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PAST, PRESENT AND POTENTIAL OF FISH ASSEMBLAGES IN THE GRAND CALUMET RIVER AND INDIANA HARBOR CANAL DRAINAGE WITH EMPHASIS ON RECOVERY OF NATIVE FISH COMMUNITIES

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ABSTRACT. The fish community of the Grand Calumet River has shown some recovery during the 1990s; however, the community has not recovered to 1900 levels. The fish community is dominated by tolerant detritivores, which are exotic or non-indigenous species. These species are capable of surviving low dissolved oxygen levels, contaminated sediments and subchronic toxicity from surface water effluents. The East Branch Grand Calumet River has the highest species richness and highest biological integrity among the Grand Calumet River sites. The Grand Calumet Lagoons, which were the former mouth of the river, still possess sensitive species including Iowa darter and lake chubsucker. Little biological integrity remains in the West Branch Grand Calumet River, with several collecting events finding "no fish." Despite the recent finding of salmon in the river, optimistically we should not assume that the river has recovered. Biological integrity scores show that the communities possess "poor" to "very poor" integrity levels, while average index scores for the past decade differed by less than 5 integrity points. Tissue consumption advisories show high contaminant levels of PAHs, mercury and inorganic metals, while others have found high levels in adjacent landfill sites. Full restoration efforts should include reducing contaminant levels in tissues, removal of contaminated sediments, physical habitat recovery of dissolved oxygen, reducing thermal profiles, increasing macroinvertebrate forage and increasing heterogenous substrates in low habitat diversity areas. Furthermore, re-creation of littoral habitat, side bank wetlands to serve as nursery habitat, and creation of braided channels could enhance fish community use of the Grand Calumet River watershed.

Keywords: Grand Calumet River, fish, area of concern, habitat restoration

The structure and function of the Grand Calumet River-Indiana Harbor Canal fish community have undergone drastic changes since the turn of the century (Meek & Hildebrand 1910; Shelford 1937; CDM/Limnetics 1976; Polls & Dennison 1984; Simon et al. 1989; Simon & Stewart 1999; Simon et al. 2000; Simon et al. in press). Changes in stream depth, water quality and land use eliminated indigenous species during the middle of the century (Meek & Hildrebrand 1910; Shelford 1937). Dredging and channelization altered the stream from a riverine wetland to a narrow channel and significantly increased the flow velocity (U.S. Environmental Protection Agency (EPA) 1985). During the early 1970s, few, if any, species of fish were documented in either the East or West Branches of the Grand Calumet River (CDM/Limnetics 1976; Polls & Dennison 1984; F. Lee Bridges, Indiana Department of Environmental Management pers. comm.). Young-of-the-year of lake-dwelling transient species were present only seasonally in the Indiana Harbor Canal (CDM/Limnetics 1976). Subchronic toxicity was documented at a few of the major dischargers to the system (Simon 1989; Hoke et al. 1993).

Documented improvements in water quality and the fish community during the 1990s suggest that there is a possibility of restoring the Grand Calumet River (Crawford & Wangsness 1987; Simon & Stewart 1999; Simon et al. 2000). The purpose of this study was to document the past, present and future recovery potential of the Grand Calumet River and Indiana Harbor Canal fish community.

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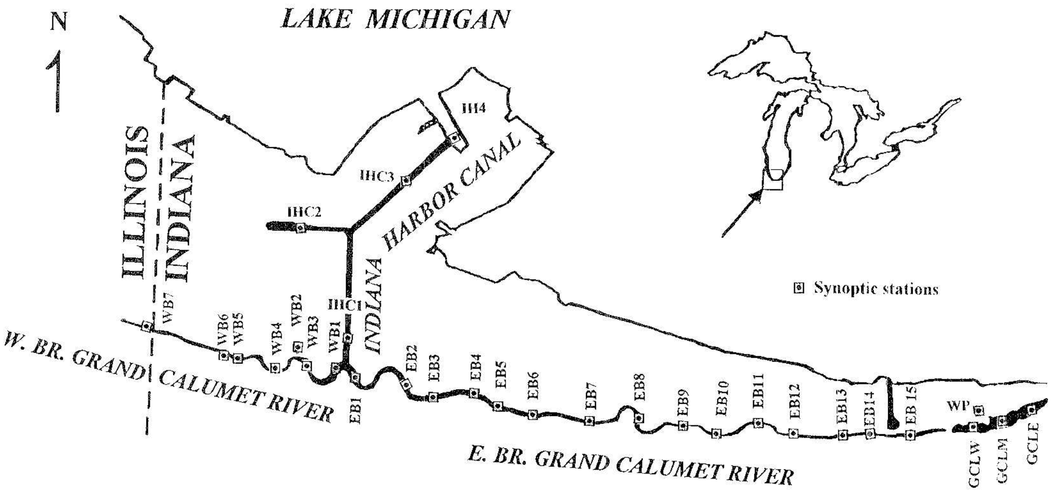

Figure 1.—Study sites collected in the Grand Calumet River and Indiana Harbor Canal between 1976 and 1998. *Abbreviations:* EB = East Branch Grand Calumet River, WB = West Branch Grand Calumet River, IHC = Indiana Harbor Canal, IH = Indiana Harbor, GCL = Grand Calumet Lagoons and WP = West Pond. Numbers refer to collection localities referred to in the text and summarized in Tables 3–6.

STUDY AREA DESCRIPTION

The Grand Calumet River basin is a small watershed located in northwestern Indiana (Fig. 1) and encompasses about 17,500 ha contained almost entirely within Lake County, Indiana (USEPA 1985). The Grand Calumet River, about 34 km in length, has been designated an Area of Concern by the International Joint Commission (IJC 1989; IDEM 1988). The Grand Calumet River and Indiana Harbor Canal occupy a low-relief area in the glacial bed of geological Lake Chicago. The general flow is sluggish and westward in the East Branch Grand Calumet River, east- or westward in the West Branch depending on Lake Michigan levels, and northward in the Indiana Harbor Canal, an artificial connection to Lake Michigan.

The river reaches discussed here include: 1) East Branch, Tennessee Street (EB15), East Broadway (EB14), USX-West Broadway (EB13), USX downstream triple railroad tressle (EB12), West Buchanan Street (EB11), East Buchanan Street (EB10), East Bridge Street (EB8), East of Bonji (EB7), west of Clark Road (EB6), East Cline Avenue (EB5), West Cline Avenue (EB4), East Kennedy Avenue (EB3), west of Kennedy Avenue (EB2), the mouth of the East Branch (EB1); 2) West Branch, mouth of the West Branch (WB1), East Chicago Sanitary District earthen channel (WB2), East Indianapolis Boulevard (WB3), Roxanna Marsh and West Indianapolis Boulevard (WB4), East Columbia Avenue (Hammond; WB5), Culverts (WB6), and Far West including sites in Illinois (WB7); 3) Indiana Harbor and Canal, Federal Channel including the harbor mouth and breakwater, anchor and manaevering basin, canal entrance (IH4), Dickey Road and section lakeward of the forks (IHC3), Lake George (IHC2), and Columbus Avenue and Canal(IHC1); and the 4) Grand Calumet Lagoons, Eastern Lagoon (GCL1), Middle Lagoon (GCL2), and Western Lagoon(GCL3).

