenol (PCP). Invertebrate tissue samples were analyzed for dioxins, furans, organochlorine pesticides and total PCBs, PAHs, congener-specific PCBs, TPHs, and trace elements. Acceptable performance (recovery variation average of <20% for all chemicals detected) on spikes, blanks, and duplicates were documented in laboratory quality control reports.

Analyses for trace elements were performed by either inductively coupled plasma emission spectrometry (ICP) or graphite furnace atomic absorption (GFAA) spectrometry (Haseltine *et al.* 1981, Perkin-Elmer Corporation 1985). ICP measurements used a Leeman Labs Plasma Spectrometer I sequential or an ES2000 simultaneous spectrometer. GFAA measurements used either a Perkin-Elmer Zeeman 3030 or 4100ZL atomic absorption spectrometer. Mercury was analyzed by cold vapor atomic absorption (CVAA) and employed a Leeman PS200 Hg Analyzer using carbon-14 labeled tin as the reducing agent.

Organochlorine, aromatic, and aliphatic compounds in water, sediment, and tissues were extracted using alumina/silica gel chromatography. Concentrations were determined by capillary gas chromatography (CGC) with electron capture for organochlorines and PCBs, a mass spectrometry detector (SIM mode) for aromatic hydrocarbons, and a CGC with a flame

ionization detector for aliphatic hydrocarbons (Wade *et al.* 1988). TPHs in sediment and tissues were extracted using methods developed by the National Oceanic and Atmospheric Administration (NOAA) Status and Trends Program (MacLeod *et al.* 1985), with minor revisions (Brooks *et al.* 1989; Wade *et al.* 1988). TPH concentrations in all matrices were determined using gravimetry. Pentachlorophenol concentrations in water and sediment were determined using mass spectrometry. Dioxin and furan concentrations in invertebrate tissue were determined using high-resolution gas chromatography/high resolution mass spectrometry as described by Tondeur (1987) and U.S. Environmental Protection Agency (1990). All analytes and detection limits are presented in the appendices.

Data Interpretation

Contaminants found in various matrices in the present study were evaluated by comparisons to criteria, guidelines, and other research to determine if concentrations could be hazardous to fish and wildlife. Potential environmental impacts from contaminants considered in the present study are discussed in detail for each sampling matrix. Relatively little is known about the interactive effects of multiple compounds on biological systems.

Interpretation of contaminant concentrations in sample matrices and extrapolation to impacts on fish and wildlife populations is difficult to determine in estuarine environments. Such systems are subject to both freshwater and marine influences, and it is difficult to determine the specific threshold of effect for each compound. Consequently, both freshwater and marine criteria were considered when discussing the results. Most of our interpretations are based on freshwater criteria, as they are generally more conservative and more readily available than marine criteria.

Because information is sparse regarding guidelines for sediment contamination, results obtained during this investigation were compared to both sediment criteria (when available) and soil criteria. Although the use of soil criteria to evaluate sediment contamination is not accurate because contaminants in sediments are generally more bioavailable than those in soils, it does provide a frame of reference for evaluating contaminant concentration. Moreover, it should be noted that contaminant concentrations in soils that pose no risk to fish and wildlife may in fact be hazardous when present at the same concentrations in sediment due to increased bioavailability in sediments.

Compounds that were not detected were assigned a value of one-half the detection limit for computational purposes. Concentrations of aliphatic compounds were summed for each sediment sample to provide a total aliphatic concentration for data comparison. PAH compounds were classified as either carcinogenic or noncarcinogenic according to Eisler (1987) and summed for comparison between sampling locations (Appendix V).

RESULTS AND DISCUSSION

Trace Elements

Trace elements can be lethal to aquatic organisms over a wide range of concentrations, with toxicity depending on a number of biotic and abiotic factors. Toxicities of cadmium, chromium, copper, lead, nickel, and zinc are affected by temperature, pH, presence of inorganic and organic matter, hardness, and interactions with other elements. In general, these elements are less readily dissolved in water with high organic matter, suspended particles, or elevated hardness. Thus, their availability and apparent toxicity are substantially reduced under these conditions. Anthropogenic sources that may elevate trace elements above background levels in surface water include electroplating, smelting, and mining industries; industrial and municipal discharges and sewage; atmospheric deposition from combustion of fossil fuels and solid wastes; road surface

runoff; and fertilizers, some pesticides, and erosion from agricultural areas.

Water Samples

Fourteen elements were present at concentrations above detection limits; however, established water quality criteria and guidelines were available for only six elements: cadmium, chromium, iron, lead, nickel, and zinc (Table 2). Total chromium and zinc concentrations were below the Lowest Ambient Water Quality Criteria (LAWQC) issued by the U.S. Environmental Protection Agency (1995). Concentrations of lead and nickel exceeded the LAWQC in samples from all locations. Although method detection limits for cadmium exceeded the LAWQC criteria, intermediate and refuge samples were detected above criteria levels. The LAWQC represents the lowest of the freshwater, marine, or human health water quality criteria established by the U.S. Environmental Protection Agency (EPA), where hardness-dependent freshwater aquatic life criteria was adjusted to reflect the worst case scenario of 25 mg/L CaCO₃ (U.S. Environmental Protection Agency 1995).

The Oregon Department of Environmental Quality (1991) and Environmental Protection Agency (1986) hardness-dependent freshwater guidelines for acute and chronic exposure presented in Table 2 were calculated using a concentration of 100 mg/L CaCO₃. Because toxicity decreases as hardness increases, and the water hardness of samples collected at Bandon was not known, the relationship between these guidelines and levels detected in collected samples may not represent the actual trace element contamination in water in the area. Criteria from the Environmental Protection Agency (1986) and the Oregon Department of Environmental Quality (1991) are more conservative than the LAWQC, which represents the worst case scenario.

Boron concentrations were similar in water from all sampling locations. Limited data suggests that the no-observable-effect levels for aquatic macroinvertebrates were 13,600 µg/L for freshwater organisms and 37,000 µg/L for marine biota (Eisler 1990). The 16-day LC50 value for coho salmon (*Oncorhynchus kisutch*) was 12,000 µg/L, and other studies suggest that a reduction in reproductive potential and survival impairment in fish may occur at concentrations greater than 200 µg/L (Birge and Black 1977). Eisler (1990) reported the boron criteria recommended for the protection of sensitive aquatic species as less than 1,000 µg/L. Water samples collected at all three Bandon locations are slightly above this criteria (Table 2); therefore, some species of sensitive fish in the area could be effected by boron.

Effects on aquatic organisms of barium and molybdenum are discussed in Flora *et al.* (1984) and Eisler (1989). In both fresh and marine waters, concentrations of soluble barium must exceed 50 mg/L before toxic effects on aquatic life occur (Flora *et al.* 1984). Molybdenum also is reported to have adverse effects on the growth and survival of aquatic organisms at water concentrations greater than 50 mg/L (Eisler 1989). Bioconcentration of molybdenum has also been reported in some algae and invertebrates, but the potential hazard to upper trophic levels is not clear. Concentrations of barium and molybdenum in the Bandon water samples were well below the previously mentioned adverse effect levels, and therefore should not pose a threat to aquatic resources in the area.

Chromium concentrations in water were measured as total recoverable chromium; trivalent chromium and hexavalent chromium were not distinguished in this study. Hexavalent chromium is generally more prevalent in water than trivalent chromium, and would most likely be the predominant form in samples collected from the area. Chromium concentrations in two dump samples exceeded LAWQC and freshwater guidelines for exposure to hexavalent chromium, but were well below criteria for trivalent chromium (Table 2). Although proposed chromium criteria vary widely, sensitive species of freshwater aquatic organisms were shown to be adversely affected at hexavalent chromium concentrations of 10.0 µg/L and 30.0 µg/L of trivalent chromium; marine organisms were affected at 5.0 µg/L hexavalent chromium (Eisler 1986a). For hexavalent chromium, two dump samples exceeded the freshwater adverse effect level and

Table 2. Trace element concentrations in water samples (µg/L) collected in 1993 from Bandon, Coos County, Oregon, and established water quality criteria and guidelines. Concentrations presented are only those elements that exceeded detection limits (see Appendix I for detection limits). Values in bold exceed available guidelines.

Trace Element	Sampling Location ^a			Lowest Ambient WQC ^d	Guidelines ^b			
	Dump (n=3) ^c	Intermediate (n=1) ^c	Refuge (n=2) ^c		Freshwater		Marine	
					Acute	Chronic	Acute	Chronic
Aluminum	998-1,500	788	614-679	-- ^e	--	--	--	--
Barium	26-127	18	20-23	--	--	--	--	--
Boron	217-3,152	3,854	2,235-3,181	--	--	--	--	--
Cadmium	<0.5	0.7	<0.5- 0.6	0.32	3.9	1.1	43	9.3
Chromium	9.8-13.7	6.8	6.6-9.7	57 ^f , 10.5^g	1,700 ^f , 16 ^g	210 ^f , 11^g	1,100 ^g	50 ^g
Iron	1,302-3,746	640	561- 1,050	--	--	1,000	--	--
Lead	<5.0- 28.1	14.5	15.7-32.3	0.14	82	3.2	140	5.6
Magnesium	60,980-1,145,000	1,144,000	807,400-1,124,000	--	--	--	--	--
Manganese	93 -350	21	38-62	--	--	--	--	--
Molybdenum	<4.0-5.0	10.1	8.5-10.4	--	--	--	--	--
Nickel	11.4-12.6	11.5	7.2-10.2	7.1	1,400	160	75	8.3
Strontium	278-5,640	5,255	3,362-4,941	--	--	--	--	--
Vanadium	5.2-8.7	<4.0	<4.0	--	--	--	--	--
Zinc	<10.0-13.5	<10.0	21.9-22.7	28	120	110	95	86

^a See Figure 1 for sampling locations. Dump = Northern dump boundary, Intermediate = area between dump and refuge, Refuge = Southern refuge boundary

^b Sources: Oregon Department of Environmental Quality (1991), U.S. Environmental Protection Agency (1986).

