SCREENING-LEVEL ECOLOGICAL RISK ASSESSMENT OF PCDD/FS AND COPLANAR PCBS IN LOBSTERS AND SEDIMENTS FROM CASCO BAY, MAINE USA

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Introduction

Recent studies indicate that polychlorinated dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs) and other persistent organochlorines are widespread in sediments, lobsters, and sport fish at relatively low levels in Casco Bay, Maine [1,2,3]. A fish consumption advisory established by the Maine Department of Environmental Protection (DEP) advised against consumption of more than one fish meal per week by pregnant women and children [4]. Sources of the contamination have not been determined with certainty, but likely include combined sewer outfalls and storm water from the city of Portland and smaller coastal communities, paper mills and other manufacturing industries located along the Androscoggin and Kennebec Rivers, motorboat traffic, and aerial deposition from distant sources [4].

This paper presents the results of a screening-level ecological risk assessment (ERA) to evaluate the risks to wildlife posed by 2,3,7,8-substituted PCDD/Fs and coplanar polychlorinated biphenyls (PCBs) in sediments, aquatic invertebrates, and fish. The purpose of this study was to provide a preliminary indication of the possible risks, if any, to representative aquatic biota and wildlife receptors at different trophic levels. Sources of PCDD/Fs were evaluated based on comparisons to environmental levels from other coastal marine environments in Western Europe, North America and Asia. Recommendations for future investigation are discussed.

Methods

Environmental Data. PCDD/Fs and coplanar PCBs (IUPAC #77, #81, #126, and #169) in sediment and meat and tomalley (liver) in lobster (*Homarus americanus*) from Casco Bay were compiled from Maine DEP investigations conducted between 1994 and 1996 [2,3]. For non-detect concentrations, one-half the detection limit was assumed for the ERA; for PCA, $1x10^{-10}$ was assumed. Toxic equivalency quotients (TEQs) were calculated using toxic equivalency factors (TEFs) proposed by the World Health Organization [5]. A summary of the environmental data is presented in Table 1.

Source Identification. Principal components analysis (PCA) was used to compare and contrast the relative distributions of 2,3,7,8-substituted PCDD/F and coplanar PCB congeners in sediments and lobster. PCA modeling was conducted using Pirouette (version 1.4, InfoMetrix, Seattle, WA). Congener patterns in sediment and lobster were compared to those from different

anthropogenic sources [6,7]. Sampling results in lobster were compared to calculated whole body burdens using biota-sediment-accumulation-factors [8].

Ecological Risk Assessment. The screening-level ERA was conducted in a manner consistent with U.S. Environmental Protection Agency (USEPA) ERA guidance [9,10]. Two species of birds and mammals were selected as receptors of interest (ROIs), including the osprey (*Pandion haliaetus*) and Atlantic harbor seal (*Phoca vitulina*) as representative piscivores and the spotted sandpiper (*Actitis macularia*) and river otter (*Lutra canadensis*) as representative aquatic invertivores. Wildlife ROI exposures to PCDD/Fs and coplanar PCBs with "dioxin-like" effects were estimated by calculating an average daily dose (ADD, mg of chemical per kg body weight). Wildlife ADDs were calculated based on incidental ingestion of sediment and consumption of prey. The effects assessment and risk characterization for wildlife were conducted by comparing measured or predicted whole body burdens expressed as TEQs to available no-observed-adverse-effect-level (NOAEL) and lowest-observed-adverse-effect-level (LOAEL) wildlife toxicological reference values (TRVs) [8, 11]. For fish and aquatic invertebrates, body burdens were compared to a range of acute and chronic lowest-observed-effect concentrations (LOEC).

Results and Discussion

PCDD/F Patterns in Sediment and Lobster. The first two principal components from the PCA results reveal distinct differences between the distribution of PCDD/Fs in sediment and lobsters. The results presented in Figure 1 explain 56% of the variance in the data sets. Dissimilar results in sediment and biota collected from the same area have been observed elsewhere [12, 13]. The distribution of PCDD/Fs in lobster tomalley is different from that in the edible meat portion (Figure 1). Congener profiles in sediment are similar, despite variations in concentrations; OCDD accounts for at least 75% of the total PCDD/Fs in each sample, while no PCDF congener accounts for more than 8% of the total. In lobster, congener profiles vary and more congeners comprise significant portions of the total PCDD/Fs. Interestingly, 2,3,4,7,8-PeCDF and 2,3,7,8-TCDF, two congeners with the highest BSAFs, are important congeners in lobster despite being relatively insignificant in sediment.

