Levels of polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) in biota and sediments near potential

Levels of Polychlorinated Dibenzo-p-dioxins (PCDDs) and Polychlorinated Dibenzofurans (PCDFs) in Biota and Sediments Near Potential Sources of Contamination in British Columbia, 1987

by

R.J. Norstrom and M. Simon
Environment Canada
Canadian Wildlife Service
National Wildlife Research Centre
Ottawa, Ontario K1A 0H3

P.E. Whitehead
Environment Canada
Conservation and Protection, Pacific Region
Canadian Wildlife Service
Delta, British Columbia V4K 3Y3

R. Kussat and C. Garrett
Environment Canada
Conservation and Protection, Pacific Region
Kapilano 100 - Park Royal South
West Vancouver, B.C. V7T 1A2

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INTRODUCTION

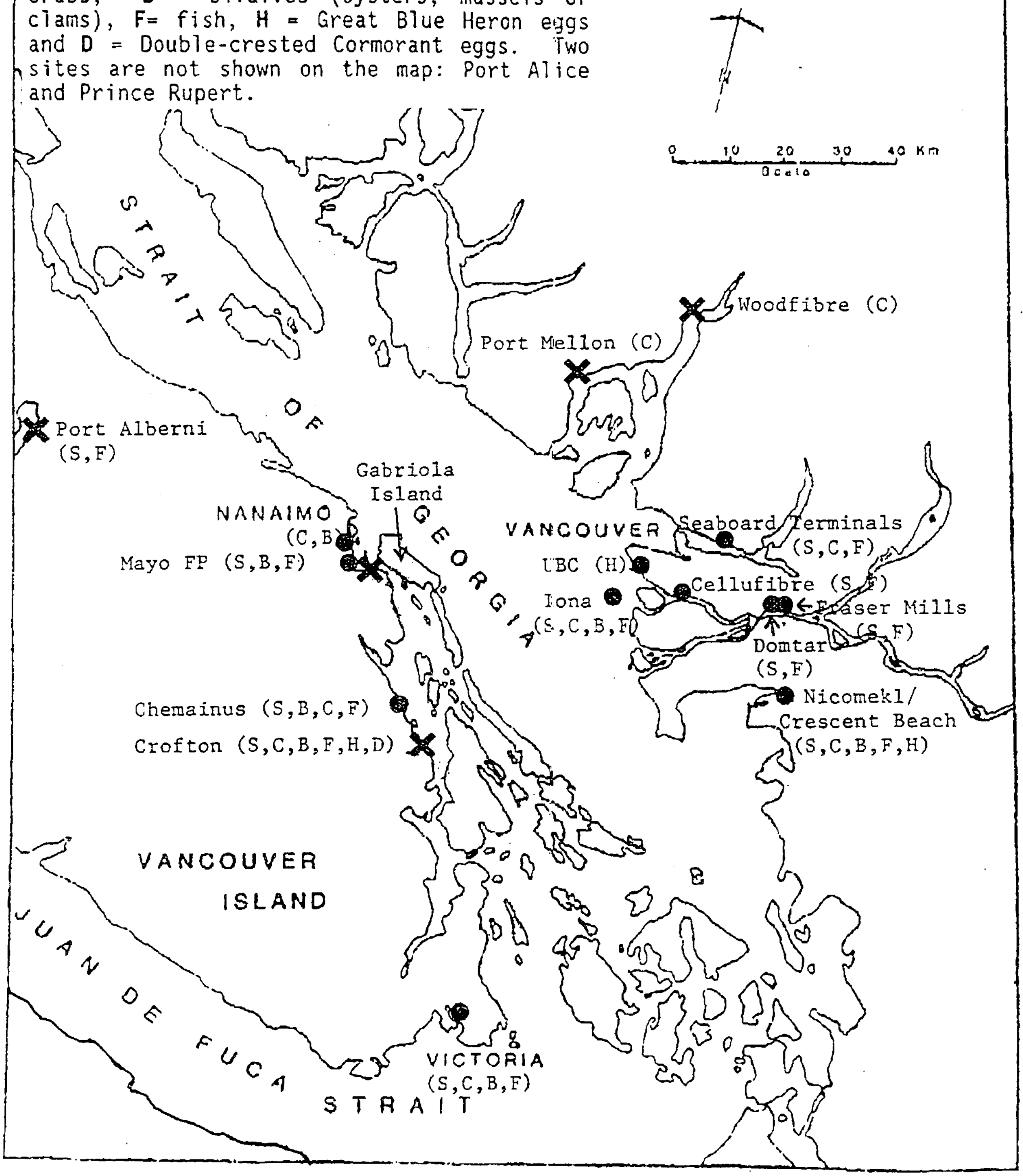
This report is intended to bring together in one place all of the chemical data obtained as part of the joint CWS/HQ and C&P, Pacific Region Pestfund projects on levels in biota and sediments and sources of PCDDs and PCDFs in the Strait of Georgia area in British Columbia in 1987. Details of the description of samples and their collection, analytical methodology, quality control data, and so on are not provided, although a map indicating the approximate sampling areas is included for orientation (Fig. 1). Many of the missing details are contained in previous analytical reports CRD-88-4, CRD-88-1 and CRD-87-13. Collation and analysis of the data are, however, not yet complete, therefore this report must be treated as a preliminary presentation of an extremely complex and difficult to interpret subject - "dioxins" or polychlorinated dibenzo-p-dioxins (PCDDs) and and polychlorinated dibenzofurans (PCDFs). General analytical methodology may be found in Norstrom et al. (1986) and Norstrom and Simon (1988).

