Status, Trends, and Potential of Biological Communities of the Grand Calumet River Basin

submitted by

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INTRODUCTION

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Once the downstream section of the Calumet River system that dominated most of Northwest Indiana, the now highly modified Grand Calumet River now constitutes one of the smallest major watersheds of the Calumet region. Though only 13 miles long and with almost no natural surface drainage area, it now flows through one of the most industrialized areas in the United States. Despite intensive urban and industrial development, the Grand Calumet watershed still contains extraordinary vestiges of once highly rich and varied natural communities. These features, along with other remnant natural areas reserved and protected by both public and private groups, conceivably still possess the potential for at least partial recovery. The approach and framework for the recovery from past cultural insults of the Calumet landscape require a geological and ecological context from which mitigation targets can be developed.

Changes over the course of Lake Michigan's geological history strongly influenced the landscape of the present Calumet region. Wind, erosion, and fluvial and Lake recession helped produce dune and swale ecosystems, and climate and hydrology encouraged wetlands, forests, savannas, and prairies. The convergence of three major biomes (eastern deciduous forest, boreal remnants, and tall grasslands) coupled with succession over a small area and a large variety of hydrological regimes (streams, lakes, wetlands) helped make the Grand Calumet area biologically diverse. Ironically, one might argue that biodiversity should be low since complete scouring by the Laurentian ice sheet (12,000 years ago) completely eliminated local biological communities, and thus, present day biological communities represent recolonization from outside sources.

Today, habitat destruction has not been due to ice sheet advances but due to industrial and urban development and the introduction of non-native, invasive species. The natural ecosystems have been continually cleared, drained, and fragmented, and roads and railways cut through the dunes and wetlands for commercial and municipal development. Human enterprises dominates the landscape and controls the region. The Grand Calumet River itself serves as a dumping site for industrial and municipal wastes. Little natural flow of the river exists due to channeling, deepening and flow augmentation.

Establishing a unity between industrial and natural areas is necessary to preserve the ecosystems that remain without destroying the livelihood that supports the Calumet region. Only by revitalizing some of the more heavily damaged areas can the ecological integrity of the Grand Calumet River be restored to resemble its historical natural appearance and function. The remnant natural areas that were created by thousands of years of geologic forces must be preserved from further degradation, or that natural history might be irretrievably lost. The resiliency of nature is well-illustrated by the millennia of biological recolonization and ecological recovery since the last ace age. While we can not afford this time span for ecological restoration, this natural experience demonstrates the feasibility of a parallel human experiment. In effect, the perspective and questions of this experiment are simply, what are the status and trends of existing natural resources of the Grand Calumet River basin? Can these natural areas and present day cultural pressures co-exist? Can these natural communities be re-established in a sustainable manner? What is the most effective restoration approach for achieving such goals? Finally, can the social, economical, and political support be focused to attend to these objectives? These following chapters attempt to answer the former questions, the last question can only be settled after considered implementation of ecological restoration plans.

REGIONAL GEOGRAPHY

The natural watershed of the Grand Calumet River is located between Tolleston Beach and the present-day shore of Lake Michigan. It lies within the Calumet lacustrine plain, or lake plain, which extends from the modern Lake Michigan shore to the Valparaiso terminal moraine. After the Wisconsin glaciation, the Lake Michigan lobe of the Laurentian ice sheet began to retreat, and the Valparaiso terminal moraine marks its furthest southern advance before receding. The moraine also serves as the continental divide and the southern boundary of the Lake Michigan watershed. Drainage from areas to the north of the moraine enter the Atlantic Ocean via the Calumet River, Lake Michigan, Lake Huron, the St. Clair River, Lake Erie, Lake Ontario, and the St. Lawrence River. Drainage from areas south of the divide typically flows to the Gulf of Mexico via the Mississippi River. The Calumet region is the land on the northern side of the Valparaiso Moraine, draining the historic Calumet River system.

The last glacial retreat from the Great Lakes occurred about 18,000 years ago (Chrzastowski and Thompson 1992). As the glacier retreated, isostatic rebound caused Lake levels to decline three distinct times. The archaic beaches remain today at 60, 40, and 20 feet above contemporary Lake Michigan levels: Glenwood, Calumet and Tolleston, respectively. Many ridges were built by wave activity and wind-blown dune deposits, and the valleys between them collected water to form marshes, ponds, and swamps.

Changes in the drainage patterns of the lakeplain led to the formation of the Grand Calumet River. The Little Calumet River was located south of Tolleston Beach, and the area of the River that passed through a break in the ridge became the Grand Calumet River.

Many habitats were created in the new warmer environment where new plant and animal species evolved. Remnant cold climate biota (arctic disjunct) such as the spruce and the fir followed the glacier’s retreat northward as ambient temperature increased at a rate of 1-2 degrees every 1000 years (Schneider 1989). A few cold climate plants adapted to the warming conditions, including bearberry (*Arctostaphylos unaursi*). Extensive coastal marshes and wetlands formed between the dune ridges at the southern end of the Lake Michigan basin with rich habitat for shore birds, waterfowl, fishes, mammals, amphibians, reptiles, invertebrates, and plants.

According to Bailey (1972), northwestern Indiana was dominated by open spruce parkland 12,000 years ago. From 11,000-10,400 years ago, red and jack pines were dominant, and from 10,000-2,500 years ago, the area was primarily oak dominated hardwoods. After that, mesic species such as beech, maple, oak, and butternut took over. Surveys from 1829-1834 list the most important trees in the dune complex communities as black oak, white pine, jack pine, white cedar, and tamarack (Bacone and Campbell 1983).

EARLY CULTURE

Early artifacts found in the back dunes of the Calumet Beach Ridge by Lynott (1990), including fire-cracked rock, chipped stone tools, lithic debris, and ceramics were dated to the Late Woodland stage. The earliest historic records of settlement relate to the Potawatomi who occupied the area until about 1833. The Potawatomi were nomadic. They lived in the Calumet region during the summer for hunting, fishing, foraging, and cultivating, and they returned south in the winter. Food was abundant for the Potawatomi. Wild currants, cranberries, whortleberries, gooseberries, huckleberries, and wintergreen berries were plentiful among the dune and swales. Other abundant foods were grapes, pawpaws, wild plums, crabapples, hazel nuts, honey, sassafras, and maple syrup. Wild game included whitetail deer, black bear, wild turkey, prairie chickens, geese, and ducks. Early European settlers traded tobacco and food with the Potawatomi for fur, cranberries, venison, and beaded items.

The United States government bought much of the Potawatomi land between 1826-1832, and extensive European settlement began. Many of the Potawatomi were removed to a Kansas reservation in 1832 though some remained in the area (Meyer 1956). Despite the abundance of food, the settlers eagerly cleared the dense timber and cultivated wherever they could. Much of the area was too wet to cultivate. The Calumet rivers meandered lazily through impassable marshes, so travel in the area was also difficult. Transporting goods to outside markets was costly, so settlers practiced primarily subsistence farming for wheat, oats, maize, turnips, buckwheat, and potatoes (Meyer 1956).

Traffic across the Calumet region became heavy as settlement increased to the west. Any travel from Chicago to the east had to cross the area because of Lake Michigan (Cook and Jackson 1978). A mail route was established in 1831, and in 1833, a stage began operation along the route from Chicago to Niles, Michigan (Cook and Jackson 1978). As a crossroads, the area was ideally suited for industry and commerce, and it eventually took over.

INDUSTRIALIZATION

The sawmill quickly became the most important industry to the settlers. Mills were located in the heavily wooded sections of the Calumet region, but due to the low flow of the

Grand Calumet River, only the Little Calumet was utilized for lumber transportation (Meyer 1956). Also a large industry, gristmills appeared in response to land cultivation. Though ideally situated near prairies, gristmills had to be located near the river and therefore, they sprung up near the sawmills in the forested areas. Other tradespeople soon occupied the area including blacksmiths, wagon makers, coppers, tanners, and cabinet makers. As logging continued and sand mining spread into the area, the Grand Calumet River began to be impacted. Forests were removed, and within 20 years, a 184 foot sand dune was leveled (Lerner 1977). Understandably, erosion became a problem.

It was not until the 1840's that heavy industry began to enter the Calumet region due to the blooming transportation networks. By 1848 the Illinois Central Railroad traversed the Calumet region, and in 1852 the Michigan Southern and Northern Indiana (South Shore) Railroads connected the region to the east and to the west. Settlement occurred at a much higher rate with employment opportunities in railroad building. The railroads also made it possible to transport heavy farming equipment into the region (Cook and Jackson 1978). Water transport was also important in settling the Calumet region. The Grand Calumet River was eventually channelized and manipulated to create usable waterways. In 1862, the Calumet Feeder Canal was created to allow the Grand Calumet River to flow east into the Illinois and Michigan Canal (I&M). This reversed the northward flow of the River, so Grand Calumet River waters flowed away from Lake Michigan.

The first major industry in the area was a meat-packing company, the George H. Hammond Packing Company, that slaughtered and shipped meats to the eastern United States and Europe with a patented refrigeration process. Around 1870, the Calumet River was converted into a navigable passage for ships, so industry could expand further. Sand bars were removed, piers were erected, and the channel was straightened and deepened (Ryder 1995). By 1889, the three branches of the Indiana Harbor Canal were completed by private industry, and the Grand Calumet River was effectively connected to Lake George, Wolf Lake, and Lake Michigan (Ryder 1995). Industry now had major modes of transport, so expansion was inevitable. Sediment and water contamination of the Grand Calumet River started to become a problem around 1885 as effluent was directly discharged from foundries, refineries, packing plants, inadequate sewage plants, and eventually, steel mills (Ryder 1995).

The Calumet region began to change dramatically and rapidly with the arrival of the Standard Oil Company in 1889. Shortly thereafter, Inland Steel Company arrived, in 1902, and the city of Gary was established with the 1905 building of U.S. Steel. From 1885-1895, the Army Corps of Engineers attempted to rectify the contamination situation by dredging the Grand Calumet River. The effort was unsuccessful as industrial and municipal pollution filled the basin faster than they could remove the sediments (Ryder 1995). Another steel company purchased land in the area in 1929, Midwest Steel, and industry and expansion continued (Cook and Jackson 1978). Severe air pollution also arrived with the steel mills and refineries by the 1920's.

With the growth of industry came population expansion. Small family farms were disappearing due to the urbanization that came along with industrialization (Meyer 1945). Immigrants from all over Europe and Mexico came to the area for work in industry (Lerner 1977). The region was changing quickly.

Industrial expansion experienced a lull with the onset of the Great Depression that extended through World War II (Cook and Jackson 1978). This lack of activity lasted into the 1950's, but the effects of industries already present were still apparent. In 1930, the Grand Calumet River was described by Peattie (1930) as a stagnant lagoon, an "open sewer" devoid of plant life, though bordering marshes still offered "favorable localities for plant growth." Air pollution in 1966 was comprised of 41% fuel combustion (458,000 tons per year), 35% industry (392,000 tons per year), 22% transportation (241,000 tons per year), and 0.02% refuse disposal (Lerner 1977).

The establishment of industry created the landscape apparent today. The Grand Calumet River experiences the great force of pollution inherent in industry and urbanization. Years of un-managed pollution from rapid industrial growth is now buried in the sediments, and any ecological integrity of the system has been severely degraded.

POLLUTANTS

The 1972 Federal Water Pollution Control Act required the Indiana Stream Pollution Control Board (ISPCB) to issue permits to stream dischargers through the National Pollution Discharge Elimination System, and a chance at reviving the Grand Calumet River was granted. The steel mills removed solid and acid wastes from their effluent by installing catch basins and by using aeration and filtration techniques. Though there have been numerous reports of non-compliance, the NPDES system is recognized as a contributor to improved water quality.

Recognized pollutant sources include urban runoff, landfills, dumpsites, industrial effluent, and sewage treatment plants. The Grand Calumet River has a history of high levels of bacteria, nutrients, cyanides, lead, arsenic, cadmium, PCBs, phenols, oils, grease, chlorides, and other contaminants in the water and sediments. Combined sewer overflows from Gary, East Chicago, and Hammond sewage treatment plants flush raw sewage and fecal contamination into the Grand Calumet River and also Lake Michigan via the Indiana Harbor Canal.

The effects of these pollutants on humans and on the River ecology are great. Ammonia is released from stock yards and in the coking operation of steel production, and both ammonia and phosphorus are found in sewage, fertilizer, meat packing and industrial waste, and detergents. These two nutrients contribute to toxic algal blooms, increased aquatic plant and algal growth, and lower oxygen levels when they are flushed into Lake Michigan. Problems with Lake ecology and fisheries can occur when nutrient levels are high.

Other contaminants produced by industry also cause adverse health effects in humans. Hydrocarbons from refineries have an acute lethal toxicity and will decrease the dissolved oxygen concentration in water. Lead can cause convulsions, anemia, and kidney and brain damage. PCBs were once used in transformers and diodes, but they were banned in the 1970's. They resist degradation and remain in the environment and can cause vomiting, rashes, abdominal pain, temporary blindness, liver damage, cancer, and birth defects in humans.

Despite successful attempts to improve the River's water quality, the sediments will not be cleaned simply by changing current pollution practices. For over 100 years these contaminants have accumulated in the system, and only by removing them completely will the River ecosystem be improved. The toxic effects to the environment surrounding the River are biologically acute, and many River sections are still devoid of life as Peattie (1930) observed years ago.

The fast pace of industrialization has taken its toll on the environment of the Calumet region. Some natural areas still survive, and preserving and extending these ecosystem fragments will help to restore the integrity of the Grand Calumet River and its surrounding environs. Dredging the sediment is the first step in the process, and by doing this, years of industrial degradation will be removed from the River. Merely dredging the main channel is ecologically inadequate. Watersheds are intricate ecosystems that must be restored and managed at an ecosystem level. Components of the Calumet watershed include riparian wetlands, slack water, savannas, prairies, and dune and swale habitats. Restoration should be integrated, proportional, and with a clear sight on targeted recovery objectives. Preventing re-contamination will be an important part of restoration, but with the appropriate regulations in place, the Grand Calumet River might experience some of its natural history again.

LITERATURE CITED

Bacone, J.A., and R.K. Campbell. 1983. Presettlement vegetation of Lake County. Proceedings of the 7th National Prairie Conference. Southwest Missouri State University. 27-37.

Bailey, R.E. 1972. Late- and postglacial environmental changes in northwestern Indiana. Dissertation. Department of Plant Sciences, Indiana University, Bloomington, Indiana, USA.

Chrzastowski, M.J. and T.A. Thompson. 1992. Late Wisconsin and Holocene coastal evolution of the southern shore of Lake Michigan. Society for Sedimentary Geology **48**:397-413.

Cook, S.G. and R.S. Jackson. 1978. The Bailly Area of Porter County, Indiana. Final Report to the Indiana Dunes National Lakeshore.

Lerner, S. And L. Trusty. 1977. Environmentalism and the Calumet region. Purdue University-Calumet, Calumet, Indiana, USA.

Lynott, M.J. 1990. Prehistoric occupation of the Calumet dune ridge. Indiana Dunes National Lakeshore, Northwest Indiana. 1990 Midwest Archaeological Conference, Evanston, Illinois, USA.

Meyer, A.H. 1945. Toponomy in sequent geography. Calumet region, Indiana-Illinois. Proceedings of the Indiana Academy of Science 142-158.

Meyer, A.H. 1956. Circulation and settlement patterns of the Calumet region of Northwest Indiana and Northeast Illinois: the second stage of occupance-pioneer settler subsistence economy, 1830-1850. Annals of the Association of American Geographers **46**(3):312-356.

Ryder, K. 1995. Chicago waterways history. U.S. Army Corps of Engineers. Chicago, Illinois, USA.

Schneider, S.H. 1989. The changing climate. Scientific American **261**(3):70-79.

Peattie, P.C. 1930. Flora of the Indiana Dunes. Field Museum of Natural History. Chicago, Illinois, USA.

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INTRODUCTION

The southern Lake Michigan lakeplain is a landscape of contradictions. It has suffered extensive environmental degradation, yet it remains home to globally significant natural areas. The Grand Calumet River is an integral part of the lakeplain. Its watershed, the heart of the Calumet region, is a graphic illustration of the head on collision between industrial development and the natural lakeplain ecosystem. Commonly held images of the Calumet region include hulking steel mills, acres upon acres of white tanks holding petrochemicals from the region's oil refineries, channelized waterways, and working class neighborhoods in various states of repair. At the same time, scattered throughout the landscape are small tracts of relatively undisturbed natural areas that support some of the most complex biotic communities in the Great Lakes basin.

The native landscape of the Calumet region supported a diverse assemblage of species in communities that were adapted to the full range of environmental conditions and ecological processes present at that time. Urban industrial development brought about radical changes to the landscape that disrupted abiotic conditions and impaired natural processes. Physical destruction of habitat, changes in hydrologic cycling, introduction of exotic species, and fire suppression have all taken their toll on the native ecosystem.

One measure of the ecological health of the Grand Calumet River corridor is its ability to continue to support viable populations of native species and community types. Currently, the most biologically diverse communities along the river corridor are restricted to a series of small tracts that have escaped physical disruption of the natural terrain. These sites include DuPont Dune and Swale, Clark and Pine East, the Grand Calumet Lagoons and the Miller Woods unit of the Indiana Dunes National Lakeshore. There are somewhat disturbed areas, such as the NIPSCO Roxanna Substation, that support degraded native communities. Still other areas are extremely degraded in most aspects but maintain specific ecological functions. Roxanna Marsh is the best example of the latter; it bears little resemblance to any native community type, yet it is a crucial stopover point for long range migratory waterfowl.

The remnants of the native landscape are snapshots of what was once a beautiful and dynamic natural system and they offer us a model and raw materials from which we can create a new, more diverse and well-integrated landscape. Conservation of these natural resources will depend on our ability to both recognize their intrinsic value and to protect and restore the ecological processes that support them.

Remediation of historic contamination will be the first step in the restoration of ecological health to the river. Habitat restoration that accompanies any cleanup will probably take the form of discrete projects associated with specific dredging responsibilities. The success of these isolated projects will depend on our ability to incorporate their design into regional conservation efforts. Ecological improvements to the River channel and associated wetlands have the potential to impact not only the Grand Calumet River watershed but also the southern Lake Michigan lakeplain, and ultimately the entire Great Lakes basin

The purpose of this chapter is to describe the special habitats along the Grand Calumet River corridor that support diverse biotic communities. The ecological significance of these sites will be outlined in the contexts of the River's watershed, the southern Lake Michigan lakeplain, and the Great Lakes basin. Potential impacts of dredging and of associated habitat restoration projects will also be discussed.

PRE-SETTLEMENT CONDITIONS

The southern Lake Michigan lakeplain

The post-glacial landscape of the southern Lake Michigan lakeplain is the product of constant change. For most of its history, regional physical processes such as climatic conditions, glacial mechanics, and fluctuating lake levels drove this dynamic system. The region's biotic communities have been influenced by three major biomes; eastern deciduous forest, tallgrass prairie, and boreal. The physically changing terrain together with the availability of diverse genetic material created an ecological rhythm that marked time with constantly evolving biotic communities.

The Great Lakes are relatively young in geologic terms; their history encompasses only the last several thousand years. During the Pleistocene Epoch climatic changes caused glaciers to advance southward across North America, extending as far south as Ohio and the Missouri River. As the glaciers flowed across the landscape, they carved out the Great Lakes basin. With the end of the Wisconsin Glaciation, some 11,000 years ago, the ice fields retreated from the region leaving behind the predecessors of the modern Great Lakes (Brown 1997).

The following geologic history of the lakeplain and formation of the Grand Calumet River are summarized from *Geologic History of the Little Calumet and Grand Calumet Rivers* by Steve E. Brown. Sixteen-thousand years ago the Lake Michigan Lobe of the Wisconsin Glacier covered the southern Lake Michigan area. Over the next 4,000 years, the glacier receded and advanced several times. With each successive wave of glaciation the melting ice deposited till that formed moraines. As the ice margin retreated north, meltwater trapped between the moraines and receding ice formed ancestral Lake Michigan.

The lake took on different forms as water levels fluctuated with changes in the drainage outlet and precipitation. Overall the lake has dropped sixty feet to its current level. The land exposed by the receding water, the southern Lake Michigan lakeplain, is marked by sand dunes, relict beaches, sandbars and spits. The land forms of the southern Lake Michigan lakeplain mark three distinct periods of the lake. They are from oldest to most recent, Glenwood Beach (13,500 to 12,400 years ago), Calumet Beach (11,800 to 11,000 years ago) and Tolleston Beach (6,300 years ago to present).

The subsurface of the lakeplain consists of lacustrine sediments that form the Calumet Aquifer. Beneath the aquifer is a layer of nearly impermeable clay. This formation holds groundwater close to the surface, resulting in poor surface water drainage. Poor drainage combined with relatively flat topography caused marshes, shallow lakes, and sluggish rivers and creeks to form throughout the new landscape.

Boreal and tundra flora established along the receding edge of the glacier. As the ice field retreated for the final time, plants from the surrounding landscape migrated in and colonized the freshly exposed land. By the end of the Calumet Phase of Lake Chicago, a spruce and fir dominated coniferous forest followed the receding water north. During this time a mild semi-arid period began that spanned several stages of the lake's evolution, allowing deciduous forest to migrate in from the south and east and eventually prairie from the west (Bacone 1979).

By the beginning of the Holocene Period, 10,000 years ago, most of the glacial ice had retreated from the Great Lakes region. Deciduous forest followed the coniferous forest north. The continuing warm dry conditions favored prairie species, that pushed in from the west dividing the coniferous and deciduous forest. Eventually the Prairie Peninsula extended to Ohio and eastern Indiana. Mesic deciduous species migrated north following more favorable moisture conditions. Xyrophytic species from the north and deciduous forest mixed with the prairie flora forming a mosaic of communities across the newly created habitat (Bacone 1979).

The Grand Calumet River

The natural watershed of the Grand Calumet River is located between Tolleston Beach and the shore of Lake Michigan. Over the past 4,500 years, the Tolleston strandplain has formed on the lakeward side of Tolleston Beach. At its east end, Tolleston Beach begins as a high dune and widens into the strandplain as it moves west. Prior to urban development, the surface topography was dominated by a series of ancient linear beach ridges and intervening swales. Near the Indiana-Illinois border there were as many as 100 of these ridges.

The Grand Calumet River formed on the Tolleston strandplain due to changes in the drainage pattern of the southern Lake Michigan lakeplain. Prior to the development of Tolleston Beach early forms of the Little Calumet River, Salt Creek, and Deep River served as watershed for the area, draining into ancestral Lake Michigan. With the development of Tolleston Beach these rivers could no longer flow directly into the lake. Instead, they emptied into Tolleston Lagoon; a large lagoon that had formed landward of the newly developed beach ridge. Between 4,500 and 4,000 years ago, Tolleston Lagoon emptied into ancestral Lake Michigan near the Indiana-Illinois border, where together they drained southward through the Sag channel. Eventually, the lake level dropped below the Sag Channel outlet, and a drainage network developed that joined the Little Calumet River, Salt Creek, Deep River, and Thorn Creek.

Approximately 2,200 years ago, the Little Calumet flowed west landward of Tolleston Beach and turned northeast to flow lakeward at a break in the ridge near early Lake Calumet. The lakeward reach became the Grand Calumet River, which emptied into Lake Michigan. As the lake level continued to drop and expose more of the lake plain, eastward moving longshore currents forced the mouth of the Grand Calumet River to migrate from west to east along the shoreline. The mouth of the river reached the area now occupied by the Grand Calumet Lagoons about 350 years ago.

The strandplain consists of nearshore deposits, very fine grained sand to sandy gravel, overlain by onshore sediments, fine to medium grained sand. Each individual ridge took from tens to hundreds of years to form as the level of Lake Michigan fluctuated. The ridges are built of layers of sand and gravel sediments deposited by shoreline wave activity and capped with wind blown dune deposits.

Wetlands formed where the swales dip below the groundwater table. The well-drained sandy soils of the ridges grading into the marshy swales created a wide range of moisture conditions that were complicated by the natural fluctuations in the groundwater table including seasonal changes, short term fluctuations of Lake Michigan water level, and the long term retreat of the lake. This is reflected in the variety of natural communities found throughout the ridge and swale region. From the dry sand savannas to the interdunal ponds, these communities are interwoven into a fine tapestry of living organisms responding to each temporal or spatial change in the landscape.

The ridges and swales mark stages in the evolution of the lakeplain. Those formed most recently are closest to the lake, while the oldest lie furthest away. Bacone (1979) distinguishes between the lakeside ridge and swale, north of the Grand Calumet river, and inland ridge and swale, south of the Grand Calumet river. The lakeside system is more influenced by the effects of Lake Michigan. It has a higher water table, is more calcareous, and tends to have fewer trees. Prior to logging, white and jack pine occupied the ridges and white cedar was found throughout the swales. The inland system has a lower pH, and it is more heavily forested. Black and white oaks are the dominant trees as opposed to cedar and pine. He also makes the important point that succession on the strandplain is different from the classic succession patterns of the parabolic dunes to the east. Succession on the strandplain took place over thousands of years in response to environmental changes related to the receding waters of Lake Michigan and long term fluctuations in climatic conditions.

During the formation of the Tolleston strandplain human activity began to have a direct influence on the lakeplain landscape. Climatic conditions became more moist and favored the deciduous forest. The forest migrated across the landscape from the south and east pushing the prairie back west. The advance of the forest was checked by Native Americans, who used fire as a hunting tool. Fires swept across the prairies into the edge of the forest, creating openings for prairie species to establish with fire tolerant deciduous species (Bacone 1979). Over the next 4,000 years, the biotic communities of the lakeplain evolved under the influence of fire, creating and maintaining the openness of the prairie and savanna communities.

At the time Europeans began settling the Calumet region, the natural communities of the strandplain formed a transition from sand savanna and sand prairie associated with the dune region in the east to the black-soil tallgrass prairie that flows across the Illinois landscape to the west. From the shoreline landward the biotic communities reflect the natural succession through which sand and gravel beaches were transformed into living marshes, prairies and savannas. The ability of diverse species to interact freely across the landscape as communities in response to the constantly changing environmental conditions was fundamental to the ecology of the region.

European settlement

At the beginning of the nineteenth century the Little Calumet and Grand Calumet still formed one river. Native Americans and European settlers dragged their canoes between the Little Calumet River and Lake Calumet opening a channel sometime between 1809 and

1820. The new channel redirected the flow of the Little Calumet River through Lake Calumet into Lake Michigan. The Grand Calumet was now isolated and slowed considerably. By 1872 the mouth of the Grand Calumet River was completely silted in with sand and clogged with aquatic vegetation (Moore 1959).

By the middle of the nineteenth century Europeans had begun to settle on the lakeplain. Most of the early settlers were farmers. Between 1840 and 1850 the population of Lake County more than doubled from 1,468 to 3,991. Of those, only 97 persons lived north of the Little Calumet River (Moore 1959). The ridge and swale was of no agricultural value, so those who lived there depended on hunting, fishing, and trapping. Wildlife was so abundant that several hunting and fishing clubs were founded in the area. There are several accounts of the rich harvest of game from the area including: ". . . it was not unusual to bag a hundred ducks in a single day. The record for ducks killed by one of the members was 189 between sunrise and 10:00 A.M." (Moore 1959) and "The marshes adjacent to the Calumet rivers abounded in mink and muskrats . . . An estimated 30,000 muskrats were taken each year . . ." (Moore 1959).

In 1870 work began on a harbor at the mouth of the Calumet River in south Chicago, marking the beginning of industrial expansion of the Calumet region. Alterations to the landscape, such as dredging and channeling the rivers and draining and filling wetlands, changed both the land use and ecology of the region.

The scientific study of the unique ecology of the lakeplain began during this same time. By the early 1900s the work of Dr. Henry Cowles had created great interest in the dune region of northwestern Indiana. During this time detailed surveys of both flora and fauna were compiled for the region. The richness of plant species found in the ridge and swale region is described in H. S. Pepoon's 1927 book, *An Annotated Flora of the Chicago Area*. One passage describes plant species found in the area near Clark and Pine between 1892 and 1906. It should be noted that most of the sites mentioned have been destroyed or severely degraded by urban development.

> It was adjacent to this slough and other depressions and ribbon like waters that orchids abounded, such as small yellow lady's slipper (*Cypripedium parviflorum*), the large yellow lady's slipper (C. *parviflorum pubescencens*), which at B [B is a location on the banks of the Grand Calumet River] on the map was found in 1894 in a colony of some hundred plants , the small white lady's slipper (*C. canadidum*) at N [N is near present site of Clark Junction natural area.], the showy lady slipper (*C. hirsutum*) at J, bracted orchis (*Habenaria bracteata*) at E, *Habenaria clavellata* at G, *Habenaria hookeri* at M, *Pogonia ophioglossoides* at G, calapogon at G, *Spirantes gracilis* at J, *twayblade (Lipares Loeselli*) at N, a colony of pitcher-plant flourished at D, . . . Twinflower (*Linnaea*) occurred at E, one of the few stations for this plant in the Chicago Area. . . . *Nelumbo lutea*, the lotus grew in the Grand Calumet at A . . . At this station only. Sundew (*Drosera rotundiflia*) was found on nearly all waterfilled half submerged logs at A.

While one segment of modern culture was beginning to understand the biological significance of the lakeplain ecosystem another was systematically destroying the ecological processes and patterns that had produced it. Pepoon laments the destruction of habitat that had already occurred by 1927: "... Very much of this rare flora has disappeared forever, owing to drainage, railroad building, sand hauling and filling, extension of urban communities, and the tremendous influx of factories. Much of the pond water remaining is practically sewage. The choice plants of these sloughs and marshes, as far east as Dune Park, have disappeared or are vanishing rapidly" (Pepoon 1927).

CURRENT CONDITIONS

The landscape of the Calumet region has changed dramatically during the past 100 years. The Grand Calumet River typifies these changes. It was once described as being more like a bayou than a river (Moore 1959), but it has since been channelized and redirected to flow into the Mississippi River basin. Today roughly ninety percent of its water comes from industrial and municipal discharges. The sandy soils of the river bed have been replaced by sediments contaminated with the residue of urban industrial activities. Despite these changes, aspects of the natural systems are still evident along the river corridor and throughout the watershed. Identifying and understanding the significance of the native species and community types is an integral part of assessing the ecological state of the river corridor.

The Indiana portion of the strandplain covers over 30,000 acres, and within that roughly 2,000 acres of ridge and swale still exist. Aerial photographs taken over the last sixty years document the physical transformation of the region from a natural system to an urban industrial complex. The first complete set of aerial photographs of the Calumet region date back to 1938. Undisturbed sections of ridge and swale topography are easily recognized by their distinctive linear pattern. The 1938 photographs show that the strandplain had already been divided into three distinct units. The city of Gary separated the Miller Woods area in the east from the central ridge and swale section in west Gary, Hammond, and East Chicago. The central ridge and swale section was divided from the Wolf Lake - George Lake area by the cities of Hammond, East Chicago, and Whiting. Shoreline armoring and fill, that would ultimately isolate the strandplain from Lake Michigan, had also begun. Although these areas were isolated from each other, there were still fairly large blocks of natural terrain in the Miller Woods and central ridge and swale area.

The Miller Woods area currently contains roughly one thousand acres of fairly contiguous native landscape including the Miller Woods Unit of the Indiana Dunes National Lakeshore, the City of Gary's Marquette Park, and private property. Over 430 species of native plants have been documented in the Miller Woods unit of the Indiana Dunes National Lakeshore. The dune complex north of the Lagoons supports panne and foredune communities. The ridge and swale complex to the south of the lagoons supports some of the highest quality black oak savanna in the Chicago Region (Wilhelm 1990). The Miller area supplies habitat for at least 70 floristic elements considered rare or limited to a unique niche within the Indiana Dunes National Lakeshore (Wilhelm 1990).

There are approximately one thousand acres of natural terrain left in the central ridge and swale area. The habitat has been fragmented into isolated pockets ranging in size from 170 acres to as little as five acres. The construction and expansion of the Gary airport over the past forty years divided the lakeside remnants near Clarke and Pine from those in west Gary, Hammond, and East Chicago. Industrial expansion, residential development, and landfills contributed to the overall loss of habitat. Despite fragmentation these remnants still support dense assemblages of native plants and animals.

The Wolf Lake and George Lake area has suffered the greatest loss of habitat. Of the five shallow lakes that occupied the northwest section of the strandplain, Berry Lake George Lake, and a portion of Wolf Lake were in Indiana. Berry Lake was filled and converted to industrial property in the early part of this century. The practice of draining and filling the lakes and marshes and converting them to industrial use reduced George Lake by over half its original size to its current surface area of roughly 200 acres. A large portion of the southern end of Wolf Lake was also filled. Only a handful of small fragments, less than ten acres apiece, remain of the marshes that surrounded these lakes.

Natural Heritage data

The following Natural Heritage information is summarized from *The Conservation of Biological Diversity in the Great Lakes Ecosystem: Issues and Opportunities* (Crispin and Rankin 1994). This document was prepared by The Nature Conservancy, using Natural Heritage data, in order to foster discussion on ways of identifying and protecting special biodiversity resources in the Great Lakes basin.

Natural Heritage Programs throughout the Great Lakes basin have inventoried and analyzed data to target protection of the natural resources of the basin's unique ecosystem. Heritage data focus on natural communities and native species, which are both referred to as "elements" of biological diversity. A community is an assemblage of species that re- occurs under similar habitat conditions and disturbance regimes. Native species and communities are those found naturally in an area, not those introduced purposefully or accidentally by people. The Heritage Program uses a two tier system to identify elements and plan protection strategies. First, all natural communities are identified. These communities are used as a "coarse filter", based on the assumption that they include most, but not all, of the diversity of life forms. The second tier forms the "fine filter," and is composed of species too rare to be accounted for within community types.

The conservation status of each element is evaluated and ranked at both global and state levels. There are five global ranks based primarily on the number of occurrences of an element They are: G1 - critically imperiled - an element occurs in less than five sites or is highly vulnerable to extinction; G2 - imperiled - an element occurs in six to 20 places or is vulnerable to extinction; G3 - rare - elements may be locally abundant but occur in 21 to 100 sites; G4 - apparently secure - an element appears not to be at risk; and G5 - demonstrably secure.

The following is a breakdown of G1 to G3 element occurrences throughout the Great Lakes basin. Twenty-two elements (species or communities) have been ranked as critically imperiled on a global scale. Seventeen of these occur entirely or predominately within the basin or have their best examples here. Thirty elements are ranked imperiled, of which thirteen occur exclusively or predominately within the basin, or have their best example there. Seventy-nine elements are ranked as rare, and 33 of these occur exclusively or are best represented within the basin.

Seven natural systems have been identified that support biodiversity in the Great Lakes basin. They are: open lake, coastal shore, coastal marsh, lakeplain, tributary and connecting channel, inland terrestrial upland, and inland wetland. Open lakes, coastal marsh, coastal shore and lakeplain are unique to the basin. Of these, coastal shore and lakeplain support a disproportionate amount of the basin's special biological diversity. Of the 61 Great Lakes dependent, globally significant elements (G1 or G2), 26 percent are supported by coastal shore, while 21 percent are supported by lakeplain systems.

The southern Lake Michigan region of the Great Lakes basin supports both lakeplain and coastal shore systems. The parabolic dunes that stretch along the shoreline from Gary, Indiana to southwestern Michigan are a type of coastal shore system. The exceptionally high levels of biological diversity in these dunes is underscored by the fact that the Indiana Dunes National Lakeshore has the third highest plant diversity of all national parks, despite having less than three percent of the total acreage of either of the top two (National Park Service 1987). The lakeplain system persists in a series of remnants of native landscape, scattered along the southern shore of Lake Michigan from the southeastern side of Chicago, Illinois to the western side of Gary, Indiana and extending southward to the southern edge of the lakeplain. This area is referred to as the Greater Calumet Wetlands Site.

Illinois and Indiana Natural Heritage Programs have identified 18 natural community types within the Greater Calumet Wetlands Site. There are also several severely degraded wetlands, located throughout the site, that serve as nesting and foraging habitat for regionally rare birds. Inventories include listings for more than 700 species of native plants, of which 85 are globally or state significant (rare, threatened, or endangered) and 200 species of birds, including 18 globally or state significant species that have been confirmed to nest within the site.

In the northeastern section of the site are a series of high quality remnants of the ridge and swale complex that once covered the entire Grand Calumet River watershed. Clark and Pine Nature Preserve, Gibson Woods Nature Preserve, Ivanhoe Dune and Swale Nature Preserve, and Tolleston Ridges Nature Preserve are examples of these islands of biodiversity set in the midst of the urban industrial landscape. These sites support a mosaic of interconnected natural communities that at times defy mapping. Seven of the community types are globally rare: panne, wet mesic sand prairie, mesic prairie, dry mesic sand prairie, dry mesic sand savanna, dry sand savanna, and sedge meadow. These communities harbor 66 state rare or endangered species (Shuey). Clark and Pine Nature Preserve's 47 acres support the highest concentration of rare and endangered species in the state of Indiana.

Four of the tracts within the Greater Calumet Wetlands Site are adjacent to the Grand Calumet River. DuPont Dune and Swale and Clark and Pine East both support high quality remnants of ridge and swale and have riparian wetlands with direct surface water connections to the river channel. The DuPont natural area contains four globally rare communities: wet-mesic sand prairie, dry sand savanna, dry-mesic sand prairie, and sedge meadow. Roxanna Marsh and the Calumet Tern Site are both degraded wetlands that are noted as foraging and nesting habitat for regionally rare birds including; great egret (*Casmerodius albus*), black tern (*Chlidonias niger*) and black-crowned night heron (*Nycticorax nycticorax*).

At the easternmost end of the River, there are three sites that have been inventoried by the Indiana Natural Heritage Program: Miller Beach and Dunes, the USX Site and sections of Marquette Park. All three sites harbor significant natural areas that are associated with the Grand Calumet River Lagoons. All are a part of or are adjacent to the larger Miller Woods unit of the Indiana Dunes National Lakeshore, an approximately 900-acre remnant of native lakeplain landscape. This area is the transition zone between the Tolleston strandplain and the high dunes to the east.

The natural course of the Grand Calumet River was altered to accommodate the building of the USX steel mill in Gary. The relocation of the River channel isolated the section of the River east of the USX facility, and as a result, the Grand Calumet Lagoons formed. Tolleston Beach fans out from a single dune ridge in the east to about 50 dune capped beach ridges south of the Lagoons. The ridges have a linear form that parallels the lakeshore and are capped by moderate size dunes making them higher than those found further west on the strandplain. Windblown sand has divided sections of the swales into separate ponds. High parabolic dunes occur lakeward of the lagoons (Brown 1997). Prior to urban development, Miller Woods graded into the Greater Calumet Wetlands Site. Now the two sites are physically separated by the city of Gary.

The area surrounding the Lagoons can be separated into two units: the area to the north of the Lagoons consists primarily of foredune and dune complex, and the area to the south is a savanna complex (Wilhelm 1990). Natural Heritage data for Miller Woods and for the Grand Calumet Lagoons area is sparse. The northern unit is known to support two globally rare communities: panne and foredune. There is no Natural Heritage data available on community classification in the savanna complex to the south of the Lagoons.

Floristic quality assessment

The integrity of a natural area is indicated by its ability to support native species. When natural processes are still intact, the native species dependent on them will continue to thrive. If, on the other hand, those processes are impaired or destroyed, then those dependent species will vanish. The flora of the Chicago region shows varying degrees of fidelity to specific habitat conditions and of tolerance for disturbance. The overall health of a natural area is reflected in its diversity of “conservative species.” These are species that are adapted to survive and thrive under a habitat-specific, niche-specific regime of biotic and abiotic conditions (Swink and Wilhelm 1994).

The practice of floristic quality assessment, as described by Swink and Wilhelm (1994) in *Plants of the Chicago Region*, assigns a coefficient of conservatism, or “C value,” to all native plant species in a region. Plants are ranked from 0 to 10, with 10 being the most conservative species. Two different floristic assessment systems use the C value ranking scale. The first system uses a “Native C value,” which is the mean C value of plants at a site, as its index of conservatism**.** The second system uses a “Floristic Quality Index,” which looks at the absolute number of species with high C values that are found at a site (Swink and Wilhelm 1994).

The following is a summary of Native C values and Floristic Quality Index ratings from *Plants of the Chicago Region*:

> Based upon 15 years of application of this assessment system to all types of land in the Chicago region, certain patterns have emerged. We have found that the mean C values in the preponderance of our open land range from 0 to 2. In light of the fact that 89% of our native flora has a C value of 4 or greater, and a mean C value of 7.3, it is evident that the principal elements of our native systems are uninvolved in the Chicago region landscape today.
>
> The vast majority of land in the region registers I values [Floristic Quality Index] of less than 20 and essentially has no significance from a natural area perspective. Areas with I values higher than 35 possess sufficient conservatism and richness to be of profound importance from a regional perspective. Areas registering in the 50's and higher are extremely rare and of paramount importance they represent less than 0.5% of the land area in the Chicago region. (Swink and Wilhelm 1994)

Floristic quality assessments were performed for all the large dune and swale remnants in the Greater Calumet Wetlands Site and included as one component of the *Illinois-Indiana regional Airport Site Selection Report* in 1991 (Mierzwa et al. 1991). The assessments were updated in 1994 (Table 1). The two units of the Miller Woods site were surveyed in August of 1978 and again in August of 1989 (Table 2) (Wilhelm 1990).

The Grand Calumet River corridor

The U.S. Army Corps of Engineers has identified several reaches of the Grand Calumet River that are associated with specific proposed dredging projects. The land adjacent to four of these reaches supports significant pockets of biodiversity. At the easternmost end of the river, Miller Woods and Dunes surround much of the Lagoons reach. Clark and Pine East flanks both sides of the River at the west end of the USX reach. DuPont Dune and Swale runs along the north bank of the western half of the DuPont reach. On the southern bank of the river across from DuPont, smaller natural areas support native upland and wetland communities, including the Calumet Tern Site. At the east end of the reach are two small remnants of dune and swale and a large degraded wetland complex on the USS Lead property north of the river. The Roxanna Marsh reach contains degraded wetlands that are important habitat for migratory waterfowl.

Table 1 Floristic Quality Assessments for Greater Calumet Wetlands Complex Ridge and Swale Sites

Greater Calumet Wetlands Complex Ridge and Swale Remnant Sites	Native Taxa	Floristic Quality Index	Native C Value

Brunswick Savanna	68	38.81	4.71
Clark & Pine Addition # 1	92	44.00	4.59
Clark & Pine Addition # 2	152	75.03	6.09
Clark & Pine Nature Preserve	277	128	7.7
Clark & Pine East	212	88.58	5.74
Clark Junction	245	101.96	6.51
Clark Junction East	187	76.93	5.63
Cline Ave. Dune & Swale	106	53.52	5.20
DuPont Dune & Swale	226	76.10	5.06
Gibson Woods Nature Preserve	297	103.00	6.0
Ivanhoe Dune & Swale	272	89.62	5.43
Lakeshore Prairie	151	72.02	5.86
Tolleston Ridges	261	101.00	6.1
Tolleston Woods	93	44.59	4.62

Table 2 Floristic Quality Assessments for Miller Section

Miller Woods and Dunes Sites	Native Taxa	Floristic Quality Index	Native C Value
Unit A Foredune and Dune Complex	210	97.00	6.70
Unit B Savanna Complex	179	78.00	5.81

Miller Woods and Dunes

The remnant natural areas in the Miller area cover roughly 1,000 acres and include the Miller Woods and Dunes unit of the Indiana Dunes National Lakeshore, the City of Gary's Marquette Park, and private property owned by USX Corporation and NIPSCO. The best available resource on community types and vegetation of the Miller area is *Special Vegetation of the Indiana Dunes National Lakeshore* by Gerould Wilhelm (1990). The 870 acres of the Miller area contained within the boundaries of the Indiana Dunes National Lakeshore were surveyed for this report. Although natural areas outside the park boundaries were not surveyed, the text can be taken as a general description of the entire Miller area. The following information is summarized from Wilhelm’s report.

The dune complex to the north of the Lagoons supports panne and foredune communities. The ridge and swale complex to the south of the Lagoons is dominated by a savanna and marsh complex. The Miller area provides habitat for at least 70 floristic elements considered rare or limited to a unique niche within the Indiana Dunes National Lakeshore.

Foredune communities occupy the windward exposure of the first line of dunes from the lake shore. Characteristic plants of the foredune include: *Ammophila breviligulata, Andropogon scorparius, Artemisia caudata, Calamovilfa longifolia, Cirsium pitcheri, Cornus stolonifera baileyi, Lathyrus japonicus glaber, Populus detoides, Rhus aromatica arenaria,* and *Solidago racemosa gillamani.*

In the Miller dunes area, panne communities inhabit a series of interdunal depressions that form on the lee sides of the first or second line of dunes. The depressions intersect the groundwater table forming calcareous wetlands and ponds. Pannes are unique in floristic composition, containing species that grow nowhere else in the Chicago region or in the State of Indiana. Plants of the panne community include: *Aster ptarmicoides, Carex garberi, Carex viridula, Gentiana crinata, Liparis loeselii, Lobelia kalmii, Rynochospora capillacea, Sabatia angularis, Scleria verticillata,* and *Utricularia cornuta*.

The ridges and swales south of the Lagoons support some of the highest quality black oak savanna in the Chicago region. The more open sand prairie areas support: *Andropogon scoparius, Arabis lyrata, Asclepias amplexicaulis, Carex mulenburgii, Koelaria cristata, Krigia biflora, Linaria canadensis, Opuntia humifusa, Polygonum tenue,* and *Viola pedata lineariloba*. The black oak savannas contain: *Aquilegia canadensis, Aralia nudicaulis, Aster linariifolius, Carex pensylvanica, Diervilla lonicera, Liatris aspera, Lupinus perennis occidentalis, Maiathemum canadense interius, Tephrosia virginiana,* and *Vaccinium angustifolium laevifolium.*

More than 430 species of native plants have been documented in the Miller Woods and Dunes section of the Indiana Dunes National Lakeshore. The area as a whole has a mean C value of 6.84 and a Floristic Quality Index rating of 142.

Clark and Pine East

The Clark and Pine East preserve is not uniform in habitat quality. The entire tract is 253 acres, within which are roughly 50 acres of remnant ridge and swale. The ridge and swale areas support the most complex plant communities in the preserve. There are approximately 100 acres of sand mined dune ridges that have revegetated with predominately native plant communities. The remaining acreage includes highly degraded swales, areas filled with fly-ash, and two large borrow pits from a sand mining operation.

The ridge and swale remnants support sand savanna and sand prairie on the upland ridges, and wet prairies, sedge meadows, emergent marsh, and shrub swamps in the swales. Generally, the crests of the ridges that are populated by black oaks also support *Andropogon scorparius, Carex pennsylvanica, Euphorbia corollata, Helianthus divaricatus, Krigia biflora, Lithospermum canescens,* and *Stipa spartea*. At mid-slope of the savanna-dominated ridges *Amelanchier arborea, Aquilegia canadensis, Pedicularis canadensis, Physocarpus opulifolius* and *Pteridium aquilinum latiusculum* are more common. *Betula papyrifera,* *Calamagrostis canadensis, Cornus racemosa, Cornus stolonifera, Iris virginica*, and *Osmunda regalis spectabilis* grow along the margins of the swales.

In areas with little or no canopy, common species along the crest of the ridge include *Andropogon scorparius, Arabis lyrata, Calamovilfa longifolia magna, Coreopsis lanceolota, Liatris aspera, Liatris cylindracea,* and *Lithospermum croceum*. At midslope *Andropogon gerardii* becomes the more dominant grass, and *Pedicularis canadensis, Senecio pauperculus,* and *Castilleja coccinea* are fairly common as well. *Calamagrostis canadensis* is the dominant grass of wet sand prairie areas. Other common plants *include Eupatorium perfoliatum, Liatris spicata, Oxypolis rigidor, Pycanthemum virginiana, Rosa palustris,* and *Solidago gramnifolia.*

The sand mining operation scraped away the dunes to the water table, creating habitat conditions similar to the natural pannes. Many panne associates are now found growing in these areas, including*: Aster ptarmicoides, Carex viridula, Gentiana crinata, Hypericum kalmianum, Liparis loeselii, Potentilla fruticosa, Rynchospora capillacea,* and *Sabatia angularis*.

The plant species list for Clark and Pine East contains 212 native species and 40 adventives, with a Floristic Quality Index of 78.23 and Native C Value of 5.03 with adventives. These numbers indicate that the site is of extreme importance as a relatively natural area in a region of highly degraded ecosystems.

DuPont Dune and Swale

There are approximately 170 acres of remnant dune and swale included in DuPont's corporate land holdings around its East Chicago plant. Four globally rare communities have been identified at the DuPont natural area: wet-mesic sand prairie, dry-mesic sand prairie, dry sand savanna and sedge meadow.

Approximately 50 acres of the DuPont area comprise a unique formation of dune and swale that has a natural surface water connection with the Grand Calumet River. Marshes along the river curve to the west and grade into linear swales. Near the river, the marshes are generally filled with cattails (*Typha ssp.*), common reed (*Phragmites australis*), and purple loosestrife (*Lythrum salicaria*). The swales support high quality wet prairie and sedge meadow communities. Species that are common throughout the swales include *Aster ptarmicoides, Calamagrostis canadensis, Carex stricta, Chelone glabra, Coreopsis tripteris, Eryngium yuccifolium, Eupatorium maculatum, Liatris spicata, Muhlenbergia glomerata, Pycanthemum virginianum, Scirpus pungens,* and *Scirpus validus creber*. Cattails, common reed, and purple loosestrife are well established in deeper parts of the swales.

The plant species list as of 1993 contains 226 native plant species and 35 adventives. It has a Floristic Quality Index rating of 70.8 and Native C value of 4.38 with adventives. The DuPont property survives as a rare and highly valuable remnant of the ridge and swale habitat-type. Floristic communities of this complexity are extremely rare within the Chicago region.

THE IMPACTS OF THE DREDGING PROCESS

The two major ecological risks of dredging are the possibility for ecologically harmful disposal of sediments and for sloughing of land adjacent to dredged areas. The primary objective in designing restoration measures to accompany dredging is to minimize these risks. Restoration measures of a slightly broader scope also merit consideration in the dredging-planning process. These would enhance the habitat value of high-priority natural areas adjacent to the Grand Calumet River and would serve as preventative measures against further degradation of these areas. Possible sites for various restoration activities are discussed in the section titled "Restoration," included below.

Sloughing of the banks could negatively impact natural areas by destroying existing high quality habitat or by opening degraded habitat to invasion by exotic species. The dunes that encompass the Grand Calumet Lagoons support unique biotic communities that could be negatively impacted by changes in the natural dynamics of dune development. The integrity of the dunes and ridges in this area should be protected during the dredging process. At Clark and Pine East, there is concern for the artificial bank that separates the river channel from the borrow pit at the southern end of the preserve. At DuPont, the high quality sections of the swales are currently separated from the river by a buffer zone of degraded marshes. Changes to these marshes could impact the quality of habitat throughout the swales.

When sediments are removed, their disposal should not impact natural areas or systems. High quality natural areas and key restoration sites should not be used for sediment disposal. Potential impacts to natural processes should also be studied if disposal sites are located near, though not within the borders of, natural areas. Impacts to be studied in this case include changes in run-off patterns and in ground water movement.

RESTORATION

A landscape by design

During the past one hundred years our industrial culture has dramatically restructured the landscape of the Calumet region to fit its needs. Dunes were leveled, wetlands drained and filled, and rivers channelized in order to make the area more suitable for urban development. The destruction of habitat disrupted ecological processes, thereby shattering the natural landscape. Today, only small fragments remain, and these are out of context in their current surroundings. Storm water that once recharged the groundwater table is now urban run-off, that is collected in sewer systems and piped away. Native species no longer range freely across the lakeplain to form and reshape communities. A small number of exotic species thrive in the wake of urban development and dominate the landscape.

In total, over ninety percent of the natural landscape of the Tolleston strandplain has now been destroyed. The remaining fragments are the last refuge for the biotic communities native to this area. Significant ecological interaction is restricted, for the most part, to these fragments. They hold the only biological reserves of native species sufficient to fuel any future reintroduction efforts, and they are also the last models available of the natural ecological systems of the region function.

Finding relevance for these natural areas in the current landscape is difficult. The natural systems that controlled the ecology of the lakeplain have been eclipsed by conditions created by human activity. The industrial landscape has created a new set of environmental conditions that will shape the future of these remnants as much as the natural systems shaped their past. Restoration of the River as a functional ecosystem presents this basic problem: remnants of the pre-industrial landscape offer the best opportunities for conservation and restoration of ecological health to the system, yet the natural processes that created and kept them dynamic have been changed forever. If we are to conserve our natural heritage for future generations we must account for the long term viability of these sites in our land use planning. Preservation and stewardship of these lands will require a conservation ethic that reaches beyond their immediate borders, making ecological restoration a process of integrating biological diversity into the broader landscape through planning and design.

Until recently, little attention was paid to conservation in land use planning in the Calumet Region. The first attempt to develop a Coastal Zone Management Plan in the mid 1970s produced a list of high quality natural areas in Lake County. These inventories combined with a growing awareness of the value of our biological heritage led to the purchase and dedication of a handful of these sites as Nature Preserves. Until then, these tracts were areas that had escaped urban industrial development by chance. The protection of Hoosier Prairie, Gibson Woods, Tolleston Ridges, Clark and Pine, and Ivanhoe Dune and Swale was the first successful effort at systematic conservation of natural resources in northern Lake County. By establishing these preserves, a means for maintaining biological diversity in the industrialized heart of the Calumet Region was developed.

Nature preserves are created to protect the highest quality examples of natural communities; their intrinsic value as a natural area controls their cultural land use. They are like gardens that operate independent of the surrounding landscape. At present, our best efforts at ecological management keep the natural systems functioning only within the borders of individual preserves. This conservation is severely restricted in its range.

Preservation of natural lands and systems will require a conservation ethic that reaches beyond the immediate borders of designated nature preserves. Such an ethic will challenge the assumption that there is a dichotomy between conservation and human demands on the land. Without ignoring or displacing the human inhabitants of the region, thoughtful land planners will find ways to expand the available habitat options for native species, and will thereby re-introduce natural ecosystem functioning to areas currently devoid of natural-area value. By creating buffers around existing natural areas, developing biological corridors, and replacing exotics with native species on properties not solely dedicated to conservation, we can begin to re-unify our human landscape with the natural ecological system. Such a wide-ranging effort will require that conservation and restoration activities be coordinated with activities that enhance the economic welfare and community development of the region. Plans will be implemented not by narrow constituencies, but through partnerships between government agencies, private landowners, and conservation organizations.

Conservation issues, remediation of environmental degradation, economic development, and community development will all help shape the changing landscape. Several broad-based initiatives in the Calumet Region are assessing current and future land use. The Remedial Action Plan, Corridor Planning, Brownfield Redevelopment, and Sustainable Development all offer opportunities for incorporating the unique conservation needs of the Grand Calumet ecosystem into broader land use planning.

Restoration goals for today's strandplain

The Grand Calumet River formed as a natural land feature during the long evolution of the Tolleston strandplain. The biotic communities created by the combination of natural succession, the interplay of tallgrass prairie, eastern deciduous forest, and boreal species, the hydrologic link between the groundwater table and Lake Michigan, and periodic fires are restricted to the relatively undisturbed tracts of native landscape. Despite fragmentation and environmental degradation, the River corridor and remnant ridge and swale sites share a common ecological heritage. No matter how disturbed the surrounding landscape, the remnant natural areas are elements of a larger system. Understanding how that system functions and its potential for improvement gives context to habitat restoration projects along the River corridor. The long-term viability of the remaining biological diversity depends on our ability to restore ecological processes and enhance the dynamic interaction of the native communities along the river and throughout the watershed. The ecosystem disruptions created by urban industrial development are artificial impairments to the natural ecological processes that shaped the native landscape.

The physical destruction of habitat has created a host of problems associated with fragmented communities. Changes in habitat conditions along the edges of fragments disrupt the biotic communities along these edges and allow for the influx of exotic species. Small habitat patches generally have higher rates of extinction, lower rates of recolonization, and lower levels of species diversity than large undisturbed tracts. Species that once interacted across the broader landscape are isolated within these small islands, and ecological interactions, such as succession, pollination, and predator-prey relationships, are thereby impaired. The ecological niches created by natural and human influences on the landscape are unfilled without the influx of new species. The establishment of buffer zones around natural areas and the restoration of connectivity between sites can help to compensate for some of the negative impacts of fragmentation.

Fire suppression has had a dramatic impact on the natural succession of communities in the region. Without fire, the savannas and prairies become choked with saplings and brush, shading out herbaceous species. Areas left unburned build up heavy fuel loads that, in the event of a wildfire, can be dangerous to people, property, and the natural system. Controlled burns re-introduce fire as a process to maintain the balance of woody and herbaceous species. Dividing natural areas into burn units, so that an entire tract is never completely burned in any single fire, helps insure recolonization of fire sensitive species.

The proliferation of exotic species is one of the greatest management concerns in the region. Species introduced by humans, that have no natural controls, need to be removed manually. Although they will never be completely eradicated, effective management programs can prevent their spread. Common reed and purple loosestrife are exotic species that are well-established throughout the entire River corridor, and this problem needs to be addressed at a system-wide level. Each purple loosestrife plant can produce as many as 250,000 seeds that are dispersed through flowing water. Common reed spreads by sending off long rhizomes and seeds. Both of these plants form large monocultures, choking out beneficial native species. The long-term viability of all wetland habitat is subject to our ability to control these plants throughout the entire River system. Control of non-native species will be an ongoing management issue. Programs to control exotic species need to be in place to insure the integrity of both natural areas and restored habitat.

Without proper management, the long-term viability of conservation and restoration efforts is questionable. In order to assure that management activities take place and run smoothly, potential land management agencies or organizations willing to contribute to any restoration efforts must be identified. This seeking-out of management organizations is a necessary part of the restoration-project planning process.

The level to which we can restore natural processes along the Grand Calumet River corridor will be determined in large part by how highly we prioritize restoration in future land use planning and remedial actions. The drainage pattern and flow of the River have been dramatically altered in the past 150 years. Ninety percent of the River's water now comes from industrial and municipal discharge. In this context, both quantity and quality of water in the River are determined more by government regulation than by natural processes. Natural wetland complexes currently occur only sporadically along the River, with artificial berms forming large sections of the bank. Along much of the riverbank, industrial and residential development pushes all the way to the water's edge. This situation dictates that habitat quality will not be consistent throughout the corridor.

Protection of core natural areas will maximize habitat potential in key stretches of the River and will preserve the biological reserves necessary for restoration throughout the entire River system. Establishing system-wide standards that support diversity, such as control of invasive exotic species and protection of local genotypes, will also lead to improvements in the ecology of the River.

The Grand Calumet Lagoons reach

Management of the surrounding natural areas is needed to maintain the biological diversity in this reach. Control of exotics and prescribed burning are priorities. Common reed and purple loosestrife are both present in the pannes and swales. Regular fires are needed to maintain the savanna complex to the south. The ecological integrity of the pannes depends upon the integrity of the surrounding dunes. Foot traffic and off-road vehicle abuse are causing erosion and are disrupting natural processes. Methods for controlling inappropriate recreational use of sensitive areas should be developed. Restoration and management activities should be coordinated through the offices of the Indiana Dunes National Lakeshore.

The USX reach

The western extreme of this reach runs through Clark and Pine East Nature Preserve. The eastern end includes parts of the Grand Calumet Lagoons and Miller Woods. The middle section runs through residential and industrial areas, and it currently has little value as a natural area.

USX section of the Grand Calumet Lagoons

The juxtaposition of the "moonscape" of the USX slag piles with the fragile beauty of the natural dune complex in this landscape is a striking reminder of the restoration challenges we face. Gerould Wilhelm (1990) aptly described the problem: “Half of the westernmost pond, still the richest and most stable Panne in existence, has been unceremoniously obliterated by a large slag pile which remains to this day, and should probably continue to remain in place lest the activity of removal obliterate the Panne altogether.” Ideally, restoration of this site would include removal of fill, repair of historic degradation, and creation of a buffer between the remaining natural area and the industrial site.

Clark and Pine East Nature Preserve

The preserve serves as a direct link between the River and some of the highest quality natural areas in the state. The cluster of sites around Clark and Pine are legendary among botanists in the Chicago region. Clark and Pine East is owned by the Indiana Department of Natural Resources (IDNR) and managed by the Division of Nature Preserves (DNP). Restoration projects in this area would have to be coordinated with IDNR management objectives for the site.

Restoration of this property is a high priority. Large sections of the preserve have suffered disturbances that have left the ground open for invasive exotic species. Along with common reed and purple loosestrife, European buckthorn is a problem at this preserve. Buckthorn forms dense stands that must be removed manually. Fire suppression has also caused large areas of the preserve to become overgrown. Department of Nature Preserves staff have conducted controlled burns at the site for the past two years. Volunteers have worked under the direction of DNP and Nature Conservancy staff to carry out restoration projects such as clean-ups and exotic species control.

The areas of the preserve adjacent to the River cover the full spectrum of habitat quality. The northern edge of the river is divided into two sections by the USX outfall. To the east of the outfall is an artificial berm, created in part by construction debris, that separates the preserve from the River. The bank is currently overrun with a number of exotic species, and it could potentially be damaged by sloughing during the dredging process. A potential restoration project would be bank reconstruction and stabilization with native species. To the west of the outfall, a cattail marsh borders the River and merges at its outer edge with a small section of ridge and swale. The topography of this area indicates that it is probably an ancient mouth of the Grand Calumet River, created when lake levels were much higher (see description under DuPont Dune and Swale). The marsh is not very diverse, but it does serve a useful ecological function as a buffer zone between the swale and the polluted River channel. It is currently being overrun with purple loosestrife and common reed, threatening an area of sedge meadow that grows in the adjacent swale. The upland ridge that parallels the swale has a closed canopy, which consists mostly of black oaks. The exotic species black locust (*Robinia pseudoacacia*) competes in this upland area with native tree species, and the understory grows thick with sassafras (*Sassafras albidum*) saplings. Despite the overgrown condition of the savanna, the herbaceous layer still supports plant species associated with a more open canopy, such as *Baptisia leucantha, Pedicularis canadensis,* and *Euphorbia corallata*. The swale supports primarily *Carex stricta* and *Calamagrostis canadensis*. Also present *are Eupatorium maculatum, Eupatorium perfoliatum, Scirpus validus,* and *Scutellaria epilobiifolia*. Restoration of the marsh and ridge and swale area would entail exotic removal and re-introduction of fire, with possible manual thinning of the canopy.

The Clark and Pine East Preserve is flanked by several smaller tracts of lesser, but still significant, value as natural areas. There are small wetlands flanking both sides of the preserve along the River. To the west is a small pond and cattail marsh (less than five acres), that is cut off from the preserve by two sets of railroad tracks. To the east, a small pond and a scrap of oak savanna on American Bridge property are separated from the preserve by a NIPSCO right-of-way. The habitat value of these two sites is greatly enhanced by their proximity to Clark and Pine East. Further to the east is a larger marshy area that is overgrown with cottonwoods. Historic aerial photographs indicate that this area was once open marsh. It is similar to parts of Clark and Pine East and DuPont that are adjacent to the river and appear to have been filled at some point, perhaps with sediments from earlier dredging projects. Both the marshy area adjacent to Clark and Pine East and the similar areas within the Clark and Pine East and DuPont tracts have apparent potential for restoration to higher quality habitat. More information should be gathered on these areas, so that the need for restoration there can be adequately assessed.

Gary Sanitary District reach

No high quality natural areas directly contact this stretch of the River. Ivanhoe Dune and Swale Nature Preserve is approximately 500 feet south of the River, but they are separated from it by the Indiana Toll Road and the South Shore rail line. Most of the native landscape has been destroyed on the Gary Airport property, which extends along most of the north edge of this reach. The marshes that run along this stretch of the River channel support a large population of purple loosestrife and common reed, which poses a threat to sites downstream, such as DuPont. Restoration efforts in this section of the River should focus foremost on controlling populations of non-native species.

DuPont reach

From a habitat standpoint, the DuPont property anchors this stretch of the River. The DuPont natural area is the largest unprotected remnant of dune and swale in the region. Preservation of this site is fundamental to the ecological restoration of the River. It supports the most biologically diverse wetlands with surface water connections to the River channel. Its 170 acres of remnant dune and swale comprise a large core reserve of native species and enhance the potential habitat value of nearby, smaller, more degraded natural areas. Formal protection and management of this site will be crucial to any habitat restoration effort in the DuPont reach of the River.

Outside the boundaries of the DuPont property, but within the DuPont reach, are Siedner Dune and Swale Nature Preserve, the Beamsterboer property, the Harbison Walker property and the USS Lead Refinery. All of these are sites with potential for restoration projects.

The stretch that extends through the East Chicago Sanitary District, Roxanna Marsh, and DuPont reaches of the River holds the largest local complex of riparian wetlands. They are divided only by Kennedy Ave., which crosses the DuPont reach, and Indianapolis Blvd., which crosses between the East Chicago Sanitary District reach and the Roxanna Marsh reach. Most of these are cattail marshes that have become infested with common reed and purple loosestrife. Included in this complex are Roxanna Marsh and the Calumet Tern Site, both noted as important habitat for nesting and migratory birds. These marshes could potentially support a variety of habitat conditions, covering the range from open pond to wet prairie.

Particular characteristics of various sites within the DuPont reach are analyzed site-by-site below. Decisions about restoration of marshes associated with any one of these sites should be prioritized based on the needs of the complex as a whole. Exotic species will have to be brought under control before any additional habitat improvements begin in this area.

DuPont Property

Fire suppression and encroachment of exotic species pose the greatest threats to the habitat integrity of the DuPont natural area. Wildfires have swept through the DuPont tract periodically, most recently in April of 1996. Although periodic fires play a crucial role in the maintenance of dune and swale community-types, those that rage out of control pose a threat to people, property, and the natural systems. To ensure the survival of certain species, it is necessary to divide natural areas in small units that are burned in different years, rather than all at once. Development and implementation of a controlled burn plan will restore fire as an ecological process at DuPont. Common reed and purple loosestrife are present throughout the swales at the DuPont tract. Control of these two species should begin immediately. Any delay will increase the risk of losing native wetland communities and their replacement by monocultures of exotic species.

Approximately twenty-five acres along the River's edge are covered by a stand of cottonwood trees. The ground cover consists primarily of weedy native species. Historic aerial photographs indicate that this area was once marsh and open pond. Enhancing the habitat value of this site or recreating historic conditions are potential restoration projects for this area. The community and soil types occurring at this site will need to be researched further before appropriate decisions can be made concerning restoration here. This research should include a study of the types of fill materials, if any, that have been deposited here during past dredging projects.

The western edge of the DuPont natural area is bordered by a large open field that was formerly an industrial facility. It has since grown over with a mixture of native and non-native grasses. Restoration could be coordinated with potential redevelopment of this brownfield site. Creating a buffer on this degraded land for the adjacent natural area would protect and expand habitat for native species. Restoration activities would include: removal of old roads, parking areas, and building foundations, re-introduction of native plant species, and control of exotics. Currently there are large stands of *Andropogon scorparius*, and smaller patches of *Panicum virgatum*, *Calamovilfa longifolia, Andropogon gerardii*, and *Sorghastrum nutans* scattered throughout the field. Planting a mixture of these grasses and associated species such as *Asclepias tuberosa, Coreopsis lanceolata, Euphorbia corallata, Heianthus helianthoides*, *Liatris aspera*, and *Lupinus perennis* would begin the process of re-establishing productive habitat to this part of the site.

