Howe Sound, Dungeness Crab: Delicacy or Deadly?

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Howe Sound, the first inlet northwest of Vancouver on the Strait of Georgia, is an estuary system opening onto the Strait of Georgia and fed primarily by the Squamish River at the head of the Sound. Howe Sound has been divided into five fishery sub-areas (28-1, 28-2, 28-3, 28-4, and 28-5) by the Department of Fisheries and Oceans (DFO).

Dioxins and furans in aquatic biota from Howe Sound were measured by DFO through 1988 and 1989 as part of the national dioxin and furan sampling and monitoring program. In addition, an independent monitoring of dioxin and furan concentrations in sediments and crabs was conducted by the two pulp mills on Howe Sound. Effective December 1, 1988, commercial and recreational prawn, shrimp and crab fishing was closed in sub-areas 28-3, 28-4, and 28-5 of Howe Sound[1]. Health and Welfare Canada stated that the concentrations of dioxins and furans in crabs (both body meat and hepatopancreas), prawns and shrimp caught in these areas could pose a health hazard if consumed regularly[2]. On June 14, 1989[3], the closure was extended by the DFO to include prawn and shrimp fishing for a small portion of area 28-1 in the vicinity of Keats Island and Gower Point, and commercial crab fishing was closed for the remainder of the Sound (areas 28-1 and 28-2). Recreational crab fishing was permitted in areas 28-1 and 28-2, subject to a health advisory warning that the hepatopancreas should not be consumed. Dioxin and furan monitoring continued during 1991, 1992, 1993, and 1994.

In February 1995, DFO announced the reopening to non-commercial crab harvesting of sub-areas 28-4, 28-5, and the eastern portion of 28-1, subject to a consumption advisory on hepatopancreas of 40 g/week[4]. All crab fishing remains closed in sub-area 28-3 and the western portion of sub-area 28-1[4]. Sub-area 28-2 and the eastern portion of 28-1 remain closed to commercial crab harvesting[4]. All sub-areas of Howe Sound are reopened to shrimp and prawn harvesting[4]. These decisions are based on subsequent monitoring data that indicates a continuing decline in tissue concentrations of dioxins and furans. For example, crab muscle collected from sub-area 28-3 in 1992 and 1993 had 0.3 and 3 ppt 2,3,7,8-TCDD TEQs, respectively (Hatfield Consultants, personal communication). Crab muscle sampled in 1989 from the same site in sub-area 28-3 had mean 2,3,7,8-TCDF TEQs of 66.94 ppt (Table 1). A similar decline in TEQs has been observed in crab muscle and hepatopancreas samples from other sub-areas of the Sound.

This paper summarizes the findings of a human health risk assessment of 2,3,7,8-TCDD TEQ exposure through consumption of Dungeness crab collected from Howe Sound.

Concentrations in Crab

The following risk assessment addresses concentrations of dioxins and furans measured in Howe Sound Dungeness crab collected in 1989[5,6,7] when the closure was implemented.

The average 1989/90 concentration of dioxins and furans, expressed as 2,3,7,8-T_4CDD TEQs, measured in crab muscle and hepatopancreas samples from each sub-area 28-1, 28-2, 28-3, 28-4, and 28-5 of Howe Sound are presented in Table 1. Dioxin and furan concentrations reported to be less than the detection limit were assumed to equal one-half the reported detection limit, since the actual concentration in such samples could be anywhere between the analytical detection limit and zero. A substantial number of muscle samples were of non-detectable values, in contrast to hepatopancreas samples. However, the hepatopancreas represents only 5% of the total body weight of marine invertebrates compared to 25% that is muscle[8].

Exposure Assessment for Adult and Child

A deterministic exposure assessment of 2,3,7,8-TCDD TEQ through the consumption of Howe Sound Dungeness crab and Canadian fish products was conducted for an average Canadian adult (70 kg) and child (13 kg)[9]. 2,3,7,8-TCDD TEQ concentrations in other fish products for Canadian consumption were assumed to equal the geometric mean 2,3,7,8-TCDD concentration of 2.29 ppt for fish from the Great Lakes region[10].