All freshwater criteria reflect a hardness-dependent criteria of 100 mg/L CaCO₃.

^c n equals the number of sampling sites within a given collection area

^d Lowest Ambient Water Quality Criteria for total dissolved element (chronic criteria; U.S. Environmental Protection Agency 1995).

Hardness-dependent freshwater aquatic life adjusted to reflect the worst case hardness of 25 mg/L CaCO₃.

^e -- equals not available

^f Criteria for trivalent chromium

^g Criteria for hexavalent chromium

all samples surpassed the adverse affect level for marine organisms (Table 2). Chromium in samples from the dump were above criteria for the hexavalent form and higher than values from the other locations sampled. Data indicate that aquatic life near the dump could be impacted by chromium; however, additional sampling is necessary to distinguish between the oxidative states of chromium concentrations before assessing the potential threat to aquatic resources in the area.

Concentrations of iron, lead, and nickel all exceeded various aquatic guidelines. Iron and nickel concentrations were higher in the dump samples than the refuge samples. Iron concentrations in all dump samples and one refuge sample exceeded the criteria for chronic exposure in freshwater systems (U.S. Environmental Protection Agency 1986, Oregon Department of Environmental Quality 1991). Criteria for iron in marine systems were not available. Iron levels that exceed chronic criteria may cause sublethal effects (e.g., reduced growth, decreased disease resistance) in exposed organisms. Sublethal stressors decrease the health of an organism and may cause direct mortality through continued exposure or when combined with other stressors (e.g., food shortage). Lead concentrations in water samples collected from all three sampling locations exceeded the LAWQC (U.S. Environmental Protection Agency 1995) and chronic exposure guidelines for both freshwater and marine systems (U.S. Environmental Protection Agency 1986, Oregon Department of Environmental Quality 1991). Lead is an animal carcinogen, and the EPA has classified it as a B2 human carcinogen. A B2 classification means that it is considered a probable human carcinogen based on sufficient evidence in animals but inadequate or no evidence in humans (U.S. Environmental Protection Agency 1989). Adverse effects on aquatic biota have been documented in association with lead concentrations of 1.0 to 5.1 $\mu\text{g/L}$ in water (Eisler 1988b). These concentrations were exceeded at all sampling sites. Nickel concentrations in water samples taken from all three sampling locations also exceeded LAWQC (U.S. Environmental Protection Agency 1995) and chronic exposure guidelines for saltwater (U.S. Environmental Protection Agency 1986, Oregon Department of Environmental Quality 1991). Although it is unclear if the elevated concentrations of iron, lead and nickel originated from the dump site, these elements may pose a threat to fish and wildlife in the area.

Zinc concentrations were highest in the refuge samples, but values in all samples were well below the guidelines established by the Environmental Protection Agency (1986) and adopted by the Oregon Department of Environmental Quality (1991), presented in Table 2. Proposed criteria for the protection of aquatic life are substantially lower than current criteria and include mean zinc concentrations of $<47 \mu\text{g}$ total recoverable zinc per liter in freshwater and $<58 \mu\text{g/L}$ in saltwater (Environmental Protection Agency 1980, 1987 *as cited in* Eisler 1993). However, significant adverse effects on representative sensitive aquatic species (including molluscs) have been shown to occur at concentrations between 10 and 25 $\mu\text{g/L}$ (Eisler 1993). Recent studies also indicate that zinc concentrations ranging from 5-51 and 9-50 $\mu\text{g/L}$ have significant effects on freshwater and saltwater organisms, respectively. These studies suggest that the current and proposed criteria for zinc are too high and should be lower to adequately protect aquatic organisms. Water samples collected from the dump and refuge fall within this range of reported adverse effects, but do not exceed the current or proposed criteria. The results indicate a potential for harm to fish and wildlife from zinc, although the dump site does not appear to be the source. Information on the effects of aluminum, magnesium, manganese, strontium, and vanadium on aquatic organisms was not available.

Sediment Samples

Sediment samples were compared to various guidelines established by agencies within the United States and Canada (Table 3). The Lowest Effect Level (LEL) guideline established by the Ontario Ministry of the Environment describes the lowest level at which sediment contamination will adversely affect benthic organisms (Persaud *et al.* 1993). The NOAA Status and Trends Program established the Effect Range-Low (ER-L) level and suggests concentrations at the low

Table 3. Trace element concentrations in sediment samples ($\mu\text{g/g}$, dry weight) collected in 1993 from Bandon, Coos County, Oregon, and sediment guidelines (see Appendix I for detection limits). Values in bold exceed available guidelines.

Trace Element	Sampling Location ^a			Freshwater Guidelines				Marine Guidelines
	Dump (n=3) ^b	Intermediate (n=1) ^b	Refuge (n=2) ^b	Long & Morgan ER-L ^c	Ontario LEL ^d	EPA Heavy Polluted ^e	U.S. Mean ^f	WA Dept Ecology ^g
Aluminum	7,762-13,330	14,180	11,280-11,710	-- ^h	--	--	58,000	--
Arsenic	3.49 - 5.09	8.85	5.27 - 5.81	33	6	>8	5.5	57
Barium	16.1 - 62.3	22.7	16.0 - 16.7	--	--	>60	580	--
Beryllium	<0.18 - 0.21	0.23	0.20 - 0.23	--	--	--	0.68	--
Boron	11.7 - 24.1	40.4	18.1 - 18.9	--	--	--	23	--
Chromium	46.5 - 76.7	81.5	59.7 - 68.6	80	26	>75	41	260
Copper	9.85 - 20.7	16.5	12.9 - 14.0	70	16	>50	21	390
Iron	12,410-18,810	20,746	17,000 - 18,700	--	20,000	>25,000	21,000	--
Lead	<4.56 - 13.5	10.9	6.30 - 7.52	35	31	>60	17	450
Magnesium	7,148 - 8,893	12,330	9,653 - 10,660	--	--	--	7,400	--
Manganese	139 - 262	228	164 - 170	--	460	>500	380	--
Nickel	40.5 - 46.2	69.7	55.7 - 63.4	30	16	>50	15	--
Strontium	22.4 - 71.1	39.4	25.7 - 27.2	--	--	--	200	--
Vanadium	20.4 - 36.3	40.7	33.1 - 34.0	--	--	--	70	--
Zinc	28.2 - 71.2	51.4	44.1 - 51.1	120	120	>200	55	410

^a See Figure 1 for sampling locations. Dump = Northern dump boundary, Intermediate = area between dump and refuge, Refuge = Southern refuge boundary.

^b n equals the number of sampling sites within a given collection area.

^c Effect Range-Low (ER-L) for NOAA's Status and Trends Program (Long and Morgan 1990).

^d Lowest Effect Level (LEL) guideline established by Ontario Ministry of the Environment (Persaud *et al.* 1993)

^e Heavily Polluted classification of Great Lakes harbor sediments (U.S. Environmental Protection Agency 1977 *as cited in* Beyer 1990).

^f Geometric mean concentrations of trace element in soils and other surficial materials in the western United States (Schacklette and Boerngen 1984).

^g Marine Sediment Quality standards of the Washington State Department of Ecology (1991).

^h -- equals not available.

end of the range (lower ten percentile) should be used to protect biota, and above which adverse effects to sensitive organisms may begin (Long and Morgan 1990). Trace elements in sediment were also compared to values classified as Heavily Polluted for Great Lakes sediments (U.S. Environmental Protection Agency 1977, *as cited in* Beyer 1990) and to the mean concentrations of trace elements in soils and other surface materials in the United States (Schacklette and Boerngen 1984). Because the Bandon Marsh study site is estuarine, it may be occupied by both marine and freshwater organisms. Therefore, Marine Sediment Quality (MSQ) standards developed by the Washington State Department of Ecology (1991) were also used for comparison.

Sediment samples contained fifteen trace elements at concentrations above detection limits. Eight of these elements (arsenic, barium, boron, chromium, copper, iron, magnesium, and nickel) exceeded various guidelines (Table 3). The intermediate sample generally had higher trace element concentrations as compared to the dump and refuge samples.

The arsenic concentration (8.85 $\mu\text{g/g}$) in the intermediate sample was slightly elevated relative to the LEL established for sediments in Ontario (Persaud *et al.* 1993) and the Heavily Polluted classification for Great Lakes sediments (U.S. Environmental Protection Agency 1977, *as cited in* Beyer 1990). However, this concentration falls well below the ER-L developed for NOAA's Status and Trends Program (Long and Morgan 1990). Barium was found in one dump sample at 62.3 $\mu\text{g/g}$, which slightly exceeded the Great Lakes Heavily Polluted classification (U.S. Environmental Protection Agency 1977, *as cited in* Beyer 1990). Copper concentrations were below the national mean in soils (Schacklette and Boerngen 1984), but one sample from the dump and one sample from the intermediate area exceeded the LEL guideline of 16 $\mu\text{g/g}$ (Persaud *et al.* 1993). The iron concentration in the intermediate sample exceeded the LEL guideline for Ontario (Persaud *et al.* 1993). Iron concentrations at all three sampling locations (ranging from 12,410 to 20,746 $\mu\text{g/g}$) were below the national mean in soils (Schacklette and Boerngen 1984) and below the Great Lakes Heavily Polluted classification (Environmental Protection Agency 1977, *as cited in* Beyer 1990). All elements listed above were well below marine sediment standards (Washington State Department of Ecology 1991).