Research into PCDD and PCDF contamination in the Strait of Georgia began as a result of a survey of PCDD contamination in fish-eating birds in Canada (Norstrom and Simon, 1983) in which 740 ng/kg (ppt) of 123678-hexachlorodibenzo-p-dioxin (HxCDD), 490 ng/kg of 12378-pentachlorodibenzo-p-dioxin (PnCDD) and 76 ng/kg of 2378-tetrachlorodibenzo-p-dioxin (TCDD) were discovered in pooled eggs of the Great Blue Heron (Ardea herodius) from a colony on the Endowment Lands of the University of British Columbia (UBC, Fig. 1) in 1982. These levels would be embryotoxic in a sensitive species such as the chicken, although there was no evidence of reproductive failure in this colony of herons. The Great Blue Heron feeds mainly in shallow water on small fish such as sculpins, gunnels and perch, but will also feed on fish, shrimp, or any aquatic animal of suitable size. In addition to aquatic animals, Great Blue Herons in British Columbia have been known to forage for small rodents in farmer's fields . Great Blue Herons are year-round residents in Coastal British Columbia (Butler, 1988). There is, therefore, little doubt that the PCDD and PCDF contamination in their eggs is of local origin.

The monitoring program was extended to three more colonies of Great Blue Herons in 1983, including one "control" site in an uncontaminated area just south of Vancouver (Nikomekl/Crescent Beach), and two sites on the mainland, Crofton and Gabriola Island (Fig. 1). Neither of the latter two sites were chosen for any reason other than that their location was known, but both colonies are near bleached kraft mills, sawmills and lumber mills.

The Crofton and Gabriola Island colonies proved to be more contaminated than that at UBC in 1983, and the colony at Nikomekl was significantly less contaminated (Elliott et al., 1988). Again there was no direct evidence of reproductive problems at any colony, but the levels were unusually high in comparison to other known contaminated areas such as the Great Lakes (Stalling et al. 1986), especially levels of 123678-HxCDD and 12378-PnCDD. Because of the large use of chlorophenols in British Columbia for anti-sapstain treatment (fungicide) in the lumber industry (Garrett and Shrimpton, 1988) , this source was suspected for 123678-HxCDD, which had been identified in chlorophenol formulations used in Canada (Miles et al., 1985). The source of the 12378-PnCDD and 2378-TCDD was, however, more difficult to deduce, since neither was found in the formulations of chlorophenols used in

FIG. 1. Sample collection sites are indicated by circles, bleached kraft sites are indicated by crosses. The letters beside each symbol indicate the type of sample collected at that site: S = sediment, C = crabs, B = bivalves (oysters, mussels or clams), F= fish, H = Great Blue Heron eggs and D = Double-crested Cormorant eggs. Two sites are not shown on the map: Port Alice and Prince Rupert.



British Columbia (mainly 2346-tetrachlorophenol with some pentachlorophenol as active ingredients). Nevertheless, the ratio of all three PCDDs was relatively constant, regardless of site and absolute concentration in heron eggs, suggesting a common source.

In 1986, activities were confined to measurement of PCDD levels in individual heron eggs from Crofton, UBC and another "control" colony on Sydney Island to determine the variance in PCDD concentrations (Elliott et al., 1988). Mean concentrations of 2378-TCDD remained the same at UBC as in 1983, but levels of 123678-HxCDD and 12378-PnCDD decreased about a factor of 2. At Crofton, mean levels of 2378-TCDD increased about a factor of 2, while 123678-HxCDD and 12378-PnCDD levels remained about the same. The net result was that the relative levels of all three PCDDs were the same at both colonies, although levels were significantly higher at Crofton ($p < 0.1$).

Analysis of Dungeness crab (Cancer magister) hepatopancreas as part of an assessment of the effects of a chlorophenol spill in Boundary Bay, near Vancouver in 1984 (Colodey, 1986) showed that a wide range of PCDD and PCDF congeners accumulated in this organ of the crab. Patterns of HxCDDs and HxCDFs in crabs were similar to those expected from chlorophenols, but were higher in the control site (Buntzen Bay in Burrard Inlet) than in Boundary Bay. As a result of these findings, a joint project was planned for 1987 by the Chemistry Research Division of the Canadian Wildlife Service in Ottawa and Canadian Wildlife Service and Environmental Protection Branches in Conservation and Protection, Pacific Region, to address the question of sources, with the aid of the Environment Canada Pestfund.

Initial choice of sites was based on the assumption that chlorophenols were the main source of PCDDs. However, because contamination in heron eggs was high near two pulp mills, these sites were also included. This was a fortuitous decision since it was revealed at the Dioxin '87 conference in Las Vegas that pulp mills were a specific source of 2378-TCDF and 2378-TCDD (Amendola et al., 1987). Twelve sites were initially chosen: Crofton (pulp mill); Harmac (pulp mill, wood-treatment and chlorine plant); Chemainus (wood-treatment); Mayo Forest Products, Nanaimo (wood-treatment); BCFP, Victoria (wood-treatment); Port Alberni (pulp mill and wood treatment); Seaboard Terminals, Vancouver harbour (wood-treatment); three sites on the north arm of the Fraser River delta - Fraser Mills, West Coast Cellufibre and Domtar - (all wood-treatment); Fraser Estuary (Iona Island sewage outfall for the City of Vancouver); and Crescent Beach/Nikomekl (control site), as indicated in Fig. 1. Sediments were obtained at all of these sites, and attempts were made to obtain Dungeness Crab, Staghorn Sculpin (Leptocottus armatus) and bivalves (oysters, mussels or clams) at the marine sites and Prickly Sculpin (Cottus asper) at the Fraser River sites. In addition, Great Blue Heron eggs were collected at UBC, Crofton and Nikomekl, and Double-Crested Cormorant (Phalocrocorax auritus) eggs were collected from a colony nesting at Crofton near the pulp mill. Cormorants feed mainly on fish, but since they dive and chase their prey in the water, they feed more offshore in deeper water than herons.