The developed areas of the DuPont property are built above the level of the River. The riverbank here is steep. At its base, a series of degraded marshes are found growing along the edge of the River channel. The steep banks are currently subject to high rates of erosion, which could likely be decreased by the planting of native species along these banks. Improvements could also be made to the plant communities of the marshes, which are currently dominated by cattails, common reed, and purple loosestrife.

Siedner Dune and Swale Nature Preserve, Beamsterboer, and Harbison Walker Property

To the south and across the river from the DuPont Property is a narrow strip of remnant dune and swale that covers approximately 80 acres. It is bounded by the River to the north, Cline Ave to the east, Kennedy Ave. to the west, and by a rail line and the Indiana Toll Road to the south. The habitat is degraded from off-road vehicle use, illegal dumping, fire suppression, and the spread of exotic species. The conservation value of this area is greatly enhanced by its proximity to the DuPont Property. Management activities in the area should include actions to keep off-road vehicles out of the area, re-introduction of fire (possibly accompanied by mechanical thinning of trees to open the canopy), and aggressive control of purple loosestrife and common reed. The Siedner Dune and Swale Nature Preserve was recently established by the Shirley Hienze Environmental Fund, so work in around that site should be coordinated through their organization.

U.S.S. Lead Refinery

To the west of DuPont, across Kennedy Avenue, is the former U.S.S. Lead Refinery. Contained within the site are a large cattail marsh that runs along the edge of the River, and two small remnants of dune and swale. A large slag field extends into the wetlands along the River. The U.S.S. Lead property is currently under an enforcement action by USEPA An interim clean-up plan for contaminated materials is being implemented at the site. The plan includes an on-site containment unit for the contaminated materials. Any restoration plans will have to be coordinated through the final clean-up plan.

The marsh is large enough that mechanical control of the water level or regrading of specific areas could expand the number of available habitat niches. It is part of the larger wetland complex mentioned above and should be managed and restored accordingly.

The dune and swale remnants in this tract cover fewer than twenty acres in total, and they are in a late stage of succession, due to the absence of fire. Few inventories are available for this site; however, most savannas that are as overgrown as these support only depauperate herbaceous communities. Restoration projects for this area could include controlled burning, mechanical thinning of the trees to re-open the canopy, and re-introduction of native species to enhance the herbaceous communities.

East Chicago Sanitary District reach

City of East Chicago property

The old East Chicago municipal dump is a capped landfill that sits on the south side of the River at the confluence of the Grand Calumet and the Indiana Harbor Ship Canal. It is overgrown with mostly non-native weeds. The root systems of most native prairie plants grow considerably deeper than those of non-native species, which limits their use as cover on landfills. Any restoration project would have to take into account the integrity of the cap. The landfill grades into a large cattail marsh to the north and to the east. The River channel separates this marsh from the U.S.S. Lead property; together they support nearly 50 acres of wetlands.

Northern Indiana Public Service Company property

The Northern Indiana Public Service Company's Roxanna sub-station is surrounded by approximately 20 acres of open land. Although much of the natural topography has been altered, the area supports a predominantly native plant community. Restoration projects for this area should be designed to enhance the biological diversity already present. Management activities should include controlled burning, removal of exotics, and re-introduction of appropriate native species.

SUMMARY

The southern Lake Michigan lakeplain has been identified as an area that supports elements of biological diversity unique to the Great Lakes basin. The biodiversity persists as remnants of the natural communities that evolved as a result of the ecological processes that shaped the native lakeplain landscape. As the waters of ancestral Lake Michigan receded, they left the lands of the lake’s edge open for colonization by terrestrial flora and fauna. The interface of successive waves of boreal, deciduous forest, and prairie flora created a mosaic of natural communities across the lakeplain.

The Grand Calumet River and the ridge and swale topography of the Tolleston strandplain formed together during the past 4,500 years. The newly formed landscape is home to a rich assemblage of natural communities. The character of any particular localized community is determined in large part by the community’s stage in the course of natural succession, by the diversity of species present on the lakeplain, and by the moisture conditions of the site where the community is found. Human activities have also played an important role in shaping the ridge and swale landscape. Before the advent of industrial society, Native Americans living in the region used fire to drive prey from the prairies into forested areas (Bacone 1979). The natural communities evolved during this time with fire creating and maintaining a balance between prairie and fire-tolerant deciduous species.

During the past century, industrial and residential development have severely impacted the natural processes of the lakeplain. Most of the Tolleston strandplain has been altered by industrialization, leaving behind only small fragments of the native landscape. Natural processes have been severely impaired throughout the region, and significant ecological interactions are now almost entirely restricted to the small patches of native habitat that remain . The remnant tracts continue to support surprisingly high levels of biological diversity, but they are increasingly threatened by fragmentation, invasion of exotic species, and fire suppression. The long-term viability of these sites will depend on our ability to restore and maintain the ecological processes necessary for their survival.

Given the urban character of the landscape, habitat quality cannot realistically be made consistent throughout the River corridor. Sites that support high-quality habitat are priorities for protection and management. They hold the biological reserves that are needed as raw material for re-introductions of native species, and they serve as models for restoration. Setting aside land for conservation purposes helps to prevent further physical destruction of natural areas; however, lands must be actively managed for the ecological processes upon which natural communities depend to be maintained.

Sound management for healthy ecological systems in the region will require a whole-landscape approach to planning. Nature preserves do not exist in a vacuum, and adequate management plans must therefore take into account the areas beyond the nature preserves' borders. Wisely negotiated plans can integrate efforts to restore natural processes essential to the long-term viability of these site with compatible human uses of the land. Buffers can be created around existing natural areas. Biological corridors can be developed, and exotics can be replaced with native species on land that is not solely dedicated to conservation. Biological diversity can be integrated into the broader landscape through the application of a conservation ethic to the land-use-planning process.

Removal of historic contamination will be the first step in the process of restoring ecological health to the River. The removal of sediments from the riverbed will likely cause sloughing of soil from the riverbanks. This process could destroy existing habitat and open the ground for invasive exotic species. High-quality natural areas and key restoration sites should not be used as disposal sites. Care should be taken to protect the integrity of natural areas and of potential restoration sites during the dredging process.

Habitat restoration projects that accompany the dredging process should address the need for preservation of existing habitat by removing impairments to key ecological processes, and should include plans for ongoing-management activities. There are three core areas along that River that support significant native communities. The Grand Calumet Lagoons are surrounded by both dune and ridge and swale systems that support globally rare natural communities. Clark and Pine East connects the river with a cluster of natural areas that are both important regionally, and are rated as significant Natural Heritage sites for the Great Lakes basin as a whole. The DuPont natural area supports the most biologically diverse wetlands with a surface water connection to the river. By preserving core natural areas and creating system-wide standards that support biological diversity, restoration efforts along the river will complement regional conservation efforts.

In the end, the greatest threat of all to Grand Calumet River ecosystem is indiscriminate human impacts on the ecological processes that sustain it. Improving the ecological health of river will require a conservation ethic that recognizes the need to protect and restore ecosystem integrity throughout the Calumet region.

LITERATURE CITED

Bacone, J.A. October 1979. Shell Oil Dune and Swale: A report on a natural area. Division of Nature Preserves, Indiana Department of Natural Resources, State of Indiana.

Brown, S.E. 1997. Geologic history of the Little Calumet and Grand Calumet Rivers. Indiana Geologic Survey, Indiana University

Crispin, S. and D. Rankin. January 1994. The conservation of biological diversity in the Great Lakes ecosystem: issues and opportunities. The Nature Conservancy Great Lakes Program, Chicago, Illinois, USA.

Moore, P. A. 1959. The Calumet Region: Indiana's last frontier. Indiana Historic Bureau, Indianapolis, Indiana, USA.

National Park Service. 1987. NPFLORA/COMMON: Coverage by Acreage of National Park Service Units, Unpublished NPS document.

Pepoon, H. S. 1927. An annotated flora of the Chicago area. Chicago Academy of Science, Chicago, Illinois, USA.

Swink, F. and G. Wilhelm. 1994. Plants of the Chicago region. Indiana Academy of Science. The Morton Arboretum. Lisle, Illinois, USA.

Mierzwa, K.S., S. Culberson, K.S. King, and C. Ross. 1991. Illinois-Indiana regional airport study: Biotic communities. Technical Paper No. 7, Appendix E, Volume II. TAMS Consultants, Inc. Chicago, Illinois, USA.

Wilhelm, G.S. 1990. Special vegetation of the Indiana Dunes National Lakeshore. The Morton Arboretum. Lisle, Illinois, USA.

PLANTS

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INTRODUCTION

With its 14,000-year geologic history, northwestern Indiana natural areas support unusually diverse biological communities (Reshkin 1990). The diverse flora on the dune-and-swale complex in the southern shore of Lake Michigan, especially, has attracted world-wide attention as Cowles (1899) published his bench-mark study on the plant successions in this area. Grand Calumet River, along with Little Calumet River, was once called as “River Styx” by early settlers (Bacone et al. 1980). With European settlement, the geomorphology of this river system has been altered significantly by human activities. The rivers have become straighter and narrower as a result of channelization. Also, drainage and filling, along with industrial pollution of marshes and ponds adjacent to the river, altered local hydrology, and this resulted in drastic changes in species composition of riparian plant communities. This chapter will discuss (1) pre-settlement and present-day wetland plant communities, and (2) potential impacts of the proposed dredging project on wetland vegetation in the Grand calumet River basin. Recommendations will also be made for restoration activities that might be performed in conjunction with sediment clean-up, in order to restore and conserve wetland plant communities in the area of dredging reaches.

NATIVE FLORA OF PRE-SETTLEMENT TIMES

Extirpated species

Peattie (1930), in his publication *Flora of the Indiana Dunes*, estimated that 1,400 plant species occurred in the Indiana Dunes area. Nineteen of these species have not been seen in Indiana since Peattie's sightings, and they have now been classified as extirpated species (species that had not been seen in Indiana for 50 years) by Aldrich et al. (1986). A list of the extirpated species is given below:

Scientific name	Common name
Betula populifolia	gray birch
Carex scabrata	
Corallorrhiza trifida	coral root
Gerardia pedicularia ambigens	clammy flase foxglove
Hemicarpa drummondii	
Hippuris vulgaris	Mare's tail
Lechea stricta	bush pinweed
Lemna perpusilla	least duckweed
Linnaea borealis	twin flower
Lonicera canadensis	American fly honeysuckle
Oryzopsis pungens	short-horned rice grass
Panicum lucidum	bog panic grass
Psilocarya nitens	bald rush
Pyrola secunda	one-sided shinleaf
Scleria reticularis	netted nut rush
Shepherdia canadensis	Russet buffaloberry
Trillium cernuum macranthum	nodding trillium
Utricularia resupinata	small purple bladderwort

Historic plant community types

Bacone et al. (1980) reconstructed the pre-settlement vegetation characteristics of northwestern Indiana by analyzing land survey records that were compiled between 1829 and 1834. Of the community types recognized by this study, aquatic communities, marshes, swamps, bottomland forests, beach communities, and pannes are considered as wetland community types. Summary descriptions of these community types are given below.

Aquatic communities consist of macrophytes and phytoplankton in standing or running water. The 1829-1834 survey record noted *Polygonum* spp., *Nuphar advena*, and *Nymphaea tuberosa* as typical macrophytes (Bacone et al. 1980). Although there is no documented list of phytoplankton in the pre-settlement times, the phytoplankton communities were likely dominated by such genera in the Division Chlorophyta as *Chlamydomonas, Oedogonium, Spirogyra*, and *Volvox*. Since European settlement, species composition of this community has been changed significantly by numerous human activities such as loading of nutrients, silts and other pollutants, alteration of local hydrology through channelization, drainage and filling of the river and its adjacent wetlands. Current species composition of aquatic community will be discussed later.

Marshes are probably the most prominent plant community type along the Grand Calumet River. Marshes are open (non-forested) wetlands that are dominated by sedges and/or grasses. On the wet end of the moisture gradient, sedge meadow is found directly adjacent to aquatic communities. At the other extreme, wet prairie overlaps with the borders of mesophytic prairies and savanna complex. As is indicated by its name, sedge meadow is characterized by abundant sedges (Cyperaceae); wet prairies are dominated by grasses (Poaceae). Typical plant species in this community type include *Aster puniceus firmus, Bidens coronata tenuiloba, Carex aquatilis altior, Decodon verticillatus, Polygonum punctatum,* and *Scirpus acutus*. Historically, periodic fires, both natural and man-made, have been a crucial factor in maintaining marshes because fires prohibit the invasion of woody shrubs and trees. Since European settlement, however, most marshes have been heavily disturbed by drainage, by invasion of woody species facilitated by artificial fire suppression, and by intentional or accidental introduction of alien species. Shrub carr is a marginal type of marsh community, found along the borders of swamp and marsh. Typical woody species include *Alnus* spp. and *Salix* spp. According to the 1829-1834 survey record, woody species (e.g., *Populus tremuloides* and *Populus grandidentata*) were less abundant in presettlement than the present times. However, significant alterations in the level of the water table, and a long-lasting policy of fire suppression have resulted in significant invasion of overgrown shrubs into marshes, sedge meadows, and wet prairies.

Swamps are forested wetlands where the water level is maintained near or at the surface of the substrate by ground water or by rain. In the land survey records, the swamps in northwestern Indiana were classified into three major types. Coniferous swamps occurred only in dune-swale systems, and were dominated by *Pinus banksiana* and *Thuja occidentalis*. Timbered swamps, now classified as green ash (*Fraxinus pennsylvanica subintegerrima*) swamps, are inhabited by *Populus deltoides*, *Platanus occidentalis*, *Fraxinus nigra*, *Acer saccharinum*, and *Ulmus* spp. This type of swamp occurred along the Kankakee River. However, extensive draining and logging have destroyed much of this community in this century. Shrub swamps overlap with shrub carrs at the edges of marshes and of timbered swamps. The species compositions of these two community types are, as would be expected, quite similar. Shared species include *Alnus rugosa americana* and *Salix* spp. This type of swamp, like the shrub carrs, has become more common than during pre-settlement times as a result of long-term drainage and fire suppression.

Bottomland forests consist of several woody strata underlain by herbaceous cover, and they are located along the banks of water courses. They are characterized by annual deposition of silt during flooding. Major canopy species in these forests include *Acer negundo, Acer saccharinum, Platanus occidentalis, Salix nigra, Ulmus americana,* and *Ulmus rubra*. Small scattered patches of bottomland forest still occur today, although most of these have been heavily disturbed.

Beach communities are narrow specialized strips adjacent to the littoral zone of the lake shore, and they are dominated by *Ammophila breviligulata*. Pannes are moist interdunal depressions in calcareous sands on the lee-side of a dunes, containing such species as *Aster ptarmicoides* and *Carex* spp.

EXISTING WETLAND PLANT COMMUNITIES

Recent vegetation survey and classification

Bowles et al. (1990) listed ten natural communities within the boundary of Indiana Dunes National Lakeshore (INDU). Six of these communities are considered wetland communities (Table 1). These communities include beach, forested fens, graminoid fens, forested bogs, flatwoods, and graminoid wetlands. Wilhelm (1990) also described 11 community types along the gradients of moisture and arborescent development. Among these communities, swamp complex, bog, marsh complex bottomland, and beach are considered as wetland communities (Figure 1). Wilhelm's (1990) list of vascular plants in the Miller Woods area, along with the species list compiled by Peloquin and O'Brien (1990), provides invaluable information on the floristic compositions of wetlands adjacent to the Grand Calumet River.

Natural communities in Lake, LaPorte, and Porter Counties, excluding those found at INDU, were surveyed by Kurz et al. (1978). In this inventory, a total of 258 potential natural areas (PNA) were identified. These PNAs were then placed into three categories. Natural areas are of statewide significance whereas notable areas are those which do not meet the criteria established for natural areas, but do have considerable importance for education, research, and recreation. The third category, eliminated areas, consists of areas that still retain some traces of natural characters, but which have been so severely disturbed that it is highly unlikely that they will recover the functions or structure of undisturbed natural areas. These authors also listed a total of 49 natural community types, including 26 aquatic and wetland types, that they had observed in the northwestern Indiana (Table 2). In Lake County, a total of 38 wetlands were identified, and seven of them were found adjacent to the Grand Calumet River. These wetlands were located in the DuPont tract, in the Ivanhoe Nature Preserve, and in the Clark and Pine Nature Preserve (Figure 2). Of the seven wetlands, three were placed in the natural area category, one was in the notable category, and three were in the eliminated category. In addition, an environmental assessment report that was submitted by the TAMS Consultants, Inc. (Mierzwa et al. 1991) for the Illinois-Indiana regional airport project, updated the lists of plant species for the DuPont tract, and for the Clark and Pine nature preserve.

Summary of the recent vegetation classification systems

Concurrent use of different classification systems for the same natural areas (e.g., Kurz et al. 1978, Bowles 1990, Wilhelm 1990) often causes a great deal of confusion because (1) different terms are used to refer to the same community type, (2) similar terms are used for different communities, and/or (3) the borders between community categories are delineated differently. To reduce such confusion, under the classification scheme of Indiana Department of Natural Resources (IDNR), a standardized classification system is proposed in

Table 3. In this table, for example, Wilhelm's (1990) "marsh complex" is separated into marsh, fen, and sedge meadow. The "wet prairie" is a part of "marsh complex" in the Wilhelm's classification, but the proposed classification places it in the category of "prairie." In addition, "hydromesophytic forest" is a part of Wilhelm's "swamp complex," but it is placed the categories of "forest" and "shrub swamp" in the proposed classification system.

Table 1. Eleven natural plant communities listed by Bowles et al. (1990) in Indiana Dunes National Lakeshore. Wetland types are signified by *italics*.

COMMUNITY	CHARACTERISTICS
Beach/Foredune	Wave actions and sandy substrate Annuals and rhizomatous perennial plants
Dune Complex	Cycle of sand erosion in steep topography & blow-outs
Sand Savanna	Dominant presettlement plant community type on irregular dune topography Open dune conditions with frequent fires
Sand Prairie	Flat topography with frequent burns
Upland Forest	Protected from intense fires (e.g., dune hollow and ravine slopes) Occasional ground fires
Forested Fen	Calcareous peat soils Relict boreal community Structure affected by fire and water table
Graminoid Fen	Calcareous peat soils Boreal and prairie affinities Open conditions with frequent fires and high water table
Forested Bog	Acid peat soils Relict boreal community

	High species diversity in openings and pools
Flatwoods	Wet mineral soils or seepages with high species diversity
Graminoid Wetlands	Complex of fen and marsh in interdunal areas High water tables and frequent fires

Figure 1. Eleven plant communities of Indiana Dunes National Lakeshore, depicted by Wilhelm (1990).

Table 2. Forty-nine plant community types of Indiana coastal zone listed by Kurz et al. (1978). Wetland types are signified by *italics*

CATEGORY	COMMUNITY TYPE
Forest	Dry-mesic upland forest Mesic upland forest Wet-mesic upland forest Dry dune forest Dry-mesic dune forest Mesic floodplain forest *Wet-mesic floodplain forest* *Wet floodplain forest* *Flatwoods*
Prairie	Dry-mesic prairie Mesic prairie *Wet-mesic prairie* *Wet prairie* Dry sand prairie Dry-mesic sand prairie Mesic sand prairie *Wet-mesic sand prairie* *Wet sand prairie* Glacial drift hill prairie Gravel hill prairie Sand hill (dune) prairie Shrub prairie
Savanna	Dry-mesic savanna Mesic savanna Dry sand savanna Dry-mesic sand savanna Mesic sand savanna
Aquatic	*Perennial stream* *Lake* *Pond* *Marsh* *Shrub swamp* *Graminoid bog* *Low shrub bog* *Tall shrub bog* *Forested bog* *Calcareous floating map*

Aquatic (continued)	*Graminoid fen* *Low shrub fen* *Tall shrub fen* *Forested fen* *Sedge meadow* *Panne* *Seep* *Calcareous seep* *Sand seep* *Spring*
Primary	*Beach* Foredune/Blowout

Figure 2. Areas of special conservation needs (Roxanna Marsh, DuPont Tract, Clark and Pine East Nature Preserve-Bongi Ponds, and Grand Calumet River Lagoon in Miller Woods), and fifteen proposed sediment disposal sites.

Special conservation needs

Among the riparian wetlands of the Grand Calumet River, Roxanna marsh, DuPont tract, Clark and Pine East nature preserve (also known as Bongi Pond), and Grand Calumet Lagoons are especially in need of conservation because they are considered as high quality habitats for endangered, threatened and/or rare animals and plants. After a compilation of the existing plant species records (Wilhelm 1990, Mierzwa et al. 1991, IDNR unpublished), a total of 665 plant species were found in DuPont tract, Clark and Pine East, and Miller Woods. Of these 665 species, 16 species were classified as endangered species (inhabit between 1 and 5 extant sites). Another 16 were classified as threatened species (inhabit between 6 and 10 sites), and 21 were classified as rare species (inhabit between 11 and 20 sites) (Aldrich et al. 1986). Key aspects of the areas with high conservation value are discussed below. The possibility of conserving and/or restoring populations of endangered, threatened, and rare species is also discussed individually for each area.

No published data are available on aquatic communities in the open channel of the Grand Calumet River. Discussions in this section are therefore based upon the author's field observations and best educated speculation. Since the Grand Calumet River has been polluted severely, the diversity and productivity of aquatic plants are likely very low. Numerous species of blue green algae (e.g., *Anabaena* spp., *Cylindrospermum* spp., *Gleocapsa* spp., *Mycrocystis* spp., *Nodularia* spp., *Nostoc* spp., *Oscillatoria* spp., and *Spirulina* spp.) are common "weeds" of polluted water (Cole 1979). Thus, these species are very likely the dominating elements of primary production in the Grand Calumet River. Blue-green algae are extremely tolerant of inorganic and/or organic nutrient pollutant loads. When nutrient-pollutant concentration is high, excessive growth of these algae results in unpleasant "algal blooms." Bulky masses of algae accumulate on the shores where they are unsightly and often dangerous. Often their respiratory demands surpass their daylight oxygen production thereby depleting dissolved oxygen supplies in the bodies of water where they live. In addition, certain species produce dangerous toxins that can cause massive deaths of fish and wildlife (Cole 1979). Therefore, the control of blue-green algae should be a top priority for the restoration of native aquatic plant communities. Wilhelm (1990) provided a list of species typically found in relatively undisturbed aquatic ecosystems in INDU. This list, which is included below, is recommended as a restoration model.

Table 3. Synthesized wetland plant community types under the classification scheme of the Indiana Department of Natural Resources.

Communities by Kurz et al. (1978)	*Communities by Bowles et al. (1990) and Wilhelm (1990)*
Wet-mesic floodplain forest Wet floodplain forest	Bottomland forest* Hydromesophytic forest in the Swamp Complex*
Flatwoods	Flatwoods in the Swamp Complex* Flatwoods**
Wet-mesic prairie Wet prairie Wet-mesic Sand prairie Wet sand prairie	Mesophytic prairie* Wet prairie of in the Marsh Complex* Graminoid wetlands**
Perennial stream Lake Pond	Aquatic*
Marsh	Marsh in the Marsh Complex* Graminoid wetlands**
Shrub swamp	Hydromesophytic forest and conifer swamp in the Swamp Complex*
Graminoid bog Low shrub bog Tall shrub bog Forested bog Calcareous floating mat	Bog* Forested bog** Graminoid wetlands**
Graminoid fen Low shrub fen Tall shrub fen Forested fen	Fen in the Marsh Complex* Forested fen** Graminoid fen**
Sedge meadow	Sedge meadow in the Marsh Complex* Graminoid wetlands**
Panne	Panne*
Seep Calcareous seep Sand seep Spring	Flatwoods**

*: Wetland communities classified by Wilhelm (1990).
**: Wetland Communities classified by Bowles et al. (1990).

<u>Scientific Name</u>	<u>Common Name</u>
Brasenia schreberi	water shield
Ceratophyllum demersum	coontail
Nuphar advena	yellow pond lily
Nymphea tuberosa	white water lily
Polygonum coccineum	water heartsease
Pontederia cordata	pickerel weed
Potamogeton gramineus	grass-leaved pondweed
Potamogeton illinoensis	Illinois pondweed
Potamogeton pusillus	small pondweed
Sagittaria latifolia	common arrowhead

Roxanna marsh is a severely degraded riparian wetland that is located where the Grand Calumet River intersects Route 41 in Hammond (Figure 2). There has been no systematic survey for plant species or community types in this area. According to the author's visual inspection, the entire area was infested by undesirable species (alien, invasive, or both) such as *Lythrum salicaria*, *Phragmites communis*, *Typha angustifolia*, and *T. latifolia*. Several woody species (e.g., *Acer negundo*, *Populus deltoides*, and *Salix* spp.) have also invaded the wetland from adjacent river banks or woodlands. All of these species have very little or no value as elements of natural communities (Swink and Wilhelm 1979), and thus restoration of native vegetation is urgent in this area. As models of restoration, marsh, sedge meadow, and wet prairie are suggested because these were probably the most common wetland community types in the region's pre-settlement landscape, and their abundances have since been decreased significantly. Suggested species to be restored in marsh, sedge meadow, and wet prairie are as follows (Wilhelm 1990):

<u>Model</u>	<u>Scientific name</u>	<u>Common name</u>	
Marsh	*Aster puniceus firmus*	marsh aster	
	Carex comosa	bristle sedge	
	Carex haydenii	long-scaled meadow sedge	
	Carex lacustris		*Carex lanu*
	Carex lasiocarpa americana	narrow-leaved woolly sedge	
	Carex sartwellii		*Carex stric*
loosestrife	*Lysimachia thyrsiflora*	tufted	
loosestrife	*Polygonum hydropiperoides*	mild water	
pepper	*Potentilla palustris*	marsh	
cinquefoil	*Proserpinaca palustris crebra*	mermaid weed	
bulrush	*Scutellaria epilobiifolia*	marsh	
skullcap	*Sium suave*	water parsnip	
Sedge	*Aster junciformis*	rush aster	

meadow *Bidens comosa* swamp tickseed *Dryopteris*
madder *Hypericum virginicum fraseri* marsh St.
John's
wort
Lycopus uniflorus northern bugle weed *Mentha arv*
leaved
tear-thumb

Wet	*Aletris farinosa*	colic root
prarie	*Cladium mariscoides*	twig rush
	Eleocharis melanocarpa	black-fruited spike rush
	Gentiana crinita	fringed gentian
	Juncus canadensis	Canadian rush
	Ludwigia alternifolia	seedbox
	Oxypolis rigidior	cowbane
	Rubus hispidus obovalis	swamp dewberry
	Sisyrinchium atlanticum	eastern blue-eyed grass
	Spiranthes cernua	nodding lady's tresses

Upon the restoration of any of the above wetlands, periodic fires would be necessary to discourage the invasion of shrubs and trees (Henderson and Long 1984). Wet flood plain forest is very commonly found in the riparian community in the flood-plains of streams and rivers, so it may serve as the model of restoration for Roxanna Marsh. Typical floristic elements of wet flood plain forest are as follows (Wilhelm 1990):

Scientific name	Common name
Acer saccharinum	silver maple
Cardamaine bulbosa	smooth spring cress
Carex amphibola turgida	gray sedge
Carya laciniosa	big shellbark hickory
Chaerophyllum procumbens	wild chevil
Floerkea proserpinacoides	false mermaid
Fraxinus pennsylvanica	green ash
Populus deltoides	cottonwood
Salix nigra	black willow
Viola striata	striped white violet

Among the suggested species for wet floodplain forest restoration are highly invasive shrubs (e.g., *Populus deltoides* and *Salix nigra*) that produce quantities of seeds or that exhibit rapid vegetative growth. Periodic fires may be necessary to prevent over-growth of these species.

DuPont tract, owned by DuPont Chemical Company, is located to the east of Cline Avenue in Hammond, Indiana (Figure 2). Despite extensive industrial development during the 1950s and the 1970s, significant portions of classical "dune and swale systems" are preserved in this property. A total of 205 native species were documented here by TAMS (Mierzwa et al. 1991) and IDNR (unpublished) (Attachment 1), and four of these species are listed as threatened or rare species by IDNR, as follows:

Scientific name	Common name	Status
Carex bebbi	Bebb's sedge	threatened
Eriophorum angustifolium	narrow-leaved cotton grass	threatened
Baptisia leucantha	white wild indigo	rare
Betula papyrifera	paper birch	rare

Clark & Pine East Nature Preserve, owned by the State of Indiana, is located in the southeastern corner of the East Chicago-Gary Regional Airport property (Figure 2). Like the DuPont tract, this area is a classical example of a dune and swale system. TAMS (Mierzwa et al. 1991) and IDNR records for the area (unpublished) list 213 native species (Attachment 1), along with five endangered, five threatened, and ten rare species, as shown below:

Scientific name	Common name	Status
Carex brunnescens		endangered
Carex richardsonii		endangered
Gerardia skinneriana		endangered
Lycopus americanus	common water horehound	endangered
Sceleria pauciflora caroliniana		endangered
Aster ptarmicoides	stiff aster	threatened
Carex bushii		threatened
Carex crawei		threatened
Carex garberi	false golden sedge	threatened
Eleocharis geniculata	panne spike rush	threatened
Arctostaphylos uva-ursi coactilis	arctic bearberry	rare
Aristata intermedia	false arrow feather	rare
Carex aurea	golden sedge	rare
Cypripedium calceolus parviflorum	small yellow lady's slipper	rare
Cypripedium calceolus pubescens	large yellow lady's slipper	rare
Eleocharis pauciflora fernaldi		rare
Juncus balticus littoralis	lake shore rush	rare
Liparis loeselii	green twayblade	rare
Solidago ptarmicoides	stiff aster	rare

Tofieldia glutinosa		rare

Aggressive expansions of invasive species, both alien and native, pose serious threats to populations of native species in this reach/tract. The river banks in these natural areas are heavily infested with *Phragmites communis berlandieri*, *Lythrum salicaria*, *Typha angustifolia*, and *Typha latifolia*. Spread of these species is generally facilitated by their effective pollination systems, seed dispersal (mostly by wind), breeding systems (e.g., facultative apomixis), and, in many circumstances, rapid vegetative growth by "root-suckering" or "stem sprouts" (Baker 1986). These characteristics make this group of species very likely to continue expand aggressively in the wetlands of this tract, thereby out-competing native species. Forty alien species have already been found in the natural areas of DuPont and Clark and Pine East tracts (Attachment 6). Invasive species, both native or alien, should be eradicated from these tracts as soon as possible.

Most wetlands of the Grand Calumet Lagoons are located within the Miller Woods area, which is a part of INDU (Figure 2). This is home to what probably is the best-preserved and most diverse flora in northwestern Indiana. Wilhelm (1990) documented 559 species including 11 endangered, 12 threatened, and 12 rare species. These are listed below. The integrity of natural communities in the Grand Calumet Lagoons and Miller Woods tract, like that of natural areas at DuPont and at Clark and Pine East is threatened by the presence of many invasive species. Eighty-six alien species have been documented in the Grand Calumet Lagoons and Miller Woods area (Attachment 6).

Scientific name	Common name	Status
Equisetum variegatum	small scouring rush	endangered
Glyceria borealis	northern manna grass	endangered
Juncus scirpoides	round-headed rush	endangered
Ludwigia sphaerocarpa deamii	round-fruited loosestrife	endangered
Panicum dichotomiflorum	knee grass	endangered
Polygonum piperoides		endangered
Potamogeton pulcher	spotted pondweed	endangered
Potamogeton robbinsii	fern pondweed	endangered
Satureja arkansana	low calamint	endangered
Talinum rugospermum	fame flower	endangered
Utricularia minor	small bladderwort	endangered
Aster ptarmicoides	stiff aster	threatened
Cakile edentula	sea rocket	threatened
Carex garberi	false golden sedge	threatened
Cirsium pitcheri	sand thistle	threatened
Cornus rugosa	speckled dogwood	threatened
Eleocharis geniculata	panne spike bush	threatened
Euphorbia polygonifolia	seaside spurge	threatened
Juncus pelocarpus	brown-fruited rush	threatened
Lathyrus orchroleucus	pale vetchling	threatened

Polygonella articulata	jointweed	threatened
Utricularia cornuta	horned bladderwort	threatened
Arctostaphylos uva-ursi coactilis	arctic bearberry	rare
Aristata intermedia	false arrow feather	rare
Aster junciformis	rush aster	rare
Baptisia leucantha	white wild indigo	rare
Carex alata	winged sedge	rare
Carex aurea	golden sedge	rare
Diervilla lonicera	bush honeysuckle	rare
Drosera intermedia	narrow-leaved sundew	rare
Eleocharis pauciflora fernaldii		rare
Hypericum kalmianum	Kalm's St. John's wort	rare
Pogonia ophioglossoides	snake-mouth orchid	rare
Potamogeton pusillus	small pondweed	rare

Potential Impacts of Sediment Removal and Recommendations

The wetland communities along the Grand Calumet River are delicate composites of numerous environmental factors: local climate, hydrology, geomorphology, soil characteristics, and species interactions. Therefore, it is certain that these communities will be affected directly and indirectly in various ways by dredging activities. The particular nature of these impacts may depend upon the types of dredging methods employed. It is practically impossible to address all direct and indirect impacts at this time. A long-term study is needed for this purpose. This section will discuss key potential impacts of dredging and some recommendations in relation to the sediment-removal project.

Potential impacts of sediment removal

U.S. Army Corps of Engineers and the Environmental Protection Agency (1995), after a study of 18 sediment treatment methods, recommended mechanical dredging with a closed bucket (often called a clam-shell bucket). Three potential impacts of the dredging operation on the Grand Calumet River riparian wetlands are discussed as follows.

First, mechanical dredging may cause direct physical damages (e.g., trampling) to the riparian wetlands. Preparation of staging areas and an access road would inevitably remove some riparian vegetation. Some physical damages could be critically disruptive if done in sensitive wetland habitats such as the DuPont tract, Clark and Pine East, and Miller Woods.

Second, the removal of sediments would certainly deepen the River bed, steepen the shores, and eventually facilitate soil erosion on the stream-banks. This stream-bank erosion would likely deteriorate the quality of "presumably clean water after the dredging," and decrease the River width.

Third, local wetland hydrology could be modified by a deepening the river. More specifically, deepening of the River bed may facilitate drainage from the adjacent wetlands, and this “probable” drainage may cause drastic changes in plant species composition (e.g. from *Carex* spp. to *Typha* spp.) as evidenced in the nearby Cowles Bog in INDU (Wilcox and Simonin 1987).

Based on the above analysis of existing wetland plant communities and potential impacts of sediment removal, six recommendations are made as follows:

(1) Any sediment removal project should aim to restore full ecosystem function and structure of the Grand Calumet River and its adjacent wetlands. The project should not be limited to the simple activity of “getting the dirt out.” As noted by Mitsch and Gosselink (1986), wetlands play a pivotal role in water quality control, flood mitigation, storm abatement, aquifer recharges and many other ecosystem functions. The river cannot attain full ecological functioning without having its riparian wetlands restored. Only removing the sediment will certainly waste resources. For this reason, it is critical that the proposed sediment dredging be accompanied by the restoration of riparian wetlands.

(2) Physical damages to the wetland communities must be avoided, or at least minimized, during the sediment removal operation. Toward this end, the staging areas must be located as far as possible from the sensitive habitats, such as DuPont tract, Clark and Pine East Nature Preserve, and Miller Woods. The Roxanna Marsh area is an ideal candidate for a staging area, provided that the operation is not done during the breeding seasons for fish and wildlife. The area is considered to be severely degraded land. Such undesirable plants as *Typha* spp. and *Phragmites* spp. would be removed during the preparation of staging area. After sediment-removal operations, this area could be restored as wildlife habitat, by establishing native plant communities such as sedge meadow or wet prairie.

(3) Disposal sites for removed sediment should be located a safe distance from sensitive wetland habitats. Ecological feasibility of disposal at any proposed disposal site should be evaluated. Restoration of wetland ecosystems in the riparian lands (the areas immediately adjacent to the river) are crucial for establishing full ecological functions of the Grand Calumet River. Therefore, it is recommended that all riparian lands along the Grand Calumet River be excluded from the sediment disposal.

(4) Stream-bank erosion should be prevented by the construction of appropriate anti-erosion structures. For example, BioLogs^{TM} (long rolls of coconut fiber encased in coconut netting) may serve as submersible substrate to anchor native aquatic plants and create calm “eddies” that protect and enhance wildlife. These structures are commercially available, and they have been used successfully (e.g., marsh restoration in Hackensack Meadowlands, New Jersey) (Driver 1993).

(5) After removing the sediments, it is recommended that the river beds be lined with sand to make a gentle slope from both stream sides to the center. This approach has been

used for stream bank stabilization (Abt et al. 1995). The gentle slopes not only prevent drastic bank erosion, but they also provide an important feeding habitat for wildlife because birds (especially wading birds and possibly other animals too) favor gentle dish-shaped basins over steep cup-shaped ones (Smith et al. 1994).

(6) To investigate the impact of the proposed sediment removal on the local hydrology and plant communities of adjacent wetlands, an experimental pilot dredging project is recommended.

SUMMARY

The flora of northwestern Indiana is unusually diverse, with more than 1,400 species in 57 natural community types. As human settlement expanded in this region, the abundance and diversity of these plant communities dwindled significantly. The riparian wetlands along the Grand Calumet River have been degraded or destroyed, mainly due to stream channelization, sedimentation, fire suppression, and industrial pollution. During the last 50 years, 19 plant species were extirpated, and now a total of 53 plant species are endangered, threatened, or rare. Roxanna Marsh, the DuPont tract, Clark and Pine East Nature Preserve, and Miller Woods are the local riparian wetland with the greatest habitat value to animals and plants, and they have the greatest need for conservation. Potential impacts of sediment removal on these wetlands may include direct physical damage (such as trampling), stream-bank erosion, and modification of local hydrology and plant species composition. To minimize such impacts, the following recommendations are made: (1) fully restore the riparian wetland ecosystem, (2) minimize physical disturbance by locating staging areas in such degraded lands as Roxanna Marsh, and then follow sediment removal with wetland restoration, (3) locate sediment disposal sites at a safe distance from high quality natural areas such as the DuPont tract, Clark and Pine East nature Preserve, and Miller Woods, (4) construct anti-erosion structures in the stream bank, (5) grade the river beds to create a gentle slope, and (6) perform an experimental dredging project to study its effect on local hydrology and plant communities.

Literature Cited

Abt, S. R., C. C. Watson, J. C. Fisbenich, and M. R. Peters. 1995. Bank stabilization and habitat aspects of low-flow channels. Land and Water January/February:11 - 13.

Aldrich, J. R., J. A. Bacone, and M. A. Homoya. 1986. List of extirpated, endangered, threatened and rare vascular plants in Indiana: an update. Indiana Academy of Science **95**:413-419.

Bacone, J. A., R. K. Campbell, and G. Wilhelm. 1980. Presettlement vegetation of Indiana Dunes National Lakeshore. Pages 156-191 *in* Proceedings of Second Annual Symposium on Scientific Research in National Parks, National Park Service, Washington, D. C., USA.

Baker, H. G. 1986. Patterns of plant invasion in North America. Pages 44-57 *in* H. A. Mooney and J. A. Drake, editors. Ecology of biological invasions of North America and Hawaii. Springer-Verlag, New York, New York, USA.

Bowles, M. L., M. M. DeMauro, N. Pavlovic, and R. D. Hiebert. 1990. Effects of anthropogenic disturbances on endangered and threatened plants at the Indiana Dunes National Lakeshore. Natural Areas Journal **10**:187-200.

Cole, G. A. 1979. Textbook of limnology. The C. V. Mosby Company, St. Louis, Missouri, USA. 426 p.

Cowles, H. C. 1899. Ecological relations of the vegetation on sand dunes of Lake Michigan. Botanical Gazette **27**:95-117, 167-202, 281-308, 361-388.

Driver, T. 1993. The Transco Trail of the Hackensack Meadowlands. Land and Water September/October:28-32.

Indiana State Department of Natural Resources (IDNR). Unpublished. List of endangered, threatened, and rare plants in DuPont tract and Clark and Pine East Nature Preserve. Indiana Department of Natural Resources, Indianapolis, Indiana, USA.

Henderson, N. R., and J. N. Long. 1984. A comparison of stand structure and fire history in two black oak woodlands in northwestern Indiana. Botanical Gazette **145**:222-228.

Kurz, D. R., G. A. Paulson, D. W. Morgan, and J. W. Burling. 1978. Inventory of natural areas in the Indiana coastal zone. Natural Land Institute and Indiana Department of Natural Resources, Indianapolis, Indiana, USA. 119 p.

Mierzwa, K. S., S. D. Culberson, K. S. King, and C. Ross. 1991. Illinois-Indiana Regional Airport - site selection, environmental assessment, and master plan. Technical Paper No. 7, TAMS Consultants, Chicago, Illinois, USA.

Mitsch, W. J., and J. G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold Company, New York, New York, USA. 539 p.

Peattie, D. C. 1930. Flora of the Indiana dunes. Field Museum of Natural History, Chicago, Illinois, USA. 432 p.

Peloquin, R. L., and S. O'Brien. 1990. Terrestrial vascular plants. Pages 1-26 *in* Ecology of Miller Woods, Research Program Report 90-01, Indiana Dunes National Lakeshore,Porter, Indiana, USA.

Reshkin, M. 1990. Indiana dunes natural resource management. Natural Areas Journal **10**:176-180.

Smith, R. B., D. H. Zonies, K. A. Mumford, T. M. Patterson, and Y. D. Choi. 1994. Use of roadside ditches as a wading birdhabitat at the Kennedy Space Center. Bulletin of the Ecological Society of America **75** (Supplement):214-215.

Swink, F., and G. Wilhelm. 1979. Plants of the Chicago region. The Morton Arboretum, Lisle, Illinois, USA. 922 p.

U.S. Army Corps of Engineers and U.S. Environmental Protection Agency. 1995. Indiana Harbor and Ship Canal, a review of the draft environmental impact statement for dredging and special activities. An information brochure, U.S. Army Corps of Engineers - Chicago District and U.S. Environmental Protection Agency - Region 5, Chicago, Illinois, USA.

Wilcox, D. A., and H. A. Simonin. 1987. A chronosequence of aquatic macrophyte communities in dune ponds. Aquatic Botany **28**:227-242.

Wilhelm, G. S. 1990. Special vegetation of the Indiana Dunes National Lakeshore. Research Program Report 90-02. Indiana Dunes National Lakeshore, Porter, Indiana. 373 p.

Attachment 1. List of plant species in DuPont tract, Clark and Pine East Nature Preserve, and Miller Woods.

Legends:
DT - DuPont Tract
CP - Clark and Pine East Nature Preserve (Bongi Ponds)
MW - Miller Woods (Grand Calumet River Lagoon)
A - Alien species
E - Endangered sepces
T - Threatened species
R - Rare species

		Location			
Scientific Name	Common Name	DT	CP	MW	Class
Abutilon theophrasti	velvetleaf			X	A
Acer negundo	boxelder	X		X	
Acer platanoides	Norway maple			X	A
Acer rubrum	red maple		X	X	
Acer saccharinum	silver maple	X	X	X	
Achillia millefolium	yarrow	X		X	A
Agropyron repens	quack grass			X	A
Agropyron smithii	western wheat grass			X	A
Agropyron trachycaulum unilaterale	slender wheat grass		X	X	
Agrostis alba	redtop grass	X	X	X	A
Agrostis hyemalis	tickle grass			X	
Ailanthus altissima	tree-of-heaven	X			A
Alestris farinosa	colic root			X	
Alisma subcordatum	common water plantain		X	X	
Alisma triviale	large-leaved water plantain	X		X	
Alliaria officinalis	garlic mustard			X	A
Allium cernuum	nodding wild onion			X	
Althaea rosea	hollyhock	X			A
Ambrosia artemisiifolia elatior	common ragweed	X		X	
Ambrosia psilostachya coronopifolis	western ragweed			X	A
Ambrosia trifida	giant ragweed	X	X	X	
Amelanchier arborea	serviceberry			X	
Amelanchier interior	dwarf shadbush			X	
Amelanchier laevis	Allegheny shadbush			X	
Ammophila breviligulata	Merram grass			X	
Amorpha canescens	lead plant	X			
Amphicarpa bracteata	hog peanut			X	
Andropogon gerardii	big bluestem	X	X	X	
Andropogon scoparius	little bluestem	X	X	X	
Anemone canadensis	meadow anemone			X	
Anomone cylindrica	timbleweed	X	X	X	
Antennaria neglecta	cat’s foot		X		
Antennaria plantaginifolia	pussy toes		X	X	
Anthriscus scandicina	chervil			X	A
Apios americana	ground nut	X		X	
Apocynum androsaemifolium	spearding dogbane			X	
Apocynum cannabinum	Indian hemp	X	X	X	
Apocynum sibiricum	Indian hemp	X	X	X	
Arctostaphylos uva-ursi coatilis	arctic bearberry	X	X	X	

Aquilegia canadensis	garden columbine	X	X		
Arabis lyrata	sand cress	X	X	X	
Aralia nudicaulis	wild sasaparilla		X	X	R
Arenaria serphyllifolia	thyme-leaved sandwort			X	A
Arenaria lateriflora	wood sandwort	X			
Arenaria stricta	stiff sandwort			X	R
Aristata intermedia	false arrow feather		X	X	R
Aristata oligantha	plains three-awn grass			X	A
Aristata purpurascens	arrow feather			X	A
Arizona melanocarpa			X		
Artemisia caudata	beach wormwood	X	X	X	
Artemisia vulgaris	mugwort			X	A
Asclepias amplexicaulis	sand milkweed		X		
Asclepias incarnata	swamp milkweed		X	X	
Asclepias syriaca	common milkweed	X	X	X	
Asclepias tuberosa	butterfly weed	X	X	X	
Asclepias verticillata	whorled milkweed	X	X	X	
Asclepias viridiflora	short green milkweed			X	
Asparagus officinalis	asparagus	X	X	X	A
Aster azureus	sky-blue aster	X	X	X	
Aster dumosus	rice button aster	X	X		
Aster ericoides	heath aster	X		X	
Aster junciformis	rush aster			X	R
Aster laevis	smooth blue aster		X		
Aster lateriflorus	side-flowering aster		X	X	
Aster linariifolius	flax-leaved aster		X		
Aster novae-angliae	New England aster		X	X	
Aster pilosus	hairy aster			X	
Aster ptarmicoides	stiff aster		X	X	T
Aster puniceus firmus	marsh aster			X	
Aster sagittifolius	arrow-leaved aster			X	
Aster sagittifolius drummondii	Drummond’s aster			X	
Aster simplex	panicled aster	X	X	X	
Aster umbellatus	flat-top aster		X	X	
Baptisia leucantha	white wild indigo	X		X	R
Barbarea vulgaris	yellow rocket			X	A
Betula papyrifera	paper birch	X	X		R
Bidens cernua	nodding bur marigold			X	
Bidens comosa	swamp tickseed		X		
Bidens coronata	purple-stemmed tickseed	X	X		
Boehmeria cyclindrica	false nettle	X		X	
Boltonia latisquama recognita	false aster			X	
Bromus inermis	Hungarian brome			X	A
Bromus japonicus	Japanese brome			X	A
Bromus kalmii	prairie brome		X	X	
Bromus tectorum	downy brome	X		X	A
Bulbostylis capillaris	hair sedge			X	
Cacalia tuberosa	prairie Indian plantain		X		
Cakile edentula	sea rocket			X	T
Calamagrostis canadensis	blue joint grass	X	X	X	
Calamovifila longifolia	sand reed	X	X	X	
Camassia scilloides	wild hyacinth			X	
Campanula aparinoides	marsh bellflower	X	X	X	

Campanula rotundifolia	harebell	X			
Campanula uliginosa	large marsh bellflower	X			
Cannabis sativa	hemp		X		A
Capsella bursa-pastoris	shepherd's purse			X	A
Carduus nutans	musk thistle	X			A
Carex alata	winged sedge			X	R
Carex aurea	golden sedge	X	X	X	R
Carex bebbii	Bebb's sedge	X			T
Carex brevior			X		X
Carex brunnescens sphaerostachya			X		E
Carex bushii	bush sedge		X		T
Carex buxbaumii		X	X		
Carex comosa	bristly sedge			X	
Carex crawei			X		T
Carex emoryi				X	
Carex foenea				X	
Carex garberi	false golden sedge		X	X	
Carex granularis				X	
Carex haydenii	long-scaled meadow sedge		X		
Carex hystricina	bottlebrush sedge	X			
Carex interia			X		
Carex lanuginosa	woolly sedge		X	X	
Carex lasiocarpa americana	narrow-leaved woolly sedge		X	X	
Carex muhlenbergii	sand sedge	X		X	
Carex pensylvanica	early sedge	X		X	
Carex richardsonii			X		E
Carex sartwellii		X		X	
Carex stricta	meadow sedge	X	X	X	
Carex suberecta		X	X		
Carex tenera		X			
Carex tetanica		X			
Carex tonosa	early sand sedge		X		
Carex tribuloides				X	
Carex umbellata	hairy early sedge	X	X	X	
Carex viridula	panne sedge		X	X	
Carex vulpinoidea	fox sedge		X		
Cassia fasciculata	partridge pea			X	
Cassia nictitans	wild sensitive plant			X	
Castilleja coccinea	Indian paint brush	X	X	X	
Catalpa speciosa	hairy catalpa	X			*A*
Ceanothus americanus	New Jersey tea	X		X	
Celastrus scandens	climbing bittersweet	X	X		
Cenchrus longispinus	sandbur	X		X	
Centaurium pulchellum	showy centaury	X	X		A
Cephalanthus occidentalis	bottonbush	X	X	X	
Chelone glabra	turtlehead	X			A
Chenopodium album	lamb's quarters			X	A
Chenopodium boscianum	woodland goosefoot			X	
Chenopodium leptophyllum	narrow-leaved goosefoot		X		
Cicuta bulbifera	bubblet-bearing water hemlock		X		
Cinna arundinacea	common wood reed	X	X		
Cirsium arvense	field thistle		X	X	A
Cirsium discolor	pasture thistle	X	X	X	

Cirsium muticum	swamp thistle	X	X	X			
Cirsium pitcheri	pitcher thistle			X	T		
Cirsium vulgare	bull thistle	X	X	X	A		
Cladium mariscoides	twig rush	X	X	X			
Comandra richardsiana	false toadflax	X		X			
Commelina communis	common day flower	X			A		
Commelina erecta deamiana	savanna day flower			X			
Conium maculatum	poison hemlock	X			A		
Convolulus arvensis	field bindweed	X			A		
Convolulus sepium	hedge bindweed	X		X			
Coreopsis lanceolata	sand coreopsis	X	X	X			
Coreopsis palmata	prairie coreopsis	X	X				
Coreopsis tripteris	tall coreopsis	X	X	X			
Corispermum hyssopifolium	common bugseed		X				
Cornus obliqua	pale dogwood	X	X	X			
Cornus racemosa	gray dogwood	X	X				
Cornus rugosa	speckled dogwood		X		T		
Cornus stolonifera	red-osier dogwood	X	X	X			
Cornus stolonifera baileyi	dunes dogwood	X					
Crepis capillaris	hawk's beard			X	A		
Cuscuta coryli	hazel dodder	X					
Cuscuta gronovii	common dodder		X				
Cycloloma atriplicifolium	winged pigweed	X	X				
Cyperus erythrorhizos	red-rooted sedge		X				
Cyperus esculentus	caufa		X				
Cyperus ferruginescens	fragile sedge	X	X	X			
Cyperus filicumilis	sand cyperus		X				
Cyperus rivularis	brook sedge	X	X	X			
Cyperus schweinitzii	rough sand cyperus	X		X			
Cyperus strigosus		X		X			
Cypripedium acaule	stemless lady's slipper	X					
Cypripedium calceolus parviflorum	small yellow lady's slipper	X		R			
Cypripedium calceolus pubescens	large yellow lady's slipper			X		R	
Daucus carota	wild carrot			X	X	X	A
Descurainia sophia	tangy mustard					X	A
Desmodium canadense	showy tick trefoil		X	X	X		
Desmodium paniculatum	panicled tick trefoil			X	X	X	
Desmodium sessifolium	sessile-leaved trefoil			X			
Dianthus armeria	deptford pink					X	A
Diervilla lonicera	bush honeysuckle				X	R	
Digitaria ischaemum	smooth crab grass					X	A
Digitaria sanguinalis	hairy crab grass				X	A	
Diplotaxis muralis	wall rocket				X	X	A
Diplotaxis tenuifolia	sand rocket				X		A
Drosera intermedia	arrow-leaved sundew				X	R	
Dryopteris spinulosa	spinulose shield fern					X	
Dryopteris thelypteris pubescens	marsh shield fern		X	X	X		
Dulichium arundinaceum	pond sedge					X	
Echinochloa crusgalli	barnyard grass			X	X		
Echinocystis lobata	wild cucumber			X			
Echium vulgare	viper's bugloss		X			A	
Eleocharis acicularis	needle spikerush				X		
Eleocharis calva	red-rooted spike rush			X	X	X	

Eleocharis compressa	flat-stemmed spike rush			X		
Eleocharis elliptica	golden-seeded spike rush	X	X	X		
Eleocharis engelmanni				X		
Eleocharis geniculata	panne spike rush		X	X	T	
Eleocharis intermedia	matted spike rush			X		
Eleocharis olivacea	loose-sheathed spike rush			X		
Eleocharis pauciflora fernaldii			X	X	R	
Eleocharis smallii					X	
Elodea canadensis	common waterweed				X	
Elodea nuttallii					X	
Elymus canadensis	Canadian wild rye		X	X	X	
Epilobium glandulosum adenocaulon	northern willow herb				X	
Equisetum arvense	horsetail	X	X	X		
Equisetum hymale affine	tall scouring rush	X	X	X		
Equisetum hymale intermedium	smooth scouring rush		X		X	
Equisetum trachyodon				X		
Equisetum X ferrissii				X		
Equisetum variegatum	small scouring rush				X	E
Eragrostis hypnoides	creeping love grass		X			A
Eragrostis megastachya	stink grass				X	A
Eragrostis pectinacea	small love grass			X		
Eragrostis poaeoides	low love grass		X	X		A
Eragrostis spectabilis	purple love grass	X		X		
Eragrostis trichodes	tall love grass				X	A
Erechtites hieracifolia	fireweed			X		
Erigeron annus	annual fleabane			X		
Erigeron canadensis	horseweed		X	X	X	
Erigeron philadelphicus	marsh fleabane			X		
Erigeron pulchellus	Robin’s plantain		X			
Erigeron strigosus	daisy fleabane		X	X	X	
Eriophorum angustifolium	narrow-leaved cotton grass			X		T
Eryingium yuccigolium	rattle snake master			X		
Eupatorium altissimum	tall boneset		X	X	X	
Eupatorium macualtum	spotted joe pye weed		X	X	X	
Eupatorium perfoliatum	common boneset	X	X	X		
Eupatorium rugosum	white snakeroot		X			
Eupatorium serotinum	late boneset		X	X	X	
Euphorbia corollata	flowering spurge	X	X	X		
Euphorbia dentata	toothed spurge			X	A	
Euphorbia maculata	nodding spurge			X	A	
Euphorbia polygonifolia	seaside spurge				X	T
Euphorbia supina	creeping spurge			X	A	
Festuca elatior	meadow fescue		X		A	
Fragaria virginiana	wild strawberry	X	X	X		
Fraxinus americana	white ash				X	
Fraxinus pennsylvanica subintegerrima	green ash			X		
Galium aparine	annual bedstraw			X		
Galium cocinnum	shining bedstraw			X		
Galium obtusum	wild madder		X	X		
Galium pilosum	hairy bedstraw			X		
Galium tinctorium	stiff bedstraw				X	
Gaylussacia baccata	huckleberry				X	

Gentiana andrewsii	closed gentain				X	
Gentiana crinita	fringed gentain		X	X		
Gentiana procera	small fringed gentain			X		
Geranium carolinianum	Carolina cranesbill				X	
Geranium maculatum	wild geranium				X	
Gerardia paupercula	purple false foxglove			X	X	
Gerardia pedicularia ambigens	clammy false foxglove			X		
Gerardia purpurea	purple false foxglove		X	X	X	
Gerardia skinneriana	pale false foxglove			X		E
Gerardia tenuifolia	slender false foxglove				X	
Geum laciniatum trichocarpum	rough avens		X			
Glechoma hederacea	ground ivy				X	A
Gleditsia triacanthos	honey locust		X		X	A
Glyceria borealis	northern manna grass				X	E
Glyceria septentrionalis	floating manna grass				X	
Glyceria striata	fowl meadow grass		X	X	X	
Gnaphalium obtusifolium	old-field balsam			X		
Habenaria ciliaris	orange fringed orchid				X	
Habenaria clavellata	small green fringed orchid			X		
Habenaria flava herbiola	tubercled orchid	X		X		
Habenaria hyperborea huronensis	northern fringed orchid			X		
Habenaria psycodes	purple fringed orchid				X	
Hamamelis virginiana	witch hazel				X	
Helianthemum canadense	common rockrose			X		
Helianthus divaricatus	woodland sunflower		X	X	X	
Helianthus grosseserratus	sawtooth sunflower		X		X	
Helianthus helianthoides				X		
Helianthus laetiflorus rigidus	prairie sunflower			X		
Helianthus occidentalis	western sunflower		X		X	
Helianthus petiolaris	petioled sunflower				X	A
Heteranthera dubia	water star grass			X		
Hieracium canadense fasciculatum	Canada hawkweed				X	
Hieracium gronovii	hairy hawkweed			X		
Hieracium pratense	field hawkweed			X	A	
Hieracium scabrum	rough hawkweed			X		
Hordeum jubatum	squirrel-tail grass			X	A	
Hypericum canadense	Canadian St. John’s wort			X		
Hypericum kalmianum	Kalm’s St. John’s wort	X	X		R	
Hypericum majus	clapsing St. John’s wort			X		
Hypericum virginicum fraseri	marsh St. John’s wort				X	
Hypoxis hirsuta	yellow star grass	X				
Hystrix patula	bottlebrush grass			X		
Ilex verticillata	winterberry			X	X	
Impatiens capensis	spotted touch-me-not		X		X	
Impatiens pallida	pale touch-me-not				X	
Iris germanica	German iris				X	A
Iris pseudacorus	yellow iris				X	A
Iris virginiana shrevei	blue flag	X	X	X		
Juncus acuminatus	sharp-fruited rush			X		
Juncus alpinus rariflorus	Richardson’s rush		X	X	X	
Juncus balticus littoralis	Lake shore rush	X	X	X	R	
Juncus brachycephalus	short-headed rush		X	X		
Juncus canadensis	Canadian rush			X	X	

Juncus diffusissimus					X	
Juncus dudleyi	Dudley’s rush		X	X	X	
Juncus effusus solutus	common rush				X	
Juncus greenei	Green’s rush				X	
Juncus interia	inland rush			X		
Juncus marginatus	grass-leaved rush			X		
Juncus nodosus	joint rush		X	X	X	
Juncus pelocarpus	brown-fruited rush				X	T
Juncus scirpoides	round-headed rush				X	E
Juncus tenuis	path rush				X	
Juncus torreyi	Torrey’s rush		X	X	X	
Juniperus virginiana crebra	eastern red cedar			X		
Koeleria cristata	June grass		X		X	
Krigia biflora	false dandelion	X		X		
Krigia virginica	dwarf dandelion			X		
Kuhnia eupatorioides corybulosa	false boneset				X	
Lactuca canadensis	wild lettuce		X		X	
Lactuca scariola	prickly lettuce		X			A
Lathyrus japonicus glaber	beach pea				X	
Lathyrus ochroleucus	pale vetchling				X	T
Lathyrus palustris myrtifolius	marsh vetchling	X		X		
Lechea villosa	hairy pinweed				X	
Leersia oryzoides	rice cut grass			X	X	
Leersia virginica	white grass		X			
Lepidium virginicum	common peppercress				X	
Leptoloma cognatum	fall witch grass			X		
Lespedeza capitata	round-headed bush clover	X		X		
Lespedeza virginica	slender bush clover				X	
Liastris aspera	rough blazing star		X	X	X	
Liastris cyclindracea	cylindrical blazing star	X	X	X		
Liastris spicata	marsh blazing star		X	X	X	
Lilium philadelphicum andinum	prairie lily		X	X	X	
Linaria canadensis	blue toadflax				X	
Linaria vularis	butter-and-eggs			X		
Linum medium texanum	small yellow flax		X	X		
Liriodendron tulipifera	tulip tree		X			
Liparis lilifolia	purple twayblade	X		X		
Liparis loeselii	green twayblade		X	X	R	
Lithospermum canescens	hoary puccoon	X	X	X		
Lithospermum croceum	hairy puccoon		X	X	X	
Lobelia kalmii	bog lobelia			X	X	
Lobelia siphilitica	great blue lobelia	X		X		
Lobelia spicata	pale spiked lobelia		X	X		
Lonicera dioica	red honeysuckle		X	X		
Lonicera x muendeniensis	yellow downy bush honeysuckle		X	X	X	A
Lonicera tatarica	tartarian honeysuckle		X	X		A
Ludwigia alternifolia	seedbox			X		
Ludwigia palustris americana	marsh purpleslane				X	
Ludwigia polycarpa	false loosestrife			X		
Ludwigia sphaerocarpa deamii	round-fruited loosestrife			X	E	
Lupinus perennis occidentalis	wild lupine		X		X	
Lychnis alba	white campion	X		X	A	

Lycopus americanus	common water horehound	X	X	X	E	
Lycopus asper	rough water horehound	X		X	A	
Lycopus rubellus	stalked water horehound			X		
Lycopus uniflorus	northern bugle weed			X	X	
Lycopus virginicus	bugle weed				X	
Lysimachia lanceolata	lance-leaved loosestrife	X		X		
Lysimachia quadrifolia	narrow-leaved loosestrife	X	X			
Lysimachia terrestris	swamp candles	X		X		
Lysimachia thysiflora	tufted loosestrife			X		
Lythrum alatum	winged loosestrife		X	X	X	
Lythrum salicaria	purple loosestrife	X	X	X	A	
Maianthemum canadense interius	hairy Canada mayflower	X	X	X		
Medicago luplina	black medick		X		X	A
Melampyrum lineare latifolium	cow wheat				X	
Melilotus alba	white sweet clover		X	X	X	A
Melilotus officinalis	yellow sweet clover				X	A
Mentha arvensis villosa	wild mint				X	
Mimulus ringens	monkey flower		X	X		
Mirabilis nyctaginea	wild four o’clock			X	A	
Mollugo verticillata	carpet weed				X	A
Monarda fistulosa	wild bergamot		X	X	X	
Monarda punctata villicaulis	horse mint		X	X	X	
Monotropa uniflora	Indian pipe				X	
Morus alba	white mulberry		X	X	A	
Muhlenbergia mexicana	leafy satin grass			X		
Muhlenbergia racemosa	upland wild timothy				X	A
Myosotis scorpiodes	common forget-me-not			X	A	
Myriophyllum exalbescens	spiked water milfoil				X	
Myriophyllum verticullatum pectinatum	whorled water milfoil				X	
Najas flexilis	slender naiad				X	
Nepeta cataria	catnip		X		X	A
Nuphar advena	yellow pond lily		X	X		
Nuphar variegatum	yellow pond lily			X		
Nymphaea tuberosa	white water lily		X	X		
Nyssa sylvatica	black gum				X	
Oenothera biennis	evening primrose	X	X	X		
Oenothera rhombipetala	sand primrose			X	X	
Onoclea sensibilis	sensitive fern		X		X	
Opuntia humifusa	prickly pear		X	X	X	
Orobanche uniflora	one-flowered broom rape			X		
Osmunda cinnamomea	cinnamon fern				X	
Osmunda regalis spectabilis	royal fern		X	X	X	
Oxalis europaea	tall wood sorrel			X		
Oxypolis rigidior	cowbane	X	X	X		
Panicum agrostoides	Munro grass				X	
Panicum capillare	old witch grass			X		
Panicum columbianum	hemlock panic grass				X	
Panicum depauperatum	starved panic grass				X	
Panicum dichotomiflorum	knee grass				X	
Panicum flexile	wiry panic grass		X	X		
Panicum implicatum	woolly panic grass		X	X	X	
Panicum latifolium	broad-leaved panic grass			X		

Panicum lindheimeri	smooth panic grass				X	
Panicum oligosanthes scribnerinum	Scribner’s panic grass		X		X	
Panicum perlongum	long-stalked panic grass			X		
Panicum villosissimum	white-haird panic grass		X	X		
Panicum villosissimum pseudopubescens					X	
Panicum virgatum	switch grass		X	X	X	
Parnassia glauca	grass of parnassus				X	
Parthenocissus inserta	thicket creeper	X	X	X		
Parthenocissus quinquefolia	Virginia creeper	X	X	X		
Pedicularis canadensis	wood betony		X	X	X	
Penthorum sedoides	ditch stonecrop			X		
Petalostemum purpureum	purple prairie clover			X		
Phalaris arundinacea	reed canary grass	X		X		
Phleum pratense	Timothy grass				X	A
Phlox divaricata	blue phlox			X		
Phlox glaberrima interior	marsh phlox				X	
Phlox paniculata	garden phlox				X	A
Phlox pilosa	prairie phlox		X	X	X	
Phragmites communis berlandieri	common reed		X	X	X	
Physalis heterophylla	clammy ground cherry	X				
Physalis pubescens	hairy ground cherry				X	A
Physalis subglabrata	tall ground cherry			X		
Physalis virginiana	lance-leaved ground cherry			X		
Physocarpus opulofolius	ninebark		X	X		
Physostegia virginiana	false dragonhead	X				
Phytolacca americana	pokeweed				X	
Pinus banksiana	Jack pine				X	
Plantago major	common plantain			X	A	
Plantago rugelii	red-stalked plantain		X		X	
Platanus occidentalis	sycamore				X	
Poa annua	annual blue grass			X	A	
Poa compressa	Canada blue grass		X	X	X	A
Poa pratensis	Kentucky blue grass		X	X	X	A
Pogonia ophioglossoides	snake-mouth orchid				X	R
Polanisia graveolens	clammy weed				X	A
Polygala cruciata aquilonia	cross milk wort			X		
Polygala polygama obtusata	purple milk wort			X		
Polygonatum canaliculatum	smooth Solomon’s seal	X	X	X		
Polygonella articulata	jointweed				X	T
Polygonum amphibium stipulaceum	water knotweed	X	X	X		
Polygonum aviculare	common knotweed				X	A
Polygonum coccinium	water heartsease		X	X		
Polygonum convolvulus	black bindweed			X	A	
Polygonum hydropiperoides	mild water pepper				X	E
Polygonum lapathifolium	heartsease				X	
Polygonum pensylvanicum laevigatum	Pennsylvania knotweed			X		
Polygonum persicaria	lady’s thumb				X	A
Polygonum punctatum	smartweed		X		X	
Polygonum scandens	climbing false buckwheat			X		
Polygonum tenue	slender knotweed			X		
Pontederia cordata	pickerel weed				X	
Populus deltoides	cottonwood		X	X	X	
Populus grandidentata	big-tooth aspen		X			