Chromium and nickel concentrations were detected in sediment from all sampling locations but were most elevated at the intermediate site (Table 3). All three sampling locations were elevated with respect to all freshwater sediment guidelines (Table 3). However, chromium concentrations did not exceed the MSQ standards (Washington State Department of Ecology 1991). A MSQ standard was not available for nickel.

Concentrations of boron and magnesium in the intermediate sample (34 and 9,200 $\mu\text{g/g}$, respectively) exceeded the national mean (Schacklette and Boerngen 1984). Both refuge samples also exceeded the national mean for magnesium. It is difficult to determine whether the levels of boron and magnesium present in the Bandon sediments are biologically significant due to the paucity of guidelines for these trace elements.

Although various freshwater guidelines were exceeded in all sampling locations, no distinct pattern was apparent. Data do not readily suggest that metals are migrating off of the former Moore Lumber dump site. Based on comparisons to available guidelines, some limited effects may occur as a result of trace elements arsenic, barium, boron, chromium, copper, iron, magnesium and nickel. Of these elements, chromium and nickel may pose the most serious threat to aquatic organisms.

Tissue Samples

Sixteen trace elements were detected in clam tissue samples. Aluminum, barium, boron, cadmium, copper, molybdenum, and zinc were slightly higher at the dump location than other locations, indicating clams near the dump may be accumulating some elements to a greater extent than in other areas (Table 4). However, trace element residues were within the range of

Table 4. Trace element concentrations in softshell clam (*Mya arenaria*) tissue ($\mu\text{g/g}$, wet weight, unless otherwise noted) collected in 1993 from Bandon, Coos County, Oregon, and established tissue guidelines (see Appendix I for detection limits).

Element	Sampling Location ^a			Guidelines	
	Dump (n=1) ^b	Intermediate (n=1) ^b	Refuge (n=2) ^b	Field Collections ^c	U.S. FDA 90th Percentile ^d
Aluminum	349	280	233-306	-- ^e	--
Arsenic	2.20 8.85 DW ^f	2.44 10.1 DW	2.31-2.70 11.2-12.8 DW	2-20 --	86
Barium	1.48	1.16	0.86-1.35	--	--
Boron	3.43 13.8 DW	3.22 13.3 DW	2.42-2.55 11.5-12.3 DW	1.6-4.5 --	--
Cadmium	0.25 1.0 DW	0.20 0.82 DW	0.14-0.15 0.70-0.73 DW	-- 2.3-10.5 DW	3.7
Chromium	3.63 14.6 DW	5.31 21.9 DW	2.79-3.85 13.5-18.3 DW	0.2-5.8 3.3-24.7 DW ($> 4.0 \text{ DW}^g$)	13
Copper	4.27	3.08	2.41-2.85	--	--
Iron	658	622	699-798	--	--
Magnesium	837	874	853-897	--	--
Manganese	8.09	8.04	5.59-10.4	--	--
Molybdenum	0.45 1.82 DW	0.39 1.61 DW	0.29-0.44 1.38-2.10 DW	$<0.1-0.6$ --	--
Nickel	2.17	2.22	1.92-1.94	--	80
Selenium	0.39	0.43	0.32-0.41	--	--
Strontium	7.74	9.26	8.55-10.5	--	--
Vanadium	1.31	1.15	1.03-1.30	--	--
Zinc	14.2 56.9 DW	12.9 53.1 DW	10.4-10.7 50.7-50.9 DW	-- 81-115 DW	--

^a See Figure 1 for sampling locations. Dump = Northern dump boundary, Intermediate = area between dump and refuge, Refuge = Southern refuge boundary.

^b n equals the number of sampling sites within a given collection area.

^c Values reflect a range of concentrations detected in molluscan bivalves from a variety of field collections as reported in Eisler (1985, 1986a, 1988a, 1989, 1990, 1993).

^d Level of Concern for individuals consuming molluscan bivalves on a chronic basis at the 90th percentile average among eaters (U.S. Food and Drug Administration 1993a, 1993b, 1993c, 1993d).

^e -- equals not available.

^f DW = value in dry weight.

^g Eisler suggests that organs and tissues containing total chromium $> 4.0 \mu\text{g/g}$, dry weight, should be viewed as presumptive evidence of chromium contamination.

concentrations found in clam species collected at various locations in the United States, and four trace elements (arsenic, cadmium, chromium, and nickel) were well below the FDA's level of concern for humans consuming molluscan bivalves (U.S. Food and Drug Administration 1993a, 1993b, 1993c, 1993d; Table 4).

Chromium levels in all clam tissue samples (13.49-21.89 $\mu\text{g/g}$, dry weight) exceeded Eisler's (1986a) recommended criteria (4.0 $\mu\text{g/g}$, dry weight) but were well below the U.S. Food and Drug Administration's (1993c) Level of Concern for shellfish consumers of 13 $\mu\text{g/g}$, wet weight (Table 4). Chromium is not biomagnified but is mutagenic, teratogenic, and carcinogenic at high concentrations. Chromium accumulation in clams may reflect the higher chromium concentrations in sediment observed at all sites. Values for chromium in both sediment and tissue were highest in samples from the intermediate site.

Aluminum, barium, iron, magnesium, manganese, strontium, and vanadium were found in tissue from all sampling sites. These same metals were found in water and sediment as well, although there was no indication that the elements originated from the dump location. Aluminum and iron toxicity are dependent on many environmental variables and the relationships between their toxicity and tissue concentrations is not well understood. Little information was found in the literature on concentrations of these elements in aquatic organisms. Additional information would be necessary to ascertain the potential hazards of these elements to fish and wildlife.

Organochlorine Pesticides and Total Polychlorinated Biphenyls

Water Samples

Water samples from the dump and intermediate areas contained detectable levels of five organochlorine (OC) pesticides: p,p -dichlorodiphenyldichloroethane (DDD), p,p -dichlorodiphenyldichloroethylene (DDE), alpha and gamma benzene hexachloride (BHC), and hexachlorobenzene (HCB) (Table 5). The OC concentrations in water samples collected from the refuge were all below detection limits. Concentrations of p,p -DDD and p,p -DDE in water samples were at or below ODEQ groundwater reference concentrations of 0.4 and 0.3 $\mu\text{g/L}$, respectively (Oregon Department of Environmental Quality 1994a). Alpha BHC was detected in water samples collected from the northern dump boundary; gamma BHC (also known as lindane) was detected in the intermediate water sample. Criteria for alpha BHC (both freshwater and marine) and marine criteria for gamma BHC were unavailable. However, gamma BHC levels from the dump locations exceeded ODEQ's freshwater chronic criteria of 0.08 $\mu\text{g/L}$ (Oregon Department of Environmental Quality 1991). HCB was detected in the intermediate water sample, but was well below the level of no effect at 5.0 $\mu\text{g/L}$ for four species of invertebrates and fish reported by Nebeker *et al.* (1989). Gamma BHC might pose a problem to aquatic organisms near the dump site.

Total PCB concentrations were above detection limits in water samples from the dump and intermediate locations. Total PCBs were not detected in refuge samples, although the analytical detection limit (<0.10 $\mu\text{g/L}$) was above available criteria. Water samples from both the dump and intermediate sampling sites grossly exceeded ODEQ's acute (2.0 $\mu\text{g/L}$) and chronic (0.014 $\mu\text{g/L}$) criteria for freshwater systems, as well as the 0.03 $\mu\text{g/L}$ marine chronic criteria (Table 8; Oregon Department of Environmental Quality 1991). One dump sample also exceeded the marine acute criteria (Table 8; Oregon Department of Environmental Quality 1991). Eisler (1986b) reported that PCBs at concentrations as low as 0.006 $\mu\text{g/L}$ accumulate in various species of filter-feeding shellfish. No mortality has been reported from chronic exposures (>96 hour) of

Table 5. Concentrations of organochlorine pesticides and total polychlorinated biphenyls detected in water samples ($\mu\text{g/L}$), sediment samples ($\mu\text{g/g}$, dry weight), and biota samples ($\mu\text{g/g}$, wet weight) collected in 1993 from Bandon, Coos County, Oregon, and water and tissue guidelines (see Appendix II for detection limits). Bold values exceed available guidelines.

Analyte	Matrix	Sampling Location ^a			Guidelines
		Dump (n=3) ^b	Intermediate	Refuge (n=2) ^b	
HCB	water	<0.100	0.160	<0.10	-- ^c
alpha BHC	water	<0.100-0.110	<0.100	<0.10	--
alpha chlordane	tissue	0.009	<0.005	<0.004	--
beta BHC	tissue	0.016	<0.005	<0.005	--
cis-nonachlor	tissue	0.016	<0.005	<0.005	--
delta BHC	tissue	0.014	<0.005	<0.005	--
gamma BHC (lindane)	water	<0.100	0.110	<0.100	0.08^d
gamma chlordane	tissue	0.010	<0.005	<0.005	--
heptachlor epoxide	tissue	0.007	<0.005	<0.005	0.1 ^e , 0.005^f
mirex	tissue	0.011	<0.005	<0.005	0.05 ^f
o,p -DDT	tissue	0.014	<0.005	<0.005	--
o,p -DDD	tissue	0.016	<0.005	<0.005	--
o,p -DDE	tissue	0.012	<0.005	<0.005	--
oxychlordane	tissue	0.008	<0.005	<0.005	--
p,p -DDT	tissue	0.017	<0.005	<0.005	--
p,p -DDD	water	<0.100-0.140	<0.100	<0.100	0.4 ^g
	tissue	0.035	0.0061	<0.005	--
p,p -DDE	water	<0.100- 0.320	<0.100	<0.100	0.3^g
	tissue	0.017	<0.005	<0.005	--
trans-nonachlor	tissue	0.008	<0.005	<0.005	--

Table 5. (Continued)

Analyte	Matrix	Sampling Location ^a			Guidelines
		Dump (n=3) ^b	Intermediate (n=1) ^b	Refuge (n=2) ^b	
total DDT ^h	water	0.0005	<0.0001	<0.0001	0.001 ^{d,i}
	tissue	0.1112	0.0061	<0.005	1.0 ^e , 0.05^f
total PCB	water	<0.100- 11.1	3.20	<0.10	2.0^l , 10.0^k
	tissue	0.741	0.140	0.085-0.096	0.10^l , 0.5^{e,f}
	sediment	<0.002-0.002	0.003	<0.002-0.002	0.01 ^m , 12 ⁿ

^a See Figure 1 for sampling locations. Dump = Northern dump boundary, Intermediate = area between dump and refuge, Refuge = Southern refuge boundary.