STATUS OF FISH COMMUNITIES

Sampling in the Middle and Western Lagoons, the former mouth of the Grand Calumet River, has revealed the presence of several sensitive indicator species, including the lake chubsucker (*Erimyzon sucetta*) and Iowa darter (*Etheostoma exile*). The Middle Lagoon has been isolated from much of the degrading influences found throughout the rest of the river basin (Simon & Stewart 1998). The presence of these species in the Middle Lagoon suggests that sensitive species once existed in the Grand Calumet River. Currently, the fish communities of the remainder of the Grand Calumet River exhibit "poor" to "very poor" biological integrity. The biological integrity of the fish community in the East Branch of the Grand Calumet River is substantially better than in the West Branch. The lower integrity score in the West Branch is due primarily to biosolid impacts in the vicinity of Columbia Avenue and the resulting depletion of dissolved oxygen in a substantial reach of the river as it flows towards Illinois. Roxanna Marsh and areas to the east have low water depths and contaminated sediments, and they are impacted by municipal sewage treatment plant discharges from the cities of East Chicago and Hammond.

The fish community varies along the length of the East Branch of the Grand Calumet River and is affected by effluent quality, water quantity and sediment quality (Crawford & Wangsness 1987). Past reduction in effluents and combined sewer overflows, closure of point sources and removal of contaminated sediments in the upper 10 miles (18 km) of the East Branch have improved the diversity and integrity of the fish community. Fish communities near Cline Avenue bear some resemblance to the fish community that should be supported by the habitat, but they exhibit severely altered community function.

The Indiana Harbor Canal is a man-made connection between the Grand Calumet River and Lake Michigan. The habitat in the Indiana Harbor Canal can be divided into the Lake Michigan breakwall border and turning basin and the Lake George channels. Improvements in fish community diversity in the Indiana Harbor Canal can be directly attributed to the removal of contaminated sediments. This allowed opportunistic, transient young-of-the-year of lake dwelling species to use portions of the detrital food base. Unfortunately, redistribution of contaminated materials and the increase in the population number and abundance of alien species has compromised the recovery of the nearshore zone of Lake Michigan along the breakwalls (Simon et al. 1998). The European round goby (*Neogobius melanostomus*) has been documented from the breakwall. Water and habitat quality improvements will facilitate expansion of round goby populations, which pose a serious threat to indigenous species such as mottled sculpin (*Cottus bairdi*) and johnny darter (*Etheostoma nigrum*).

Early studies of fish in the Grand Calumet River examined basic distribution, ecology and natural history of the communities. A number of studies were completed between the turn of the century and 1945. Meek & Hildebrand (1910) studied the distribution of fish within 50 miles (92 km) of Chicago. Seth Meek, a former student of David Starr Jordan, Indiana University, became curator of fishes with the Columbia Museum of Natural History (now called the Field Museum of Natural History). He and Samuel Hildebrand produced one of the first documented inventories of Grand Calumet River species. It is not clear whether Victor Shelford (1937), an early ecologist from the University of Chicago, actually sampled the Lagoons of the Grand Calumet or whether he simply used the data of Meek and Hildebrand. The species lists in the two papers are so similar that it seems likely they are drawn from the same data. No further fish sampling efforts were conducted in the Grand Calumet River during this period. Gerking (1945) did not specifically sample the Grand Calumet River while completing his epic evaluation of the distribution of Indiana fish, but he did summarize previously published distribution records and changes in nomenclature. Species distribution in the Grand Calumet River was not further studied until collaborative efforts between Indiana Department of Environmental Management and the U.S. Environmental Protection Agency were started during the mid-to late-1980s. This effort resulted in a published study of three years of intensive collection (Simon et al. 1989). Prior to 1985, the collection of fish from the Grand Calumet River was considered a futile effort because either few or no fish species would be collected after extensive sampling effort (C. Lee Bridges (IDEM) pers. comm.).

Extensive monitoring and assessment has been completed during the last decade (Simon et al. 1989; Simon 1991; Sobiech et al. 1994). The Indiana Department of Environmental Management has conducted annual sampling to assess and evaluate fish consumption advisories (IDEM 1997). The U.S. Army Corps of Engineers has been sampling the Indiana Harbor Canal breakwall for several years to gather data on changes in the nearshore fish communities of Lake Michigan. The U.S. Environmental Protection Agency has rigorously sampled the East and West Branches of the River to assess point source dischargers (Simon 1989; Simon et al. 1989; Sobiech et al. 1994).

STATUS OF THE GRAND CALUMET RIVER FISHES PRIOR TO 1970

Changes in the fish community of the Grand Calumet River are a direct result of the flow alteration during the early-to-mid 1800s. Prior to these alterations, the Grand Calumet was comprised of palustrine wetlands, a series of shallow pools connected by narrow flowages between pools (Moore 1959). These pools and flowages enabled movement of species between Lake Michigan and the important wetland nursery and spawning habitat provided by the slow-flowing river. Shelford (1937) compared the physical status of the Grand Calumet River to other Lake Michigan tributaries such as the lower St. Joseph River, Michigan; lower Galien River, Michigan; and Dead River, Illinois. Although Shelford did not specifically describe the condition of the Grand Calumet River, the river certainly possessed characteristics similar to the other streams he mentioned.

These rivers characteristically have fine sand or fine organic sediments with little or no rock. The rivers originate in wetland habitats characterized by emergent rooted macrophytes. Differentiation of pools and riffles is not common. Instead, deep pools and narrow, shallow connections (termed flowages) enable passage of water between pools. The flow of water is mostly determined by the depth of Lake Michigan and reflects annual climatologic and hydrologic conditions. The deeper portions of these streams support rooted aquatic macrophytes such as (*Potemogeton* sp.) and water lilies (*Nuphar* and *Nelumbo*). Bulrushes (*Scirpus* sp.) and cattails (*Typha*) line the shore and the banks along back bays and side channels.

Meek & Hildebrand (1910) evaluated the distribution of fish species within a 50 mile (92 km) radius of Chicago and indicated that as many as 22 species occurred in the Grand Calumet River drainage (Table 1). Shelford documented 12 species of fish during 1909, including species such as blacknose shiner, lake chubsucker, northern pike, redhorse, and tadpole madtom (Table 2). The Dead River (Illinois) has a much smaller drainage area than the Grand Calumet River; but unlike the Grand Calumet River, Dead River has not been extensively modified. The Dead River is a designated nature preserve contained within the Illinois Beach State Park near Zion, Illinois, which is one of the few remaining areas of dune and swale topography in Illinois. In 1996, 14 species were captured in the Dead River, six of which were present in the 1909 sample. Of the 20 total species collected from the Dead River during the two events, fewer than 30% were found in both 1909 and 1996.

Table 1.—The fish collected from the Grand Calumet River drainage and deposited in the Field Museum of Natural History by Meek & Hildebrand (1910). Specimens were collected near the former mouth, Clarks junction, Gary, and from the Lagoons.

Bowfin	*Amia calva*
Carp	*Cyprinus carpio*
Golden shiner	*Notemigonus crysoleucas*
Emerald shiner	*Notropis atherinoides*
Spottail shiner	*Notropis hudsonius*
Bluntnose minnow	*Pimephales notatus*
White sucker	*Catostomus commersoni*
Channel catfish	*Ictalurus punctatus*
Black bullhead	*Ameiurus melas*
Yellow bullhead	*Ameiurus natalis*
Brown bullhead	*Ameiurus nebulosus*
Tadpole madtom	*Noturus gyrinus*
Northern pike	*Esox lucius*
Grass pickerel	*Esox americanus*
Central mudminnow	*Umbra limi*
Green sunfish	*Lepomis cyanellus*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Black crappie	*Pomoxis nigromaculatus*
Yellow perch	*Perca flavescens*
Logperch	*Percina caprodes*
Freshwater drum	*Aplodinotus grunniens*

Until the 1960s, the Grand Calumet River suffered from chemical and physical degradation caused by municipal and industrial pollution. Untreated sewage and waste from packing plants and heavy industry eliminated most of the natural aquatic communities. Surveys of the river during the early 1960s found only 20–108 oligochaetes/m^2 in the mouth of the Indiana Harbor Canal. By the early 1970s, the abundance of oligochaetes had increased to 2400–500,000/m^2. The increase in biomass was considered sufficient to support native fish populations; however, it reflected extensively disturbed habitat.