Populus x jackii					X	
Populus tremuloides	quaking aspen		X	X	X	
Portulaca oleracea	purslane		X		A	
Potamogeton amplifolius	large-leaved pondweed			X		
Potamogeton foliosus	leafy pondweed			X		
Potamogeton gramineus	grass-leaved pondweed			X		
Potamogeton illinoensis	Illinois pondweed			X		
Potamogeton natans	long-leaved ponweed				X	
Potamogeton pectinatus	sago pondweed			X		
Potamogeton pulcher	spotted pondweed				X	E
Potamogeton pusillus	small pondweed			X	R	
Potamogeton robbinsii	fern pondweed			X	E	
Potentilla fruticosa	shruby cinquefoil		X	X		
Potentilla palustris	marsh cinquefoil		X	X		
Potentilla recta	sulfur cinquefoil			X	A	
Potentilla simplex	common cinquefoil				X	
Prenanthes alba	white lettuce			X	X	
Prenanthes racemosa	glaucous white lettuce		X	X		
Proserpinaca palustris crebra	mermaid weed		X	X		
Prunella vulgaris lanceolata	self heal		X	X		
Prunus pumila	sand cherry			X	X	
Prunus serotina	black cherry		X	X	X	
Prunus virginiana	choke cherry		X	X	X	
Ptelea trifoliata	hop tree			X		
Ptelea trifoliata mollis	dunes hop tree			X		
Pteridium aquilinum latiusculm	bracken fern		X	X	X	
Pycnanthemum virginianum	common mountain mint	X	X	X		
Pyrus floribunda	purple chokeberry			X	X	
Pyrus ioensis	Iowa crabapple	X	X	X		
Pyrus melanocarpa	black chokeberry			X		
Quercus alba	white oak		X	X	X	
Quercus ellipsoidalis	Hill’s oak		X			
Quercus velutina	black oak		X	X	X	
Ranunculus flabellaris	yellow water buttercup			X		
Ranunculus sceleratus	cursed crowfoot			X		
Ratibida pinnata	yellow coneflower		X			
Rhamnus cathartica	common buckthorn		X	X		A
Rhamnus frangula	glossy buckthorn	X	X	X	A	
Rhus aromatica	fragrant sumac	X	X	X		
Rhus aromatica arenaria	sand fragrant sumac			X	X	
Rhus copallina latifolia	winged sumac		X	X	X	
Rhus glabra	smooth sumac			X		
Rhus radicans	poison sumac		X	X	X	
Rhus typhina	staghorn sumac	X	X	X		
Rhynchospora capillacea	hair beak rush			X	X	
Rhynchospora macrostachya	giant beak rush			X		
Ribes americanum	wild black currant		X			
Robinia pseudo-acacia	black locust				X	A
Rorippa islandica hispida	marsh cress		X		X	
Rosa blanda	early wild rose			X		
Rosa carolina	pasture rose		X	X	X	
Rosa multiflora	multiflora rose	X		X	A	
Rosa palustris	swamp rose			X	X	

Rotala ramosior	wheelwort				X	
Rubus flagellaris	common dewberry		X		X	
Rubus hispidus obovalis	swamp dewberry			X		
Rubus idaeus strigosus	red raspberry			X	X	
Rubus occidentalis	black raspberry			X		
Rudbeckia hirta	black-eyed Susan	X	X	X		
Rumex acetosella	field sorrel				X	
Rumex altissimus	pale dock				X	
Rumex crispus	curly dock				X	A
Satabia angularis	rose gentian			X	X	
Sagittaria graminea	grass-leaved arrowhead			X		
Sagittaria latifolia	common arrowhead				X	
Salix amygdaloides	peach-leaved willow		X	X	X	
Salix discolor	pussy willow		X		X	
Salix glaucophylloides glaucophylla	blue-leaved willow		X	X	X	
Salix gracilis textoris	petioled willow			X		
Salix humilis	prairie willow		X	X	X	
Salix interia	sandbar willow	X	X	X		
Salix nigra	black willow			X	X	
Salix pedicellaris hypoglauca	bog willow				X	
Salix purpurea	purple willow			X		A
Salix rigida	heart-leaved willow				X	
Salix syrticola	dune willow				X	
Salsola kali tenuifolia	Russian thistle			X	X	A
Sambucus canadensis	elderberry		X	X	X	
Sanguinaria canadensis	bloodroot				X	
Sanicula marilandica	black snakeroot			X		
Saponaria officinalis	bouncing bet		X		X	A
Sassafras albidum	sassafras	X	X	X		
Satureja arkansana	dogmint			X	E	
Saxifraga pensylvanica	swamp saxifrage		X			
Scirpus acutus	hard-stemmed bulrush		X	X		
Scirpus americanus	chairmaker's rush	X	X	X		
Scirpus atrovirens	dark green rush		X	X		
Scirpus cyperinus	wool grass				X	
Scirpus lineatus	red bulrush			X		
Scirpus validus creber	great bulrush	X	X	X		
Scleria triglomerata	tall nut rush				X	
Scleria pauciflora caroliniana	few-flowered nut rush		X		E	
Scleria verticillata	low nut rush			X	X	
Scrophularia lanceolata	early figwort				X	
Scutellaria epilobiifolia	marsh skullcap	X		X		
Scutellaria lateriflora	mad-dog skullcap	X	X	X		
Selaginella apoda	marsh club moss	X				
Senecio pauperculus balsamitae	balsam ragwort		X	X		
Setaria faberii	giant foxtail				X	A
Setaria glauca	yellow foxtail				X	A
Setaria viridis	green foxtail			X	X	A
Silene antirrhina	sleepy catchfly	X		X		
Silene cserei	glaucous campion				X	A
Silene cucubalus	bladder campion			X	A	
Silphium integrifolium	rosin weed		X			

Sisymbrium altissimum	tumble mustard			X	*A*	
Sisyrinchium albidum	common blue-eyed grass	X	X	X		
Sium suave	water parsnip			X	X	
Smilacina racemosa	feathery false Solomon's seal	X		X		
Smilacina stellata	starry false Solomon's seal	X	X	X		
Smilax lasioneura	common carrion flower	X		X		
Smilax rotundifolia	green brier				X	
Smilax tamnoides hispida	bristly green brier	X	X			
Solanum americana	black nightshade			X	A	
Solanum dulcamara	bittersweet nightshade	X	X	X	A	
Solidago altissima	tall goldenrod		X	X	X	
Solidago caesia	blue-stem goldenrod			X	X	
Solidago gigantia	late goldenrod			X	X	
Solidago graminifolia media	smooth grass-leaved goldenrod			X	X	
Solidago graminifolia nutallii	rough grass-leaved goldenrod		X	X	X	
Solidago gymnospermoides	shiny grass-leaved goldenrod			X	X	
Solidago juncea	early goldenrod			X		
Solidago missouriensis fasciculata	Missouri goldenrod			X	X	
Solidago nemoralis	old field goldenrod		X	X	X	
Solidago ohiensis	Ohio goldenrod		X	X		
Solidago ptarmicoides	stiff goldenrod			X	R	
Solidago racemosa gillmani	dune goldenrod			X		
Solidago riddellii	Riddell's goldenrod			X		
Solidago rigida	stiff goldenrod			X		
Solidago rugosa	rough goldenrod		X	X		
Solidago sempervirens	seaside goldenrod		X		A	
Solidago speciosa	showy goldenrod	X	X	X		
Solidago tenuifolia	slender-leaved goldenrod			X		
Solidago uliginosa	bog goldenrod		X			
Sonchus asper	spiny sow thistle			X	A	
Sonchus oleraceus	store-front sow thistle			X	A	
Sonchus uliginosus	common sow thistle				X	A
Sorghastrum nutans	Indian grass		X	X	X	
Sparganium americanum	American bur reed				X	
Sparganium chlorocarpum	simple bur reed			X		
Sparganium eurycarpum	common bur reed			X		
Spartina pectinata	prairie cord grass	X	X	X		
Sphenopholis intermedia	slender wedge grass				X	
Spiraea alba	meadowsweet		X	X	X	
Spirea tomemtosa rosea	steeple bush			X	X	
Spiranthus cernua	nodding lady's tresses			X	X	
Sporobolus asper	rough dropseed			X	A	
Sporobolus cryptandrus	sand dropseed				X	
Stachys palustris homotricha	woundwort				X	
Stachys tenuifolia hispida	rough hedge nettle				X	
Stipa spartea	porcupine grass	X	X	X		
Strophostyles helvola	trailing wild bean			X		
Symphoricarpos orbiculatus	coral berry				X	A

Talinum rugospermum	fame flower					X	E
Taraxacum officinale	common dendelion			X		X	A
Tephrosia virginiana	goat's rue			X		X	
Teucrium canadense	germander					X	
Thalictrum dioicum	early meadow rue				X		
Tilia americana	American basswood					X	
Tofieldia glutinosa	false asphodel				X		R
Tradescantia ohiensis	spider wort			X		X	
Tragopogon major	sand goat's beard		X		X	A	
Tragopogon pratensis	common goat's beard					X	A
Trifolium hybridum	alsike clover					X	A
Trifolium pratense	red clover					X	A
Trifolium repens	white clover					X	A
Triglochin maritima	common bog arrow grass			X	X		
Triplasis purpurea	sand grass					X	
Triticum aestivm	wheat					X	A
Typha angustifolia	narrow-leaved cattail			X	X	X	A
Typha latifolia	broad-leaved cattail			X	X	X	
Ulmus pumila	Siberian elm					X	A
Utricularia cornuta	horned bladderwort					X	T
Utricularia gibba	humped bladderwort					X	
Utricularia minor	small bladderwort					X	
Utricularia vulgaris	great bladderwort				X		
Vaccinium angustifolium laevifolium	early low blueberry					X	
Vaccinium vacillans	late low blueberry					X	
Vallisneria americana	eel grass				X		
Verbascum thapsus	common mullein		X	X	X	A	
Verbena hastata	blue vervain			X	X	X	
Verbena stricta	hoary vervain			X		X	
Vernonia missurica	Missouri ironweed					X	
Veronicastrum virginicum	Culver's root				X		
Viburnum acerifolium	maple-leaved arrow-wood				X		
Viburnum lentago	nannyberry					X	
Viburnum prunifolium	black haw		X				
Viburnum rafinesquianum	downy arrow-wood					X	
Vicia americana	American vetch		X				
Viola conspersa	dog violet				X		
Viola fimbriatula	sand violet					X	
Viola lanceolata	lance-leaved violet			X			
Viola papilionacea	common blue violet				X		
Viola pedata lineariloba	bird's foot violet				X		
Viola pensylvanica	smooth yellow violet					X	
Viola sagittata	arrow-leaved violet			X			
Viola tricolor	pansy violet		X	A			
Vitis aestivalis	summer grape		X				
Vitis labrusca	fox grape			X			
Vitis riparia	riverbank grape	X	X				
Vitis vulpina			X				
Xanthium strumarium	cocklebur		X	A			
Zizania aquatica	wild rice		X				
Zizania aurea	meadow parsnip	X					

AQUATIC MACROINVERTEBRATES

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INTRODUCTION

Macroinvertebrates--animals visible to the naked eye but that do not have backbones--are an extremely large, diverse group. Those with aquatic life stages are sensitive to various degrees to the physical and chemical characteristics of their aquatic environment, such as water temperature, flow rate, acidity, dissolved oxygen concentration, siltation rate, and types of pollution present. Aquatic macroinvertebrates can therefore be quite useful in indicating the status or quality of aquatic habitats. The purpose of this chapter is to describe the historical and present distribution of aquatic macroinvertebrates in the Grand Calumet River and Indiana Harbor Canal, to ascertain present macroinvertebrate habitat quality, and to explore sediment clean-up and restoration alternatives and their possible effects on macroinvertebrate communities.

HISTORICAL MACROINVERTEBRATE COMMUNITIES

The Grand Calumet River has undergone many changes in its history, as described in detail in previous chapters of this appendix. The macroinvertebrate populations in the River responded to these changes as various characteristics of their habitat were altered. Although there are no records for the macroinvertebrate communities prior to channelization and industrialization, enough is known about the characteristics of the River to estimate community composition. The Grand and Little Calumet once formed a single slow-flowing, heavily vegetated river draining a vast wetland and emptying into Lake Michigan near present-day Marquette Park and the Grand Calumet Lagoons (Moore 1959). They probably supported what Shelford (1977) calls a sluggish river community. Even in Shelford's time (orig. pub. 1913), the Grand Calumet was a sluggish river.

Shelford divides the sluggish river community into three "formations," the pelagic formation, the sand and silt bottom formation, and the zone of vegetation formation. The pelagic, or open-water, formation is well-developed in larger rivers, and was probably most important near the mouth of the Grand Calumet. This does not differ greatly from the pelagic formation of Lake Michigan, which includes copepods, cladocerans, roundworms, planarians, and leeches.

The sand and silt bottom formation includes mussels (*Anodonta grandis* and *Quadrula undulata*), the snail *Goniobasis livescens*, midge larvae, the bryozoan *Plumatella*, and occasional caddisfly larvae (*Hydropsyche*). Near the margin, a sandy bottom will include occasional snails (*Goniobasis*, *Pleurocera*, and *Campeloma*), midge larvae, occasional burrowing mayfly larvae, a number of mussels (*Unio gibbosus* and *Quadrula rubiginosa* being most characteristic), and occasionally a long-legged dragonfly larva (*Macromia taeniolata*). A silty bottom will include the mussels *Quadrula undulata* and *Lampsilis siliquoidea*, the burrowing mayfly larva *Hexagenia*, midge larvae, segmented worms, sphaeriid clams, and the mud leech *Haemopis grandis*.

The zone of vegetation formation includes the water scorpion *Ranatra fusca*, the creeping water bug *Pelocoris femoratus*, the small water bug *Zaitha fluminea*, water boatman, the stillwater brook beetle *Elmis quadrinotatus*, several species of predaceous diving beetles, water scavenger beetles, mayfly larvae (*Caenis* and *Callibaetis*), the damselfly larva *Ischnura verticalis*, and dragonfly larvae (Aeschnidae and Libellulidae). It includes the pulmonate snails *Physa integra*, *Helisoma anceps*, and often species of *Lymnaea*. In addition, it includes the crayfish *Cambarus propinquus*, the amphipods *Hyalella azteca* and *Gammarus fasciatus*, viviparous snails (*Campeloma*), and an occasional mussel *(Anodonta grandis)*. This zone was well-developed in the Grand Calumet River.

As the area became more populated and industrialized, the Grand Calumet was degraded both physically and chemically. Canals and ditches were dug, wetlands were drained and filled, and stretches of river were dredged or moved, severely altering the hydrology of the area (Moore 1959). Industrial waste, sewage, and urban runoff increased the River's flow and contributed large amounts of solids, including organic matter and toxic chemicals. Between 1913 and 1937, many of the Chicago region's natural areas that Shelford studied were severely damaged, including a Grand Calumet site that was "destroyed by industrial waste" (Shelford 1977). Into the 1960's, most of the River was devoid of higher forms of aquatic life (FWPCA 1966). Since then, however, pollution controls have resulted in improvements in the River's water quality and aquatic communities. For example, while only 22 to 108 earthworms / m^2 were found in Indiana Harbor mouth sediments in the early 1960's, between 2,400 and 500,000 / m^2 were found in the same area in 1973 (CMSD 1980). Although aquatic earthworms are still the dominant taxon in the sediments of the Indiana Harbor and Canal, other, less pollution-tolerant, macroinvertebrates are now, at least, present (IDEM unpub. data; Risatti and Ross 1989).

MACROINVERTEBRATE STUDIES

Information from five studies was combined to develop a fairly comprehensive database on Grand Calumet River macroinvertebrates. Following is a short description of the macroinvertebrate study methods in chronological order. Please refer to Figure 1 for locations.

U.S. Geological Survey and Indiana Dunes National Lakeshore study (Hardy 1984)

Benthic (bottom) macroinvertebrate data from the Grand Calumet River Lagoons were collected by the U.S. Geological Survey from November 1978 to July 1980. Organisms were collected on jumbo multi-plate artificial substrates placed in the East (NPS1) and West (NPS2) Lagoons for six weeks. One jumbo multi-plate substrate was placed in each of the two sites. The sites were sampled on November 1978, August 1979, and July 1980. All organisms were identified to genus, except the leeches (Hirudinea), earthworms (Oligochaeta), and water mites (Acari), which were not identified any further.

Indiana Department of Environmental Management study (IDEM unpublished data)

Benthic macroinvertebrate data from the Grand Calumet River and Indiana Harbor Canal were collected by the Indiana Department of Environmental Management from 1979 to 1988. The 1986-1988 data have been summarized by Bright (1988). Macroinvertebrates were collected with one to three multi-plate Hester-Dendy artificial substrate samplers per site. The samplers were generally left in the water from six to eight weeks. Two samplers were collected from the East Branch of the Grand Calumet at Virginia Street (IDEM1) in 1987. Three samplers were collected from the East Branch at Bridge Street (IDEM2) in 1986, and two in both 1987 and 1988. Two samplers were collected from the East Branch at Cline Avenue (IDEM3) in both 1986 and 1988, and one in 1987. Three samplers were collected from the East Branch at Kennedy Avenue (IDEM4) in 1986, and two in 1988. Three samplers were collected from the West Branch of the Grand Calumet at Indianapolis Boulevard (IDEM5) in 1986. One sampler was collected from the mouth of the West Branch (IDEM6) in 1987, and two in 1988. Three samplers were collected from Lake George Canal at the railroad bridge (IDEM7) in 1986, and one in 1987. Three samplers were collected from Indiana Harbor Canal at Dickey Rd (IDEM8) in 1979, 1980, and 1981, and two in 1986, 1987, and 1988. Most organisms other than the aquatic earthworms were identified to genus or species if possible; however, the midges (Chironomidae) were usually not identified beyond family from every Hester-Dendy collected during a single sampling.

Illinois Natural History Survey study (Risatti and Ross 1989)

Benthic macroinvertebrate data from Indiana Harbor and Indiana Harbor Canal were collected by the Illinois Natural History Survey on 3 and 4 May 1988. Two petite Ponar grab samples were collected from each site, one for organism enumeration and identification, and one for determination of wet and dry biomass standing crop for the dominant taxa. Each grab sample was washed in a #30 mesh screen bucket and preserved in 10% buffered formalin. One site (INHS1) was located in Lake George Canal, just west of Indianapolis Boulevard. Three sites were located in Indiana Harbor Canal: INHS2, just downstream of Columbus Drive; INHS3, just downstream of Route 912; and INHS4, just downstream of Dickey Road. Two sites were located in Indiana Harbor: INHS5, near the south end of the harbor; and INHS6, near the north end of the harbor. Sexually mature tubificid earthworms were identified to species level; other organisms were identified to family or genus level.

TAMS Consultants, Inc., study (Mierzwa et al. *1991)*

Benthic macroinvertebrate data from the Grand Calumet River were collected by TAMS Consultants, Inc.(Mierzwa et al. 1991), in 1990 and 1991. Three petite Ponar grab samples were collected from each site for each sampling period. Each sample was washed in a #30 mesh screen bucket and then preserved in 10% buffered formalin. The East Branch was sampled at

Route 12 (TAMS1) July 1990, November 1990, and May 1991, and at Cline Avenue (TAMS2) November 1990 and May 1991; the West Branch was sampled at Burnham Avenue (TAMS3) November 1990, May 1991, and July 1991. Most organisms were identified to genus or species level, except the aquatic earthworms and midges, which were identified to family and subfamily, respectively. Numerical data were not published.

U.S. Fish and Wildlife Service study (Sobiech et al. *1994)*

Benthic macroinvertebrate data from the East Branch of the Grand Calumet River were collected by the U.S. Fish and Wildlife Service in 1994. Five multi-plate artificial substrate samplers consisting of five 5.8-cm diameter circular discs were placed at each site on 19 May 1994 and were retrieved on 29 June 1994. Qualitative (non-numerical) sampling was also performed. Only qualitative sampling was possible at the site upstream of Tennessee Street (FWS1). The East Branch was also sampled: FWS2, just downstream of Broadway Avenue; FWS3, just upstream of Interchange 13 entrance/exit ramps of I-90; FWS4, downstream of Bridge Street; and FWS5, at the Wabash railroad trestle. All organisms were identified to family level, except the aquatic earthworms (Oligochaeta), leeches (Hirudinea), scuds (Amphipoda), and crayfish (Decapoda), which were not identified any further.

MACROINVERTEBRATES BY REACH

Lagoons reach

This section includes the Grand Calumet River Lagoons east of USX, and the sites NPS1 and NPS2 (Figure 1). The Lagoons reach is different from the other reaches in that it is connected to the rest of the river by partially-constricted culverts. The most common taxa in this reach were the snail genus *Ferrissia* and the scud genus *Hyalella* in the East Lagoon and *Hyalella*, the midge genus *Glyptotendipes*, and the damselfly genus *Ischnura* in the West Lagoon (Hardy 1984) (Attachment 1). Although none of these taxa are considered particularly sensitive to pollution, the highest diversity of benthic invertebrates was found in this reach, including several sensitive taxa that were not found anywhere else (Attachments 1and 2).

Interestingly, the diversity indexes in the West Lagoon were lower than in the East Lagoon during wet periods--November 1978 and August 1979--and higher during the dry period--July 1980 (Hardy 1984). The suggested causes were lower seepage from the landfills north and south of the West Lagoon and greater organic enrichment in the East Lagoon. In addition, high ammonium concentrations in the West Lagoon (130 to 160 times those common in surface water) corresponded with low diversity indexes, suggesting a possible source of stress on the West Lagoon community.

USX reach

This reach includes the East Branch of the Grand Calumet River bordering the USX property. Sampling sites from east to west are: FWS1, IDEM1, FWS2, FWS3, IDEM2, FWS4, and FWS5 (Figure 1). The most common taxa found in this reach were midges, the snail family

Physidae, aquatic earthworms, and leeches (Attachment 1). In addition, the snail genus *Ferrissia* was common at IDEM2. At IDEM2, the only site at which midges were identified below family level, the most common midge was *Cricotopus bicinctus*. Invertebrate Community Index (ICI) metric evaluation of the FWS study indicated that the invertebrate community of this reach was severely impaired (Sobiech *et al.* 1994). All sites received a total ICI score of 2 or lower and were classified as having very poor or poor invertebrate biotic integrity. The unbalanced trophic structure of the community, which was dominated by gathering collectors, also indicated degraded environmental conditions.

Gary Sanitary District reach

This reach includes the East Branch of the Grand Calumet River from the USX property to Cline Avenue. Sampling sites from east to west include: TAMS1, TAMS2, and IDEM3 (Figure 1). The most common taxa in this reach were aquatic earthworms, leeches, and the snail family Physidae, plus midges at IDEM3 (Attachment 1). The midges *Cricotopus* (unidentified) and *Cricotopus bicinctus* (possibly the same species) were common at IDEM3. The identification of damselfies and higher numbers of midges at IDEM3 is probably due to the use of Hester-Dendy artificial substrates at that site versus a petite Ponar at the TAMS sites. Mierzwa *et al*. (1991) found that, although the species richness, species diversity, and equitability of TAMS1 and TAMS2 were fair, the Macroinvertebrate Biotic Indexes (MBIs) were quite poor, indicating pollution stress. In addition, the investigators noted a strong petroleum and sulfur odor and an anoxic appearance of the sediments.

DuPont reach

This section includes the East Branch of the Grand Calumet River from Cline Avenue to the Indiana Harbor Canal. Sampling sites from east to west include: TAMS2, IDEM3, and IDEM4 (Figure 1). Note that TAMS2 and IDEM3 are also included in the Gary Sanitary District Reach and are listed under that reach in Figure 1. The most common taxa found in the DuPont Reach were aquatic earthworms, leeches, and the snail family Physidae, plus midges at IDEM3 and IDEM4 (Attachment 1). The midges *Cricotopus* (unidentified) and *Cricotopus bicinctus* (possibly the same species) were common at IDEM3. The identification of damselfies and higher numbers of midges at the IDEM sites is probably due to the use of Hester-Dendy artificial substrates at those sites versus a petite Ponar at TAMS2. Mierzwa *et al*. (1991) found that, although the species richness, species diversity, and equitability of TAMS2 were fair, the Macroinvertebrate Biotic Index (MBI) was quite poor, indicating pollution stress. In addition, the investigators noted a strong petroleum and sulfur odor and an anoxic appearance of the sediments.

Far West reach

This reach includes the West Branch of the Grand Calumet River from the Illinois/Indiana state line to the Little Calumet River, and the site TAMS3 (Figure 1). Only two taxa were identified at this site--the aquatic earthworm family Lumbriculidae and midge subfamily Chironominae (Attachment 1). Mierzwa *et al*. (1991) found this site to have very poor macroinvertebrate habitat, as indicated by its consistently low species richness, diversity, and equitability, and high (low quality) MBI.

Culverts reach

This reach includes the West Branch of the Grand Calumet River from Columbia Avenue to the Illinois/Indiana state line. None of the sampling sites are found within this reach. However, due to industrial and municipal impacts on sediment and water quality in the area, it is unlikely that the macroinvertebrate habitat is better than that in the Roxanna Marsh reach.

Hammond Sanitary District reach

This reach includes the West Branch of the Grand Calumet River from the Hammond/East Chicago boundary to Columbia Avenue. None of the sampling sites are found within this reach. However, due to industrial and municipal impacts on sediment and water quality in the area, it is unlikely that the macroinvertebrate habitat is better than that in the Roxanna Marsh reach.

Roxanna Marsh reach

This section includes the West Branch of the Grand Calumet River from Indianapolis Boulevard to the Hammond/East Chicago boundary, and sampling site IDEM5 (Figure 1). The most common taxa found were the snail genus *Physa*, the midge *Parachironomus abortivus*, and the midge *Chironomus decorus* (Attachment 1). All of these are quite pollution-tolerant (Attachment 2), suggesting very poor habitat. A hydrologic divide occurs at the western end of this reach, so that some of the water flows west to join the Little Calumet River and some flows east to Lake Michigan via the Indiana Harbor Canal.

East Chicago Sanitary District reach

This section includes the West Branch of the Grand Calumet River from Indianapolis Boulevard to the Indiana Harbor Canal, and sampling site IDEM6 (Figure 1). The most common taxa found were the aquatic earthworms and crane flies (Tipulidae) (Attachment 1). Since crane fly larvae are considered only slightly pollution-tolerant (Attachment 2), this site may have somewhat better macroinvertebrate habitat than most. However, although crane fly larvae were the majority of the organisms collected in 1987, earthworms were quite dominant on the two samplers collected in 1988 (IDEM unpub. data), suggesting very poor habitat.

Canal reach

This section is the portion of the Indiana Harbor Canal from the Grand Calumet River to Columbus Drive. None of the sampling sites are found within this reach. However, it is unlikely that the macroinvertebrate habitat is better than that in the Roxanna Marsh, East Chicago Sanitary District, and DuPont reaches, precede it in water flow.

Lake George reach

This section is the western portion of Lake George Canal, ending approximately 1100 ft west of Indianapolis Boulevard, and it includes the site IDEM7 (Figure 1). The most common taxa found were bryozoans (Bryozoa), aquatic earthworms, the snail genus *Physa*, and *Hydra* (Attachment 1). Most of these are highly pollution-tolerant (Attachment 2), indicating that the macroinvertebrate habitat is probably poor.

Federal Dredging Project reach

The Federal Dredging Project reach, although not specifically addressed in this study, can provide additional information on Grand Calumet macroinvertebrate populations. This section includes the Indiana Harbor and Canal from Lake Michigan to Columbus Drive and the eastern portion of Lake George Canal to approximately 1100 ft west of Indianapolis Boulevard. Sampling sites are: INHS1 in Lake George Canal; INHS2, INHS3, IDEM8, and INHS4 in Indiana Harbor Canal; and INHS5 and INHS6 in Indiana Harbor (Figure 1). The most common taxa found were aquatic earthworms, identified as the family Tubificidae in the INHS sites, the snail family Hydrobiidae and hydras (Hydridae) at INHS5, and bryozoans (Bryozoa) at IDEM8 (Attachment 1).

Many taxa, such as the midges, mayflies (Ephemeroptera), caddisflies (Trichoptera), damselflies, and snails (other than Hydrobiidae), were identified at IDEM8 but not at the INHS sites. These differences likely stem from the different sampling methods used (Hester-Dendy versus petite Ponar) and number of samples collected, rather than real differences in the communities. For example, both IDEM8 and INHS4 are in Indiana Harbor Canal near Dickey Road, yet at least 19 taxa were found at IDEM8 and only four at INHS4. The enumeration and identification data in the INHS study, however, were obtained from a single petite Ponar grab, whereas the IDEM data at this site are drawn from 15 Hester-Dendy artificial substrate collections over nine years. The IDEM data also show a general increase in richness and diversity from 1979-1988, with a peak in 1986 probably caused by historic highs in Lake Michigan water levels (Bright 1988). Although the invertebrate community in this reach is probably degraded, as indicated by the dominance of aquatic earthworms at every site, it may not be as poor as the INHS data suggest.

SPECIES LIST AND DESCRIPTIONS

Sponges (phylum Porifera)

Members of the phylum Porifera, the sponges, are the simplest of the multicellular animals. Of the more than 5000 species of sponges, the vast majority are marine, and only about 27 species occur in the fresh waters of the United States and Canada (Frost 1991). Freshwater sponges are common in unpolluted ponds, lakes, streams, and rivers, and they may be found attached to almost any stable submerged object (Pennak 1989). Most freshwater sponges obtain nourishment through both filtration and large numbers of symbiotic algae living within their cells; they use these sources in different proportions depending on environmental conditions

(Frost 1991). They may be fed upon by fish, crayfish, and possibly snails, but their primary "predators" are aquatic insects, many of which depend upon them for survival. Water mites also depend on sponges, not for food, but for structure. A sponge may also provide a home for many other small invertebrates, including protozoans, rotifers, roundworms, earthworms, bivalves, and aquatic insects. In most lakes and streams, sponge populations do not reach numbers high enough to have an important role in the ecosystem, although there are notable exceptions.

Sponges were found in Indiana Harbor Canal (Federal Dredging Project Reach) at IDEM8 in 1986 (Figure 1 and Attachment 1). They were described as "abundant" on one of the two Hester-Dendy samplers retrieved from that location, and were not identified any further. Sponges are generally sensitive to variations in environmental conditions, and several U.S. species have become extinct within the last twenty to forty years, mainly due to pollution (Pennak 1989). However, sponges have been observed in a variety of polluted waters, their distribution depending upon the type and quantity of pollutant and individual species tolerances (Harrison 1974).

Coelenterates (phylum Cnidaria/Coelenterata)

Hydras (family Hydridae)

Coelenterates, like the sponges, are primarily marine animals. Of the more than 9000 species known, only about 20 have been found in the fresh waters of the United States; these include 16 hydras, one uncommon jellyfish, one uncommon colonial polyp, and one rare protohydroid from brackish coastal waters (Pennak 1989). Hydras may be found in most ponds, spring brooks, unpolluted streams and rivers, and lake shallows, attached to stones, twigs, vegetation, or debris. All coelenterates are carnivores, using stinging capsules, called nematocysts, to paralyze and/or encumber their prey before moving it to their mouth with tentacles (Slobodkin and Bossert 1991). Prey include water fleas, copepods, insects, and segmented worms (Pennak 1989). Hydras can kill small fish, and they are sometimes serious pests of fish hatcheries (Slobodkin and Bossert 1991). Predation on freshwater coelenterates is not well studied, but appears to be minimal. Hydras are eaten by flatworms, the chydorid cladoceran *Anchistropus*, and the amoeba *Hydraamoeba hydroxena*. Commensal or parasitic ciliates, such as *Kerona* and *Trichodina*, are common on the external surfaces of hydras (Pennak 1989).

Hydras were found in 1987 and 1988 at three sites in the Federal Dredging Project reach: IDEM7, INHS5, and INHS6 (Figure 1 and Attachment 1). They were identified as *Hydra* at IDEM7 and Hydridae at the other two sites. The class Hydrozoa has been rated quite tolerant of certain natural phenomena, such as high alkalinity, sulfate concentrations, and sedimentation, and low stream gradients (USDA Forest Service 1989) (Attachment 2). Although hydras have been used as an indicator of moderately organically enriched streams and rivers in South Africa (Chutter 1972) (Attachment 2), a more recent study has found them to be characteristic of natural conditions (Patrick and Palavage 1994) (Attachment 2). Hydras are very sensitive to heavy metals and detergents (Slobodkin and Bossert 1991). It is likely that hydras inhabit other areas of the Grand Calumet River as well, since they are often either not collected or not well-preserved in routine collections due to their small size, soft bodies, and often sessile habits.

Phylum Platyhelminthes

Flatworms (class Turbellaria)

The phylum Platyhelminthes includes three classes: Cestoidea (tapeworms) and Trematoda (flukes), which are entirely parasitic; and Turbellaria (flatworms), which are almost exclusively a free-living group (Pennak 1989). Flatworms are common inhabitants of fresh waters, and more than 200 species occur in the fresh waters of North America (Kolasa 1991). They are found everywhere, usually on or associated with a substrate (Pennak 1989). The group is divided into microturbellarians, most of which are less than 1 mm in length, and macroturbellarians, most of which are greater than 10 mm in length (Kolasa 1991). The macroturbellarians are represented by the order Tricladida (planarians); these include the flatworms familiar to many high school and college biology students (Pennak 1989). Microturbellarians consume bacteria, algae, protozoans, and invertebrates, and planarians feed predominantly on larger invertebrates; scavenging is also common in both groups (Kolasa 1991). Parasites of microturbellarians include ciliates and flagellates, which frequently parasitize Catenulida and Typhloplanida, and roundworms, which have been found in Lecithoepitheliata. Microturbellarians may occasionally be eaten by invertebrates, such as the midge *Anatopynia*, or other flatworms; planarians may occasionally be eaten by fish.

Flatworms were identified at IDEM1 in the USX reach and IDEM6 in the East Chicago Sanitary District reach (Figure 1 and Attachment 1). They were not identified to a lower level than class, but were most likely planarians due to the inherent difficulty of recognizing the very small microturbellarians. Flatworms have been rated quite tolerant of certain natural phenomena and moderately tolerant of general pollution (USDA Forest Service 1989; Illinois EPA 1985) (Attachment 2). Planarians are generally intolerant of organic pollution, although some species have been observed in heavily polluted waters (Kenk 1974). They have been used as indicators of slightly enriched waters (Chutter 1972) (Attachment 2). Planarians are generally less sensitive to pesticides and herbicides than other invertebrates (Kenk 1974). It is likely that flatworms also occur in some of the other study sites but were not observed because of their often small size and/or because they often become unrecognizable after routine preservation in alcohol or formalin (Kolasa 1991).

Roundworms (phylum Nematoda)

Roundworms occur in a wide variety of habitats and are one of the most common animals on earth. They have been studied relatively little in fresh waters, mainly due to sampling, extraction, and identification difficulties (Poinar, Jr. 1991). Nearly 70 genera of freshwater roundworms have been reported in North America. These include all types of feeding habits: some eat only dead plant material; some only dead animal material; some both dead animal and dead plant material; some only live plants; and some live animals, including protozoans, earthworms, rotifers, gastrotrichs, tardigrades, and other roundworms (Pennak 1989). Freshwater roundworms are consumed by other predaceous roundworms, the crayfish *Pacifastacus leniusculus*, the flatworm *Microstomum*, and the nemertean worm *Prostoma* (Poinar, Jr. 1991).

Roundworms were found in the Gary Sanitary District and DuPont Reaches at TAMS2 (Figure 1 and Attachment 1). They were not identified any further. Freshwater roundworms have been rated quite tolerant of certain natural phenomena and indicative of organically enriched or polluted waters (Attachment 2). However, they are not uniformly sensitive to pollutants (Poinar, Jr. 1991), and a recent study did not rate them as being either pollution-tolerant or intolerant (Attachment 2). It is likely that roundworms also inhabit other areas, but their small size (most < 1 cm in length) would make it easy for them to slip through the #30 sieves or to be unobserved during the separation of the macroinvertebrates from the rest of the samples.

Bryozoans (phylum Bryozoa/Ectoprocta and Endoprocta)

Bryozoans have been called "moss animals" because colonies of some common species can resemble a mat of moss. Approximately 4000 marine species of bryozoans have been described, and only about 50 freshwater species, including about 22 in the United States (Pennak 1989). Freshwater bryozoans attach to submerged surfaces, and will grow on aquatic vegetation and almost any solid, biologically inactive material (Wood 1991). They occur in both still and running water, but are generally restricted to relatively warm water. Freshwater bryozoans use ciliated tentacles for capturing suspended food particles, which may include diatoms, desmids, dinoflagellates, green and blue-green algae, bacteria, rotifers, small roundworms, protozoa, and even microcrustaceans, along with detritus and inorganic materials. However, little is known about bryozoan nutrition other than what they ingest, and items that are ingested are not necessarily digested. Flatworms, snails, earthworms, water mites, crustaceans, caddisflies, midges, and small fish graze on bryozoans, and many small animals, especially ciliates and rotifers, live on bryozoan colonies (Pennak 1989).

Bryozoans were identified in the Lake George reach at IDEM7 and the Federal Dredging Project reach at IDEM8 in 1986, 1987, and 1988, and were described as "abundant" or "dominant" in most samples (Figure 1 and Attachment 1). They were identified as *Plumatella* on one of the Hester-Dendy samplers collected from IDEM8 in 1986. Freshwater bryozoans have various pollution tolerances, *Fredericella sultana*, *Plumatella emarginata*, and *P. repens* being particularly tolerant of contamination from sewage and industrial wastes (Bushnell 1974). However, all species have been found most often in clean or mildly polluted habitats, so none should be considered indicators of pollution.

Segmented worms (phylum Annelida)

Aquatic Earthworms (class Oligochaeta)

The segmented worms include five classes that are represented in fresh waters: Oligochaeta, Hirudinea, Polychaeta, Branchiobdellida, and Archiannelida (Pennak 1989). Of these, two--Oligochaeta and Hirudinea--were collected in the Grand Calumet River. The earthworms have ten families that include freshwater representatives. Aquatic earthworms are smaller than their amphibious and terrestrial relatives, usually between 1 and 30 mm in length. They are found in every kind of freshwater and estuarine habitat, including groundwater (Brinkhurst and Gelder

1991). The vast majority of aquatic earthworms feed by ingesting bottom sediments and digesting the organic component (Pennak 1989). *Chaetogaster*, one of the few carnivorous freshwater aquatic earthworms, feeds on entomostraca, insect larvae, protozoans, and other aquatic earthworms. *Aeolosoma* feeds on microorganisms and fine particulate debris, using cilia to sweep them toward its mouth. The burrowing activity of aquatic earthworms can contribute greatly to sediment mixing and solute transport across the mud-water interface (Brinkhurst and Gelder 1991).

Aquatic earthworms were found at every site except NPS2 in the Lagoons reach (Figure 1 and Attachment 1). They were identified simply as aquatic earthworms at the NPS, FWS, and IDEM sites. The family Lumbricidae was collected at TAMS1 and 2 (Gary Sanitary District reach), and the family Lumbriculidae was collected at TAMS1, 2, and 3 (Far West reach). The family Tubificidae was identified at the INHS sites in the Federal Dredging Project reach as: *Limnodrilus*, *Limnodrilus cervix*, *Limnodrilus hoffmeisteri*, *Potamothrix vejdovskyi*, and *Quistadrilus multisetosus*. In addition, immature worms without capilliform chaetae were found at all six sites, and those with capilliform chaetae were found at INHS2.

Aquatic earthworms are generally considered quite tolerant of pollution and/or enrichment (Attachment 2). Species composition can be a valuable indicator, however, with a series of species groups inhabiting progressively more polluted stretches of rivers or more eutrophic lakes (Brinkhurst and Gelder 1991). In the Great Lakes, there are basically three species associations of Tubificidae: *T. tubifex*, *Peloscolex multisetosus*, and several *Limnodrilus* species (dominated by *L. hoffmeisteri* and *T. tubifex*), characteristic of organically polluted bays and harbors; *Aulodrilus*, *Potamothrix*, *Limnodrilus* and *Peloscolex ferox*, characteristic of eutrophic conditions; and *L. hoffmeisteri, T. tubifex*, and many species not often found in the other areas, characteristic of "clean" waters (Brinkhurst and Cook 1974).

Leeches (class Hirudenea)

The leeches are predominantly freshwater organisms, with about 60 freshwater species known in the United States (Pennak 1989). They commonly inhabit ponds, marshes, lakes, and slow streams, particularly in the northern half of the country, and the same species may occur in a variety of environments. Leeches are represented in North America by four families: Glossiphoniidae, which either prey upon macroinvertebrates or temporarily parasitize fish, turtles, amphibians, or water birds; Piscicolidae, which parasitize fish and crustaceans; Erpobdellidae, which primarily prey upon macroinvertebrates and zooplankton; and Hirudinidae, which either prey upon macroinvertebrates or suck the blood of amphibians and mammals (Davies 1991). Predators of leeches include fish, birds, garter snakes, newts, salamanders, insects, snails, and scuds.

Leeches were identified at all sites except FWS1 in the USX reach; TAMS3 in the Far West reach; and INHS1, 3, 4, 5, and 6 in the Federal Dredging Project reach (Figure 1 and Attachment 1). No leeches were identified below class at the NPS or FWS sites. The family Erpobdellidae was identified to: family, *Dina microstoma* (uncertain), *Dina parva*, *Erpobdella punctata*, *Mooreobdella*, *Mooreobdella fervida*, and *Mooreobdella microstoma*. The family Glossiphoniidae was represented by *Helobdella*, *Helobdella stagnalis,* and *Placobdella*.

Cocoons were identified at IDEM4, 5, and 7. It is possible that the lack of leeches found at the INHS sites was partially due to the sampling methods used (*i.e.*, one petite Ponar grab per site).

Leeches are generally considered pollution tolerant (Attachment 2). However, different leech species have different tolerances to pollution, with only about a dozen in the United States and Canada that are commonly or occasionally associated with polluted water (Sawyer 1974). *Helobdella stagnalis* and *Erpobdella punctata* are by far the most important of these, but they are common and can only be considered indicator species in terms of unusually high densities. *Mooreobdella microstoma* and *Dina parva* are occasionally associated with disturbed environments. Patrick and Palavage (1994) rated *Dina parva*, *Erpobdella punctata*, and *Helobdella stagnalis* pollution-tolerant species (Attachment 2).

Mollusks (phylum Mollusca)

Snails (class Gastropoda)

The snails comprise almost three quarters of the 110,000 or so described species of mollusks (Brown 1991). In North America, there are 349 species of freshwater snails in the subclass Prosobranchia ("gilled" snails) and 150 species in the subclass Pulmonata ("lunged" snails). Snails are found in almost every type of freshwater habitat (Pennak 1989). Freshwater snails are either herbivores, preferring algae and diatoms, or detritivores, but they will occasionally eat carrion (Brown 1991). The families Ancylidae, Lymnaeidae, Neritinidae, Pleuroceridae, and Viviparidae are generally herbivores, whereas the Physidae, Planorbidae, and Viviparidae are detritivores and/or bacterial feeders. Perhaps the greatest natural enemies of snails are fish, including suckers, perch, freshwater drum, pumpkinseed sunfish, and whitefish (Pennak 1989). Many invertebrates, such as crayfish, aquatic insects, leeches, and flatworms, feed on snails (Brown 1991). Also, ducks, shorebirds, and amphibians may occasionally eat snails (Pennak 1989).

Snails were found at every site except TAMS3 in the Far West reach and INHS1, 2, 3, 4, and 6 in the Federal Dredging Project reach (Figure 1 and Attachment 1). The family Ancylidae was identified to *Ferrissia*. The family Hydrobiidae was identified to family and *Amnicola*. The family Lymnaeidae was identified to family and *Lymnaea*. The family Physidae was identified to family, *Aplexa*, *Physa*, and *Physella*. The family Planorbidae was identified to family, *Gyraulus*, *Helisoma*, *Planorbula*, and *Promenetus*. The family Valvatidae was identified to *Valvata*.

Most snails require rather high dissolved oxygen concentrations, so they are seldom found in severely polluted rivers or the deeper parts of lakes that become oxygen deficient (Pennak 1989). Other factors that can reduce the diversity of snails in a body of water are low pH values, heavy metals, pesticides, temperatures too warm or cold, and organic pollution (Harman 1974). The pulmonates (Ancylidae, Lymnaeidae, Physidae, and Planorbidae) are more resistant to organic pollution. Of the snails found in these studies, *Valvata* and *Amnicola* are the least pollution tolerant (Attachment 2).

Bivalves (Class Bivalvia/Pelecypoda)

Bivalves, including clams and mussels, occur in almost all types of freshwater habitats, but are particularly common in larger rivers (Pennak 1989). There are 266 species in North American fresh waters, including 227 in the superfamily Unionacea, 37 in the family Sphaeriidae (four introduced), and two additional exotics, *Corbicula fluminea* (Asiatic clam) and *Dreissena polymorpha* (zebra mussel) (McMahon 1991). The vast majority of freshwater bivalves feed by filtering suspended microscopic particles, such as organic detritus and plankton (Pennak 1989). Freshwater bivalves' most important predators may be fish, including shad, carp, suckers, catfish, sunfish, and freshwater drum (McMahon 1991). They are also eaten by otters, minks, muskrats, raccoons, shore birds, ducks, crayfish, fire ants (when water levels recede), turtles, frogs, and mudpuppy salamanders. Freshwater bivalves are hosts for various parasites, including flukes, roundworms, the aquatic earthworm *Chaetogaster limnaei*, and water mites of the family Unionicolidae.

Bivalves were identified at FWS2, 4, and 5 in the USX reach; TAMS1, TAMS2, and IDEM3 in the Gary Sanitary District and DuPont reaches; IDEM7 in the Lake George reach; and INHS1, 4, and 6 in the Federal Dredging Project reach (Figure 1 and Attachment 1). Asiatic clams (identified as Corbiculidae) were identified at FWS2, 4, and 5. Zebra mussels (identified as Dreissenidae) were identified at FWS2. Sphaeriidae was identified to family at IDEM3, IDEM7, INHS1, and INHS6; *Pisidium* at TAMS2 and INHS1; and *Sphaerium* TAMS1, TAMS2, and INHS4. No unionaceans were found.

Bivalves are adversely affected by various forms of pollution, including chemical wastes, asbestos, heavy metals, chlorine and paper mill effluents, urban wastewater effluents, and silt and acid discharges from mines (McMahon 1991). They have been rated both quite tolerant of certain natural phenomena and indicative of clean unpolluted waters (Attachment 2). Species diversity and density of unionaceans have declined greatly in North America in the last century, and many unionaceans are currently endangered (McMahon 1991). Many reasons have been postulated for this massive decline, including the freshwater pearling industry, extensive artificial impoundments, and channelization of drainage systems. *Corbicula* has been rated slightly tolerant of polluted conditions (Attachment 2). *Pisidium* and *Sphaerium* have been rated tolerant and somewhat tolerant of pollution (Attachment 2). Certain Sphaeriidae species, such as *Sphaerium transversum*, are tolerant of polluted, nearly septic conditions (Fuller 1974).

Crustaceans (subphylum Crustacea of phylum Arthropoda)

Water fleas (class Branchiopoda)

Although only about 10% of the nearly 40,000 species of crustaceans occur in fresh waters, they are extremely important in many freshwater ecosystem processes (Covich and Thorp 1991). Freshwater crustaceans in North America are divided into six classes: Cephalocarida, Branchiopoda, Remipedia, Maxillopoda, Ostracoda, and Malacostraca. The water fleas, also known as cladocerans, are currently grouped into four orders of the class Branchiopoda (Dodson and Frey 1991). Water fleas, small (most < 1 mm in length) transparent animals, are widespread, living in all but the harshest freshwater habitats. Some water fleas are bottom dwellers (benthos), whereas others inhabit open water. Most water fleas are filter-feeders, eating a variety of small particles including bacteria, algae, ciliates, and small rotifers. In addition, chydorids gather food by scraping, and *Leptodora*, *Polyphemus*, and *Bythotrephes* prey upon protozoans, rotifers, small midge larvae, and small crustaceans. Water fleas are an important food source for fish; in addition, they are eaten by hydras and immature and mature insects (Pennak 1989).

Water fleas were found at only one site--IDEM7 in the Lake George reach (Figure 1 and Attachment 1). Two organisms were identified in 1986, and they were not identified to a lower taxonomic level. Water fleas have been rated quite tolerant of certain natural phenomena (Attachment 2). Pollution tolerances vary among species, but most (19 out of 22) of the water flea species identified in the Delaware and Neches Estuaries and the Flint River in New England were rated characteristic of natural conditions by Patrick and Palavage (1994). It is likely that water fleas also inhabit other areas, but their small size would make it easy for them to slip through the #30 sieves or to be unobserved during the separation of the macroinvertebrates from the samples.

Class Malacostraca

Scuds (order Amphipoda)

The class Malacostraca includes the superorders Pancarida (order Thermosbaenacea), Peracarida (orders Mysidacea, Amphipoda, and Isopoda), and Eucarida (order Decapoda) (Covich and Thorp 1991). Of these, amphipods (scuds), isopods (sow bugs), and decapods (crayfish and shrimp) were found in the Grand Calumet River. Scuds occur in unpolluted lakes, ponds, streams, brooks, springs, and subterranean waters (Pennak 1989). With the exception of *Pontoporeia*, they are bottom species found only in shallow waters. Scuds are omnivorous, general scavengers or detritus feeders, or, occasionally, filter feeders. Predators of scuds include fish, birds, aquatic insects, and amphibians, and parasites include tapeworms, flukes, roundworms, and Acanthocephala. In addition, algae and protozoans thrive on their external surfaces.

Scuds were found in both of the Grand Calumet Lagoons and in the USX reach (Figure 1 and Attachment 1). They were identified simply as Amphipoda at FWS5, and to *Hyallela* (most likely *azteca*) at NPS1, NPS2, and IDEM1. They were common at NPS1 and 2. Since scuds generally require high dissolved oxygen concentrations, they are usually limited to clean, cold waters (Covich and Thorp 1991). Also, they are especially sensitive to copper and a number of other heavy metals. Scuds (and *Hyallela azteca*) have been rated quite tolerant of certain natural phenomena (Attachment 2). *Hyallela azteca* has been rated pollution-tolerant, moderately tolerant, and indicative of very significant organic pollution (Attachment 2).

Aquatic sow bugs (order Isopoda)

Most freshwater sow bugs are restricted to springs, spring brooks, streams, and interstitial and subterranean waters, but some may be found in ponds and lake shallows (Pennak 1989). Sow bugs are scavengers, eating dead and injured aquatic animals and both green and decaying vegetation. They are eaten by fish, and may be parasitized by roundworms and Acanthocephala.

Sow bugs were found only in the Lagoons reach (Figure 1 and Attachment 1). *Caecidotea (Asellus)* was identified at both NPS1 and 2, and *Lirceus* was identified at NPS1. Like scuds, sow bugs generally require high dissolved oxygen concentrations and are usually limited to clean, cold waters (Covich and Thorp 1991). Sow bugs are especially sensitive to copper and a number of other heavy metals. The family Asellidae, which includes *Caecidotea* and *Lirceus*, has been used as an indicator of severe organic pollution (Attachment 2). Asellidae and *Caecidotea* have been rated quite tolerant of certain natural phenomena (Attachment 2). *Caecidotea* has been rated pollution-tolerant and moderately tolerant, and *Lirceus* has been rated slightly tolerant (Attachment 2).

Crayfish (order Decapoda)

The order Decapoda, which includes a great diversity of marine, freshwater, and semiterrestrial crustaceans, is represented in North American fresh waters by freshwater shrimp and crayfish (Hobbs III 1991). The 386 described species and subspecies of crayfish in North America are assigned to twelve genera in two families, Astacidae and Cambaridae; only Cambaridae occurs in this area. Crayfish are common inhabitants of a wide variety of freshwater environments, including running waters, shallows of lakes, ponds, sloughs, swamps, subterranean waters, and even wet meadows (Pennak 1989). They are omnivores, eating all kinds of aquatic vegetation, snails, small fish, aquatic insects, and whatever they can scavenge. Crayfish are consumed by a variety of predators, including fish, wading birds, frogs, turtles, raccoons, otters, minks, and humans. They serve as hosts and/or growing surfaces for many organisms, including bacteria, algae, protozoans, fungi, worms, and crustaceans (Hobbs III 1991).

Crayfish (family Cambaridae) were identified at two sites, NPS1 in the Lagoons reach and FWS3 in the USX reach (Figure 1 and Attachment 1). Those found at NPS1 were identified as *Orconectes*. Channelization and siltation can be very detrimental to crayfish populations (Hobbs, Jr. and Hall, Jr. 1974). Although crayfish concentrations may increase with limited organic enrichment, organic pollution resulting in oxygen depletion will result in smaller populations of fewer species. Crayfish are highly sensitive to an increase in acidity (Hobbs III 1991). Crayfish have been rated quite tolerant of certain natural phenomena, and Cambaridae have been rated somewhat pollution-tolerant (Attachment 2).

Chelicerates (subphylum Chelicerata of phylum Arthropoda)

Arachnids (class Arachnida)

Water mites (subclass Acari)

The water mites include five distantly related groups in the subclass Acari (mites and ticks), with the most numerous and diverse group, by far, being the Hydrachnida (or Hydrachnellae, Hydracarina, or Hydrachnidia) (Smith and Cook 1991). Water mites inhabit many different habitat types, including springs, rapidly flowing areas of streams and rivers, sand and gravel deposits, cool pools, lakes, permanent ponds, wetlands, and temporary pools. Larval water mites parasitize many kinds of aquatic insects, and pre-adult and mature water mites prey on insect and fish eggs, insect larvae, ostracods, cladocerans, and copepods, scavenge on dead organisms, or parasitize bivalves. Water mites are eaten by a wide variety of aquatic invertebrates, particularly coelenterates and insects (Pennak 1989), and occasionally form a significant part of fish and turtle diets (Smith and Cook 1991).

Water mites were found at NPS2 in the Lagoons reach (Figure 1 and Attachment 1). They were not identified any further than Acari (formerly Acarina). Water mites are excellent indicators of environmental quality; their diversity is greatly reduced in chemically polluted or physically disturbed habitats (Smith and Cook 1991). Water mites have been rated as quite tolerant of certain natural phenomena and indicative of clean unpolluted waters (Attachment 2).

Subphylum Uniramia of phylum Arthropoda

Insects (class Insecta)

Mayflies (order Ephemeroptera)

The mayflies all have aquatic larvae which may be found in streams, rivers, lakes, and temporary or permanent ponds and marshes (Hilsenhoff 1991). Almost all mayfly larvae are herbivores or detritivores, but a few species prey on other invertebrates; the adults do not feed. Often, mayfly larvae are an important food source for fish in streams.

Mayflies were found at NPS1 and 2 in the Lagoons reach and IDEM8 in the Federal Dredging Project reach (Figure 1 and Attachment 1). The family Baetidae (small minnow mayflies) was represented by *Baetis* at NPS2 and IDEM8. The family Caenidae (small squaregills) was represented by *Caenis* at NPS1 and 2. The family Heptageniidae (flatheaded mayflies) was represented by *Stenonema* (*pulchellum* group) at IDEM8. Mayflies as a group are very important biological indicators for water quality because many species are very susceptible to water pollution or occur in predictable habitat types (McCafferty 1983).

Baetidae is a widespread and abundant family and can be found in a variety of streams, permanent and temporary ponds, and lake shallows (Hilsenhoff 1991). The family has been used as an indicator of clean unpolluted waters and possible slight organic pollution (Attachment 2). Habitats of *Baetis* include "torrential mountain streams, warm, meandering rivers, and still waters of northern Canada" (McCafferty 1983). *Baetis* has been rated moderately tolerant of certain natural phenomena, slightly pollution tolerant, and characteristic of natural conditions (Attachment 2).

Caenidae larvae are widespread and common in a wide variety of habitats, including streams, spring seeps, marshes, swamps, ponds, and lakes (Hilsenhoff 1991). They are generally more tolerant of low levels of dissolved oxygen than mayflies in other families. Caenidae is considered an indicator of clean, unpolluted waters, and *Caenis* has been rated moderately tolerant of certain natural phenomena, moderately pollution tolerant, indicative of significant organic pollution, and characteristic of natural conditions (Attachment 2).

Heptageniidae larvae are widespread and abundant in streams; some may also be found on waveswept shorelines or in temporary ponds next to streams (Hilsenhoff 1991). They cling to rocks, wood, or debris. Heptageniidae has been considered to be an indicator of clean unpolluted waters, and *Stenonema* has been rated somewhat tolerant of certain natural phenomena and characteristic of natural conditions (Attachment 2). *Stenonema pulchellum* has been rated slightly pollution tolerant and indicative of no apparent organic pollution (Attachment 2).

Dragonflies and Damselflies (order Odonata)

The odonates of North America are divided into two distinct suborders, Anisoptera (dragonflies) and Zygoptera (damselflies). About two-thirds of the species of dragonfly and damselfly larvae inhabit standing waters such as permanent and temporary ponds, marshes, swamps, and shallow areas of lakes, and the other one-third inhabit all types of permanent stream habitats (Hilsenhoff 1991). They are generalized carnivores, feeding on any appropriately-sized aquatic animal that they can capture (Westfall, Jr. 1984). Dragonfly and damselfly larvae are eaten by aquatic birds, fish, and large predaceous insects. They may be parasitized by immature water mites, wasps (on eggs), and biting midges.

Dragonfly larvae were found at NPS1 and 2 in the Lagoons reach; FWS1, 3, 4, and 5 in the USX reach; and IDEM7 in the Lake George reach (Figure 1 and Attachment 1). The family Aeshnidae (darners) was collected at FWS1, 3, 4, and 5. The family Corduliidae (greeneyed skimmers) was identified to *Neurocordulia* at NPS2 and *Tetragoneuria* at NPS1. The family Libellulidae (common skimmers) was identified to *Erythemis* at IDEM7.

Most Aeshnidae larvae inhabit standing waters, especially weedy permanent ponds, marshes, and the shallows of lakes, and a few inhabit streams (Hilsenhoff 1991). They prey upon a wide range of small animals, including fish, and are are sometimes highly cannibalistic (McCafferty 1983). Aeshnidae species have a wide range of tolerances (Illinois EPA 1985; Hilsenhoff 1987), and as a group have been rated moderately tolerant of certain natural phenomena, indicative of clean unpolluted streams, and indicative of unlikely organic pollution (Attachment 2).

Most Corduliidae larvae inhabit standing waters, including marshes, swamps, cool ponds, and lake shallows, but some inhabit debris in streams (Hilsenhoff 1991). Corduliidae has been considered indicative of clean unpolluted streams and some probable organic pollution, and *Neurocordulia* has been rated slightly pollution tolerant (Attachment 2).

Libellulidae larvae occur in a variety of permanent and temporary standing habitats, and are occasionally found along stream margins (Hilsenhoff 1991). Many species are very adaptable and tolerant of low dissolved oxygen concentrations or highly eutrophic habitats (McCafferty 1983). Libellulidae has been considered indicative of both clean, unpolluted streams and likely severe organic pollution, and *Erythemis* has been rated moderately tolerant of certain natural phenomena, somewhat pollution tolerant, and characteristic of natural conditions (Attachment 2). Damselfly larvae were found in the Lagoons, USX, Gary Sanitary District, DuPont, Roxanna Marsh, East Chicago Sanitary District, and Federal Dredging Project reaches (Figure 1 and Attachment 1). Unidentified damselflies were found at IDEM2, 3, 4, 5, and 6. The family Coenagrionidae (narrowwinged damselflies) was identified to family at FWS3, 4, and 5; *Argia* at

IDEM1, 3, 4, 5, and 7; *Chromagrion* at NPS1 and 2; and *Ischnura* at NPS1 and 2 and IDEM1, 2, 3, 5, 7, and 8. The family Lestidae (spreadwinged damselflies) was identified at FWS5.

Damselflies, especially *Ischnura*, can generally tolerate a wide range of chemical conditions, including high organic loading (Roback 1974). Coenagrionidae larvae occur mostly in permanent ponds, marshes, swamps, and lake shallows, and occasionally in parts of streams with little or no current; some *Argia* species inhabit riffles of streams (Hilsenhoff 1991). Coenagrionidae has been rated quite tolerant of certain natural phenomena, indicative of clean, unpolluted streams, and indicative of likely severe organic pollution (Attachment 2). *Argia* has been considered quite tolerant of certain natural phenomena, somewhat pollution-tolerant, and characteristic of natural conditions (Attachment 2). *Ischnura* has been rated somewhat tolerant of natural phenomena and moderately pollution tolerant (Attachment 2). Lestidae larvae commonly inhabit vegetation in permanent and temporary ponds and marshes, and occasionally may be found among vegetation in slow streams (Hilsenhoff 1991). They have been rated quite tolerant of certain natural conditions, indicative of clean, unpolluted streams, and indicative of likely severe organic pollution (Attachment 2).

Caddisflies (order Trichoptera)

The larvae and pupae of all but one or two species of caddisflies are aquatic (Hilsenhoff 1991). More than 1340 species are known in North America. Caddisflies occur in most types of freshwater habitats, including spring streams and seepage areas, rivers, lakes, temporary pools, and marshes (Wiggins 1984). Most larvae consume plant materials in some form, including algae and decaying plant tissue, and some are mainly predacious. Caddisflies are an important part of the stream community, and may dominate the insect biomass (Hilsenhoff 1991). Many fish species feed on the larvae and emerging adults.

Caddisflies were found at NPS1 and 2 in the Lagoons reach, TAMS2 and IDEM3 in the Gary Sanitary District and DuPont reaches, IDEM6 in the East Chicago Sanitary District reach, IDEM7 in the Lake George reach, and IDEM8 in the Federal Dredging Project reach (Figure 1 and Attachment 1). The Hydropsychidae (common netspinners) were identified to family at IDEM8, *Cheumatopsyche* at IDEM6 and 8, *Hydropsyche* at TAMS2, *Hydropsyche orris* (uncertain) at IDEM8, and *Hydropsyche simulans* at IDEM3 (pupae) and IDEM8. The Hydroptilidae (micro caddisflies) were identified to *Neotrichia* and *Orthotrichia* at NPS1. The Leptoceridae (longhorned casemakers) were identified to *Anthripsodes*, *Leptocerus*, *Nectopsyche*, and *Oecetis* at NPS2. The Polycentropodidae (trumpetnet and tubemaking caddisflies) were identified to *Cyrnellus fraternus* at IDEM3 and 7, and *Neureclipsis* at IDEM6. Caddisflies are very important in biological monitoring, due to the wide variation in pollution tolerance among species (Hilsenhoff 1991).

Hydropsychidae larvae inhabit streams of all sizes, currents, and temperatures, and most are omnivores, feeding on algae, crustacea, and insects (Hilsenhoff 1991). They, like other net-builders, are generally tolerant of organic loading but not of toxic pollutants (Roback 1974). Hydropsychidae has been rated quite tolerant of certain natural phenomena, indicative of clean, unpolluted streams, and indicative of possible slight organic pollution (Attachment 2). *Cheumatopsyche* is considered quite tolerant of certain natural phenomena, moderately pollution tolerant, indicative of some organic pollution, and characteristic of natural conditions

(Attachment 2). *Hydropsyche* is considered quite tolerant of certain natural phenomena, somewhat pollution-tolerant, and characteristic of natural conditions (Attachment 2). *H. orris* has been rated slightly pollution-tolerant, indicative of some organic pollution, and characteristic of natural conditions (Attachment 2). *H. simulans* is considered somewhat pollution tolerant and indicative of significant organic pollution (Attachment 2).

Hydroptilidae larvae may be found in a wide variety of habitats and feed on algae and other plant material (Hilsenhoff 1991). They have been rated quite tolerant of certain natural phenomena and indicative of possible slight organic pollution (Attachment 2). *Neotrichia* has been considered quite tolerant of certain natural phenomena, slightly pollution-tolerant, indicative of no apparent organic pollution, indicative of clean, unpolluted streams, and characteristic of natural conditions (Attachment 2). *Orthotrichia* has been considered pollution intolerant and indicative of clean to slightly enriched streams (Attachment 2).

Leptoceridae larvae occur in a variety of permanent aquatic habitats (Hilsenhoff 1991). Most are omnivore-detritivores, but *Oecetis* species are predators, and some *Ceraclea* feed on freshwater sponges (McCafferty 1983). They have been rated somewhat tolerant of certain natural phenomena, indicative of clean, unpolluted streams, and indicative of possible slight organic pollution (Attachment 2). *Leptocerus* has been rated slightly pollution-tolerant (Attachment 2). *Nectopsyche* has been considered slightly pollution-tolerant, indicative of no apparent organic pollution, and characteristic of natural conditions (Attachment 2). *Oecetis* has been considered somewhat tolerant of certain natural phenomena, somewhat pollution-tolerant, indicative of very significant organic pollution, and characteristic of natural conditions (Attachment 2).

Most Polycentropodidae larvae inhabit streams, but they also occur in a variety of other habitats (Hilsenhoff 1991). Most species are predators, but a few are herbivores. Polycentropodidae has been considered moderately tolerant of certain natural phenomena, indicative of likely substantial organic pollution, and indicative of clean, unpolluted streams (Attachment 2). *Cyrnellus* has been rated somewhat pollution tolerant (Attachment 2). *C. fraternus* has been considered indicative of very significant organic pollution (Attachment 2). *Neureclipsis* has been considered slightly pollution tolerant, indicative of significant organic pollution, and characteristic of natural conditions (Attachment 2).

Water bugs (order Hemiptera, suborder Heteroptera)

Heteropterans, the true bugs, are primarily terrestrial, but about 8.5% of the species are aquatic, with 217 species living in North American fresh waters and 107 species living on them (Hilsenhoff 1991). Water bugs are remarkably diverse and occupy many different habitat types, including saline ponds, mountain lakes, hot springs, and large rivers (Polhemus 1984). Most species are predators; however, many genera of the water boatmen (Corixidae) are primarily collectors, feeding on detritus. They can be important predators of mosquito larvae and adults; however, some species bite people or eat small fish in hatcheries, thereby becoming a nuisance. Most water bugs seem to be resistant to predation, possibly due to their characteristic scent glands. However, the water boatmen are preyed upon by fish, used as food for pet fish and turtles, and relished by people in Mexico, and the giant water bugs (Belostomatidae) are considered a delicacy in Asia.

Water bugs were identified at NPS1 and 2 in the Lagoons reach and FWS5 in the USX reach (Figure 1 and Attachment 1). The family Belostomatidae was identified to *Lethocerus* at NPS2. The family Corixidae was identified to family at FWS5 and *Sigara* at NPS1. The family Pleidae (pygmy backswimmers) was identified to *Plea* at NPS2. Water bugs are more tolerant of environmental extremes than most insects, except the water beetles and flies (Roback 1974).

Giant water bugs inhabit permanent standing water habitats (*Belostoma* and *Lethocerus*), especially weedy ponds, lake margins, marshes, or streams (*Abedus*), among aquatic plants or under rocks in riffles (Hilsenhoff 1991). They are powerful predators and will capture and kill fish, frogs, tadpoles, and other insects. Giant water bugs have been rated moderately tolerant of certain natural phenomena and indicative of clean, unpolluted streams; *Lethocerus* has been rated moderately tolerant of certain natural phenomena (Attachment 2).

Water boatmen are good water quality indicators in standing waters (Polhemus 1984). They are found in most permanent aquatic habitats, and frequently temporary ones as well (Hilsenhoff 1991). They feed primarily on detritus, algae, protozoans, and other very small animals; a few species will capture and eat larger insects such as mosquito larvae. *Sigara* are notable as herbivores (McCafferty 1983). Water boatmen have been rated quite tolerant of certain natural phenomena and indicative of clean, unpolluted streams, and *Sigara* has been rated quite tolerant of certain natural phenomena (Attachment 2).