^b n equals the number of sampling sites within a given collection area; only one sampling site in dump for tissue matrix.

^c -- equals not available.

^d Criteria for protection of aquatic life: freshwater, chronic exposure (Oregon Department of Environmental Quality 1991).

^e Guidelines by the National Academy of Sciences & National Academy of Engineering (1973) to protect freshwater aquatic life.

^f Guidelines by the National Academy of Sciences and National Academy of Engineering (1973) to protect marine aquatic life.

^g Groundwater reference concentration (Oregon Department of Environmental Quality 1994a).

^h Total DDT is the sum of the concentrations of p,p -DDT, p,p -DDD, p,p -DDD and their ortho-para isomers. Values below detection limits were not used in the computation of total DDT.

ⁱ Criteria for protection of aquatic life: saltwater, chronic exposure (Oregon Department of Environmental Quality 1991).

^j Criteria for protection of aquatic life: freshwater, acute exposure (Oregon Department of Environmental Quality 1991).

^k Criteria for protection of aquatic life: saltwater, acute exposure (Oregon Department of Environmental Quality 1991).

^l Predator protection criteria established by the Great Lakes International Joint Commission (International Joint Commission United States and Canada 1988).

^m Level of no effect guideline (Persaud *et al.* 1993).

ⁿ Marine sediment quality criteria (Washington State Department of Ecology 1991).

fish and shellfish to PCB mixtures at concentrations $< 1 \mu\text{g/L}$ (Beyer *et al* 1996). Concentrations of total PCBs in water near dump and intermediate locations are high enough to bioaccumulate in animal tissue but below levels reported to cause adverse affects to fish and wildlife resources.

Sediment Samples

Sediment samples did not contain detectable concentrations ($>0.001 \mu\text{g/g}$, dry weight) of OCs with the exception of total PCBs (Table 5). Total PCBs were at or below detection limits in all samples. The highest detectable concentration ($0.003 \mu\text{g/g}$) of total PCBs was found in the intermediate sample; this sample was below marine guidelines established by the Washington State Department of Ecology (1991) and the Ontario no-effect level for freshwater sediments (Persaud *et al.* 1993).

Tissue Samples

Clam tissues from the dump site contained detectable levels of 15 OC pesticides, and only one OC pesticide (p,p -DDE) was detected in tissue from the intermediate site (Table 5). No OC pesticides were detected in tissue from the refuge samples. Aldrin and heptachlor were not detected in any of the samples.

No guidelines or criteria were available for cis-nonachlor, trans-nonachlor, or oxychlordan. Mirex concentrations were below the $0.05 \mu\text{g/g}$ guideline established by the National Academy of Sciences and National Academy of Engineering (1973) to protect marine aquatic life. Heptachlor epoxide concentrations in tissues collected from the dump were below the criteria of $0.1 \mu\text{g/g}$ in fish tissue established for the protection of predators in freshwater systems, but exceeded criteria established for marine systems ($0.005 \mu\text{g/g}$; National Academy of Sciences and National Academy of Engineering 1973). Heptachlor epoxide in the dump may pose a threat to aquatic resources in the area.

Total DDT (defined as the sum of the concentrations of p,p -DDT, p,p -DDE, and p,p -DDT and their ortho-para isomers) exceeded the National Academy of Sciences and National Academy of Engineering (1973) criteria of $0.05 \mu\text{g/g}$ for the protection of predators in marine systems with a sum concentration of $0.11 \mu\text{g/g}$; total DDT concentrations were below the $1.0 \mu\text{g/g}$ criteria to protect freshwater life.

Total PCBs were found in tissue from all sampling locations, although the dump sample was 5 to 8 times higher than those for the refuge (Table 5). Total PCB concentrations in tissue samples collected from all areas greatly exceeded values of 0.004 to $0.006 \mu\text{g/g}$, wet weight, detected in mollusc species sampled in U.S. coastal waters with no known source of local contamination (O Conner 1991). Values from the dump area exceeded the National Academy of Science and National Academy of Engineering s (1973) recommended maximum concentration of $0.5 \mu\text{g/g}$ for the protection of predators in both freshwater and marine systems. Total PCB levels from both the dump and intermediate areas exceeded the predator protection criteria ($0.1 \mu\text{g/g}$) instituted by the Great Lakes International Joint Commission (1988). The predator protection criteria are for whole body fish residue and should not be exceeded to protect birds and mammals which consume fish (International Joint Commission United States and Canada 1988).

OC pesticides and total PCBs in water are readily accumulated by organisms. The highest concentrations of OC pesticides were detected in both water and tissue samples from the dump site (Table 5). This indicates that some OC pesticides and total PCBs may have originated from the dump site and pose a threat to aquatic organisms in the area.

Congener-Specific Polychlorinated Biphenyls

Water Samples

Water samples were analyzed for 75 polychlorinated biphenyl (PCB) congeners (Appendix III). Samples collected from the dump and intermediate sampling sites contained detectable levels of 20 and eight PCB congeners, respectively (Table 6). PCB congeners were not detected in water samples collected from the refuge. The highest concentration for an individual congener, PCB 138, was 2.43 $\mu\text{g/L}$ in water collected from the dump. Two other congeners, PCB 28 and PCB 47/48, were found at concentrations of 0.97 $\mu\text{g/L}$ in dump and intermediate samples, respectively. Of the individual PCBs analyzed, these three congeners contributed the most towards the total PCB value discussed in the ***Organochlorine Pesticides and Total Polychlorinated Biphenyls*** section. Guidelines for individual congeners were not available for comparison, but the concentrations detected appear elevated when compared to guidelines established for total PCBs. PCB 138 in water from the dump exceeded the freshwater acute criteria established by Oregon Department of Environmental Quality (1991) for total PCBs.

Sediment Samples

Sediment samples contained only one PCB congener at a concentration slightly above the detection limits (Table 6). Congener 172 was present at all three sampling locations and was highest from the intermediate location. Guidelines for individual PCB congeners in sediment were unavailable, but levels were well below Washington State Department of Ecology (1991) marine sediment criteria (12 $\mu\text{g/g}$) and Oregon Department of Environmental Quality (1994) soil cleanup guidelines (0.08 $\mu\text{g/g}$) for total PCBs. The significance of this specific congener relative to fish and wildlife is unknown.

Tissue Samples

Tissue samples collected from the dump location contained more PCB congeners at levels above detection than from the intermediate or refuge locations. Tissue samples from the dump site contained concentrations of 24 PCB congeners detected above analytical detection limits; intermediate and refuge samples contained 16 and eight detectable PCB congeners, respectively (Table 6). Individual PCB congener guidelines were not available for comparison. However, all tissue congener levels were below the predator protection criteria for total PCBs instituted in the Great Lakes (International Joint Commission United States and Canada 1988).

The toxicity of most individual PCB congeners to fish and wildlife is unknown. However, various impacts such as embryotoxicity, edema, and growth retardation have been attributed to mixtures of PCBs and to some individual congeners, especially the planar PCBs (Rice and O Keefe 1995). Some planar PCBs are potent inducers of the mixed function oxidase system in organisms, and have been associated with subcutaneous edema, reproductive impairment, weight loss, immune suppression, and hormonal alterations (Rice and O Keefe 1995). Only four planar PCBs (77, 105, 126, and 167) were examined in this study (Table 6). All four of these planar PCBs were detected in tissue and three were detected in water samples from the dump site. Very few tissue and water samples (three of eight) contained these planar PCBs at the intermediate location, and only one planar PCB was found at detection limits from the refuge site. This contamination pattern suggests that the dump site may be the origin of PCB congeners in the area, and indicates a potential concern for fish and wildlife. Additional analysis of congener-specific PCBs in tissues would provide a more accurate assessment of the toxicity associated with planar PCBs.

Table 6. Concentrations of polychlorinated biphenyl (PCB) congeners detected in water samples ($\mu\text{g/L}$), sediment samples ($\mu\text{g/g}$, dry weight), and tissue samples ($\mu\text{g/g}$, wet weight) collected in 1993 from Bandon, Coos County, Oregon (see Appendix III for detection limits). Congeners in bold are planar PCBs.