After it was known that pulp mills were potential sources, crab samples were obtained in the winter of 1987-88 from five additional sites: Crofton (repeat sample), Port Alice (sulfite mill), Prince Rupert, Port Mellon and Woodfibre (all bleached kraft mills).

RESULTS AND DISCUSSION

Great Blue Heron eggs

Mean levels of 123678-HxCDD and 12378-PnCDD in Great Blue Heron eggs from UBC and Crofton (Table 1) did not change significantly from 1986. Mean levels of 2378-TCDD increased significantly ($p<0.01$) at Crofton, and increased at UBC, but not significantly ($p<0.05$), between 1986 and 1987. Levels of 2378-TCDF were significantly higher ($p<0.05$) at UBC than at Crofton, and 23478-PnCDF levels were significantly higher ($p<0.05$) at Crofton than at UBC. The significant, and similar, correlation between PnCDD and HxCDD levels in heron eggs at UBC and Crofton was strong indication that the source (i.e., fungicide or process, not a geographical site) of both PCDDs was the same in these areas. Conversely, the increase in 2378-TCDD levels at Crofton indicated that the source of this contaminant was not singularly connected with that of PnCDD and HxCDD. Since the Crofton herons feed near a kraft pulp mill, one hypothesis to explain the TCDD increase is that direct (effluent from plant) or indirect (release from wood fibre beds, sediments) environmental input of 2378-TCDD increased significantly between these two years. Another hypothesis is that Crofton herons fed more on species exposed to higher levels of kraft mill contamination in 1987 than in 1986, and that levels of 2378-TCDD in these food species stayed the same in 1987, but levels of the PnCDD and HxCDD decreased, as apparently occurred at UBC.

Double-crested Cormorant eggs

Mean levels of PCDDs and PCDFs in cormorant eggs were slightly lower than those in Great Blue Heron eggs from the same site, but in the same range (Table 1). The diet of the cormorant probably overlaps that of the heron, but since the cormorant feeds further offshore, the size of the fish eaten may be larger. The Double-crested Cormorant is a resident species in B.C.

Dungeness Crab Hepatopancreas

PCDD and PCDF levels in crabs were extremely variable among sites (Table 2). Only traces were found at the control site, Crescent Beach, but this may have been influenced by the small size (9 cm, 83 g) and young age of the crabs. Levels were also low at the Port Alice site, which was near a sulfite pulp mill, rather than a bleached kraft mill. The bleached kraft mill sites were at Crofton, Harmac, Port Mellon and Woodfibre. Crab hepatopancreas from the latter three contained by far the highest levels. Crabs were relatively large (18-19 cm, 500-600g) from all these areas, which is probably a factor in the high levels. Crabs from kraft mill sites had the highest levels of 2378-TCDF and 2378-TCDD. In addition to these isomers, the main tetrachloro- isomers found were the 1278-TCDF and 1278-TCDD. This is the expected pattern for bleached kraft sources (C. Rappe, Dioxin '87 conference, Las Vegas), and clearly implicates this source. It is interesting that the Iona Jetty crabs and Chemainus crabs also displayed a bleached kraft-type pattern of TCDDs and TCDFs. In the case of Chemainus, this may have been due to influence from the nearby Crofton mill. The explanation for a bleached kraft pattern at the Iona Jetty site is less easy to find. There are no kraft mills in the immediate vicinity, but there are kraft mills in the Quesnel and Prince George areas much further up river. Another possible explanation is bleaching of recycled paper at paper mills on the lower Fraser River.

In addition to the bleached kraft pattern, there were significant levels of PnCDDs, HxCDDs, HpCDDs and OCDD in most areas. The most abundant of these was the HxCDDs, as observed in Great Blue Heron eggs. The pattern of HxCDD isomers was consistent with a chlorophenol source (Hagenmaier and Brunner, 1987) and different from that in combustion sources, in which 123468 is a major isomer. The presence of mainly 124689- and 124678-HxCDFs in Iona Jetty, Chemainus, Victoria, Harmac, Nanaimo and Seaboard Terminal crabs was another indication of chlorophenol contamination. The virtual absence of HxCDFs in Crofton, Port Mellon, Prince Rupert and Woodfibre crabs, although HxCDDs were high at these sites and also had a typical chlorophenol-related pattern, is also interesting. One explanation may be the practice of using chlorophenol contaminated wood chips as feed stock to the pulp mill. Condensation of chlorophenols or chlorophenoxyphenols to PCDDs could occur under these conditions without producing PCDFs. The high correlation between 12378-PnCDD and 12368-HxCDD levels in crabs from all sites indicates that chlorophenols were also the source of this contaminant.

<u>Bivalves</u> (Oysters, mussels and clams)

The geographical distribution of these samples was much less than for fish and crabs, and the species diversity was higher (Table 3). Oysters appeared to be the most useful indicator species. Where detectable levels were observed, the patterns were nearly identical to those in crab hepatopancreas from the same site, indicating that both species were accumulating PCDD and PCDF isomers with little or no discrimination according to chlorine substitution pattern.

