PCDDs and PCDFs in Eagle and Osprey Eggs Near Kraft Pulp Mills in British Columbia Canada.

Whitehead, P.E.[a], Elliott, J.E.[a], Van Oostdam, J.[b] and Norstrom, R.J.[c]

[a] Canadian Wildlife Service, 5421 Robertson Road, Delta, B.C., Canada V4K 3N2
[b] B.C. Environment, Lands and Parks, Victoria B.C. Canada V8V 1X5
[c] Canadian Wildlife Service, Ottawa, Ontario, Canada

1. Introduction

For several years the Canadian Wildlife Service has monitored polychlorinated dioxin (PCDD) and furan (PCDF) levels in the eggs of colonial fish-eating birds such as herons and cormorants. These studies helped focus public and regulatory attention on the issue of kraft pulp mill pollution in coastal British Columbia. Herons and cormorants, however, only nest in the southern parts of the province, and are primarily associated with marine habitats. In 1990, studies were begun to assess other possible sentinel species such as the Bald eagle (*Haeliaeetus leaucocephatus*) and Osprey (*Pandion haliaetus*), that are more widely distributed and forage in aquatic as well as marine systems. If these species could be shown to accumulate *chlorinated hydrocarbons similarly to herons and cormorants*, then analysis of their eggs would provide a broader picture of environmental contamination in the province. This paper reports the results of PCDD and PCDF analysis of Bald eagle eggs collected in the Strait of Georgia and Johnstone Strait beginning in 1990, and Osprey eggs collected annually since 1991 from nests on the Columbia and Fraser River systems in the interior of British Columbia.

2. Methods

Bald eagle eggs (1 egg/nest) were collected from 1990 through 1992 in six areas of the south coast of British Columbia (fig. 1). Four of the areas were in the Strait of Georgia basin and receive effluent from kraft pulp mills which until recently were significant sources of PCDDs and PCDFs. A reference area in Johnstone Strait distant from direct sources of PCDDs and PCDFs was also surveyed. Additional samples were collected from; 1) Alberni Inlet, 25 Km. from the pulp mill at the head of the inlet, 2) Clayoquot Sound and, 3) at Langara Island in the Queen Charlotte archipelago. In 1991 and 1992 osprey eggs (1 egg/nest) were collected from several nests upstream and downstream of kraft mills on the Thompson River near Kamloops, and the Kootenay and Columbia rivers near Castlegar (fig. 1). Additional samples were collected in 1993 and 1994 near the Castlegar mill. Individual eagle and osprey eggs were analyzed for PCDD/Fs, PCBs, several OC pesticides and chlorophenols. Only the PCDD/F data will be presented here. Detailed descriptions for the collection, storage and analytical methods are given elsewhere.[1,2] Due to the skewed nature of the data, geometric means and 95% confidence intervals were calculated.