PCB congener	Matrix	Sampling Location ^a		
		Dump (n=3) ^b	Intermediate (n=1) ^b	Refuge (n=2) ^b
PCB 8	water	0.96	<0.10	<0.10
PCB 22	water	<0.10	0.20	<0.10
PCB 28	water	<0.10-0.97	<0.10	<0.10
	tissue	0.012	<0.005	<0.005
PCB 37/42	tissue	0.007	<0.005	<0.005
PCB 44	water	<0.10-0.71	<0.10	<0.10
	tissue	0.023	0.006	0.009
PCB 46	water	<0.10	0.48	<0.10
PCB 47/48	water	<0.10	0.97	<0.10
PCB 49	tissue	<0.005	0.008	0.004-0.007
PCB 50	water	<0.10-0.56	0.21	<0.10
	tissue	0.019	0.007	0.004-0.006
PCB 52	water	<0.10-0.12	<0.10	<0.10
	tissue	0.012	<0.005	<0.005
PCB 56/60	water	<0.10-0.12	<0.10	<0.10
PCB 66	water	<0.10-0.58	<0.10	<0.10
	tissue	0.033	0.007	0.004-0.005
PCB 77	water	<0.10-0.43	<0.10	<0.10
	tissue	0.021	<0.005	<0.005
PCB 84	tissue	<0.005	<0.005	0.004
PCB 87	water	<0.10-0.41	0.23	<0.10
	tissue	0.031	0.005	<0.005
PCB 101	water	<0.10-0.11	<0.10	<0.01
	tissue	0.014	0.005	<0.005
PCB 105	water	<0.10-0.43	<0.10	<0.10
	tissue	0.071	0.011	0.004
PCB 108/118/149	water	<0.10-0.49	<0.10	<0.10
	tissue	0.035	0.005	<0.005

Table 6. (Continued)

PCB Congener	Matrix	Sampling Location ^a		
		Dump (n=3) ^b	Intermediate (n=1) ^b	Refuge (n=2) ^b
PCB 126	water tissue	<0.10-0.23 0.060	<0.10 0.007	<0.10 <0.005
PCB 128	water tissue	<0.10-0.19 0.068	<0.10 0.013	<0.10 0.004
PCB 138	water tissue	<0.10-2.43 0.052	<0.10 0.010	<0.10 0.010-0.012
PCB 153	water tissue	<0.10-0.24 0.044	<0.10 0.005	<0.10 <0.005
PCB 159/182/187	tissue	0.019	<0.005	<0.005
PCB 167	water tissue	<0.10 0.010	0.53 <0.005	<0.10 <0.005
PCB 172	sediment tissue	0.002 0.007	0.003 <0.005	<0.002-0.002 <0.005
PCB 180	water tissue	<0.10-0.15 0.036	<0.10 0.005	<0.10 <0.005
PCB 188	tissue	0.009	<0.005	<0.005
PCB 195	tissue	0.047	0.007	<0.005
PCB 200	water tissue	<0.10-0.15 0.015	<0.10 <0.005	<0.10 <0.005
PCB 205	water	<0.10	0.21	<0.10
PCB 206	water tissue	<0.10-0.14 0.046	<0.10 0.006	<0.10 <0.005
PCB 209	water tissue	<0.10-0.14 0.041	0.17 0.006	<0.10 <0.005

^a See Figure 1 for sampling locations. Dump = Northern dump boundary, Intermediate = area between refuge, Refuge = Southern refuge boundary.

^b n equals the number of sampling sites within a given collection area.

Dioxins and Furans

Three tissue samples (one sample per area) were chemically analyzed for dioxins and furans; water and sediment matrices were not analyzed. The full dioxin/furan scan included 17 compounds, and only one compound was found above the analytical detection limit (see Appendix IV). OCDD was detected at a concentration of 11.8 pg/g in the tissue sample collected from the intermediate zone. This level falls within Eisler's (1986c) suggested predator protection level of 10 to 12 pg/g.

Polyaromatic Hydrocarbons

Water Samples

Water samples did not contain detectable concentrations ($<0.1 \mu\text{g/L}$) of PAHs, with the exception of one sample; C1-naphthalenes were found just above detection limits in a sample collected from the dump. Very few guidelines were available for comparison of PAH concentrations in water. Values in this study did not approach the lowest observed effect level guidelines for total PAHs ($300 \mu\text{g/L}$), acenaphthalene ($970 \mu\text{g/L}$), and chlorinated naphthalenes ($7.5 \mu\text{g/L}$) in marine systems (Oregon Department of Environmental Quality 1991). Guidelines for other PAH compounds were not available. All PAHs investigated in this study are listed in Appendix V.

Sediment Samples

PAHs were found above detection limits (0.013 to $0.020 \mu\text{g/g}$, dry weight) in sediment from all sampling locations. Individual PAH compound concentrations were all below guidelines established by Oregon Department of Environmental Quality (1994a) for residential maximum allowable soil concentrations. PAH compounds were classified as either carcinogenic or noncarcinogenic according to Eisler (1987), and summed for comparison between sampling locations (Appendix V). Concentrations of carcinogenic PAHs were greatest in the intermediate sample ($0.251 \mu\text{g/g}$, dry weight). Sediment samples from the refuge and dump sites contained similar concentrations of carcinogenic PAHs; sediment PAH values ranged from 0.138 to $0.149 \mu\text{g/g}$, dry weight for the refuge samples and 0.123 to $0.169 \mu\text{g/g}$, dry weight for the dump samples. Concentrations of noncarcinogenic PAHs were greatest in the intermediate sample ($0.533 \mu\text{g/g}$, dry weight), and lowest in the two refuge samples (ranging from 0.315 to $0.321 \mu\text{g/g}$, dry weight). Sediment concentrations of both carcinogenic and noncarcinogenic individual PAHs were below both Washington State Department of Ecology (1991) regulations for specific carcinogenic compounds in marine sediments and background concentrations of selected individual compounds and total PAHs in soils reported by Richardson (1987, *as cited in* Beyer 1990).

Tissue Samples

Clam tissue samples did not contain detectable concentrations of PAHs. Detection limits ranged from 0.035 to $0.050 \mu\text{g/g}$, wet weight. These limits are well below levels associated with tumors in various fish species (Baumann *et al.* 1982, Baumann and Harshbarger 1985).

Aliphatic hydrocarbons

Water Samples

Aliphatic hydrocarbons were detected in only one water sample. This water sample, collected from the dump location, contained low concentrations of n-heptacosane (0.235 µg/L), n-nonacosane (0.158 µg/L), and n-octacosane (0.132 µg/L). All aliphatic hydrocarbon analytes investigated in this study are listed in Appendix V. The detection limit for all water samples was approximately 0.1 µg/L. No guidelines for aliphatic hydrocarbons in water were available for comparison.

Sediment Samples

All six sediment samples contained concentrations of aliphatic hydrocarbons above analytical detection limits (Table 7). Total aliphatic concentrations were greatest in the intermediate sample (2.58 µg/g, dry weight), and lowest in the three samples collected from the dump (ranging from 1.08 to 1.29 µg/g, dry weight). Little information is available on sediment guidelines for aliphatic concentrations and impacts of low concentrations of aliphatics on aquatic organisms. However, total aliphatic hydrocarbon concentrations are well below cleanup criteria for soil (70 µg/g in Richardson 1987, *as cited in* Beyer 1990), and are unlikely to represent a hazard to fish and wildlife.

Tissue Samples

No tissue samples were analyzed for aliphatic hydrocarbons.

Total Petroleum Hydrocarbons

Water Samples

Total petroleum hydrocarbons (TPHs) were found at the detection limit (3.0 µg/L, wet weight) in one water sample collected from the intermediate area (Table 8). Concentrations of TPHs in all other water samples were below the detection limit. These levels are well below the maximum acceptable concentration of oil-in-water of 24 to 39 µg/L (Woodward *et al.* 1981, Woodward and Riley 1983).

Sediment Samples

TPH concentrations were highest in sediments from the dump location and lowest in refuge samples (Table 8). TPH values in dump sediments ranged from 147 to 286 µg/g, dry weight, and exceeded level 3 soil cleanup standards for gasoline (Oregon Department of Environmental Quality 1994b) (Table 8). The level 3 standard (130 ppm) is the least stringent, and the level 1 standard (40 ppm) is the most stringent cleanup criteria established by ODEQ. Sediment TPH concentrations in the refuge (ranging from 59.7 to 80.7 µg/g, dry weight) and intermediate areas (112 µg/g, dry weight) also exceeded the soil cleanup standards for gasoline, at levels 1 (40 ppm) and 2 (80 ppm), respectively.

Table 7. Aliphatic hydrocarbon concentrations in sediment samples ($\mu\text{g/g}$, dry weight) collected in 1993 from Bandon, Coos County, Oregon . Detection limits ranged between 0.013 and 0.020 $\mu\text{g/g}$, dry weight. Concentrations of n-undecane, n-dodecane, n-tridecane, n-tetradecane, and n-tetratriacontane were below analytical detection limits and were therefore not included.

Analyte	Sampling Location ^a		
	Dump (n=3) ^b	Intermediate (n=1) ^b	Refuge (n=2) ^b
n-decane	0.017-0.025	0.036	0.027-0.028
n-ducosane	0.027-0.030	0.049	0.025-0.026
n-dotriacontane	<0.013-0.018	0.031	0.019-0.025
n-eicosane	0.019-0.029	0.030	<0.018
n-heneicosane	0.056-0.097	0.127	0.046-0.049
n-hentriacontane	0.034-0.082	0.194	0.221-0.233
n-heptacosane	0.114-0.176	0.488	0.373-0.377
n-heptadecane	0.041-0.397	0.128	0.222-0.317
n-hexacosane	0.019-0.027	0.054	0.038-0.039
n-hexadecane	<0.016-0.018	<0.020	<0.018-0.021
n-nonacosane	0.107-0.211	0.483	0.381-0.384
n-nonadecane	0.031-0.052	0.069	0.033-0.035
n-octacosane	0.018-0.020	0.051	0.043-0.044
n-octadecane	<0.016-0.022	0.023	<0.018-0.020
n-pentacosane	0.077-0.093	0.262	0.179-0.188
n-pentadecane	0.028-0.033	0.050	0.035-0.046
n-tetracosane	0.027-0.035	0.062	0.037-0.044
n-triacontane	0.024-0.039	0.048	0.030-0.039
n-tricosane	0.075-0.128	0.227	0.091-0.105
n-triatriacontane	<0.016	0.021	0.043-0.050
phytane	0.024-0.028	0.028	0.024-0.028
pristane	0.033-0.072	0.053	0.040-0.058
total aliphatics ^c	1.08-1.29	2.58	2.03-2.16

^a See Figure 1 for sampling locations. Dump = Northern dump boundary, Intermediate = area between dump and refuge, Refuge = Southern refuge boundary.