ASSESSMENT OF SUBCHRONIC TOXICITY

Water quantity is largely determined by effluent discharged into the Grand Calumet Riv-

Table 2.—The fish species collected in the Dead River, Illinois Beach State Park, Illinois, in 1909 (Shelford 1937) and 1996 (Moy & Simon unpubl. data).

Common name	Species name	1909	1996
Gizzard shad	*Dorosoma cepedianum*		•
Grass pickerel	*Esox americanus*	•	
Northern pike	*Esox lucius*	•	•
Redhorse	*Moxostoma* sp.	•	
Lake chubsucker	*Erimyzon sucetta*	•	
Common shiner	*Luxilus cornutus*	•	
Golden shiner	*Notemigonus crysoleucas*	•	•
Emerald shiner	*Notropis atherinoides*		•
Spottail shiner	*Notropis hudsonius*		•
Blacknose shiner	*Notropis heterolepis*	•	•
Bluntnose minnow	*Pimephales notatus*	•	
Tadpole madtom	*Noturus gyrinus*	•	
Pumpkinseed	*Lepomis gibbosus*		•
Warmouth	*Lepomis gulosus*		•
Bluegill	*Lepomis macrochirus*	•	•
White crappie	*Pomoxis annularis*	•	•
Black crappie	*Pomoxis nigromaculatus*		•
Smallmouth bass	*Micropterus dolomieu*		•
Largemouth bass	*Micropterus salmoides*	•	•
Yellow perch	*Perca flavescens*		•
	Total taxa	12	14

er. During low flow conditions, over 90% of the Grand Calumet River originates as industrial wastewater, industrial cooling and process water, stormwater runoff and municipal effluent (Crawford & Wangsness 1987). Noncontact cooling water comprises the majority of the industrial effluent. A total of 39 permitted discharge outfalls and 14 combined sewer overflow points are located along the river (U.S. Environmental Protection Agency 1984; Custer et al. 1996).

In the document entitled "Masterplan for Improving the Water Quality of the Grand Calumet River and Indiana Harbor Canal," the U.S. Environmental Protection Agency (1985) identified slow flowing water, low dissolved oxygen and sedimentation as factors limiting the habitat quality of the Grand Calumet River. In the 305(b) Report to Congress for 1992–1993, the Indiana Department of Environmental Management suggested a lack of forage, low dissolved oxygen and toxic stresses caused the unstable fish community in the Indiana Harbor Canal and Grand Calumet River. IDEM classifies the Grand Calumet River as supporting "limited aquatic life." This use designation indicates the degraded condition of the aquatic environment; the Grand Calumet River is one of the only streams in Indiana with this designation.

The high organic content, consequent high oxygen demand and resultant habitat degradation in the West Branch are evidence of previous bypass events and combined sewer overflow (CSO) discharges. Point source discharge violations in the Grand Calumet River watershed include untreated sewage and NPDES permit violations.

Simon (1989) evaluated the impact of 19 major point source dischargers along the Grand Calumet River and the Indiana Harbor Canal in 1986. Preliminary screens were used to evaluate the potential effects on fathead minnow (*Pimephales promelas*) embryos and newly-hatched larvae. Three subchronic endpoints were evaluated, including percent hatching, survival and teratogenicity. Each outfall was compared to a laboratory control population using Lake Michigan drinking water. Six preliminary positive test results were confirmed in a retest using a dilution series of 100, 77.5, 42.4, 30.0 and 17.3% solutions.

Hammond Sanitary District effluent produced a significant teratogenic response during the preliminary test but did not reduce survival of larvae. A single USX (steel industry) outfall produced positive results during the screening procedure but could not be resampled due to a plant shutdown in 1986. The East Chicago Sanitary District effluent did not elicit a chronic response for hatching or survival during definitive testing; however, statistically significant teratogenic responses were observed in larvae in all dilutions tested. Effluent from Inland Steel outfalls 008 and 014 produced a chronic response at concentrations of 77.5% and 42.4% effluent. Effluent from these outfalls produced statistically significant differences in hatchability at effluent concentrations of 100%. Only Inland Steel outfall 014 produced a statistically significant teratogenic response, affecting larvae in all dilutions tested. Within 168 hours of exposure, test organisms in effluent from E.I. DuPont de Nemours and Company (chemical industry) showed significant mortality in solutions with concentrations above 30% effluent. The DuPont effluent had a chronic value of 17.3% and statistically significant teratogenic responses were observed in concentrations above 30%. Hatchability was unaffected in all preliminary tests except USX outfall 034.

CHANGES IN FISH COMMUNITY STRUCTURE AND FUNCTION IN THE GRAND CALUMET

The fish communities of the Grand Calumet River watershed reflect the degraded condition of the stream. The dominant species include carp, goldfish and golden shiner. Pumpkinseed, central mudminnow, bluntnose minnow, chinook salmon and rainbow trout have also been collected (Simon et al. 1989). Because differential management strategies may need to be employed to restore the Grand Calumet River watershed, the watershed has been separated into four segments: 1) East Branch Grand Calumet River; 2) West Branch Grand Calumet River; 3) Indiana Harbor Canal, turning basin and outer breakwater; and 4) Grand Calumet Lagoons.

Fish communities of the Indiana Harbor Canal: Studies of the Indiana Harbor Canal were completed by Polls & Dennison (1984), Simon et al. (1989) and Risatti & Ross (1989). In addition, the U.S. Army Corps of Engineers, which is responsible for maintaining the Federal Channel of the Indiana Harbor Channel, conducted studies of the Federal Channel and outer breakwalls. Simon et al. (1989) assessed variation in fish community diversity of the Indiana Harbor Channel at Dickey Road bridge during 1986–1988. Risatti & Ross (1989) evaluated the turning basin and the outer harbor as part of a biological, toxicological and chemical evaluation for the U.S. Army Corps of Engineers.

Polls & Dennison (1984) sampled the Federal Channel in 1983 to quantify the concentration of contaminants in sediment and fish tissue. The information was used to assess the risk of removing sediments to maintain sufficient harbor depth for deep draft navigation. The canal entrance had the greatest biological diversity (11 species) and the lowest proportion of contaminant-tolerant taxa among the six stations surveyed (12.1%) (Table 3). The lowest percentage of non-native species was found in the Grand Calumet River branch (15.0%). Non-native species in this reach included alewife, carp, goldfish, carp-goldfish hybrids and brown trout (Table 3). The harbor was dominated by omnivores and detritivores such as carp, goldfish, bluntnose minnow, fathead minnow, central mudminnow and golden shiner, which represent a diverse group of fishes able to use the detrital forage base. Since 1994, the U.S. Army Corps of Engineers assessment has been restricted to electrofishing along the outer breakwaters at the Indiana Harbor entrance.

Simon et al. (1989) evaluated a single site for three years at Dickey Road bridge between 1986–1988. The unstable habitat conditions at the site prevented a stable fish community from colonizing. The number of species ranged from 2–14. Contaminant-tolerant species comprised 57.1–88.5% of the total community. The lowest percentage of tolerant species was observed during the 1988 drought when only two species were collected. The highest percentage of tolerant species was observed during 1987 when lower Lake Michigan levels enabled transient species to use the Harbor.