3. Results and Discussion

All eagle eggs sampled in the Strait of Georgia and Johnstone Strait contained PCDDs and PCDFs. Levels of 2378-substituted tetra-, penta- and hexa-chlorinated congeners were highest in eggs sampled near kraft mills at Crofton and Powell River (Table 1). Concentrations of these congeners were also high in eggs collected in Johnstone Strait, although 2378-tetrachloro-p-dibenzodioxin (TCDD) levels were generally lower than elsewhere. Eggs from Clayoquot Sound and Langara Island were the least contaminated. The general pattern of congeners in the eagle eggs (table 1), 123678 HxCDD > 12378 PnCDD > TCDD is similar to that found in the eggs and tissues of marine birds overwintering or resident in the Strait of Georgia.[3,4] Possible sources of these PCDDs in kraft mill processes have been discussed.[3,5] HpCDD and OCDD levels were near detection limits in all samples, while elevated levels of TCDF and PnCDF were present in most of the eggs. PCDFs are believed to be rapidly metabolised[6] so elevated levels would require continuous exposure to high concentrations in the diet and direct deposition in the yolk during egg formation.[3] Vermeer et al.[7] reported that more than 50% of the diet of nesting eagles in the Strait of Georgia consists of seabirds (mostly gulls but also cormorants and herons), as well as grebes, ducks and shoreline birds. Fish, marine invertebrates and mammals make up the remainder. There are no kraft mills in Johnstone Strait to account for the elevated levels of PCDD/F found in the eggs of eagles nesting there. Those eagles might be preying on waterbirds migrating northward in the spring after overwintering in the Strait of Georgia where they accumulated a substantial amounts of PCDD/F.[4] TCDF levels in eagle eggs sampled near the kraft mill at Crofton are lower than those in eggs collected in Johnstone Strait. Possibly herons and cormorants, which are abundant near Crofton and contain only small concentrations of TCDF,[3] make up a significant part of the diet of eagles nesting there.[8] Although only one nest was sampled twice during the course of this study, the data generally show PCDD levels have fallen over the sampling period (table 1). The decline is similar to that seen in other biota sampled in the Strait of Georgia over the past several years,[5] and is likely due to a sharp fall in PCDD/F output by kraft mills since 1989. Information about process and product changes made by kraft mills in the Strait of Georgia to eliminate PCDD/Fs in their effluent has been presented.[5]
Osprey forage exclusively on fish swimming near the surface or in shallow water. In the study area about half the fish delivered to the nest were whitefish or sucker. Studies have shown these fish are contaminated with 2378-substituted PCDD/Fs.[9] Measurable levels of PCDD/Fs were found in most osprey eggs sampled (table 2). Eggs collected downstream of kraft mills have significantly higher levels of 2378-TCDD and 2378-TCDF than eggs collected above mill sites. Concentrations of 2378-substituted penta- and hexa- congeners in osprey eggs are, however, much lower than in eagle eggs in the Strait of Georgia. The difference in penta- and hexa- substituted congeners is likely attributable to lower chlorophenol use by interior kraft mills compared with coastal mills. Lowest tetra-, penta- and hexa-substituted PCDD/Fs were generally found in eggs collected above the kraft mill at Castlegar and on the Nechako River (table 2). PCDD/F congener patterns are much more variable in osprey eggs than they are in eagle eggs. Some of the variability is due to differences in TCDD and TCDF levels between osprey nesting upstream of mills and those

nesting downstream. In addition, some eggs contain remarkably high levels of HpCDD and OCDD while others contain only trace amounts.[10] The presence of these congeners is unrelated to urban development or industrial activity near nest sites. Often nests with high levels of HpCDD and OCDD are located just short distances from others containing only trace amounts. Reported HpCDD and OCDD levels in fish foraged by osprey are below detection limits.[9] We suggest that the osprey accumulate these contaminants on their wintering grounds, or during migration. Studies are underway to track the seasonal movements of osprey by satellite and locate areas of contamination. In 1990, the mill at Castlegar implemented process and product changes that significantly reduced PCDD/F levels in effluent.[11] 2378-TCDD/F levels in fish have fallen since the measures were implemented.[12] 2378-TCDD/F levels in osprey eggs, however, remain elevated downstream of the kraft mill at Castlegar (table 2).

Our data show that eagle and osprey are useful sentinels of environmental contamination by persistent chlorinated hydrocarbons. However, establishing sources and pathways for contaminants in these species can be difficult. Eagles, while resident on the west coast, may move considerable distances to take advantage of seasonal foraging opportunities. As well, their diet consists of a variety of birds (migratory and non-migratory), fish, invertebrates and mammals. Osprey, of course, are migratory so contaminants are accumulated during migration and on the wintering ground, as well as at the nest site.

4. Acknowledgements
The authors gratefully acknowledge the contributions that Marlene Machmer, Mary Simon, Ian Moul, B.C. Hydro and West Kootenay Power made to this project.