<u>Sculpins</u>

As has been well established in other studies with fish, mainly 2378- substituted congeners were observed. PCDDs did not exceed 10 ng/kg at any site except at Crofton (Table 4). The relative levels of 123678-HxCDD/12378-PnCDD/2378-TCDD were very similar to that in Herons found at the same site. These small bottom-dwelling fish are typical of the food of Great Blue Herons. PCDFs consisted almost entirely of 2378-TCDF, presumably of bleached kraft origin, since levels were highest at these sites. The relatively high level of 2378-TCDF at the sites on the lower Fraser River and Iona Jetty strengthens the suggestion from the crab and heron data that there was a bleached pulp-type influence in the area.

<u>Sediments</u>

PCDDs and PCDFs in sediments were much more dominated by the highly chlorinated congeners than was the case for biota (Table 5). Experimental studies have indicated that OCDD in sediments is not readily bioavailable (Kuehl et al. 1987). The approximately 1:2 ratio of the two HpCDF isomers at all sites is a clear indication of a chlorophenol source, since the first of these isomers is always dominant in combustion sources (Swerev and Ballschmiter, in press). The suggestion from the crab data that HxCDFs are higher where chlorophenols *per se* are the source, as opposed to digested, chlorophenol contaminated wood chips, appears to be confirmed by the sediment data. HxCDFs were very high at Victoria, Nanaimo and Port Alberni, but virtually absent at Crofton.

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TABLE 1

PCDD and PCDF levels in Great Blue Heron eggs and Double-Crested Cormorant eggs, collected from B.C., 1987
Levels are in ng/kg (wet wt.)

AREA	TISSUE	USOX NO.	PCDDs								PCDFs			
			2378-T4CDD	12378-P5CDD	123478-H6CDD	123678-H6CDD	123789-H6CDD	1234679-H7CDD	1234678-H7CDD	OCDD	2378-T4CDF	23478-P5CDF	% Moisture	% Lipid
UBC	Great Blue Heron egg	37707	41	34	ND	79	4	TR	12	TR	29	13	81.9	5.49
		37709	204	109	ND	158	12	TR	10	16	20	I	81.4	6.39
		37710	9	23	4	39	7	ND	11	TR	5	10	80.9	6.36
		37711	87	42	ND	97	7	TR	11	10	50	18	82.5	5.96
		37715	78	82	ND	99	9	ND	TR	TR	19	20	82.2	5.21
		37718	80	66	ND	125	8	TR	TR	TR	7	20	80.5	7.16
		37722	28	40	TR	52	TR	TR	9	13	6	10	81.4	6.45
		37724	41	25	ND	55	TR	TR	8	10	35	12	82.0	5.02
		37727	91	55	ND	99	8	TR	10	19	39	20	83.0	6.04
		37730	55	72	ND	97	5	8	7	19	13	25	83.3	6.38
CROFTON	Great Blue Heron egg	37692	380	728	ND	799	40	ND	TR	TR	7	64	80.3	8.17
		37693	67	107	ND	185	9	ND	7	TR	1	16	82.4	6.35
		37694	444	582	ND	1052	58	ND	7	TR	3	104	81.3	5.33
		37695	173	232	ND	434	27	ND	TR	ND	3	42	81.5	6.50
		37696	59	73	ND	110	8	ND	ND	ND	1	10	80.8	6.97
		37697	234	256	ND	580	35	ND	TR	TR	3	45	82.2	5.69
		37698	331	392	ND	661	45	ND	6	TR	17	47	82.8	5.52
		37699	369	216	ND	530	39	ND	7	TR	6	34	83.5	5.50
		37700	307	264	ND	456	34	ND	TR	ND	4	46	83.6	5.49
		37701	158	291	ND	357	18	ND	8	10	3	37	82.2	5.13
	Double-Crested Cormorant egg	37702	69	105	ND	226	25	ND	TR	TR	8	20	83.1	3.86
		37703	56	97	ND	242	22	ND	11	TR	5	22	83.0	4.14
		37704	100	212	ND	602	63	ND	9	TR	11	34	77.6	5.61
		37705	58	68	ND	133	14	ND	7	10	5	11	81.3	5.07
		37706	85	275	ND	962	125	ND	11	TR	15	36	78.6	4.67
MDC signal/noise=3			1	3	4	4	4	6	6	10	1	2		

ND No peak observed (sinal/noise 2);
TR trace level below the minimum detectable concentration (MDC, signal/noise between 2 and 3);
I Interferences in the monitored ion prevented determination of the contamination level.

Table 2a

PCDD levels in dungeness crab hepatopancreas, collected in BC, 1987, project 8719.
Levels are in ng/kg (wet wt.)