Risatti & Ross (1989) evaluated seasonal fish use at two locations. One site was near the anchor and turning basin; the second site included the entire channel between the Grand Calumet River Forks and the entrance to the canal (Table 3). Fewer species were collected in the anchor and turning basin than in the canal. Tolerant species comprised only 13% of the community composition at the anchor and turning basin site; tolerant species comprised over 57% of the population in the Forks to Canal reach. As in the 1984 study, Risatti and Ross found the lowest percentage of exotic species in the Canal. The outer breakwaters of the Indiana Harbor Canal have been monitored by the U.S. Army Corps of Engineers since 1994 (P. Moy, unpubl. data). The number of both species and individuals collected has increased between 1994–1996 (Table 3). This increase is attributed to greater numbers of tolerant (e.g., bluntnose minnow, fathead minnow, goldfish) and non-native (e.g., three spine stickleback and round goby) species that have colonized the area. Some contaminant-intolerant species have recently been collected including rock bass, black crappie and mottled sculpin. Unfortunately, the increased number of tolerant species has surpassed the increased numbers of intolerant taxa. The benthic habitat has apparently improved during this time, enabling species such as silver and golden redhorse, mottled sculpin and round goby to colonize. It is uncertain whether these species will be permanent residents or whether they are only transient, opportunistic species.

Fish communities of the East Branch of the Grand Calumet: Fish communities of the East Branch of the Grand Calumet River have been monitored since 1976. The East Branch was studied by CDM/Limnetic (1976), Indiana Department of Environmental Management (unpubl. data), Simon et al. (1989), Simon (1991) and Sobiech et al. (1994). The fish community of the East Branch has shown the greatest improvement of the four major reaches discussed in this paper.

CDM/Limnetics (1976) evaluated the confluence of the Grand Calumet River and the Indiana Harbor Canal during 1976. They collected only a single alewife from two sampling locations.

The Indiana Department of Environmental Management evaluated three locations in the East Branch since 1980. Fish are collected until the target number has been reached for fish tissue contaminant analyses (J. Stahl pers. comm.). During sampling, other non-target species are collected and enumerated. The 1980–1987 results show an increase in the number of species, a reduction in the percentage of tolerant species and an increase in river use by migrating transient species, including young-of-the-year yellow perch and adult rainbow trout.

Simon et al. (1989) evaluated seven locations on the East Branch between 1985–1988. The number of species increased at stations sampled multiple times. Generally, the dominant species in the East Branch fish community were carp, goldfish and golden shiner. Collections of pumpkinseed, largemouth bass, black crappie, bluegill, central mudminnow and rainbow smelt increased between 1985–1988 (Table 4). The lack of adult representatives of most species indicates that the area served as a nursery habitat and an intermittent food and habitat resource.

Simon (1991) developed biological integrity expectations for northwest Indiana as part of an evaluation of the Central Corn Belt Plain. An index of biotic integrity was developed and calibrated for the Lake Michigan subdivision of the Lake Michigan drainage. Three stations in the East Branch were sampled as part of this investigation. Although species lists were not reported by station, individual index of biotic integrity assessments were calculated for each station. The results did not differ significantly from the 1988 results (Simon et al. 1989). The 1990 survey was a high-water year, so many species that were not collected during the 1988 drought, including pumpkinseed and yellow perch, were found as they began returning to the area. An increase in the abundance of the rudd (*Scardinius erythrophthalmus*), a European non-native minnow, was noted in the East and West Branches of the Grand Calumet River. Non-native species make up the majority of the fish species collected (Table 3).

In 1988, there was a fish kill in the upper five miles (9 km) of the East Branch of the Grand Calumet River due to an upper river oil spill, which degraded water quality. Fish kills provide an opportunity to assess fish abundance and community composition. Significant numbers of alewife, carp and goldfish were reported from this fish kill. Notably, additional species, including northern pike, walleye and bluntnose minnow, were also killed. Sobiech et al. (1994) evaluated the upper five miles (9 km) of the East Branch of the Grand Calumet River as part of a pre-remediation assessment of the area. These authors did not find a resident fish community above Broadway, but a resident community composed of

Table 3.—A summary of the fish species collected from the Indiana Harbor Canal: A = harbor mouth breakwaters (IH4); B = anchor and maneuvering basin (IH4); C = canal entrance (IH4); D = canal section lakeward of the Forks (IHC3); E = the Lake George branch (IHC2); F = the Calumet River branch (IHC1); and G = Indiana Harbor at the Dickey Road bridge (IHC3). [1] = Polls & Dennison (1984); [2] = Simon et al. (1989); [3] = Risatti & Ross (1989); [4] = U.S. Army Corps of Engineers (unpublished data).

	1983						1986	1987	1988			1994	1995	1996
Species	A[1]	B[1]	C[1]	D[1]	E[1]	F[1]	G[2]	G[2]	G[2]	D, E, F[3]	B[3]	A[4]	A[4]	A[4]
Gizzard shad (*Dorosoma cepedianum*)	41	8	705	47	3	72		65		25	14	13	3	4
Alewife (*Alosa pseudoharengus*)	6		74			1		4		2	25	23		14
Chinook salmon (*Oncorhynchus tschawytscha*)												1		2
Coho salmon (*Oncorhynchus kisutch*)								1						
Brown trout (*Salmo trutta*)	1												1	
Rainbow trout (*Oncorhynchus mykiss*)							10	1			1			
Carp (*Cyprinus carpio*)	20	63	20	16	1	7	28	16		6	3	25	44	81
Goldfish (*Carassius auratus*)	1		106	26	133	25	3	22	4	5				1
Carp × goldfish hybrid					3			1						
Spotfin shiner (*Cyprinella spiloptera*)								1						
Golden shiner (*Notemigous crysoleucas*)				1			1	12		24				
Emerald shiner (*Notropis atherinoides*)			20				5	2		1		2	1	3
Spottail shiner (*Notropis hudsonius*)			18									7	3	10
Bluntnose minnow (*Pimephales notatus*)			3					10				3		4
Fathead minnow (*Pimephales promelas*)			5	6		22		1					2	8
Silver redhorse (*Moxostoma anisurum*)												4	2	1
Golden redhorse (*Moxostoma erythurum*)													2	
Three-spine stickleback (*Gasterosteus aculeatus*)														8
Rock bass (*Ambloplites rupestris*)			1									1	1	2
Pumpkinseed (*Lepomis gibbosus*)	2	2	10	22	22	28	1	8	3			3	4	9
Bluegill (*Lepomis macrochirus*)				1				2						
Bluegill × pumpkinseed hybrid										3	3			
Green sunfish (*Lepomis cyanellus*)					1									
Smallmouth bass (*Micropterus dolomieu*)												1	5	16
Black crappie (*Pomoxis nigromaculatus*)														1
Yellow perch (*Perca flavescens*)	7	8	371	39	4	64	1	2						
Mottled sculpin (*Cottus bairdi*)														2
Round goby (*Neogobius melanostomus*)														1
Freshwater drum (*Aplodinotus grunniens*)												2	7	1

Table 3.—Continued.

Species	1983						1986	1987	1988			1994	1995	1996
	A[1]	B[1]	C[1]	D[1]	E[1]	F[1]	G[2]	G[2]	G[2]	D, E, F[3]	B[3]	A[4]	A[4]	A[4]
Total number	78	81	1333	158	167	220	49	148	7	66	45	85	75	168
Total species	7	5	11	10	7	8	7	14	2	6	3	11	14	19
Tolerant species (%)	29.5	79.3	12.1	46.9	95.7	37.7	63.3	88.5	57.1	57.6	13.0	47.1	78.9	73.2
Exotic species (%)	35.9	76.8	65.0	27.8	81.2	15.0	83.7	30.4	57.1	19.7	62.2	56.5	60.5	63.7

tolerant and exotic species was observed downstream of this area. The rudd was also collected in this reach and was hybridizing with the native golden shiner.