4. References

1. Turle R., R.J. Norstrom, B. Collins. 1991. Chemosphere 22:201-213.
2. Norstrom R.J., M. Simon, D.C.G. Muir. 1990. Environ. Pollut. 66:1-19.
3. Elliott J.E., R.W. Butler, R.J. Norstrom and P.E. Whitehead. 1989. Environ. Pollut. 59:91-114.
4. Whitehead P.E., J.E. Elliott, R.J. Norstrom and K. Vermeer. 1990. Dioxin '90 vol. 1:459-462.
5. Whitehead P.E., R.J. Norstrom and J.E. Elliott. 1989. Dioxin '92 vol. 9:325-328.
6. Van Den Berg M., J. DeJongh, H. Poiger and J.R. Olson. 1994. Crit. Rev. Toxicol. 24:1-74.
7. Vermeer K., K.H. Morgan, R.W. Butler and G.E.J. Smith. 1989. K. The Ecology and Status of Marine and Shoreline Birds in the Strait of Georgia, British Columbia. Vermeer & R. Butler eds. pp 123.
8. Norman D.M., A.M. Breault and I.E. Moul. 1989. Colonial Waterbirds 12:215-217.
9. Mah F.T.S., D.D. MacDonald, S.W. Sheehan, T.M. Tuominen, D. Valiela. 1989. Environment Canada.
10. Whitehead P.E., J.E. Elliott, R.J. Norstrom, C. Steeger, J. Van Oostdam and G.E.J. Smith. 1993. Dioxin '93 vol. 12:231-234.
11. Celgar Pulp Company 1992 Environmental Performance Report. 1993. pp. 21. Celgar Pulp Company, P.O. Box 1000 Castlegar, B.C. Canada V1N 3H9.
12. Serdar D., W. Yake and J. Cubbage. 1994. Wash. State Dep. Ecol. publ. no. 94-185.