^b n equals the number of sampling sites within a given collection area.

^c sum of all aliphatic compounds per sample using one-half the detection limit for those compounds not detected.

Table 8. Total petroleum hydrocarbon (TPH) concentrations detected in water samples ($\mu\text{g/L}$), sediment samples ($\mu\text{g/g}$, dry weight), and tissue samples ($\mu\text{g/g}$, wet weight) collected in 1993 from Bandon, Coos County, Oregon.

Matrix	Sampling Location ^a		
	Dump (n=3) ^b	Intermediate (n=1) ^b	Refuge (n=2) ^b
Water	<3.00	3.05	<3.00
Sediment	147-286 ^{c,d}	112 ^d	59.7-80.7 ^{c,d}
Tissue	189 ^c	348	157-238 ^c

^a See Figure 1 for sampling locations. Dump = Northern dump boundary, Intermediate = area between dump and refuge, Refuge = Southern refuge boundary.

^b n equals the number of sampling sites within a given collection area.

^c Values represent range.

^d Soil Cleanup Standards for TPHs (gasoline) are 40 ppm (level 1), 80 ppm (level 2), and 130 ppm (level 3). Level 1 is the most stringent and level 3 is the least stringent cleanup criteria (Oregon Department of Environmental Quality 1994b).

^e Only one tissue sample was collected from the dump for TPH analysis.

The elevated TPH concentrations indicated the presence of highly contaminated sediments. However, scans for individual aromatic hydrocarbon compounds showed only low levels of PAHs present in sediments (see the *Polyaromatic Hydrocarbons* and *Aliphatic Hydrocarbons* sections) which may indicate the presence of non-petrogenic compounds. Unidentified petroleum compounds, reported as unresolved complex mixtures, were found at low concentrations (5.92 to 29.9 $\mu\text{g/g}$, dry weight) at all sampling sites. These mixtures often indicate petrogenic contamination but could include biogenic hydrocarbons common in soils high in organic matter (Tom McDonald, analytical chemist, Geochemical and Environmental Research Group, Texas A&M University, pers. comm.). Therefore, much of the aliphatic fraction of the TPH concentrations may be from biogenic hydrocarbons (Woodward *et al.* 1981). High TPH concentrations coupled with low levels of individual PAHs and unresolved complex mixtures in collected samples may indicate a high contribution of primarily biogenic hydrocarbons.

Tissue Samples

TPH concentrations were highest in clam tissue from the intermediate zone; TPH from the dump and refuge were generally similar (Table 8). Levels of TPHs in clam tissues appeared elevated (Table 8). However, analyzing tissue samples for TPHs does not accurately represent concentrations of petrogenic hydrocarbons present in the environment. Naturally occurring hydrocarbons in the tissues cannot be removed without altering TPH concentrations. Thus, TPH concentrations reported in tissues are artificially elevated due to the inclusion of substances such as lignins, fatty acids, and tannins inherent in the tissue (Tom McDonald, analytical chemist, Geochemical and Environmental Research Group, Texas A&M University, pers. comm.). Sample analysis did not discern between the contribution of biogenic and anthropogenic substances existing at the dump site. The pattern of TPH contamination in sediment (i.e., highest at the dump, lowest at the refuge) is not reflected in the tissue samples. This indicates the TPH values may not be due to petrogenic compounds.

Pentachlorophenol

Water and sediment samples did not contain detectable levels of pentachlorophenol. Detection limits of <0.01 µg/L for water and <0.01 µg/g, dry weight, for sediments were below guidelines established for groundwater reference concentrations (0.7 µg/L, wet weight) by Oregon Department of Environmental Quality (1994) and marine sediment management (0.36 µg/g, dry weight) by Washington State Department of Ecology (1991). Tissue samples were not analyzed for pentachlorophenol.

SUMMARY AND CONCLUSIONS

Bandon Marsh National Wildlife Refuge is adjacent to an abandoned wood treatment facility that was cited for contaminant-related operational deficiencies several times during the course of its operation. Sampling conducted by ODEQ and Ecology and Environment, Inc. (1988) before and after the company's closure indicated that contamination was still present at the site. Service personnel collected water, sediment, and clam tissue samples from a dump associated with the wood treatment facility, Bandon Marsh NWR, and the area between the dump and refuge. The purpose of the collections was to assess the potential hazard from contamination on the site to fish and wildlife resources, and determine if clean-up activities were required. Samples were analyzed for trace elements, organochlorine pesticides, total and congener-specific PCBs, dioxins and furans, polyaromatic and aliphatic hydrocarbons, total petroleum hydrocarbons, and pentachlorophenol.

Analysis of water samples collected from Bandon Marsh NWR revealed five trace elements (cadmium, chromium, iron, lead, and nickel) above freshwater or marine criteria; none of these elements exceeded acute criteria (Table 2). With the exception of lead, these elements only slightly exceeded chronic criteria. Lead concentrations were well above chronic criteria, and boron and zinc concentrations exceeded effect levels reported by Eisler (1990, 1993). Some trace elements detected in water samples, particularly boron, chromium, lead, nickel and zinc, were at levels that could impact aquatic species. Concentrations of these elements exceeded criteria at all sampling locations; however, the dump does not appear to be the sole source of these elements. Additional information regarding oxidative states of trace elements, as well as temperature, pH, alkalinity, and hardness is required to fully assess impacts to the aquatic community.

Sediment samples contained eight trace elements near or slightly above freshwater guidelines or above U.S. geometric mean concentrations for surface soils; all elements were well below marine sediment standards (Table 3). Trace element concentrations in intermediate sediment samples were generally greater than those in refuge or dump sediments. Arsenic, chromium, and nickel in sediments exceeded most guidelines and may pose the most serious threat to aquatic organisms. All but one sediment sample contained barium concentrations below guidelines; barium concentrations in one dump sample slightly exceeded the EPA's Heavily Polluted classification (U.S. Environmental Protection Agency 1977, as cited in Beyer 1990). Copper concentrations in sediment samples were below the national mean (Schacklette and Boerngen 1984) and guidelines used by the EPA (U.S. Environmental Protection Agency 1977, as cited in Beyer 1990) and NOAA (Long and Morgan 1990). However, two samples (one each from the dump and intermediate areas) slightly exceeded the LEL established by the Ontario Ministry of the Environment (Persaud *et al.* 1993). The distribution of samples with trace elements above guidelines suggests that there are localized areas in which contaminants may pose a threat to fish and wildlife, but does not indicate that the dump is the source. Additional sampling and sediment bioassays would be necessary to ascertain if these elements pose a threat to trust resources.

Sixteen trace elements were detected in clam tissue samples. Arsenic, boron, cadmium, chromium, molybdenum, and zinc residues were within the range of concentrations detected in molluscan bivalves from a variety of field collections (Eisler 1985, 1986a, 1988a, 1989, 1990, 1993), and arsenic, cadmium, chromium, and nickel concentrations were below the FDA's level of concern for humans consuming molluscs (U.S. Food and Drug Administration 1993a, 1993b, 1993c, 1993d; Table 4). Chromium levels in all clam tissue samples exceeded recommended criteria (Eisler 1986a). Aluminum, barium, iron, magnesium, manganese, strontium, and vanadium were found in water, sediment, and tissue from all sampling sites, although there was no indication that these elements originated from the dump location. Variability in accumulation strategies, physiological differences among aquatic invertebrate species (as well as between individuals) and environmental factors makes it difficult to define absolutely a body concentration range reflecting normal conditions (Rainbow 1996). Because of the uncertainty surrounding the interpretation of tissue residues, additional information would be necessary to ascertain the potential hazards of these elements to fish and wildlife.

Most water and sediment OC pesticide concentrations did not appear to be at levels harmful to fish and wildlife. Three OC pesticide compounds were detected in water samples from the dump. HCB and gamma BHC (lindane) were detected in the intermediate sample; gamma BHC (lindane) was detected above freshwater chronic criteria. All other samples, including all refuge samples, were below detection limits (Table 5). Presence of these OC pesticides in water indicates a relatively recent exposure.

Clam tissues from the dump site contained detectable levels of 15 OC pesticides and only one OC pesticide (p,p'-DDE) was detected in tissue from the intermediate site (Table 5). No OC pesticides were detected in tissue from the refuge samples. Tissue concentrations of heptachlor epoxide were elevated (Table 5); in one sample collected from the dump, heptachlor epoxide exceeded the criteria for the protection of marine organisms and therefore may represent a hazard to fish and wildlife. The total DDT concentration (sum of the concentrations of p,p'-DDT, p,p'-DDE, and p,p'-DDT and their ortho-para isomers) in clam tissue also exceeded criteria for the protection of predators in marine systems. The presence and distribution of OC pesticides in water and tissue indicates that the dump is the contaminant source.

Although concentrations of total PCBs in sediments were negligible, total PCB residues in water and tissue samples were well above available guidelines. Concentrations of total PCBs in water near the dump and intermediate locations were elevated to the extent that bioaccumulation in animal tissue could present a serious threat to fish and wildlife resources (Table 5). Similarly, total PCB concentrations in clam tissues exceeded a variety of guidelines for predator protection. Total PCBs were found in tissue from all sampling locations, although the dump sample was 5 to 8 times higher than those for the refuge (Table 5).

In both the water and tissue matrices, concentrations of some OC pesticides and total PCBs in the dump location were higher than concentrations in intermediate samples, which were in turn higher than concentrations in samples collected from the refuge location. This pattern suggests a potential movement of OC pesticides and total PCBs from the dump location, posing a threat to aquatic organisms in the area.