Fish communities of the West Branch of the Grand Calumet: Few studies have been conducted in the West Branch of the Grand Calumet River (Table 5). The West Branch is the most degraded section of the entire watershed. Poor dissolved oxygen conditions, contaminated sediments, frequent bypass events from a municipal discharger and combined sewer overflows have severely degraded habitat in this reach.

Simon et al. (1989) and Simon (unpubl. data) evaluated the fish community at several stations in the West Branch, including sites up- and downstream of Indianapolis Boulevard, Roxanna Marsh and the discharge canal of the East Chicago Sanitary District. Spacek (1996) provides an account of unsubstantiated reports of salmon spawning from the East Chicago Sanitary District.

Between 1985–1988, Simon et al. (1989) sampled fish at three stations including the area around Indianapolis Boulevard, east of the I-90 highway bridge to the eastern edge of Roxanna Marsh and east of Columbia Avenue to the western side of the I-90 bridge. Only four species were collected during this period. No fish were collected on several occasions in 1985 at the Columbia Avenue site and in 1988 at Indianapolis Boulevard. During the 1988 drought, the depth of the river declined to only a few inches. This prevented all but the smallest young-of-the-year fish from using the area. Dissolved oxygen concentrations were too low to support aquatic life. During 1985–1988, tolerant and exotic species comprised the majority of the fish collected.

The State of Indiana Department of Environmental Management has collected fish tissue samples from the West Branch at Indianapolis Boulevard since 1980 (J. Stahl pers. comm.). Their collections show that the West Branch fish community is dominated by exotic species including carp, goldfish and their hybrids. Water depth in the West Branch is influenced by Lake Michigan surface water levels. Often, as the surface of Lake Michigan drops, the reduced water depth in the West Branch prevents fish migration and may preclude use of the area by some fish species. The reduced water depth forces fish to remain

Table 4.—A summary of the fish collections completed in the East Branch of the Grand Calumet River: A = East Branch at its junction with the West Branch and the Indiana Harbor Canal (EB1); B = Kennedy Avenue (EB2); C = Cline Avenue (EB4/5); D = Bridge Street (EB8); E = East Broadway (EB13); F = adjacent to DuPont de Nemours (EB3); G = West Buchanan Street (EB11); H = Wabash Railroad (EB12); I = Wilson Street; J = I-90 ramp (EB10); K = West Broadway (EB14); and L = Tennessee Street (EB15). [1]= CDM/Limnetics; [2]= Indiana Department of Environmental Management, unpublished data; [3]= Simon et al. 1988; [4]= Sobiech et al. 1994.

	1976	1980	1982	1984	1985	1986	1987	1986	1987	1988	1994				
Species	A[1]	B, C, D[2]	B, C, D[2]	B, C, D[2]	B, C, E[2]	B, C, D[2]	B, C, D[2]	B, C, D[3]	B-G[3]	B, C, D[3]	H[4]	I[4]	J[4]	K[4]	L[4]
Gizzard shad (*Dorosoma cepedianum*)							96		157						
Alewife (*Alosa pseudoharengus*)	2						1		2	8					
Central mudminnow (*Umbra limi*)		1			3				16	1					
Chinook salmon (*Oncorhynchus tschawytscha*)								1							
Rainbow trout (*Oncorhynchus mykiss*)						11									
Carp (*Cyprinus carpio*)		5	18	5	31	111	19	59	165	36	1	4	3	13	
Goldfish (*Carassius auratus*)					34		113	157	140	161	6	128	10		
Carp × goldfish hybrid											1			13	
Rudd (*Scardinius erythrophthalmus*)											1	3	8	33	
Spotfin shiner (*Cyprinella spiloptera*)		1					1			12					
Golden shiner (*Notemigonus crysoleucas*)			1	10	124	64	25	222	140	239	61	53	53	15	
Golden shiner × rudd hybrid															1
Emerald shiner (*Notropis atherinoides*)							2			14					
Bluntnose minnow (*Pimephales notatus*)						92	21	1	5	3	2	9	14	16	2
Fathead minnow (*Pimephales promelas*)							1	1		1					
Black bullhead (*Ameiurus melas*)					1		1								

Table 4.—Continued

Species	1976	1980	1982	1984	1985	1986	1987	1986	1987	1988	1994				
	A[1]	B, C, D[2]	B, C, D[2]	B, C, D[2]	B, C, E[2]	B, C, D[2]	B, C, D[2]	B, C, D[3]	B-G[3]	B, C, D[3]	H[4]	I[4]	J[4]	K[4]	L[4]
White sucker															
(*Catostomus commersoni*)												1	2	1	
Rainbow smelt															
(*Osmerus mordax*)									1	1					
Pumpkinseed															
(*Lepomis gibbosus*)						48	14	59	41	1	2				
Bluegill															
(*Lepomis macrochirus*)							2	6	2	2					
Green sunfish															
(*Lepomis cyanellus*)					3			6			2	4	3		1
Largemouth bass															
(*Micropterus salmoides*)										2		1	2		
Black crappie															
(*Pomoxis nigromaculatus*)										1					
Yellow perch															
(*Perca flavescens*)		1				3	142		4			1		1	
Unidentified darter															
(Percidae)				1											
Total number	2	8	19	16	197	281	471	470	691	519	75	90	93	102	4
Total species	1	4	2	3	7	11	7	7	11	6	6	10	9	7	2
Tolerant species (%)	0.0	75.0	100.0	93.0	100.0	48.3	63.3	92.3	73.3	57.6	100.0	96.6	95.8	99.0	100.0
Exotic species (%)	100.0	0.0	94.7	31.3	33.0	28.1	83.7	45.0	22.2	19.7	12.2	21.3	20.0	68.0	0.0
Number of collections	2	3	3	3	3	3	3	6	11	61	1	1	1	1	1

Table 5.—A summary of the fish collected from sites in the West Branch of the Grand Calumet River: A = junction between the West Branch and the East Branch of the Grand Calumet River (WB1); B = Indianapolis Boulevard (WB3/including WB2); C = East I-90 to the east side of Roxanna Marsh (WB4); and West I-90 east to Columbia Avenue (WB5). [1] = Simon et al. 1988; [2] = Simon 1991; [3] = Simon unpublished data.

	1985		1986		1987		1988	1990		1994
Species	C	D[1]	B[1]	A[1]	B[1]	C[1]	B[1]	B[2]	B[3]	C[3]
Gizzard shad (*Dorosoma cepedianum*)					3					
Carp (*Cyprinus carpio*)	2		20	21	17			6	18	10
Goldfish (*Carassius auratus*)	12		22			1		2	9	5
Carp × goldfish hybrid								1		
Golden shiner (*Notemigonus crysoleucas*)				1	1		9	7		
Rudd (*Scardinius erythrophthalmus*)							1	10	1	
Bluntnose minnow (*Pimephales notatus*)								90		
Fathead minnow (*Pimephales promelas*)								1		
Black bullhead (*Ameiurus melas*)								1		
Green sunfish (*Lepomis cyanellus*)								2	1	
Pumpkinseed (*Lepomis gibbosus*)								1		
Total number	14	0	42	22	21	1	0	112	47	16
Total species	2	0	2	2	3	1	0	7	6	3
Tolerant species (%)	100.0	0	100.0	100.0	85.7	100.0	0	100.0	97.8	100.0
Exotic species (%)	100.0	0	100.0	95.4	80.9	100.0	0	8.0	80.9	100.0
Number of collections	2	0	2	1	3	1	2	1	1	1

close to the contaminated sediment characteristic of the area.