Pygmy backswimmers inhabit vegetation, primarily in permanent ponds but also in lake shallows, stream backwaters, and swamps (Hilsenhoff 1991). They feed on small invertebrates. Pygmy backswimmers have been considered to be indicative of clean unpolluted streams (Attachment 2).

Water beetles (order Coleoptera)

Only about 3% of Coleoptera species have an aquatic life stage, but since it is the largest insect order, this amounts to more than 1100 aquatic species in North America (Hilsenhoff 1991). Three suborders have aquatic representatives: Adephaga, represented by five families in which all species have aquatic larvae and adults; Myxophaga, represented by a single species in North America in which both larvae and adults are aquatic; and Polyphaga, represented by species in several families in which larvae, adults, or both are aquatic. Water beetles inhabit a broad range of aquatic environments, and most are usually found on surfaces rather than in open water (White *et al*. 1984). Feeding habits of water beetles are extremely variable.

Water beetles were found at NPS2 in the Lagoons reach, IDEM1 in the USX reach, and IDEM6 in the East Chicago Sanitary District reach (Figure 1 and Attachment 1). The family Dytiscidae (predaceous diving beetles) was identified as *Dytiscus* at IDEM1 and *Laccophilus* at NPS2. The family Gyrinidae (whirligig beetles) was identified as *Dineutus* at NPS2 and *Gyrinus* (uncertain) at IDEM6. The family Haliplidae (crawling water beetles) was identified as *Haliplus* at NPS2. Water beetles are more tolerant of environmental extremes than most insects (Roback 1974).

Predaceous diving beetles are the largest family of water beetles, with more than 500 species in North America (Hilsenhoff 1991). They inhabit all types of permanent and temporary habitats, preferring the shallow, vegetated margins of ponds, marshes, bogs, and swamps. Both adults and larvae are predators, feeding primarily on other invertebrates and small vertebrates.

They have been considered moderately tolerant of certain natural phenomena and indicative of clean, unpolluted streams (Attachment 2). *Dytiscus* has been considered moderately tolerant of certain natural phenomena, and *Laccophilus* has been considered moderately tolerant of certain natural phenomena and pollution-tolerant (Attachment 2).

Whirligig beetles are widespread and often abundant (Hilsenhoff 1991). Larvae are predators, feeding mostly on other invertebrates; adults are scavengers on dead animals or predators of small invertebrates. They have been considered quite tolerant of certain natural phenomena and indicative of clean, unpolluted streams (Attachment 2). *Dineutus* has been considered slightly pollution-tolerant, and *Gyrinus* has been rated quite tolerant of certain natural phenomena and pollution-tolerant (Attachment 2).

Crawling water beetles are often abundant in shallow vegetation-choked habitats (Hilsenhoff 1991). Both larvae and adults are herbivores, feeding on algae or aquatic plants. They (and *Haliplus*) have been rated somewhat tolerant of certain natural phenomena (Attachment 2).

Flies and midges (order Diptera)

Biting midges (suborder Nematocera, family Ceratopogonidae)

Although Diptera (flies and midges) is mostly a terrestrial order, it is the dominant order of insects in the aquatic environment (Hilsenhoff 1991). The order is divided into two suborders: Nematocera, which dominates the aquatic fauna, and Brachycera. Biting midge larvae live in a variety of aquatic habitats, including tree holes, marshes, swamps, ponds, lakes, and streams. Most larvae are carnivores, and others are herbivores or detritivores. Adults of some aquatic species feed on people; most others (including *Palpomyia*) feed on small insects (McCafferty 1983). Biting midges were found at NPS1 and 2 in the Lagoons reach, FWS5 in the USX reach, and IDEM6 in the East Chicago Sanitary District reach (Figure 1 and Attachment 1). They were identified to family at FWS5 and IDEM6, and to *Palpomyia* at NPS1 and 2. Biting midges have been rated quite tolerant of certain natural phenomena, somewhat pollution-tolerant, indicative of clean unpolluted streams, and indicative of likely substantial organic pollution (Attachment 2). *Palpomyia* has been considered moderately pollution-tolerant, indicative of likely substantial organic pollution, and pollution-tolerant (Attachment 2).

Phantom midges (suborder Nematocera, family Chaoboridae)

Phantom midges, so called because of the near transparency of their larvae, occur in a wide variety of standing waters, including lakes, permanent ponds, spring ponds, temporary ponds, and swamp margins (Hilsenhoff 1991). The larvae prey on small animals such as insect larvae and crustaceans; adults do not feed. Phantom midges were identified as *Chaoborus* at IDEM2 in the USX reach and INHS1 in the Federal Dredging Project reach (Figure 1 and Attachment 1). They have been rated moderately pollution-tolerant and indicative of clean, unpolluted streams, and *Chaoborus* has been rated indicative of very significant organic pollution (Attachment 2).

Midges (suborder Nematocera, family Chironomidae)

Larvae of the family Chironomidae, by far the largest family of aquatic insects, inhabit all types of permanent and temporary aquatic habitats (Hilsenhoff 1991). They are found under a wider range of environmental conditions than any other group of aquatic insects, and often occur in high densities and diversity (Coffman and Ferrington, Jr. 1984). Midge larvae have a wide variety of feeding habits, with herbivore-detritivores and carnivores all commonly represented; adults do not feed (Hilsenhoff 1991). The larvae and adults are fundamental to the diets of many other aquatic invertebrates, fish, and birds (Williams and Feltmate 1992).

Midges were found at all sites except TAMS2 in the Gary Sanitary District and DuPont reaches and the INHS sites in the Federal Dredging Project reach (Figure 1 and Attachment 1). There were unidentified midge larvae at all FWS sites and all IDEM sites. Pupae were found at IDEM2, 3, and 5. The subfamily Chironominae tribe Chironomini was identified to: *Chironomus*, *Chironomus decorus*, *Dicrotendipes* (=*Limnochironomus*), *Dicrotendipes nervosus*, *Glyptotendipes*, *Microtendipes*, *Parachironomus*, *Parachironomus abortivus*, *Phaenopsectra*, *Polypedilum*, *Polypedilum convictum*, and *Stenochironomus*. The subfamily Chironominae tribe Tanytarsini was identified to *Cladotanytarsus* and *Rheotanytarsus*. The subfamily Orthocladiinae was identified to: *Cricotopus*, *Cricotopus bicinctus*, *Cricotopus intersectus*, *Cricotopus sylvestris*, *Eukiefferiella*, and *Eukiefferiella discoloripes*. The subfamily Tanypodinae was identified to: *Ablabesmyia*, *Labrundinia*, *Procladius sublettei*, and *Thienemannimyia* group. Midge larvae have been used as biological water quality indicators because different species or species groups may be associated with different pollutants or environmental conditions (Williams and Feltmate 1992). As a group, they have been rated quite tolerant of certain natural phenomena, and indicative of likely substantial organic pollution if they are not blood-red or likely severe organic pollution if they are blood-red (Attachment 2).

The subfamily Chironominae includes species with various tolerances to pollution (Illinois EPA 1985; Hilsenhoff 1987). The tribe Chironomini (except *Chironomus*) has been given a sliding scale of tolerance values by Chutter (1972) with the values dependent on the diversity and abundance of Baetid mayflies; in these studies, the tribe indicates organically enriched to polluted waters. Of the Chironomini genera found in these studies, *Chironomus* has been rated the most tolerant and *Stenochironomus* the least (Attachment 2). The tribe Tanytarsini has been used to indicate clean, unpolluted waters (Attachment 2). *Cladotanytarsus* has been rated moderately pollution-tolerant, indicative of significant organic pollution, and pollution-tolerant (Attachment 2). *Rheotanytarsus* has been rated moderately pollution tolerant, indicative of fairly significant organic pollution, and pollution-tolerant (Attachment 2).

The subfamily Orthocladiinae contains species with a wide range of pollution tolerances (Illinois EPA 1985; Hilsenhoff 1987). It has been given a sliding scale of tolerance values by Chutter (1972) with the values dependent on the diversity and abundance of Baetid mayflies; in these studies, the subfamily indicates organically enriched to polluted waters. *Cricotopus* has been rated moderately pollution-tolerant and indicative of significant organic pollution, and *Cricotopus bicinctus* has been rated very pollution-tolerant, indicative of severe organic pollution, and pollution-tolerant (Attachment 2). *Eukiefferiella* has been rated slightly pollution-tolerant, indicative of very significant organic pollution, and characteristic of natural conditions (Attachment 2).

The subfamily Tanypodinae also contains species with a wide range of tolerances (Illinois EPA 1985; Hilsenhoff 1987). It has been considered indicative of clean unpolluted streams (Attachment 2). *Ablabesmyia* has been rated moderately pollution tolerant, indicative of very significant organic pollution, and pollution-tolerant (Attachment 2). *Labrundinia* has been rated slightly pollution-tolerant and indicative of significant organic pollution (Attachment 2).

Procladius has been rated moderately pollution-tolerant, indicative of severe organic pollution, and characteristic of natural conditions (Attachment 2). *Thienemannimyia* group has been rated moderately pollution-tolerant and characteristic of natural conditions (Attachment 2).

Mosquitoes (suborder Nematocera, family Culicidae)

Mosquito larvae inhabit a variety of shallow, standing waters, including tree holes, artificial containers, catch basins, pitcher plants, swamps, shallow temporary or permanent ponds and marshes, and heavily vegetated margins of lakes and streams (Hilsenhoff 1991). Larvae feed primarily on small aquatic animals, algae, and detritus; larvae of the genus *Toxorhynchites* and some *Psorophora* are predaceous, often feeding on other species of mosquito larvae (Newson 1984). The adult females of a great majority of species feed on the blood of various cold- and warm-blooded animals, including humans. The adult males feed on plant juices and nectar. Mosquitoes are vectors of many human and animal diseases.

Mosquito larvae were identified at IDEM6 in the East Chicago Sanitary District reach (Figure 1 and Attachment 1). They were not identified to a lower taxonomic level. Mosquito larvae have been rated quite tolerant of certain natural phenomena, moderately pollution-tolerant, and indicative of organically polluted streams (Attachment 2).

Crane flies (suborder Nematocera, family Tipulidae)

The vast majority of species in Tipulidae, the largest family of Diptera, are not aquatic, but several genera have species with aquatic larvae (Hilsenhoff 1991). Crane fly larvae are found in nearly every kind of aquatic environment, including slow-flowing rivers, torrential mountain streams, margins of ponds and lakes, marshes, and tree holes (Byers 1984). Many larvae eat organic detritus--such as decaying leaves, plant fragments, and associated microorganisms--that accumulates on the bottoms of ponds or in backwaters of streams. Larvae of several species in the subfamily Limoniinae are active predators. Larval and adult crane flies are an important food source for other invertebrates, birds, mammals, fish, amphibians, and reptiles.

Crane fly larvae were common at IDEM6 in the East Chicago Sanitary District reach (Figure 1 and Attachment 1). They were not identified to a lower taxonomic level. Crane fly larvae have been rated moderately tolerant of certain natural phenomena, slightly pollution-tolerant, indicative of unlikely organic pollution, and indicative of clean unpolluted waters (Attachment 2).

Dance flies (suborder Brachycera, family Empididae)

Most species of dance flies are terrestrial or semiaquatic, but some have aquatic larvae (Hilsenhoff 1991). Most aquatic dance fly larvae and pupae live on the rocky bottoms of rapid streams, but some live on the margins of ponds and streams; larvae are predaceous (McCafferty 1983). One dance fly larva was found at FWS5 in the USX reach (Figure 1 and Attachment 1). It was not identified below family. Dance fly larvae have been rated quite tolerant of certain natural phenomena, moderately pollution-tolerant, indicative of likely substantial organic pollution, and indicative of clean, unpolluted streams (Attachment 2).

Soldier flies (suborder Brachycera, family Stratiomyidae)

Although most soldier fly larvae are terrestrial or semiaquatic, there are many species that live in shallow, vegetated standing waters (Hilsenhoff 1991). Aquatic larvae feed on detritus and algae; adults feed mostly on flowers. Soldier fly larvae were identified at FWS4 in the USX reach (Figure 1 and Attachment 1). They were not identified any further. Soldier fly larvae have been considered quite tolerant of certain natural phenomena, indicative of clean, unpolluted streams, and pollution-tolerant (Attachment 2).

Rat-tailed maggots/flower flies (suborder Brachycera, family Syrphidae)

Rat-tailed maggots inhabit shallow standing waters or margins of running waters, especially areas high in decomposing organic matter (Hilsenhoff 1991). Some species occur in tree holes. The larvae feed on detritus and microorganisms; the adult flies feed on flower nectar. Because of their very long breathing tube, rat-tailed maggots are able to inhabit very polluted, low-oxygen areas such as sewage lagoons. Rat-tailed maggots were found at FWS4 in the USX reach (Figure 1 and Attachment 1). They were not identified to a lower level. Rat-tailed maggots have been rated quite tolerant of certain natural phenomena, very pollution-tolerant, indicative of likely severe organic pollution, and indicative of clean, unpolluted streams (Attachment 2).

SUMMARY AND RECOMMENDATIONS

Current macroinvertebrate habitats in the Grand Calumet River and Indiana Harbor Canal are degraded, as is evident by the resident communities. In all reaches other than the Lagoons reach, aquatic earthworms and other pollution-tolerant organisms are dominant, and the more sensitive taxa are either scarce or non-existent, suggesting a highly degraded habitat (Attachments 1 and 2). The Lagoons reach appears to be less affected, probably because it is located above industrial and sanitary outfalls (IDEM 1991). This reach is also somewhat degraded, particularly the West Lagoon where the macroinvertebrate community appears to be stressed by extremely high ammonia levels (Hardy 1984).

So many changes have occurred over the Grand Calumet River's history that it may be nearly impossible for it to return to its presettlement state. However, several options exist for improving the River's habitat quality and bringing back a healthier and more diverse macroinvertebrate population. Since the macroinvertebrate habitat appears to be highly degraded throughout most of the River's extent, we will not discuss specific recommendations for each reach. Differences of approaches in the various reaches will certainly depend primarily on reach-specific factors other than macroinvertebrate community composition.

In-place sediment clean-up

First, the problem of contaminated sediments must be addressed. Grand Calumet River and Indiana Harbor Canal sediments are known to be contaminated by a wide variety of pollutants, including nutrients, organic matter, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and high concentrations of metals (USACE 1994a). Contaminated sediment can impact macroinvertebrates in a number of ways, both directly, as a living and foraging area and food source, and indirectly, as a source of water and prey contamination and oxygen depletion. Improving sediment quality will be necessary to restore macroinvertebrate habitat in the Grand Calumet River, and one way to achieve this is by cleaning up the contaminated sediments.

Sediment clean-up options include removal (dredging), capping with clean materials, and in-place treatment. Although it is theoretically feasible, not enough is known about in-place treatment (*e.g.*, fixation/solidification or biodegradation) to consider it seriously at this point (USACE 1994a). Dredging--the excavation of bottom sediments from a waterway--may be performed with a variety of equipment (USACE 1994b). The two basic types of dredges are mechanical dredges, which remove sediments using a large bucket or shovel, and hydraulic dredges, which remove and transport the sediments in a water slurry. The particular method selected depends on reach-specific factors that will not be discussed here.

The positive impacts of dredging on the aquatic macroinvertebrates, provided that it would remove the total depth of contaminated sediments, would be the removal of the contaminants (and thus their direct and indirect negative impacts) from the system, and the uncovering of uncontaminated sediments for recolonization. However, both of these benefits would be greatly reduced without sediment source controls (see below). Removal of only part of the contaminated sediments would be of little benefit unless water depth was maintained with capping.

The negative impacts of dredging would include the removal of existing benthic macroinvertebrates and rooted vegetation, potentially severe adverse habitat impacts due to changes in channel morphology, and temporary, localized degradation of water and habitat quality. Although little could be done about the first impact, the macroinvertebrate communities that would be removed are degraded, and the newly exposed sediments would be recolonized and revegetated over time. The other two negative impacts could be minimized by taking certain steps during and after dredging. The placement of weirs up- and downstream of the dredging operation would help maintain water flow and surface levels and could increase localization of turbidity during dredging. Care should be taken not to dig the channel too deep or the banks too steep in order to encourage the re-establishment of rooted vegetation and minimize flow pattern changes and riverbank sloughing. In reaches where the contaminated sediment is quite deep or the River is already too channelized, the bottom could be filled in with clean sediment.

Capping is the covering of contaminated sediment by clean materials (USACE 1994a). The contamination remains in the waterway, but its availability to the water column and aquatic life is reduced. The cap must isolate sediment contamination from the overlying water, prevent penetration by benthic or burrowing organisms, and be resistant to scour. Cap design depends on various factors, including the hydraulic system, sediment characteristics, and types of contamination. One concern with leaving the sediment in place is that groundwater may still interact with the contaminants.

The positive impacts of capping on the aquatic macroinvertebrates, provided that it would isolate and stabilize the contaminated sediments, would be the removal of the possibility of direct and indirect negative impacts from the contaminants and the availability of new, uncontaminated sediments for recolonization. However, both of these benefits would be greatly reduced without sediment source controls.

The negative impacts of capping would include the covering of existing benthic macroinvertebrates and rooted vegetation and possible adverse habitat impacts due to water depth reduction in shallow areas. Although little could be done about the first impact, the macroinvertebrate communities that would be buried are degraded, and the newly exposed sediments would be recolonized and revegetated over time. In shallow areas, partial dredging prior to capping could compensate for water depth loss.

Sediment source controls

Source controls, which reduce the quantity and contamination level of sediments entering the River, will be very important in improving sediment quality and macroinvertebrate habitat in the Grand Calumet River and Indiana Harbor Canal. If done properly, they could only impact the macroinvertebrate communities positively. Reductions in the quantity of sediment entering the River would improve habitat by decreasing siltation and turbidity, both of which can be very detrimental to some macroinvertebrates. Without reductions in contamination levels of sediments entering the river, sediment clean-up would only provide a temporary solution, since uncontaminated sediment would simply be covered and replaced by more contaminated sediment (USACE 1994a).

There are three major sources of sediments to the Grand Calumet River and Indiana Harbor Canal: municipal and industrial point discharges, combined sewer overflows (CSOs), and urban runoff. Point sources include three municipal wastewater treatment plants and over 40 outfalls for discharges from industries and manufacturers. Over 90% of the system's dry-weather flow originates as treated municipal and industrial wastewater (McCown *et al*. 1976). Point discharges are regulated under the Clean Water Act (NPDES permit program); effects of this regulation can be seen in the 56% reduction of suspended solids loadings from point sources between 1974 and 1984 (USACE 1994a). The Remedial Action Plan (RAP) calls for full compliance of all NPDES discharges and the resolution of enforcement actions against violators (IDEM 1991).

Combined sewer overflows are not as easily controlled as point discharges (USACE 1994a). CSOs occur when heavy rainfall events increase flow in a combined sewer system so that it exceeds the capacity of the sewer or the wastewater treatment plant. This causes a mixture of stormwater and raw sewage to be discharged directly to the river. Possible solutions to CSOs include separating sewers into sanitary and storm sewers and constructing a detention basin or tunnel for temporary storage of combined sewer flows during storms for later treatment and discharge. The NPDES permits with the sanitary districts of East Chicago, Hammond, and Gary would be modified by IDEM to require satisfactory maintenance and operation of the combined sewer systems.

Urban runoff is the most difficult source to control (USACE 1994a). Approximately 47% of the Grand Calumet River watershed east of the Illinois/Indiana border is occupied by heavy industry, while only 7.6% is open space (Ketcham *et al*. 1992). Measures that could be taken to control sediment in stormwater released into the river (other than making large changes to the existing land-use practices) include: detention basins, retention devices, constructed wetlands, vegetative controls, construction erosion controls, and source controls (*e.g.*, street sweeping and protection of stockpiled materials from rainfall).

Sediment transport controls

Transport controls reduce the resuspension and transport of sediments that have already been deposited on the river bottom. Reductions in sediment resuspension and transport would improve macroinvertebrate habitat by reducing turbidity, erosion, and the exposure of the organisms and the water column to sediment contaminants (USACE 1994a). Sediment impacts on water quality and aquatic organisms are directly related to the sediment surface area exposed, and when sediments are in suspension, surface area is greatly increased. Sediment resuspension could be reduced by changing the hydrology and hydraulics of the River and Canal or by controlling physical disturbances which cause resuspension, such as boat traffic and dredging.

Due to the effects of urbanization on the Grand Calumet River watershed, stormwater flows in the river can be much greater than normal flows, resulting in scouring and resuspension of sediments. In addition to the other ecological problems created by these high flows, they could make capping of contaminated sediment more difficult or infeasible, since the capping material may be washed downstream (USACE 1994a). Many of the same methods mentioned above for decreasing sediments in urban runoff and CSOs would also reduce peak storm flows.

Another method that has been used to control sediment transport is a sediment trap or settling basin (USACE 1994a). A deepened channel or basin is excavated within a waterway to catch sediments from upstream, and the sediments are then dredged and disposed nearby. This practice is useful for prevention of deposition in a high quality reach and is more cost-effective than removing sediments from a long stretch of river.

Water quality improvement

Historically, the Grand Calumet River and Indiana Harbor Canal have been plagued with water quality problems, including low oxygen levels and high levels of ammonia, total dissolved solids, total phosphorus, chlorides, fluorides, sulfates, oil and grease, bacteria, cyanide, metals, and PCBs (IDEM 1991). Although most of these parameters have improved, many still exceed applicable water quality standards. Improving the water quality of the waterway would also better the health of its macroinvertebrate community.

The sources of water pollution to the Grand Calumet River and Indiana Harbor Canal include municipal and industrial point discharges, CSOs, urban runoff, air deposition, groundwater contamination, and contaminated sediments (IDEM 1991; USACE 1994a). The first three of these are also major sediment sources and are described more fully in the previous section. The NPDES permit program regulates pollutants in point discharges. In general, methods used to decrease the quantity and contamination level of sediments entering the River from CSOs and urban runoff would also decrease the input of other water-borne contaminants.

Air deposition includes both wet deposition, which is precipitation of any type, and dry deposition, which is the settling of dry particles from the air. Because the area is highly industrialized, air deposition may be an important source of contaminants to the Grand Calumet River and Indiana Harbor Canal. Northwestern Indiana has the highest levels of precipitation-borne lead in the Great Lakes region (Gatz *et al*. 1989), and Indiana Dunes National Lakeshore has the highest levels of precipitational sulfate and nitrate of any monitored national park unit in the country (NADP 1993). Both direct and indirect deposition to the River and Canal could be decreased through better emissions controls, and indirect deposition could be decreased by many of the same methods used for decreasing sediment levels in urban runoff and CSOs.

Groundwater contamination may be another source of water pollution to the Grand Calumet River and Indiana Harbor Canal. Analysis of water samples taken from 128 wells in the Calumet Region indicated that groundwater quality has changed in parts of the study area as a result of industrialization and urbanization (Duwelius *et al*. 1996). The largest concentrations of trace elements and organic compounds were detected in samples from wells located in or near industrial areas or areas of waste disposal. A total of 14 volatile organic compounds, 23 semivolatile organic compounds, and 18 pesticide compounds were detected in 20, 56, and 29 of the samples, respectively. Compounds containing PCB's were detected in water from three of the wells.

Contaminated sediments can have a significant impact on water quality by acting as a source for nutrients and contaminants and as a sink for dissolved oxygen (USACE 1994a). Brannon *et al*. (1989) found that the overall transport and migration of sediment contamination in the Grand Calumet River and Indiana Harbor Canal was influenced by the following factors in descending order of importance: transport of contaminants associated with particulates, transport of contaminants desorbed from resuspended particulates, and transport of soluble contaminants released from deposited sediment. Release of contaminants from deposited sediment is the least important factor because sediments have a much greater exposed surface area when suspended, and the exposed surface area directly affects the release of contaminants, as well as the release of nutrients and the rate of oxygen demand (USACE 1994a). In-place sediment clean-up, sediment source controls, and sediment transport controls would all help to improve the water quality of the Grand Calumet River and Indiana Harbor Canal.

The River corridor

Restoration of the Grand Calumet River and its macroinvertebrate populations must involve more than the river itself. The river is just one part of the larger ecosystem, and its health is related to the health of all other parts. There are several important natural habitat areas along the River corridor, such as Miller Woods in the Lagoons reach and Clark and Pine East Nature Preserve in the USX reach, that need to be preserved and protected. Wetlands and riparian areas need to be restored and protected wherever possible. The impacts of restoration alternatives, particularly sediment clean-up options, must be considered for the whole system rather than for the River alone. In some areas, such as the East Grand Calumet Lagoon, it may be preferable to leave the contaminated sediments in place rather than risk damaging the surrounding natural area with dredging and disposal activities.

The challenge

The greatest challenge will be to restore the Grand Calumet River and Indiana Harbor Canal to their best possible ecological health given the various social, economical, and political constraints. Restoration would require the cooperation of federal and state agencies, local governments, industries, municipal wastewater treatment plants, and the public, and many compromises would be necessary. Industrial and residential development have severely altered the landscape and the River itself, yet there remains a great potential for improving the health of the River and the whole ecosystem. Let us take the challenge, and future generations will surely thank us for it.

LITERATURE CITED

Brannon, J.M., D. Gunnison, D. Averett, J.L. Martin, R.L. Chen, and R.F. Athow, Jr. 1989. Analysis of impacts of bottom sediments from Grand Calumet River and Indiana Harbor Canal on water quality. Misc. Paper D-89-1. U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS. Not read; cited in USACE 1994a.

Bright, G.R. 1988. Recent water quality in the Grand Calumet River as measured by benthic invertebrates. Proceedings of the Indiana Academy of Science **98**:229-233.

Brinkhurst, R.O., and D.G. Cook. 1974. Aquatic earthworms (Annelida: Oligochaeta). Pages 143-156 *in* C.W. Hart, Jr., and S.L.H. Fuller, editors. Pollution ecology of freshwater invertebrates. Academic Press, New York, New York, USA.

Brinkhurst, R.O., and S.R. Gelder. 1991. Annelida: Oligochaeta and Branchiobdellida. Pages 401-435 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

Brown, K.M. 1991. Mollusca: Gastropoda. Pages 285-314 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

Bushnell, J.H. 1974. Bryozoans (Ectoprocta). Pages 157-194 *in* C.W. Hart, Jr., and S.L.H. Fuller, editors. Pollution ecology of freshwater invertebrates. Academic Press, New York, New York, USA.

Byers, G.W. 1984. Tipulidae. Pages 491-514 *in* R.W. Merritt and K.W. Cummins, editors. An introduction to the aquatic insects of North America, 2nd edition. Kendall / Hunt Publishing Co., Dubuque, Iowa, USA.

Chutter, F.M. 1972. An empirical biotic index of the quality of water in South African streams and rivers. Water Research **6**:19-30.

CMSD. 1980. Benthic macroinvertebrates as pollution indicators in the Indiana Harbor Canal. Report No. 80-17. Not read; cited in USEPA 1985.

Coffman, W.P., and L.C. Ferrington, Jr. 1984. Chironomidae. Pages 551-652 *in* R.W. Merritt and K.W. Cummins, editors. An introduction to the aquatic insects of North America, 2nd edition. Kendall / Hunt Publishing Co., Dubuque, Iowa, USA.

Covich, A.P., and J.H. Thorp. 1991. Crustacea: introduction and Paracarida. Pages 665-689 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

Davies, R.W. 1991. Annelida: leeches, polychaetes, and acanthobdellids. Pages 437-479 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

Dodson, S.I., and D.G. Frey. 1991. Cladocera and other Branchiopoda. Pages 723-786 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

Duwelius, R.F., R.T. Kay, and S.T. Prinos. 1996. Ground-water quality in the Calumet Region of northwestern Indiana and northeastern Illinois, June 1993. Water-Resources Investigations Report 95-4244. United States Geological Survey, Denver, Colorado, USA.

FWPCA. 1966. In the matter of pollution of the interstate waters of the Grand Calumet River, Little Calumet River, Calumet River, Wolf Lake, Lake Michigan and their tributaries. Conclusions of Technical Session February 2, 1966. Federal Water Pollution Control Administration. Not read; cited in USACE 1994a.

Frost, T.M. 1991. Porifera. Pages 95-124 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

Fuller, S.L.H. 1974. Clams and mussels (Mollusca: Bivalvia). Pages 215-273 *in* C.W. Hart, Jr., and S.L.H. Fuller, editors. Pollution ecology of freshwater invertebrates. Academic Press, New York, New York, USA.

Gatz, D.F., V.C. Bowersox, and J. Su. 1989. Lead and cadmium loadings to the Great Lakes from precipitation. Journal of Great Lakes Research **15**(2):246-264.

Hardy, M. 1984. Chemical and biological quality of streams at the Indiana Dunes National Lakeshore, Indiana, 1978-80. Water-Resources Investigations Report 83-4208. USGS, Indianapolis, Indiana, USA. 95 p.

Harman, W.N. 1974. Snails (Mollusca: Gastropoda). Pages 275-312 *in* C.W. Hart, Jr., and S.L.H. Fuller, editors. Pollution ecology of freshwater invertebrates. Academic Press, New York, New York, USA.

Harrison, F.W. 1974. Sponges (Porifera: Spongillidae). Pages 29-66 *in* C.W. Hart, Jr., and S.L.H. Fuller, editors. Pollution ecology of freshwater invertebrates. Academic Press, New York, New York, USA.

Hilsenhoff, W.L. 1987. An improved biotic index of organic stream pollution. The Great Lakes Entomologist **20**:31-39.

Hilsenhoff, W.L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of the North American Benthological Society **7**:65-68.

Hilsenhoff, W.L. 1991. Diversity and classification of insects and Collembola. Pages 593-663 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

Hobbs, H.H., III. 1991. Decapoda. Pages 823-858 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

Hobbs, H.H., Jr., and E.T. Hall, Jr. 1974. Crayfishes (Decapoda: Astacidae). Pages 195-214 *in* C.W. Hart, Jr., and S.L.H. Fuller, editors. Pollution ecology of freshwater invertebrates. Academic Press, New York, New York, USA.

IDEM. 1991. The Remedial Action Plan for the Indiana Harbor Canal, the Grand Calumet River and the nearshore Lake Michigan, Stage One. Indiana Department of Environmental Management, Indianapolis, Indiana, USA.

Illinois EPA. 1985. Illinois Environmental Protection Agency macroinvertebrate tolerance list.

Kenk, R. 1974. Flatworms (Platyhelminthes: Tricladida). Pages 67-80 *in* C.W. Hart, Jr., and S.L.H. Fuller, editors. Pollution ecology of freshwater invertebrates. Academic Press, New York, New York, USA.

Ketcham, M.L., V.P. Kunchakarra, and C.T. Jafvert. 1992. Urban targeting of nonpoint source pollution in the Grand Calumet River watershed. Report to USDA Soil Conservation Service, Lake County Soil and Water Conservation District, Crown Point, Indiana, USA.

Kolasa, J. 1991. Flatworms: Turbellaria and Nemertea. Pages 145-171 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

McCafferty, W.P. 1983. Aquatic entomology: the fishermen's and ecologist's illustrated guide to insects and their relatives. Jones and Bartlett Publishers, Inc., Boston, Massachussetts, USA. (Orig. pub. 1981 by Science Books International, Inc.)

McCown, D.L., W. Harrison, and W. Orvosh. 1976. Transport and dispersion of oil-refinery water in the coastal waters of southwest Lake Michigan (experimental design--sinking-plume condition). Argonne National Laboratory, Argonne, Illinois, USA. Not read; cited in USACE 1994a.

McMahon, R.F. 1991. Mollusca: Bivalvia. Pages 315-399 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

Mierzwa, K.S., S.D. Culberson, K.S. King, and C. Ross. 1991. Illinois - Indiana Regional Airport Site Selection Report, Technical Paper No. 7 (biotic communities). TAMS Consultants, Inc., Chicago, Illinois, USA. 312 p.

Moore, P.A. 1959. The Calumet Region: Indiana's last frontier. Indiana Historical Bureau, Indianapolis, Indiana, USA.

NADP. 1993. National Atmospheric Deposition Program. Colorado State University, Fort Collins, Colorado, USA.

Newson, H.D. 1984. Culicidae. Pages 515-533 *in* R.W. Merritt and K.W. Cummins, editors. An introduction to the aquatic insects of North America, 2nd edition. Kendall / Hunt Publishing Co., Dubuque, Iowa, USA.

Patrick, R., and D.M. Palavage. 1994. The value of species as indicators of water quality. Proceedings of the Academy of Natural Sciences of Philadelphia **145**:55-92.

Pennak, R.W. 1989. Fresh-water invertebrates of the United States: Protozoa to Mollusca, 3rd edition. John Wiley & Sons, Inc., New York, New York, USA.

Poinar, G.O., Jr. 1991. Nematoda and Nematomorpha. Pages 249-283 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

Polhemus, J.T. 1984. Aquatic and semiaquatic Hemiptera. Pages 231-260 *in* R.W. Merritt and K.W. Cummins, editors. An introduction to the aquatic insects of North America, 2nd edition. Kendall / Hunt Publishing Co., Dubuque, Iowa, USA.

Risatti, J.B., and P. E. Ross, editors. 1989. Chemical, biological and toxicological study of sediments from Indiana Harbor, Canal and adjacent Lake Michigan. Final Rep. to USACE, Chicago District, Chicago, Illinois. 83 p.

Roback, S.S. 1974. Insects (Arthropoda: Insecta). Pages 313-376 *in* C.W. Hart, Jr., and S.L.H. Fuller, editors. Pollution ecology of freshwater invertebrates. Academic Press, New York, New York, USA.

Sawyer, R.T. 1974. Leeches (Annelida: Hirudinea). Pages 81-142 *in* C.W. Hart, Jr., and S.L.H. Fuller, editors. Pollution ecology of freshwater invertebrates. Academic Press, New York, New York, USA.

Shelford, V.E. 1977. Animal communities in temperate America: as illustrated in the Chicago region. Arno Press, New York, New York, USA. (Orig. pub. 1937 by the University of Chicago Press, Chicago, IL.)

Slobodkin, L.B., and P.E. Bossert. 1991. The freshwater Cnidaria--or coelenterates. Pages 125-143 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

Smith, I.M., and D.R. Cook. 1991. Water mites. Pages 523-592 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

Sobiech, S.A., T.P. Simon, and D.W. Sparks. 1994. Pre-remedial biological and water quality assessment of the East Branch Grand Calumet River Gary, Indiana, June 1994. USFWS, Bloomington, Indiana, USA 112 p.

USACE. 1994a. Appendix C: “No action” alternative. Comprehensive management plan, Indiana Harbor and Canal maintenance dredging and disposal activities. U.S. Army Corps of Engineers, Chicago District, Chicago, Illinois, USA.

USACE. 1994b. Appendix H: Dredging technologies and impacts. Comprehensive management plan, Indiana Harbor and Canal maintenance dredging and disposal activities. U.S. Army Corps of Engineers, Chicago District, Chicago, Illinois, USA.

USDA Forest Service. 1989. Fisheries habitat surveys handbook, chapter 5--Aquatic macroinvertebrate surveys. U.S. Department of Agriculture Forest Service, Intermountain Region, Fisheries and Wildlife Management.

USEPA. 1985. Master plan for improving water quality in the Grand Calumet River / Indiana Harbor Canal. U.S. Environmental Protection Agency, Region V, Water Division, Chicago, Illinois, USA.

Westfall, M.J., Jr. 1984. Odonata. Pages 126-176 *in* R.W. Merritt and K.W. Cummins, editors. An introduction to the aquatic insects of North America, 2nd edition. Kendall / Hunt Publishing Co., Dubuque, Iowa, USA.

White, D.S., W.U. Brigham, and J.T. Doyen. 1984. Aquatic Coleoptera. Pages 361-437 *in* R.W. Merritt and K.W. Cummins, editors. An introduction to the aquatic insects of North America, 2nd edition. Kendall / Hunt Publishing Co., Dubuque, Iowa, USA.

Wiggins, G.B. 1984. Trichoptera. Pages 271-311 *in* R.W. Merritt and K.W. Cummins, editors. An introduction to the aquatic insects of North America, 2nd edition. Kendall / Hunt Publishing Co., Dubuque, Iowa, USA.

Williams, D.D., and B.W. Feltmate. 1992. Aquatic insects. Cab International, Wallingford, United Kingdom.

Wood, T.S. 1991. Bryozoans. Pages 481-499 *in* J.H. Thorp and A.P. Covich, editors. Ecology and classification of North American freshwater invertebrates. Academic Press, New York, New York, USA.

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INTRODUCTION

The Grand Calumet River - Indiana Harbor Canal fish community structure and function have undergone drastic changes since the turn of the century. Changes in stream depth, water quality, and land use eliminated indigenous species during the middle of the century. Dredging and channelizing altered the stream from a riverine wetland to a narrow channel and significantly increased the flow velocity. During the early 1970's, few if any species of fish were documented in either the East or West Branches of the Grand Calumet River. Young-of-the-year of lake dwelling transient species were present only seasonally in the Indiana Harbor Canal. Subchronic toxicity was documented at a few of the major dischargers to the system. Documented improvements in water quality and the fish community in this decade suggest that the possibility of restoring the Grand Calumet River is not only a dream but a distinct possibility. The river reaches discussed here include the following study reaches: 1) East Branch; a) USX, b) Gary Sanitary District, c) DuPont; 2) West Branch: a) East Chicago, b) Roxanna Marsh, c) Hammond, d) Culverts, e) Far West; 3) Indiana Harbor and Canal: a) Federal Channel, b) Lake George, c) Canal; 4) Grand Calumet Lagoons: a) Eastern Lagoon, b) Middle Lagoon, c) Western Lagoon.

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 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. The presence of these species in the Middle Lagoon suggests that sensitive species had 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 resultant 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 it is affected by effluent quality, water quantity, and sediment quality. Past reduction in effluents and combined sewer overflows (CSO's), closure of point sources, and removal of contaminated sediments in the upper ten miles 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 expected to 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 the turning basin and Lake George channels. Improvements in fish community diversity in the Indiana Harbor Canal can be directly attributed to the removal of contaminated sediments which allowed opportunistic, transient young-of-the-year of lake dwelling species to utilize 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. 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 and Hildebrand (1910) studied the distribution of fish within fifty miles of Chicago. Seth Meek, a former student of the legendary David Starr Jordan of Indiana University, took a position as 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 utilized the data collection efforts of Meek and Hildebrand. The species lists in the two papers are so similar that it seems likely they are drawn from the same dataset. 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, though 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 1980's. This effort resulted in a published study of three years of intensive collection (Simon et al. 1988). Prior to 1985, the collection of fish from the Grand Calumet River was considered a futile effort when either few or no fish species would be collected after extensive sampling effort (C. Lee Bridges, personal communication).

Extensive monitoring and assessment has been completed during the last decade (Simon et al. 1988; Simon 1990; Sobiech et al. 1994). The Indiana Department of Environmental Management has conducted annual sampling to assess and evaluate fish consumption advisories. The U.S. Army Corps of Engineers has been sampling the Indiana Harbor Canal breakwall for several years providing trend data for 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 for assessment of point source dischargers (Simon 1988; Simon et al. 1988; Sobiech et al. 1994). The purpose of this paper is to document the historical and present distribution of fishes from the Grand Calumet River and Indiana Harbor Canal and to evaluate the biological integrity of the fish community based on structural and functional attributes.

Historical status of Grand Calumet River fishes: prior to 1970

The change in the fish community of the Grand Calumet River is a direct result of the flow changes during the early- to mid 1800's. Prior to these changes, the Grand Calumet was comprised of palustrine wetlands, a series of shallow pools connected by narrow flowages between pools. 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, lower Galien, and Dead River. Although Shelford did not specifically describe the condition of the Grand Calumet River, it can be supposed that the river possessed characteristics similar to the other streams he mentioned.

These rivers characteristically possess bottoms of either fine sand or fine organic materials with little or no rock. The rivers originate in wetland habitats characterized by emergent rooted macrophytes. Differentiation of pools and riffles are 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 various pondweeds (*Potemogeton* sp.), and the water lilies, *Nuphar* and *Nelumbo*, thrive. Bullrushes (*Scirpus* sp.) and cattails (*Typha*) line the shoreline and gradually sloping banks along back bays and side channel margins.

Meek and Hildebrand (1910) evaluated the distribution of fish species within a fifty mile radius from 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 (*Notropis heterolepis*) lake chubsucker, northern pike, redhorse, and tadpole madtom (*Noturus gyrinus*) (Table 2). The Dead River has a much smaller drainage area than the Grand Calumet River, but unlike the Grand Calumet River, it has not been extensively modified. The Dead River is a designated nature preserve contained within the Illinois Beach State Park near Zion, Illinois that is one of the few remaining areas of dune and swale topography in Illinois. When we sampled the Dead River in 1996 we captured 14 species, six of which were present in the 1909 sample. Of the 20 total species collected from the Dead River during the two events, less than 30% were found in both the 1909 and 1996 collections.

TABLE 1. Fishes collected by Meek and Hildebrand (1910) from the Grand Calumet River drainage and deposited at the Field Museum of Natural History.

Common Name	Species Name
bowfin	*Amia calva*
carp	*Cyprinus carpio*
golden shiner	*Notemigonus crysoleucas*
emerald shiner	*Notropis atherinoides*
spottail shiner	*N. hudsonius*
bluntnose minnow	*Pimephales notatus*

white sucker	*Catostomus commersoni*
channel catfish	*Ictalurus punctatus*
black bullhead	*Ameiurus melas*
yellow bullhead	*A. natalis*
brown bullhead	*A. nebulosus*
tadpole madtom	*Noturus gyrinus*
northern pike	*Esox lucius*
grass pickerel	*E. americanus*
central mudminnow	*Umbra limi*
green sunfish	*Lepomis cyanellus*
pumpkinseed	*L. gibbosus*
bluegill	*L. macrochirus*
black crappie	*Pomoxis nigromaculatus*
yellow perch	*Perca flavescens*
logperch	*Percina caprodes*
freshwater drum	*Aplodinotus grunniens*

Until the 1960's, 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 1960's found only 20-108 oligochaetes/m^2 in the Indiana Harbor Canal mouth. By the early 1970's, the abundance of oligochaetes had increased to 2,400-500,000/m^2. The increase in biomass was considered sufficient to support native fish populations.

TABLE 2. Species of Fish collected from the Dead River in 1909 (Shelford 1937) and 1996 (Moy and Simon, unpublished data).

		Year	
Common Name	Species Name	1909	1996
gizzard shad	*Dorosoma cepedianum*	--	X
grass pickerel	*Esox americanus*	X	--
northern pike	*Esox lucius*	X	X
redhorse	*Moxostoma* sp.	X	--
lake chubsucker	*Erimyzon sucetta*	X	--
common shiner	*Luxilus cornutus*	X	--
golden shiner	*Notemigonus crysoleucas*	X	X
emerald shiner	*Notropis atherinoides* --	X	
spottail shiner	*Notropis hudsonius*	--	X
blacknose shiner	*Notropis heterolepis*	X	X
bluntnose minnow	*Pimephales notatus*	X	--
tadpole madtom	*Noturus gyrinus*	X	--

pumpkinseed	*Lepomis gibbosus*	--	X
warmouth	*Lepomis gulosus*	--	X
bluegill	*Lepomis macrochirus*	X	X
white crappie	*Pomoxis annularis*	X	X
black crappie	*Pomoxis nigromaculatus*	--	X
smallmouth bass	*Micropterus dolomieui*	--	X
largemouth bass	*Micropterus salmoides*	X	X
yellow perch	*Perca flavescens*	--	X
	TOTAL TAXA	12	14

ASSESSMENT OF SUBCHRONIC TOXICITY

Water quantity is largely determined by the effluent discharged into the Grand Calumet River. 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 and Wangsness 1987). Non-contact cooling water comprises the majority of the industrial effluent. A total of 39 permitted discharge outfalls and 14 combined sewer overflow points occur along the river (U.S. EPA 1984; Custer et al. 1996).

In the document entitled, "Masterplan for Improving the Water Quality of the Grand Calumet River and Indiana Harbor Canal" (1984), the U.S. EPA 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 State of Indiana Department of Environmental Management (IDEM) 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 use as supporting "limited aquatic life". This use designation is indicative of the degraded condition of the aquatic environment; the Grand Calumet River is one of the only streams in the State of 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 CSO discharges. In terms of point discharge violations in the Grand Calumet River watershed, impacts to the river are attributed to untreated sewage and NPDES permit violations.

Simon (1988) evaluated the impact of 19 major point source dischargers along the Grand Calumet River and the Indiana Harbor Canal in 1986. Preliminary screens were utilized to evaluate potential effects to 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 positive test results observed during screening tests and were resampled and tested as definitive tests using a dilution series of 100, 77.5, 42.4, 30.0 and 17.3 percent solutions.

Hammond SD effluent produced a significant teratogenic response during the preliminary test but did not reduce survival or larvae. A single USX outfall produced positive results during the screening procedure but could not be resampled due to a plant shutdown in 1986. 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, respectively. 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 showed significant mortality in solutions with concentrations above 30% effluent. The DuPont effluent had a chronic value of 17.3% effluent and statistically significant teratogenic responses were observed in concentrations above 30% effluent. Hatchability was unaffected in all preliminary tests except USX outfall 034.

CHANGES IN FISH COMMUNITY STRUCTURE AND FUNCTION IN THE GRAND CALUMET RIVER WATERSHED

The fish communities of the Grand Calumet River watershed reflect the degraded condition of the stream. The dominant species composing the fish community include carp, goldfish, and golden shiner. Pumpkinseed, central mudminnow, bluntnose minnow, chinook salmon, and rainbow trout have also been collected (Simon et al. 1988). Since we recognize that differential management strategies may need to be employed in order for restoration in the Grand Calumet River watershed, we have separated the watershed into four segments. The four segments include: 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 have been completed by Polls and Dennison (1984), Simon et al. (1988), and Risatti and Ross (1989). The Corps of Engineers is responsible for maintaining the Federal Channel of the Indiana Harbor Channel. Simon et al. (1988) assessed variation in fish community diversity of the Indiana Harbor Channel at Dickey Road bridge during 1986-1988. Risatti and 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 and Dennison (1984) sampled the Federal Channel in 1983 to quantify the concentration of contaminants in the sediment and in fish tissue. The information was used to assess the risk of removing sediments from the channel in order to maintain sufficient harbor depth for deep draft navigation. The study found that the Canal entrance possessed 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 proportion of exotic species was found in the Grand Calumet River branch (15.0%). Exotic species in this reach included alewife, carp, goldfish, carp - goldfish hybrids, and brown trout (Table 3). The harbor is dominated by omnivorous and detritivorous species such as carp, goldfish, bluntnose minnow, fathead minnow, central mudminnow, and golden shiner, which represent a diverse group of fishes able to utilize the predominantly detrital forage base. Since 1994, the Corps assessment has been restricted to electrofishing along the breakwaters at the entrance of the Indiana Harbor.

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

Risatti and Ross (1989) evaluated seasonal fish use at two locations. One site was near the anchor and turning basin; the second site consisted of 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 proportion of exotic species in the Canal. The outer breakwaters of the Indiana Harbor Canal have been monitored by the Army Corps of Engineers since 1994 (P. Moy, unpublished data). Both the number of species and the number of individuals collected have increased between 1994-1996 (Table 3). This increase is attributable to greater numbers of tolerant (bluntnose minnow, fathead minnow, goldfish) and exotic (three spine stickleback and round goby) species which 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 same time frame enabling species such as silver and golden redhorse, mottled sculpin, and round goby to colonize. It is not yet certain if these species will be permanent residents or whether they are only transient, opportunistic species.

Fish communities of the East Branch Grand Calumet River

Fish communities of the East Branch of the Grand Calumet River has been monitored since 1976. The East Branch has been studied by CDM/Limnetic (1976), Indiana Department of Environmental Management (unpublished data), Simon et al. (1988), Simon (1991), and Sobiech et al. (1994). The fish community of the East Branch has shown the greatest improvement among any 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 has evaluated three locations in the East Branch since 1980. Fish are collected for fish tissue contaminant analyses (J. Stahl, personal communication). Sites are sampled until the number of target organisms collected is sufficient for the analyses. During the sampling, other non-target species are collected and enumerated. The 1980 to 1987 results suggest an increase in the number of species, a reduction in the proportion of tolerant species, and an increase in the use of the River by migrating transient species, including young-of-the-year yellow perch and adult rainbow trout.

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

Simon (1991) developed biological integrity expectations for northwestern 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 a part of this investigation. Although species lists were not reported by station, individual IBI assessments were calculated for each station. The results did not differ significantly from the 1988 results (Simon et al. 1988). The 1990 survey was a high water year so many species, including pumpkinseed and yellow perch which were not collected during the 1988 drought, were found again as they began to return to the area. An increase in abundance of the rudd (*Scardinius erythrophthalmus*), a European exotic, was noted in the East and West Branches of the Grand Calumet River. Exotic species have become the majority of the fish species collected (Table 3).

TABLE 3. Summary of fish species collected from the Indiana Harbor Canal segment ([1] Polls and Dennison 1984; [2] Simon et al. 1988; [3] Risatti and Ross 1989).

			List of sites										
								1983					
	1986	1987	1988	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]
Gizzard shad, *Dorosoma cepedianum*			41	8	705	47	3	72		65		25	14
Alewife, *Alosa psuedoharengus*			6		74			1		4		2	25
Chinook salmon, *Oncorhynchus tschawytscha*													
Coho salmon, *Oncorhynchus kisutch*										1			
Brown trout, *Salmo trutta*			1										
Rainbow trout, *Oncorhynchus mykiss*									10	1			1
Carp, *Cyprinus carpio*		20	63	20	16	1	7	28	16		6	3	25
Goldfish, *Carassius auratus*			1		106	26	133	25	3	22	4	5	
Carp x Goldfish hybrid							3			1			
Spotfin shiner, *Cyprinella spiloptera*										1			
Golden shiner, *Notemigonus crysoleucas*						1			1	12		24	
Emerald shiner, *Notropis atherinoides*					20				5	2		1	
Spottail shiner, *Notropis hudsonius*					18								
Fathead minnow, *Pimephales promelas*					5	6		22		1			
Silver redhorse, *Moxostoma anisurum*													
Golden redhorse, *Moxostoma erythrurum*													
Three-spine stickleback, *Gasterosteus aculeatus*													
Rock bass, *Ambloplites rupestris*					1								
Pumpkinseed, *Lepomis gibbosus*			2	2	10	22	22	28	1	8	3		
Bluegill, *Lepomis macrochirus*						1				2			
Bluegill x Pumpkinseed hybrid												3	3
Green sunfish, *Lepomis cyanellus*							1						
Smallmouth bass, *Micropterus dolomieui*													

Black crappie, *Pomoxis nigromaculatus*											
Yellow perch, *Perca flavescens*	7	8	371	39	4	64	1	2			
Mottled sculpin, *Cottus bairdi*											
Round goby, *Neogobius melanostomus*											
Freshwater drum, *Aplodinotus grunniens*											
Total Number					78	81	1333	158	167	220	49
Total Species	7	5	11	10	7	8	7	14	2	6	3
% Tolerant Species	29.5%	79.3%	12.1%	46.9%	95.7%	37.7%	63.3%	88.5%	57.1%	57.6%	13.0%
% Exotic Species	35.9%	76.8%	65.0%	27.8%	81.2%	15.0%	83.7%	30.4%	57.1%	19.7%	62.2%

A = Harbor mouth breakwaters; B = anchor and maneuvering basin; C = canal entrance; D = canal section lakeward of the Forks; E = Lake George branch; F = Calumet River branch;
G = Indiana Harbor at Dickey Road bridge.

TABLE 4. Summary of fish collections completed in the East Branch of the Grand Calumet River ([1] CDM/Limnetics; [2] IDEM unpublished data; [3] Simon et al. 1988; [4] Simon 1990; and [5] Sobiech et al. 1994).

Species	List of sites									
	1976 A[1]	1980 B,C,D[2]	1982 B,C,D[2]	1984 B,C,D[2]	1985 B,C,E[3]	1986 B,C,D[2]	1987 B,C,D[2]	1986 B,C,D[3]	1987 B-G[3]	1988 B,C,D[3]
Gizzard shad, *Dorosoma cepedianum*							96		157	
Alewife, *Alosa psuedoharengus*	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
Goldfish, *Carassius auratus*					34		113	157	140	161
Carp x Goldfish hybrid										
Rudd, *Scardinius erythrophthalmus*										
Spotfin shiner, *Cyprinella spiloptera*		1					1			12
Golden shiner, *Notemigonus crysoleucas*			1	10	124	64	25	222	140	239
Golden shiner x Rudd hybrid										
Emerald shiner, *Notropis atherinoides*							2			14
Bluntnose minnow, *Pimephales notatus*						92	21	1	5	3
Fathead minnow, *Pimephales promelas*					1		1			1
Black bullhead, *Ameiurus melas*				1			1			
White sucker, *Catostomus commersoni*										
Rainbow smelt, *Osmerus mordax*								1	1	
Pumpkinseed, *Lepomis gibbosus*						48	14	59	41	1
Bluegill, *Lepomis macrochirus*							2	6	2	2
Green sunfish, *Lepomis cyanellus*					3			6		
Largemouth bass, *Micropterus salmoides*								2		
Black crappie, *Pomoxis nigromaculatus*								1		
Yellow perch, *Perca flavescens*		1				3	142		4	
unidentified darter, Percidae species				1						
Total Number	2	8	19	16	197	281	471	470	691	519
Total Species	1	4	2	3	7	11	7	7	11	6
% Tolerant Species	0.0	75.0	100	93	100	48.3	63.3	92.3	73.3	57.6
% Exotic Species	100	0.0	94.7	31.3	33.0	28.1	83.7	45.0	22.2	19.7
Number of Collections	2	3	3	3	3	3	3	6	11	6

A = East Branch at junction with West Branch and Indiana Harbor Canal; B = Kennedy Ave; C= Cline Ave; D = Bridge Street; E = East Broadway; F = adj. DuPont de Nemours; G = Grant Street; H = Wabash Rail Road; I = Wilson Street; J = I-90 Ramp; K = West Broadway; L = Tennessee Street.

In 1988, a fish kill occurred in the upper five miles of the East Branch of the Grand Calumet River due to an upper River oil spill which caused degradation of 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 two game species, i.e., northern pike and walleye, and bluntnose minnow were also killed.

Sobiech et al. (1994) evaluated the upper five miles of the East Branch 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 tolerant and exotic species was observed downstream of this area. The rudd was also collected in this reach. It was determined that the rudd was hybridizing with the native golden shiner.

Fish communities of the West Branch Grand Calumet River

Few studies have been conducted in the West Branch 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 overflow events have severely degraded habitat in this reach.

Simon et al. (1988), and Simon (1990 and unpublished data) evaluated the fish community at several stations in the West Branch including sites up and down stream from 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. (1988) sampled fish at three stations including the area around Indianapolis Boulevard, east of the I-90 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 from these stations during this time period. On several occasions in 1985, no fish were collected from the Columbia Avenue site, and the same was true for the Indianapolis Boulevard area in 1988. 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 collections.

The State of Indiana Department of Environmental Management has collected fish tissue samples from the West Branch at Indianapolis Boulevard since 1980 (J. Stahl, personal communication). Their collections indicated the West Branch fish community is dominated by exotic species including carp and goldfish and their hybrids. Water depth in the West Branch is influenced by Lake Michigan water surface levels. Often as the surface of Lake Michigan drops, the reduced depth of water 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 in proximity to the contaminated sediment characteristic of the area.

TABLE 5. Summary of fish collected from sites in the West Branch Grand Calumet River ([1] Simon et al. 1988; [2] Simon 1990; [3] Simon, unpublished data).

	List of sites								
	1985		1986	1987			1988	1990	1994
Species	C	D[1]	B[1]	A[1]	B[1]	C[1]	B[1]	B[2]	B[3]
Gizzard shad, *Dorosoma cepedianum*					3				
Carp, *Cyprinus carpio*	2	20	21	17			6	18	10
Goldfish, *Carassius auratus*	12		22			1		2	9
Carp x 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
Total Species	2	0	2	2	3	1	0	7	6
% Tolerant Species	100	0	100	100	85.7	100	0	100	97.8
% Exotic Species	100	0	100	95.4	80.9	100	0	8.0	80.9
Number of Collections	2	0	2	1	3	1	2	1	1

A = Junction between West Branch and East Branch Grand Calumet River; B = Indianapolis Blvd.; C= East I-90 to east side of Roxanna Marsh; D = west I-90 to east Columbia Ave.

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 taken that year produced the greatest number of fish from the West Branch representing seven species (Simon 1991). The first Indiana collection of the eurasian rudd (*Scardinius erythrophthalmus*) was included with this catch. The water quality of the discharge canal at East Chicago 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 proportion of exotic species was significantly reduced as the number of native species such as bluntnose minnow and green sunfish increased (Table 5). Fish at this site had high proportions (4.5%) of deformities, eroded fins, lesions, and tumors (DELT anomalies); fish were collected which had eroded fins, fungus, and lesions.

Simon (unpublished data) sampled the West Branch in the vicinity of Indianapolis Boulevard and Roxanna Marsh again 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 is still not at the same level of 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, detritivorous, exotic species. These taxa with flexible forage habits are pioneer species and often are 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. 1988).

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 brought the species composition back to that observed in 1985. The presence of carp and goldfish hybrids indicates disruption of reproductive strategies and is considered a reduction in biological integrity. The presence of high proportions of DELT anomalies also suggest that biological integrity is declining.

One of the reasons it has been suggested that water quality in the Grand Calumet River is improving is 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". The report proposes that one male and one female salmon were "confused" by the scent of the Grand Calumet River and instead of swimming into the Little Calumet River swam instead into the Indiana Harbor Canal. These two fish then would have had to travel past the Steel Mills which line the entrance to the Harbor, swam several miles up the Indiana Harbor Canal into the West Branch of the Grand Calumet River. Fish would have had to swim through poorly oxygenated water to the East Chicago Sanitary District discharge canal. The natural channel is referred to as the “earthen channel”. These two fish would have had to travel up the 213.4 m long discharge canal, and jump through a 1.52 m pipe elevated approximately 0.5 m above the surface of the water. The fish would then need to swim through a 45.7 m long pipe and jump over a 1.37 m wall into the final effluent chamber over a weir to reach the contact disinfection chamber. The East Chicago Sanitary District speculates that these two fish brought freshwater sponge gemmules on their bodies which colonized the chambers. Experts suggest that the movement of sponges on the salmon is an impossibility. Although salmon are known to create redds and spawn in nests constructed from large gravel and cobble substrates, these chinook salmon presumably spawned on the bottom of the concrete disinfection chamber. Alevins which usually incubate several weeks in the redd, supposedly incubated in the baffle system on concrete. They were not detected until they were close to 75 mm TL. Once found, the fish were tested and genetic evidence indicated that the juvenile fishes found in the baffle system were all from a single parental combination. Spacek (1996) suggested that this evidence is the first of Pacific salmon spawning in southern Lake Michigan.

Problems with the documented evidence are substantial. Disregarding the possibility of two fish, a male and a female, were actually able to make the journey, spawn in the chamber and the young survive to a length of 75 mm before being discovered has yet to be substantiated. Problems with reproductive mode, early life history and development of the progeny found detected at sizes typical of commercially available lengths does not prove that the West Branch of the Grand Calumet River has improved.

Grand Calumet Lagoons

Simon et al. (1988) investigated the East Lagoon during 1986. The State of Indiana Department of Environmental Management has collected fish from this area for tissue contaminant analyses. Stewart and Simon (unpublished data) investigated the Middle and Western Lagoons during 1994 and 1995 to investigate the status of the fish community as part of a larger investigation of the Lagoons (Stewart and Butcher this report). The two Lagoons are located east of U.S. Steel, and they are a part of the Indiana Dunes National Lake Shore. 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 and Hildebrand, 1910) reflect the least impacted condition of the Grand Calumet since the flow of the River had only recently been reversed via 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 1960's. 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 stocking began in 1982 and occurred regularly between 1984 and 1992.

The western portion of the East Lagoon was rotenoned 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% to 38.4%, though few were of catchable size. A survey during

1973 collected a total of 646 fish including golden shiner (45.7%), bluegill (17%), and lake chubsucker (11.4%). Largemouth bass, bluegill, black crappie, and yellow perch comprised 30% of the sample. Robertson (1986) reported rosyface shiner in the East Lagoon, but these specimens probably represent misidentified emerald shiners.

Simon and Stewart (unpublished data) studied the fish community structure and function 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 while warmouth, central mudminnow, and lake chubsucker are found in the Middle Lagoon. Pumpkinseed is present in both the East and West Ponds, however, grass pickerel is 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 and 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 is the first record of this species for northwestern Indiana. The Wolf Lake population is thought to be extirpated (Smith 1979).

Stewart and Simon (1995) report the fish community of the West Lagoon is comprised of a greater proportion of tolerant species. This is probably a reflection of a more disturbed habitat, and this 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 the communities had "poor" to "very poor" integrity. Simon (1990) developed expected indices of biological integrity (IBI) 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. (1988) sampled a minimum of two or three times per year for four years to determine whether biological integrity changed substantially at any of the twelve stations sampled. For the nine stations which had repeat sampling, the average IBI score differed by less than 5 IBI points (range: 0-10 IBI points).

TABLE 6. Summary of fish community structure and function found in the Grand Calumet Lagoons ([1] Shelford 1937; [2] Robertson 1986; [3] Simon et al. 1988; [4] Stewart and Simon 1995, Simon and Stewart, unpublished data).

	List of sites						
	1937	1973	1986	1995			
Species	A[1]	B[1]	B[3]	B[4]	C[4]	D[4]	E[4]
Bowfin, *Amia calva*	x						

Central mudminnow, *Umbra limi*	x			1			
Grass pickerel, *Esox americanus*	x	x		6		x	
Northern pike, *Esox lucius*	x						
Carp, *Cyprinus carpio*	x	18	2	17			
Goldfish, *Carassius auratus*	x			1			
Carp x Goldfish hybrid							
Common shiner, *Luxilus cornutus*	x						
Golden shiner, *Notemigonus crysoleucas*	x	x			2		
Emerald shiner, *Notropis atherinoides*		x					
Blackchin shiner, *Notropis heterolepis*	x				51		
Bluntnose minnow, *Pimephales notatus*							
Lake chubsucker, *Erimyzon sucetta*	x	x	1	13			
Black redhorse, *Moxostoma duquesnei*	x						
Black bullhead, *Ameiurus melas*	x		1				
Yellow bullhead, *Ameiurus natalis*	x	x		1			
Brown bullhead, *Ameiurus nebulosus*	x						
Tadpole madtom, *Noturus gyrinus*	x			1			
Green sunfish, *Lepomis cyanellus*	x	x	2	12	15		
Pumpkinseed, *Lepomis gibbosus*	x	x	1	70	32	x	x
Warmouth, *Lepomis gulosus*	x	x		20	2		
Bluegill, *Lepomis macrochirus*	x	x	5	113	27		
Largemouth bass, *Micropterus salmoides*	x	x	2	26	94		
White crappie, *Pomoxis annularis*	x						
Black crappie, *Pomoxis nigromaculatus*		x	1	1			
Yellow perch, *Perca flavescens*	x	x		9	25		
Iowa darter, *Etheostoma exile*		8	4				
Total Number	--	--	30	297	281	--	--
Total Species	20	14	7	14	11	1	1
% Tolerant Species	30	30	70	5.4	30.6	0	0
% Exotic Species	0	14.3	60	0.1	6.4	0	0
Number of Collections	--	--	1	3	3	2	2

A = Dunal ponds identified by Shelford speculated to be Grand Calumet Lagoons; B = Middle Lagoon; C= West Lagoon; D = East Pond; E = West Pond.

Other assessment categories were used at the stations that had no fish. At these stations the IBI scores differed by more than 10 IBI points. An Ohio study found the largest departures in IBI scores were due to large scale disturbance (Yoder and Rankin 1995). In the Grand Calumet River, the wider fluctuations in IBI points also reflected highly disturbed conditions. The largest difference observed in IBI points within any single year occurred at the site to the east of Indianapolis Boulevard during 1987, when a difference of 6 IBI points was observed (Table 7).

FISH CONSUMPTION ADVISORIES

The Indiana State Department of Health (ISDH 1997) states that fish from the Grand Calumet River should not be consumed, primarily due to contamination by PCB's and mercury. Table 8 lists the fish species and sizes included in the consumption advisory. The advisory is less restrictive for the Marquette Park Lagoon, recommending only that largemouth bass more than 12 inches long be avoided. There is a state-wide advisory on carp consumption: 1 meal/ month of carp 15-20" long, 1 meal/2months for carp 20-25" in length and no carp over 25" should be consumed.

Numerous species in the nearshore of Lake Michigan also are restricted for consumption. Factors which would limit complete removal of consumption advisories and eventual recovery and delisting of the Grand Calumet River are: 1) Lake Michigan species which 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 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 should initially strive toward the goal of reaching the same levels as Lake Michigan.

Fish bioaccumulation, body burdens, and contaminant levels

Steffek (1989) evaluated three abandoned hazardous waste dump sites located 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 levels of effect. Earthworms were absent from many of the sites but showed mixed results as a result of 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 and 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

TABLE 7. Index of Biotic Integrity values for the Grand Calumet Watershed from 1985 to 1990 (Simon et al. 1988; Simon 1991). Sites indicated below are: 1) Western Lagoon; 2) East Branch Grand Calumet River, Broadway; 3) East Branch, Bridge Street;
East Branch, Grant Street; 5) East Branch, Cline Avenue; 6) East Branch, Kennedy Ave; 7) East Branch, Dupont de Nemours outfall; 8) Junction of East and West Branch Grand Calumet River; 9) West Branch Grand Calumet River, Indianapolis Blvd.;
10) West Branch, I-90 bridge; 11) West Branch, Columbia Ave., 12) Indiana Harbor Canal, Dickey Road.

	Index of Biotic Integrity Score											
Year	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
Avg IBI	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
SD	--	3	1.0	--	1.33	1.14	1.0	--	3.0	0	--	3.0
N	1	2	8	1	9	7	2	1	8	2	1	6

Table 8. Study area fish consumption advisories.

Marquette Park Lagoon	Species	Total length (in)	Concern	(meals/month)
	Largemouth Bass	12+	PCB's	1
Lake Michigan	Black crappie	7-8	PCB's	1
		8+	PCB's	0.5
	Brook trout	All	PCB's	1
	Brown trout	<18	PCB's	1
		18-27	PCB's	0.5
		27+	PCB's	0
	Carp	All	PCB's, Mercury	0
	Catfish	All	PCB's	0
	Chinook salmon	<26	PCB's	1
		26+	PCB's	0.5
	Coho salmon	17-28	PCB's	1
		28+	PCB's	0.5
	Goldfish	4+	PCB's	0
	Golden shiner	3-6	PCB's	0
	Lake trout	<21	PCB's	1
		21-26	PCB's	0.5
		26+	PCB's	0
	Largemouth bass	4-7	PCB's	1
		7+	PCB's	0.5
	Longnose sucker	14-23	PCB's, Mercury	0.5
		23+	PCB's	0
	Northern pike	10-14	PCB's	1
		14+	PCB's	0.5
Lake Michigan	Pink salmon	All	PCB's	1

	Rainbow trout	<22	PCB's	1
		22+	PCB's	0.5
	Walleye	17-26	PCB's	1
		26+	PCB's	0.5
	Whitefish	<23	PCB's	1
		23+	PCB's	0.5
	White sucker	15-23	PCB's, Mercury	1
		23+	PCB's	0.5
Grand Calumet River/IHC	All species	All	PCB's, Mercury	0

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 RECOMMENDATIONS

Construction of Indiana Harbor and development and expansion of heavy industry along the Grand Calumet River have severely degraded the fish habitat. This degradation was evidenced by the low catch rates and minimal diversity of the fish community during the mid 1970's. Improvements in water quality through the later 1970's and into the 1980's 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 improvements and maintenance of water quality will be an essential factor in the recovery of the aquatic community. First, Simon et al. (1988) observed that the fish community rebounded during the USX shutdown. This could only have been in response to a change in water quality, as no sediment remediation took place. Second, the presence of salmonids in both the East Chicago and Gary sewage treatment plant discharges suggest 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 occassionally 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 much beyond its presently degraded condition. A combination of low dissolved oxygen concentration, relatively high water temperatures, inadequate invertebrate forage, and lack of heterogenous substrates, e.g., clean sand, gravel or cobble substrate, 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. Channel depth through the length of the study area is highly variable ranging from 8 to 10 feet in the Grand Calumet Lagoons to one foot 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. However, deepening of the channel will create a more pool-like habitat resulting in slowed current, and possibly reduced dissolved oxygen concentrations. The additional water depth may prohibit the reestablishment of rooted vegetation which provides substrate for invertebrates, cover for fish and is a source of oxygen.