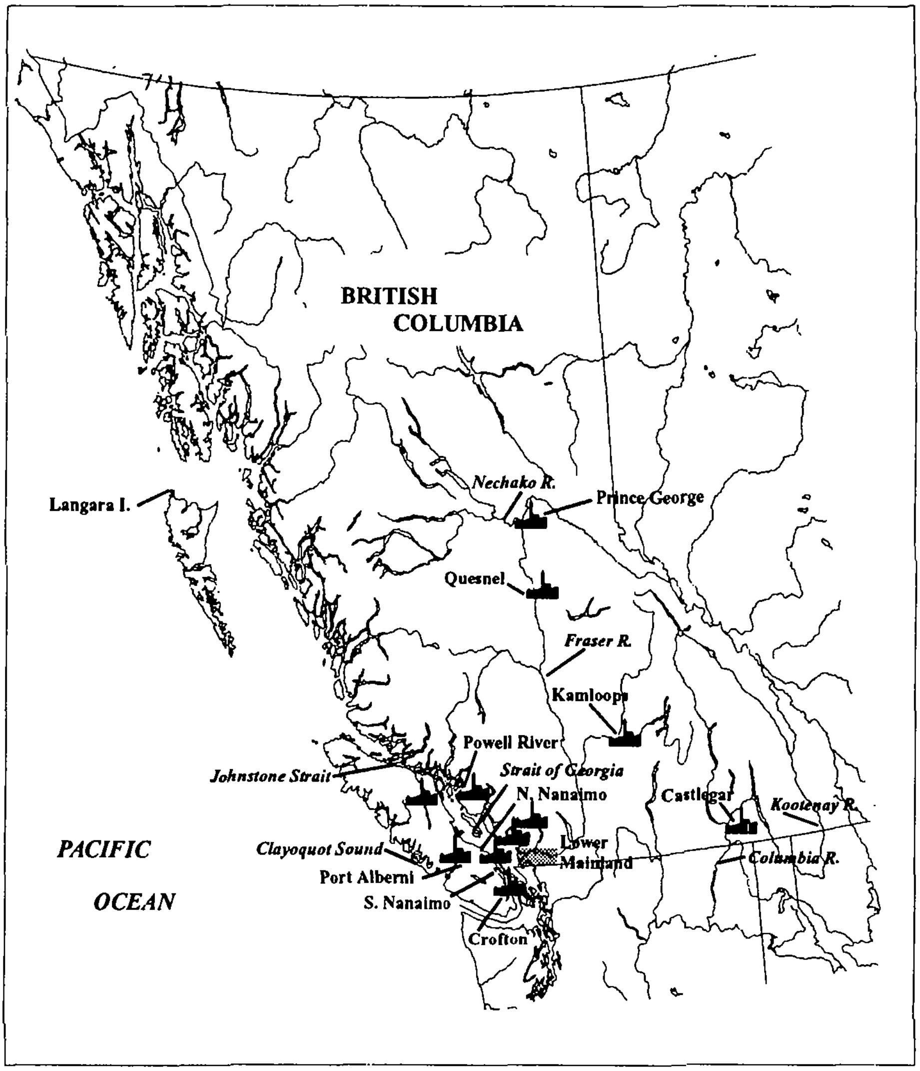

Figure 1. Egg collection sites.

TABLE 1. PCDD and PCDF levels in eagle eggs collected in southwestern British Columbia.

RESIDUE LEVEL (ppt wet wt.) GEOMETRIC MEAN
95% CONFIDENCE INTERVAL, (RANGE)

LOCATION	LOWERMAINLAND		CROFTON		S. NANAIMO		N. NANAIMO		POWELL RIVER			JOHN.ST.	PT. ALB.	CLAY.S.	LANG. IS.
YEAR	1990	1991	1990	1991	1990	1992	1991	1992	1990	1991	1992	1991	1992	1992	1992
NESTS	1,2,3	4,5,6	14,15	16	7,8,9,10	10	12,13	11	17,18	19	20,21,21,22	23-29	30	31	32
2378-TCDD	52 33-83 (42-58)	38 13-100 (23-51)	107 - (104-110)	51	70 54-91 (59-62)	24	44 - (28-70)	14	93 - (88-98)	41	38 8-175 (10-61)	15 10-22 (10-32)	17	10	2
12378-PnCDD	47 28-80 (37-55)	9 2-28 (6-15)	177 - (149-211)	108	114 93-138 (99-133)	31	55 - (29-104)	22	129 - (128-129)	59	56 14-207 (18-106)	35 26-48 (25-64)	54	16	5
123678-HxCDD	64 18-223 (42-112)	17 13-21 (15-18)	341 - (310-374)	172	250 171-364 (198-346)	54	117 - (79-173)	37	301 - (244-372)	186	118 76-184 (80-146)	78 51-118 (43-167)	38	7	3
1234678-HpCDD	2 0-50 (0-9)	0 0-4 (0-2)	0 - (0-0)	2	1 0-2 (0-2)	0	1 - (0-2)	0	0 - (0-1)	2	0 0-0 (0-0)	1 0-2 (0-3)	0	0	0
OCDD	1 0-8 (0-2)	1 0-19 (0-5)	0 - (0-0)	2	1 0-2 (0-2)	3	2 - (2-4)	4	0 - (0-1)	2	2 2-3 (2-3)	1 0-3 (0-7)	3	2	0
2378-TCDF	62 7-498 (23-112)	51 4-602 (16-110)	20 - (16-26)	60	35 24-52 (29-49)	56	88 - (65-119)	18	76 - (59-97)	110	67 11-383 (18-168)	47 33-66 (29-80)	7	7	5
23478-PnCDF	13 11-16 (12-14)	3 0-245 (0-24)	30 - (27-34)	22	21 13-33 (16-31)	6	21 - (12-35)	5	32 - (27-37)	24	18 2-113 (5-50)	8 6-11 (5-14)	4	4	2

TABLE 2. PCDD and PCDF levels in osprey eggs.