The fish and shellfish consumption rates used in the exposure assessment were based on the population average adult and child data for the Pacific region[11]. The average adult was assumed to consume 0.8 g/day of crab and 12.43 g/day of finfish; and the average child was assumed to consume 0.2 g/day of crab and 5.32 g/day of finfish. The reported 50th-percentile shellfish consumption for both child and adult of the Pacific region was 0 g/day[11]. The corresponding 50th-percentile finfish consumption rate for a child and adult were 3.26 and 7.84 g/d, respectively.

Exposures to 2,3,7,8-T_4CDD TEQs from fish consumption were calculated for an adult and child using Pacific region population average fish consumption rates, assuming that all crab consumed contained comparable concentrations of dioxins and furans to those reported for Howe Sound in 1989.

The average lifetime daily exposure through consumption of fish and/or crab (pg/kg body weight/day) was calculated, accordingly:

$$\text{2,3,7,8-TCDD TEQ} = \text{DPCC} \times C_f \times / \text{BW}$$

where;
2,3,7,8-TCDD TEQ = estimated 2,3,7,8-TCDD TEQ exposure (pg/kg body weight/day)
DPCC = daily per capita consumption of fish and/or crab (g/day)
C_f = concentration of 2,3,7,8-T_4CDD equivalent in fish and/or crab (pg/g)
BW = body weight (kg); 70 kg for adult, 13 kg for child

The estimated 2,3,7,8-T_4CDD TEQ lifetime exposures (in pg/kg body weight/day) for an average adult and child from consumption of 1989 crab, fish products and total fish and crab consumption are presented in Table 1. The use of the 1989 crab concentrations of dioxins and furans provides a conservative assessment because the 1990 data indicate lower concentrations in crab. Subsequent monitoring data collected during 1991 through 1993 reveal a continuing decline in tissue concentrations of 2,3,7,8-TCDD TEQs.

Recommended Exposure Limit for 2,3,7,8-T_4CDD

A daily lifetime exposure limit of 0.00001 μg 2,3,7,8-T_4CDD TEQ/kg body weight/day, or 10 pg/kg body weight/day is recommended by Health and Welfare Canada[12] based on the NOAEL for adverse effects on reproduction (decreased fertility) in rats of 0.001 μg 2,3,7,8-T_4CDD TEQ/kg body weight/day[13] and a 100-fold safety factor. This exposure limit for protection of human health is consistent with the weight-of-toxicological data demonstrating that dioxins and furans can cause adverse reproductive effects and can promote the production of cancer caused by other agents.

Since fish represent the primary dietary source of dioxin and furan exposure for humans[4,9], the exposure limit was apportioned to allow 80% of the maximum exposure limit of 10 pg/kg body weight/day (*i.e.*, 8 pg/kg body weight/day) to assess the potential health risks from seafood.

Interpretation of the Human Health Risk Assessment

The assessment of the potential health risks from the consumption of fish and crab presented below is based on the calculation of an Exposure Ratio (ER) for an adult and a child through the consumption of commercially caught fish and crab. The ER value equals the estimated exposure divided by the exposure limit.

None of the ERs predicted exceeded a value of one (Table 1). The highest ER value predicted for the adult was 0.51 (consuming total edible portion of crab, *i.e.*, muscle plus hepatopancreas based on the maximum concentrations measured in Howe Sound for all crab consumed). The predicted ER value for the combined exposure from consumption of commercial fish and the total edible portion of crab was 0.56.

For the child, the highest ER value predicted was 0.69 (consuming the total edible portion of crab based on the maximum concentrations measured in Howe Sound for all crab consumed). The estimated ER value for the combined exposure to consumption of commercial fish and the total edible portion of crab was 0.81. The assessment of the child was highly conservative, since it was assumed that the ratio of the child's fish consumption-to-body weight remained constant over a lifetime,. In conclusion, no health risk would be expected for a child consuming Howe Sound Dungeness crab based on the estimated levels of exposure and the exposure limit for 2,3,7,8-T_4CDD. Similar to the adult, quantities of Howe Sound Dungeness crab far in excess of average consumption rates would have to be consumed regularly to exceed the recommended lifetime 2,3,7,8-T_4CDD TEQ acceptable exposure limit of 8 pg/kg body weight/day.