In 1990, most of northwestern Indiana was affected by significant flooding. The surface elevation of Lake Michigan and the depth of the West Branch increased. Samples from the Indianapolis Boulevard area included the greatest number of fish from the West Branch: seven species (Simon 1991). The first West Branch collection of the eurasian rudd (*Scardinius erythrophthalmus*) was included with this catch. The water quality of the discharge canal at East Chicago Sanitary District enabled several very tolerant species, such as green sunfish and bluntnose minnow, to inhabit the West Branch. The fish community downstream of Indianapolis Boulevard was numerically dominated by carp and goldfish; however, the percentage of exotic species was significantly reduced and native species, such as bluntnose minnow and green sunfish, increased (Table 5). Fish at this site had high percentages (4.5%) of deformities, eroded fins, lesions and tumor (DELT) anomalies; fish were collected that had eroded fins, fungus, and lesions.

Simon (unpubl. data) sampled the West Branch in the vicinity of Indianapolis Boulevard and Roxanna Marsh during 1994. One site extended from the east side of Indianapolis Boulevard to an area approximately 50 m upstream from the junction of the East and West Branches. The East Chicago Sanitary District discharge canal was included in this sampling site. The second location included the area from Indianapolis Boulevard west along the edge of Roxanna Marsh to the I-90 bridge. The fish community of the West Branch exhibited some improvement since sampling began in 1985; however, it still does not have the same biological integrity as the East Branch. Significant loss of community function has occurred in the West Branch; and as of 1994, many of the resident fish are tolerant, exotic detritivores. These taxa with flexible forage habits are often the first to occupy an area when pollution impacts and water quantity limitations are reduced and environmental conditions begin to improve. The fish community west of Indianapolis Boulevard, including Roxanna Marsh, has remained similar since monitoring began in 1985 (Simon et al. 1989).

Dominance by pollution-tolerant carp and goldfish and the absence of native species indicate extreme degradation. During the drought of 1988, even tolerant species were unable to inhabit the West Branch because of low water depths and poor dissolved oxygen conditions. Recolonization by carp and goldfish created a species composition similar to that observed in 1985. The presence of carp and goldfish hybrids shows disruption of reproductive strategies and is considered a reduction in biological integrity. The presence of high proportions of DELT anomalies also suggests that biological integrity is declining.

One reason that water quality in the Grand Calumet River is improving might be the presence of chinook salmon adults and fingerlings in the East Chicago Sanitary District's contact disinfection chamber. Spacek (1996) reported that chinook salmon were able to spawn in the district's contact disinfection chamber because of "well-oxygenated, high quality effluent water." Spacek (1996) suggested that this evidence is the first of Pacific salmon spawning in southern Lake Michigan. The problems with the documented evidence are substantial, and these problems make it difficult to conclude that the water quality of the West Branch of the Grand Calumet River has improved.

Grand Calumet Lagoons: Simon et al. (1989), Stewart & Simon (1995) and Simon & Stewart (1998) investigated the Grand Calumet Lagoon beginning in 1986. The State of Indiana Department of Environmental Management has collected fish from this area for tissue contaminant analyses. Simon & Stewart (1998) investigated the Middle and Western Lagoons during 1994–1995 to determine the status of the fish community as part of a larger study. The two lagoons are located east of the U.S. Steel site, and they are part of the Indiana Dunes National Lakeshore. The Lagoons are connected by a small stream, which usually drains to the west. Two small ponds, which were once backwaters or bays of the Grand Calumet Lagoons, are separated from the larger lagoons and are referred to as the West and East Ponds.

Shelford (1937) reported 20 species from the Grand Calumet Lagoons. Species collected during this period (Meek & Hildebrand 1910) reflect the least-impacted condition of the Grand Calumet since the flow of the river had only recently been reversed due to construction of the Indiana Harbor Canal.

The Indiana Department of Natural Resources (IDNR) has managed the recreational fishery in the East Lagoon since the mid-1960s. The lagoon is heavily fished, and over 60% of the shoreline is developed. The east end of the Lagoon is surrounded by homes, and a storm sewer empties into the East Lagoon near a pavilion. The IDNR collected channel catfish, bluegill, yellow perch, black crappie, largemouth bass, golden shiner, carp, lake chubsucker and goldfish from the East Lagoon (Robertson 1986). Largemouth bass, bluegill and black crappie were stocked in the East Lagoon in 1965. Channel catfish were stocked in 1982 and regularly between 1984–1992.

The western portion of the East Lagoon was treated with rotenone in 1966 to remove "rough fish" (e.g., carp and suckers). Robertson (1986) reported that after the rotenone treatment, bluegill abundance increased from 17.6–38.4%, though few were of catchable size. In 1973, 646 fish, including golden shiner (45.7%), bluegill (17%) and lake chubsucker (11.4%), were collected in the western portion of the East Lagoon. Largemouth bass, bluegill, black crappie and yellow perch comprised 30% of the sample. Robertson (1986) reported rosyface shiners in the East Lagoon, but these fish were probably misidentified emerald shiners.

Simon & Stewart (1998) studied the structure and function of the fish community of the Grand Calumet Lagoons. In many respects, the fish community of the Middle Lagoon resembles that reported for the Grand Calumet River basin by Meek and Hildebrand at the turn of the century (Table 1). Species such as lake chubsucker, Iowa darter, warmouth and pumpkinseed are found in the Middle Lagoon; centrarchids dominate the community (Table 6).

The array of subdominant fish species in the Middle Lagoon differs substantially from that in the West Lagoon. Species such as goldfish and bluntnose minnow are present in the West Lagoon; but warmouth, central mudminnow and lake chubsucker are found in the Middle Lagoon. Pumpkinseed are present in both the East and West Ponds; however, grass pickerel are present only in the East Pond. Exotic and tolerant species comprise a very low proportion of the fish community in the Middle Lagoon and both ponds. Stewart & Simon (1995) found Iowa darter (*Etheostoma exile*) in the East Lagoon. The species had previously been found in eastern Illinois and in Wolf Lake, but this report was the first record of this species in northwestern Indiana. The Wolf Lake population was thought by Smith (1979) to be extirpated; however, recent surveys have found them to be persistent (Simon unpubl. data).

Stewart & Simon (1995) and Simon & Stewart (1998) reported that the fish community of the West Lagoon is comprised of a greater percentage of tolerant species. This is probably a reflection of a more disturbed habitat, which provides a competitive edge for opportunistic, tolerant, detritivores such as carp, goldfish and bluntnose minnows.

BIOLOGICAL INTEGRITY

The biological integrity scores for fish communities of the Grand Calumet watershed indicated that the communities had "poor" to "very poor" integrity. Simon (1991) developed expected indices of biological integrity for fish communities in northwestern Indiana and the Central Corn Belt Plain Ecoregion. The Lake Michigan subdivision of the Lake Michigan Division shows declining water resource integrity with increasing drainage order for the entire Lake Michigan drainage. The Grand Calumet River achieved scores of poor (27.1%), poor-very poor (43.8%), very poor (20.8%) and no fish (8.3%); the West Branch had the lowest biological integrity. Simon et al. (1989) sampled a minimum of 2–3 times per year for four years to determine if biological integrity changed substantially at any of the twelve stations sampled. Of the nine stations that were sampled, the average index of biotic integrity score differed by less than 5 integrity points (range: 0–10 integrity points).

Other assessment categories were used at stations without fish. At these stations, the index of biotic integrity scores differed by more than 10 points. An Ohio study found that the largest departures in IBI scores were due to large scale disturbance (Yoder & Rankin 1995). In the Grand Calumet River, the wider fluctuations in IBI points also reflected highly disturbed conditions. The largest difference in IBI, within a single year, was 6 points at the

Table 6.—A summary of fish community structure and function found in the Grand Calumet Lagoons: A = dunal ponds identified by Shelford and assumed to be the Grand Calumet Lagoons; B = Middle Lagoon; C = West Lagoon; D = East Lagoon; E = West Pond; and ● = Presence data). [1] = Shelford 1937; [2] = Robertson 1986; [3] = Simon *et al.* 1988; [4] = Stewart & Simon 1995, and Simon & Stewart unpublished data.