LOCATION		IONA JETTY, VANCOUVER	M & B, CHEMAINUS	BCFP, VICTORIA	BCFP, CROFTON	M & B, HARMAC	ASSEMBLY WHARF, NANAIMO	SEABOARD TERMINALS	CRESCENT BEACH	WESTERN PULP, PORT ALICE	MDC SIGNAL/NOISE=3
	USOX NO.	38036	38037	38038	38039	38040	38041	38042	38043	38117	
	Specimen No.	PF-29	PF-30	PF-31	PF-33	PF-34	PF-36	PF-37	PF-38	-	
	No. in pool	9	11	10	8	37	13	4	17	UN	
T4CDDs	TD1 500	ND	ND	2	ND	ND	ND	ND	ND	ND	2
	TD2 501	ND	2	9	ND	ND	ND	ND	ND	ND	2
	1378 502	3	5	20	3	2	ND	ND	ND	ND	2
	TD3 503	ND	ND	7	ND	ND	ND	ND	ND	ND	2
	TD4 504	ND	ND	7	ND	ND	ND	ND	ND	ND	2
	TD5 505	11	2	18	ND	(1)	ND	4	ND	ND	2
	2378 506	22	10	10	100	16	4	5	2	3	2
	1278 507	(1)	2	7	4	2	ND	ND	ND	ND	2
P5CDDs	12479/12468 530	4	5	23	5	5	(1)	3	ND	ND	3
	12368 531	8	13	47	8	7	3	6	ND	ND	3
	12478 532	16	24	98	39	19	3	7	ND	ND	3
	PD1 533	(1)	5	13	5	(2)	ND	ND	ND	ND	3
	PD2 534	ND	ND	7	ND	ND	ND	ND	ND	ND	3
	12379 535	(2)	(2)	12	7	(2)	ND	ND	ND	ND	3
	PD3 536	ND	ND	11	ND	ND	ND	ND	ND	ND	3
	12378 537	16	26	73	66	23	7	7	ND	ND	3
	12489/12467 538	(2)	3	19	8	3	ND	(1)	ND	ND	3
	12389 539	(1)	ND	10	5	ND	ND	ND	ND	ND	3
H6CDDs	124679/124689 560	10	18	90	48	24	10	13	ND	ND	4
	123468 561	ND	15	53	ND	ND	ND	ND	ND	ND	4
	123679/123689 562	125	269	901	617	279	76	92	6	ND	4
	123478 563	ND	ND	ND	ND	ND	ND	ND	ND	ND	4
	123678 564	82	188	437	278	136	58	49	5	ND	4
	123789 565	11	37	33	84	32	9	5	ND	ND	4
H7CDDs	1234679 591	5	47	81	11	12	24	20	(2)	ND	4
	1234678 592	9	93	144	21	17	18	25	5	(3)	4
	OCDD 599	ND	38	33	(6)	(5)	8	12	(3)	ND	6
	% Moisture	80.7	73.3	72.3	79.7	70.2	63.4	74.6	73.7	80.5	
	% Lipid	6.50	10.1	11.0	8.15	11.9	11.3	11.7	7.04	4.24	

ND no peak observed (signal/noise < 2);
( ) trace level below the minimum detectable concentration (<MDC, signal/noise between 2 and 3);
TD1 to TD5, PD1 to PD3 are tetra- penta- hexachloro PCDDs. but their chlorine substitution is unidentified at the present time;
UN number of samples in the pool is unknown (it was not recorded).

Table 2b

PCDD levels in dungeness crab hepatopancreas, collected in BC, 1987, project 8719. Levels are in ng/kg (wet wt.)

LOCATION		CROFTON	PORT MELLON CFP	PRINCE RUPERT WESTSTAR	WPPL WOODFIBRE	MDC, SIGNAL/NOISE=3
	USOX NO.					
	Specimen No.	FO 12	FO 21	FO 24	FO 17	
	No. in pool	3	5	6	4	
T4CDDs	TD1 500	ND	ND	ND	ND	2
	TD2 501	ND	ND	ND	ND	2
	1378 502	ND	ND	ND	ND	2
	TD3 503	ND	ND	ND	ND	2
	TD4 504	ND	ND	ND	ND	2
	TD5 505	ND	ND	ND	ND	2
	2378 506	76	662	487	356	2
	1278 507	3	33	13	18	2
P5CDDs	12479/12468 530	4	7	12	14	4
	12368 531	7	16	35	23	4
	12478 532	28	60	108	93	4
	PD1 533	9	15	15	20	4
	PD2 534	ND	ND	ND	ND	4
	12379 535	7	15	7	13	4
	PD3 536	ND	ND	ND	ND	4
	12378 537	64	130	167	172	4
	12489/12467 538	10	19	14	23	4
	12389 539	6	9	5	9	4
H6CDDs	124679/124689 560	45	76	81	223	6
	123468 561	ND	ND	ND	ND	6
	123679/123689 562	662	1,419	1,470	2,949	6
	123478 563	ND	ND	ND	ND	6
	123678 564	308	554	837	1,193	6
	123789 565	105	173	188	317	6
H7CDDs	1234679 590	10	14	23	80	8
	1234678 591	18	29	41	90	8
	OCDD 599	(7)	15	22	31	15
	% Moisture	80.4	76.4	79.4	75.2	
	% Lipid	8.61	7.88	6.78	9.72	

ND no peak observed (signal/noise < 2);

( ) trace level below the minimum detectable concentration (<MDC, signal/noise between 2 and 3);

TD1 to TD5, PD1 to PD3 are tetra- penta- hexachloro PCDDs. but their chlorine substitution is unidentified at the present time;

UN number of samples in the pool is unknown (it was not recorded).

Table 2c

PCDF levels in dungeness crab hepatopancreas, collected in BC, 1987, project 8719. Levels are in ng/kg (wet wt.)