The dredging and 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 the dissolved contaminant concentration and reduce dissolved oxygen concentrations. These impacts tend to be temporary, and ambient levels return shortly after dredging ceases. Discharge from the dewatering site must be treated to reduce the concentration of contaminants in order to meet state water quality standards. Care must be taken to assure that the discharge does not adversely affect instream dissolved oxygen levels and that concentrations of toxic chemicals such as ammonia are within acceptable limits. Weirs surrounding the dredge site can help to contain water quality impacts within the immediate area of dredging.

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. Water depths and clarity after dredging must be such that light can penetrate to the bottom of the channel to assure reestablishment of this important aquatic habitat component.

Suggestions for aquatic habitat improvements

The U.S.EPA in 1985 identified factors which reduced the quality of biological habitat in portions of the Grand Calumet River system. Slow flowing or stagnant water in the West Branch warms causing decreased dissolved oxygen concentrations. Particulates settle over detrital matter and suffocate benthic organisms. The U.S.EPA (1985) stated that these conditions are typical of many Great Lakes stream mouth environments, but they 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 at USX. Without a high volume of industrial discharges, the majority of the Grand Calumet River system would probably be much less suitable for fish and aquatic life (assuming adequate control of pollutants in the effluent) (U.S.EPA 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, i.e., roof drains, 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 and depresses low flows, reduces dilution of groundwater contaminants, and slows dispersion from origin to point of discharge along the river.

Establishment of aeration stations, either using injected air or elevated sidestream aerators such as those present on the Cal-Sag Channel and Chicago River in Illinois, could help to improve the aquatic habitat by maintaining adequate dissolved oxygen concentrations, as well as by assisting in the breakdown of organic debris.

After the contaminated sediment is removed, care should be taken to assure that the remaining channel profile is designed to allow establishment of 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. Creation of a littoral zone may involve replacement of dredged material with clean material in some portions of the river. Replacement with gravel or other substrate will provide substrate heterogeneity suitable for lithophilic spawners and nest builders such as sucker, darters, and sunfish, and it may facilitate the reestablishment 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 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 (U.S.EPA 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 a side channel through the heavily choked *Typha, Phragmites*, and purple loosestrife stands adjacent to the River. These side-channels could be staggered and would be 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 created 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, water quality of industrial and municipal discharges will need to continue 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 episodes. A single episode of oxygen depletion could be sufficient to 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.

LITERATURE CITED

Baumann, P.C. 1989. PAH, metabolites, and neoplasia in feral fish populations. Pp. 269-289 *in* U. Varanasi, editor. Metabolism of polycyclic aromatic hydrocarbons in the aquatic environment. CRC Press, Boca Raton, Florida, USA. 341 p.

Baumann, P.C., W.D. Smith, and W.K. Parland. 1987. Tumor frequencies and contaminant concentrations in brown bullheads from an industrialized river and recreational lake. Transactions of the American Fisheries Society **116**: 79-89.

Baumann, P.C., M.J. Mac, S.B. Smith, and J.C. Harshbarger. 1991. Tumor frequencies in walleye (*Stizostedion vitreum*) and brown bullhead (*Ictalurus nebulosus*) and sediment contaminants in tributaries of the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences **48**:1084-1810.

CDM/Limnetics. 1976. Report on the November 1976 fisheries study in southern Lake Michigan for Rooks, Pitts, Fullagar and Poust. CDM/Limnetics.

Crawford, C.G. and D.J. Wangsness. 1987. Streamflow and water quality of the Grand Calumet River, Lake County, Indiana, and Cook County, Illinois. U.S. Geological Survey Water Investigations Report. 86-4108.

Custer, C.M., T.W. Custer, D.W. Sparks, R.K. Hines, and C.O. Kochany. 1996. Movement patterns of wintering lesser scaup in Grand Calumet River - Indiana Harbor Canal, Indiana. J. Great Lakes Res. **22**(**1**):95-99.

Gerking, S.D. 1945. The distribution of the Fishes of Indiana. Investigations of Indiana Lakes and Streams **3**:1-137.

Indiana Department of Environmental Management. 1988. Northwest Indiana Environmental Action Plan. Area of Concern remedial action plan. Indiana Department of Environmental Management, Indianapolis, Indiana, U.S.A.

Indiana Department of Environmental Management. 1994. Indiana 305(b) report. 1992-1993. Indiana Department of Environmental Management, Indianapolis, Indiana, USA.

Indiana State Department of Health. 1997. Indiana fish consumption advisory. Indiana State Department of Health, Indianapolis, Indiana, USA.

Meek, S.E and S.F. Hildebrand. 1910. A synoptic list of the fishes known to occur within fifty miles of Chicago. Field Museum of Natural history Zoological Series Publication 142, **7**:223-338.

Moore, P.A. 1959. The Calumet Region: Indiana's last frontier. Indiana Historical Bureau.

Polls, I. and S.G. Dennison. 1984. Biological and chemical water quality survey in Indiana Harbor, the Indiana Harbor Canal, and southwestern Lake Michigan for the U.S. Army Corps of Engineers Chicago District. Metropolitan Sanitary District of Greater Chicago, Chicago, Illinois, USA.

Risatti, J.B. and P. Ross. eds. 1989. Chemical, biological and toxicological study of sediments from Indiana Harbor Canal and adjacent Lake Michigan. Final Report for U.S. Army Corps of Engineers, Chicago District, Chicago, Illinois, USA.

Robertson, B. 1986. Evaluation of 1984 supplementally stocked channel catfish in far northwest Indiana lakes. Indiana Department of Natural Resources, Division of Fish and Wildlife, Fisheries Section, Indianapolis, Indiana, USA.

Shelford, V.E. 1937. Animal communities in temperate America. As illustrated in the Chicago Region. Arno Press, New York, USA.

Simon, T.P. 1988. Sub-chronic toxicity evaluation of major point source dischargers in the Grand Calumet River and Indiana Harbor Canal, Indiana, using the embryo-larval survival and teratogenicity test. Proceedings of the Indiana Academy of Science **98**:241-255.

Simon, T.P. 1991. Development of Index of Biotic Integrity expectations for the ecoregions of Indiana. I. Central Corn Belt Plain. U.S. Environmental Protection Agency, Chicago, Illinois. EPA 905/9-91/025.

Simon, T.P., G.R. Bright, J. Rudd, and J. Stahl. 1988. Water quality characterization of the Grand Calumet River basin using the Index of Biotic Integrity. Proceedings of the Indiana Academy of Science **98**:257-265.

Smith, P.W. 1979. The Fishes of Illinois. The University of Illinois Press: Champaign, Illinois, USA.

Sobiech, S.A., T.P. Simon, and D. Sparks. 1994. Pre-remedial biological and water quality assessment of the East Branch Grand Calumet River, Gary, Indiana. U.S. Fish and Wildlife Service, Bloomington, Indiana, USA.

Spacek, J. 1996. Wastewater plant's success spawns chinook salmon and freshwater sponges. Water Engineering and Management **1996**:26-29.

Sparks, D. and D. Hudak. 1996. Final fish and wildlife coordination act report for the Indiana Harbor and Ship Canal maintenance Dredging Disposal Project at east Chicago in Lake County, Indiana. U.S. Fish and Wildlife Service, Blomington, Indiana, USA.

Steffek, D.W. 1989. A survey for contaminants in biota near the Midco I, Midco II, and Ninth Avenue Dump hazardous waste sites in Gary, Lake County, Indiana. U.S. Fish and Wildlife Service, Bloomington, Indiana, USA. 34 p.

Stewart, P.M. and T.P. Simon. 1995. Industrial landfill effects on fish communities at Indiana Dunes National Lakeshore (INDU). SETAC Second World Congress. Global Environmental

Protection: Science, Politics, and Common Sense. Vancouver, British Columbia, Canada. p. 281 (Abstract).

U.S. Environmental Protection Agency. 1984. EPA master plan for improving water quality in the Grand Calumet River/Indiana Harbor Canal. U.S. Environmental Protection Agency, Water Division, Chicago, Illinois, USA. EPA 905/9-84/003A.

U.S. Fish and Wildlife Service. 1987. Polycyclic aromatic hydrocarbon hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Department of the Interior, Biological Report 85(1.11). Contaminant Hazard Reviews Report 11.

Yoder, C.O. and E.T. Rankin. 1995. Biological criteria program development and implementation in Ohio. Pp. 109-144 *in* W.S. Davis and T.P. Simon, editors. Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making. Lewis Press: Boca Raton, Florida, USA.

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INTRODUCTION

The ridge and swale area surrounding the Grand Calumet River is home to one of the more diverse assemblages of amphibians and reptiles in northwestern Indiana. Here, as a result of a series of recent geological and climatic events, species more typical of areas to the north, south, east, and west come together and occur in close proximity. Surprisingly, despite the long and intensive industrial history of the region, several relatively pristine natural areas have survived along with most of their salamander, frog, turtle, lizard, and snake species. The survival of these natural areas and their associated faunas provides unique opportunities for preservation and restoration.

We have looked beyond the immediate riparian area, in part because much more is known about the contiguous ridge and swale sites. Since amphibians and reptiles are less mobile than many other vertebrates, and less likely to colonize remote or isolated habitats, it is important to inventory existing centers of biodiversity and factor that information into management decisions.

We have largely relied on information available from recent inventories and older museum specimens and publications, interpreted in the context of our own field experience in the area.

Nomenclature follows Collins (1990), except for the recent elevation of *Bufo fowleri* to specific status (Sullivan et al. 1996).

PRESETTLEMENT CONDITIONS

Origins of the herpetofaunal assemblages

Presumably, amphibians and reptiles entered what is now the Grand Calumet River area shortly after the end of the Wisconsinan glaciation. Remains of the cold-tolerant turtles *Chelydra serpentina* and *Chrysemys picta* have been found in association with mastodon bones in southeastern Michigan and east central Indiana (Holman and Andrews 1994), at sites dated to 13,000-11,000 years before present (ybp). Other species which today have northern distributions must have also been present in the boreal forest which covered northwestern Indiana at that time. However, the present day site of the Grand Calumet River was still covered by the waters of post-glacial Lake Chicago. Subsequent fluctuation of lake levels (Chrzastowski and Thompson 1992; Chrzastowski et al. 1991) and climate change (Ahearn and Kapp 1984; Ebbers 1984) profoundly influenced the sequence and location of later colonization events.

The diverse herpetofauna includes northern elements such as blue-spotted salamanders, *Ambystoma laterale,* and Blanding's turtles, *Emydoidea blandingii;* and eastern species like eastern newts, *Notophthalmus viridescens,* and green frogs, *Rana clamitans*. These species may have been present since not long after the glacial retreat, and they persist today in moist woodland and wetland habitats. Species of western or southern origin and characteristic of warmer or drier conditions, such as Fowler's toads, *Bufo fowleri*, six-lined racerunners, *Cnemidophorus sexlineatus*, and western slender glass lizards, *Ophisaurus attenuatus,* presumably entered the Calumet region during a hypsithermal interval (Smith and Minton 1957) about 6200 to 5050 ybp (Ahearn and Kapp 1984). These species today inhabit xeric dunes or open grasslands.

The parallel sand ridges north of the Grand Calumet River did not form until about 2500 to 1000 ybp (Thompson 1992). This landscape is very young, even for our recently glaciated region. Amphibian and reptile populations inhabiting areas south of the Toleston beach must have colonized new wetlands and ridges as they formed.

In the 1830s, the Grand Calumet River was a shallow, sluggish body of water bordered by emergent marshes. Nearby upland ridges were usually open sand savanna interspersed with areas of dry-mesic to wet sand prairie. Adjacent swales were equally diverse, with open water, marsh, and shrub swamp communities. Because of the diversity of available habitat and the unusual history of the area, a unique assemblage of amphibians and reptiles was present at the time of settlement.

Sources of information

Any reconstruction of the presettlement herpetofauna must rely in part on somewhat later sources. The first museum specimens from the area were collected in 1902, and there are no published records of amphibians or reptiles in the Grand Calumet River area prior to Shelford (1913), who listed species at a few localities west of Gary.

Combining early published sources, specimens in area museum collections, and knowledge based on the best remaining natural areas and examples of particular habitat types, the following list of potential presettlement amphibians and reptiles has been compiled:

Mudpuppy, *Necturus maculosus*
Blue-spotted salamander, *Ambystoma laterale*
Tiger salamander, *Ambystoma tigrinum*
Eastern newt, *Notophthalmus viridescens*
Redback salamander, *Plethodon cinereus*
American toad, *Bufo americanus*
Fowler's toad, *Bufo fowleri*
Northern cricket frog, *Acris crepitans*
Spring peeper, *Pseudacris crucifer*
Western chorus frog, *Pseudacris triseriata*
Gray tree frog, *Hyla versicolor*
Bullfrog, *Rana catesbeiana*
Green frog, *Rana clamitans*
Northern leopard frog, *Rana pipiens*
Snapping turtle, *Chelydra serpentina*
Musk turtle, *Sternotherus odoratus*
Painted turtle, *Chrysemys picta*
Spotted turtle, *Clemmys guttata*
Blanding's turtle, *Emydoidea blandingii*
Map turtle, *Graptemys geographica*
Six-lined racerunner, *Cnemidophorus sexlineatus*
Western slender glass lizard, *Ophisaurus attenuatus*
Five-lined skink, *Eumeces fasciatus*
Eastern hognose snake, *Heterodon platirhinos*
Blue racer, *Coluber constrictor*
Smooth green snake, *Opheodrys vernalis*
Fox snake, *Elaphe vulpina*
Milk snake, *Lampropeltis triangulum*
Northern water snake, *Nerodia sipedon*
Queen snake, *Regina septemvittata*
Brown snake, *Storeria dekayi*
Western ribbon snake, *Thamnophis proximus*
Plains garter snake, *Thamnophis radix*
Common garter snake, *Thamnophis sirtalis*

The sluggish open-water channel of the Grand Calumet River must have been inhabited by a variety of fully aquatic species. Snapping turtles, *Chelydra serpentina*; musk turtles, *Sternotherus odoratus*; and painted turtles, *Chrysemys picta*; were certainly present in the lagoons near the town of Miller in the early part of this century, and they are documented by museum specimens. Shelford (1913) reported the three species listed above, as well as map turtles, *Graptemys geographica*, in ponds to the north of the river at Clark Street, and these may have been present in the channel as well. Mudpuppies, *Necturus maculosus*, formerly were present in Wolf Lake and still occur in Lake Michigan; these may have entered the channel before water quality degradation became severe.

Riparian wetlands probably provided foraging areas for all of the above species, as well as semi-aquatic species such as bullfrogs, *Rana catesbeiana*; green frogs, *Rana clamitans*; Blanding's turtles, *Emydoidea blandingii*; and northern water snakes, *Nerodia sipedon*. Terrestrial species may have entered riparian areas on occasion but did not permanently reside there.

Swales adjacent to the river provided habitat for a rich array of species. Salamanders and frogs used these wetlands for breeding, and several types of turtles and snakes likely reached maximum abundance there. Shelford (1913) listed tiger salamanders, red-spotted newts, northern leopard frogs, snapping turtles, musk turtles, painted turtles, map turtles, and garter snakes from swales near Clark Street. Various terrestrial species occupied the intervening sand prairie and savanna.

CURRENT STATUS

Grand Calumet River channel

Because of severe water quality degradation, only a few tolerant reptiles are known presently to inhabit the Grand Calumet River channel. Snapping turtles and painted turtles have been reported recently from the eastern reaches of the river (Sobiech et al. 1994), and the authors observed both species at several locations from the Hammond Sanitary District east to USX. Both species are relatively tolerant of poor water quality. It is unlikely that any amphibians presently are permanent residents of the open channel, although individual animals may enter the area from time to time.

Riparian areas

Recent searches of riparian marshes have not revealed any amphibians or reptiles. Monotypic stands of common reed, which now dominate the vast majority of wetlands in the Calumet region (see Choi, this appendix), probably do not provide useful habitat for most species. Areas dominated by cattails, which are also very common, provide better habitat structure. Here, however, poor water quality and dense layers of cattail thatch may be limiting habitat. It is probable that some common species such as garter snakes (*Thamnophis sirtalis*) enter the riparian wetlands on occasion.

Stands of young floodplain forest, characterized by pioneer species such as cottonwood and usually by a dense understory, are present at several locations along the river margin. These habitats are largely impenetrable now. If wetlands isolated from the river are present they could be utilized by some common amphibians for breeding, but the sites are probably too heavily overgrown and shaded for most reptiles.

Adjacent sites

While the Grand Calumet River and bordering riparian wetlands support a depauperate herpetofauna, several natural areas contiguous with the river are noted for their species richness. Some parcels of lesser quality also support amphibians or reptiles tolerant of habitat modification. These sites are described individually below, on a reach-by-reach basis, from east to west.

Grand Calumet Lagoons reach

The lagoons at the easternmost end of the Grand Calumet River are partially bordered on the north and south by Miller Woods, which are a part of Indiana Dunes National Lakeshore. Areas immediately to the south of the lagoons consist largely of dry-mesic sand savanna with interspersed marsh and pond communities in swales. The area to the north is a diverse dune complex in immediate proximity to Lake Michigan, and includes unusual communities such as pannes (Wilhelm 1990). The Miller area is located in a transition from the more mesic, sheltered forest areas which become increasingly common to the east, and the more open and increasingly prairie and savanna dominated sites to the west.

Specimens of amphibians and reptiles from "Miller" are available from as early as 1902. Several prominent scientists visited the area during the first half of the 20th Century, including Carl Hubbs, Karl P. Schmidt, and Walter Stille; however, locality data for these early specimens are usually vague and many of them may have been collected outside of the current National Lakeshore boundaries.

More recent data, gathered in the mid-1980s, is available from Resetar (1988) and Werth (1990). The study site of Werth (1990) was located a little over one kilometer south of the Lagoons, but it included habitat representative of the general area.

Resetar (1988) listed 18 species of amphibians and reptiles occurring within the Miller Woods Unit at the time of his study. One of these, the Fowler's toad (*Bufo fowleri*), is characteristic of the pannes and blowouts to the north of the Grand Calumet Lagoons, while the other 17 species are more general in occurrence. All 18 species could occur in the immediate proximity of the Lagoons. Only two other sections of the National Lakeshore, the Cowles Unit and the Eastern Unit, are known to support greater herpetofaunal species richness (Resetar 1988).

The following list of Miller Woods amphibians and reptiles was compiled from Resetar (1988) and Werth (1990):

Blue-spotted salamander, *Ambystoma laterale*
Tiger salamander, *Ambystoma tigrinum*
Eastern newt, *Notophthalmus viridescens*
Fowler's toad, *Bufo fowleri*
Spring peeper, *Pseudacris crucifer*
Western chorus frog, *Pseudacris triseriata*
Gray tree frog, *Hyla versicolor*
Bullfrog, *Rana catesbeiana*
Green frog, *Rana clamitans*
Snapping turtle, *Chelydra serpentina*

Musk turtle, *Sternotherus odoratus*
Painted turtle, *Chrysemys picta*
Blanding's turtle, *Emydoidea blandingii*
Six-lined racerunner, *Cnemidophorus sexlineatus*
Eastern hognose snake, *Heterodon platirhinos*
Brown snake, *Storeria dekayi*
Western ribbon snake, *Thamnophis proximus*
Common garter snake, *Thamnophis sirtalis*

Additional species have been reported historically from the "Miller" area, but are not documented from Miller Woods within the Indiana Dunes National Lakeshore:

Redback salamander, *Plethodon cinereus*
Northern cricket frog, *Acris crepitans*
Northern leopard frog, *Rana pipiens*
Five-lined skink, *Eumeces fasciatus*
Blue racer, *Coluber constrictor*
Fox snake, *Elaphe vulpina*
Northern water snake, *Nerodia sipedon*
Plains garter snake, *Thamnophis radix*

Some of these species may once have occurred within what is now Miller Woods; for example, northern cricket frogs and northern leopard frogs have disappeared from many historical localities in northwestern Indiana. Others may have been restricted to unique microhabitats outside the National Lakeshore boundaries. Wilhelm (1990) noted that many localities in the Miller area visited by early botanists have been destroyed. The existence of a redback salamander labeled "Miller" in a museum collection implies that, as Wilhelm (1990) suggests, mesic forest pockets once existed near Miller; this species is still common near Dune Acres, not far to the east, where the required habitat is present.

USX reach

The USX reach of the Grand Calumet River corridor includes some remnant ridge areas with black oak as well as successional species such as cottonwood. A botanical survey would help determine the extent of potential reptile habitat. If this site is used to bury contaminated sediments, a full floral and faunal survey should be conducted in advance. An effort to relocate animals prior to construction should be considered.

Gary Sanitary District reach

The Clark and Pine complex of seven sites is located north of the Grand Calumet River at the eastern end of the Gary Sanitary District reach, and extends slightly into the adjacent USX reach. The seven natural areas include perhaps the highest concentration of rare and endangered plant and animal species remaining in the state of Indiana (Bowles 1989). Although only Clark and Pine East directly borders the Grand Calumet River, several of the areas are divided from each other only by railroad tracks or roads, and to some extent they probably still function as a unit. Several of the ponds studied by Shelford (1913) were within or near the Clark and Pine complex. Others who collected in the general area included Hubbs and Meek, and specimens are available from as early as 1902.

Clark and Pine East, sometimes referred to as the Bongi site, borders the Grand Calumet River just east of the U.S. Route 12 bridge and extends to the north. The approximately 102 hectare site was acquired by the Division of Nature Preserves, Indiana Department of Natural Resources, in 1993. The area was originally a classic example of ridge and swale habitat. Several of the ridges were mined for sand at various times in the recent past. The resulting low, wet, flat areas subsequently revegetated with mostly native species, including an unusual panne-like assemblage. Relatively undisturbed but overgrown sand savanna alternates with swales in the east-central part of the site. Management of Clark and Pine East is now underway, and consists largely of brush clearing and controlled burning. Amphibians and reptiles were inventoried during 1990 and 1991 by Mierzwa et al. (1991) as part of the Illinois-Indiana Regional Airport Study. The most intensive inventory effort, including quantitative drift fence sampling using pitfall and funnel traps (see Heyer et al. 1994 for a detailed discussion of drift fence techniques), was focused within a complex of dry-mesic sand savanna, mesic to wet sand prairie, marsh, and shrub swamp in the least disturbed portion of the site. Frequent searches were also carried out in other parts of the site.

The 17 hectare Clark and Pine Nature Preserve is located just to the northwest of Clark and Pine East. The two sites are separated by Clark Street. The nature preserve has been under state ownership for some time, and it has been intensively managed. It is generally wetter and more open than the preceding site, with extensive areas of pond, marsh, sand prairie, and open sand savanna. The sand savanna includes both black oak (*Quercus velutina*) and jack pine (*Pinus banksiana*); plant communities were described in detail by Bowles (1989). Clark and Pine Nature Preserve was sampled for amphibians and reptiles by Resetar (1988), using a combination of drift fence and random search techniques.

Other sites within the complex are privately owned. Lakeshore Railroad Prairie, a small site located just to the north of Clark and Pine East, has pond, marsh, panne, sand prairie, and sand savanna communities, the latter dominated by jack pine. Clarke Junction East and Clarke Junction West are located to the northwest of Clark and Pine Nature Preserve. These sites also include pond, marsh, panne, and sand prairie communities, but suffer from shrub encroachment. Limited information on the herpetofauna of these sites, based on only a few visits, is included in Mierzwa et al. (1991). Morgan and Burling (1979) visited several Clark and Pine complex sites and reported the presence of some amphibians and reptiles, but their lists include at least one apparent misidentification and therefore should be used with caution.

A list of amphibians and reptiles observed by Mierzwa et al. (1991) and Resetar (1988) within the Clark and Pine complex is included below. Eighteen species are known to occur within the complex at present, an unusually high number for a relatively small site. Unusual species include the northern cricket frog, a once common species which has nearly disappeared from northern Indiana, and the state threatened spotted turtle.

Tiger salamander, *Ambystoma tigrinum*
Eastern newt, *Notophthalmus viridescens*
American toad, *Bufo americanus*
Northern cricket frog, *Acris crepitans*
Western chorus frog, *Pseudacris triseriata*
Bullfrog, *Rana catesbeiana*
Green frog, *Rana clamitans*
Snapping turtle, *Chelydra serpentina*
Painted turtle, *Chrysemys picta*
Spotted turtle, *Clemmys guttata*
Blanding's turtle, *Emydoidea blandingii*
Six-lined racerunner, *Cnemidophorus sexlineatus*
Western slender glass lizard, *Ophisaurus attenuatus*
Milk snake, *Lampropeltis triangulum*
Northern water snake, *Nerodia sipedon*
Brown snake, *Storeria dekayi*
Western ribbon snake, *Thamnophis proximus*
Common garter snake, *Thamnophis sirtalis*

A few additional species have been reported from the general vicinity of Clark and Pine, but are based either on old museum specimens or on more recent anecdotal reports without specimen documentation:

Blue-spotted salamander, *Ambystoma laterale* (1978)
Fowler's toad, *Bufo fowleri* (1917)
Gray tree frog, *Hyla versicolor* (1904)
Eastern hognose snake, *Heterodon platirhinos* (1902)
Queen snake, *Regina septemvittata* (1990)

Little is known of the herpetofauna along other portions of the Gary Sanitary District reach. Some degraded habitat is present on the Gary Airport property, and the authors have collected common garter snakes and western slender glass lizards there. Mierzwa et al. (1991) reported on the herpetofauna of Ivanhoe Dune and Swale, a site owned by The Nature Conservancy. However, this site is south of the Indiana Tollroad and effectively isolated from the Grand Calumet River, so it is not addressed here.

DuPont reach

The privately owned DuPont site extends along the northern bank of the Grand Calumet River between Cline Avenue and Kennedy Avenue. In addition to marsh and floodplain forest along the river, the site includes extensive areas of dry-mesic to wet sand prairie, dry-mesic sand savanna, and swales with sedge meadow and marsh. No historical information is available on the herpetofauna. The site was sampled in 1990 and 1991 for amphibians and reptiles by Mierzwa et al. (1991) using a drift fence and occasional visual searches. Although the DuPont site is not as species rich as the preserves described above, a minimum of nine species are known to occur there. Not all habitat types were intensively sampled, so it is possible that additional species are present at the site. Species reported for the DuPont site by Mierzwa et al. (1991) are listed below:

Tiger salamander, *Ambystoma tigrinum*
American toad, *Bufo americanus*
Western chorus frog, *Pseudacris triseriata*
Green frog, *Rana clamitans*
Snapping turtle, *Chelydra serpentina*
Blanding's turtle, *Emydoidea blandingii*
Painted turtle, *Chrysemys picta*
Brown snake, *Storeria dekayi*
Common garter snake, *Thamnophis sirtalis*

An area of open marsh is located to the south of the Grand Calumet River, between the DuPont site and the confluence with the Indiana Harbor Canal. It is directly across the river from a J-shaped channel. River water swirls through this site, which can be characterized as a partially open marsh habitat located in a river bend. The area is inhabited by snapping turtles and painted turtles, which benefit from the interspersion of open water and emergent marsh.

Two high-quality natural areas, Gibson Woods Nature Preserve and Tolleston Ridges Nature Preserve (also known as the Shell Oil Tract) are located south of this reach. Bacone (1979) included a list of amphibians and reptiles for Tolleston Ridges. However, these sites are effectively isolated by the Indiana Tollroad, so they are not discussed in detail here.

East Chicago Sanitary District reach

An area of upland meadow is located south of the River between the confluence of the Indiana Harbor Canal and a substation; it is just to the southeast of the East Chicago Sanitary District Plant. The meadow is dominated by a variety of herbaceous plant species. No amphibians or reptiles were noted during a site visit, but suitable habitat is present for several upland species.

Roxana Marsh reach

Little information is available on amphibian and reptile populations for Roxana Marsh. The northern leopard frog was reported for the site in 1984 (Indiana Department of Natural Resources 1992). This represents the most recent record of the species from the Indiana portion of the Grand Calumet River watershed. The same survey recorded snapping turtles and painted turtles as common in open water areas. The marsh habitat is of relatively low quality, and it probably supports few species of amphibians and reptiles.

Hammond Sanitary District reach

Land to the south of the treatment plant is separated from the river by a dike. Much of the area is overgrown with herbaceous vegetation. Water is ponded in some areas and supports a breeding population of toads. The site has been severely altered, but it could support additional species and might benefit from restoration or management.

Culverts reach

No information is available for this segment of the Grand Calumet River.

Far West reach

Burnham Prairie is located along the Grand Calumet River approximately 2.0 km to the west of the Illinois-Indiana state line. Although outside of the primary study area, it is discussed here as an example of the very different Chicago lake plain ecosystem. While the Indiana sites discussed above are on beach or nearshore sand deposits, Burnham Prairie is on silt-loam soils deposited in somewhat deeper water. It is one of the last remaining examples of the black soil prairies once widespread in the Lake Calumet region and discussed at length by Cowles (1901). The site includes marsh, wet, wet-mesic, and dry-mesic prairie, and a small dry-mesic savanna grove with bur oak, *Quercus macrocarpa*. Amphibians and reptiles were sampled with drift fences and random searches by Mierzwa et al. (1991). Species richness is relatively low, possibly because of the small area of the site. However, all six species found at Burnham Prairie are relatively abundant there. It is noteworthy that two species common on the black soil site, the northern leopard frog and the plains garter snake, are rare only a few kilometers away in northwestern Indiana. A list of Burnham Prairie amphibians and reptiles, from Mierzwa et al. (1991) follows:

American toad, *Bufo americanus*
Western chorus frog, *Pseudacris triseriata*
Northern leopard frog, *Rana pipiens*
Brown snake, *Storeria dekayi*
Plains garter snake, *Thamnophis radix*
Common garter snake, *Thamnophis sirtalis*

SPECIES ACCOUNTS

A total of 33 species of amphibians and reptiles have been recorded within the watershed of the Grand Calumet River. Seven of these were recorded historically but have not been reported recently. At least 26 species are still present today The habitat, distribution, and status of each species is briefly summarized below.

Extant species

Blue-spotted salamander, *Ambystoma laterale*. This species occurs in wooded communities including relatively open savanna, woodland, mesic forest, and swamp forest. Breeding likely takes place in the swales. Blue-spotted salamanders are uncommon within the study area. Werth (1990) found one specimen at Miller Woods. Mierzwa et al. (1991) collected two in the western part of Ivanhoe Dune and Swale. Morgan and Burling (1979) reported one from the Clark and Pine area. The blue-spotted salamander is a northern species, and it is near the southern limit of its range here.

Tiger salamander, *Ambystoma tigrinum*. Although seldom seen because of burrowing habits, the tiger salamander is relatively widespread and common in the vicinity of the Grand Calumet River. The species breeds in marsh or shrub swamp within swales, and resides for the remainder of the year in dry-mesic sand savanna on the dune ridges. Individual salamanders are often found in surprisingly open locations; one Illinois population of tiger salamanders increased dramatically as savannas were opened up with brush clearing and prescribed burns (Mierzwa in press). Adult tiger salamanders usually do not travel far from breeding sites; recent studies in areas of sandy soil in New York have indicated that up to 80 percent of the population remains within 100 meters of the breeding wetland with a few individuals moving as far as 300 meters. Tiger salamanders spend most of their time in burrows created by shrews or other small mammals (Madison 1993), with limited surface activity on rainy nights.

Eastern newt, *Notophthalmus viridescens*. Newts are aquatic as adults, but they are capable of terrestrial movements if ponds dry. The adult phase may be preceded by a terrestrial eft stage lasting up to several years. Newts are common at Miller Woods (Werth 1990) and uncommon but present in the Clark and Pine area, where they were reported by Shelford (1913) and Mierzwa et al. (1991). In both areas newts inhabit pond and marsh communities in permanent and semi-permanent swales.

American toad, *Bufo americanus*. American toads are common in the western part of the study area, and they occur at Clark and Pine, DuPont, Ivanhoe Dune and Swale, near the Hammond Sanitary District treatment plant and at Burnham Prairie (Mierzwa et al. 1991). They have not been reported at Miller Woods. Elsewhere in northwestern Indiana, populations frequently occur on river floodplains. Water quality may constrain the toads' use of Grand Calumet riparian areas, but some have been observed in swales immediately adjacent to the river at DuPont.

Fowler's toad, *Bufo fowleri*. In northwestern Indiana this species, more characteristic of areas well to the south, is restricted to sandy soil. In the dunes area it typically breeds in blowout ponds and pannes in the immediate vicinity of Lake Michigan (Breden 1988). A population at Miller Woods, to the north of the Grand Calumet Lagoons, may be the westernmost one extant in the dunes area. Historically, the species occurred at Pine, where in 1917 a specimen was collected at the pond closest to Lake Michigan.

Northern cricket frog, *Acris crepitans*. Cricket frogs are associated with the margins of permanent ponds and streams, and they must have been common at one time along the banks of the Grand Calumet River. Sometime in the late 1970s or early 1980s, this once abundant frog disappeared from most localities in the northern part of its range. A population at the Clark and

Pine complex (Mierzwa et al. 1991) is the only one known to persist in Lake County. Cricket frogs are quite common at both Clark and Pine Nature Preserve and Clark and Pine East, and they are frequently seen along swale edges during the summer months.

Spring peeper, *Pseudacris crucifer*. Spring peepers are common at Miller Woods and in the eastern part of the dunes region where woodland and forest are widespread. In the western part of our study area they have been reported only from Tolleston Ridges Nature Preserve. Breeding occurs in shrub swamps, marshes, and vernal ponds, and adults spend the summer in shrubs and trees.

Western chorus frog, *Pseudacris triseriata*. This species is characteristic of grassland and savanna areas. It is abundant in the western part of the study area but less common and more sporadically distributed in the eastern part. Breeding occurs in marshes, and during the summer months adults forage in herbaceous vegetation.

Gray tree frog, *Hyla versicolor* complex. Gray tree frogs are common at Miller Woods, but the only record of their occurring elsewhere in the study area is based on a 1904 specimen. A variety of semi-permanent wetlands are used for breeding, with adults spending the rest of the year in nearby trees and shrubs. Populations in northwestern Indiana are thought to be *Hyla versicolor*, and the nearest report of the cryptic sibling species *Hyla chrysoscelis* was in Berrien County, Michigan (Bogart 1979).

Bullfrog, *Rana catesbeiana*. Bullfrogs are semiaquatic, and they are usually observed at the margins of permanent ponds or rivers. There are recent records from Miller Woods and Clark and Pine East; bullfrogs are probably widespread in the area but relatively uncommon.

Green frog, *Rana clamitans*. Green frogs have been observed at all Grand Calumet sites sampled in recent years, and they are relatively common at the larger natural areas. They are semiaquatic, inhabiting permanent marshes, ponds, and streams.

Northern leopard frog, *Rana pipiens*. This species is usually associated with herbaceous vegetation, including sedge meadow, wet prairie, wet savanna, and marsh. There are records of leopard frogs from Miller in 1922 and 1935, and from Hessville in 1923, but the only recent report from the Indiana portion of the study area is a Natural Heritage database entry for Roxana Marsh from 1984 (Indiana Department of Natural Resources 1992). Leopard frogs were notably absent at the Indiana sites sampled in recent years (Mierzwa et al. 1991, Werth, 1990). Leopard frogs have reportedly declined in parts of the Midwest recently (Harding and Holman 1992). At nearby Illinois sites, including Burnham Prairie and Powderhorn Lake, northern leopard frogs are still common (Mierzwa et al. 1991).

Snapping turtle, *Chelydra serpentina*. Snapping turtles are tolerant of pollution, and they are still present in the Grand Calumet River and in riparian marshes, as well as in most of the nearby wetlands. Because this species is fully aquatic and seldom basks in the sun, it is usually more common than the available records indicate. It has been reported from the Grand Calumet Lagoons, Miller Woods, DuPont, and the Clark and Pine complex. The snapping turtle is a habitat generalist, and it can be found in most permanent water bodies.

Musk turtle, *Sternotherus odoratus*. There are several records of this aquatic turtle from the Grand Calumet area. In 1918 Carl Hubbs collected a specimen that is now in the Field Museum collection from the Grand Calumet River near Miller. Other specimens are available from the Grand Calumet Lagoons, and from Buffington. Shelford (1913) listed musk turtles as characteristic of the more open swales close to Lake Michigan. The species probably still occurs in some wetlands near the river. Werth (1990) found musk turtles at Miller Woods, and a single specimen sited crossing a road in Hammond in 1996 turned in at Gibson Woods Nature Center.

Painted turtle, *Chrysemys picta*. There are numerous records of this species from the study area, as early as 1909 and as recently as 1996. It is one of the few species still occasionally found in the main channel. Permanent swales close to the river support sometimes dense populations, especially at Miller Woods, DuPont, and the Clark and Pine complex. Painted turtles inhabit both ponds and rivers, and they are easily observed because of their tendency to bask on logs or other objects.

Spotted turtle, *Clemmys guttata*. This small, attractive turtle is threatened in Indiana and endangered in Illinois. It is characteristic of shallow, sedge dominated wetlands and adjacent marsh borders. The Clark and Pine complex supports one of the larger spotted turtle populations in northwestern Indiana, but it has recently suffered from illegal collecting. Suitable habitat is present in swales very close to the Grand Calumet River at Clark and Pine East. This locality is nearly at the western distributional limits of the species.

Blanding's turtle, *Emydoidea blandingii*. This is a federal "species at risk" (formerly "Category 2"), and it is included on special concern or watch lists in most states in which they occur. Recent attention has focused on the long life span (> 60 years) and late age of maturity (14-20 years) of this species (Congdon et al. 1993). Because of these life-history characteristics, loss of reproductive females through highway mortality, over collecting, or other causes may have significant long-term effects on population viability. Blanding's turtles occur throughout the study area, with recent reports from Miller Woods, Clark and Pine East, Clark and Pine Nature Preserve, Lakeshore Railroad Prairie, Ivanhoe Dune and Swale, and DuPont. Populations appear to be at low density at most sites. Blanding's turtles are most common in swales which include pond and marsh communities, and particularly those with considerable submerged vegetation. Individuals are occasionally encountered on land. Short-term movements in excess of 800 meters have been observed (Mierzwa unpublished data), suggesting that relatively large sites may be needed to support a viable population. Blanding's turtles have been observed in sluggish, well vegetated rivers such as Dead River at Illinois Beach State Park, and may have once occurred in the Grand Calumet; however, early observers apparently overlooked this species. The range of the Blanding's turtle is mostly to the north of the Grand Calumet River area.

Six-lined racerunner, *Cnemidophorus sexlineatus*. This lizard inhabits xeric, sparsely vegetated dunes. Populations in northwestern Indiana are widely disjunct from the main body of the range, well to the south, and presumably represent a relict from a time of warmer or drier climate. Although the racerunner is strictly an upland species, it occurs in close proximity to the river at several locations where sand prairie or open sand savanna communities persist. Recent records are available from Clark and Pine, Brunswick Center Savanna (Mierzwa et al. 1991; Resetar 1988), and Miller Woods (Werth 1990).

Western slender glass lizard, *Ophisaurus attenuatus*. This legless lizard is common in the more open western part of the study area. Recent observations have been mostly in xeric to dry-mesic sand prairie openings on ridges, but one specimen attempted to escape by swimming along the margin of a swale (Mierzwa unpublished field notes). Extant populations are known from the Clark and Pine complex and Ivanhoe Dune and Swale, and from disturbed areas at Gary Airport (Mierzwa et al. 1991). Additional populations are probably present. Populations in the study area are disjunct and near the northern limits of the distribution, and they may represent remnants from warmer or drier times.

Eastern hognose snake, *Heterodon platirhinos*. The only recent reports of hognose snakes have been from Miller Woods (Werth 1990). The species historically occurred at Pine (Richards 1987). This is an upland species found in sand prairie and sand savanna; it may occasionally forage for toads near wetland margins.

Milk snake, *Lampropeltis triangulum*. Milk snakes are uncommon in the study area. Resetar (1988) reported the species from Clark and Pine Nature Preserve, and Mierzwa et al. (1991) collected two specimens at Clark and Pine East over two field seasons. One of these was caught in a drift fence in dry-mesic sand savanna, and the other was found under roadside debris along Clark Street. Elsewhere in the region milk snakes are characteristic of upland savannas, but they are occasionally collected in sedge meadows (Mierzwa 1993).

Northern water snake, *Nerodia sipedon*. This semi-aquatic snake may have once inhabited the margins of the Grand Calumet River, but recent observations have been limited to swales in the Clark and Pine complex (Resetar 1988; Mierzwa et al. 1991). Historically, the species occurred in the Miller area, with two specimens collected in 1902. Northern water snakes are thought to be relatively uncommon in the study area today.

Brown snake, *Storeria dekayi*. This small, secretive species is the second most common snake at most locations within the study area. Most individuals have been caught in drift fences or found under boards or other debris. Dry-mesic sand savanna is probably the preferred habitat of the brown snake, but some individuals have been found in sedge meadows, wet prairies, or along the margins of marshes at Clark and Pine (Mierzwa et al. 1991).

Western ribbon snake, *Thamnophis proximus*. This semi-aquatic species is characteristic of shrubby wetland margins (Rossman et al. 1996). It is uncommon in the study area, and so far it has been reported only at Miller Woods and Clark and Pine Nature Preserve (Resetar 1988). A specimen collected near Miller in 1919 was found within the “pine-oak association.”

Plains garter snake, *Thamnophis radix*. This species is characteristic of black-soil mesic prairie. It is abundant just to the west of the Illinois state line, but it is extremely rare in northwestern Indiana. This is a western species, and except for disjunct Ohio populations, it is near the limits of its range here. The only Indiana records from the vicinity of the study area are from Miller (1902) and Hessville (1923 and 1935). In contrast, during a brief drift fence effort in 1991, 38 plains garter snakes were caught in drift fences at Burnham Prairie, and several more were found under boards just to the west of Wolf Lake and just to the north of Powderhorn Lake (Mierzwa et al. 1991). Seibert (1950) studied this species in the Lake Calumet area, and reported a density of 840 plains garter snakes per hectare in a vacant lot near 103rd and Stony Island.

Common garter snake, *Thamnophis sirtalis*. This is by far the most widespread and abundant snake in the Grand Calumet River area. It has been reported from every site studied to date, usually in substantial numbers. In the study area, common garter snakes are abundant in dry-mesic sand savanna and in successional fields. They are easily collected from under debris in vacant lots. Common garter snakes do not hesitate to enter marshes and ponds to forage for frogs and fish. This species has been found on fill within meters of the Grand Calumet River, and in 1996 a specimen was observed along railroad right-of-way about 50 meters north of the river at Clark and Pine East.

Species present historically

Mudpuppy, *Necturus maculosus*. Minton (1972) reported this species from Wolf Lake. It still occurs in Lake Michigan, and mudpuppies probably entered the Grand Calumet River before the mouth closed. Poor water quality and contaminated sediments may preclude the presence of this bottom-dwelling aquatic species at present.

Redback salamander, *Plethodon cinereus*. Carl Hubbs collected a redback salamander "near Miller" in 1917. This species is characteristic of mesic forest, and it is common east of the study area in the National Lakeshore. A small area of suitable habitat was presumably present near the town of Miller at one time but may have since been destroyed.

Map turtle, *Graptemys geographica*. Shelford (1913) mentioned map turtles from swales near Lake Michigan, and museum specimens are available from Deep River in Lake County. Although the map turtle is not documented in the immediate vicinity of the Grand Calumet River, it may once have occurred there, and it certainly was present within a few kilometers of the study area.

Five-lined skink, *Eumeces fasciatus*. This lizard is known from a single old specimen collected at "Miller" (Schmidt and Necker 1935).

Blue racer, *Coluber constrictor*. Two old specimens from "Miller" are available (Schmidt and Necker 1935), and one of them was collected by Meek in 1908. Morgan and Burling (1979) reported a blue racer from a site southeast of but apparently isolated from Miller Woods.

Smooth green snake, *Opheodrys vernalis*. A single specimen (FMNH 2110) was collected at "Miller" in 1902. Green snakes were once common on the black soil prairies just to the west of the Illinois state line (Seibert 1950). The nearest known extant population is at Van Vlissengen Prairie, which is located just to the northeast of Lake Calumet.

Fox snake, *Elaphe vulpina*. A single undated, but old, specimen (FMNH 2864) was collected at "Miller."

Problematic species

A few additional species have been reported anecdotally, could occur in the study area but have not been reported, or have been reported based on probable misidentifications:

The spiny softshell, *Apalone spinifera*, occurs in Lake Michigan in Illinois. It is not known from the study area, but could have been present historically. The queen snake, *Regina septemvittata*, was reported from Clark and Pine Nature Preserve in 1990, but the specimen was not collected (Griggs and Balzano personal communication). The observers were from the east coast and were not familiar with the local fauna, so the record is considered questionable. However, queen snakes do occur in the headwaters of the Little Calumet River in Porter County, so they could be present elsewhere in the drainage. The pickerel frog, *Rana palustris*, was reported from the Clark and Pine complex by Morgan and Burling (1979), but not by later investigators who spent much more time on the sites. The cool fen and wooded stream habitats frequented by this species are not present at Clark and Pine, and there are no other Lake County records. Because the nearest known extant populations are several counties away, we are skeptical of the report. Finally, we reject a report of the massasauga, *Sistrurus catenatus*, from

Clark and Pine East (Lake Michigan Federation 1984). Extensive sampling there by several workers, including two with considerable massasauga experience, failed to confirm the record (Mierzwa et al. 1991). The habitat at Clark and Pine is also quite different from that typically utilized by the species. The report may be based on a sighting of the superficially similar northern water snake.

POTENTIAL IMPACTS OF DREDGING

Dredging of the Grand Calumet River will have little direct impact on amphibians and reptiles. Only two species (snapping turtle and painted turtle) are known to inhabit the channel at present. Some direct injury or mortality could result from dredging operations, but because both species are common in nearby wetlands, the river population would probably soon be supplemented from those sources. A few other species may occasionally enter the river, but these transient individuals represent a tiny fraction of the available population.

Terrestrial or wetland habitat adjacent to the river could be impacted by sloughing of banks, soil compaction by heavy machinery, or elevation change or hydrology alteration related to sediment disposal.

The primary concern is to protect wetland and terrestrial habitat contiguous to the river at the higher quality natural areas, such as Miller Woods, Clark and Pine East, and DuPont. These sites include rare communities utilized by relatively high densities of amphibians and reptiles. Several rare or uncommon species, including the state threatened spotted turtle, state endangered Blanding's turtle, and state special concern western slender glass lizard, could occur very near the river at some of these sites.

HABITAT ENHANCEMENT AND MANAGEMENT

Considering the long history of industrial use along the Grand Calumet River, it is perhaps amazing that so many amphibians and reptiles, some of them rare, persist in the area. However, because of the presence of several high quality natural areas contiguous to the river, unique restoration opportunities are available. Appropriate management of some of the sites described above could enhance the viability of amphibian and reptile populations.

Water quality in the Grand Calumet River has improved considerably since point source pollution has been reduced. However, most of the water in the system still originates as industrial discharge or treatment plant effluent. With the removal of contaminated sediments, it is possible that the Grand Calumet or riparian wetlands in direct contact with the river will eventually be able to support a herpetofaunal assemblage of at least tolerant species.

Clean-up of the river will provide an opportunity to speed or expand restoration of the better quality core areas already in public ownership, to lobby for acquisition of or the negotiation of management agreements for other remnants of natural land, and ultimately to take advantage of the river corridor to once again link up some of the core areas.

Acquisition of additional core natural areas

Several sites identified by the Indiana Natural Areas Inventory, including parts of the Clark and Pine complex, remain in private ownership and are at risk of degradation. Acquisition of these sites would help to preserve a number of rare species.

Acquisition of buffer areas

Acquisition of land contiguous to core natural areas, in conjunction with restoration activities discussed below, could greatly improve the long-term viability of sites which currently support high levels of biodiversity.

Restoration of core natural areas

The best quality sites are in need of woody vegetation management, including manual removal of exotic shrubs and the regular use of controlled fire. Enforcement activities to discourage illegal dumping and poaching would also be helpful.

Restoration of degraded sites

Because most of the landscape around the Grand Calumet River once consisted of alternating ridges and swales, some of the amphibians and reptiles in the area are capable of utilizing both upland and wetland habitat. Restoration efforts which address both habitat components are likely to support the greatest diversity of wildlife, especially if restoration areas are adjacent to the existing core natural areas. Early efforts can serve to create buffer areas for existing preserves. Over time these buffers could be extended to serve as connections between preserves. The challenges to this process will be many in this complex urban landscape, but opportunities should be pursued as they present themselves.

Wetlands with a direct river connection could contribute to water quality renovation and potentially provide habitat for some semi-aquatic amphibians and reptiles such as mudpuppies, bullfrogs, green frogs, snapping turtles, painted turtles, and northern water snakes. Turtles could benefit from opening the existing dense cattail marshes in riparian areas. Deepening of selected areas in conjunction with dredging operations could improve interspersion of marsh and open water habitats.

Many amphibians do not breed in riparian wetlands because of fish predation on eggs and larvae. Creation of a few palustrine emergent wetlands isolated from direct contact with the river could provide habitat for these species, including tiger salamanders, American toads, western chorus frogs, and northern leopard frogs. Because groundwater generally flows toward larger water bodies such as the Grand Calumet River (Watson et al. 1989), wetlands of excellent quality have been able to persist at DuPont, Clark and Pine East, Miller Woods, and other sites, only meters from the main channel. Restored or created wetlands separated from the channel by narrow areas of upland may have a reasonable chance of maintaining good water quality and supporting a variety of plants and animals.

In addition to traditional enhancement and restoration techniques such as woody vegetation control or wetland excavation, complex but innovative opportunities are possible near the Grand Calumet River. Some areas of degraded habitat are at present of minimal value to amphibians and reptiles, but they are immediately adjacent to the high quality natural areas. Areas impacted by heavy machinery movement or other dredging activity could be excavated to below the water table then covered with clean sand, mimicking the ridge and swale topography once present as recorded in early aerial photographs. If native vegetation can be established on both wetlands and intervening uplands, buffer or corridor areas could be established in this way. Technical feasibility of such an effort should first be carefully reviewed by appropriate specialists. Potentially suitable locations are present within the Gary Sanitary District and DuPont reaches, and others may be located through additional field efforts.

The Far West reach, particularly near Burnham Prairie, also offers potential buffer restoration opportunities. Fill material between the river and the natural area could be excavated, assuming that it can be disposed of safely and economically, and wetlands could be restored in the excavated areas.

Similarly, the proposed CAMU site on USX property could be restored with the addition of native soil and vegetation on top of any cap material. Reintroduction of animal species might then be feasible. This could be a fine opportunity to address an environmental problem and recover a semi-natural ecological system at the same time.

The Grand Calumet Lagoons within and near Miller Woods may be better able to support aquatic life than more contaminated reaches to the west. After dredging operations are concluded, any measures to control water movement between this and other reaches could help in maintaining suitable habitat conditions.

Corridor linkages

Enhancement of existing riparian wetlands or restoration of wetlands in areas filled in the past could help to establish corridors linking some of the core natural areas. Such corridors would be especially useful if they included, in addition to riparian wetlands, at least a narrow upland border seeded with native grassland vegetation and scattered depressions with seasonal wetlands.

Gary Regional Airport in particular should be investigated for restoration feasibility along the river. In the area are bordering marshes and degraded remnants of ridge and swale topography and at least one state special concern species, the western slender glass lizard. Political and security considerations could constrain restoration efforts at this location. Wetlands near runways should be designed to minimize the risk of bird strikes. The control tower is located near the river, and visibility during controlled burns could be an issue.

Habitat enhancement and management summary

Areas adjacent to the Grand Calumet River today support a surprisingly diverse herpetofauna although the remaining habitat is fragmented by past industrial land uses. Management and enhancement of remnant natural areas, restoration of wetlands and adjacent upland at more degraded sites, and a long-term strategy for linking or buffering core areas of open space could help maintain biodiversity well into the future.

LITERATURE CITED

Ahearn, P. J., and R. O. Kapp. 1984. Pollen analysis and vegetational history associated with archaeological sites in Berrien County, Michigan. Pages 113-123 *in* E. B. Garland, editor. Late Archaic and early Woodland adaptation in the lower St. Joseph River valley, Berrien County, Michigan. Unpublished Report to the State of Michigan Department of Transportation.

Bacone, J. A. 1979. Shell Oil Dune and Swale: A report on a natural area. Unpublished report, Division of Nature Preserves, Department of Natural Resources, Indianapolis, Indiana, USA.

Bogart, J. P., and A. P. Jaslow. 1979. Distribution and call parameters of *Hyla chrysoscelis* and *Hyla versicolor* in Michigan. Royal Ontario Museum Life Science Contributions **117**:3-13.

Bowles, M. 1989. Evaluation of Clarke and Pine, Tolleston Ridges, and Gibson Woods, Lake County, Indiana, as potential National Natural Landmarks. Unpublished report, The Morton Arboretum, Lisle, Illinois, USA.

Breden, F. 1988. Natural history and ecology of Fowler's toad, *Bufo woodhousei fowleri* (Amphibia: Bufonidae) in the Indiana Dunes National Lakeshore. Fieldiana Zoology, New Series **49**:1-16.

Chrzastowski, M. J., and T. A. Thompson. 1992. Late Wisconsinan and Holocene coastal evolution of the southern shore of Lake Michigan. Quaternary coasts of the United States: Marine and lacustrine systems. SEPM Special Publication **48**:397-413.

Chrzastowski, M. J., F. A. Pranschke, and C. W. Shabica. 1991. Discovery and preliminary investigations of the remains of an early Holocene forest on the floor of southern Lake Michigan. Journal of Great Lakes Research **17**:543-552.

Collins, J. T. 1990. Standard common and current scientific names for North American amphibians and reptiles. Third edition. Society for the Study of Amphibians and Reptiles Herpetological Circular **19**. iii + 41p.

Congdon, J. D., A. E. Dunham, and R. C. van Loben Sels. 1993. Delayed sexual maturity and demographics of Blanding's turtles (*Emydoidea blandingii*): Implications for conservation and management of long-lived organisms. Conservation Biology **7**:826-833.

Cowles, H. C. 1901. The plant societies of Chicago and vicinity. Geographic Society of Chicago Bulletin **2**:1-76.

Ebbers, B. C. 1984. Reconstruction of the floristic environment in central Berrien County, Michigan, 2000 B.C. to nineteenth Century A.D. Pages 83-107 *in* E. B. Garland, editor. Late Archaic and early Woodland adaptation in the lower St. Joseph River valley, Berrien County, Michigan. Unpublished Report to the State of Michigan Department of Transportation.

Griggs, D., and S. Balzano. Personal communication, May 1990.

Heyer, W. R., M. A. Donnelly, R. W. McDiarmid, L. C. Hayek, and M. S. Foster. 1994. Measuring and monitoring biological diversity: Standard methods for amphibians. Smithsonian Institution Press, Washington, D.C., USA.

Holman, J. A., and K. D. Andrews. 1994. North American Quaternary cold-tolerant turtles: Distributional adaptations and constraints. Boreas **23**:44-52.

Harding, J. H., and J. A. Holman. 1992. Michigan frogs, toads, and salamanders. Michigan State University Museum.

Indiana Department of Natural Resources. 1992. Endangered, threatened, and rare species and high quality natural communities and natural areas documented from or adjacent to the Grand Calumet River on the Highland and Gary quadrangles in Lake County, Indiana. Database printouts. Division of Nature Preserves, Indianapolis, Indiana, USA.

Lake Michigan Federation. 1984. The Grand Calumet: Exploring the rivers potential. The Lake Michigan Federation, Chicago, Illinois, USA.

Madison, D. M. 1993. Tiger salamander habitat use. Unpublished report to the New York Department of Environmental Conservation, Endangered Species Unit. Delmar, New York, USA.

Mierzwa, K. S. 1993. Amphibians and reptiles of two macrosites in McHenry County, Illinois. Unpublished Report to the McHenry County Conservation District.

Mierzwa, K. S. In press. The status of Chicago region amphibians. *in* M. J. Lannoo, editor. Status and conservation of Midwestern amphibians. University of Iowa Press, Iowa City, Iowa, USA.

Mierzwa, K. S., S. Culberson, K. S. King, and C. Ross. 1991. Illinois-Indiana regional airport study: Biotic communities. Technical Paper No. 7, Appendix E, Volume II. TAMS Consultants, Inc., Chicago, Illinois, USA.

Minton, S. A., Jr. 1972. Amphibians and reptiles of Indiana. Indiana Academy of Science Monograph **3**, Indianapolis, Indiana, USA.

Morgan, D., and J. Burling. 1979. Listing of vertebrates seen on selected Lake County natural areas during August, 1978 with comments on preservation values. *in* Indiana Department of Natural Resources and Natural Land Institute. An inventory of natural areas in the Indiana Coastal Zone study area. Indiana State Planning Services Agency Technical Report **302**.

Resetar, A. 1988. Distribution and ecology of amphibians and reptiles in selected areas of Lake, Porter, LaPorte and Newton Counties, Indiana with emphasis on state-listed species. Unpublished Report to the Indiana Department of Natural Resources, Nongame and Endangered Wildlife Program, Indianapolis, Indiana, USA.

Richards, R. L. 1987. The vertebrate collection of the Indiana State Museum: "Old" specimens and records. Proceedings of the Indiana Academy of Science **97**:547-570.

Rossman, D. A., N. B. Ford, and R. A. Seigel. 1996. The garter snakes: Evolution and ecology. University of Oklahoma Press, Norman, Oklahoma, USA.

Schmidt, K. P., and W. L. Necker. 1935. Amphibians and reptiles of the Chicago region. Chicago Academy of Science Bulletin **5**:57-77.

Seibert, H. C. 1950. Population density of snakes in an area near Chicago. Copeia **1950**:229-230.

Shelford, V. E. 1913. Animal communities in temperate America, as illustrated in the Chicago region. University of Chicago Press, Chicago, Illinois, USA.

Smith, P. W., and S. A. Minton, Jr. 1957. A distributional summary of the herpetofauna of Indiana and Illinois. American Midland Naturalist **58**:341-357.

Sobiech, S. A., T. P. Simon, and D. W. Sparks. 1994. Pre-remedial biological and water quality assessment of the East Branch Grand Calumet River, Gary, Indiana, June 1994. U. S. Fish and Wildlife Service Biological Report. Bloomington, Indiana, USA.

Sullivan, B. K., K. B. Malmos, and M. F. Given. 1996. Systematics of the *Bufo woodhousii* complex (Anura: Bufonidae): Advertisement call variation. Copeia **1996**:274-279.

Thompson, T. A. 1992. Beach-ridge development and lake-level variation in southern Lake Michigan. Sedimentary Geology **80**:305-318.

Watson, L. R., R. J. Shedlock, K. J. Banaszak, L. D. Arihood, and P. K. Doss. 1989. Preliminary analysis of the shallow ground-water system in the vicinity of the Grand Calumet River/

Werth, R. J. 1990. Terrestrial vertebrates: Amphibians, reptiles and mammals. *in* R. L. Peloquin, R. L. Whitman, and R. J. Werth. Ecology of Miller Woods. Indiana Dunes National Lakeshore Research Program Report **90-01**.

Wilhelm, G. S. 1990. Special vegetation of the Indiana Dunes National Lakeshore. Indiana Dunes National Lakeshore Research Program Report **90-02**.

BIRDS

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INTRODUCTION

Birdlife, and especially breeding species of birds, constitutes a very sensitive environmental barometer. It is therefore surprising that, despite years of abuse, the Grand Calumet River system still supports a remarkably diverse avifauna.

In recent decades the sluggish channel and lush wetlands of the River floodplain have provided breeding habitat, resting areas, and foraging sites for numerous birds. Contemporary records suggest that at least 64 species either nest or forage on the River floodplain during the breeding season; importantly, four of these species, American Bittern, Least Bittern, Black-crowned Night-Heron, and Black Tern, are listed among Indiana's endangered species (Buskirk 1993). More than 167 bird species use the channel, ponds, and wetlands of the river corridor for resting and feeding during migration. Four of these migrants, Osprey, Northern Harrier, Peregrine Falcon, and Golden-winged Warbler, are on the Indiana endangered species list. Open waters of the channel provide winter habitat for at least 41 avian species.

Data for the pre-settlement era are sparse, but suggest the following minimum numbers: summer residents - 32 species; migrants - 126 species; and winter residents - 15 species. These estimates are extremely conservative, since the pre-settlement Grand Calumet River system surely supported an exceedingly luxuriant selection of avian habitats.

This paper summarizes current knowledge about the birdlife of the Grand Calumet River corridor, including pre-settlement data. Species names and phylogenetic arrangement follow the 6th edition of the *American Ornithologists' Union Checklist* (1983) and subsequent supplements.

PRE-SETTLEMENT BIRD LIFE

Information sources: historical publications

The primary historical data sources available are Butler (1898), Woodruff (1907), and Ford, Sanborn and Coursen (1934). For the most part, the historical evidence is circumstantial. Of the birds known to have nested in northwestern Indiana or in the Chicago Region, those that frequent Grand Calumet River habitat types are presumed to have constituted part of the river's avifauna. When available, however, specific references to the Grand Calumet River system are cited. Pre-settlement avian communities were almost certainly far richer in species composition than is indicated by the following listing.

Pre-settlement summer residents

Pied-Billed Grebe, *Podilymbus podiceps*. Butler (1898) describes this species as occurring throughout the greater part of the state. It is almost certain that Pied-billed Grebes nested in wetlands along the Grand Calumet River.

Horned Grebe, *Podiceps auritus*. It is doubtful that this species ever nested in the Grand Calumet River marshes; however, Woodruff (1907) reports that a downy juvenile was collected on May 24 of 1878 at Sheffield (now part of Hammond). West (1956) questions the validity of this report.

American Bittern, *Botaurus lentiginosus*. Butler (1898) notes that this species was a summer resident at suitable localities, especially in northern parts of the state. Additionally, Ford, Sanborn and Coursen (1934) state that many breeding records exist for the Chicago area. It is, therefore, very likely that *B. lentiginosus* nested in cattail marshes on the Grand Calumet River floodplain.

Least Bittern, *Ixobrychus exilis*. According to Butler (1898), the Least Bittern was a summer resident at suitable localities. These almost certainly included wetlands along the Grand Calumet River.

Great Blue Heron, *Ardea herodias*. Several authors, including Butler (1898), suggest that the Great Blue Heron was a common nesting species across the northern half of Indiana. There is no evidence of local nesting, but *A. herodias* almost certainly occupied the Grand Calumet River floodplain during late summer dispersal.

Green Heron, *Butorides striatus*. Both Butler (1898) and Woodruff (1907) list this species as a common summer resident. It very likely inhabited scrubby trees along the River.

Black-Crowned Night Heron, *Nycticorax nycticorax*. Woodruff (1907) gives the following statement from E.W. Nelson, "The first of July, 1874, I saw a few young of the year in the Calumet Marshes." Birds present at this date could represent either locally fledged individuals or post-nesting dispersals from colonies outside the Grand Calumet River system.

Mallard, *Anas platyrhynchos*. Butler (1898) suggests that this species was a permanent resident in the state. It likely nested on the floodplain.

Blue-Winged Teal, *Anas discors*. Butler (1898) referred to this small duck as a local summer resident. It very likely nested in we tlands on the Grand Calumet River floodplain.

Northern Shoveler, *Anas clypeata*. Mumford and Keller (1984) state that Butler (no reference or date given) reported nesting in Lake County. Wetlands along the Grand Calumet River would have included appropriate nesting habitat for this dabbler.

Ruddy Duck, *Oxyura jamaicensis*. Without specifying exact locations, Mumford and Keller (1984) state that *O. jamaicensis* nested in Lake County in the years 1953, 1959, 1961, 1962, and 1965. It is likely that historical nestings occurred along the Grand Calumet River.

King Rail, *Rallus elegans*. During the 19th century this species was a summer resident north of the Wabash Valley (Butler 1898). King Rails almost certainly occupied marshes on the Grand Calumet River floodplain.

Virginia Rail, *Rallus limicola*. Butler (1898) referred to Virginia Rails as local summer residents, principally in northern parts of the state. There is little question that this rail nested in the Grand Calumet River wetlands.

Sora, *Porzana carolina*. According to Butler (1898), the Sora was a common breeder in northern portions of the state.

Common Moorhen, *Gallinula chloropus*. *G. chloropus*, a summer resident that breeds in the more extensive swamps (Butler 1898), almost certainly nested in the Grand Calumet River wetlands.

American Coot, *Fulica americana*. Butler (1898) deemed *F. americana* to be a common summer resident in northern portions of Indiana.

Wilson's Phalarope, *Phalaropus tricolor*. According to Butler (1898), *P. tricolor* was a common breeding species in the extreme northwestern part of Indiana. The last recorded nesting was in 1941 (Mumford and Keller 1984).

Black Tern, *Chlidonias niger*. Black Terns were summer residents in marshes north of the Kankakee River; they bred commonly at some locations (Butler 1898). Mumford and Keller (1984) indicate that 40 nests were found on nearby Wolf Lake in 1924, rendering it likely that some nested within the Grand Calumet River system.

Marsh Wren, *Cistothorus palustris*. Butler (1898) referred to this species as an abundant resident of Indiana's marshes. *C. palustris* surely nested at every site that provided the requisite cattail stands.

Gray Catbird, *Dumetella carolinensis*.Woodruff (1907) deemed *D. carolinensis* to be an abundant summer resident in the Chicago region. It probably nested in dense shrubbery on the River floodplain.

Cedar Waxwing, *Bombycilla cedrorum*. A common summer resident in the Chicago area (Woodruff 1907), *Bombycilla cedrorum* very likely foraged, and perhaps nested, on the Grand Calumet River floodplain.

Yellow Warbler, *Dendroica petechia*. This species was an abundant summer resident of the Chicago region (Butler 1898). Undoubtedly, *D. petechia* nested along the Grand Calumet River.

Common Yellowthroat, *Geothlypis trichas*. Butler (1898) referred to this species as a common summer resident of the Chicago region. It almost certainly nested in cattail marshes on the Grand Calumet River floodplain.

Indigo Bunting, *Passerina cyanea*. According to Woodruff (1907), *P. cyanea* was a common summer resident within the Chicago area. It probably nested in scrubby trees on the River floodplain.