Species	1909	1909	1986	1986	1995			
	A[1]	B[1]	D[2]	B[3]	B[4]	C[4]	D[4]	E[4]
Bowfin (*Amia calva*)	●							
Central mudminnow (*Umbra limi*)	●				1			
Grass pickerel (*Esox americanus*)	●	●			6		●	
Northern pike (*Esox lucius*)	●							
Carp (*Cyprinus carpio*)		●	●	18	2	17		
Goldfish (*Carassius auratus*)	●		●		1			
Carp × goldfish hybrid								
Common shiner (*Luxilus cornutus*)	●							
Golden shiner (*Notemigonus crysoleucas*)	●	●	●			2		
Emerald shiner (*Notropis atherinoides*)		●	●?					
Blackchin shiner (*Notropis heterolepis*)	●					51		
Bluntnose minnow (*Pimephales notatus*)								
Lake chubsucker (*Erimyzon sucetta*)	●	●	●	1	13			
Black redhorse (*Moxostoma duquesnei*)	●							
Black bullhead (*Ameiurus melas*)	●			1				
Yellow bullhead (*Ameiurus natalis*)	●	●			1			
Brown bullhead (*Ameiurus nebulosus*)	●							
Channel catfish (*Ictalurus punctatus*)			●					
Tadpole madtom (*Noturus gyrinus*)	●				1			
Green sunfish (*Lepomis cyanellus*)	●	●		2	12	15		
Pumpkinseed (*Lepomis gibbosus*)	●	●		1	70	32	●	●
Warmouth (*Lepomis gulosus*)	●	●			20	2		
Bluegill (*Lepomis macrochirus*)	●	●	●	5	113	27		
Largemouth bass (*Micropterus salmoides*)	●	●	●	2	26	94		
White crappie (*Pomoxis annularis*)		●						
Black crappie (*Pomoxis nigromaculatus*)		●	●	1	1			
Yellow perch (*Perca flavescens*)	●	●	●		9	25		
Iowa darter (*Etheostoma exile*)				8	4			
Total number	—	—	—	30	297	281	—	—
Total species	20	14	10	7	14	11	1	1
Tolerant species (%)	30.0	30.0	30.0	70.0	5.4	30.6	0.0	0.0
Exotic species (%)	0.0	14.3	20	60	0.1	6.4	0.0	0.0
Number of collections	—	—	1	1	3	3	2	2

site to the east of Indianapolis Boulevard in 1987 (Table 7).

FISH CONSUMPTION ADVISORIES

The Indiana State Department of Health (ISDH) (1997) found that fish from the Grand Calumet River should not be consumed, primarily due to contamination by PCBs and mercury. Table 8 lists the fish species and sizes (total length in cm) included in the consumption advisory. The advisory is less restrictive for the Marquette Park Lagoon, recommending only that largemouth bass more than 30 cm long be avoided. A statewide advisory exists on carp consumption: 1 meal/month of carp 37.5–50 cm long, 1 meal/2 months for carp 50–62.5 cm long and no carp over 62.5 cm should be consumed.

Numerous species in the nearshore of Lake Michigan also are restricted for consumption. Factors that would limit complete removal of consumption advisories and eventual recovery and delisting of the Grand Calumet River are: 1) Lake Michigan species that enter the river during migration include wide-ranging salmonids; 2) resident species in the Grand Calumet River would require several generations to reduce body burdens; and 3) stocking of

Table 7.—The index of biotic integrity values for the Grand Calumet watershed from 1985 to 1990 (Simon et al. 1988; Simon 1991). The sites indicated below are: 1 = West Lagoon; 2 = East Branch Grand Calumet River at Broadway (EB13); 3 = East Branch Grand Calumet River at Bridge Street (EB8); 4 = East Branch Grand Calumet River at East Buchanan Street (EB10); 5 = East Branch Grand Calumet River at Cline Avenue (EB4); 6 = East Branch Grand Calumet River at Kennedy Avenue (EB2); 7 = East Branch Grand Calumet River at the DuPont de Nemours outfall (EB4); 8 = Junction of the East and West Branches of the Grand Calumet River (EB1/WB1); 9 = West Branch Grand Calumet River at Indianapolis Boulevard (WB3); 10 = West Branch Grand Calumet River at the I-90 bridge (WB4); 11 = West Branch Grand Calumet River at Columbia Avenue (WB5); and 12 = Indiana Harbor Canal at Dickey Road (IHC3).

		Sites											
Year	Month	1	2	3	4	5	6	7	8	9	10	11	12
1985	October			24			24		24			24	0
1986	June	32		26		24	24			22			24
	October			28		30	28			20			26
1987	April		30	32	24	22		22	22	24	24		
	April			24		24	26			22			28
	November			32		30	30			0			34
1988	May			26		22	24			0			
	July			28		32	26			0			24
1990	July			24		20	32			21			16
Index of Biotic integrity													
Average		32	27	27.5	24	25.3	27.1	23	22	13.6	24	0	25.3
Minimum		32	24	24	24	20	24	22	22	0	24	0	16
Maximum		32	30	32	24	32	32	24	22	24	24	0	34
Standard deviation		—	3	1.0	—	1.33	1.14	1.0	—	3.0	0	—	3.0
Number of collections		1	2	8	1	9	7	2	1	8	2	1	6

Table 8.—Fish consumption advisories issued for the study area.

	Species	Length (cm.)	Concern	Meals/ month
Lake Michigan	Black crappie	17.5–20.0	PCB's	1
		20+	PCB's	0.5
	Brook trout	All	PCB's	1
	Brown trout	<45	PCB's	1
		45–67.5	PCB's	0.5
		67.5+	PCB's	0
	Carp	All	PCB's, mercury	0
	Catfish	All	PCB's	0
	Chinook salmon	<65	PCB's	1
		65+	PCB's	0.5
	Coho salmon	42.5–70	PCB's	1
		70+	PCB's	0.5
	Goldfish	10+	PCB's	0
	Golden shiner	7.5–15	PCB's	0
	Lake trout	<52.5	PCB's	1
		52.5–65	PCB's	0.5
		65+	PCB's	0
	Largemouth bass	10–17.5	PCB's	1
		17.5+	PCB's	0.5
	Longnose sucker	35–57.5	PCB's, mercury	0.5
		57.5+	PCB's	0
	Northern pike	25–35	PCB's	1
		35+	PCB's	0.5
	Pink salmon	All	PCB's	1
	Rainbow trout	<55	PCB's	1
		55+	PCB's	0.5
	Walleye	42.5–65	PCB's	1
		65+	PCB's	0.5
	Whitefish	<57.5	PCB's	1
		57.5+	PCB's	0.5
	White sucker	37.5–57.5	PCB's, mercury	1
		57.5+	PCB's	0.5
Grand Calumet River and the Indiana Harbor Canal	All species	All	PCB's, mercury	0

non-indigenous species and migration of species from other more contaminated areas into the river will require more time to see decline in contaminant body burdens. Recovery and restoration objectives for fish communities in the Grand Calumet River could initially strive to reach the same contaminant levels as Lake Michigan fish.

Fish bioaccumulation, body burdens and contaminant levels: Steffek (1989) evaluated three abandoned hazardous waste dumps in the Grand Calumet River watershed. Steffek collected a variety of organisms representing various trophic levels and feeding regimes. Earthworms, turtles, crayfish, fish and small mammals were tested for body burdens. Compounds found at elevated levels in whole body tissue samples included acetone, 2-butanone, benzene, trichloroethane, toluene, ethylbenzene, total xylenes, aluminum, copper, chromium, lead, manganese and silver. Values for lead were above the national levels obtained from the national biomonitoring program (Lowe et al. 1985). Taxa collected as environmental indicators showed various effects. Earthworms were absent from many of the sites but showed mixed results due to illegal dumping and mixed contamination. Fish, mudpuppy and crayfish provided important bioaccumulation information for inorganic and volatile compounds, while turtles did not show significant results.