ERA Results. Predicted wildlife ADDs are summarized in Table 1. When expressed on a total TEQ basis, ADDs of PCDD/Fs and coplanar PCBs exceed NOAEL TRVs by as much as 11-fold for piscivorous birds and mammals and invertivorous mammals. Predicted body burdens of coplanar PCBs are significantly higher than PCDD/Fs in forage fish and wildlife, and contribute approximately 50% of the total TEQ in piscivorous birds and invertivorous mammals. Hazard quotients (HQs) calculated from the ratio of predicted PCDD/F and coplanar PCB body burdens to NOAEL and LOAEL TRVs are generally well below one, suggesting a minimal risk of adverse effects to forage fish. 2,3,7,8-TCDD concentrations in surficial sediments (ranging from ND-2 pg/g dw) are well below the 25 ppb no-effect concentration identified in recent estuarine sediment toxicity testing [17]. The derivation of no-effect and effect thresholds for different organochlorines using site-specific sediment toxicity tests would improve the assessment of risks to benthic invertebrates. Although additional organochlorine data on forage fish and other lower trophic level organisms are needed to improve this screening-level assessment, the results provide a foundation for future monitoring and management activities.

Acknowledgments
The authors wish to thank Mr. John Sowles, Surface Water Ambient Toxic Monitoring Program, at Maine Department of Environmental Protection for their encouragement and support.

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Table 1. 95% Upper Confidence Limit PCDD/F and coplanar PCB concentrations in sediment, lobster (meat and tomalley) and fish (estimated), and predicted ADDs for representative wildlife receptors in a simplified food web for Casco Bay, Maine

PCDD/F and Coplanar PCBs	Sediment (ng/kg dw) N=30	Fish (ng/kg ww) Estimated	Lobster (ng/kg ww) N=24	Total Average Daily Dose (ADD; ng/kg-day)[2] Piscivorous Bird	Piscivorous Mammal	Invertivorous Bird	Invertivorous Mammal
2,3,7,8-TCDD	1.1	0.28	4.4	0.06	0.03	4.5	0.5
1,2,3,7,8-PeCDD	2.5	0.63	6.2	0.13	0.06	6.2	0.7
1,2,3,4,7,8-HxCDD	2.5	0.63	1.6	0.13	0.06	1.7	0.19
1,2,3,6,7,8-HxCDD	9.3	2.3	15	0.47	0.23	15	1.7
1,2,3,7,8,9-HxCDD	5.6	1.4	4.2	0.28	0.14	4.4	0.49
1,2,3,4,6,7,8-HpCDD	153	38	21	7.7	3.8	27	2.8
OCDD	1562	391	30	78	39	89	7.3
2,3,7,8-TCDF	8.0	2.0	48	0.40	0.20	48	5.4
1,2,3,7,8-PeCDF	2.1	0.54	2.8	0.11	0.05	2.9	0.32
2,3,4,7,8-PeCDF	2.8	0.71	12.1	0.14	0.07	12	1.4
1,2,3,4,7,8-HxCDF	4.7	1.2	0.94	0.23	0.12	1.1	0.12
1,2,3,6,7,8-HxCDF	2.5	0.62	ND[5]	0.12	0.06	0.09	0.01
1,2,3,7,8,9-HxCDF	1.4	0.34	ND	0.07	0.03	0.05	0.003
2,3,4,6,7,8-HxCDF	3.9	0.99	ND	0.20	0.10	0.15	0.01
1,2,3,4,6,7,8-HpCDF	53	13	0.70	2.6	1.3	2.7	0.21
1,2,3,4,7,8,9-HpCDF	3.2	0.81	ND	0.16	0.08	0.12	0.01
OCDF	102	26	0.48	5.1	2.6	4.3	0.31
3,3',4,4'-TetraCB (IUPAC #77)	120	33	788	6.7	3.3	793	89
3,4,4',5-TetraCB (IUPAC #81)	ND	NE	49	--	--	49	5.5
3,3',4,4',5-PentaCB (IUPAC #126)	15	4.0	229	0.80	0.40	230	26
3,3',4,4',5,5'-HexaCB (IUPAC #169)	ND	NE	29	--	--	29	3.3
Total PCDD/Fs[3]	1919	480	148	96	48	220	21
Total Coplanar PCBs[3]	135	37	1096	7.5	3.7	1101	124
Total TEQs[4]	9.1	2.3	20	1.3	0.32	140	5.3

1. Data from reference (2) and (3).
2. A screening-level ADD was calculated based on assumption that exposure is due to incidental ingestion of sediment and diet comprised entirely of aquatic invertebrates (invertivores) or a diet comprised entirely of fish (piscivores).
3. Sum of all congeners.
4. TEQs calculated using proposed WHO (1997) TEFs.
5. ND (not detected); NE (not estimated)

Figure 1. PCA scores plot of 2,3,7,8-PCDD/Fs in sediment and lobster (meat and tomalley). PC1 and PC2 explain 56% of the data variance.