Individual PCB congeners were detected in water and tissue samples, and in one sediment sample. Water and tissue from the dump contained more PCB congeners above detection limits than from the other locations. PCB congeners were not detected in water and very few were detected in tissue from the refuge samples. This contamination pattern indicates the dump site may be the origin of PCB congeners in the area. The analytical detection limits for PCB congeners in water were above recommended guidelines for marine or freshwater systems. However, congeners above the detection limit suggests that these PCBs are potentially hazardous

to aquatic organisms. The toxicity of most individual PCB congeners to fish and wildlife is unknown. Most information available documented problems associated with the planer PCB congeners. Planar PCBs are potent mixed function oxidase system inducers and have been associated with a variety of developmental and hormonal impacts (Rice and O Keefe 1995). In the present study, four planar PCBs were detected in water and tissue samples, suggesting a potential threat to fish and wildlife. Additional analysis of congener-specific PCBs, particularly planar PCBs, would provide a more accurate assessment of the threat to fish and wildlife.

Dioxins and furans, polyaromatic and aliphatic hydrocarbons, and pentachlorophenol were not found at levels thought to be harmful to aquatic organisms. Few PAHs or aliphatic hydrocarbons were detected in water, sediment, or tissue samples. The compounds that were detected were generally at relatively low levels and not believed to pose a threat to fish and wildlife. Dioxin and furan concentrations in tissue samples were below detection limits with the exception of one sample, which fell within predator protection criteria (Eisler 1986c). Pentachlorophenol concentrations were below detection limits in both water and sediment samples.

Concentrations of total petroleum hydrocarbons (TPHs) in water samples were near or below detection limits (Table 8). TPH levels in all sediments exceeded soil cleanup standards for gasoline (Oregon Department of Environmental Quality 1994b). However, analyses for individual PAHs and aliphatic hydrocarbons in sediments and tissues detected only low concentrations. In addition, unresolved complex mixture levels were low; these mixtures often indicate petrogenic contamination but could include biogenic hydrocarbons present in highly organic soils (Tom McDonald, analytical chemist, Geochemical and Environmental Research Group, Texas A&M University, pers. comm.). Sediment TPH concentrations were greatest in the dump location and lowest in refuge samples; however, tissue concentrations did not reflect a similar pattern. Clam tissues contained elevated TPH concentrations, particularly in the intermediate sample, but these values may be artificially elevated due to the inclusion of naturally occurring hydrocarbons inherent in tissue (e.g., lignins, fatty acids and tannins; Tom McDonald, analytical chemist, Geochemical and Environmental Research Group, Texas A&M University, pers. comm.). The disparity between concentration patterns in sediment and tissue samples and low concentrations of individual polyaromatic and aliphatic hydrocarbons suggest that TPH values in samples from the Bandon Marsh area may not result from petrogenic contamination. However, it must be noted that additional information on the organic content of sediments in the area and further guidance on how to discern biogenic from petrogenic hydrocarbons in tissues is necessary to accurately determine the degree of petroleum contamination in the area.

MANAGEMENT RECOMMENDATIONS

The results of this study revealed that total PCBs, as well as some OC pesticides and trace elements, occur in water, sediment, or clam tissue in the estuary around the dump site. Several trace element concentrations were at or slightly above guidelines, and the pattern of contamination did not indicate that the trace elements originated from the dump site. In contrast, the distribution of total PCBs and several OC pesticides in water and tissue indicates these compounds originate from the dump site, enter into the estuary, and impact estuarine life. These results are based on only a limited number of samples. *The contaminant evidence suggests further sampling and characterization of the site is warranted and cleanup actions are necessary to adequately protect aquatic life in the area.* Specific recommendations are described below.

Some trace elements in water slightly exceeded freshwater chronic criteria. However, water criteria is hardness-dependent and more information is needed on pH and hardness in the area before it can be determined whether or not these elements harm aquatic life. In sediment, trace elements were near or above guidance levels, but may be within natural concentrations for

elements in the area. Bioassays conducted using sediment from these areas and an organism suited to estuarine environments would provide a more reliable assessment of trace element toxicity. The levels found in this investigation indicate that trace elements in water and sediment are not a serious threat to aquatic resources in the area, and it is not likely that trace elements originated from the dump. To confirm these determinations, the Service recommends additional analyses of water samples for trace elements, using criteria adjusted for local pH and hardness values. Bioassays would also assist in the evaluation of sediment toxicity.

The contaminant pattern of total PCBs and some OC pesticides in water and tissue indicates the dump as the contaminant source. Total PCBs in water may present a serious threat to aquatic organisms, and tissue concentrations indicate a threat to predators at higher trophic levels from bioaccumulation. The Service recommends 1) further sampling of water near the dump site to confirm total PCB and OC pesticide concentrations; 2) sampling of water and soil from the dump area to identify specific sources of these compounds; and 3) cleanup or removal of any PCBs or other organochlorine contaminants found at elevated concentrations at the dump.

Land in between the dump and the refuge is within the approved boundary of Bandon Marsh NWR and has been considered for acquisition. Once acquired, the Service would assume responsibility for the current condition of the land and would be liable for any cleanup and remediation of this intermediate area. Currently, contaminants in the intermediate area do not appear to pose a serious threat to fish and wildlife using the refuge. Sediment concentrations of PCBs and OC pesticides were primarily below detection limits or guidelines and did not indicate sediment contamination would be a liability if the intermediate area was purchased. However, PCBs and some OC pesticides were found in water at the intermediate site, indicating possible migration of contaminants from the dump site. Therefore, purchase of this area should not occur until the source of the contaminants in water can be determined and remediated. The benefit of inclusion to trust resources could then be better evaluated relative to the potential costs associated with the acquisition.

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Appendix I. Method detection limits for selected elements in water, sediment, and clam tissue collected in Bandon, Coos County, Oregon, in 1994. Concentrations are in micrograms per liter (μL) in water and micrograms per gram ($\mu\text{g/g}$) in sediment and clam tissue.

ELEMENT	METHOD DETECTION LIMIT		
	Water ($\mu\text{g/L}$) wet weight	Sediment ($\mu\text{g/g}$) dry weight	Tissue ($\mu\text{g/g}$) wet weight
Aluminum	20.0	91.2-101.4	1.69-2.00
Arsenic	5.6	0.50-0.51	0.17-0.21
Barium	1.0	2.74-3.01	0.17-0.20
Beryllium	0.5	0.18-0.20	0.3-0.4
Boron	3.0	4.56-5.07	2.42-3.43
Cadmium	0.5	0.18-0.20	0.16-0.17
Chromium	5.0	4.6-5.1	0.17-0.20
Copper	5.0	4.6-5.1	0.17-0.20
Iron	20.0	91.2-101.4	3.39-4.00
Lead	5.0	4.6-5.1	0.17-0.20
Magnesium	20.0	91.2-101.4	3.39-4.00
Manganese	2.0	3.65-4.06	0.14-0.16
Mercury	2.0	0.10	0.03-0.04
Molybdenum	4.0	4.6-5.1	0.17-0.20
Nickel	5.0	4.6-5.1	0.17-0.20
Selenium	5.6	0.50-0.51	0.17-0.21
Strontium	2.0	1.8-2.0	0.07-0.08
Vanadium	4.0	4.6-5.1	0.17-0.20
Zinc	10.0	4.6-5.1	0.34-0.40

Appendix II. Method detection limits for organochlorine compounds in water, sediment, and clam tissue collected from Bandon, Coos County, Oregon, in 1994. [DDD = dichlorodiphenyl dichloroethane, DDE = dichlorodiphenyldichloroethylene; DDT = dichlorodiphenyltrichloroethane; PCB = polychlorinated biphenyl; BHC = benzene hexachloride; HCB = hexachlorobenzene]. Concentrations are in micrograms per liter ($\mu\text{g/L}$) in water and micrograms per gram ($\mu\text{g/g}$) in sediment and clam tissue.

METHOD DETECTION LIMIT			
ANALYTE	Water ($\mu\text{g/L}$) wet weight	Sediment ($\mu\text{g/g}$) dry weight	Tissue ($\mu\text{g/g}$) wet weight
Aldrin	0.10	0.001-0.002	0.004-0.005
HCB	0.10	0.001-0.002	0.004-0.005
Heptachlor	0.10	0.001-0.002	0.004-0.005
Total PCB	0.10	0.001-0.002	0.004-0.005
Alpha BHC	0.10	0.001-0.002	0.004-0.005
Alpha chlordane	0.10	0.001-0.002	0.004-0.005
Beta BHC	0.10	0.001-0.002	0.004-0.005
Cis-nonachlor	0.10	0.001-0.002	0.004-0.005
Delta BHC	0.10	0.001-0.002	0.004-0.005
Gamma BHC	0.10	0.001-0.002	0.004-0.005
Gamma chlordane	0.10	0.001-0.002	0.004-0.005
Heptachlor epoxide	0.10	0.001-0.002	0.004-0.005
Mirex	0.10	0.001-0.002	0.004-0.005
o,p -DDD	0.10	0.001-0.002	0.004-0.005
o,p -DDE	0.10	0.001-0.002	0.004-0.005
o,p -DDT	0.10	0.001-0.002	0.004-0.005
Oxychlordane	0.10	0.001-0.002	0.004-0.005
p,p -DDD	0.10	0.001-0.002	0.004-0.005
p,p -DDE	0.10	0.001-0.002	0.004-0.005
p,p -DDT	0.10	0.001-0.002	0.004-0.005
Trans-nonachlor	0.10	0.001-0.002	0.004-0.005

