Assessment of Injury to Fish and Wildlife Resources in the Grand Calumet River and Indiana Harbor Area of Concern, USA

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Abstract. This article is the second in a series of three that describes the results of a Natural Resource Damage Assessment (NRDA) conducted in the Grand Calumet River and Indiana Harbor Area of Concern (IHAOC). The assessment area is located in northwest Indiana and was divided into nine

[PAHs]), and metals. Based on the activities that have been conducted in the assessment area, various pesticides, cyanide, phenols, and conventional variables—such as total organic carbon (TOC), dissolved oxygen (DO), sediment oxygen demand (SOD), and unionized ammonia (NH_3)—were identified as additional COPCs.

This investigation was conducted to support the NRDA of the assessment area by (1) determining if discharges of oil or releases of other hazardous substances have injured or are likely to have injured fish and wildlife resources (*i.e.*, fish, amphibians, reptiles, birds, or mammals) within the assessment area; and (2) identifying contaminants of concern (COCs; *i.e.*, those substances that are causing or substantially contributing to sediment injury) in the assessment area. Definitions of injury to natural resources are provided by MacDonald *et al.* (2002). The indicators of injury to fish and wildlife resources that were used in this investigation included toxicity to fish, fish community structure, sediment fish health, chemistry, and tissue chemistry. An evaluation of injury to sediments and sediment-dwelling organisms was also conducted and is presented in the first manuscript in this series (MacDonald *et al.*, 2002). The third manuscript in the series will describes the results of an assessment of sediment toxicity that was recently conducted in the assessment area.

Materials and Methods

Description of the Assessment Area

This investigation was focused on the GCR, IHC, IH, and associated LM environments (Figure 1). The riparian and upland habitats closely associated with these waters were also considered in this assessment, including lands within the boundaries of the Indiana Dunes National Lakeshore. A description of the assessment area is provided by MacDonald *et al.* (2002).

Identification of Key Indicators of Sediment Quality Conditions

This assessment, which was conducted in accordance with the Department of the Interior regulations (US DOI 1996), was undertaken to determine if fish and wildlife resources within the assessment area have been injured by discharges of oil or releases of other hazardous substances from industrial, municipal, and nonpoint sources. To support this assessment, a suite of five indicators of sediment quality conditions was identified that could be used to assess injury to fish and wildlife resources, including sediment toxicity, fish health, fish community status, sediment chemistry, and tissue chemistry.

Sediment Toxicity Tests: In this investigation, the results of toxicity tests with fish were considered to be a primary indicator of injury to fish and wildlife resources. More specifically, demonstration of toxicity to fish was considered to provide the necessary evidence to conclude that contaminated sediments have the potential to adversely affect fish in the assessment area. The toxicity tests that were used in this evaluation included 10-day elutriate and 4- to 12-day whole sediment toxicity tests with fathead minnow (*Pimephales promelas*; endpoints: survival and growth; Lucas and Steinfeld 1972; Burton 1994; Gillespie *et al.* 1998). Sediment samples were designated as toxic to fish if the response of the test organism exposed to IHAOC sediments was reported to be significantly different from the response that was observed in an appropriately selected control or reference sediment.

Fish Health: Data on fish health provide important information for determining if fish have been adversely affected by discharges of oil or releases of other hazardous substances. Fish health represents a relevant indicator of sediment quality conditions because fish that are exposed to contaminated sediment can exhibit impaired health, such as an increased incidence of tumors (Malins *et al.* 1985; Goyette *et al.* 1988; Payne *et al.* 1988). In turn, impaired fish health can result in increased rates of fish mortality and associated effects on fish populations and fi

investigation, sediment chemistry data (*i.e.*, organic carbon-normalized concentrations of total PCBs and organochlorine pesticides) were compared to the bioaccumulation-based SQGs for the protection of piscivorus wildlife that have been developed by the New York State Department of Environmental Conservation (NYSDEC 1999). The presence of elevated levels of contaminants in sediments, relative to the SQGs, was considered to be indicative of sediment injury relative to fish-eating wildlife species in the assessment area (*i.e.*, contaminated sediments pose a hazard to piscivorus wildlife due to the potential for bioaccumulation in the food web). The sediment chemistry data used in this evaluation were obtained from 30 studies conducted within the IHAOC between 1979 and 1999, the results of which are reported by MacDonald and Ingersoll (2000a, 2000b).