Sparks & Hudak (1996) reviewed available information on environmental impacts associated with the dredging of the Indiana Harbor Canal. High sediment levels of polycyclic aromatic hydrocarbons (PAHs), phenols, cyanide, metals and ammonia have been detected in the Harbor sediments. Although bullhead species are not common in this study area, Baumann et al. (1987), Baumann (1989) and Baumann et al. (1991) have documented a stressor-response effect between PAH-contaminated sediments and incidence of liver neoplasia in brown bullheads. Levels of PAHs detected in the sediments of the Indiana Harbor Canal would be sufficient to cause elevated incidences of hepatic neoplasias.

SUMMARY AND RESTORATION POSSIBILITIES

Construction of Indiana Harbor, development and changes in land use, and expansion of heavy industry along the Grand Calumet River have severely degraded the fish habitat. This degradation was evident by the low catch rates and minimal diversity of the fish community during the mid 1970s. Improvements in water quality through the later 1970s and into the 1980s allowed for significant improvements in the Grand Calumet River fish community; however, current biotic integrity indices still characterize the community as "very poor."

Two pieces of evidence suggest that improvement and maintenance of water quality will be an essential factor in the recovery of the aquatic community. First, Simon et al. (1989) observed that the fish community rebounded during the USX shutdown. This could only have been a result of improved water quality because no sediment remediation took place. Second, the presence of salmonids in both the East Chicago and Gary sewage treatment plant discharges suggests that improvements in the quality of the discharge water have been sufficient to attract these fish on their spawning migrations. Departures in water quality standards and violations of NPDES permits still occasionally occur, and they are sufficient to cause mortality of young salmonids and other species.

Removal of contaminated sediment from the Grand Calumet River would likely improve the benthic macroinvertebrate community, which supplies forage for bottom-feeding fishes such as native suckers; and it would also reduce the potential for bioaccumulation from contaminated sediment. However, without sufficient water quality, the fish community is unlikely to recover beyond its present degraded condition. A combination of low dissolved oxygen, relatively high water temperatures, inadequate invertebrate forage and lack of heterogenous substrates result in low habitat diversity and suppressed community diversity.

Dredging/sediment clean-up impacts: Flow velocity in the Grand Calumet River varies with effluent discharge volumes (Crawford & Wangsness 1987). Channel depth through the length of the study area is highly variable, ranging from 8–10 feet (~ 3 m) in the Grand Calumet Lagoons to one foot (~ ⅓ m) or less in portions of the West Branch near the State Line. Removal or isolation of contaminated sediment and consequent reduction of sediment resuspension may improve water quality after sediment remediation is complete. Deepening the channel, however, will create a pool-like habitat with slower current and possibly reduce dissolved oxygen. The additional water depth may prohibit the re-establishment of rooted vegetation which provides substrate for invertebrates, cover for fish and an oxygen source.

The dredging and the sediment clean-up process may temporarily degrade water quality and reduce aqueous habitat quality. Dredging suspends sediment in the water column, which can increase turbidity and dissolved contaminant concentrations and reduce dissolved oxygen. These impacts tend to be temporary, and ambient levels return shortly after dredging ceases. Discharge from the dewatering site must be treated to reduce contaminant concentration and thereby meet state water quality standards. Care must be taken to assure that the discharge does not adversely affect instream dissolved oxygen and that toxic chemical concentrations, such as ammonia, are within acceptable limits. Weirs surrounding the dredge site can help contain water quality impacts within the immediate dredging area.

Long-term habitat impacts would result as dredging converts shallow littoral habitat to more pelagic habitat with steep banks and a narrow littoral zone. The vegetation in the littoral zone forms important foraging and nursery habitat for young fish. In order to re-establish this important aquatic habitat, water depths and clarity after dredging need to be created so that light can penetrate to the bottom.

Opportunities for improving aquatic habitat: In 1985, the USEPA identified two factors that reduced the quality of biological habitat in portions of the Grand Calumet River: slow-flowing or stagnant water in the West Branch warms quickly, causing decreased dissolved oxygen concentrations; and particulates settle over detrital matter and suffocate benthic organisms. The USEPA (1985) stated that these conditions are typical of many stream-mouth environments in the Great Lakes, but the conditions are exaggerated in the West Branch of the Grand Calumet River.

Flow reversals due to fluctuations in Lake Michigan water levels have less impact on the East Branch and main stem due to the high lakeward flow rate sustained by industrial effluent, particularly from USX. Without a high volume of industrial discharges, the majority of the Grand Calumet River would probably be less suitable for fish and aquatic life (assuming adequate control of pollutants in the effluent) (USEPA 1985).

An additional obstacle to restoration is the intensity of urban and industrial development within the watershed. Most precipitation falling to the basin is captured on non-porous surfaces, such as roof drains or parking lots and roadways, and is then diverted to the river via storm drains. This reduces the opportunity for soil filtration of dissolved and suspended pollutants, exaggerates peak flows, depresses low flows, reduces dilution of groundwater contaminants and slows dispersion from origin to discharge point along the river. Establishing aeration stations that use either injected air or elevated sidestream aerators could help to improve the aquatic habitat by maintaining adequate dissolved oxygen concentrations and by assisting in the breakdown of organic debris.

After the contaminated sediment is removed, the remaining channel profile needs a littoral zone. The rooted vegetation that grows in the littoral zone provides forage and cover for invertebrates and young fish, as well as ambush sites for predatory species. Creating a littoral zone could involve replacing dredged material with clean material in some portions of the river. Replacement with gravel or other substrate would provide substrate heterogeneity suitable for lithophilic spawners and nest builders such as suckers, darters and sunfish; and it may facilitate the re-establishment and maintenance of these populations. Woody debris, such as brush piles, stumps or logs placed along the channel border, can form current breaks, nesting cavities, hard surfaces for the attachment of adhesive eggs and habitat for invertebrates. Half-logs can be placed in the center of the channel to provide cover and shaded areas for species that previously would have used aquatic vegetation. Wetland, bog and dune areas adjacent to the river may serve as spawning and rearing areas for many important fish species (USEPA 1985). Creation of artificial wetlands and shallow side channels would form more of this important limiting habitat.

Innovative dredging techniques could be used to create side channels through the heavily choked *Typha*, *Phragmites* and purple loosestrife stands adjacent to the river. These side channels could be staggered and parallel to the channel to emulate a braided wetland channel. The entrance to these areas could be kept open by installing deflector logs to scour and divert flow from the main channel. In addition, many depth profiles could be established by refilling with clean sand. Also, side-channel wetlands could be created by dredging perpendicular to the channel and then filling with clean sand to create a shelf zone. This area could be planted with native emergent wetland plants which would serve as fish nursery habitat and as foraging and resting areas for wading birds, reptiles and mammals. A rigorous effort to control exotic, invasive plant species would have to be implemented to control reinvasion of exotic plant species after initial efforts are implemented.

After sediment clean-up, the water quality of industrial and municipal discharges will need to meet NPDES permit requirements. Further treatment and design improvements are needed to reduce impacts attributable to thermal pollution, nutrient enrichment, combined sewer overflows and other non-point source influences. A single episode of oxygen depletion could eliminate an entire year class of young fish. Without continued emphasis on meeting designated uses and NPDES permit limits, little or no improvement of the fish community can be expected.

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