Nelson's Sharp-tailed Sparrow, *Ammodramus nelsoni*. Woodruff (1907), quotes Nelson (1875) as follows, "The 12th of June, 1975, I saw several of these birds in the dense grass bordering Lake Calumet, where they were undoubtedly breeding." Although Lake Calumet is slightly outside the study area, this report raises the intriguing possibility of historical nesting along the Grand Calumet River. There is no modern evidence that the Sharp-tailed Sparrow breeds anywhere in the Chicago region.

Song Sparrow, *Melospiza melodia*. Butler (1898) characterized *M. melodia* as a permanent Chicago area resident; no doubt a few individuals nested in scrubby habitat on the floodplain.

Swamp Sparrow, *Melospiza georgiana*. Woodruff (1907) deemed this species to be a common summer resident of the Chicago area; it almost certainly nested in the floodplain marshes.

Red-Winged Blackbird, *Agelaius phoeniceus*. This widespread and common species (deemed to be an abundant summer resident by Butler (1898)), almost certainly nested in cattail marshes along the River.

Yellow-Headed Blackbird, *Xanthocephalus xanthocephalus*. According to Butler (1898) *X. xanthocephalus* was a summer resident of some localities in northwestern Indiana. It is likely that this species inhabited some of the cattail marshes along the Grand Calumet River.

Common Grackle, *Quiscalus quiscula*. Butler (1898) considered *Q. quiscula* a common summer resident; it probably foraged on the River floodplain.

Brown-Headed Cowbird, *Molothrus ater*. According to Butler (1898), *M. ater* was a common summer resident in Indiana. There is little doubt that it was present on the floodplain.

American Goldfinch, *Carduelis tristis*. This species, deemed to be a permanent resident of the Chicago region by Butler (1898), almost certainly bred in the Grand Calumet River marshes.

Pre-settlement migrants

The elongate geometry of Lake Michigan imposes a major geographical limitation on southbound migrants, directing thousands to the southern tip of Lake Michigan and across the Grand Calumet River (Brock 1986). As occurs today, untold numbers surely passed over the Grand Calumet River during historical migrations. Those species preferring habitats provided by the River floodplain probably stopped to feed and rest.

The literature provides little first-hand evidence as to which species were actually observed on the Grand Calumet River; indeed specific references were obtained for only the two following species:

Osprey, *Pandion haliaetus*. Woodruff (1907) reports seeing migrants on both Lake Calumet and Berry Lake. Osprey probably hunted over waters of the Grand Calumet River.

Le Conte's Sparrow, *Ammodramus leconteii*. Woodruff (1907) quotes E.W. Nelson, who refers to a specimen collected in May 1875, as follows, "...The specimen in my possession was flushed from a small depression in the prairie near the Calumet River (in Illinois)..."

Species known to migrate through the Chicago area, whose habitat preferences included the types provided by the Grand Calumet River, are tabulated in Attachment 1 at the end of this chapter.

Pre-settlement winter residents

The following species include those known to nest in the Chicago area (Woodruff 1907) or in the northwestern corner of Indiana (Butler 1898), that likely wintered in the waters or marshes of the Grand Calumet River.

Canada Goose, *Branta canadensis*
Mallard, *Anas platyrhynchos*
Bufflehead, *Bucephala albeola*
Red-Breasted Merganser, *Mergus serrator*
American Coot, *Fulica americana*
American Crow, *Corvus brachyrhynchos*
Cedar Waxwing, *Bombycilla cedrorum*
Northern Shrike, *Lanius excubitor*
American Tree Sparrow, *Spizella arborea*
Dark-Eyed Junco, *Junco hyemalis*
Red-Winged Blackbird, *Agelaius phoeniceus*
Common Grackle, *Quiscalus quiscula*
Brown-Headed Cowbird, *Molothrus ater*
Common Redpoll, *Carduelis flammea*
American Goldfinch, *Carduelis tristis*

CURRENT BIRD LIFE

Data sources

Information included below concerning current birdlife in the Grand Calumet River system is drawn from recent publications and from unpublished field data. Contemporary literature sources include: Brock (1986), Mumford and Keller (1984), Mierzwa et al. (1991), and Mlodinow (1984).

Unpublished field data include observations made by the author and by various other competent observers. These data, which include more than 100,000 individual records, are stored in computer files accessible by personal computer.

Field data are not distributed uniformly along the River; a disproportionate fraction of the reports are concentrated at easily accessible sites. The most thoroughly sampled locations, in order of descending importance, are: the Roxanna Marsh reach, the Hammond Sanitary District reach, the Lagoons reach, the DuPont reach, and the Gary Sanitary District reach.

Modern data reveal that the Grand Calumet River system supports an unusually rich avifauna. Wetlands provide breeding or summer foraging habitat for at least 64 species, including several that are included on Indiana's endangered and threatened species lists. Additionally, the floodplain serves as a resting and feeding area for numerous migrants. Indeed, it is during migration periods that the greatest avian diversity is present.

Figure I shows variation in species diversity based on monthly data collected at the DuPont property by Mierzwa et al. (1991). Figure I reveals that the maximum number of species occur during the May and August migration peaks. The lowest diversity occurs during the winter months.

Figure I. Species Diversity throughout the year based on monthly data collected at the DuPont property by Mierzwa et al. (1991).

Contemporary breeding species and summer residents

Habitat availability and habitat quality are the most critical factors for breeding birds. Dominant avian habitats within the Grand Calumet River system include: sluggish perennial stream, pond, cattail marsh, lake, artificial pond, and alien vegetated marshes. Several of these provide important breeding habitat from a state-wide perspective, as many species on Indiana's list of endangered and threatened species nest in wetland habitats.

It is also worth noting that many wetland breeding species have successfully adapted to cattail marshes, but none appear able to accommodate the invading common reed and purple loosestrife.

Current data indicate that the following 63 species occupy the Grand Calumet River floodplain during the summer breeding season (June and July).

Recent changes in the River's bird population include a significant increase in non-breeding heron and egret numbers. In addition, a substantial decrease in nesting Common Moorhens and American Coots was noted during the 1990s. Two species, the Black Tern and Yellow-headed Blackbird, have been extirpated as breeding species from the Grand Calumet River system.

Pied-Billed Grebe, *Podilymbus podiceps*. This grebe is a common summer resident on the channel; it is seen regularly from late April through early October, but it is most frequently reported in July and August. The observation of three juveniles at Roxanna Pond in August 1984 and five young at the Bongi Pond June 1991 confirms local breeding (seen by author).

American Bittern, *Botaurus lentiginosus.* This Indiana endangered species has virtually disappeared as a breeding species in the state. The only summer record for the study area consists of a single bird flushed from cattail marshes of the DuPont property on July 11, 1991 (Mierzwa et al. 1991).

Least Bittern, *Ixobrychus exilis. I. exilis*, an Indiana endangered species, is a rare summer resident of cattail marshes on the River floodplain. It was seen at Roxanna Pond in August 1983, and at least two adults were at that location in July of the following year (seen by author). The most recent summer reports were made in the DuPont wetlands, where one or two pairs were present throughout the summer months of 1991 (Mierzwa et al. 1991).

Great Blue Heron, *Ardea herodias*. Though evidence of nesting is lacking, foraging birds are seen regularly along muddy banks of the channel and especially at Roxanna Pond. During 1996, this species nested on the nearby Little Calumet River floodplain in Lake County (*Indiana Audubon Quarterly* in press).

Great Egret, *Ardea albus. Over* the last decade, observations of this species have increased dramatically, paralleling the establishment of a nesting colony at nearby Lake Calumet, Illinois. This expansion is especially encouraging because *A. albus* is currently on Indiana's "species of special concern" list. Today, feeding birds are frequently observed along the channel and especially at Roxanna Pond. During June and July at the latter site, a mean of 9.3 birds per year were recorded over the past twelve years; the peak count was 30, on June 15, 1996. No evidence of nesting exists for the Grand Calumet River floodplain; presumably the summer birds represent either foraging individuals from the Illinois colony or non-breeding wanderers.

Green Heron, *Butorides striatus*. During the summer months, small numbers of *B. striatus* are seen regularly along the channel. The peak count of three was recorded at Roxanna Pond on July 3, 1985. Though nesting has not been confirmed, this species very likely breeds in the region sparingly, in scrubby trees along the channel.

Black-Crowned Night Heron, *Nycticorax nycticorax*. Currently on the Indiana endangered species list, *N. nycticorax* is a common summer visitor on the Grand Calumet River floodplain. At Roxanna Pond, a mean of 5.5 birds per year were observed during June and July over the past dozen years. The eleven birds counted at Roxanna July 8, 1986, were probably post-nesting dispersals from the Lake Calumet, Illinois rookery. Evidence of local nesting is lacking; consequently, most birds observed are presumed to be foraging birds from the enormous colony at Lake Calumet, Illinois.

Canada Goose, *Branta canadensis*. This species is an abundant summer resident that frequently nests on the floodplain.

Wood Duck, *Aix sponsa*. *A. sponsa* is seen regularly on the channel during the summer months. It occasionally nests there, as was evidenced by the observation of two young birds at Roxanna Pond June 1, 1985 (seen by the author). The peak summer count was 12 on June 5, 1987 (seen by the author).

Mallard, *Anas platyrhynchos*. Substantial numbers of Mallards inhabit the Grand Calumet River channel during the summer months. The peak summer count was 60 at Roxanna Pond on July

10, 1982. Counts of downy young at Roxanna include: seven on July 12, 1984, six on June 1, 1985, 18 on June 5, 1987, and 20 on July 3, 1987.

Blue-Winged Teal, *Anas discors*. *A. discors* is uncommon during the summer months. The peak summer count was four at Roxanna Pond on July 26, 1986, and a mean of one bird per year was recorded at that location during the past twelve years. Though it is quite likely that it occurs, breeding in the Grand Calumet River system has not been confirmed.

Ruddy Duck, *Oxyura jamaicensis*. Though there are several nesting records for this species in the Calumet Region, the only summer observation within the Grand Calumet River system involves a breeding plumed male sited at Roxanna Pond on June 24, 1983. Recent nesting has occurred on the Little Calumet River floodplain (Brock 1986).

Red-tailed Hawk, *Buteo jamaicensis*. During the summer period, this species is regularly seen flying above the floodplain. No nests have been found.

American Kestrel, *Falco sparverius*. This diminutive falcon is seen regularly in the Calumet Region during the summer months. Breeding on the floodplain has not been confirmed, but small numbers may nest.

Ring-necked Pheasant, *Phasianus colchicus*. This introduced species has been rec
orded regularly throughout the summer months at Roxanna Pond. It was also noted on the DuPont property in June by Mierzwa et al. (1991).

Virginia Rail, *Rallus limicola*. Tough rarely seen, *R. limicola*, which is listed among Indiana's "species of special concern," is a fairly common breeder in cattail marshes on the floodplain. Summer period birds were observed at Roxanna Pond on July 20, 1982 (seen by the author) and in the DuPont wetlands during the summer of 1991. Specific records at the latter site included a pair seen June 15, and a family group, two adults and two young, observed July 11, 1991 (Mierzwa et al. 1991).

Sora, *Porzana carolina*. Distribution of the Sora is similar to that of the Virginia Rail. June and July records include an adult with three young in the DuPont Marsh on July 11, 1991, an adult at Ivanhoe on June 11, 1991, and a single bird in a Clark & Pine swale on June 8, 1991 (Mierzwa et al. 1991). Additionally, fully feathered juveniles have been recorded at Roxanna Pond on four occasions during the fall; the largest count consisted of five, seen on September 16, 1995.

Common Moorhen, *Gallinula chloropus*. An abundant nesting species at Roxanna Pond during the 1980s, *G. chloropus* has declined in numbers markedly during the past six years. The mean summer count between 1980-1989 was 17.5 per year; in contrast, the average for annual June-July counts from 1990-1995 was only 1.3. Peak counts of young during the halcyon 1980s included 50 on June 28, 1984, and 13 on July 26, 1986.

American Coot, *Fulica americana*. Nesting Coot populations on the floodplain, like those of Sora and Common Moorhen, have declined in recent years. During the 1980s, numerous nestings were recorded at Roxanna Pond (seen by the author); the peak downy young count was 15, seen on July 16, 1983 (seen by the author). Breeding has not been confirmed at Roxanna since 1990. The most recent confirmed nesting on the floodplain was at the DuPont marshes, where two young were found June 15, 1991 (Mierzwa et al. 1991).

Killdeer, *Charadrius vociferus*. This species is a common summer resident of the floodplain and breeds when appropriate nesting habitat is available. Young birds were recorded at Roxanna Pond on June 5, 1987. Peak counts during the summer period include eleven at Roxanna Pond on June 25, 1988, and four at DuPont on June 15, 1991.

Spotted Sandpiper, *Actitis macularia*. *A. macularia* is fairly common along the Grand Calumet River during June and July and almost certainly breeds on the floodplain. Spotted Sandpipers have been recorded at Roxanna Pond 13 times during the summer months (seen by the author); the peak count was three on July 9, 1988 (seen by the author). Additionally, two birds were observed in appropriate breeding habitat at the Bongi Pond on June 8, 1991 (Mierzwa et al. 1991).

American Woodcock, *Scolopax minor*. This secretive species frequents the DuPont property, where it undoubtedly breeds. Mierzwa et al. (1991) recorded Woodcocks during the summer period at DuPont as follows: four on June 7, three on June 25, and one on July 11.

Ring-billed Gull, *Larus delawarensis*. Though this species does not breed in the Grand Calumet River system, foraging birds are abundant throughout the summer months. The peak count of 60 was observed at the Cline Avenue crossing on June 24, 1995.

Black Tern, *Chlidonias niger*. This Indiana endangered species, which is on the brink of extirpation as a breeding species in Indiana, formerly nested on the floodplain. Black Terns were last recorded breeding in the Grand Calumet River system in June of 1991 when a nest containing three eggs was discovered in the DuPont marsh; the nest was abandoned by early July (Mierzwa et al. 1991). Eggs were previously discovered at this site in 1986 and 1987 (unpublished IDNR survey). The decline of the Black Tern is graphically illustrated by the decrease that has been observed in annual summer counts. During the 1980s, a mean of seven terns per year was recorded during the summer months. In contrast, only 1.2 birds per breeding season were recorded in the 1990s (based on the reports from all observers who visited the site during the nesting period). Summer period Black Terns have not been reported from the Grand Calumet River system since 1991, suggesting the total absence of breeding birds.

Rock Dove, *Columba livia*. An abundant resident of nearby industrial sites, *C. livia* is frequently seen in flocks flying over the floodplain. Rarely, a few individuals are noted feeding on exposed mudflats at Roxanna Pond.

Mourning Dove, *Zenaida macroura*. Small numbers of this spec ies are seen frequently during the summer. *Z. macroura* likely nests, on occasion, in scrubby floodplain trees. The peak count of five individuals has been duplicated on three different dates, 1988 and twice in 1991 (seen by the author and Mierzwa et al. 1991).

Black-billed Cuckoo, *Coccyzus erythropthalmus*. Although it may occasionally nest in floodplain shrubs or oak savannah, *C. erythropthalmus* is rare along the Grand Calumet River. The only summer record of this species was an observation at Roxanna Pond on July 11, 1981.

Yellow-billed Cuckoo, *Coccyzus americanus*. The distribution and occurrence of *C. americanus* is similar to that of the Black-billed Cuckoo. Summer records include the observation of lone birds at Roxanna Pond July 25, 1987, and at Ivanhoe, June 15, 1991.
Great Horned Owl, *Bubo virginianus*. Active *B. virginianus* nests have been observed in cottonwoods along the Grand Calumet River channel in the USX Reach.

Common Nighthawk, *Chordeiles minor*. Although this species does not nest on the floodplain, birds forage above the River throughout the summer months. Records during the summer period include two birds at Roxanna Pond on July 21, 1988, and one at the DuPont property on July 11, 1991 (Mierzwa et al. 1991).

Chimney Swift, *Chaetura pelagica*. Although the floodplain probably contains no appropriate nesting habitat for *C. pelagica*, the species is frequently seen foraging above the Grand Calumet channel and associated ponds. The peak summer count was 20 individuals, observed over Roxanna Pond on June 23, 1990.

Belted Kingfisher, *Ceryle alcyon*. The Kingfisher is seen occasionally along the channel, and it may nest in sandy embankments on the floodplain. Summer records include three at Bongi Pond, three birds at Roxanna Pond, two at the Cline Avenue bridge, and one at DuPont (observed by the author).

Downy Woodpecker, *Picoides pubescens*. Although it has not been confirmed to nest on the floodplain, *P. pubescens* is occasionally observed foraging in the marshes and scrubby vegetation of the floodplain during the summer months. One was noted at the DuPont marsh on June 25, 1991, and two were seen at that location on July 11, 1991 (Mierzwa et al. 1991).

Northern Flicker, *Colaptes auratus*. This species has been observed foraging in scrubby vegetation of the floodplain and in the oak savannah habitat of the DuPont property. It was recorded at the latter site on June 7 and July 11, 1991 (Mierzwa et al. 1991).

Willow Flycatcher, *Empidonax traillii*. *E. traillii* is sited regularly during the summer months and it is very likely that it breeds in the floodplain marshes. Summer period records include five birds at DuPont and three at Roxanna Pond. The peak count was three at DuPont on June 25, 1991 (Mierzwa et al. 1991).

Eastern Kingbird, *Tyrannus tyrannus*. The Kingbird probably breeds locally on the floodplain where it is seen regularly during the summer months. Breeding period records include eight birds on the DuPont property during the summer of 1991 (Mierzwa et al. 1991) and singletons at Roxanna Pond in 1985, 1986, and 1991.

Purple Martin, *Progne subis*. This large swallow is occasionally observed foraging over the floodplain during the summer months. Additionally, late July pre-migratory flocks are sometimes noted on power-line wires at Grand Calumet Lagoons (e.g., 20 birds seen on July 25, 1995, observed by the author).

Tree Swallow, *Tachycineta bicolor*. A few *T. bicolor* very likely nest locally on the floodplain wherever the requisite cavities or nest boxes are available. Many others forage over the waterways and wetlands of the Grand Calumet River. Summer period records include seven birds at DuPont, four at Roxanna, and one at the Cline Avenue bridge.

Barn Swallow, *Hirundo rustica*. *H. rustica* is an abundant summer resident of the floodplain; the species may nest beneath bridges that span the channel. The peak summer count is 70, recorded at Roxanna Pond on June 23, 1990.

Blue Jay, *Cyanocitta cristata*. This widespread corvid is regularly noted on the floodplain during the summer months.

American Crow, *Corvus brachyrhynchos*. Crows occasionally forage on the floodplain during the summer months. The largest count was four birds, seen at Roxanna Pond on June 23, 1990.

House Wren, *Troglodytes aedon*. This species breeds sparingly in oak savannah and scrubby second growth areas of the floodplain.

Marsh Wren, *Cistothorus palustris*. *C. palustris*, a threatened species in Indiana, is a common nesting species in cattail stands along the channel and in adjacent marshes. Summer records include 31birds (over 14 years) at Roxanna Pond and 35 at the DuPont marsh in 1991. Birds performing display flights were observed at the latter site on July 11, 1991 (Mierzwa et al. 1991).

American Robin, *Turdus migratorius*. This widespread species is occasionally observed in the Grand Calumet River system during the summer. It may nest in oak savannah or scrubby second growth areas on the floodplain. The peak summer period count was 30 at the DuPont property on July 11, 1991 (Mierzwa et al. 1991).

Gray Catbird, *Dumetella carolinensis*. *D. carolinensis* is a common summer resident on the floodplain. The species almost certainly breeds where the requisite scrubby habitat is available. The peak summer count was three at the DuPont property on July 11, 1991 (Mierzwa et al. 1991).

Brown Thrasher, *Toxostoma rufum.* The thrasher is a local breeder that frequents the oak savannah habitat. Mierzwa et al. (1991) recorded this species regularly on the DuPont property.

Cedar Waxwing, *Bombycilla cedrorum*. *B. cedrorum* is a fairly common summer resident and sporadic breeder on the floodplain. A peak summer count of four was recorded in 1991 by Mierzwa et al. (1991).

European Starling, *Sturnus vulgaris*. This invasive species, first recorded in the Chicago area in 1925 (Mlodinow 1984), is now abundant throughout the region. Although nesting habitat for this species is quite limited on the floodplain, flocks of brownish juveniles from nearby residential areas fly into the River corridor. By early June these flocks are common along the River. The largest count was 25 juveniles at Roxanna Pond on June 5, 1987.

Yellow Warbler, *Dendroica petechia*. *D. petechia* is a fairly common summer resident on the floodplain, and it probably breeds there in small numbers. Summer records include two reports from the DuPont property: one bird at Roxanna Pond, and one at the Cline Avenue bridge (seen by author).

Common Yellowthroat, *Geothlypis trichas*. A common species in the cattail marshes, *G. trichas* nests regularly on the floodplain. The peak summer period count was five at the DuPont marsh on July 11, 1991, one of which was performing display flights (Mierzwa et al. 1991).

Northern Cardinal, *Cardinalis cardinalis*. Small numbers of this species frequent scrubby vegetated and oak savannah habitats on the floodplain.

Indigo Bunting, *Passerina cyanea*. This colorful species is a common summer resident of wooded portions of the Grand Calumet River system. Summer period records have come from Roxanna Pond, the DuPont property, and the Cline Avenue bridge (observed by the author).

Eastern Towhee, Pipilo erythrophthalmus. The Towhee nests in oak savannah habitat on the floodplain. A young bird, in fresh juvenile plumage, was seen on the DuPont property on June 25, 1991 (Mierzwa et al. 1991).

Song Sparrow, *Melospiza melodia*. This sparrow is a common summer resident on the floodplain where it is assumed to breed. The peak count was seven Song Sparrows on the DuPont property on July 11, 1991 (Mierzwa et al. 1991).

Swamp Sparrow, *Melospiza georgiana*. *M. georgiana* is a fairly common floodplain resident during the summer months, with multiple reports from both Roxanna Pond and the DuPont property. The peak count was two individuals at the DuPont site June 25, 1991 (Mierzwa et al. 1991).

Red-Winged Blackbird, *Agelaius phoeniceus*. The Red-winged Blackbird is an abundant breeding species in the floodplain marshes. It is present at virtually any site that supports substantial cattail growth. The peak summer period count of 17 was recorded on the DuPont property on July 11, 1991 (Mierzwa et al. 1991).

Yellow-headed Blackbird, *Xanthocephalus xanthocephalus*. This species, which is currently listed among Indiana's threatened birds, formerly nested on the Grand Calumet River floodplain. Yellow-headed Blackbirds are now believed to be absent, as a breeding species, from the entire state. *X. xanthocephalus* nested at Roxanna Pond in 1984 (at least two pair), 1985(at least one pair), and 1986(at least one pair). Additionally, at least one pair nested in cattails just east of the Kennedy Avenue bridge (DuPont Reach) in 1986 and 1987.
Common Grackle, *Quiscalus quiscula*. Foraging Grackles are common on the floodplain during the summer months. The peak summer period count was nine at the DuPont site on June 7, 1991 (Mierzwa et al. 1991).

Brown-Headed Cowbird, *Molothrus ater* Small numbers of this widespread nest parasite are common along the floodplain during summer. The peak count was two Cowbirds at DuPont on July 11, 1991 (Mierzwa et al. 1991).

Baltimore Oriole, *Icterus galbula*. Although the Grand Calumet River system provides sub-optimal breeding habitat for *I. galbula*, a few birds of this species probably nest in isolated trees along the floodplain margin. One bird was recorded at DuPont on July, 11, 1991 (Mierzwa et al. 1991).

House Finch, *Carpodacus mexicanus*. Beginning in the early 1980s, *C. mexicanus* invaded the Calumet Region. It is now a common resident there throughout the year. It has been recorded at Roxanna Pond, DuPont, and Cline Avenue bridge during the summer months.

American Goldfinch, *Carduelis tristis*. *C. tristis* is a common summer resident that almost certainly breeds in marshes along the Grand Calumet River system. The peak summer count was five birds at the DuPont marsh on July 11, 1991 (Mierzwa et al. 1991).

House Sparrow, *Passer domesticus.* This species nests abundantly in suburban and industrial areas adjacent to the River. Foraging birds frequently appear along the floodplain in summer.

Contemporary migrants

It is probable that every species that regularly migrates through the Chicago area has passed over the floodplain; however, only those species actually recorded on or above the Grand Calumet River system are included in the migrant list.

All migrants that have been recorded in the Grand Calumet River system are tabulated in Attachment I. An annotated list of rare and uncommon migrants is given below. The rarity of these species is listed in Brock (1986). Dominating the migrant list are 26 waterfowl species and 30 shorebird species.

Red-throated Loon, *Gavia stellata*. One was seen on the Grand Calumet Lagoons on April 1, 1979.

Common Loon, *Gavia immer* A common migrant on Lake Michigan, this species occurs rarely on the Grand Calumet Lagoons.

Red-Necked Grebe, *Podiceps grisegena*. This species, rare throughout the Chicago region, has been sited twice at the Grand Calumet Lagoons: once in November of 1993 and again in November of 1995.
Eared Grebe, *Podiceps nigricollis*. A single bird was present on Roxanna Pond from August 19, 1978, until the pond froze over on November 25, 1978. Another was seen on the pond on September 27, 1980.

American White Pelican, *Pelecanus erythrorhynchos*. One was present at the Grand Calumet Lagoons during the summer of 1967 (Brock 1986).

Cattle Egret, *Bubulcus ibis*. A breeding-plumed bird was at Roxanna Pond on May 26, 1989 (seen by the author).

Tundra Swan, *Cygnus columbianus*. In fall, migrants occasio nally land on the Grand Calumet Lagoons. An enormous flock of 108 birds was noted at that location on December 1, 1985(seen by the author).

Snow Goose, *Chen caerulescens*. Although this species regularly migrates across the Calumet Region, it rarely lands there. *C. caerulescens* has been recorded three times at Roxanna Pond (twice in fall and once in spring). The largest count of six was seen on April 11, 1987 (seen by the author).

Greater Scaup, *Aythya marila*. Though common on Lake Michigan in winter, *A. marila* is rarely seen away from the Lake. The only report in the Grand Calumet River system consists of two birds at Roxanna Pond on April 24, 1982 (seen by the author).

Black Scoter, *Melanitta nigra*. This species, which is a regular fall migrant on Lake Michigan, was seen on the Grand Calumet Lagoons on October 26, 1980 (seen by the author).

White-Winged Scoter, *Melanitta fusca*. A single bird was seen on the Grand Calumet Lagoons on March 14, 1992 (seen by the author).

Osprey, *Pandion haliaetus*. This Indiana endangered species has been recorded at Roxanna Pond on four occasions during the migration period (seen by the author).

Peregrine Falcon, *Falco peregrinus*. Evidence that this federally endangered species occasionally forages on the floodplain was provided by the sighting of an adult perched on a transmission tower adjacent to Roxanna Pond on October 31, 1987 (seen by the author).

American Avocet, *Recurvirostra americana*. A singleton was observed at Roxanna Pond on May 11, 1980 (seen by the author).

Hudsonian Godwit, *Limosa haemastica*. Eight birds were seen at Roxanna Pond on May 11, 1978. This record constitutes the largest number ever recorded in Indiana (Mumford and Keller 1984).

Marbled Godwit, *Limosa fedoa*. One bird was seen at Roxanna Pond on May 10 and 11, 1978 (Brock 1986).

Ruddy Turnstone, *Arenaria interpres*. A flock of 15 birds was seen at Roxanna Pond on May 26, 1988 (seen by the author).

Red Knot, *Calidris canutus*. This species is rarely recorded away from the sandy beaches of Lake Michigan. A juvenile was seen along the muddy channel banks in the Hammond Sanitary District reach on August 17, 1977 (seen by the author).

Sanderling, *Calidris alba*. A Sanderling was seen at Roxanna Pond on May 28, 1983 (seen by the author).

Western Sandpiper, *Calidris mauri*. This species, which is remarkably rare in the Calumet Region, has been recorded four times in the area comprised of Roxanna Pond and the adjacent Hammond Sanitary District reach (seen by the author).

White-rumped Sandpiper, *Calidris fuscicollis*. Fall migrants have been recorded on four occasions at Roxanna Pond (seen by the author).

Baird's Sandpiper, *Calidris bairdii*. Juveniles were seen at Roxanna Pond on August 19, 1988 (two) and on September 21, 1989 (one) (seen by the author).

Buff-Breasted Sandpiper, *Tryngites subruficollis*. This rare shorebird was observed on the extensive mudflats of the Roxanna Pond reach, during a low water period, September 10, 1988 (seen by the author).

Ruff, *Philomachus pugnax*. A female was seen in a Gary Sanitary District settling pond on August 9 and 10, 1986 (Peterjohn 1987).

Wilson's Phalarope, *Phalaropus tricolor*. *P. tricolor* has become quite rare in the Calumet Region during the past decade; consequently, the 28 birds recorded at Roxanna Pond on May 9, 1978 (Kleen 1979) are noteworthy.

Red-Necked Phalarope, *Phalaropus lobatus*. Only one record of this species exists for the Grand Calumet River system; a single bird was seen at Roxanna Pond on July 15, 1982 (seen by the author).

Franklin's Gull, *Larus pipixcan*. An adult bird was observed on the Grand Calumet Lagoons, on November 5, 1991 (seen by the author).

White-Winged Tern, *Chlidonias leucopterus*. Indiana's only record of this Eurasian species is a bird seen at Roxanna Pond on July 19, 1979 (Brock, 1983).

Golden-winged Warbler, *Vermivora chrysoptera*. This Indiana endangered species was recorded at the DuPont wetlands on August 23, 1991 (Mierzwa et al. 1991).

Northern Parula, *Parula americana*. This warbler, which is rare in the Calumet Region, was observed in cottonwoods along the Grand Calumet River channel in the Hammond Sanitary District reach on September 27, 1980 (seen by the author).

Connecticut Warbler, *Oporornis agilis*. On May 24, 1991, a migrant was flushed from the oak savannah at DuPont by Mierzwa et al. (1991).

Contemporary winter residents

Birds that winter in the Grand Calumet River corridor are primarily aquatic species that take advantage of open water created by effluent from local industries. All species listed below have been recorded on or above the floodplain during the winter months (December through February). If open water was not present far fewer species would be present during the winter. Species marked by "*" are rare (not present most years).

*Pied-Billed Grebe, *Podilymbus podiceps*
*Double-Crested Cormorant, *Phalacrocorax auritus*
*Great Blue Heron, *Ardea herodias*
*Black-Crowned Night Heron, *Nycticorax nycticorax*
Canada Goose, *Branta canadensis*
*Green-Winged Teal, *Anas crecca*
American Black Duck, *Anas rubripes*
Mallard, *Anas platyrhynchos*
*Northern Shoveler, *Anas clypeata*
*Redhead, *Aythya americana*
Common Goldeneye, *Bucephala clangula*
Bufflehead, *Bucephala albeola*
*Hooded Merganser, *Lophodytes cucullatus*
Common Merganser, *Mergus merganser*
Red-Breasted Merganser, *Mergus serrator*
Ring-necked Pheasant, *Phasianus colchicus*

*Common Moorhen, *Gallinula chloropus*
American Coot, *Fulica americana*
Ring-billed Gull, *Larus delawarensis*
Herring Gull, *Larus argentatus*
*Glaucous Gull, *Larus hyperboreus*
Rock Dove, *Columba livia*
Mourning Dove, *Zenaida macroura*
Belted Kingfisher, *Ceryle alcyon*
Downy Woodpecker, *Picoides pubescens*
Blue Jay, *Cyanocitta cristata*
American Crow, *Corvus brachyrhynchos*
Cedar Waxwing, *Bombycilla cedrorum*
European Starling, *Sturnus vulgaris*
Northern Cardinal, *Cardinalis cardinalis*
American Tree Sparrow, *Spizella arborea*
*Fox Sparrow, *Passerella iliaca*
Song Sparrow, *Melospiza melodia*
Swamp Sparrow, *Melospiza georgiana*
Dark-Eyed Junco, *Junco hyemalis*
Red-Winged Blackbird, *Agelaius phoeniceus*
Common Grackle, *Quiscalus quiscula*
Brown-Headed Cowbird, *Molothrus ater*
House Finch, *Carpodacus mexicanus*
*Common Redpoll, *Carduelis flammea*
American Goldfinch, *Carduelis tristis*

IMPACT OF DREDGING

Considerable evidence suggests that the muddy substrate of the Grand Calumet River channel is contaminated (see USFWS 1996 for a discussion of the contaminants and potential effects on birdlife). The detection of Hg and PCB residues in failed eggs at the East Chicago Peregrine Falcon nest site (USFWS 1996) indicates that some contaminants have entered the avian food web.

The presence of pollutants in the muddy substrate poses an unassessed potential risk for birds that feed in the channel. Many birds spend extensive time foraging in this contaminated environment. On December 30, 1995, for example, 970 Mallards, plus other waterfowl species, were counted in the Roxanna marsh and Hammond Sanitary District reaches. These birds winter on the River, apparently feeding exclusively on channel vegetation. Although the long-term effects of prolonged exposure to Grand Calumet River pollutants on birds are unknown, lengthy exposure is certainly undesirable.

Perhaps at even greater risk are the migrant shorebirds that consume invertebrate infauna living within the substrate. Most migrant shorebirds depart within a few days, rendering their exposure brief, but the potential for accumulating toxins is high because they feed on organisms extracted directly from the contaminated sediment.

Thus, it is very likely that removal of contaminated sediment through dredging will have a positive long-term effect on the avifauna. A major concern is that the dredging operation itself might increase contamination through the resuspension of sediment during dredging. This possibility should be examined carefully within the context of the dredging mechanism employed.

OPPORTUNITIES

Roxanna Pond lies within the Grand Calumet River meander to the north of Roxanna Street and about 0.4 km to the west of Indianapolis Boulevard (Roxanna Reach of the Grand Calumet River). Water levels in this shallow pond fluctuate widely, and they are seemingly more dependent upon the rate of effluent discharge from local industries than on precipitation rates. Low water levels expose extensive mudflats, which provide feeding habitat for migrant shorebirds. When water levels are appropriate, the pond serves as a resting and feeding area for hundreds of spring and fall shorebird migrants. High water conditions, however, entirely eliminate the mudflats; on these occasions shorebirds cannot land at the pond.

At least 29 different shorebird species have been recorded at Roxanna Pond. The most common species are: Lesser Yellowlegs, Least Sandpiper, and Pectoral Sandpiper. Several rare shorebird species ("rare" as defined by Mumford and Keller 1984) have also been recorded at Roxanna Pond. Among the rarities are: American Avocet, Marbled Godwit, Hudsonian Godwit, Red Knot, Western Sandpiper, White-rumped Sandpiper, Baird's Sandpiper, Buff-breasted Sandpiper, Long-billed Dowitcher, and Red-necked Phalarope.

Shorebird numbers at Roxanna Pond vary widely from year to year depending upon the availability of mudflats during migration periods (April through May and July through October). In August of 1988, a year when low water generated extensive mudflats, 1150 Pectoral Sandpipers were counted at the site. In contrast, during August of the following year, water levels were too high, and only 11 birds were recorded. The positive correlation between shorebird numbers and mudflat exposure holds for all other shorebird species.

As was pointed out by Helmers (1992), shorebirds need staging areas to rest before completing their migration. For this reason, the management of water levels at Roxanna Pond would prove extremely beneficial to migrating shorebirds. The establishment of a site specifically managed for migrating shorebirds would provide a sorely needed resting and feeding area for these long range migrants.

In addition to the proposed dredging, site preparation will require the restoration of a muddy substrate and the construction of a low dike and gate between the pond and the channel. The soft sediment floor will provide habitat for an invertebrate infauna, which constitutes the primary food source of migrating shorebirds. The dike will restrict flow to and from the river, allowing water levels within the pond to be adjusted through the gate. If the gate proves inadequate for regulating water levels, it may become necessary to install a pump.

Routine maintenance (see Helmers 1992) will involve monitoring water levels to insure: 1) that appropriate habitat is available during critical migration periods (April through May and

July through October), 2) that pre-migration water levels are appropriate for development of an adequate invertebrate infauna, on which shorebirds can feed, and 3) controlling vegetation to maintain mudflat habitat. Vegetation will be controlled by flooding during the non-migratory periods.

LITERATURE CITED

Brock, K. J. 1983. Indiana's first White-winged Black Tern: an Inland Sight Record. American Birds **37**:109-111.

Brock, K.J. 1986. Birds of the Indiana Dunes. Indiana University Press, Bloomington, Indiana, USA.

Buskirk, W. B. 1993. Unpublished Minutes of the July 23, 1993 IDNR Nongame Bird Technical Advisory Committee.

Butler, Amos W. 1998. The Birds of Indiana. 22nd Annual Report, Indiana Department of Geology and Natural Resources, pp. 575-1187.

Ford, E. R., C. C. Sanborn, and C. B. Coursen. 1934. Birds of the Chicago Region. Chicago Academy of Science, Chicago, Illinois, USA.

Helmers, D. L. 1992. Shorebird Management Manual. Western Hemisphere Shorebird Reserve Network. Manomet, Massachusetts, USA.

Kleen, V. M. 1979. The Changing Seasons: Spring 1978. American Birds **32**:1014.

Mlodinow, S. 1984. Chicago Area Birds. Chicago Review Press, Chicago, Illinois, USA.

Mumford, R. E., and C. E. Keller. 1984. The Birds of Indiana. Indiana University Press, Bloomington, Indiana, USA.

Nelson, E. W. 1875. Proceedings of the Boston Society of Natural History XVII.

Peterjohn, B. G. 1987. The Changing Seasons: Fall 1986. American Birds **41**:96.

Mierzwa, K.S., S. Culberson, K.S. King, and C. Ross. 1991. Illinois-Indiana regional airport study: Biotic communities. Technical Paper No. 7, Appendix E, Volume II. TAMS Consultants, Inc., Chicago, Illinois, USA.

U.S. Fish and Wildlife Service. 1996. Endangered Species Act, Consultation- Biological Opinion: Dredging of Indiana Harbor and Canal. 46p.

West, H. C. 1956. The Status of the Grebe Family in Indiana. Indiana Audubon Quarterly **34**:42-55.

Woodruff, F. M. 1907. The Birds of the Chicago Area. Natural History Survey, Bulletin No VI, Chicago Academy of Sciences, Chicago, Illinois, USA.

Attachment 1

Migrant Birds

The following species are migrants through the Grand Calumet River system. Prefixes define the Indiana status of species according to Buskirk, 1993. Prefix explanations are: e = endangered, t = threatened, s = special concern, and x = extirpated as a breeding species.

	Historical	Modern
x Red-throated Loon, *Gavia stellata*		X
Common Loon, *Gavia* immer		X
Pied-Billed Grebe, *Podilymbus podiceps*	X	X
Horned Grebe, *Podiceps auritus*		X
Red-Necked Grebe, *Podiceps grisegena*		X
Eared Grebe, *Podiceps nigricollis*		X
American White Pelican, *Pelecanus erythrorhynchos*		X
x Double-Crested Cormorant, *Phalacrocorax auritus*	X	X
e American Bittern, *Botaurus lentiginosus*	X	X
e Least Bittern, *Ixobrychus exilis*	X	X
Great Blue Heron, *Ardea herodias*	X	X
Great Egret, *Ardea albus*	X	X
Cattle Egret, *Bubulcus ibis*		X
Green Heron, *Butorides striatus*	X	X
e Black-Crowned Night Heron, *Nycticorax nycticorax*	X	X
Tundra Swan, *Cygnus columbianus*	X	X
Mute Swan, *Cygnus olor*		X
Canada Goose, *Branta canadensis*	X	X
Snow Goose, *Chen caerulescens*		X
Wood Duck, *Aix sponsa*	X	X
Green-Winged Teal, *Anas crecca*	X	X
American Black Duck, *Anas rubripes*	X	X
Mallard, *Anas platyrhynchos*	X	X
Northern Pintail, *Anas acuta*	X	X
Blue-Winged Teal, *Anas discors*	X	X
Northern Shoveler, *Anas clypeata*	X	X
Gadwall, *Anas strepera*	X	X
American Wigeon, *Anas americana*	X	X
Canvasback, *Aythya valisineria*	X	X
Redhead, *Aythya americana*	X	X
Ring-necked Duck, *Aythya collaris*	X	X
Greater Scaup, *Aythya marila*		X
Lesser Scaup, *Aythya affinis*	X	X
Black Scoter, *Melanitta nigra*		X
White-Winged Scoter, *Melanitta fusca*		X

Common Goldeneye, *Bucephala clangula*		X
Bufflehead, *Bucephala albeola*	X	X
Hooded Merganser, *Lophodytes cucullatus*	X	X
Common Merganser, *Mergus merganser*	X	X
Red-Breasted Merganser, *Mergus serrator*	X	X
Ruddy Duck, *Oxyura jamaicensis*	X	X
e Osprey, *Pandion haliaetus*	X	X

	Historical	Modern
e Northern Harrier, *Circus cyaneus*	X	X
Cooper's Hawk, *Accipiter cooperii*	X	X
Red-tailed Hawk, *Buteo jamaicensis*	X	X
American Kestrel, *Falco sparverius*	X	X
e Peregrine Falcon, *Falco peregrinus*	X	X
s Virginia Rail, *Rallus limicola*	X	X
Sora, *Porzana carolina*	X	X
Common Moorhen, *Gallinula chloropus*	X	X
American Coot, *Fulica americana*	X	X
Black-Bellied Plover, *Pluvialis squatarola*	X	X
American Golden Plover, *Pluvialis dominicus*	X	X
Semipalmated Plover, *Charadrius semipalmatus*	X	X
Killdeer, *Charadrius vociferus*	X	X
American Avocet, *Recurvirostra americana*		X
Greater Yellowlegs, *Tringa melanoleuca*	X	X
Lesser Yellowlegs, *Tringa flavipes*	X	X
Solitary Sandpiper, *Tringa solitari*a	X	X
Spotted Sandpiper, *Actitis macularia*	X	X
Hudsonian Godwit, *Limosa haemastic*a		X
Marbled Godwit, *Limosa fedoa*		X
Ruddy Turnstone, *Arenaria interpres*		X
Red Knot, *Calidris canutus*		X
Sanderling, *Calidris alba*		X
Semipalmated Sandpiper, *Calidris pusilla*	X	X
Western Sandpiper, *Calidris mauri*		X
Least Sandpiper, *Calidris minutilla*	X	X
White-rumped Sandpiper, *Calidris fuscicollis*		X
Baird's Sandpiper, *Calidris bairdii*		X
Pectoral Sandpiper, *Calidris melanotos*	X	X
Dunlin, *Calidris alpina*	X	X
Stilt Sandpiper, *Calidris himantopus*	X	X
Buff-Breasted Sandpiper, *Tryngites subruficollis*		X
Ruff, *Philomachus pugnax*		X
Short-Billed Dowitcher, *Limnodromus griseus*	X	X
Long-Billed Dowitcher, *Limnodromus scolopaceus*	X	X
Common Snipe, *Gallinago gallinago*	X	X
American Woodcock, *Scolopax minor*	X	X
x Wilson's Phalarope, *Phalaropus tricolor*	X	X
Red-Necked Phalarope, *Phalaropus lobatus*		X
Franklin's Gull, *Larus pipixcan*		X
Bonaparte's Gull, *Larus philadelphia*	X	X
Ring-billed Gull, *Larus delawarensis*		X
Herring Gull, *Larus argentatus*		X
Caspian Tern, *Sterna caspia*		X
x Forster's Tern, *Sterna forsteri*	X	X

White-Winged Tern, *Chlidonias leucopterus*		X
e Black Tern, *Chlidonias niger*	X	X
Mourning Dove, *Zenaida macroura*		X

	Historical	Modern
Black-billed Cuckoo, *Coccyzus erythropthalmus*		X
Yellow-billed Cuckoo, *Coccyzus americanus*		X
Common Nighthawk, *Chordeiles minor*		X
Chimney Swift, *Chaetura pelagica*		X
Belted Kingfisher, *Ceryle alcyon*	X	X
Yellow-Bellied Sapsucker, S*phyrapicus varius*		X
Northern Flicker, *Colaptes auratus*		X
Olive-Sided Flycatcher, *Contopus borealis*		X
Eastern Wood-Pewee, *Contopus virens*		X
Alder Flycatcher, *Empidonax alnorum*	X	X
Willow Flycatcher, *Empidonax traillii*	X	X
Least Flycatcher, *Empidonax minimus*	X	X
Eastern Phoebe, *Sayornis phoebe*	X	X
Eastern Kingbird, *Tyrannus tyrannus*	X	X
Purple Martin, *Progne subis*	X	X
Tree Swallow, *Tachycineta bicolor*	X	X
N. Rough-winged Swallow, *Stelgidopteryx serripennis*	X	X
Bank Swallow, *Riparia riparia*	X	X
Cliff Swallow, *Hirundo pyrrhonota*	X	X
Barn Swallow, *Hirundo rustica*	X	X
Blue Jay, *Cyanocitta cristata*C	X	X
American Crow, *Corvus brachyrhynchos*	X	X
Black-Capped Chickadee, *Parus atricapillus*	X	X
Brown Creeper, *Certhia americana*	X	X
House Wren, *Troglodytes aedon*		X
Winter Wren, *Troglodytes troglodytes*	X	X
t Marsh Wren, *Cistothorus palustris*	X	X
Golden-Crowned Kinglet, *Regulus satrapa*	X	X
Ruby-Crowned Kinglet, *Regulus calendula*	X	X
Gray-cheeked Thrush, Catharus minimus	X	X
Swainson's Thrush, *Catharus ustulatus*	X	X
Hermit Thrush, *Catharus guttatus*	X	X
Wood Thrush, *Hylocichla mustelina*	X	X
American Robin, *Turdus migratorius*	X	X
Gray Catbird, *Dumetella carolinensis*	X	X
Brown Thrasher, *Toxostoma rufum*	X	X
American Pipit, *Anthus spinoletta*	X	X
Cedar Waxwing, *Bombycilla cedrorum*	X	X
European Starling, *Sturnus vulgaris*	X	X
Warbling Vireo, *Vireo gilvus*		X
Red-eyed Vireo, *Vireo olivaceus*	X	X
e Golden-winged Warbler, *Vermivora chrysoptera*	X	X
Tennessee Warbler, *Vermivora peregrina*	X	X
Orange-crowned Warbler, *Vermivora celata*	X	X
Nashville Warbler, *Vermivora ruficapilla*	X	X
Northern Parula, *Parula americana*		X

	Historical	Modern
Yellow Warbler, *Dendroica petechia*	X	X
Magnolia Warbler, *Dendroica magnolia*	X	X
Cape May Warbler, *Dendroica tigrina*	X	X
Yellow-Rumped Warbler, D*endroica coronata*	X	X
Black-Throated Green Warbler, *Dendroica virens*	X	X
Blackburnian Warbler, *Dendroica fusca*	X	X
Palm Warbler, *Dendroica palmarum*	X	X
Bay-breasted Warbler, *Dendroica castanea*	X	X
Blackpoll Warbler, *Dendroica striata*	X	X
American Redstart, *Setophaga ruticilla*	X	X
Ovenbird, *Seiurus aurocapillus*	X	X
Northern Waterthrush, *Seiurus noveboracensis*S	X	X
Connecticut Warbler, *Oporornis agilis*		X
Mourning Warbler, *Oporornis philadelphia*	X	X
Common Yellowthroat, Geothlypis trichas	X	X
Wilson's Warbler, *Wilsonia pusilla*	X	X
Canada Warbler, *Wilsonia canadensis*	X	X
Common Yellowthroat, *Geothlypis trichas*	X	X
Indigo Bunting, *Passerina cyanea*	X	X
Nelson's Sharp-tailed Sparrow, *Ammodramus nelsoni*	X	X
Fox Sparrow, *Passerella iliaca*	X	X
Song Sparrow, Melospiza melodia	X	X
Lincoln's Sparrow, *Melospiza lincolnii*	X	X
Swamp Sparrow , *Melospiza georgiana*	X	X
White-throated Sparrow, *Zonotrichia albicollis*	X	X
White-crowned Sparrow, *Zonotrichia eucophrys*	X	X
Dark-Eyed Junco, *Junco hyemalis*	X	X
Red-winged Blackbird, *Agelaius phoeniceus*	X	X
Yellow-headed Blackbird, *Xanthocephalus xanthocephalus*	X	X
Eastern Meadowlark, *Sturnella magna*		X
Rusty Blackbird, *Euphagus carolinus*	X	X
Common Grackle, *Quiscalus quiscula*	X	X
Brown-Headed Cowbird, *Molothrus ater*	X	X
House Finch, *Carpodacus mexicanus*		X
Pine Siskin, *Carduelis pinus*		X
American Goldfinch, *Carduelis tristis*	X	X

Attachment 2

Birds Distribution by Reach

The following bird species were identified within the Grand Calumet River corridor. It must be emphasized that the data are based on limited sampling; data for each reach were collected at only those few sites accessible from land.

Culverts reach

American Black Duck, *Anas rubripes*
Mallard, *Anas platyrhynchos*

Hammond Sanitary District reach

Pied-Billed Grebe, *Podilymbus podiceps*
Black-Crowned Night Heron, *Nycticorax nycticorax*
Canada Goose, *Branta canadensis*
Green-Winged Teal, *Anas crecca*
American Black Duck, *Anas rubripes*
Mallard, *Anas platyrhynchos*
Northern Shoveler, Anas clypeata
Sora, *Porzana carolina*
Common Moorhen, *Gallinula chloropus*
American Coot, *Fulica americana*
Killdeer, *Charadrius vociferus*
Lesser Yellowlegs, *Tringa flavipes*
Solitary Sandpiper, *Tringa solitari*a
Spotted Sandpiper, *Actitis macularia*
Red Knot, *Calidris canutus*
Sanderling, *Calidris alba*
Semipalmated Sandpiper, *Calidris pusilla*
Western Sandpiper, *Calidris mauri*
Least Sandpiper, *Calidris minutilla*
Pectoral Sandpiper, *Calidris melanotos*
Dunlin, *Calidris alpina*
Stilt Sandpiper, *Calidris himantopus*
Short-Billed Dowitcher, *Limnodromus griseus*
Common Snipe, *Gallinago gallinago*
Ring-billed Gull, *Larus delawarensis*
Mourning Dove, *Zenaida macroura*
Belted Kingfisher, *Ceryle alcyon*
Northern Flicker, *Colaptes auratus*
American Crow, *Corvus brachyrhynchos*
Barn Swallow, *Hirundo rustica*

American Robin, *Turdus migratorius*
Yellow-Rumped Warbler, D*endroica coronata*
Blackpoll Warbler, *Dendroica striata*
Song Sparrow, *Melospiza melodia*
Dark-Eyed Junco, *Junco hyemalis*
Red-winged Blackbird, *Agelaius phoeniceus*
Common Grackle, *Quiscalus quiscula*
Brown-Headed Cowbird, *Molothrus ater*
House Finch, *Carpodacus mexicanus*
American Goldfinch, *Carduelis tristis*

Roxanna Marsh reach

Pied-Billed Grebe, *Podilymbus podiceps*
Horned Grebe, *Podiceps auritus*
Eared Grebe, *Podiceps nigricollis*
Double-Crested Cormorant, *Phalacrocorax auritus*
Least Bittern, *Ixobrychus exilis*
Great Blue Heron, *Ardea herodias*
Great Egret, *Ardea albus*
Cattle Egret, *Bubulcus ibis*
Green Heron, *Butorides striatus*
Black-Crowned Night Heron, *Nycticorax nycticorax*
Mute Swan, *Cygnus olor*
Canada Goose, *Branta canadensis*
Snow Goose, *Chen caerulescens*
Wood Duck, *Aix sponsa*
Green-Winged Teal, *Anas crecca*
American Black Duck, *Anas rubripes*
Mallard, *Anas platyrhynchos*
Northern Pintail, *Anas acuta*
Blue-Winged Teal, *Anas discors*
Northern Shoveler, *Anas clypeata*
Gadwall, *Anas strepera*
American Wigeon, *Anas americana*
Canvasback, *Aythya valisineria*
Redhead, *Aythya americana*
Ring-necked Duck, *Aythya collaris*
Greater Scaup, *Aythya marila*
Lesser Scaup, *Aythya affinis*
Bufflehead, *Bucephala albeola*
Hooded Merganser, *Lophodytes cucullatus*
Red-Breasted Merganser, *Mergus serrator*
Ruddy Duck, *Oxyura jamaicensis*

Osprey, *Pandion haliaetus*
Northern Harrier, *Circus cyaneus*
Cooper's Hawk, *Accipiter cooperii*
Red-tailed Hawk, *Buteo jamaicensis*
American Kestrel, *Falco sparverius*
Peregrine Falcon, *Falco peregrinus*
Virginia Rail, *Rallus limicola*
Sora, *Porzana carolina*
Common Moorhen, *Gallinula chloropus*
American Coot, *Fulica americana*
Black-Bellied Plover, *Pluvialis squatarola*
American Golden Plover, *Pluvialis dominicus*
Semipalmated Plover, *Charadrius semipalmatus*
Killdeer, *Charadrius vociferus*
American Avocet, *Recurvirostra americana*
Greater Yellowlegs, *Tringa melanoleuca*
Lesser Yellowlegs, *Tringa flavipes*
Solitary Sandpiper, *Tringa solitari*a
Spotted Sandpiper, *Actitis macularia*
Hudsonian Godwit, *Limosa haemastic*a
Marbled Godwit, *Limosa fedoa*
Ruddy Turnstone, *Arenaria interpres*
Sanderling, *Calidris alba*
Semipalmated Sandpiper, *Calidris pusilla*
Western Sandpiper, *Calidris mauri*
Least Sandpiper, *Calidris minutilla*
White-rumped Sandpiper, *Calidris fuscicollis*
Baird's Sandpiper, *Calidris bairdii*
Pectoral Sandpiper, *Calidris melanotos*
Dunlin, *Calidris alpina*
Stilt Sandpiper, *Calidris himantopus*
Buff-Breasted Sandpiper, *Tryngites subruficollis*
Short-Billed Dowitcher, *Limnodromus griseus*
Long-Billed Dowitcher, *Limnodromus scolopaceus*
Common Snipe, *Gallinago gallinago*
American Woodcock, *Scolopax minor*
Wilson's Phalarope, *Phalaropus tricolor*
Red-Necked Phalarope, *Phalaropus lobatus*
Bonaparte's Gull, *Larus philadelphia*
Ring-billed Gull, *Larus delawarensis*
Herring Gull, *Larus argentatus*
Caspian Tern, *Sterna caspia*
Forster's Tern, *Sterna forsteri*
White-Winged Tern, *Chlidonias leucopterus*
Black Tern, *Chlidonias niger*

Common Nighthawk, *Chordeiles minor*
Chimney Swift, *Chaetura pelagica*
Belted Kingfisher, *Ceryle alcyon*
Yellow-Bellied Sapsucker, S*phyrapicus varius*
Northern Flicker, *Colaptes auratus*
Willow Flycatcher, *Empidonax traillii*
Eastern Phoebe, *Sayornis phoebe*
Eastern Kingbird, *Tyrannus tyrannus*
Purple Martin, *Progne subis*
Tree Swallow, *Tachycineta bicolor*
N. Rough-winged Swallow, *Stelgidopteryx serripennis*
Bank Swallow, *Riparia riparia*
Cliff Swallow, *Hirundo pyrrhonota*
Barn Swallow, *Hirundo rustica*
Blue Jay, *Cyanocitta cristata*C
American Crow, *Corvus brachyrhynchos*
Black-Capped Chickadee, *Parus atricapillus*
Brown Creeper, *Certhia americana*
House Wren, *Troglodytes aedon*
Winter Wren, *Troglodytes troglodytes*
Marsh Wren, *Cistothorus palustris*
Golden-Crowned Kinglet, *Regulus satrapa*
Ruby-Crowned Kinglet, *Regulus calendula*
Gray-cheeked Thrush, *Catharus minimus*
Swainson's Thrush, *Catharus ustulatus*
Hermit Thrush, *Catharus guttatus*
American Robin, *Turdus migratorius*
Gray Catbird, *Dumetella carolinensis*
American Pipit, *Anthus spinoletta*
Cedar Waxwing, *Bombycilla cedrorum*
European Starling, *Sturnus vulgaris*
Warbling Vireo, *Vireo gilvus*
Red-eyed Vireo, *Vireo olivaceus*
Tennessee Warbler, *Vermivora peregrina*
Orange-crowned Warbler, *Vermivora celata*
Nashville Warbler, *Vermivora ruficapilla*
Northern Parula, *Parula american*
Yellow Warbler, *Dendroica petechia*
Magnolia Warbler, *Dendroica magnolia*
Cape May Warbler, *Dendroica tigrina*
Yellow-Rumped Warbler, *Dendroica coronata*
Black-Throated Green Warbler, *Dendroica virens*
Palm Warbler, *Dendroica palmarum*
Bay-breasted Warbler, *Dendroica castanea*
Blackpoll Warbler, *Dendroica striata*

American Redstart, *Setophaga ruticilla*
Northern Waterthrush, *Seiurus noveboracensis*S
Common Yellowthroat, *Geothlypis trichas*
Wilson's Warbler, *Wilsonia pusilla*
Indigo Bunting, *Passerina cyanea*
Fox Sparrow, *Passerella iliaca*
Song Sparrow, *Melospiza melodia*
Lincoln's Sparrow, *Melospiza lincolnii*
Swamp Sparrow, *Melospiza georgiana*
White-throated Sparrow, *Zonotrichia albicollis*
Dark-Eyed Junco, *Junco hyemalis*
Red-winged Blackbird, *Agelaius phoeniceus*
Yellow-headed Blackbird, *Xanthocephalus xanthocephalus*
Rusty Blackbird, *Euphagus carolinus*
Common Grackle, *Quiscalus quiscula*
Brown-Headed Cowbird, *Molothrus ater*
House Finch, *Carpodacus mexicanus*
American Goldfinch, *Carduelis tristis*

East Chicago Sanitary reach

Great Blue Heron, *Ardea herodias*
Great Egret, *Ardea albus*
Cattle Egret, *Bubulcus ibis*
Mallard, *Anas platyrhynchos*

DuPont reach

Pied-Billed Grebe, *Podilymbus podiceps*
American Bittern, *Botaurus lentiginosus*
Least Bittern, *Ixobrychus exilis*
Great Blue Heron, *Ardea herodias*
Green Heron, *Butorides striatus*
Black-Crowned Night Heron, *Nycticorax nycticorax*
Canada Goose, *Branta canadensis*
Wood Duck, *Aix sponsa*
Mallard, *Anas platyrhynchos*
Blue-Winged Teal, *Anas discors*
Red-tailed Hawk, *Buteo jamaicensis*
American Kestrel, *Falco sparverius*
Virginia Rail, *Rallus limicola*
Sora, *Porzana carolina*
Common Moorhen, *Gallinula chloropus*
American Coot, *Fulica americana*
Killdeer, *Charadrius vociferus*

American Woodcock, *Scolopax minor*
Ring-billed Gull, *Larus delawarensis*
Herring Gull, *Larus argentatus*
Black Tern, *Chlidonias niger*
Mourning Dove, *Zenaida macroura*
Common Nighthawk, *Chordeiles minor*
Chimney Swift, *Chaetura pelagica*
Belted Kingfisher, *Ceryle alcyon*
Downy Woodpecker, *Picoides pubescens*
Northern Flicker, *Colaptes auratus*
Olive-Sided Flycatcher, *Contopus borealis*
Eastern Wood-Pewee, *Contopus virens*
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Black-Throated Green Warbler, *Dendroica virens*
Blackburnian Warbler, *Dendroica fusca*
Palm Warbler, *Dendroica palmarum*
Bay-breasted Warbler, *Dendroica castanea*

Blackpoll Warbler, *Dendroica striata*
American Redstart, *Setophaga ruticilla*
Ovenbird, *Seiurus aurocapillus*
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Connecticut Warbler, *Oporornis agilis*
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Eastern Towhee, *Pipilo erythrophthalmus*
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Red-winged Blackbird, *Agelaius phoeniceus*
Eastern Meadowlark, *Sturnella magna*
Common Grackle, *Quiscalus quiscula*
Brown-Headed Cowbird, *Molothrus ater*
House Finch, *Carpodacus mexicanus*
American Goldfinch, *Carduelis tristis*

Gary Sanitary District reach

Double-Crested Cormorant, *Phalacrocorax auritus*
Great Blue Heron, *Ardea herodias*
Great Egret, *Ardea albus*
Mallard, *Anas platyrhynchos*
Lesser Scaup, *Aythya affinis*
American Kestrel, *Falco sparverius*
Semipalmated Plover, *Charadrius semipalmatus*
Killdeer, *Charadrius vociferus*
Lesser Yellowlegs, *Tringa flavipes*
Solitary Sandpiper, *Tringa solitari*a
Spotted Sandpiper, *Actitis macularia*
Semipalmated Sandpiper, *Calidris pusilla*
Western Sandpiper, *Calidris mauri*
Least Sandpiper, *Calidris minutilla*
Baird's Sandpiper, *Calidris bairdii*
Pectoral Sandpiper, *Calidris melanotos*
Stilt Sandpiper, *Calidris himantopus*
Ruff, *Philomachus pugnax*

Short-Billed Dowitcher, *Limnodromus griseus*
Common Snipe, *Gallinago gallinago*
Chimney Swift, *Chaetura pelagica*
Swamp Sparrow, *Melospiza georgiana*

Lagoons reach

Red-throated Loon, *Gavia stellata*
Common Loon, *Gavia immer*
Pied-Billed Grebe, *Podilymbus podiceps*
Horned Grebe, *Podiceps auritus*
Red-Necked Grebe, *Podiceps grisegena*
American White Pelican, *Pelecanus erythrorhynchos*
Double-Crested Cormorant, *Phalacrocorax auritus*
Great Blue Heron, *Ardea herodias*
Cattle Egret, *Bubulcus ibis*
Green Heron, *Butorides striatus*
Tundra Swan, *Cygnus columbianus*
Mute Swan, *Cygnus olor*
Canada Goose, *Branta canadensis*
Wood Duck, *Aix sponsa*
Green-Winged Teal, *Anas crecca*
American Black Duck, *Anas rubripes*
Mallard, *Anas platyrhynchos*
Blue-Winged Teal, *Anas discors*
Gadwall, *Anas strepera*
Canvasback, *Aythya valisineria*
Redhead, *Aythya americana*
Ring-necked Duck, *Aythya collaris*
Black Scoter, *Melanitta nigra*
White-Winged Scoter, *Melanitta fusca*
Common Goldeneye, *Bucephala clangula*
Bufflehead, *Bucephala albeola*
Hooded Merganser, *Lophodytes cucullatus*
Common Merganser, *Mergus merganser*
Red-Breasted Merganser, *Mergus serrator*
Ruddy Duck, *Oxyura jamaicensis*
Cooper's Hawk, *Accipiter cooperii*
Red-tailed Hawk, *Buteo jamaicensis*
American Coot, *Fulica americana*
Franklin's Gull, *Larus pipixcan*
Ring-billed Gull, *Larus delawarensis*
Herring Gull, *Larus argentatus*
Chimney Swift, *Chaetura pelagica*
Belted Kingfisher, *Ceryle alcyon*

Yellow-Bellied Sapsucker, S*phyrapicus varius*
Northern Flicker, *Colaptes auratus*
Purple Martin, *Progne subis*
Barn Swallow, *Hirundo rustica*
Blue Jay, *Cyanocitta cristata*C
American Crow, *Corvus brachyrhynchos*
Cedar Waxwing, *Bombycilla cedrorum*
European Starling, *Sturnus vulgaris*
Cape May Warbler, *Dendroica tigrina*
Yellow-Rumped Warbler, *Dendroica coronata*
White-crowned Sparrow, *Zonotrichia eucophrys*
Dark-Eyed Junco, *Junco hyemalis*
Red-winged Blackbird, *Agelaius phoeniceus*
House Finch, *Carpodacus mexicanus*
American Goldfinch, *Carduelis tristis*

MAMMALS

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INTRODUCTION

The objectives of this chapter are to describe the pre-settlement and present mammal communities of the Grand Calumet River basin, and to discuss how dredging operations may affect these communities. A further objective is to produce recommendations that might be implemented during the dredging operations to enhance the mammal populations of the area.

Pre-settlement/early settlement mammal community

Presettlement records of northwestern Indiana are scant and consist mainly of diary records of explorers such as Father Marquette and LaSalle, and of trading-post fur records. Records from the 1600's mentioned the Virginia opossum (*Didelphis virginiana*), the American beaver (*Castor canadensis*) and the bison (*Bos bison*). "Panther" (mountain lion or possibly bobcats) were reported in the 1830's. White-tailed deer were plentiful until the 1870's, but they and beavers were extirpated from the state by the turn of the century (Mumford and Whitaker 1982). Deer reintroductions began in the 1930's. There were an estimated 900 deer in Indiana by 1943, 5000 by 1951, and there were probably deer in every county by 1966. Both deer and beaver were still scarce in the 1960's but have become abundant in the last two decades in northwestern Indiana and elsewhere. Wolves (possibly coyotes) were reported as late as 1914 (Lyon 1923), and black bears (*Ursus americana*) were present until about 1870.

A total of about ten species of large mammals that were here prior to European settlement are no longer present (Table 1). Large mammals are generally most subject to extirpation when humans populate the land because they are more feared (bear, wolf, mountain lion) than smaller animals, or they are hunted and trapped (deer, elk, bison, fisher, beaver) than smaller mammals. Also, they usually need larger tracts of undisturbed habitat. Smaller mammals live alongside humans more easily because they are not usually heavily persecuted by humans, and they can use smaller patches of habitat. The extirpated mammals are discussed below. Two species, the white-tailed deer and the American beaver, were extirpated by the turn of the century and then reintroduced. These will be discussed later.

Extirpated species

American porcupine, *Erethizon dorsatum.* The American porcupine was clearly present in presettlement times; skeletal remains were found by Rand and Rand (1951). The last known specimen was from 1918.

Gray wolf, *Canis lupus.* There are several reports of Timber wolves from Indiana, but there is some question as to whether they were wolves or coyotes. The last report of a timber wolf in the state was from 1908 (Mumford and Whitaker 1982).

Black bear, *Ursus americanus*. There are records of black bears in the area in the presettlement records, and Rand and Rand (1951) found skeletal remains of black bear. The last report of a bear living in Indiana was in 1850. The last one actually seen in the Calumet region was seen in 1871, but that individual was apparently a stray driven south from Michigan by a great fire (Brennan 1923).

Fisher, *Martes pennanti*. Rand and Rand (1951) found fisher remains in the region, indicating that they were clearly present. The last report of a fisher in Indiana was in 1859 (Mumford and Whitaker, 1982).

River otter, *Lutra canadensis*. The last record of the river otter in northwestern Indiana is from 1900. The otter was first reintroduced into Indiana at Muscatatuck National Fish and Wildlife Refuge in 1995. Additional releases were made in other areas in 1996 and 1997, and more are planned. The otter perhaps could be reintroduced eventually into northwestern Indiana.

Mountain lion, *Felis concolor*. Panthers were reported in the 1660's, and the last mountain lion recorded from Indiana was seen in 1830, although there is some question as to whether it was identified correctly.

Canada lynx, *Felis lynx*. The last Canada lynx in the region was reportedly killed by Hunter Green in 1873 at Tremont, although the identification of this species in Indiana has been questioned. The last record in the state is from 1880.

Bobcat, *Felis rufus*. The bobcat is rare in Indiana, but there have been 15 confirmed reports in the state since 1970. It is possible that this species still occurs at the Indiana Dunes National Lakeshore, but the last record there was in 1888.

Bison, *Bos bison*. The bison was present in northwestern Indiana until well into the 19th century. The last record was in 1850.