LOCATION		IONA JETTY, VANCOUVER	M & B, CHEMAINUS	BCFP, VICTORIA	BCFP, CROFTON	M & B, HARMAC	ASSEMBLY WHARF, NANAIMO	SEABOARD TERMINALS	CRESCENT BEACH	WESTERN PULP, PORT ALICE	MDC SIGNAL/NOISE=3
	USOX NO.	38036	38037	38038	38039	38040	38041	38042	38043	38117	
	Specimen No.	PF-29	PF-30	PF-31	PF-33	PF-34	PF-36	PF-37	PF-38		
	No. in pool	9	11	10	8	37	13	4	17	UN	
T4CDFs	TF1 600	ND	ND	7	ND	ND	ND	ND	ND	ND	2
	TF2 601	ND	ND	18	ND	ND	ND	ND	ND	ND	2
	2468 603	9	5	15	7	ND	ND	ND	ND	ND	2
	TF3 604	7	ND	15	ND	ND	ND	ND	ND	ND	2
	2368 605	16	ND	29	20	9	ND	6	(1)	ND	2
	TF4 606	6	ND	6	14	ND	ND	ND	ND	ND	2
	1278 607	50	24	17	286	42	9	17	(1)	2	2
	2378 608	290	161	99	2605	353	93	123	9	6	2
	2367 609	19	8	33	107	16	4	7	ND	ND	2
P5CDFs	12468 630	37	4	64	ND	4	6	14	ND	ND	3
	12478/13479/12368 631	14	9	105	3	5	6	ND	ND	ND	3
	23468/12469 632	8	7	52	3	(2)	(2)	6	ND	ND	3
	12378/12348 633	3	4	23	12	3	5	ND	ND	ND	3
	PF1 634	ND	ND	5	ND	ND	ND	ND	ND	ND	3
	23489 635	(2)	3	14	(2)	(1)	(2)	ND	ND	ND	3
	23478/13489 636	9	8	36	22	4	5	ND	ND	5	3
	12489/23467 637	(2)	3	17	4	(1)	(1)	ND	ND	ND	3
H6CDFs	123468 660	8	6	73	ND	(3)	8	23	ND	ND	4
	124678 661	25	33	253	(2)	14	27	49	(2)	ND	4
	HF1 662	ND	ND	8	ND	ND	ND	ND	ND	ND	4
	124689 663	19	70	318	7	16	46	101	ND	ND	4
	123478 664	(1)	5	22	ND	ND	(3)	4	ND	ND	4
	123678 665	(1)	4	21	ND	ND	(2)	(3)	ND	ND	4
	123469/123689 666	ND	ND	4	ND	ND	ND	ND	ND	ND	4
	234678 667	(1)	5	19	ND	ND	(2)	(3)	ND	ND	4
H7CDFs	1234678 690	5	49	125	ND	8	15	24	ND	ND	4
	1234689 691	(3)	9	80	ND	6	14	25	ND	ND	4
	OCDF 699	ND	ND	(4)	ND	ND	ND	ND	ND	ND	6

ND no peak observed (signal/noise < 2);
( ) trace level below the minimum detectable concentration (<MDC, signal/noise between 2 and 3);
TF1 to TF4, PF1 to HF1 are tetra- penta- hexachloro PCDFs. but their chlorine substitution is not identified at the present time.
UN number of samples in the pool is unknown (it was not recorded).

Table 2d
PCDF levels in dungeness crab hepatopancreas, collected in BC, 1987, project 8719.
Levels are in ng/kg (wet wt.)

LOCATION		CROFTON	PORT MELLON CFP	PRINCE RUPERT WESTSTAR	WPPL WOODFIBRE	MDC, SIGNAL/NOISE=3
	USOX NO.					
	Specimen No.	FO 12	FO 21	FO 24	FO 17	
	No. in pool	3	5	6	4	
T4CDFs	TF1	ND	ND	ND	ND	5
	TF2	ND	ND	10	ND	5
	2468	ND	ND	37	38	5
	TF3	ND	ND	18	ND	5
	2368	7	94	156	87	5
	TF4	9	132	70	138	5
	1278	260	2,866	1,326	2,801	5
	2378	2,416	24,968	11,890	16,547	5
	2367	92	1,196	413	585	5
P5CDFs	12468	ND	ND	ND	ND	4
	12478/13479/12368	ND	4	10	13	4
	23468/12469	ND	12	11	17	4
	12378/12348	12	81	44	156	4
	PF1	ND	ND	ND	ND	4
	23489	ND	12	9	25	4
	23478/13489	23	149	75	253	4
	12489/23467	(3)	21	5	37	4
H6CDFs	123468	ND	ND	ND	ND	6
	124678	ND	ND	ND	ND	6
	HF1	ND	ND	ND	ND	6
	124689	(5)	ND	ND	11	6
	123478	ND	ND	ND	ND	6
	123678	ND	ND	ND	ND	6
	123469/123689	ND	ND	ND	ND	6
	234678	ND	ND	ND	ND	6
H7CDFs	1234678	ND	ND	ND	10	8
	1234689	ND	ND	ND	10	8
	OCDF	ND	ND	ND	ND	15

ND no peak observed (signal/noise < 2);
( ) trace level below the minimum detectable concentration (<MDC, signal/noise between 2 and 3);
TF1 to TF4, PF1 to HF1 are tetra- penta- hexachloro PCDFs. but their chlorine substitution is not identified at the present time.
UN number of samples in the pool is unknown (it was not recorded).

Table 3a

PCDD levels in mussels, oysters and clams collected from BC in 1987 project 8719
Levels are in ng/kg (wet wt.)