Tissue Chemistry: Data on the concentrations of COPCs in the tissues of aquatic organisms provides important information for assessing the extent to which bioaccumulative substances have accumulated in the tissues of sediment-dwelling species and fish. Comparison of these data to tissue residue guidelines (TRGs) provides a basis for determining if contaminants have accumulated in the tissues of aquatic organisms to such an extent that adverse effects on piscivorus wildlife species are likely to occur. In this investigation, the available tissue residue data were compared to the TRGs for the protection of piscivorus wildlife that have been developed by NYSDEC (Newell *et al.* 1987) and the Canadian Council of Ministers of the Environment (CCME 1999). The presence of elevated levels of contaminants in tissues relative to the TRGs was considered to indicate the potential for adverse effects on fish-eating wildlife species in the assessment area. Information on the levels of bioaccumulative substances in the tissues of fish and aquatic invertebrates were obtained from nine studies conducted in the IHAOC between 1982 and 1999, the results of which are reported by MacDonald and Ingersoll (2000a, 2000b).

Acquisition and Evaluation of Sediment Quality Data and Related Information

To support this assessment, several types of data were acquired and evaluated. First, information on the toxicity of whole sediments and elutriates to fish was assembled for the assessment area. Information on fish health and fish community structure was also compiled from studies that had been conducted within the IHAOC. Furthermore, the available information on the chemical composition of whole sediments was compiled for both surficial and subsurface sediment samples (samples from all sediment depths were used in this analysis to evaluate potential exposures that could occur if surficial sediments are removed). Surficial sediment samples were those that were collected from over

2000b).

Table 1. Summary of assessment of effects on fish and wildlife resources

Reach	Indicator of Injury on Fish and Wildlife Resources[a]					# of Lines of Evidence Demonstrating Injury to Fish and Wildlife Resources
	Toxicity to Fish[b]	Fish Health[c]	Fish Community[d]	Whole Sediment Chemistry[e]	Tissue Chemistry[f]	
Grand Calumet Lagoons	14% (n = 7)	0% (n = 12)	38% (n = 13)*	84% (n = 58)*	100% (n = 18)*	3
East Branch Grand Calumet River-I	57% (n = 23)*	40% (n = 10)*	100% (n = 29)*	74% (n = 110)*	100% (n = 22)*	5
East Branch Grand Calumet River-II	85% (n = 40)*	75% (n = 4)*	100% (n = 22)*	66% (n = 90)*	100% (n = 5)*	5
West Branch Grand Calumet River-I	ID (n = 0)[g]	100% (n = 3)*	100% (n = 12)*	29% (n = 7)*	100% (n = 7)*	4
West Branch Grand Calumet River-II	100% (n = 7)*	100% (n = 1)	100% (n = 17)*	18% (n = 17)*	100% (n = 5)*	4
Indiana Harbor Canal	ID (n = 0)	33% (n = 3)	100% (n = 4)*	93% (n = 15)*	100% (n = 7)*	3
Lake George Branch	ID (n = 0)	50% (n = 2)	50% (n = 2)	83% (n = 29)*	ID (n = 0)	1
US Canal	ID (n = 0)	50% (n = 2)	100% (n = 8)*	84% (n = 37)*	100% (n = 18)*	3
Indiana Harbor/Lake Michigan	ID (n = 0)	100% (n = 1)	100% (n = 1)	88% (n = 33)*	86% (n = 21)*	2
Overall	71% (n = 77)*	39% (n = 38)*	92% (n = 108)*	74% (n = 396)*	97% (n = 103)*	5

[a] For each line of evidence, sediment injury is indicated if two or more samples have conditions sufficient to cause or substantially contribute to sediment injury. Evidence of sediment injury is denoted with an asterisk (*).
[b] Percent of sediment samples that were toxic to fish in laboratory tests.
[c] Percent of fish samples with > shsamples with3F5 1 Tf 19.5486 0 TD (Þ)Tj /F9 1 Tf 0.556 0 TD [(sh)-332.9(in)-332.96F9 1 TfIBI oneerisk

Overall, 55 of the 77 samples (71%) that were tested were shown to be toxic to fish (Table 1). The incidence of sediment toxicity ranged from 14% in the GCL to 100% in the WBGCR-II (Table 1). Only one sample from the GCL was toxic to fish, which indicates that conditions sufficient to cause acute toxicity to fish were observed only in the West Lagoon.