RESIDUE LEVEL (ppt wet wt.), GEOMETRIC MEAN,
95% CONFIDENCE INTERVAL, (RANGE)

LOCATION	KAMLOOPS				QUESNEL		NECHAKO	CASTLEGAR						
YEAR	1991			1992	1991	1992	1992	1991		1992	1993		1994	
	Above mill	Below mill	Above mill	Below mill	Below mill	Below mill	Above mill	Above mill	Below mill	Below mill	Above mill	Below mill	Above mill	Below mill
N	6	5	5	5	4	5	5	10	9	5	5	4	5	5
2378-TCDD	11 6-22 (3-22)	47 21-103 (23-95)	6 2-16 (2-13)	29 6-118 (4-119)	6 0-54 (0-15)	7 5-10 (6-10)	1 0-2 (1-2)	1 0-4 (0-50)	20 10-37 (6-57)	17 4-61 (5-56)	0 0-2 (0-3)	21 7-58 (9-38)	1 1-2 (1-2)	21 10-44 (11-46)
12378-PnCDD	0 0-2 (0-7)	3 0-16 (0-13)	3 1-12 (0-7)	5 2-13 (2-13)	1 0-11 (0-9)	5 2-11 (3-12)	2 0-6 (0-5)	1 0-5 (0-29)	6 3-9 (2-16)	3 2-6 (2-5)	1 0-6 (0-11)	1 0-6 (0-6)	3 2-4 (1-4)	4 3-5 (3-5)
123678-HxCDD	15 8-25 (6-26)	22 10-44 (10-39)	15 8-27 (10-33)	12 3-38 (2-25)	7 0-93 (0-46)	13 7-41 (3-18)	6 1-29 (5-17)	8 2-32 (0-160)	7 3-15 (0-35)	6 2-18 (1-17)	0 0-0 (0-0)	2 0-11 (0-6)	5 1-15 (1-14)	4 2-6 (2-7)
1234678-HpCDD	94 36-240 (18-210)	72 13-368 (10-250)	138 83-231 (95-261)	41 8-202 (4-100)	15 0-1952 (0-1100)	36 4-326 (4-401)	19 1-201 (14-124)	26 5-110 (0-880)	10 3-34 (0-248)	17 1-171 (2-188)	5 0-34 (0-26)	4 0-34 (0-17)	10 0-90 (1-91)	10 2-37 (3-36)
OCDD	374 82-1695 (22-1200)	92 2-2670 (0-950)	472 246-906 (230-837)	94 13-641 (6-303)	21 0-16704 (0-7000)	144 15-1331 (19-1179)	50 2-894 (64-352)	41 5-274 (0-4100)	17 2-101 (0-1339)	37 1-592 (3-1147)	9 0-104 (0-93)	32 11-87 (14-65)	24 2-241 (3-253)	32 5-191 (7-220)
2378-TCDF	1 0-3 (0-5)	2 0-11 (0-15)	1 0-2 (0-2)	4 2-7 (2-6)	0 0-0 (0-0)	1 0-1 (0-2)	0 0-1 (0-2)	0 0-2 (0-16)	16 7-33 (5-61)	35 20-60 (23-68)	1 0-6 (0-9)	25 9-63 (11-47)	1 1-2 (1-2)	25 10-61 (10-58)
23478-PnCDF	0 0-1 (0-2)	2 0-7 (0-5)	2 1-3 (1-3)	3 1-6 (1-7)	0 0-2 (0-1)	2 1-5 (1-6)	1 0-2 (1-3)	1 0-2 (0-2)	7 5-11 (3-14)	7 3-15 (3-17)	0 0-0 (0-0)	1 0-7 (0-6)	1 0-2 (0-2)	1 0-4 (0-8)