TISSUE		MUSSEL *					OYSTER *								BUTTER CLAM			BENTNOSE CLAM		HORSE CLAM	GEODUCK CLAM	MDC, SIGNAL/NOISE = 3
LOCATION		IONA ISLAND	BCFP CROFTON	OSBORNE BAY CROFTON	SHOAL ISLAND CROFTON	CRESCENT BEACH	SHOAL ISLAND CROFTON	BCFP CROFTON REEF	WILLIE ISL. LEASE CROFTON	ASSEMBLY WHARF NANAIMO	CIPA FOREST PROD. NANAIMO	M & B HARMAC HOOKER	M & B HARMAC JACK PT. 2	CRESCENT BEACH	SHOAL ISLAND CROFTON	M & B HARMAC JACK PT. 2	M & B CHEMAINUS	BCFP VICTORIA	CRESCENT BEACH	M & B CHEMAINUS	MAYO FOREST PRODUCTS NANAIMO	
USOX NO.		38114	38028	3R029	38030	38113	38031	38032	30833	38116	38120	38110	38109	38112	38034	38108	38118	38115	38111	38119	38121	
Specimen No.		PF-1	PF-2	P^c-7	PF-9	PF-76	PF-17	PF-18	PF-19	PF-20	PF-22	PF-23	-	PF-74	PF-24	-	PF-26	PF-54	PF-75	PF-25	PF-82	
No. in pool		UN	142	19	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	
T4	2378 506	ND	Int.	Int.	5	ND	31	14	12	ND	ND	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	2
P5CDDs	12479/12468 530	ND	3	(1)	4	ND	11	8	3	(1)	ND	3	ND	ND	(2)	ND	ND	ND	ND	ND	ND	3
	12368 531	ND	3	(2)	3	ND	16	10	6	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	3
	12478 532	ND	4	4	4	ND	38	13	8	(2)	ND	6	ND	ND	(2)	ND	ND	ND	ND	ND	ND	3
	PD1 535	ND	ND	ND	(2)	ND	5	3	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3
	12378 537	ND	4	5	ND	ND	25	14	9	(2)	11	8	ND	ND	(1)	ND	ND	ND	ND	ND	ND	3
	12489/12467 538	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	(2)	ND	ND	ND	ND	ND	ND	ND	ND	ND	3
H6CDDs	124679/124689 560	ND	16	15	14	ND	11	12	13	(3)	30	4	ND	ND	10	ND	ND	(3)	ND	ND	ND	4
	123468 561	ND	ND	ND	ND	ND	52	ND	ND	(3)	ND	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	4
	123679/123689 562	(3)	76	77	80	ND	120	105	110	17	166	34	4	ND	49	ND	(3)	11	ND	(3)	4	4
	123478 563	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4
	123678 564	ND	12	21	22	ND	75	46	46	9	59	20	(3)	ND	12	ND	ND	6	ND	(2)	(2)	4
	123789 565	ND	5	7	9	ND	17	14	11	(1)	ND	4	ND	ND	5	ND	ND	ND	ND	ND	ND	4
H7CDDs	1234679 590	ND	11	11	4	ND	ND	ND	ND	(3)	21	ND	ND	ND	(2)	ND	(3)	11	ND	4	(3)	4
	1234678 591	5	6	7	5	ND	4	(2)	(2)	(3)	34	ND	ND	ND	(2)	ND	5	17	ND	6	6	4
	OCDD 599	ND	15	13	(3)	ND	(3)	ND	ND	ND	ND	ND	ND	ND	ND	ND	(4)	15	ND	7	ND	6
	% Moisture	91.2	85.8	85.2	82.8	85.7	79.9	80.8	78.5	76.0	82.8	78.8	89.2	81.8	81.5	90.4	82.0	81.2	81.2	80.7	89.9	
	% Lipid	0.663	1.31	1.28	0.754	0.468	2.44	1.52	2.74	3.00	2.44	3.56	0.981	1.95	0.853	0.243	1.03	0.635	0.500	0.941	0.175	

ND no peak observed (signal/noise < 2);
( ) trace level below the minimum detectable concentration (<MDC, signal/noise between 2 and 3);
UN number of samples in the pool is unknown (it was not recorded);
* all mussels and oysters were unpurged;
Int levels can not be determined because of interferences.

Table 3b

PCDF levels in mussels, oysters and clams collected from BC in 1987, project 8719
Levels are in ng/kg (wet wt.)

TISSUE		MUSSEL*					OYSTER*								BUTTER CLAM			BENTNOSE CLAM		HORSE CLAM	GEODUCK CLAM	
LOCATION		IONA ISLAND	BCFP CROFTON	OSBORNE BAY CROFTON	SHOAL ISLAND CROFTON	CRESCENT BEACH	SHOAL ISLAND CROFTON	BCFP CROFTON REEF	WILLIE ISLAND LEASE CROFTON	ASSEMBLY WHARF NANAIMO	CIPA FOREST PRODUCTS NANAIMO	M & B HARMAC HOOKER	M & B HARMAC JACK PT.2	CRESCENT BEACH	SHOAL ISLAND CROFTON	M & B HARMAC JACK PT.2	M & B CHEMAINUS	BCFP VICTORIA	CRESCENT BEACH	M & B CHEMAINUS	MAYO FOREST PRODUCTS NANAIMO	MDC, SIGNAL/NOISE = 3
USOX NO.		38114	38028	38029	38030	38113	38031	38032	30833	38116	38120	38110	38109	38112	38034	38108	38118	38115	38111	38119	38121	
Specimen No.		PF-1	PF-2	PF-7	PF-9	PF-76	PF-17	PF-18	PF-19	PF-20	PF-22	PF 23	-	PF-74	PF-24	-	PF-26	PF-56	PF-75	PF-25	PF-82	
No. in pool		UN	142	19	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	UN	
T4CDFs	2368 603	ND	Int	Int	ND	ND	15	15	ND	ND	Int	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2
	1278 697	ND	Int	Int	4	ND	144	77	76	5	Int	16	2	ND	8	(1)	ND	ND	ND	ND	ND	2
	2378 608	6	Int	Int	75	ND	604	313	317	23	48	98	8	ND	36	4	2	ND	ND	2	2	2
	2367 609	ND	Int	Int	3	ND	ND	12	14	ND	ND	4	ND	ND	(1)	(1)	ND	ND	ND	ND	ND	2
P5CDFs	12468 630	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3
	23478/13489 636	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	3
H6CDFs	124678 [redacted] 661	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4
	124689 663	ND	ND	ND	ND	ND	ND	ND	ND	4	4	ND	ND	ND	ND	ND	ND	4	ND	(1)	5	4
H7CDFs	1234678 640	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	6	ND	(3)	(3)	4
	1234689 691	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	12	ND	4	8	4