The available information on incidence of DELT abnormalities indicated that fish health has been compromised in the assessment area (*i.e.*, relative to other riverine sites in the Central Corn Belt Plain ecoregion; Table 2). Based on the information that was compiled, fish health has been compromised in several of the reaches, including EBGCR-I, EBGCR-II, and WBGCR-I (Simon 1993; Sobiech *et al.* 1994; Simon and Stewart 1998; Simon *et al.* 2000). The average incidence of DELT abnormalities ranged from 0% in the GCLs to 12.8% in IH/LM (Table 2). The highest incidence of DELT abnormalities (17.4%) was observed in the EBGCR-II (Table 2).

A number of field surveys have been conducted over the past 15 years to evaluate the status of fish communities in the assessment area (Simon *et al.* 1989, 2000; Simon and Moy 1997; Sobiech *et al.* 1994; Simon 1993; Simon and Stewart 1998). The results of these surveys demonstrate that the integrity of fish communities has been impaired, relative to reference sites in the Central Corn Belt Plain ecoregion, in all of the reaches that have been sufficiently examined. Overall, 99 of the 108 samples that have been collected had characteristics that were indicative of impaired fish communities (Table 3). The IBI scores ranged from 0 to 43 in the various stream reaches, which classifies fish communities as no fish, very poor, poor, or fair (Simon 1991). The lowest average IBI scores were reported for the IH/LM (14.0; n = 1), WBGCR-II (15.9 ± 9.8; n = 17), WBGCR-I (16.5 ± 10.4; n = 12), and IHC (17.5 ± 4.4; n = 4). Based on these IBI scores, the integrity of fish communities in these four reaches would be classified as very poor. Somewhat higher average IBI scores were reported for the EBGCR-I, EBGCR-II, LGB, and USC; average IBI scores in these reaches ranged from 22.8 to 26.0. As such, fish communities in these four reaches would be classified as having poor to very poor integrity. Within the LGB, the wetland areas that are located to the west of the Lake George Canal had the highest IBI score (38; Simon *et al.* 2000). Relatively higher IBI scores were also reported for the GCL, with IBI scores ranging from 31 to 43 (mean IBI score of 38.1 ± 5.0; n = 13). In the GCL, the lowest IBI scores (*i.e.*, 31 to 38) were reported for the West Lagoon (classified as having poor to fair-poor integrity; located closest to an iron and steel manufacturer's slag landfill; Simon and Stewart 1998). In contrast, IBI scores for three of the other GCL segments were 42 to 43, indicating fish communities with fair integrity. These data show that the assessment area is capable of supporting fish communities that are similar to those that have been observed in the Central Corn Belt Plain ecoregion (Simon 1991). However, fish communities with fair or better integrity have been observed only rarely within the assessment area (MacDonald and Ingersoll 2000a, 2000b).

The potential for injury to fish and wildlife resources was also evaluated using sediment chemistry data. More specifically, the measured concentrations of bioaccumulative sub-

stances were compared to bioaccumulation-based SQGs for the protection of wildlife (NYSDEC 1999). The results of this evaluation demonstrated that the concentrations of various sediment-associated contaminants were sufficient to adversely affect fish and wildlife species that utilize habitats within the GCR watershed (*i.e.*, through bioaccumulation of contaminants in sediment-dwelling organisms and subsequent food web

several reaches of the assessment area have been demonstrated

Table 3. Summary of IBI scores for the various reaches in the assessment area, 1985–1998 (from Sobiech *et al.* 1994; Simon and Stewart 1998; Simon 1993; Stewart *et al.* 1999; Simon *et al.* 2000)

		Reach of Assessment Area				
Sampling Date	Sample Number	Grand Calumet Lagoons	East Branch Grand Calumet River-I	East Branch Grand Calumet River-II	West Branch Grand Calumet River-I	West Branch Grand Calumet

Table 4. Summary of the available data on the concentrations of bioaccumulative substances (in μg/kg organic carbon) in assessment area sediments (MacDonald and Ingersoll 2000b).