American elk, *Cervus canadensis.* Rand and Rand (1951) found skeletal material of elk at the Indiana Dunes National Lakeshore.

Probably all of the species of mammals now present except two were present in presettlement times. The exceptions are the two species of old world rats and mice, the housemouse, *Mus musculus*, and the Norway rat, *Rattus norvegicus*. They are exotics that came into North America on ships with the early settlers. Another species possibly present now that was absent in presettlement times is the western harvest mouse, *Reithrodontomys megalotis*. It moved across Illinois between 1953 and 1969 and into Newton County, Indiana around 1969, where it was first found at Willow Slough Fish and Wildlife Area (Whitaker and Sly 1970). By 1974 (Ford 1975), this species occurred in at least seven counties, but it had not crossed the Kankakee River. If it is not already in the vicinity of the Grand Calumet River, the harvest mouse will likely make its way across the Kankakee to the Grand Calumet area relatively soon. Other than these two or three recent introductions, all of the species now present in the Grand Calumet Region were probably also present in presettlement times (Attachment 1).

MAMMALS CURRENTLY PRESENT OR LIKELY TO BE PRESENT

Much information is available on mammals of Indiana (Mumford and Whitaker 1982), Illinois (Hoffmeister 1989) and the Indiana Dunes National Lakeshore (Whitaker et al. 1994), but little is available specifically on mammals of the Grand Calumet River basin.

Three papers present data from areas actually within the Grand Calumet River basin: Whitman (1986), Mierzwa et al. (1991), and Whitaker et al. (1994).

Whitman et al. (1990) found 16 species of mammals at Miller Woods: opossum, short-tailed shrew, masked shrew, eastern mole, cottontail, white-footed mouse, prairie deer mouse, meadow vole, muskrat, fox squirrel, gray squirrel, thirteen-lined ground squirrel, red squirrel, raccoon, long-tailed weasel, and white-tailed deer.

Mierzwa et al. (1991) studied mammals at 15 sites in five different study areas in northeastern Illinois and northwestern Indiana as possible sites at which to establish an airport. Two of the areas were in the Grand Calumet River area: one at an area in Gary, the other near Lake Calumet. However, they reported only ten species of mammals in these two areas (Attachment 2): Virginia opossum, masked and short-tailed shrews, gray and Franklin's ground squirrels, deer and white-footed mice, meadow vole, house mouse and Norway rat.

Whitaker et al. (1994) included information on Miller Woods, but otherwise they did not study areas within the Grand Calumet River basin. However, the habitats, and therefore the mammals, of the Grand Calumet River basin are similar to those of the Indiana Dunes National Lakeshore. Therefore, information from that work and from other papers on the Indiana Dunes were used extensively in this work.

The first significant publication on the mammals of the Indiana Dunes was by Lyon (1923). Lyon reported 22 species: opossum, short-tailed shrew, eastern mole, eastern red bat, eastern cottontail, eastern chipmunk, woodchuck, thirteen-lined ground squirrel, fox squirrel, red squirrel, prairie deer mouse, white-footed mouse, prairie vole, woodland vole, muskrat, Norway rat, house mouse, red fox, raccoon, long-tailed weasel, mink, and striped skunk. He did not personally observe specimens of eastern mole, muskrat, Norway rat, raccoon (a few were taken for fur each year) or long-tailed weasel. He apparently felt these records were reliable. That he personally saw no raccoons would indicate that this species must have been uncommon at that time. He reported that white-tailed deer, although extirpated for many years, had been fairly numerous in around 1875. Lyon reported that the white-footed mouse was the most abundant mammal at the Lakeshore, and it was especially abundant in wooded dunes, swamps, and marshes. From foredunes he reported prairie deer mice and a few house mice. From interdunal meadows, he reported white-footed mouse, prairie deer mouse, prairie vole, pine vole, and short-tailed shrew. Lyon did not take the masked shrew, the meadow vole, or the meadow jumping mouse. In addition to the 22 species that he observed, Lyon (1923) listed the following nine species as "almost certain to be found": little brown myotis, northern myotis (keen's myotis until recently), big brown bat, silver-haired bat, hoary bat, meadow vole, meadow jumping mouse, southern flying squirrel, and gray squirrel. He listed the following six species as probably occurring: star-nosed mole, least shrew, masked shrew, southern bog lemming, American badger, and coyote. Lyon listed 11 species as "not now extant but whose remains may possibly be found," as "extinct", or as "probably extinct,": timber wolf, *Canis lupus*; fisher, *Martes pennanti*; black bear, *Ursus americanus*; river otter, *Lutra canadensis*; mountain lion, *Felis concolor*; Canada lynx, *Felis lynx*; bobcat, *Felis rufus*; porcupine, *Erethizon dorsatum*; snowshoe hare, *Lepus americanus*; bison, *Bison bison*; and elk, *Cervus canadensis*. We have listed all of these above as extirpated species of the Grand Calumet basin except for the snowshoe hare, for which we find no evidence of occurrence.

Brennan (1923) relates early reports of bison, black bear (last seen in the region in 1871, when it was probably driven there from Michigan by the great fire; the entire east shore of Lake Michigan was on fire), mountain lion, Canada lynx (last one seen in the region was killed by Hunter Green in 1873 at Tremont), bobcat, white-tailed deer (the last one shot was in the early 1870's), elk, coyotes (Brennan cited many reports of timber wolves, and stated that there were a few left between Dunes Park and Michigan City until 1919; It is suspected by Whitaker et al. (1994) that all or many of these were actually coyotes), porcupine (a dog attacked one in 1918 at Furnessville), river otter, and beaver. Brennan reported the following as still present as of 1923: opossum, red fox (family near the Furnessville Blowout), gray fox, raccoon (raccoon hunts were held by the neighbors), mink (many in streams and marshes), eastern skunk, muskrat (thousands in the marshes), cottontail (common), eastern mole (exceedingly common as indicated by burrows), woodchuck (thousands present), red squirrel, gray squirrel, badger (Brennan saw a gray squirrel and a badger on the same day near the Furnessville Blowout in November of 1918), and fox squirrel.

Lyon (1936) reported the least shrew, masked shrew, silver-haired bat, Franklin's ground squirrel, meadow vole, meadow jumping mouse, and badger from the Lakeshore.

Rand and Rand (1951) reported skeletal remains of 32 species of mammals in blowouts in Indiana Dunes State Park, including 26 species still present and six that had been extirpated. The extirpated species were black bear, fisher, beaver, porcupine, elk, and white-tailed deer. Species still present were opossum, masked shrew, northern short-tailed shrew, eastern mole, silver-haired bat, big brown bat, eastern red bat, eastern cottontail rabbit, eastern chipmunk, woodchuck, thirteen-lined ground squirrel, Franklin’s ground squirrel, fox squirrel, red squirrel, southern flying squirrel, white-footed and prairie deer mouse, meadow vole, muskrat, southern bog lemming, Norway rat, house mouse, raccoon, least weasel, long-tailed weasel, mink, and striped skunk. New species records by Rand and Rand were the big brown bat, the southern flying squirrel, the southern bog lemming, and the least weasel, so the new total species number from the area was 34.

A Texas Instruments team studied the Cowles Bog area from 1975 to 1980, and they collected or observed 25 species of mammals. Some of their more interesting records include the little brown bat, the woodland vole, and the least weasel. Suprisingly, they failed to capture any prairie deer mice, meadow voles, or prairie voles. Species reported for the first time from the area by Texas Instruments were the little brown bat and the white-tailed deer, making a total of 36 species known from the area.

Krekeler (1981) stated that the gray squirrel had been extirpated at one time but was now common in certain areas. He indicated that the beaver had been extirpated but reintroduced, and it had caused high water problems at Dune Acres. His was the first definite recent record of the beaver at the Lakeshore. Krekeler stated that skunks forage on the beach and that tracks of the white-tailed deer are now regularly seen at the Lakeshore. This brings the number of species recorded at the Lakeshore to 37.

Whitaker et al. (1994) reported opossum, two species of shrews (masked and northern short-tailed), eastern mole, three bats (red, silver-haired, and big brown), eastern cottontail, seven squirrels (chipmunk, woodchuck, thirteen-lined ground squirrel, and fox, gray, red and southern flying squirrels), beaver, eight mice and rats (white-footed mouse and prairie deer mouse, Norway rat, house mouse, prairie, woodland and meadow voles, and meadow jumping mouse), ten species of carnivores (coyote, red and gray foxes, raccoon, long-tailed and least weasels, mink, American badger, striped skunk, and feral cat), and white-tailed deer. Gray fox brought to 38 the number of species known to occur at the Lakeshore.

The diverse habitats of the Lakeshore thus create a home for approximately 38 of the 57 species of mammals presently known to occur in Indiana (including the river otter which was reintroduced in Indiana in 1995). The beaver and white-tailed deer were extirpated from the state during the last century, but both occur there now. Franklin's ground squirrel was probably present at the Lakeshore through the 1940's, but then it apparently disappeared from there. However, it was recorded in the Grand Calumet River basin by Mierzwa et al. (1991). Feral dogs and cats are present, and they may partially fill the predator niche. Bobcat (state endangered) signs have been reported in the Heron Rookery area of the Lakeshore, but their presence has not been verified.

Species of mammals suspected to currently reside in the Grand Calumet River basin are discussed below and are indicated in Attachment 1.

Didelphidae, the opossums

Virginia opossum, *Didelphis virginiana* Kerr. The opossum is common in the Lakeshore area, and likewise it is surely common throughout the Grand Calumet River region. It was found in ten of the 24 habitats sampled at the Indiana Dunes National Lakeshore and also 93 were recorded as roadkill (Whitaker et al. 1994). Texas Instruments Inc. found this species in all six of the terrestrial habitats they sampled, and Whitman et al. (1990) found it to be common at Miller Woods. Mierzwa et. al. (1991) recorded one in Eggers Woods, near Wolf Lake.

Insectivora, shrews and moles

The Insectivora consists of the moles and shrews, six species of which conceivably could occur in the Grand Calumet River area, four species of shrews and two of moles. Only three species of shrews (masked, short-tailed and least) and one mole (eastern) have been confirmed to occur there.

Northern short-tailed shrew, *Blarina brevicauda*. The short-tailed shrew is one of the most common mammals in northwestern Indiana, and it is common in the Grand Calumet River basin (Mumford and Whitaker 1982, Krekeler 1981, Texas Instruments 1975-80, Whitman et al. 1990, and Whitaker et al. 1994). Whitaker et al. (1994) took short-tailed shrews in 17 of the 24 habitats studied. They were most abundant in upland terrestrial shrubland, wet prairie, old field, ephemeral lowland forest, and mixed deciduous savanna. Mierzwa et al. (1991) trapped nine short-tailed shrews: four at the DuPont area, four at the Burnham Prairie/Powderhorn Prairie area, and one at the Clark & Pine area.

Least shrew, *Cryptotis parva* (Say).The least shrew is a small brownish short-tailed shrew, much smaller than *Blarina*. Its total length is only about 63 to 88 mm, its tail only 11 to 20 mm. It usually occurs in fairly dry open fields. It occurs throughout Indiana, but it is not taken often. There are few records in the northern part of the state. Lyon trapped a least shrew in "subdunal woods" on October 31, 1924. It was apparently from Tremont, as Sanborn (1925) reported that Lyon took one there in the fall of 1924. The specimen was deposited in the U.S. National Museum (#240630). Whitaker et al. (1994) did not take it at the Indiana Dunes National Lakeshore, but it most likely occurs sparingly in dry fields in the Calumet River area.

Masked shrew, *Sorex cinereus* Kerr. The masked shrew is common in several habitats at the Indiana Dunes National Lakeshore and in the Grand Calumet River area, especially in wet areas. Mierzwa et al. (1991) captured 35 individuals in their Lake Calumet study area: four in the Big Marsh/Indiana Ridge area, 20 in the Burnham Prairie/Powderhorn Prairie area, and 11 at Egger's Woods. Mumford and Whitaker (1982) found masked shrews in several habitats east of the Bailey Generating Station, and 124 of 178 mammals (69.7 %) taken at Cowles and Pinhook Bogs and at Trail Creek Fen were masked shrews. Whitman et al. (1990) reported masked shrew from Miller Woods. Whitaker et al. (1994) took only 35 during their study of mammals at the Indiana Dunes National Lakeshore. This included individuals from eight habitats, although they were most abundant in wet prairie (1.83 per 100 trap-nights) and marsh (1.17 per 100 trap-nights). Shrew populations were apparently low at the time of this study. The masked shrew lives in areas where the soil retains moisture sufficient to maintain burrows 100% saturated. Because of this moisture requirement, the species often lives in dense vegetation or in mossy areas.

Pygmy shrew, *Sorex (Microsorex) hoyi* Baird. The pygmy shrew has long been thought to be exceedingly rare, but pitfall trapping has shown it is much more abundant than was previously realized. The pygmy shrew could occur in the Calumet River basin, but it has not been found at the Indiana Dunes National Lakeshore or elsewhere in northern Indiana. It does not occur in the southern portion of the lower peninsula of Michigan either (Baker 1983). There are records from Wisconsin including one at the extreme southeast corner, or less than 80 miles from the Grand Calumet River area. Also, one was taken in mid-winter in a garage at Palatine which is northwest of Chicago in Cook County, Illinois, and about 50 miles from the Grand Calumet. No pygmy shrews were taken in extensive trapping at Bailly, Cowles', or Pinhook Bogs (Mumford and Whitaker 1982) and none were taken in other areas at the Indiana Dunes National Lakeshore (Whitaker et al. 1994). Thus, this shrew's occurrence in the Grand Calumet River area is unlikely. However, the unicuspid teeth of all long-tailed shrews (*Sorex*) from that area should be carefully examined. (*Sorex cinereus* has four "large" unicuspids and one small unicuspid, all easily visible from the side. *Sorex hoyi* has the third and fifth extremely reduced, thus only 3 unicuspids are readily visible from the side).

Talipidae, the moles

Eastern mole, *Scalopus aquaticus* (Linnaeus). The eastern mole is common at Indiana Dunes National Lakeshore (Krekeler 1981, Whitman et al. 1990, Whitaker et al. 1994) and in the Grand Calumet River region. Whitaker et al. (1994) found burrows of the eastern mole in ten of 24 habitats examined at the Indiana Dunes National Lakeshore. This species was most abundant in pine plantations, oak savanna, excavated sand, and mixed deciduous forest. The author saw a number of its burrows in the sand on July 20, 1996 at the DuPont and Clark and Pine areas in the

Grand Calumet River basin. The eastern mole is common in many of the drier habitats at the Lakeshore.

Star-nosed mole, *Condylura cristata* (Linnaeus). The star-nosed mole is a species that lives in muckland habitats. Its burrows are usually quite evident, since they are in muck, whereas the burrows of eastern moles are usually in drier areas. The star-nosed mole has been documented only in the northeast portion of the state, and its range has apparently contracted in this century. This species has never been taken at the Indiana Dunes National Lakeshore. However, on October 28, 1982, Whitaker trapped one at Trail Creek Fen at the southern edge of Michigan City. This site is just east of INDU. On the basis of this record, we expect it to occur at the INDU. Muckland habitats suitable for star-nose moles are abundant in the Grand Calumet River basin, and it is conceivable, though unlikely, that it occurs there.

Chiroptera, the bats

Twelve species of bats are found (or were found- two are probably extirpated) in Indiana, all in the family Vespertilionidae. All are nocturnal and have well developed echolocation abilities, and all feed almost exclusively on flying insects. Little information is available on bats of Indiana Dunes National Lakeshore or of northwestern Indiana. There are definite records at INDU for only three species: the big brown bat, the red bat, and the silver-haired bat. There is an early record of the evening bat, but this species probably does not exist there (see account, pg xxx13). There is an unverified record of the little brown myotis, but this species surely exists there. The northern myotis and hoary bat are undoubtedly present, and it seems likely that the Indiana myotis is also there. Rand and Rand (1951) reported silver-haired, red, and big brown bats. Information on bats of northwestern Indiana is given below. Most of these species should occur in the area of the Grand Calumet River, at least where adequate woodland exists.

Big brown bat, *Eptesicus fuscus* (Beauvois). Whitaker et al. (1994) found one big brown bat in a large building on the north side of Route 12 just west of Mineral Springs Road, and a post-lactation colony occurs behind the barn doors at Chellberg Farm. A total of 113 bats emerged from behind this door on August 27, 1988. Several maternity colonies were found by Whitaker et al. (1994), as follows: 1) about 100 individuals in a well-kept brick house 0.2 miles east of 33E on U.S. Route 20, 2) about 20 individuals at the Lutheran Church at the south end of Mineral Springs Road (just north of I-94), 3) about 80 individuals on September 9, 1988 at the barn at Portage Park, SW of I-94 and State Road 249, 4) on May 16, 43 bats emerged from the soffit of an old but well-preserved two story brick house near US road 49 north of Road 6. There are undoubtedly many maternity colonies of big brown bats in buildings in the Grand Calumet basin. This is the only species likely to winter (hibernate) at INDU, since there are no caves present and the big brown bat is the only species in Indiana that hibernates in buildings.

Red bat, *Lasiurus borealis* (Muller). Lyon (1923) observed a female red bat roosting in blackberry bushes in the Lakeshore region. Whitaker (Mumford and Whitaker 1982) shot a female red bat at daybreak on August 26, 1963 as it was flying over the beach in what is now the Lakeshore. Whitaker et al. (1994) recorded red bats as follows: 1) a young female collected in

July of 1987 at the West Beach bathhouse; 2) a red bat observed flying at Indiana Dunes State Park on August 27, 1988; and 3) two individuals netted (1 male, 1 female) over Dunes Creek, Indiana Dunes State Park, on September 23, 1988. The red bat is solitary and hangs in trees during the daytime. It is one of the most common bats in wooded areas of northwestern Indiana, and it should occur in areas of the Grand Calumet River basin where enough trees are present.

Little brown myotis, *Myotis lucifugus* (LeConte). Neither Lyon (1936) nor Mumford and Whitaker (1982) recorded the little brown myotis in Lake, Porter, or LaPorte Counties. The only specific record of this species at INDU is that of Texas Instruments (1975-80), but this record needs verification. The author has often seen small bats flying about over openings in Indiana Dunes State Park and vicinity which I think are this species and/or perhaps the northern myotis, *Myotis septentrionalis*. The little brown myotis migrates to the karst regions of southern Indiana where it hibernates in caves.

Silver-haired bat, *Lasionycteris noctivagans* (LeConte). Hahn (1909) reported this species from Michigan City, LaPorte County. Mumford and Whitaker (1982) reported three individuals taken at the Indiana Dunes State Park, a female taken on September 24, 1928 by W.A. Weber, and two individuals taken on May 3, 1936 by J. Schmidt. Whitaker et al. (1994) netted one individual on September 9, 1988, about one mile northeast of the visitors center at the INDU.

The silver-haired bat is a migratory solitary bat. It spends the summer and has its young to the north of Indiana and then migrates southward. A few individuals hibernate in caves or mines in southern Indiana, but most winter in states to the south. This species is fairly common in Indiana during migration from about April 18 to May 28 and from about August 29 to November 6, when it should be relatively common at the Lakeshore (Mumford and Whitaker 1982).

Evening bat, *Nycticeius humeralis* (Rafinesque). Russell E. Mumford shot an evening bat two miles to the northwest of Porter (Porter County) on August 5, 1958. However, populations of this species have decreased greatly in Indiana in recent years, and we doubt that it presently occurs in northwestern Indiana. For that matter, the single record could have been a stray.

Bat species probably present but unsupported by records

Northern myotis, *Myotis septentrionalis* (Merriam). This species has often been referred to as Keen's bat, *Myotis keenii septentrionalis*. However, the populations in the eastern regions of the United States are currently recognized as a separate species from the populations in the western U.S. (Van Zyll de Jong 1979). The eastern species is known as the northern myotis, *Myotis septentrionalis*. There are no records of this species for any of the Lake shore counties (Mumford and Whitaker 1982). However, since wooded habitat is abundant, and since it is a northern species, the author suspects further work will reveal it to be present. It forms small summer colonies under the bark of trees or in buildings, it then migrates to caves and mines where it hibernates individually rather than in groups. Kurta (1982) found it was relatively uncommon in southern Michigan, and Long (1974) reported it as less common than the little brown myotis in the Lake Michigan drainage.

Hoary bat, *Lasiurus cinereus* (Palisot de Beauvois). Like the red and silver-haired bats, this is a solitary, migratory species which roosts in trees. It is the largest and one of the most colorful bats of Indiana. It occurs throughout the state, but it is nowhere common. It probably occurs in the Grand Calumet River basin in areas with adequate trees.

Indiana myotis, *Myotis sodalis* (Miller and Allen). The Indiana myotis is listed as endangered primarily because huge numbers congregate in very few caves in winter. There are no records for the northwestern 15 or so counties of the state (Mumford and Whitaker 1982); however, Kurta (1982) recorded this species, and Kurta et al. (1993) later recorded a maternity colony of this species from southern Michigan. The Indiana myotis is probably present in northwestern Indiana, including the Grand Calumet River area, where enough forest with large trees is present. It forms small summer colonies under the bark of dead trees, often along watercourses. It hibernates in large numbers in a very few caves, some of which are found in southern Indiana.

Lagomorpha, rabbits and hares

Eastern cottontail, *Sylvilagus floridanus* (Allen). The eastern cottontail is the only lagomorph in northwestern Indiana. Lyon (1923), Krekeler (1981), Texas Instruments, and Whitaker et al. (1994) all listed it as common in the area of the Indiana Dunes National Lakeshore. It was observed occasionally in Miller Woods by Whitman et al. (1990). Fecal pellets and tracks are commonly seen throughout INDU and 65 cottontails were recorded as roadkills (Whitaker et al.1994). This species was often seen by Mierzwa et al. (1991) at Clark and Pine, Lakeshore Railroad Prairie, DuPont and Burnham Prairie. Cottontails are fairly common in the Grand Calumet River basin.

Rodentia, the rodents

Rodents constitute the largest group of mammals in northwestern Indiana (and in the world) in number of species and number of individuals. A total of rodent species for the area have been found since the harvest mouse, *Reithrodontomys megalotis* (Sigmodontinae) crossed the Kankakee River from the south: seven species in the squirrel family; the beaver; two sigmodontine rodents (= old Cricetinae), both of which are in the genus *Peromyscus;* at least four and probably five species of arvicoline rodents (= old Microtinae), muskrat, three voles and probably the bog lemming); two Old World mice (Murinae), the Norway rat and house mouse; and meadow jumping mouse.

Sciuridae, the squirrels

Seven species of squirrels occur in northwestern Indiana, including Franklin's ground squirrel, currently listed as state endangered. Squirrels are some of the most conspicuous mammals, partly because most are diurnal. The largest member of the squirrel family is the woodchuck, which many probably do not realize is a squirrel. Also, much in evidence at INDU are fox and red squirrels. Besides being diurnal, these two are common and quite noisy. The gray squirrel and chipmunk are obvious where common. The flying squirrel may often be common, but it is seldom observed because it is nocturnal. The thirteen-lined ground squirrel has a spotty distribution, but it is found at several Indiana Dunes National Lakeshore localities (Whitaker et al. 1994). Gray and Franklin's ground squirrels have been documented within the Grand Calumet River basin (Mierzwa et al. 1991). The various squirrels are discussed below.

Eastern chipmunk, *Tamias striatus* (Linnaeus). The chipmunk is common in many of the wooded habitats of northwestern Indiana, although it is sporadic in occurrence. Lyon (1923) stated that "chipmunks do not appear to be very common in the dunes." Krekeler (1981) listed it as abundant in open woods, thickets, and suburbs. Texas Instruments (1975-80) recorded numerous captures of chipmunks in several habitats. Whitman et. al. (1990) did not mention them in their Miller Woods report. Whitaker et. al. (1994) captured 24 chipmunks in nine habitats at the Indiana Dunes National Lakeshore, and sign or sight observations were made in 11 plots in seven habitats. Seventeen were seen dead on the road, and numerous individuals were seen elsewhere at INDU. The chipmunk should be fairly common in the Grand Calumet River basin, but Mierzwa et al. (1991) did not report it.

Woodchuck, *Marmota monax* (Linnaeus). Lyon (1923) and Whitaker et al. (1994) found woodchucks to be common in several habitats at the Indiana Dunes National Lakeshore. They were observed up to October 4. Whitman et al. (1990) does not mention them from Miller Woods, but Mierzwa noted them from DuPont and Burnham Prairie.

Thirteen-lined ground squirrel, *Spermophilus tridecemlineatus* (Mitchill). Lyon (1923) found this species "not uncommon along the Chicago, Lake Shore and South Bend Railway just south of the dunes," and reported one "just north of Oak Hill Station and a few feet above the subdunal swamp." Krekeler (1981) listed it as "common" at INDU and indicated its habitat as "pastures, road borders, dunes, weedy or cultivated fields." Texas Instruments (1975-80) reported three individuals: two from the Cowles Marsh area and one from the transmission corridor. Whitman et al. (1990) saw this species along the railroad bed "at the north end of the study area." Whitaker et al. (1994) found a roadkilled individual on Wagner Road just north of Route 20, and two additional roadkills just south of route 20. Fifteen individuals were trapped in nine plots in four habitats, four in dry prairie, four in terrestrial shrubland, three in oak savanna, and four in coniferous savanna. Ten of the 15 were at West Beach. Mierzwa et al. (1991) saw this species only at Wolf Lake where it was very common on the Illinois side of the lake on grassy roadsides. The species should be present in dry open areas with little ground cover near the Grand Calumet River.

Franklin's ground squirrel, *Spermophilus franklinii* (Sabine). Neither Lyon (1923), Krekeler (1981), Texas Instruments (1975-80), nor Whitaker et al. (1994) reported Franklin's ground squirrels from INDU. Three Franklin's ground squirrels were taken by Alex Bognar, from "Miller" in Lake County, Indiana in 1947. The specimens apparently are in the Field Museum (CNHM #'s 73872, 73873, and 73874). We assume these were from or near Miller Station, which is about half a mile south of Miller Woods. In 1986-87, Scott Johnson and other Indiana DNR personnel used two sets of ten live traps to examine the area along the railroad at Miller

Station for Franklin's ground squirrels. This locality would appear to be very close to the locality where Bognar collected this species, but no Franklin's ground squirrels were seen or taken there.

Mierzwa et al. (1991) trapped two Franklin's ground squirrels on low dunes between swales: one at the Dupont area and one at the Big Marsh/Indian Ridge area. Also, they found it to be common at Powderhorn Lake, and present at Burnham Prairie and near Lake Calumet. These records are exceedingly interesting since this species is listed as endangered in Indiana. Most of the currently known populations are along railroads, although a few are along roadsides.

Gray squirrel, *Sciurus carolinensis* (Gmelin). Lyon (1923) did not report this species from the Lakeshore area; however, Krekeler (1981) recorded it as common in woods and suburbs, and Texas Instruments (1975-80) reported 23 from three habitats at the Lakeshore. Whitaker et al. (1994) recorded it in upland oak forest and in oak savanna, and also reported several road killed individuals. Also, a number were seen in black oak forest at Miller Woods and one was observed in black oak forest at Dune Acres. Whitman et al. 1990 also observed gray squirrels at Miller Woods.

Mierzwa et al. (1991) recorded 23 gray squirrels in the Grand Calumet River area: seven in the DuPont area, two in the Ivanhoe area, two in the Burnham Prairie/Powderhorn Prairie area, and 12 at Egger's Woods. This species is relatively uncommon at INDU, but it appears to be more common in the Grand Calumet River basin.

Fox squirrel, *Sciurus niger* Linnaeus. Lyon (1923), Krekeler (1981), Texas Instruments (1975-80), and Whitaker et al. (1994) all reported this species as common at Indiana Dunes National Lakeshore, and it is common in proper habitat in all of northwestern Indiana. This species was not reported by Mierzwa et al. (1991) in their study plots, but it should be fairly common in the Grand Calumet River basin.

Red Squirrel, *Tamiasciurus hudsonicus* (Erxleben). Lyon (1923), Krekeler (1981) Texas Instruments (1975-80), and Whitaker et al. (1994) reported the red squirrel to be fairly common in the wooded portions of INDU. Whitman et al. (1990) took it in traps along the edges of ponds in Miller Woods. Mierzwa et al. (1991) found no red squirrels in the vicinity of the Grand Calumet River, and this species is likely rare or absent there because of the lack of forest, and particularly of conifers.

Southern flying squirrel, *Glaucomys volans* (Linnaeus). Lyon (1923) did not see flying squirrels but listed them as almost certain to be present at INDU. Texas Instruments (1975-80) collected three from black oak/swamp forest at INDU, and Whitaker et al. (1994) trapped two flying squirrels, one in black oak forest and one in black oak savanna. Scrubby black oak is a good habitat for flying squirrels because old woodpecker holes and other openings can be used as nest sites or refuges for this species. Flying squirrels were not reported by Mierzwa et al. (1991), and they are probably not common in the Grand Calumet area because of the lack of suitable forest. Flying squirrels feed heavily on nuts and seeds but also will readily eat insect material or even young birds and their eggs.

Beaver, *Castor canadensis* Kuhl. Beavers had nearly disappeared from Indiana by about 1840 (Lyon 1936). They were reintroduced into Jasper-Pulaski and Kankakee Fish and Wildlife Areas in 1935 from Wisconsin and Michigan, and later introductions were made into other areas. Brooks (1955) knew of 326 colonies in 43 counties of Indiana. The majority were in portions of northwestern Indiana and some were in Lake County. There is a photograph taken in 1968 of a beaver lodge at Cowles Bog (Lindsey et al. 1969). Krekeler (1981) listed the beaver as uncommon at INDU, but he did say that it had caused high water problems on the road leading into Dune Acres (at Cowles marsh). There is presently a beaver colony on the Salt Creek watershed, and signs of beaver were seen by Whitaker et al. (1994) on the lower portions of the Little Calumet River. There had been a colony on the Little Calumet north of Chesterton, but all of the beavers there have been trapped. Tom Sobat reported fresh beaver cuttings along Derby Ditch on October 17, 1990. Mierzwa et al. (1991) did not mention beaver in their studies of the Grand Calumet River area. The beaver should be a prominent species in wooded portions of a clean Grand Calumet River.

Muridae, mice and rats

Most mice and rats are currently placed in the family Muridae, which contains three subfamilies: the Sigmodontinae (previously the Cricetinae), the Arvicolinae (previously the Microtinae) and the Murinae. The Murinae are the Old World rats and mice, *Mus* and *Rattus*.

Sigmodontinae

The Sigmodontinae are the native rats and mice and constitute constitute one of the largest groups of mammals in North America both in number of species and in number of individuals. However, there are only two (or possibly three) species in this group in the Grand Calumet River basin, although one of them, *Peromyscus leucopus*, is the most abundant mammal there.

Western harvest mouse, *Reithrodontomys megalotis* (Baird). The western harvest mouse was probably first taken in Indiana in 1969 at Willow Slough State Fish and Wildlife area in Newton County (Whitaker and Sly 1970) when it moved into Indiana. By 1975 it had extended its range to include at least seven counties of northwestern Indiana (Ford 1975), but it had not crossed the Kankakee River to the north into Lake and Porter Counties. By 1994 (Whitaker unpublished), it had extended its range to the south into Vigo County. By 1995 it had crossed the Wabash River into Clay County, and by 1997 it had crossed the Kankakee. Now that that barrier has been crossed, harvest mice should become part of the fauna of the rest of northwestern Indiana.

Deer mouse, *Peromyscus maniculatus* (Wagner). The deer mouse occupies a variety of habitats ranging from woods to dry open areas. Its prime habitat in Indiana is in cultivated fields where it lives even when the fields are bare (Whitaker 1967). However, only the prairie deer mouse, *P. m. bairdii* occurs in Indiana. It lives in dry open areas. It is never found in woods, although it can be abundant in savanna with open sand. Unlike all of the other species of small mammals that occur in Indiana, its habitat is inversely related to plant cover, and it can live in areas with little or even no herbaceous vegetation, such as recently plowed or harvested fields or open sandy areas. Its prime habitat in Indiana is in cultivated fields (Whitaker 1967; Mumford and Whitaker 1982). Its tracks are often obvious in loose sand on dunes, or in light snow in plowed fields, where it emerges from one burrow and enters another. It probably occurred in areas of open sand such as on dunes in presettlement times.

Hahn (1909) recorded this species from only five counties, and did not think it was very common in Indiana. Evermann and Butler (1920) stated that it was abundant on the dunes along Lake Michigan. Lyon (1923) found numerous footprints of this species in the loose sand on the dunes but took few specimens and concluded that a few mice made many tracks. Krekeler (1981) recorded it as abundant in foredunes, grasslands, thickets, and old fields. Whitman et al. (1990) recorded it from Miller Woods. Whitaker et al. (1994) recorded *Peromyscus maniculatus* from ten habitats, but it was most common in dry prairie and on right-of-ways at the Indiana Dunes National Lakeshore. Mierzwa et al. (1991) recorded 30 individuals in open sand on the low dunes of the Grand Calumet River area, and stated that they were "so common at Lakeshore Railroad Prairie that we were able to find them under boards and debris without even trapping for them." This site is the most open one in the Clark and Pine complex (Mierzwa, pers. comm.).

White-footed mouse, *Peromyscus leucopus* (LeConte). *Peromyscus leucopus* is the most abundant small mammal at the Indiana Dunes National Lakeshore (Lyon 1923, Texas Instruments 1975-80, Krekeler 1981, Whitman et al. 1990). Whitaker et al. (1994) took a total of 445 individuals in 22 of 24 habitats they studied and in 98 of the 168 (58.3%) plots in which they trapped. The only habitats from which the white-footed mouse was not taken were barren grounds and excavated areas, both habitats lacking plant cover. It was taken at its greatest abundance in ephemeral lowland forest, oak upland forest, mixed deciduous savanna, mixed deciduous upland forest, coniferous savanna, and pine plantations. It is probably also the most abundant species in the area of the Grand Calumet River, as Mierzwa et al. 1991 took 67 individuals of this species, and found it in every one of their study sites (Attachment 2).

Arvicolinae, the voles

All five species of microtines present in Indiana are probably present both at the Lakeshore and in the area of the Grand Calumet River.

Meadow vole, *Microtus pennsylvanicus* (Ord). The meadow vole is found throughout northern Indiana where it is usually the most abundant small mammal of moist grassy meadows and wet prairies. In dry fields with sparse vegetation, it tends to be replaced by the prairie vole, *M. ochrogaster*. Lyon (1923) took prairie voles and also pine voles at INDU, but inexplicably, he did not take meadow voles. Krekeler (1981) and Texas Instruments (1975-80) indicated it as abundant. Whitman et al. (1990) trapped them in low-lying areas around one pond at Miller Woods. Whitaker et al. (1994) trapped 171 individuals in 28 plots in 13 habitats. These animals were most abundant in old field and upland terrestrial shrubland. Thirty-four were taken in one plot in this latter habitat. The cover here was heavy and mainly of forbs, but it included dogwood, poisen ivy, roses, some young pines, and few grasses. The soil was quite moist.

Mierzwa et al. (1991) captured 25 meadow voles in five of their six study areas near the Grand Calumet River, but they found them to be most abundant at the Big Marsh/Indian Ridge site.

Prairie vole, *Microtus ochrogaster* (Wagner). Lyon (1923) took seven prairie voles. Krekeler (1981) listed this species as uncommon in relatively dry fields with cover of grasses or weeds. Whitaker et al. (1994) took 17 individuals in eight plots in five habitats. The species was most abundant in old fields. Mierzwa et al. (1991) did not capture any prairie voles, but additional trapping in the drier grasslands of the Grand Calumet River will undoubtedly yield prairie voles. This species lives in much drier and more sparsely vegetated areas than the meadow vole, although it becomes much less abundant to the north.

Woodland vole/Pine vole, *Microtus pinetorum* (Le Conte). Lyon (1923) found many subterranean burrows probably used by this species, but trapped only two woodland voles in the Indiana Dunes area. Krekeler (1981) listed it as uncommon and Texas Instruments (1975-80) caught two individuals in black oak/swamp forest. Whitaker et al. (1994) did not take any individuals in their study plots, but they did take four in pitfall traps set especially for this species in black oak woods. Mierzwa et al. (1991) did not take any woodland voles in studies using surface trapping methods. The woodland vole lives in underground burrows, and thus it is often under-represented in surface trapping surveys. It occurs in the Indiana Dunes National Lakeshore and undoubtedly also occurs in the area of the Grand Calumet River.

Muskrat, *Ondatra zibethicus* (Linnaeus). The muskrat is common in the marshes, streams, and ponds of northwestern Indiana (Lyon 1923, Krekeler 1981, Texas Instruments 1975-80, Whitaker et al. 1994). Whitman et al. (1990) trapped it along ponds in Miller Woods. Mierzwa (pers. comm.) saw one dead on the highway on route 12 near the Gary Regional Airport. He thought that muskrats inhabited the swales but that the river was probably too polluted for them. Their population in the Calumet River basin could be expected to increase if the river is cleaned up.

Southern bog lemming, *Synaptomys cooperi* Baird. Lyon (1923) did not record this species from INDU, but Rand and Rand (1951) recorded it based on their identification of skeletal remains. Krekeler (1981) recorded it as uncommon in areas with lush ground cover of grass and in bogs, but we do not believe that he ever saw a specimen. Texas Instruments (1975-80) did not capture any bog lemmings. Whitaker et al. (1994) did not trap any and apparently no specimen is available as yet from Indiana Dunes National Lakeshore. Whitaker et al. (1994) did find bright green fecal pellets, probably from this species, at a razed residential site on Waverly Road on February 28, 1988. Meadow voles produce dull green or brownish fecal pellets. The name bog lemming is a misnomer. It is not primarily or even often found in wet areas. It has a broad range of habitats from woods to rank meadows and dry *Andropogon* fields.

Murinae, introduced mice and rats

Rattus norvegicus and *Mus musculus* are introduced exotics and are usually found in habitats created or disturbed by humans, such as in buildings or cultivated fields.

Norway rat, *Rattus norvegicus* (Berkenhout). This is the common rat associated with garbage dumps, barns, grain storage units, and suburban warehouses. It is a major pest almost everywhere that it occurs. It ruins foods and other materials and carries disease. It is common in larger cities and on farms in northwestern Indiana. Lyon (1923) did not trap or see any rats but said that residents reported them. Krekeler (1981) reported them as common around farms suburbs and ditches. None were reported during the Texas Instruments studies. Whitaker et al. (1994) found rat droppings in abandoned buildings. Mierzwa et al. (1991) took one Norway rat at the Big Marsh/Indian Ridge area.

House mouse, *Mus musculus* Linnaeus. This mouse has been transported around the world by humans. In Indiana, it is very common in cultivated fields when adequate cover is available but, unlike the prairie deer mouse, it vacates immediately once the cover is removed. The prairie deer mouse and house mouse are the primary small mammals of the Indiana corn and soybean fields (Whitaker 1967), although *P. leucopus* is sometimes present as well. The species also invades beaches, offshore islands, and estuarine areas.

Lyon (1923) took two individuals, both in foredune areas, and Texas Instruments (1975-80) took five from young foredunes. Surprisingly, none were taken in any of the plots in the 24 habitats studied by Whitaker et al. (1994). Their only records were sight records at residential areas and some from Chellberg Farm. Two individuals were taken among 70 mammals from snap traps at Pinhook Bog by Whitaker and Mumford in 1978 (Mumford and Whitaker 1982). It is clear that the house mouse is not abundant at the Indiana Lakeshore, probably because of the lack of agricultural land present. The same is probably true in the Grand Calumet River basin, as Mierzwa et al. (1991) recorded only one house mouse. It was found at the Big Marsh/Indian Ridge site.

Dipodidae (previously Zapodidae)

Meadow jumping mouse, *Zapus hudsonius* (Zimmermann). Lyon (1923) concluded that *Z. hudsonius* was almost certainly present in the Lakeshore region. Texas Instruments (1975-80) reported four individuals from young foredunes and 23 from the transmission corridor. Whitaker et al. (1994) took 15 individuals from three habitats, 13 of which came from one plot in aquatic shrublands. Whitaker and R.E. Mumford took one at Cowles Bog and five at Pinhook Bog in the fall of 1978, and one from a flat depression behind the foredunes east of the Bailley Generating Station in October of 1974. The meadow jumping mouse was not taken by Mierzwa et al. (1991), but it is undoubtedly present in the Grand Calumet River area.

Carnivora

The raccoon is abundant and obvious, but the other carnivores of the Grand Calumet River area are difficult to assess and count. Being relatively large, they are much less abundant than small mammals, and they are usually among the first to disappear as humans develop the land, because of habitat loss, trapping, and hunting. They are often thought of as problem animals and killed by the general public. For some species, roadkills may give us the best assessment of status.

The carnivores of northwestern Indiana that may be present in the Grand Calumet River basin are grouped in four families, the Canidae (coyote, two species of foxes, domestic dog), Procyonidae (raccoon), Mustelidae (two species of weasels, mink, badger, skunk), and the Felidae (bobcat, housecat).

Canidae

Coyote, *Canis latrans* Say. The coyote has always been present in Indiana, but in recent years its populations have increased. There are early reports of wolves and/or coyotes at INDU; however, wolves are long gone and there was no confirmed record of coyotes prior to the work of Whitaker et al. (1994). These authors report that one was seen by Noel Pavlovic at Tolleston Dunes on August 7, 1990, and that Lakeshore rangers have seen them several times near the Heron Rookery, starting in June and July of 1990. Dan Fagre saw one in a cornfield just south of INDU in 1991. It is not clear yet whether coyotes have taken up residence at the Lakeshore, but if not, it appears to be only a matter of time until they do. Unfortunately, Rand and Rand (1951) found no canid bones which could have helped determine whether coyotes or wolves or both inhabitated the dunes in presettlement times. Mierzwa et al. (1991) did not report coyotes, and it is not clear whether they now occur in the Grand Calumet area.

Red fox, *Vulpes vulpes* Linnaeus. Red and gray foxes are often confused, primarily because the gray fox has some reddish coloration. However, the red fox is easily identified because it is all red above with a white tail tip. Lyon (1923) reported red foxes at INDU. Whitaker et al. (1994) reported them from five different habitats at the Lakeshore, and one was found dead along the roadside in 1984-85. Four were seen from a helicopter during the 1991 Lakeshore survey for deer. Mierzwa (pers. comm.) saw a red fox dead on the road on route 312 just east of Cline Avenue on September 27, 1990, and he saw a skull found at Clark and Pine East on April 23, 1991. It is not clear how common this species is in the Grand Calumet River area.

Gray fox, *Urocyon cinereoargenteus* (Schreber). The gray fox is a resident of the woods and should occur in the forests of INDU. Lyon (1923) did not mention this species, but Texas Instruments (1975-80) recorded it on the basis of tracks. Whitaker et al. (1994) reported it from Howes Prairie on August 11, 1987, and more recently, Dan Fagre saw two in the area just east of Dune Acres. The gray fox could occur in the Grand Calumet River region in a wooded area such as in Miller's Woods, but it is less likely to occur than the red fox because of the scarcity of mature woods.

Procyonidae

Raccoon, *Procyon lotor* Linnaeus. The raccoon is obvious at the Indiana Dunes National Lakeshore and at the Indiana Dunes State Park because it is abundant in campgrounds and at other places where people gather. Apparently raccoons were not always so common; Lyon (1923) says "residents state that a few 'coons' are taken each season for their fur. I have no personal knowledge of the animal and I have never been fortunate enough to find foot prints that might have been made by it." Krekeler (1981), Texas Instruments (1975-80), Whitman et al. (1990) and Whitaker et al. (1994) all found the raccoon to be common at the Indiana Dunes National Lakeshore, and it should also be common in the Grand Calumet River area. Mierzwa et al. (1991) found raccoon tracks at wetland margins during their study.

Mustelidae

Least weasel, *Mustela nivalis* Linnaeus. The least weasel is a tiny prairie species with an inch-long tail. Dice (1928) reported the first least weasel from Indiana in Wells County. Lyon (1936) reported this species only from Pulaski and Wells Counties. There is an earlier record for Porter County (Mumford and Whitaker 1982). The specimen is in the Field Museum in Chicago (112538) and was taken by A. L. Rand on June 10, 1950 (Rand and Rand 1951). This species has now been taken sparingly throughout the northern three-quarters of Indiana. The first individuals from the Lakeshore were collected during the Texas Instruments studies: one from the young foredunes, and one from the black oak/swamp forest. The foredunes are suitable habitat as this species occurs in open fields and feeds heavily upon meadow mice. The latter habitat is atypical. Another least weasel was killed by a cat on 275E, just N of U.S. 20 in October 1990 (Whitaker, et. al. 1994). This species should occur in the Grand Calumet River area.

Long-tailed weasel, *Mustela frenata* Lichtenstein. This is the most common weasel in Indiana, and it is found throughout the state. It has a much longer tail than the tiny least weasel, which is the only other weasel known in Indiana. Lyon (1923) states, "These animals are fairly common in the region although I have never seen any." He reported that a trapper had taken about 200 individuals in the past three winters in the dunes region and near Chesterton, but that only two of them were in white pelage. Texas Instruments (1975-80) did not report this species. Whitman et al. (1990) observed a long-tailed weasel climbing on fallen timber in Miller Woods. Whitaker et al. (1994) took six long-tailed weasels in traps in three habitats and observed tracks of four: one at Howe's Prairie and one in upland frest. This species should be fairly common in the Grand Calumet River area.

Mink, *Mustela vison* Schreber. The mink is weasel-like, but is much larger than the long-tailed weasel and has a bushy tail. Lyon (1923) collected a dead mink and said that a number of minks are trapped each year in the Lakeshore region. Texas Instruments (1975-80) took two from Cowles Marsh. One was seen at Dune Acres on January 9, 1988 in a cattail marsh, and an adult and three young were seen by Rol Hesselbart along a marsh on Kemil Road in 1990 (Whitaker et al. 1994). The mink should be present in the Grand Calumet River area.

Badger, *Taxidea taxus* Schreber. Lyon (1923) listed the badger as occurring, or at least recently occurring in the Lakeshore region, and Brennan (1923) reported an individual from the Furnessville blowout. In the fall of 1986, a badger was found near a trash can in a parking lot at the Indiana Dunes National Lakeshore (Whitaker et al. 1994). However, its claws had been removed, probably indicating that it had been transported there from some other locality. A badger was found dead in Porter County on Highway 30 about nine miles west of Highway 49, 1/2 mile west of 600 West (at the center of section 23) on September 7, 1990. On two occasions Whitaker et al. (1994) recorded signs that may have been made by badger: tracks in black oak forest at Howe's Prairie on August 11, 1987, and excavations in dry prairie at the proposed campground on July 14, 1987. Larry Reed, a veterinarian at Weschester Animal Clinic, treated a badger captured in the east unit of INDU during 1990. On April 9, 1989, a badger was seen by Mark Harbin and Andrea Halcarz just west of the parking lot near the entrance to Dune Acres. It disappeared from view but apparently entered a burrow at the base of a tree on a sandy bank. Badger populations have been increasing in recent years, and these records all indicate that the badger could occur in the area of the Grand Calumet River.

Striped skunk, *Mephitis mephitis* Schreber. Lyon (1923) reported skunks to be common at INDU, and noted that a number were taken each year for fur. Texas Instruments (1975-80) collected two skunks and saw tracks in black oak/swamp forest and in red maple swamp forest. Krekeler (1981) stated that they forage along the beach of Lake Michigan. Whitaker et al. (1994) took two in traps and observed another. It is surprising that none were recorded as roadkills. Skunks surely must occur in the Grand Calumet River basin.

Felidae

Bobcat, *Felis rufus* Schreber. The bobcat is exceedingly rare, and it is listed as endangered in Indiana, although individuals keep turning up. The bobcat can be recognized by its very short, or "bob", tail which contrasts with the long tail of the familiar housecat (although an occcasional housecat has lost its tail). The latest confirmed records are from Monroe County (1970), Perry County (1975), Jefferson County (1982), Lawrence County (1 record in 1982, 1 in 1994, 2 in 1995, and 1 in 1996), Parke County (1987), Crawford County (1988), Warrick County (1990), Dekalb County (1993), Steuben County (1993), and Washington County (1995). Among numerous unconfirmed reports (most probably erroneus) are two from LaPorte and two from Starke Counties. It is unlikely, but not inconceivable, that the bobcat still exists in wooded areas of the Lakeshore, but it is probably not found at the Grand Calumet River area because of area development, lack of forest, and habitat fragmentation.

Housecat, *Felis silvestris* Schreber. Truly feral populations of housecats seldom exist in the eastern United States. Most housecats that forage afield have a house or other buillding that serves as a home base. Numerous housecats are present in the Grand Calumet River area. Housecats are exotics, and as such they should be controlled if they become a problem to native animals. To date, there is no indication that the housecat has become a problem in the Grand Calumet River area, but it possibly could due to the prevalence of buildings near the area.

White-tailed deer, *Odocoileus virginianus* (Zimmermann). The white-tailed deer was extirpated from the state before 1900 (Mumford and Whitaker 1982). Re-stocking deer in Indiana began in 1934 when 35 deer were released in seven counties. By 1955 more than 400 deer had been introduced into 22 counties. Population estimates for the state were 900 in 1943, 1200 in 1944, and more than 2900 by 1946. A deer season was opened in 1951 when the deer populataion of the state was estimated at 5000. By 1966, deer were probably present in all counties, and they have continued to multiply, thereby becoming very abundant in recent years.

Texas Instruments (1975-1990), Krekeler (1981), and Whitaker et al. (1994) all indicated that white-tailed deer were common at the Indiana Dunes National Lakeshore. Deer were counted by aerial census in 1982, 1984, 1988, 1989, 1991, and 1992. The counts were 85, 29, 214, 349, 166, and 207 deer in those respective years. The actual populations were probably larger because it is not known what proportion of the deer were observed, and only about 75% of the Lakeshore was flown. Whitman et al. (1990) and Mierzwa (pers. comm.) saw deer tracks during their respective studies.

THE HABITATS

At the southern end of Lake Michigan, east of Chicago and east of the Gary Hammond area, lies the Indiana Dunes National Lakeshorre. The Chicago and Gary areas are some of the more highly developed and heavily polluted regions of the world. The entire area was once composed of extensive series of dunes, and classic studies of plant and animal succession were done there (Cowles 1899; Shelford 1912 a, b); however, by the middle of the 20th century, the entire area was being developed. Senator Paul Douglas was instrumental in establishing the Indiana Dunes National Lakaeshore in the area between Gary and Michigan City. Since then, much land has been acquired, many buildings have been razed, and much of the land is being converted to resemble its original condition.

Some of the larger species are not much restricted ecologically, but they could occur in any of the terrestrial habitats. Others are more restricted or are characteristic constituents of only a few of the habitats. Some of the mammals with relatively little ecological restriction, at least within an area as small and as varied as the Grand Calumet River basin, are the following:

Eastern cottontail, *Sylvilagus floridana*
Raccoon, *Procyon lotor*
Long-tailed weasel, *Mustela frenata*
Striped skunk, *Mephitis mephitis*
White-tailed deer, *Odocoileus virginiana*

Mammals likely to be found in the various habitats within the Grand Calumet River basin are listed below separately for each of the habitats. These lists are derived from information in Whitaker et al. (1994), Mierzwa et al. (1991), Mumford and Whitaker (1982), Hoffmeister (1989), and from personal information (1994).

Agricultural land and old field

The plots designated as agricultural areas by Whitaker et al. (1994) in the Indiana Dunes National Lakeshore were actually early seral "oldfields" rather than cultivated areas, per se. Canopy was entirely absent in all of these plots, but scattered shrubs were present in some. The dominant plants were grasses and forbs. In northern Indiana, the meadow vole is the most abundant species in lush meadows, and 90 individuals of this species occurred in the nine plots in this habitat (Whitaker et al. 1994).

Mammal species likely in Agricultural fields in the Grand Calumet River basin

Meadow vole, *Microtus pennsylvanicus*
Prairie vole, *Microtus ochrogaster*
Northern short-tailed shrew, *Blarina brevicauda*
Masked shrew, *Sorex cinereus*
Meadow jumping mouse, *Zapus hudsonius*
Eastern mole, *Scalopus aquaticus*

Prairie

There is a great deal of prairie or grassy oldfield in the Grand Calumet River area with Dry Prairie often grading into or alternating with Wet Prairie.

Dry prairie

The majority of the dry prairie along the Grand Calumet River is on the low dunes between swales or marshes. Dry prairies include a variety of species of grasses and forbs. Cover is often good in this habitat, providing ample hiding spots for small mammals. Marram, sand reed grass, or little bluestem predominated in most of the plots sampled by Whitaker et al (1994) at INDU. The little bluestem plots were probably more similar to dry prairie near the Grand Calumet River than were those of the more typical dunes grasses. The dominant small mammal in Dry Prairie at the Indiana Dunes National Lakeshore was the prairie deer mouse, *Peromyscus maniculatus*, followed by the white-footed mouse, *Peromyscus leucopus* (Whitaker et al. 1994). Prairie voles occurred, perhaps somewhat surprisingly, in only one of the 11 plots sampled. The generally sparse cover in many of the plots accounts for both the abundance of deer mice and the low number of prairie voles. The prairie deer mouse is the one small mammal of Indiana that is more abundant in areas with less plant growth, and prairie voles thrive only in areas of good plant cover.

Signs observed at the Lakeshore in this habitat could have been from the bog lemming, *Synaptomys cooperi*. The thirteen-lined ground squirrel now occurs primarily in mowed areas such as on golf courses, lawns, pastures, and roadsides. Its occurrence in dry prairies in the dunes might indicate that this habitat was a presettlement habitat for this species.

Mammal species likely to be found in dry prairie in the Grand Calumet River basin

Prairie deermouse, *Peromyscus maniculatus bairdii*
White-footed mouse, *Peromyscus leucopus*
Prairie vole, *Microtus ochrogaster*
Thirteen-lined ground squirrel, *Spermophilus tridecemlineatus*

Woodchuck, *Marmota monax*
Least shrew, *Cryptotis parva*
Franklin's ground squirrel, *Spermophilus franklinii*
Southern bog lemming, *Synaptomys cooperi*
Coyote, *Canis latrans*
Red fox, *Vulpes vulpes*
Least weasel, *Mustela nivalis*
American badger, *Taxidea taxus*

Wet prairie

Wet prairie areas contained various grasses and forbs as the dominant plants, and they often contained significant amounts of shrubs such as willow or aspen. Some of the major grasses were *Calamagrostis*, *Panicum*, *Aristida*, *Phalaris*, and *Agrostis*. Cattails and rushes were also dominant in one plot. Cover ranged from fair to excellent.

The most abundant mammal species taken in wet prairie by Whitaker et al. (1994) was the masked shrew. Mumford and Whitaker (1982) earlier (April 27-28, 1977) used 1508 snap-traps for two nights and took 60 meadow voles, 22 masked shrews, 16 white-footed mice, and ten short-tailed shrews. Most of the traps were in grass sedge meadow which included clumps of willows. The voles were feeding extensively on the willow fruits. The fruiting twigs were 0.5 to 1 meter high, and the voles were getting the fruiting heads by cutting off the twigs, pulling them down, and recutting them until the heads were reached, leaving cuttings 4 to 15 cm long in piles with the fruiting leaflets and parts of the fruits on top of the piles of twigs. The stomachs of the mice were full of this material.

Mammal species likely to be found in wet prairie in the Grand Calumet River basin:

Meadow vole, *Microtus pennsylvanicus*
Masked shrew, *Sorex cinereus*
Northern short-tailed shrew, *Blarina brevicauda*
White-footed mouse, *Peromyscus leucopus*
Meadow jumping mouse, *Zapus hudsonius*
Southern bog lemming, *Synaptomys cooperi*

Lowland terrestrial shrub

There is a fair amount of terrestrial shrubland in the area of the Grand Calumet River. Shrubby species expected might be willow, aspen, red maple, or red ozier dogwood, *Cornus stolonifera*, and a variety of grasses and forbs are likely. No species of mammal was dominant or even abundant in the lowland terrestrial shrubland. The white-footed mouse was the most abundant mammal, but only six individuals were taken.

Mammal species likely in lowland terrestrial shrubland in the Grand Calumet River basin

White-footed mouse, *Peromyscus leucopus*
Eastern cottontail, *Sylvilagus floridanus*

Upland terrestrial shrub

There is a fair amount of upland terrestrial shrubland in the area of the Grand Calumet River. Four plots sampled by Whitaker et al. (1994) in upland terrestrial shrubland all were in highly disturbed transition stages between grassy oldfield or savanna and wooded habitats. One plot was highly productive, yielding 44 individuals of four mammal species. The nine shrews and 33 meadow voles taken there clearly reflected the former field habitat rather than the present transitional shrub stage, and these forms will undoubtedly disappear from this area as the transition towards more woody vegetation continues in this plot. A total of 14 species (including the domestic dog) was found in this habitat, but most were in low numbers. The author suspects that the lack of a well-developed community in shrubland is due to the ephemeral nature of the habitat.

Mammals likely in upland terrestrial shrubland in the Grand Calumet River basin

White-footed mouse, *Peromyscus leucopus*
Eastern cottontail, *Sylvilagus floridanus*
White-tailed deer, *Odocoileus virginiana*

Oak savanna

Oak savanna is a common habitat in the Grand Calumet River basin, and fifteen oak savanna plots were studied by Whitaker et al. (1994) at the Lakeshore. All had a canopy of nearly pure black oak, usually thin. Both the shrub and herb layer varied considerably. Some of the more abundant shrubs were blackberry, blueberry, rose, and Japanese honeysuckle. Abundant herbaceous plants were *Andropogon*, *Panicum*, *Carex*, goldenrod, and bracken fern. Thirty white-footed mice and 18 prairie deer mice were taken, although the prairie deer mice occurred in only three of the plots. These are the results one would expect since the prairie deer mouse occurs in sparsely vegetated, dry areas without woody vegetation. The white-footed mouse is a species of the woods, and savanna is a thinly wooded habitat.

Mammal species likely in oak savanna in the Grand Calumet River basin

White-footed mouse, *Peromyscus leucopus*
Prairie White-footed mouse, *Peromyscus maniculatus bairdii*
Prairie vole, *Microtus ochrogaster*
Eastern cottontail, *Sylvilagus floridanus*
Thirteen-lined ground squirrel, *Spermophilus tridecemlineatus*
Franklin’s Ground Squirrel, *Spermophilus franklinii*
Eastern mole, *Scalopus aquaticus*

Mixed deciduous savanna

Three plots in mixed deciduous savanna at the Lakeshore all had scattered cottonwoods with little bluestem as the principal herbaceous species (Whitaker et al. 1994). Major grasses in this habitat were old little bluestem, old witch grass and brome grass, and grape and aromatic sumac were among the more abundant shrubs. Cover was fair to good in these plots due to the grass. The white-footed mouse was the most abundant mammal, being taken at all three plots with a total of 20 individuals.

Mammal species likely in mixed deciduous savanna in the Grand Calumet River basin

White-footed mouse, *Peromyscus leucopus*
Prairie white-footed mouse, *Peromyscus maniculatus bairdii*
Prairie vole, *Microtus ochrogaster*
Eastern cottontail, *Sylvilagus floridanus*
Thirteen-lined ground squirrel, *Spermophilus tridecemlineatus*
Franklin's Ground Squirrel, *Spermophilus franklinii*
Eastern mole, *Scalopus aquaticus*

Upland forest

Upland forest, mostly oak, is widespread at INDU. (Whitaker et. al. 1994). There is relatively little mature forest in the Grand Calumet River basin, but scrubby black oaks occur on much of the forest in the Grand Calumet River basin where they grade into scrubby black oak savanna. The shrub layer at INDU was often dense and diverse in this habitat, but it often contained blueberry, *Vaccinium vacillans*. The herbaceous layer was again diverse, although often thin and depauperate, most often providing poor to fair cover. The dominant herbaceous plants there were most often Pennsylvania sedge, *Carex pennsylvanicus*, and bracken fern, *Pteridium aquilinum*. The white-footed mouse was the most abundant small mammal in upland oak forest.

Mammal species likely to be found in upland forest in the Grand Calumet River basin

White-footed mouse, *Peromyscus leucopus*
Eastern chipmunk, *Tamias striatus*
Southern flying squirrel, *Glaucomys volans*
Gray squirrel, *Sciurus carolinensis*
Fox squirrel, *Sciurus niger*
Raccoon, *Procyon lotor*
Red squirrel, *Tamiasciurus hudsonicus*
Northern short-tailed shrew, *Blarina brevicauda*
Pine vole, *Microtus pinetorum*
Gray fox, *Urocyon cinereoargenteus*

Lowland forest

Lowland forest was divided into perennial (contains water more than six months of the year) and ephemeral wet lowland forest and was the second largest habitat after upland forest in the Indiana Dunes National Lakeshore (Whitaker et al. 1994). The canopy was usually quite dense but varied in species composition. Common trees were silver or red maple followed by oak, ash, aspen, elm, and sasafrass. The shrub layer varied from sparse to dense, and it consisted mostly of seedlings of the trees mentioned above plus spicebush, *Viburnum*, *Cornus*, *Ilex*, *Rubus*, blueberries and others. Ground cover varied from fair to excellent, and species composition varied greatly between plots, with graminoid plants ferns being common. The herb and shrub layers were often clumped in hummocks. As usual in wooded habitats, the white-footed mouse was the most abundant species taken, totalling 137 in 27 plots (Whitaker et al. 1994).

Mammal species likely to be found in lowland forest in the Grand Calumet River basin

White-footed mouse, *Peromyscus leucopus*
Raccoon, *Procyon lotor*
Northern short-tailed shrew, *Blarina brevicauda*
Opossum, *Didelphis virginiana*
Gray fox, *Urocyon cinereoargenteus*
Eastern chipmunk, *Tamias striatus*

Wetlands

There is a variety of types of wetlands at the Indiana Dunes National Lakeshore, and also in the Grand Calumet River basin, marsh, aquatic shrubland, swamp, panne (depressions among the dunes), and open water.

Marsh

Marsh is prominent in the Indiana Dunes National Lakeshore and in the Grand Calumet River basin. The herb layer was most often of cattail,*Typha*; sedges, *Carex*; bullrushes, *Scirpus*; or blue joint grass, *Calamagrostis canadensis.* The canopy was absent in most areas but consisted of scattered willows or elms in a few. The shrub layer consisted of thick buttonbush, *Cephalanthus occidentalis* in most of the plots, whereas willow was present in one. Muskrats are abundant in many of the marshes, lakes, and ditches of INDU, and would be in the basin if the water was clean.

Mammal species likely to be found in Marshes in the Grand Calumet River basin

Muskrat, *Ondatra zibethicus*
White-footed mouse, *Peromyscus leucopus*

Masked shrew, *Sorex cinereus*
Meadow vole, *Microtus pennsylvanicus*
Raccoon, *Procyon lotor*
Short-tailed shrew, *Blarina brevicauda*

Aquatic shrublands

Aquatic shrublands made up a small but significant part of INDU and likewise also of the Grand Calumet River basin. Vegetation was of aspens, willows or oaks, and the herb layer was of blue joint grass, reed grass, or cattails.

Mammal species likely in aquatic shrublands in the Grand Calumet River basin

White-footed mouse, *Peromyscus leucopus*
Raccoon, *Procyon lotor*

Swamp

In the plots in swamp at the Lakeshore, (Whitaker et. al. 1994), the canopy was cottonwood and/or black willow, *Salix nigra*. The ground cover was excellent in each case, and it mainly consisted of grasses (blue joint grass or *Phalaris*), sedges (*Carex*), and cattails (*Typha*). Additional collections were made by Whitaker and R.E. Mumford in the fall of 1978 in the swamp just north of Cowles Bog. Three species were taken there, including 33 masked shrews, two short-tailed shrews, and ten white-footed mice.

Mammal species likely to be found in swamp in the Grand Calumet River basin

White-footed mouse, *Peromyscus leucopus*
Masked shrew, *Sorex cinereus*
Raccoon, *Procyon lotor*

Pannes

The pannes are shallow depressions among the dunes. They contain water much of the time and are often surrounded by grassy areas and shrubs. The canopy layer is usually absent . Shrub growth is often dense and consists of various species such as red ozier dogwood, willow, and St. John's wort, *Hypericum kalmianum*. The herb layer usually forms good cover. A number of herbaceous species were present, including several members of the family Cyperaceae, *Eleocharis*, *Cladium*, *Rhynchospora*, and a rush, *Juncus balticus*, strawberry, mountain mint *Pycnanthemum virginianum*, and others. Five species of mammals were taken by Whitaker et al. (1994) in the three plots in pannes in INDU. The meadow vole was the only regularly occurring species with 13 being taken in two of the three plots. Three white-footed mice were taken in one of the plots, and three prairie deer mice were taken in another.

Mammal species likely to be found in Pannes in the Grand Calumet River basin

Meadow vole, *Microtus pennsylvanicus*
White-footed mouse, *Peromyscus leucopus*
Prairie vole, *Microtus pennsylvanicus*

Artificial habitats

Various artificial habitats or developed lands including croplands, residential and industrial areas, right-of-ways, and excavated areas are found at INDU and also in the Grand Calumet River basin.

Right-of-ways

Right-of-ways occur along roads, railroads or trails. However, they do not form a distinct habitat. Instead, they pass through and consist of some other habitat such as mature woods, dry prairie, etc. Therefore many different plants were present, including several grasses and rushes, and several other plant species (*Melilotus*, *Saponaria*, *Solidago*, *Clematis*, *Dryopteris thelypterus*, *Carex*, *Typha*) occurred as dominants in at least one plot. Because of the high variation in these plots, no list of expected species of mammals is given.

Excavated areas

Excavated areas are places where open sand exists because of human activities. There were three plots in this habitat at INDU (Whitaker et al. 1994), and there are areas with this habitat due to sand-mining in the Grand Calumet River Watershed. One of the Indiana dunes plots had been on the site of a former fly ash seepage area and another was on the site of a steel company acid spill. All three plots completely lacked canopy, and two had poor ground cover, with scattered grasses, including little bluestem, sand reed grass, and nodding wild rye *Elymus canadensis*. The third plot had excellent cover of Joe-pye weed, *Eupatorium serotinum*; bullrush, *Scirpus cyperinus*; and spikerush, *Eleocharis sp.* Only two mammals were trapped in plots in this habitat, a meadow vole and a raccoon. As would be expected, it was not a good habitat for mammals, although mammals do pass through these areas.

RECOMMENDATIONS

Loss of natural habitat is an important problem. Through “development,” both agricultural and industrial, we have already used up most of the natural habitat of the world, at least in the more desirable areas for people. Also, agricultural land is now producing nearly to capacity to feed the people of the world. It is time to stop destroying natural habitat and agricultural land, and to learn to live within the bounds imposed by the land already developed and planted. Worldwide zoning could be implemented, with three major zones, natural habitat, agricultural lands and developed land. No more development should occur on lands designated as natural or agricultural. We would then have to limit human populations to live within our means in terms of the amount of food that can be raised on agricultural land already present, and to limit development to land already zoned as developed. "Developed" land could be returned to agricultural or natural status.

Specific Recommendations

1. Acquisition of land

The Grand Calumet watershed, like the Indiana Dunes before it, was made into an ecological showpiece under the leadership of Senator Paul Douglas. It has been greatly developed and is an ecological disaster.

Management recommendation: Efforts should be made to obtain under public ownership as much of the total Grand Calumet watershed as possible. It should then be managed in the same way as the Indiana Dunes National Lakeshore, that is, it should be acquired and reverted to the original habitat as far as possible.