The decline in dioxin and furan concentrations in crab are associated with process changes implemented by the pulp mills to eliminate the production of chlorinated dioxins and furans[14].

Table 1 2,3,7,8-T_4CDD TEQ Exposure Estimates for Average Adult and Child From Consumption of Fish and Crab

Fish/Crab	2,3,7,8-T_4CDD TEQ (ppt or pg/g)		Estimated 2,3,7,8-TEQ Exposure (pg/kg/bw/d)		ER	
			Adult (70 kg)	Child (13 kg)	Adult (70 kg)	Child (13 kg)
Fish	2.29		0.41	0.94	0.05	0.12
Dungeness crab[a]	H.S. area: Mean TEQ					
[Muscle (*i.e.*, legs)]	28-1:	20.97	0.24	0.32	0.03	0.04
	28-2:	6.62	0.076	0.10	0.0095	0.013
	28-3:	66.94	0.77	1.03	0.096	0.13
	28-4:	16.62	0.19	0.26	0.024	0.03
	28-5:	38.43[d]	0.44	0.59	0.055	0.07
	maximum[b]					
	TEQ:	141.59	1.6	2.2	0.20	0.27
Dungeness crab[c]	H.S. area: Mean TEQ					
[Total edible portion]	28-1	120.98	1.38	1.9	0.17	0.24
	28-2:	32.83	0.38	0.51	0.048	0.064
	28-3:	244.51	2.79	3.8	0.35	0.48
	28-4:	68.07	0.78	1.1	0.098	0.14
	28-5:	130.54[d]	1.49	2.0	0.19	0.25
		59.64[e]	0.68	0.92	0.085	0.12
	maximum[b]					
	TEQ:	357.88	4.1	5.5	0.51	0.69

[a] The average measured concentration of 2,3,7,8-T_4CDD TEQ (ppt) in crab muscle (leg) D. Crab collected from each sub-area of Howe Sound [i.e. 28-1 (Jan./Feb. 1989)[3], 28-2 (Jan./Feb. 1989[3], Nov. 1989[6]), 28-3 (Jan./Feb. 1989[3]), 28-4 (Jan./Feb. 1989[3], Nov. 1989[6])].

[b] The maximum measured concentration of 2,3,7,8-T_4CDD TEQ (ppt) in crab muscle (leg) and total edible portion of D. Crab collected from Howe Sound [3,6]. Both maximums from a crab at station C-10 (area 28-3) sampled in 1989.

[c] The average measured concentration of 2,3,7,8-T_4CDD TEQ (ppt) in the total edible portion of D. Crab (*i.e.*, muscle + hepatopancreas) = |25/30(M) + 5/30(H)|; where M = 2,3,7,8-T_4CDD TEQ in muscle (leg) (ppt) and H = 2,3,7,8-T_4CDD TEQ in hepatopancreas[3,6]. Based on reported relative whole body weights of 25% muscle and 5% hepatopancreas for lobster[8].

[d] The average measured concentration of 2,3,7,8-T_4CDD TEQ (ppt) in D. crab collected in sub-area 28-5, January and February 1989[3].

[e] The average measured concentration of 2,3,7,8-T_4CDD (ppt) in D. crab collected in sub-area 28-5 (3 sites), November 1989 [6].

These process changes include the discontinued use of PCP treated woodchips in the production of pulp, and ClO_2 substitution for $Cl_{2\,(g)}$ in the bleaching process. Western Pulp at Woodfibre and Howe Sound Pulp and Paper at Port Melon used 50% ClO_2 substitution in 1991 and currently use 50-100% ClO_2 substitution[14]. Effluents from these mills generally have non-detectable concentrations (< 10 ppq) of 2,3,7,8-chlorine substituted dioxins and furans.

A reanalysis of the 1989-1993 data using Monte Carlo probablistic risk assessment methodologies will be presented.

In conclusion, no measurable adverse effects on human health would be expected from exposure to 2,3,7,8-TCDD TEQ measured in Howe Sound Dungeness crab.

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