Appendix III. Method detection limits for dioxins and furans in clam tissues collected from Bandon, Coos County, Oregon, in 1994. Concentrations are in picograms per gram (pg/g) wet weight. [HpCDD= heptachlorodibenzodioxin; HxCDD = hexachlorodibenzodioxin; PeCDD= pentachlorodibenzodioxin; TCDD = tetrachlorodibenzodioxin; OCDD = octachlorodibenzodioxin; HpCDF=heptachlorodibenzofuran; HxCDF = hexachlorodibenzofuran; PeCDF = pentachlorodibenzofuran; TCDF = tetrachlorodibenzofuran; OCDF = octachlorodibenzofuran]

Analyte	Method Detection Limit (pg/g)
1,2,3,4,6,7,8-HpCDD	4.78 - 4.99
1,2,3,4,7,8-HxCDD	4.78 - 4.99
1,2,3,6,7,8-HxCDD	4.78 - 4.99
1,2,3,7,8,9-HxCDD	4.78 - 4.99
1,2,3,7,8-PeCDD	4.78 - 4.99
2,3,7,8-TCDD	0.96 - 1.00
OCDD	9.56 - 9.98
1,2,3,4,6,7,8,-HpCDF	4.78 - 4.99
1,2,3,4,7,8,9-HpCDF	4.78 - 4.99
1,2,3,4,7,8-HxCDF	4.78 - 4.99
1,2,3,6,7,8-HxCDF	4.78 - 4.99
1,2,3,7,8,9-HxCDF	4.78 - 4.99
1,2,3,7,8-PeCDF	4.78 - 4.99
2,3,4,7,8-PeCDF	4.78 - 4.99
2,3,7,8-TCDF	0.99 - 1.00
2,3,4,6,7,8-HxCDF	4.78 - 4.99
OCDF	9.56 - 9.98

Appendix IV. Method detection limits for polychlorinated biphenyls (PCBs) in water, sediment, and clam tissues collected from Bandon, Coos County, Oregon, in 1994. Concentrations are in micrograms per liter ($\mu\text{g/L}$) in water and micrograms per gram ($\mu\text{g/g}$) in sediment and clam tissue.

PCB Congener	Method Detection Limit		
	Water (wet weight)	Sediment (dry weight)	Tissue (wet weight)
PCB 7	0.10	0.001-0.002	0.004-0.005
PCB 8	0.10	0.001-0.002	0.004-0.005
PCB 15	0.10	0.001-0.002	0.004-0.005
PCB 16/32 ^a	0.10	0.001-0.002	0.004-0.005
PCB 18	0.10	0.001-0.002	0.004-0.005
PCB 22	0.10	0.001-0.002	0.004-0.005
PCB 24	0.10	0.001-0.002	0.004-0.005
PCB 25	0.10	0.001-0.002	0.004-0.005
PCB 26	0.10	0.001-0.002	0.004-0.005
PCB 28	0.10	0.001-0.002	0.004-0.005
PCB 29	0.10	0.001-0.002	0.004-0.005
PCB 33	0.10	0.001-0.002	0.004-0.005
PCB 37/42 ^a	0.10	0.001-0.002	0.004-0.005
PCB 41/64 ^a	0.10	0.001-0.002	0.004-0.005
PCB 44	0.10	0.001-0.002	0.004-0.005
PCB 45	0.10	0.001-0.002	0.004-0.005
PCB 46	0.10	0.001-0.002	0.004-0.005
PCB 47/48 ^a	0.10	0.001-0.002	0.004-0.005
PCB 49	0.10	0.001-0.002	0.004-0.005
PCB 50	0.10	0.001-0.002	0.004-0.005
PCB 52	0.10	0.001-0.002	0.004-0.005
PCB 56/60 ^a	0.10	0.001-0.002	0.004-0.005
PCB 66	0.10	0.001-0.002	0.004-0.005
PCB 70	0.10	0.001-0.002	0.004-0.005
PCB 74	0.10	0.001-0.002	0.004-0.005

PCB Congener	Method Detection Limit		
	Water (wet weight)	Sediment (dry weight)	Tissue (wet weight)
PCB 77	0.10	0.001-0.002	0.004-0.005
PCB 77/110 ^a	0.10	0.001-0.002	0.004-0.005
PCB 82	0.10	0.001-0.002	0.004-0.005
PCB 83	0.10	0.001-0.002	0.004-0.005
PCB 84	0.10	0.001-0.002	0.004-0.005
PCB 85	0.10	0.001-0.002	0.004-0.005
PCB 87	0.10	0.001-0.002	0.004-0.005
PCB 88	0.10	0.001-0.002	0.004-0.005
PCB 92	0.10	0.001-0.002	0.004-0.005
PCB 97	0.10	0.001-0.002	0.004-0.005
PCB 99	0.10	0.001-0.002	0.004-0.005
PCB 101	0.10	0.001-0.002	0.004-0.005
PCB 105	0.10	0.001-0.002	0.004-0.005
PCB 107/108/144 ^a	0.10	0.001-0.002	0.004-0.005
PCB 108/118/149 ^a	0.10	0.001-0.002	0.004-0.005
PCB 126	0.10	0.001-0.002	0.004-0.005
PCB 128	0.10	0.001-0.002	0.004-0.005
PCB 129	0.10	0.001-0.002	0.004-0.005
PCB 136	0.10	0.001-0.002	0.004-0.005
PCB 137	0.10	0.001-0.002	0.004-0.005
PCB 138	0.10	0.001-0.002	0.004-0.005
PCB 141	0.10	0.001-0.002	0.004-0.005
PCB 146	0.10	0.001-0.002	0.004-0.005
PCB 149	0.10	0.001-0.002	0.004-0.005
PCB 151	0.10	0.001-0.002	0.004-0.005
PCB 153	0.10	0.001-0.002	0.004-0.005
PCB 156/171/202 ^a	0.10	0.001-0.002	0.004-0.005

PCB Congener	Method Detection Limit		
	Water (wet weight)	Sediment (dry weight)	Tissue (wet weight)
PCB 158	0.10	0.001-0.002	0.004-0.005
PCB 159/182/187 ^a	0.10	0.001-0.002	0.004-0.005
PCB 167	0.10	0.001-0.002	0.004-0.005
PCB 170	0.10	0.001-0.002	0.004-0.005
PCB 172	0.10	0.001-0.002	0.004-0.005
PCB 174	0.10	0.001-0.002	0.004-0.005
PCB 177	0.10	0.001-0.002	0.004-0.005
PCB 178	0.10	0.001-0.002	0.004-0.005
PCB 180	0.10	0.001-0.002	0.004-0.005
PCB 183	0.10	0.001-0.002	0.004-0.005
PCB 185	0.10	0.001-0.002	0.004-0.005
PCB 188	0.10	0.001-0.002	0.004-0.005
PCB 189	0.10	0.001-0.002	0.004-0.005
PCB 191	0.10	0.001-0.002	0.004-0.005
PCB 194	0.10	0.001-0.002	0.004-0.005
PCB 195	0.10	0.001-0.002	0.004-0.005
PCB 196	0.10	0.001-0.002	0.004-0.005
PCB 200	0.10	0.001-0.002	0.004-0.005
PCB 201	0.10	0.001-0.002	0.004-0.005
PCB 205	0.10	0.001-0.002	0.004-0.005
PCB 206	0.10	0.001-0.002	0.004-0.005
PCB 209	0.10	0.001-0.002	0.004-0.005

^aInseparable congeners

Appendix V. Polyaromatic and aliphatic hydrocarbons quantitated in water, sediment, and clam tissue collected from Bandon, Coos County, Oregon, in 1994.

POLYAROMATIC HYDROCARBONS

Carcinogenic PAHs	Noncarcinogenic PAHs	
1,2,5,6-dibenzanthracene	1-methylnaphthalene	C3-dibenzothiophenes
1,2-benzanthracene	1-methylphenanthrene	fluoranthene
benzo(a)pyrene	1,6,7-trimethylnaphthalene	C1-fluoranthenes & pyrenes
chrysene	2,6-dimethylnaphthalene	fluorene
C1-chrysenes	2-methylnaphthalene	C1-fluorenes
C2-chrysenes	acenaphthalene	C2-fluorenes
C3-chrysenes	acenaphthene	C3-fluorenes
C4-chrysenes	anthracene	naphthalene
C1-phenanthrenes	benzo(b)fluoranthene	C1-naphthalenes
C2-phenanthrenes	benzo(e)pyrene	C2-naphthalenes
C3-phenanthrenes	benzo(g,h,i)perylene	C3-naphthalenes
C4-phenanthrenes	benzo(k)fluoranthene	C4-naphthalenes
indeno(1,2,3-cd)pyrene	biphenyl	perylene
	dibenzothiophene	phenanthrene
	C1-dibenzothiophenes	pyrene
	C2-dibenzothiophenes	
Aliphatic Hydrocarbons		
n-decane	n-nonadecane	n-octacosane
n-undecane	n-eicosane	n-nonacosane
n-dodecane	n-heneicosane	n-triacontane
n-tridecane	n-docosane	n-hentriacontane
n-tetradecane	n-triacosane	n-dotriacontane
n-pentadecane	n-tetracosane	n-tritriacontane
n-hexadecane	n-pentacosane	n-tetratriacontane
n-heptadecane	n-hexacosane	phytane
n-octadecane	n-heptacosane	pristane

^a Method detection limits for polyaromatic hydrocarbons: 0.1 µg/L in water, 0.013 to 0.020 µg/g dry weight in sediments, 0.035 to 0.050 µg/g wet weight in tissues.

^b Method detection limits for aliphatic hydrocarbons: 0.01 µg/L in water, 0.013 to 0.020 µg/g dry weight in sediments, tissue samples were not analyzed for aliphatic hydrocarbons.