ND no peak observed (signal/noise < 2);
( ) trace level below the minimum detectable concentration (<MDC, signal/noise between 2 and 3);
UN number of samples in the pool is unknown (it was not recorded);
* all mussels and oysters were unpurged;
Int levels can not be determined because of interferences.

Table 4a

PCDD levels in sculpins collected from BC in 1987, project 8719.
Levels are in ng/kg (wet wt.)

TISSUE		PRICKLY SCULPIN			STAGHORN SCULPIN								
LOCATION		FRASER HILLS	DOMTAR	WESTCOAST CELLUFIBRE	IONA JETTY	CRESCENT BEACH	BCFP, VICTORIA	BCFP, CROFTON	M &B CHEMAINUS	M & B HARMAC	MAYO FOREST PRODUCTS	PORT ALBERNI	SEABOARD TERMINAL
	USOX NO.	38035	38044	38045	38046	38047	38048	38049	38050	38051	38052	38053	38054
	Specimen No.	PF-28	PF-40	PF-43	PF-44	PF-50	PF-55	PF-58	PF-61	PF-64	PF-67	PF-69	PF-71
	No. in pool	49	14	32	10	10	14	7	10	7	5	8	1
T4CDDs	2378 506	ND	2	2	ND	ND	ND	10	ND	ND	(1)	9	ND
P5CDDs	12479/12468 530	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	12368 531	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	12478 532	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	PD1 533	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	12378 537	3	ND	(2)	(2)	ND	(2)	16	4	3	3	18	ND
	12489/12467 538	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
H6CDDs	124679/124689 560	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	123468 561	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	123679/123689 562	ND	ND	ND	ND	ND	ND	14	ND	ND	ND	ND	ND
	123478 563	ND	ND	ND	ND	ND	ND	ND	ND	(1)	(1)	ND	ND
	123678 564	4	4	10	(2)	ND	7	50	11	7	7	9	(2)
	123789 565	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	(1)	ND
H7CDDs	1234679 590	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	1234678 591	(3)	ND	10	(2)	ND	4	5	4	(3)	5	(3)	(3)
	OCDD 599	ND	ND	8	(3)	ND	ND	(5)	6	16	(4)	(3)	ND
	% Moisture	75.3	78.0	77.6	77.0	79.7	78.0	78.6	79.6	77.7	75.9	80.5	75.5
	% Lipid	2.13	1.10	1.82	0.993	0.853	1.10	1.48	0.837	0.504	1.01	0.400	0.958

ND no peak observed (signal/noise <2);

) trace level below the minimum detectable concentration (<MDC, signal/noise between 2 and 3);

PD1 is a penta- hexachloro PCDDs, but its chlorine substitution is unidentified at the present time.

Table 4b

PCDF levels in sculpins collected from BC in 1987, project 8719.
Levels are in ng/kg (wet wt.)

TISSUE		PRICKLY SCULPIN			STAGHORN SCULPIN									
LOCATI...		FRASER HILLS	DOMTAR	WESTCOAST CELLUFIBRE	IONA JETTY	CRESCENT BEACH	BCFP, VICTORIA	BCFP, CROFTON	M & B CHEMAINUS	M & B HARMAC	MAYO FOREST PRODUCTS	PORT ALBERNI	SEABOARD TERMINAL	MDC, SIGNAL/NOISE=3
USOX NO.		38035	38044	38045	38046	38047	38048	38049	38050	38051	38052	38053	38054	
Specimen No.		PF-28	PF-40	PF-43	PF-44	PF-50	PF-55	PF-58	PF-61	PF-64	PF-67	PF-69	PF-71	
No. in pool		49	14	32	10	10	14	7	10	7	5	8	1	
...DFs	2368 603	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	2
	1278 607	ND	ND	ND	ND	ND	ND	4	ND	ND	ND	ND	ND	2
	378 608	24	21	28	12	2	2	180	23	14	9	16	4	2
	2367 609	ND	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	2
P5C...	12468 630	ND	ND	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	3
	23478/13489 636	ND	ND	3	ND	ND	ND	4	ND	ND	ND	ND	ND	3
...DFs	124678/134678 666	ND	ND	4	ND	ND	ND	ND	ND	ND	ND	ND	ND	4
	124689 663	ND	ND	11	ND	ND	ND	ND	ND	ND	ND	ND	ND	4
H7C...	1234678 640	ND	ND	8	ND	ND	ND	ND	ND	ND	ND	ND	ND	4
	1234689 641	ND	ND	12	ND	ND	ND	ND	ND	ND	ND	ND	ND	4