Substance	n	Mean	SD	Range	SQG[a]	Number of Exceedances of SQGs (%)
Polychlorinated biphenyls						
Total PCBs	269	337,000	1,020,000	7.86–12,700,000	1,400	258 (96%)
Organochlorine pesticides						
Total DDTs	159	27,400	223,000	62.0–2,790,000	1,000	65 (41%)
Chlordane	51	4,790	7,020	106–38,100	6	51 (100%)
Endrin	145	224	436	12.6–4,340	800	4 (3%)
Heptachlor	30	3,180	7,080	10.1–36,900	30	18 (60%)
Heptachlor epoxide	27	1,780	4,950	10.1–25,700	30	16 (59%)
Lindane	246	506	2,100	10.1–25,400	1,500	10 (4%)
Dioxins/furans						
2,3,7,8-TCDD[b]	2	0.886	1.15	0.0735–1.70	0.2	1 (50%)

[a] SQG = Bioaccumulation-based sediment quality guideline (from NYSDEC 1999).
[b] 2,3,7,8-TCDD = 2,3,7,8-tetrachlorodibenzodioxin.

Table 5. Summary of the available data on the concentrations of bioaccumulative substances (μg/kg wet weight) in fish and invertebrate tissues from the assessment area (MacDonald and Ingersoll 2000b)

Substance	n	Mean	SD	Range	TRG[a]	Number of Exceedances of TRGs (%)
Polychlorinated biphenyls						
Total PCBs	136	2,530	4,130	15.1–27,100	110	130 (96%)
Organochlorine pesticides						
Total DDTs	63	282	542	11–3,350	200	15 (24%)
Chlordane	62	48.0	72.5	8–442	370	1 (2%)
Endrin	37	6.82	7.22	5–41	25	2 (5%)
Heptachlor and Heptachlor Epoxide	39	7.76	3.87	4–24	25	0 (0%)
Lindane	37	4.93	1.99	3–13	100	0 (0%)
Mirex	11	5	—	5–5	330	0 (0%)
Dieldrin and aldrin	40	23.0	39.8	5–207	22	8 (20%)

[a] TRG = Tissue residue guideline (from Newell *et al.* 1987).

(MacDonald and Ingersoll 2000a). Total PCBs frequently exceeded chemical benchmarks in surficial and subsurface sediments and/or in tissues throughout the assessment area (Tables 4 and 5). In addition, the concentrations of total PCBs in sediments often exceeded the chemical benchmarks by a substantial margin (*i.e.*, by up to a factor of 247). Therefore, total PCBs were present in whole sediment and tissues at concentrations that are sufficient to adversely affect fish and wildlife resources. It is important to note, however, that this assessment was restricted by the availability of published bioaccumulation-based SQGs, TRGs, and other benchmarks of sediment quality conditions. The availability of chemistry data for tissues also restricted this assessment in certain reaches of the assessment area. Furthermore, insufficient information was located to facilitate identification of the substances that are causing or substantially contributing to effects on fish (*i.e.*, sediment toxicity, impaired fish health, or impaired fish community structure). Therefore, substances not included on the list of COCs can not necessarily be considered to be of low priority with respect to sediment injury (*e.g.*, metals, PAHs, alkanes, alkenes, organochlorine pesticides, phthalates, dioxins, and furans, etc.).

Summary

An evaluation of injury associated with contaminated sediments was conducted in the assessment area. To support this evaluation, the assessment area was divided into nine reaches: GCL, EBGCR-I, EBGCR-II, WBGCR-I, WBGCR-II, IHC, LGB, USC, and IH/LM. The results of this evaluation demonstrate that sediments throughout the assessment area have been injured due to discharges of oil or releases of other hazardous substances. This conclusion is supported by up to five of the following separate lines of evidence (Table 1).

- Whole sediments, pore water, or elutriates from the assessment area were frequently toxic to fish
- The health of fish in the assessment area, as indicated by an elevated incidence of DELT abnormalities, has been compromised relative to fish utilizing aquatic habitats elsewhere in the Central Corn Belt Plain ecoregion
- The integrity of fish communities in the assessment area has frequently been degraded relative to reference sites in the Central Corn Belt Plain ecoregion
- Concentrations of total PCBs and other bioaccumulative

substances in sediments frequently exceeded the bioaccumulation-based SQGs for the protection of wildlife

- Concentrations of total PCBs and other bioaccumulative substances in the tissues of aquatic organisms frequently exceeded the TRGs for the protection of wildlife

Any one of these lines of evidence could be used alone to support the conclusion that sediment injury has occurred in the assessment area. When considered together, however, these five separate lines of evidence provide a weight of evidence for concluding that discharges of oil or releases of other hazardous substances have created conditions that are sufficient to adversely affect fish and wildlife resources. Total PCBsÞ

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