2. Fragmentation

One of the major problems of our times is that various human developments: agricultural, residential, industrial, etc., have broken up tracts of habitat into small fragments of what they once were. This has several implications, but probably the most important of these is that it inhibits organism dispersal, because the fragments of habitat are often separated by areas difficult or impossible for animals (or plants) to bridge. This confines the animals within smaller and smaller tracts of land. Under normal circumstances, when populations are eliminated from a patch of habitat, more individuals will move in from outside and re-populate. With increased fragmentation, patches of habitat are often not repopulated. There is no available source of emigrants. Fragmentation brings animals together in small areas with little or no genetic infusion from outside. This can result in increased inbreeding, with possible genetic ill-effects. Also, many of the dispersers presumably perish because they are unable to locate suitable habitat after they leave their birthplace.

There are other disadvantages of fragmentation. Fragmentation may allow animals from other habitats to penetrate and perhaps compete with animals normally found deep within a habitat. Perhaps the best known example of this is the cowbird, which penetrates fragmented forests and lays its eggs in nests of other birds, especially those of tropical migrants.

Management recommendation: Attempts should be made to preserve large tracts of habitat in the Grand Calumet basin, especially of marsh, dry prairie, wet prairie, and mature woodland. Also, special efforts should be made to obtain or to create additional similar habitat between the tracts to allow dispersal. The author envisions the open waters of the river, with marsh on each side, grading into wet prairie, then dry prairie. There is little mature forest remaining in the Grand Calumet basin, but it should be preserved wherever it is found.

3. Endangered/threatened species

Only one endangered or threatened species of mammal, Franklin's ground squirrel, is definitely known to inhabit the Grand Calumet River area. Two individuals were found by Mierzwa et al. (1991). Both animals were in dunes between swales. Special effort should be made to preserve or to create as much dry prairie as possible to help increase populations of this species.

The only other threatened or endangered mammal species likely to occur in the Grand Calumet River basin is the Indiana myotis. This species has not been taken there, but it could occur there if enough mature wooded habitat were present.

Management recommendations: Efforts should be made to seek, preserve and maintain dry prairie in the Grand Calumet watershed in an effort to induce populations of Franklin's ground squirrels to live and to thrive there.

Also, efforts should be made to find and to preserve mature woods, especially in the vicinity of Miller Woods, in order to produce as much contiguous mature woodland as possible. This should help all bat species as well as other woodland species.

4. Exotics

Exotic plants and animals often compete with and sometimes supplant native species. Therefore we often wish to eliminate them. There are two exotic mammals at the Grand Calumet River area, the house mouse, *Mus musculus*, and the Norway rat, *Rattus norvegicus*. However, both are uncommon in habitats such as occur at the Grand Calumet River basin, and efforts to increase natural habitat should help to control them further. I would not recommend any special control measures for these species, other than to produce and maintain native habitat.

Management recommendations: Produce and maintain native habitat.

5. Reintroduction of species

In order to restore previous habitats and communities, reintroduction should be considered for any species previously existing in the Grand Calumet River basin. However, many introductions would not be currently feasible. No species not previously present should be introduced, as there is no way to determine how such an organism would fit into local habitats. Each of the ten extirpated species of mammals was considered for possible reintroduction. Because of their size and the present developed state of the area, the following species would be completely impractical for reintroduction at this time: timber wolf, black bear, mountain lion, Canada lynx, bison and American elk. The other four are discussed below.

a. Porcupine. This species needs extensive woodland to survive, and attempts could be possibly be made to restore it to the Indiana Dunes National Lakeshore. This effort would require public education, as many people have an aversion or bias towards this species (as towards snakes and bats). Since extensive woodland is required by this species, it could not be reintroduced into the Grand Calumet watershed in the near future, except perhaps in the Miller Woods area.

b. River otter. The river otter can live and do surprisingly well alongside humans, and it is currently being reintroduced into Indiana. It requires extensive, relatively unpolluted aquatic habitat (ponds, lakes or rivers). If the Grand Calumet River could be cleaned up and protected, the river otter could be considered for reintroduction.

c. Bobcat. The bobcat was thought to be nearly extirpated in Indiana, but it is showing up in various counties. There is some evidence of its occurrence at the Indiana Dunes National Lakeshore. This species can live in fairly close proxity to humans, but it does need rather extensive natural woodland habitat because it moves about considerably. The recommendation that woodland habitat be preserved or created would favor this species. However, I would not recommend that reintroduction of this species be attempted in the Grand Calumet basin at this time because of the lack of woodland.

Management recommendations: Once the Grand Calumet River is cleaned up, some consideration could be given to reintroducing the river otter there, provided that adequate protected habitat is available for them. Consideration should be given to introducing the porcupine at the Indiana Dunes National Lakeshore but not in the Grand Calumet River basin until such time as adequate woodland might exist there.

6. Areas of special interest

There are several areas of ecological interest in the Grand Calumet River Basin such as Roxanna marsh, DuPont wetlands, and the Grand Calumet Lakeshore Lagoons because of their high quality habitat for semi-aquatic mammals. Additional areas of like quality, and also to reduce fragmentation, as many intervening areas as possible should be obtained and purchased or otherwise protected.

Management recommendations: In line with recommendation #3, attempts should be made to obtain such properties, or to reach management agreements for them.

LITERATURE CITED

Baker, R. H. 1983. Michigan mammals. Michigan State University Press, Lansing, Michigan, USA.

Brennan, G. A. 1923. The wonders of the dunes. The Bobbs-Merrill Co., Indianapolis, Indiana, USA.

Brooks, D. M. 1959. Fur animals of Indiana. Pittman-Robertson Bulletin No. 4., Indiana Department of Conservation, Division of Fish and Game. Indianapolis, Indiana, USA.

Cowles, H. C. 1899. The ecological relations of the vegetation on the sand dunes of Lake Michigan. Botanical Gazette **27**:95-117, 167-202, 281-308, 361-391.

Dice, L. R. 1928. The least weasel in Indiana. Journal of Mammalogy. **9**:63.

Evermann, B. W. and A. W. Butler. 1894. Preliminary list of Indiana mammals. Proceedings of the Indiana Academy of Science **3**:124-139.

Ford, S. D. 1977. Range, distribution and habitat of the western harvest mouse, *Reithrodontomys megalotis*, in Indiana. American Midland Naturalist 98:422-432.

Hahn, W. L. 1909. The mammals of Indiana. Pages 417-663. A descriptive catalogue of the mammals occurring in Indiana in recent times. 33rd Annual Report Department of Geology and Natural Resources of Indiana. Indiana, U.S.A.

Hoffmeister, D. F. 1989. Mammals of Illinois. University of Illinois Press, Urbana, Illinois, USA.

Krekeler, C .H. 1981. Ecosystem study of the Indiana Dunes National Lakeshore. The Biota of Indiana Dunes National Lakeshore.Vol 2. Mimeograph **1-346**.

Kurta, A. 1982. A Review of Michigan bats: Seasonal and geographic distribution. Michigan Academician **14**:295-312.

Kurta, A. D. King, J. A. Teramino, J. M. Stribley, and K. J. Williams. 1993. Summer roosts of the endangered Indiana bat (*Myotis sodalis*) on the northern edge of its range. American Midland Naturalist **129**:132-138.

Lindsey, A. A., D. V. Schmeltz and S. A. Nichols. 1969. Natural areas in Indiana and their preservation. Department of Biological Sciences, Purdue University, Lafayette, Indiana, USA.

Long, C. A. 1974. Environmental status of the Lake Michigan region. Vol. 15. Mammals of the Lake Michigan drainage basin. Volume 15. Argonne National Laboratory, Argonne, Illinois, USA.

Lyon, M. W. Jr. 1923. Notes on the mammals of the dune region of Porter County, Indiana. Proceedings of the Indiana Academy of Science **31**:209-221.

Lyon, M. W. Jr. 1936. Mammals of Indiana. American Midland Naturalist **17**:1-384.

Mierzwa, K. S., S. D. Culverson, K. S. King, and C. Ross. 1991. Illinois-Indiana regional airport study: Biotic communities Technical Paper No.7, Appendix E, Volume II. TAMS Consultants, Inc. Chicago, Illinois, USA.

Mumford, R. E., and J. O. Whitaker, Jr. 1982. Mammals of Indiana. Indiana University Press, Bloomington, Indiana, USA. 537 p.

Rand, A. L. and A. S. Rand. 1951. Mammal bones from dunes south of Lake Michigan. American Midland Naturalist **46**:649-659.

Sanborn, C. C. 1925. Mammals of the Chicago area. Field Museum of Natural History. Zoology Leaflet 8. 23 p.

Shelford, V. E. 1912a. Ecological Succession. IV, Vegetation and the control of land animal communities. Biological Bulletin **23**:59-99.

Shelford, V. E. 1912b. Ecological succession. V, Aspects of physiological classification. Biological Bulletin **23**:331-370.

Texas Instruments Inc. 1975-1980. Six annual reports, for the years 1975 through 1980. Bailly Nuclear-1 Site. Prepared for Northern Indiana Public Service Co.

Van Zyll de Jong, C. G. 1979. Distribution and systematic relationships of long-eared *Myotis* in western Canada. Canadian Journal of Zoology **57**:987-994.

Waldren, L. 1983. The Indiana Dunes. The Eastern Acorn Press. New York, New York. USA.

Whitaker, J. O. Jr. 1967. Habitat and reproduction of some of the small mammals of Vigo County, Indiana, with a list of mammals known to occur there. Occasional Papers C.C. Adams Center for Ecological Studies 16. Western Michigan University. Kalamazoo, Michigan, USA. 24p.

Whitaker, J. O. Jr., J. Gibble and E. Kjellmark. 1994. Mammals of Indiana Dunes National Lakeshore. Scientific Monograph. NPS/NRINDU/NRSM-94-24. United States Department of the Interior. National Park Service.

Whitaker, J. O. Jr., and G. R. Sly. 1970. First record of *Reithrodontomys megalotis* in Indiana. Journal of Mammalogy 51:381.

Whitman, R. L., R. L. Peloquin, and R. J. Worth. 1990. Ecology of Miller Woods. Indiana Dunes National Lakeshore. USDI, NPS, Indiana Dunes Report 90-01.

Attachment 1. Likely mammal species of Calumet basin, presettlement, present, and likely origin (native, reintroduced native, introduced exotic, extirpated)

Native mammals, probably present in presettlement times, but gone now

	PRESETTLEMENT	NOW	STATUS
RODENTIA			
Erethizon dorsatum, American porcupine	yes	no	native
CARNIVORA			
Canis lupus, gray wolf	yes	no	native
Ursus americanus, black bear	yes	no	native
Martes pennanti, fisher	yes	no	native
Lutra canadensis, river otter	yes	no	native
Felis concolor, mountain lion	yes	no	native
Felis lynx, Canada lynx	yes	no	native
Felis rufus, bobcat	yes	no	native
ARTIODACTYLA			
Cervus canadensis, American elk	yes	no	native
Bos bison, American bison	yes	no	native

Native, present in presettlement times, extirpated by 1900 then reintroduced

Castor canadensis, American beaver	yes	yes	reintrod
Odocoileus virginiana, white-tailed deer	yes	yes	native

Native mammals probably present in presettlement times and now

MARSUPIALIA-MARSUPIALS.			
Didelphis virginiana, Virginia opossum	yes	yes	native
INSECTIVORES- SHREWS AND MOLES			
Scalopus aquaticus, common mole	yes	yes	native
Cryptotis parva, least shrew	yes	yes	native
Blarina brevicauda, northern short-tailed shrew	yes	yes	native
Sorex cinereus, masked shrew	yes	yes	native
CHIROPTERA- BATS			
Myotis lucifugus, little brown myotis	yes	yes	native
Lasiurus borealis, eastern red bat	yes	yes	native
Lasionycteris noctivagans, silver-haired bat	yes	yes	native
Eptesicus fuscus, big brown bat	yes	yes	native
LAGOMORPHA- RABBITS AND HARES			
Sylvilagus floridana, eastern cottontail	yes	yes	native
RODENTIA- RODENTS			
Tamias striatus, eastern chipmunk	yes	yes	native
Marmota monax, woodchuck	yes	yes	native
Spermophilus franklinii,	yes	yes	native

Franklin's ground squirrel			
Spermophilus tridecemlineatus, thirteen-lined ground squirrel	yes	yes	native
Sciurus carolinensis, gray squirrel	yes	yes	native
Sciurus niger, fox squirrel	yes	yes	native
Tamiasciurus hudsonicus, red squirrel	yes	yes	native
Glaucomys volans, southern flying squirrel	yes	yes	native
Peromyscus leucopus, white-footed mouse	yes	yes	native
Peromyscus maniculatus bairdii, prairie deermouse	yes	yes	native
Microtus ochrogaster, prairie vole	yes	yes	native
Microtus pennsylvanicus, meadow vole	yes	yes	native
Microtus pinetorum, pine vole	yes	yes	native
Ondatra zibethicus, common muskrat	yes	yes	native
Synaptomys cooperi, southern bog lemming	yes	yes	native
Zapus hudsonius, meadow jumping mouse	yes	yes	native
CARNIVORA			
Canis latrans, coyote	yes	yes	native
Vulpes vulpes, red fox	yes	yes	native
Urocyon cinereoargenteus, gray fox	yes	yes	native
Procyon lotor, raccoon	yes	yes	native
Mustela nivalis, least weasel	yes	yes	native
Mustela frenata, New York weasel	yes	yes	native
Mustela vison, mink	yes	yes	native
Taxidea taxus, American badger	yes	yes	native
Mephitis mephitis, striped skunk	yes	yes	native
INTRODUCED EXOTICS			
Rattus norvegicus, Norway rat	no	yes	exotic
Mus musculus, house mouse	no	yes	exotic

Attachment 2. Mammals taken by Mierzwa et al. (1991) in traps in the Grand Calumet River Basin.

	Gary area			Lake Calumet area			
	GY-2	GY-3	GH-4	LC-1	LC-2	LC-3	TOTAL
Trap-nights	1388	1444	1426	1310	1352	1265	8185
Virginia opossum	0	0	0	0	0	1	1
masked shrew	0	0	0	4	20	11	35
short-tailed shrew	4	1	0	0	4	0	9
gray squirrel	7	0	2	0	2	12	23
Franklin's ground squirrel	1	0	0	1	0	0	2
white-footed mouse	12	35	4	2	6	8	67
prairie deermouse	6	1	0	23	0	0	30
meadow vole	1	3	0	8	13	0	25
house mouse	0	0	0	1	0	0	1
Norway rat	0	0	0	1	0	0	1
TOTALS	31	40	6	40	45	32	

GY-2 = DUPONT
GY-3 = CLARK & PINE
GY-4 = IVANHOE
LC-1 = BIGMARSH/INDIAN RIDGE
LC-2 = BURNHAM PRAIRIE/POWDERHORN PRAIRIE
LC-3 = EGGER'S WOODS

GRAND CALUMET LAGOONS

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INTRODUCTION

The Grand Calumet Lagoons are located in a Great Lakes Area of Concern (GL AOC), designating it as one of 42 regions of the Great Lakes watershed identified by the International Joint Commission as having severe environmental contamination (Figure 1). The Grand Calumet River and Indiana Harbor Ship Canal is the only GL AOC with all fourteen designated uses impaired (see summary chapter of this appendix).

One of the important environmental issues facing land managers in northwestern Indiana is the contamination of water, air, soil, and biota by persistent toxic substances. These include heavy metals (copper, zinc, etc.), organic contaminants (organochlorines, pesticides, poly-chlorinated bi-phenyls (PCBs), and polycyclic aromatic hydrocarbons (PAHs). Lake County, where the Grand Calumet Lagoons are located, has some of the most polluted air in the country. Lead concentrations in precipitation are higher in northwestern Indiana than in any other part of the Great Lakes region (Gatz et al. 1989). Indiana Dunes National Lakeshore (INDU), which contains part of the Lagoons, has the highest wet deposition levels of sulfate and nitrate of any monitored park in the country (NADP 1995).

Fish consumption advisories have been posted by the Indiana State Department of Health and the Indiana Department of Environmental Management for fish in Lake Michigan and in many of its tributaries. These include the Grand Calumet River, which contains the largest lake and open water wetland complex in INDU (Grand Calumet Lagoons). Former consumption advisories cited elevated levels of PCBs, chlordane, dieldrin, and DDT in fish. Current advisories primarily cite concentrations of PCBs and mercury as problems (Indiana State Department of Health 1997).

A great deal of effort has been devoted to reducing conventional point sources of water pollution. This effort includes the construction of municipal and industrial wastewater treatment plants. Remaining pollutant sources cause species diversity to be low and numbers and biomass of pollution tolerant species to be high (Lewis 1986, Knorr and Fairchild 1987, Stewart and Robertson 1992), but the national trend is toward generally improved water quality (Smith et al. 1987). Patrick et al. (1992) states that most

Figure 1. Map of the Grand Calumet Lagoons and two small ponds showing sampling sites.

problems associated with conventional parameters (dissolved oxygen, pH, etc.) are improving in this country.

Despite gains in control and remediation of conventional pollutants (e.g. nutrients, organic wastes), we still lack knowledge of the effects (especially chronic) of contaminants from non-point sources and atmospheric deposition. Baseline data on toxics (organic chemicals and heavy metals) are too limited to allow for an adequate assessment of the impacts on indigenous aquatic species or of trends in contamination levels.

Much of the western section of the Grand Calumet Lagoons is surrounded by a large industrial landfill. This landfill has received millions of tons of steel slag and other industrial waste. In areas where the landfill forms the western border of the park, it directly impinges on the aquatic resources of the park. Few data exist quantifying contaminant levels in sediments or in organisms near this landfill.

This chapter will present general information and preliminary research characterizing the biological and chemical status of the Lagoons. It will end with preliminary recommendations for study, pollution abatement, preservation, and restoration of the Lagoons.

OBJECTIVES

The purpose of the research presented in this chapter was to determine the concentrations of contaminants in sediments and organisms of the Grand Calumet Lagoons and to assess the effects of these contaminants on several trophic levels. Additionally, we generated preliminary recommendations for further research and for restoration and management of the Grand Calumet Lagoons and adjacent properties. Our comprehensive investigation of the Grand Calumet Lagoons was designed to meet the following objectives:

(1) To determine the current water quality of the Grand Calumet Lagoons.

(2) To determine the concentrations of contaminants, PCBs, PAHs, and metals in the sediments of the Lagoons.

(3) To determine the effects of these contaminants on the fish, aquatic plant, and macroinvertebrate communities in the Lagoons.

(4) To determine the effects of these contaminants bioconcentrating in aquatic plant and fish tissues collected from the Lagoons.

(5) To assess the toxicity to aquatic organisms of the water and sediments of the Grand Calumet Lagoons.

The organisms and communities found in the Lagoon and pond (closest to the industrial) were compared to those found upstream (Middle Lagoon) or across the dune ridge (East Pond) from the industrial area. Various indices, including measures of species richness and species diversity, were used to analyze community structure. The U.S. Environmental Protection Agency's Rapid Assessment Protocol (Plafkin et al. 1989) and Hilsenhoff's Family Biotic Index (Hilsenhoff 1988) were used for the assessment of macroinvertebrate communities.

Conventional water quality variables were analyzed bracketing macroinvertebrate sampling. These parameters included dissolved oxygen content, pH, specific conductance, total alkalinity, total hardness, and concentrations of chloride, sulfate, and nutrients (ammonia, nitrite, nitrate, reactive phosphate, and total phosphorus). Plants, fish tissues, and sediments were collected and analyzed for contaminant concentrations.

COLLABORATORS

Personnel from several agencies collaborated and assisted in this project. Tom Swinford, David Gilbey and Mark Zucker assisted with data collection, water chemistry analysis, and the macroinvertebrate survey. Robin Scribailo, Purdue University North Central, performed plant surveys and arranged for heavy metals analysis on plant tissues at Purdue University. Robert Gillespie and Julie Speelman, both of Purdue University, performed aquatic toxicity testing. Tom Simon of the U.S. Environmental Protection Agency (U.S. EPA) collected fish and performed the biocriteria analysis. Bob Hesselberg and Larry Schmidt of the Great Lakes Science Center, U.S. Geological Survey, performed PAH fish tissue analysis. Phil Moy and his associates at the U.S. Army Corps of Engineers sampled water and sediments for contaminants.

The National Park Service, through their Water Resources Division, has funded a continued study of the area. The final report on this project will be made in that venue. The work presented in this report is intended to be a progress report of research performed to date. Additional research being done includes further assessment of water quality, algal communities, and contaminants in fish and sediments.

STUDY AREA/METHODS

Lake and area description

The Grand Calumet Lagoon Sub-Area includes the watershed of a series of lagoons and small ponds. The Grand Calumet Lagoons border the east side of the City of Gary in Lake County, Indiana, and are located within the Grand Calumet River and Indiana Harbor Ship Canal and Nearshore Lake Michigan Area of Concern (GL AOC). It is an area of intense land use including parks and recreational areas, residences, light and heavy industry, and areas of additional heavy use, among which is a large industrial landfill.

The Grand Calumet Lagoons (Figure 1) were formed during the latter half of the 19th century by siltation damming of the former Grand Calumet River outlet to Lake Michigan. The Grand Calumet River now flows westward, making our study area part of its headwaters. The 32.6 hectare Grand Calumet Lagoons system drains a 3.5 km^2 watershed and is located on the eastern edge of the Area of Concern (AOC). While the Lagoons are considered waters of the state, the shoreline of the Lagoons is owned jointly by the city of Gary, homeowners, industry, and the National Park Service (INDU). The Lagoons are divided into three similarly sized sections: the East, Middle, and West Lagoons. The East Lagoon (7.9 hectares) is located in the city of Gary’s Marquette Park and borders grassy areas, parking lots, roads, black oak savannas, and scenic walkways. Entering into the East Lagoon are numerous non-point sources including runoff from parking lots, residential areas, and park property.

The East and Middle Lagoons are connected by a wide channel under the Lake Street bridge. The shoreline of the Middle Lagoon (9.9 hectares) is shared by the city of Gary, homeowners, and the National Park Service. This includes the Miller Woods Unit of INDU with dunes and scattered vegetation to the north and black oak savanna to the south of the Lagoon.

The West Lagoon (14.8 hectares) is connected to the Middle Lagoon by a shallow stream that normally flows to the west. The creek was flowing to the east once during the summer of 1994 (P.M. Stewart, personal observation). This occurred after a storm event with subsequent elevated water levels. A fence along the shore separates the eastern section (approximately one third) of the West Lagoon (owned by INDU) from the section owned by private industry. North of the INDU section are dunes and scattered vegetation, and the black oak savanna continues to the south. This natural landscape continues west slightly beyond the fence, and finally yields to an industrial area with mixed uses. These uses include slag disposal, industrial storage, refuse dumping, scrap preparation, basic oxidation sludge processing, and coal, coke, and rail car storage as well as hazardous waste dump number two (a recipient of tar decanter sludges and other wastes during its active life).

Two small ponds located to the north of the Middle Lagoon were also sampled: East Pond and West Pond (Figure 1). These ponds are separated from each other by a high dune ridge. An abundance of aquatic plants is present in the ponds. Two sample stations were selected for each pond for all studies except for aquatic plant censuses, in which only one sampling site was used for each pond. The landfill makes up the western berm of the West Pond, and from archived photographs, it is evident that a large portion of the West Pond has been filled by formation of the industrial landfill.

SUMMARY OF AVAILABLE CHEMICAL AND BIOLOGICAL DATA

Indiana Department of Environmental Management's 305 (b) report for 1992-93 presents limited water quality data for the Grand Calumet Lagoons. The National Park Service has data for samples collected monthly in the Middle Lagoon near Lake Street, Gary, Indiana. Some water quality information was collected (Hardy 1984) from two Lagoon sites, located in the Middle Lagoon and in the West Lagoon.

During the summer of 1994, the following data were collected by the U.S. Geological Survey:

- water quality variables and several nutrient concentrations
- water/sediment metals and selected organic contaminants in sediments and fish tissue
- metal concentrations in stems and roots for selected plant species
- aquatic toxicity of water and sediments
- plant distribution and abundance
- macroinvertebrates identified to family level
- fish distribution and abundance

During the summer of 1996 water quality data were again collected at twelve sites. Fish were collected at three sites, and these are currently being analyzed for PAH concentrations.

Algae and periphyton were also collected for identification by site. Data from these samples will be presented and discussed in the final report for this project to the National Park Service.

Water quality

Water quality data at twelve sites were collected four times during the summer of 1994 and three times during the summer of 1996. Only the 1994 data will be discussed here. Variables measured include dissolved oxygen, water temperature, pH, specific conductance, total hardness, total alkalinity, and concentrations of sulfate, chloride, ammonia, nitrite, nitrate, reactive phosphate, and total phosphate.

Dissolved oxygen, pH, specific conductance, and temperature were measured in the field with calibrated meters. Water samples were collected at each site in acid-washed polyethylene bottles. The samples were placed on ice for transport to the laboratory where the remaining variables were measured. All variables were analyzed within a suitable time frame following standard methods (APHA 1992).

According to an independent t-test, alkalinity, total hardness, sulfate, ammonia, and nitrate were significantly higher in the West Lagoon than in the Middle Lagoon. The same variables were significantly higher in the West Pond than in the East Pond ($p<0.001$). Total phosphate was not significantly different between the water bodies. Chloride was significantly higher in the Middle Lagoon and the East Pond than in the West Lagoon and the West Pond ($p<0.001$). Ammonia concentrations were correlated with location in the Lagoons ($r=0.860$, $p<0.001$) and were highest at the western sites and lowest in the eastern sites.

High concentrations of ammonia were found throughout the Lagoons and levels were especially high in the West Lagoon, where mean concentration for site WL5 was 2.07 mg/l in 1994. The high levels of ammonia in the West Lagoon and the West Pond, combined with the high pH of these systems, may contribute to the production of high concentrations of undissociated ammonia hydroxide. This form of ammonia [$NH_4OH + NH_3$(dissolved)] is toxic to many aquatic organisms. According to Trussell (1972), the toxic fraction of ammonia is 15% at a pH of 8.5 and a temperature of 25 ^{0}C. Ammonia is removed from the water by plants thus decreasing CO_2 and increasing pH. If future conditions cause an increase in pH to 9.0, the percentage of the more toxic form of ammonia would exceed 35%, leading to elevated toxicity.

In summary, many of the water quality parameters tested in this study, especially ammonia, total hardness, and sulfate, were significantly higher in the West Lagoon and West Pond. These water bodies were most closely associated with the industrial area. Overall, the variables indicated poorer water quality in the impacted areas, and in some areas the water may be toxic to aquatic life.

Plant communities

Aquatic plant species in the Grand Calumet Lagoons were enumerated with an abundance scale (observed=1, rare=2, rare/common=3, common=4, very common=5, abundant=6) (Table 1). Aquatic plant species were also assigned a growth habit for further evaluation (floating, emergent, submergent). Using inductively coupled plasma techniques (ICP), aquatic vascular tissues (roots and shoots) were analyzed for heavy metal concentrations.

The aquatic vascular plant taxa found at each site in the Grand Calumet Lagoons are presented along with their abundance scale values (Table 1). Site ML3 had the greatest number of aquatic plant species with all growth habits represented. Site ML2 had only 11 species with no emergent representatives. The number of aquatic plant taxa was significantly reduced at the WL3-5 sites (Figure 2). The Middle Lagoon had the greatest number of aquatic plant taxa, but this number was only significantly different from the WL 3-5 sites. Floating plant species were absent from the West Lagoon at the time of our sampling (Table 2), yet these had been observed

Figure 2. The mean number of aquatic vascular plant taxa per site in the Middle Lagoon (ML1-3), West Lagoon (WL1-2) and (WL3-5), East Pond (EP), and West Pond (WP).

Table 1. Aquatic plant species collected from the Grand Calumet Lagoons and ponds. Numbers refer to abundance scale (observed=1, rare=2, rare/common=3, common=4, very common=5, abundant=6).

on previous trips to the Lagoons. An exotic plant species, *Myrophyllum spicatum*, was found throughout the Middle Lagoon and at several sites in the West Lagoon earlier in the season. Submergent plant species were reduced at the West Lagoon sites and were non-existent at WL3-5.

Table 2. Number of aquatic plant taxa that occupy the growth habits of submergent, floating, and emergent at each site.

Site	Submergent	Floating	Emergent	Total
WL5			7	7
WL4			10	10
WL3			7	7
WL2	4		10	14
WL1	5		5	10
ML3	9	2	9	20
ML2	8	1		9
ML1	7	2	4	13
WP	6	1	5	12
EP	6	2	6	14

Cluster analysis (an assessment of similarity) based on the coefficient of similarity was done to examine relationships among sites based on aquatic plant distribution (Pearson and Pinkham 1992, Gonzales et al. 1993). Results showed two main groupings (Figure 3). The Middle Lagoon sites and the East and West Ponds formed one such cluster, and the five West Lagoon sites formed another cluster. This suggests that there are differences in aquatic plant distribution that can be attributed to landfill proximity.

Representative aquatic vascular plants were collected from several sites and analyzed for heavy metal content (Table 3). Several heavy metals, including zinc, iron, and aluminum, were at elevated concentrations in some of the tissue samples analyzed. *Scirpus americanus* collected from the pond sites had higher tissue aluminum concentrations in the plant roots than in the shoots (Figure 4). The same species collected from the Lagoons showed the opposite trend. Compared to values found in the literature, aquatic plant tissue metal concentrations at several sites in the Grand Calumet Lagoons and ponds are quite high (Table 4).

Aquatic plant communities in the Grand Calumet Lagoons are impacted by their proximity to industrial areas. Elevated plant tissue metal levels were found, and certain growth habits were not found in the more westerly sites in the West Lagoon.

Figure 3. Cluster analysis of aquatic vascular plant species found in the Grand Calumet Lagoons (ML 1,2,3; WL 1,2,3,4, and 5) and two small ponds (EP, WP).

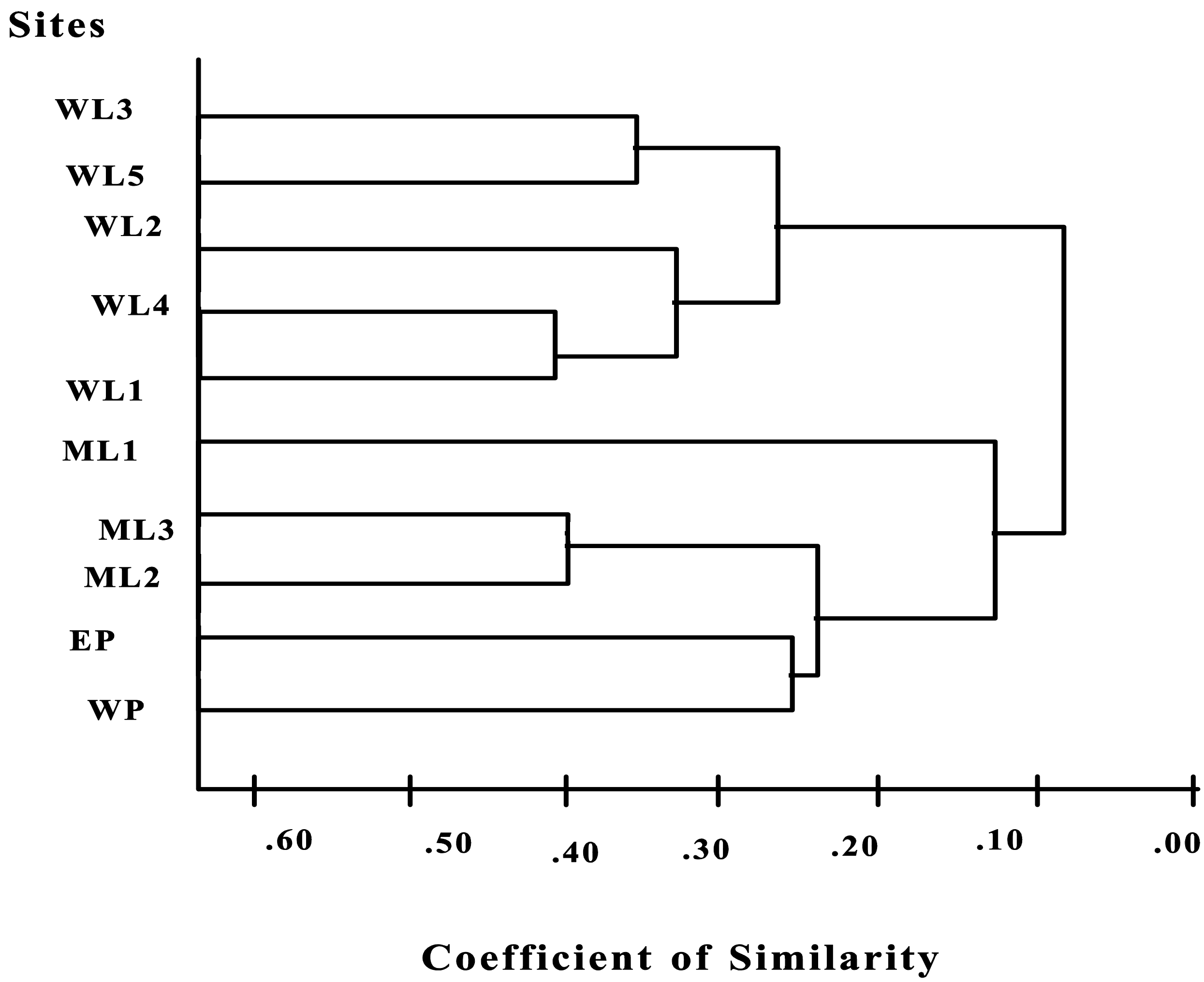


Table 3. Selected plant species and heavy metal root and shoot concentrations (mg/kg) for several sites in the Grand Calumet Lagoons and ponds. ND=Not detectable.

Figure 4.

Aluminum concentrations in the tissue (shoot and root) of *Scirpus americanus* collected from sites WL4, ML3, WP, and EP.

Table 4. A comparison of the metal levels in Grand Calumet Lagoons plant tissues (µg/g) with values reported in other literature.

Metal	Grand Calumet Lagoons (Root)	Grand Calumet Lagoons (Shoot)	Other Studies
Fe	55660 (EP)	17225 (WL4)	[1]7030
Al	1254 (WL5)	587 (ML1)	[2]1730
Zn	298 (WL5)	953 (WP)	[3]2875

[1] Bosserman (1985), *Utricularia sp*. from Okefenokee Swamp.
[2] Cowgill (1973), aquatic plants from Connecticut.
[3] St. Cyr and Campbell (1994), shoots from *Potamogeton richardsonii*

Macroinvertebrates

Macroinvertebrate communities were sampled in the Grand Calumet Lagoons using both Hester-Dendy multiplate samplers (Table 5) and sweep nets of the vegetation (Table 6). The Hester-Dendy plates were left in the field for a month (less than the recommended time of six weeks), and the results were inconclusive. The macroinvertebrate data collected by sweep nets of the vegetation showed more definite results.

Both Shannon-Weaver and Simpson Diversity indices of the sweep net macroinvertebrate data showed significantly ($p<0.05$) lower species diversity at the WL3-5 sites than at the other sites (Figure 5). The Hester-Dendy plate data from the Grand Calumet Lagoons show little discrimination between sites. This lack of difference must be viewed with caution because organisms were only identified to the family level. Genus and species level taxonomic identifications allow for finer discrimination. In addition, Hester-Dendy plates are not normally used in lentic systems (Merritt and Cummins 1984). The sweep net samples show clear differences between community dominants found at ML1-3, WL1-2, and WL3-5 sites (Figure 6). Talitrids were dominant at WL3-5 (more than 95% of the organisms counted at WL5), were fewest at WL1-2, and were present in moderate numbers at ML1-3. Chironomids were most abundant in the center of the Lagoons at sites ML2 and WL2. They comprised a small percentage of the community at ML1 and WL3-5. Coenagrionids were present at all of the Middle Lagoon sites and at WL2, but they were absent from all other sites. Overall, the macroinvertebrate communities at WL3-5 show a negative response to environmental impact.

Figure 5. Macroinvertebrate diversity (Simpson and Shannon-Weaver) from sweep net samples collected from the Grand Calumet Lagoons.

Table 5. List of macroinvertebrate species collected with Hester-Dendy multiplate samplers.

Table 6. List of macroinvertebrate species collected by sweep netting of vegetation.

Figure 6. Dominant macroinvertebrate taxa composition from the Grand Calumet Lagoons. Organisms collected by sweep net sampling of the aquatic vegetation.

The sweep net samples from the East and West Ponds differed greatly from each other (Figure 7). The East Pond had 20-45% Talitrids, and the West Pond had none. The West Pond had 15-60% Chironomids, and the East Pond had none. Planorbid mollusks were also more abundant in the East Pond vegetation than in the West Pond. There were no Asselids found in the West Pond, and no Coengrionids found in the East Pond. These differences in the macroinvertebrate community show a marked response to landfill proximity. The Hester-Dendy data for the ponds suffers from the same weaknesses as the Lagoons.

A cluster analysis of the taxa (families) at each site shows four major groups (Figure 8). WL3-5 formed one cluster, the East Pond sites a second, and the West Pond sites a third. The fourth cluster included samples collected from both the Middle Lagoon and WL1-2. This shows, for the macroinvertebrate community living among the aquatic vegetation, that there were differences between communities found at the far-western locations of the West Lagoon and those of the eastern section of the West Lagoon. The latter were more similar to those communities collected from the Middle Lagoon.

Jokinen (1994) found certain gill-breathing mollusks (prosobranchs) in the East Pond (furthest and over a dune ridge from the slag landfill) but not in the West Pond when she investigated the mollusks of the Indiana Dunes National Lakeshore. These include *Valvata tricarinata* and *Amnicola limosa*. In addition, she found a member of the Lymnaeidae family (*Fossaria exigua*) in the West Pond but not in the East Pond. Three additional species of mollusks, *Pisidium casertanum*, *Physa gyrina*, and *Gyralus parvus*, were found in both ponds.

Macroinvertebrate communities based on family level taxonomic identification clearly demonstrate a difference in community composition relative to their proximity to the industrial landfill. Further taxonomic identification to the genus and species level would undoubtedly strengthen these findings. Sites WL3-5 formed a separate cluster and had fewer taxa and lower species diversity than other sites sampled. These data support the conclusion that the macroinvertebrate community responded to impacts from the industrial landfill and were related to landfill proximity.

Fish communities and metrics

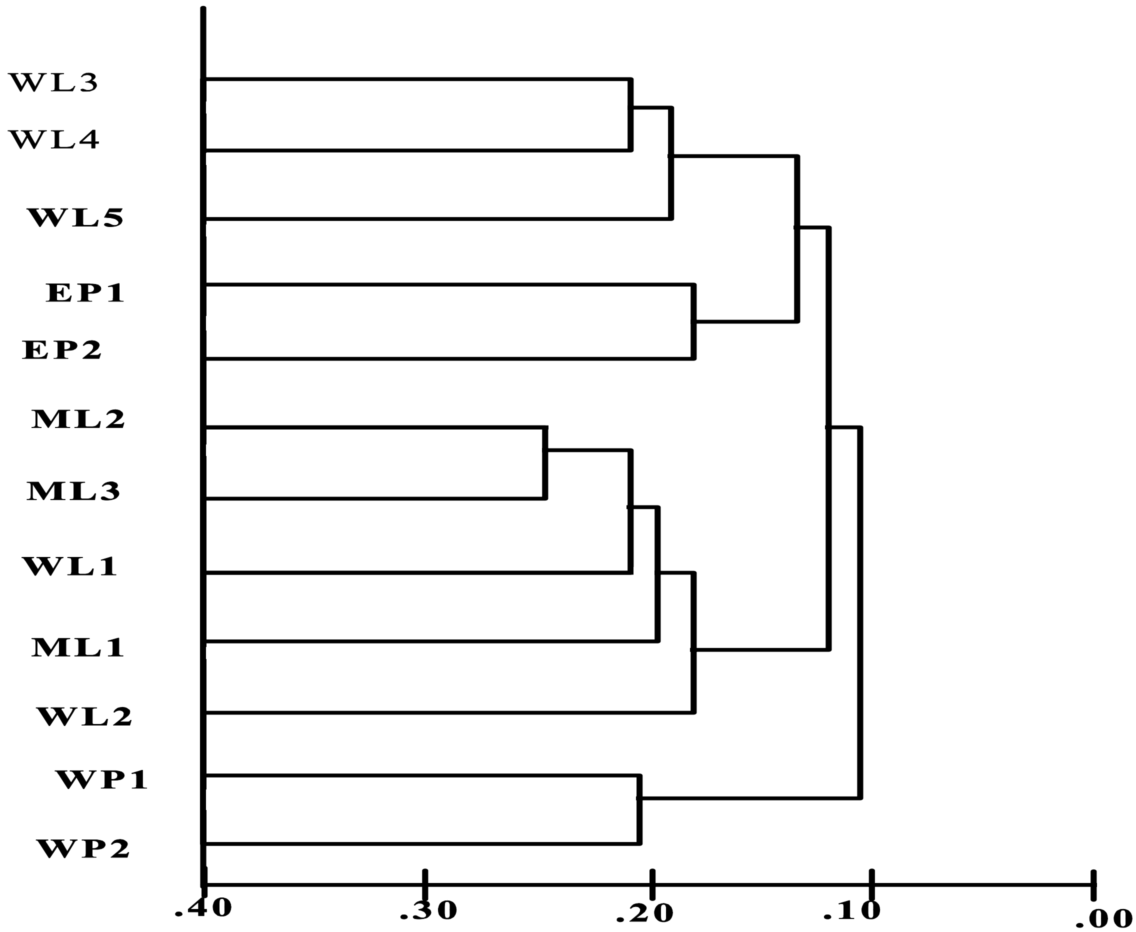
Fish communities were sampled at all twelve sites. Sampling was performed by electroshocking for 100 m in each of the Middle and West Lagoon sites. The ponds were sampled by repeated seines at each of the sites. Fish were counted and identified in the field. Community biometrics were performed for each site. At several sites carp (*Cyprinus carpio*) were collected, placed on ice, and brought to the laboratory for whole tissue analysis of PAH concentrations.

Seventeen species of fish were collected in the sampling effort (Table 7). The East and West Ponds had two species each, and both were heavily dominated by pumpkinseed sunfish (*Lepomis gibbosus*) (more than 300 collected). The second species present was the grass pickerel (*Esox americanus*) in the East Pond and the lake chubsucker (*Erimyzon sucetta*) in the West Pond. Only one lake chubsucker was collected from the West Pond.

Figure 7. Dominant macroinvertebrate taxa composition from the East Pond and West Pond. Organisms collected by sweep net sampling of the aquatic vegetation.

Figure 8. Cluster analysis of the macroinvertebrate community based on a coefficient of similarity. Sweep net samples from the Grand Calumet Lagoons and Ponds on June 17, 1994.

Coefficient of Similarity


WL3
WL4
WL5
EP1
EP2
ML2
ML3
WL1
ML1
WL2
WP1
WP2
.40
.30
.20
.10
.00

Notable in the Grand Calumet Lagoons was the collection of the Iowa darter (*Etheostoma exile*) at several sites, including WL3 and WL4, which had not been previously recorded in northwestern Indiana (Tom Simon, U.S. EPA, personal communication). Sites ML1, ML2, ML3, and WL3 each had nine species of fish collected. Sites WL1, WL4, and WL5 had seven species each. There was no difference between the Middle Lagoon and the West Lagoon in either the number of species collected or in their dominant species. In contrast, there were differences in the subdominant species composition between the West Lagoon and the Middle Lagoon (Table 8). The lake chubsucker and the grass pickerel were only found in the samples collected from the Middle Lagoon. In contrast, the bluntnose minnow (*Pimephales notatus*) was collected from none of the Middle Lagoon sites but was found at all of the West Lagoon sites.

Table 7. Fish and taxa counts from the Grand Calumet Lagoons and two ponds.

	Middle Lagoon			West Lagoon					East Pond		West Pond	
	1	2	3	1	2	3	4	5	1	2	1	2
Ameirus natalis			1									
Carassius auratus						1						
Cyprinus carpio	2			5	4	6	1	1				
Erimyzon sucetta	2		11								1	
Etheostoma exile	2	4	2			2	2					

Esox americanus	2	2	2						4	6		
Lepomis cyanellus	3	7	2	4	1	10						
Lepomis gibbosus	4	31	35	4	6	1	4	17	198	110	265	220
Lepomis gulosus		5	15		1	1						
Lepomis macrochirus	10	36	67	8	11	1	6	1				
Micropterus salmoides	6	15	5	21	7	25	21	20				
Notemigonus crysoleucas								2				
Noturus gyriunus		1										
Perca flavescens	1	5	3	11	5	3	4	2				
Pimephales notatus				10	3	23	2	13				
Pomoxis nigromaculatus	1											
Umbra limi		1										

Table 8. Sub-dominant fish species from the Middle Lagoon and West Lagoon.

Species	ML1	ML2	ML3	WL1	WL2	WL3	WL4	WL5
Erimyzon sucetta	2		11					
Esox americanus	2	2	2					
Etheostoma exile	2	4	2			1	2	
Lepomis gulosus		5	15	1		1		
Pimephales notatus				10	3	23	2	13

The index of biotic integrity (IBI) is based on the addition of numerous metrics (Table 9) that characterize different aspects of the fish community (Karr et al. 1986, Simon 1991, Simon and Stewart in review). Scores from IBI indicated fair health in all of the Middle Lagoon sites and for the East and West Pond communities (Stewart and Simon in review) (Table 10). The West Lagoon sites range from Fair/Poor at WL4 to Poor/Very Poor at WL3. The other three West Lagoon sites had IBI scores indicative of poor fish community quality.

Results from a cluster analysis of the fish community at each site differ somewhat from the macroinvertebrate community cluster analysis mentioned above (Figure 9). For fish, three major clusters are formed. The East and West Pond form one cluster and are dominated by pumpkinseed sunfish and one other species. The second cluster was made up of Middle Lagoon sites, and the third cluster included all of the sites from the West Lagoon. A small stream choked with cattails forms a barrier between the Middle and West Lagoons. It appears that some fish are capable of swimming the entire length of the West Lagoon, but they are separated from the Middle Lagoon by the cattail barrier.

Several carp were collected from the Middle and West Lagoons and were analyzed for PAH concentrations in whole tissues. PAH levels were quite high in fish samples, and they were of a form that normally breaks down or is metabolized very quickly (Table 11). This may suggest either a recent origin or that the PAHs were in the stomachs of the fish and had not yet been metabolized. Unfortunately, no attempt was made to determine concentrations in separate tissues. Two carp collected from WL5 had a mean total PAH concentration of more than 1110 µg/kg, which is similar to concentrations from some of the most contaminated sites around the Great Lakes. Carp collected from WL3 had a mean PAH concentration of more than 250µg/kg in whole tissues.

Fish communities sampled from the Grand Calumet Lagoons show differences that can be attributed to their proximity to the landfill. Several species were found in only the Middle Lagoon or the West Lagoon exclusively, and PAH concentrations in whole carp tissues were elevated.

Table 9. Metrics used in calculating the Index of Biotic Integrity (IBI).

Metric	Expected Score
1. Total number of species	**2-8**
2. Number of darter/sculpin/madtom species	**1**
3. Number of sunfish species	**2-4**
4. Number of minnow species	**1-2**
5. Number of sensitive species	**1-3**
6. % Tolerant species	**24.7 - 49.4 %**
7. % Omnivores	**12.5 - 27.5 %**
8. % Insectivores	**13 - 33 %**
9. % Pioneering species	**24.7 - 49.4 %**
10. Catch per unit effort	**100 - 275**

11. % Simple lithophils	**16.6 - 33.9 %**
12. % DELT anomalies	**0.1 - 1.3 %**

Table 10. IBI scores and assessment for fish communities in the Grand Calumet Lagoons.

Site	Score	Assessment
ML1	42	fair
ML2	42	fair
ML3	42	fair
WL1	34	poor
WL2	32	poor
WL3	31	poor/very poor
WL4	38	fair/poor
WL5	32	poor
EP	43	fair
WP	42.5	fair

Figure 9. Cluster analysis of the fish community based on a coefficient of similarity. Electroshocking and seine samples from the Grand Calumet Lagoons and Ponds on September 15, 1994.

Table 11. Whole fish tissue PAH concentrations from sites in the Grand Calumet Lagoons.

Analyte (µg/kg)	WL3-A	WL3-B	WL5-A	WL5-B
Napthalene	29.5	29.6	212.1	145.9
Acenaphthene	80.9	34.3	450.9	446.6
Fluorene	14.0	11.1	138.6	105.5
Fluoranthene	11.6	36.5	84.5	18.5
Total PAHs	257.4	282.4	1413.4	807.3

Sediment chemistry

Sediments were sampled and analyzed for contaminants at several of the Lagoon sites. Elevated heavy metal concentrations were found at WP2, WL4, and WL5. In most cases results were not indicative of gross heavy metal pollution but were comparable to sediment concentrations from other contaminated areas around the Great Lakes (U.S. Environmental Protection Agency 1977).Concentrations of several metals may be a problem including iron, lead, and zinc.

All samples were heavily diluted in order to detect contaminant concentrations for WL5, but this dilution obscured PAH detection at ML2 and WL4. Dibenzofuran was found in the sediments at 4184 µg/g at WL5. Total PAH at WL5 was 12.3% of the sediment, and of that, 9.5% of the sediment was naphthalene (Table 12). These concentrations were extremely high and indicate a major PAH contamination problem. Concentrations at WL5 was much higher than those reported from the other rivers in the Great Lakes basin (Table 13). Total PAH concentration at WL5 was more than 18,000 times that of Great Lakes sediment in an area exhibiting major biological effects (Clark and Jarvis 1990).

Table 12. Concentrations of seventeen PAHs from sediments at WL5 of the Grand Calumet Lagoons. Concentrations in mg/kg wet weight. BDL=below detection limit.

Contaminant	WL4	WL5
Napthalene	BDL	95,455
Acenaphthene	BDL	5,666
2-Methyl napthalene	BDL	4,800
Dibenzofuran	BDL	4,184
Phenanthrene	BDL	3,286
Fluorene	BDL	2,470
Fluoranthene	0.70	2,122

Pyrene	BDL	1,694
Anthracene	BDL	792
Benzoanthracene	BDL	523
Chrysene	BDL	453
Benzopyrene	BDL	444
Benzo(b) Fluoranthene	0.80	440
Acenapthalene	BDL	420
Benzoperylene	BDL	300
Idenopyrene	BDL	221
Benzo(k) Fluoranthene	1.00	206

Table 13. Several PAH concentrations found in sediments from the Great Lakes Region rivers and the Grand Calumet Lagoons.

Analyte (µg/g)	Black River[1]	Cuyahoga River[1]	Fox River[1]	Hersey River[2]	WL5
Benz[a]anthracene	11.0	2.20	0.70	3.50	523
Benzo[a]pyrene	8.80	2.60	1.00	1.20	444
Ideno[1,2,3-cd]pyrene	6.40	1.40	BDL	-	221
Phenanthrene	-	-	-	4.10	3286

[1] Baumann et al. 1991
[2] Black et al. 1981

These data prompted additional investigations of contaminant chemistry by the U.S. Army Corps of Engineers (ACOE) on July 16 and 17, 1996 (Phil Moy, U.S. ACOE, personal communication). The U.S. ACOE collected six sediment samples and two water samples from the sediments of the Grand Calumet Lagoons. These samples were not collected from the exact locations of our (U.S. Geological Survey) samples. The samples were analyzed for priority metals, volatiles, semivolatiles, pesticides, and additional parameters. Few contaminants were detected in either the eluriate or the water samples analyzed. The sediment analyses yielded some interesting results. Several heavy metals were found in the West Pond near an area of wire burning and recycling. People in the area gather scattered wire and remove the insulation by burning it. The remaining metal is sold. The burning process releases ash containing metals which may be affecting metal concentrations in the pond.

Contaminant data collected by the U.S. ACOE revealed high PAH concentrations at several locations in the Lagoons. These are, for the most part, a different suite of contaminants than the ones reported in this study. Phenanthrene was found at concentrations as high as 18,000,000 µg/kg. PAH detection limits between WL4 and WL5 were quite high due to interference from sample contaminants that subsequently caused problems with the analytical chemistry. As in our sampling, the sediments between WL4 and WL5 were loose, black, oily, and flocculent, with a strong hydrocarbon odor.

Limited evidence (few samples, but high levels of PAHs) suggests that a major contaminant problem exists in the sediments of the Grand Calumet Lagoons. The PVC pipe used for sediment sampling became covered in a black, tarry coating between sites WL4 and WL5. WL5 has high PAH concentrations, and they are much higher than levels exhibiting major biological effects.

Aquatic toxicity testing

Aquatic toxicity testing was performed on the water and sediments from the West Pond. Despite apparent contamination, neither surface water nor sediments appeared to be toxic. This lack of toxicity could be due to modifying or interfering factors in the tests, such as hardness. It also may have been due to procedural problems which must be addressed.

There is no strong evidence that surface waters in the Lagoons were toxic, so toxicity testing was focussed on the Lagoon sediments. All fathead minnows died within twelve hours when exposed to the sediments from WL5. These sediments (WL5) were not tested further due to their extremely contaminated nature.

Whole sediments from WL4 affected survival and growth rates of amphipods, *Hyalella*, and sediment eluriate was toxic to *Ceriodaphnia*. This suggests that sediments from WL4 may also be toxic to aquatic organisms in the Grand Calumet Lagoons. Sediments at the other sites in the Grand Calumet Lagoons are contaminated with heavy metals. Despite this contamination, neither whole sediments nor eluriate from these sites decreased survival or growth in fathead larvae. Sediments from WL1 and WL3 appeared to affect growth in amphipods, while sediments and eluriate from WL2 and WL3 appeared to affect survival and reproduction in *Ceriodaphnia*. This evidence suggests that sediments from WL2 and WL3 have negative effects on aquatic organisms.

The results of these toxicity assays should be considered preliminary. In some cases, no toxicity was observed from sediments that had previously shown elevated concentrations of contaminants. A resampling effort with further aquatic toxicity testing is necessary to elucidate fully the extent of sediment toxicity in the Grand Calumet Lagoons.

CONCLUSIONS

An obviously impaired aquatic community exists within and surrounding the Grand Calumet Lagoons and ponds. The ponds and surrounding areas include wetlands, dune and swale habitat, and a savanna community. This habitat type is considered to be among the most endangered ecosystems on the planet. Rare habitat and federally endangered and threatened species exist within the area.

There are high levels of contaminants in some areas of the Grand Calumet Lagoons and in the ponds located near the landfill. Of these, PAHs elicit the greatest concern. Heavy metal concentrations are elevated at some sites, and this may be an additional cause for concern.

These data show that there were differences between the two sub-basins in several water quality parameters. For example, chloride and ammonia concentrations were significantly different between the two sub-basins. Aquatic plant communities also show marked differences among the sites with entire growth habits not appearing in the West Lagoon during our sampling. Family level macroinvertebrate data show differences among sites based on landfill proximity. Community composition of non-dominant fish also differ between the Middle and West Lagoons. In addition, carp collected from WL5 had PAH levels that greatly exceeded those of other lagoon sites sampled, in excess of 1000 µg/kg--extremely high levels for PAH concentrations in whole fish tissues.

Sediment collected from the western section of the West Lagoon was toxic to organisms used in toxicity testing. Other areas showed mixed results, and repetition of the tests is merited. Heavy metal sediment concentrations during the summer of 1994 were not exceptionally high, but concentrations at stations WL4, WL5, and WP2 were above those at other sites. Concentrations of several PAHs at the WL5 site were much higher than the levels associated with major biological effects. In fact, naphthalene comprised nearly 10% of the total sediment at WL5.

The Grand Calumet Lagoons are part of the headwaters of the Grand Calumet River, which continues from the end of the culvert to the west of the lagoons. Organisms in the Lagoons are affected by the influx of contaminants from the adjacent landfill, and the Lagoons will act as a continued source of PAH, heavy metals, and other pollutants to the Grand Calumet River unless the problems discussed here are rectified.

What would be some management recommendations for the Lagoons? This is, of course, a controversial subject. Many interested parties should be involved in a discussion of the options: the National Park Service, the City of Gary, U.S. Steel, the U.S. Fish and Wildlife Service, the U.S. EPA, the U.S. ACOE, Indiana Department of Environmental Management, Indiana Department of Natural Resources, the Save the Dunes Council, the Grand Calumet Task Force, the Biological Resources Division of the U.S. Geological Survey, and the public. More than 100 years of environmental degradation will not be easily corrected. The most pressing issues are the hazardous waste areas, such as the hazardous waste dump number 2, and the coke piles located near the Lagoons that are the most likely sources for the PAHs at site WL4 to WL5. Other issues include the heavy metal contamination throughout the site and the uptake of these metals by aquatic organisms.

We must first determine the restoration and remediation goals. Do we want simply to clean up the Ponds and the Lagoons, or do we want to protect and enhance the native biota?

Several options have been proposed during the past few years. Some possible benefits and drawbacks of these options will be analyzed briefly to encourage discussions of how to solve the problems that exist in the area. Discussions with Joseph Thomas, of the Indiana Department of Environmental Management helped to elucidate some of the finer points.

Option 1 - Leave all material where it is now.

This option would allow continued degradation of the park and its biota due to extensive contamination that already exists. Since the Lagoons are the headwaters of the Grand Calumet River, this would allow for continued contamination of the Grand Calumet River west of the culvert. This would leave surface contaminants containing more than 12% PAH in the area, and aquatic toxicity testing has shown the sediments in the far-western regions to be extremely toxic. Further contaminant uptake in the water column would add to downstream discharges. Positive aspects of the option would include avoiding sediment resuspension during dredging and the associated turbidity problems. Existing ecosystems would not be disturbed, so there would be little risk of removing some species from the area. It is the least costly option, at least in the short term.

Option 2 - Remove contaminated material from the area.

This option comes in three related forms. One option is removing hot spots which must first be more clearly identified. The second option is removing a substantial portion of the contamination, and the third option is to remove all contaminants in the area. There is little difference between removing the hot spots and removing a portion of the contamination, and both options would leave a great deal of contamination behind. The more contaminants and sediments are removed, the more this would cost.

Removing all the contaminants in the area would require the removal of a great deal of sediment and fill. This includes the slag piles, hazardous waste dump number 2 , metal burning sites, and the sediments from the Grand Calumet Lagoons. This removal would necessitate the construction and maintenance of a large, lined storage facility. Complete removal of contamination is expensive and extremely difficult. Removal of contaminants past a certain point to the east would destroy the resource that we are trying to protect. Building a landfill on park property would be an extremely contentious issue.

The benefits of this option include the reduced contaminant impact on the park and biota including unique and fragile habitats of oak savanna, dune and swale, and wetlands. The proper disposal of a large volume of material should be addressed including potential locations of a fill site and proper site construction to prevent future recontamination.

Option 3 - Cap the contaminated areas (the landfill), and form a physical containment barrier between more contaminated and less contaminated sediments.

No barrier system will last forever because it assumes complete separation between the upper and lower aquifers. Numerous wells throughout the region need to be studied and perhaps removed because they may have aided in contamination of the lower aquifer. Groundwater monitoring should be instituted. If necessary, pumping and remediation efforts should be initiated to clean up the aquifer and to keep contamination from spreading. Capping the contaminated sediment and then adding clean sediment to the system would potentially benefit the aquatic ecosystem, but further contamination of ground water is also possible. Existing conditions would be dramatically altered. It may be necessary to establish a groundwater divide that separates moving landfill contaminants in the Lagoons from Lake Michigan.

LITERATURE CITED

APHA. 1992. Standard methods for the examination of water and wastewater, 18th edition. Washington, D.C., USA.

Baumann, P.C., M.J. Mac, S.B. Smith, and J.C. Harshbarger. 1991. Tumor frequencies in Walleye (*Stizostedion vitreum*) and Brown bullhead (*Ictalurus nebulosus*) and sediment contaminants in tributaries of the Laurentian Great Lakes. Canadian Journal of Fisheries and Aquatic Sciences **48**:1804-1810.

Black, J.J., T.F. Hart, Jr. and E. Evans. 1981. HPLC studies of PAH pollution in a Michigan trout stream. Pages 343-355 in M. Cooke and A.J. Dennis, editors. Chemical analysis and biological fate:polynuclear aromatic hydrocarbons. Fifth international symposium. Batelle Press, Columbus, Ohio, USA.

Bosserman, R.W. 1985. Distribution of heavy metals in aquatic macrophytes from Okefenokee Swamp. Heavy metals in water organisms. Pages 31-39 in Symposia Biologica Hungarica Volume 29. Akademiai Kiado, Budapest, Hungary.

Clark, J.U. and A.S. Jarvis. 1990. Regulatory evaluation of petroleum hydrocarbons in dredged material. Miscellaneous paper EL-90-11. U.S. Army Corps of Engineers Waterways Experimental Station, Vicksburg, Mississippi, USA.

Cowgill, U.M. 1973. The determination of all detectable elements in the aquatic plants of Linsley Pond and Cedar Lake (North Bradford, Connecticut) by x-ray emission and optical emission spectroscopy. Applied Spectroscopy **17**:5-9.

Gatz, D.F., V.C. Bowersox, and J. Su. 1989. Lead and cadmium loadings to the Great Lakes from precipitation. Journal of Great Lakes Research **15**:246-264.

Gonzales, D.A., J.G. Pearson, and C.F.A. Pinkham. 1993. User's manual BIOSIM1, Beta version 1.0. A program that applies the coefficient of biotic similarity to complex data matrices. EPA 600-R-93-219. U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Las Vegas, Nevada, USA.

Hardy, M.A. 1984. Chemical and biological quality of streams at the Indiana Dunes National Lakeshore, Indiana, 1978-1980. U.S. Geological Survey, Water Resources Investigations 83-2408. Indianapolis, Indiana, USA.

Hilsenhoff, W.L. 1988. Rapid field assessment of organic pollution with a family-level biotic index. Journal of the North American Benthological Society **7**:65-68.

Indiana State Department of Health. 1997. Indiana Fish Consumption Advisory. Environmental Epidemiology Section, Indiana State Department of Health, Indianapolis, Indiana, USA.

Jokinen, E. 1994. The freshwater mollusks of the inland waters of the Indiana Dunes National Lakeshore. INDU Research Program Report, Porter, Indiana, USA.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant, and I.J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publications 5.

Knorr, D.F. and G.W. Fairchild. 1987. Periphyton, benthic invertebrates and fishes as biological indicators of water quality in the East Branch Brandywine Creek. Proceedings of the Pennsylvania Academy of Science **66**:61-66.

Lewis, M. 1986. Impact of municipal wastewater effluent on water quality, periphyton, and invertebrates in the Little Miami River near Xenia, Ohio. Ohio Journal of Science **86**:2-8.

Merritt, R.W. and K.W. Cummins. 1984. An introduction to the aquatic insects of North America, 2nd edition. Kendall/Hunt Publishing Company, Dubuque, Iowa, USA.

NADP. 1995. National Atmospheric Deposition Program. Colorado State University, Fort Collins, Colorado, USA.

Patrick, R., F. Douglass, D.M. Palavage, and P.M. Stewart. 1992. Surface water quality: have the laws been successful? Princeton University Press, Princeton, New Jersey, USA.

Pearson, J.G. and C.F.A. Pinkham. 1992. Strategy for data analysis in environmental surveys emphasizing the index of biotic similarity and BIOSIM1. Water and Environmental Research **64**:901-909.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers: benthic macroinvertebrates and fish. U.S. EPA, Office of Water. EPA/440/4-89/001.

Simon, T.P. 1991. Development of an index of biotic integrity expectations for the ecoregions of Indiana, I. Central Corn Belt. U.S. Environmental Protection Agency, Region 5, Environmental Sciences Division, Monitoring and Quality Assurance Branch: Ambient Monitoring Section, EPA 905-9-91-025. Chicago, Illinois, USA.

Simon, T.P. and P.M. Stewart. In review. Development of fish community reference conditions for diurnal, palustrine wetlands: an emphasis on assessment of non-point source landfill effects. Aquatic Ecosystem Health and Restoration.

Smith, R.A., R.B. Alexander, and M.G. Wolman. 1987. Water-quality trends in the nation’s rivers. Science **235**:1607-1615.

St. Cyr, L. and P.G.C. Campbell. 1993. Trace metals in submerged plants of the St. Lawrence River. Canadian Journal of Botany **72**:429-439.

Steffeck, D.W. date unknown. A survey for contaminants near the Midco I, Midco II, and Ninth Avenue Dump hazardous waste sites in Gary, Lake County, Indiana. U.S. Fish and Wildlife Service, Bloomington, Indiana, USA.

Stewart, P.M. and D.J. Robertson. 1992. Aquatic organisms as indicators of water quality in suburban streams of the lower Delaware River Region, USA. Journal of the Pennsylvania Academy of Science **66**:135-141.

Trussell, R.P. 1972. The percent of unionized ammonia in aqueous ammonia solutions at different pH levels and temperatures. Journal of Fisheries Research Board of Canada **29**:1505-1507.

U.S. Environmental Protection Agency. 1977. Guidelines for the pollution classification of Great Lakes Harbor sediments. U.S. Environmental Protection Agency, Region V, Chicago, Illinois, USA.

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INTRODUCTION

The preceding chapters discussed the status of each major component of the flora and fauna of the Grand Calumet River study area. This final chapter presents an executive summary and a set of recommendations for the study area. These recommendations were formulated at a meeting of all project authors and represent their collective vision for the Grand Calumet River and its associated ecosystems. The chapter also includes a discussion of the impaired uses that serve as the rationale for river dredging and of ways in which habitat restoration measures will reduce impairments.

Recommendations were generated with the following goals: Flora, fauna and habitats of the study area should be identified, restored and protected, and pollution in the area should be abated. To the greatest of our ability, we hope to ensure that the study area will possess the structural and functional attributes of a native and natural community, consistent with the Lake Michigan dune and swale ecotone. The first step in this process will be to define the region under consideration. Establishment of such an area should serve to focus efforts on attempts to establish and enhance as much of the regional ecosystem as possible. It should not negate the efforts to include suitable areas adjacent to the region as they become available. The second step will be to protect and enhance existing high-quality natural areas so that these can serve as refugia and as models to guide restoration projects. Other areas of the river corridor should then be enhanced and restored, and pollution there should be abated. These restored areas will serve as buffers for core natural areas and will provide migration connections between natural and "least" disturbed habitats. Establishment of habitat heterogeneity and control of exotic species is imperative for management goals to be met. To achieve long-term goals for restoration and ecological integrity, it will be necessary to establish partnerships between private and governmental bodies to remediate degradation, to provide ongoing stewardship of lands, and to integrate ecological issues into urban planning from the beginning to the end of each project.

THE STUDY AREA

The study area for this report extends from the first dune ridge south of Lake Michigan to the Tolleston Beach ridge summit (located to the south of the Grand Calumet River), and from the Grand Calumet Lagoons at the eastern end of the river to the confluence with the Calumet River in Illinois at the western end. Some portions of this area have been examined more thoroughly than others; the purpose of the study was to examine functional relationships among habitat areas whose hydrology is connected to and dependent on that of the Grand Calumet River. Historically, the borders just described marked the extent of the Grand Calumet watershed, but the hydrology of the region has been so altered by human activities that some areas have lost their connection to the River. Additionally, the greatest focus has been on sites that retain some value as natural areas, since these are the sites most likely to benefit from preservation, restoration, and abatement.

The areas along the shores of the Grand Calumet River are of highly variable habitat quality, ranging from contaminated Superfund sites to remnant natural areas that are globally significant for their rarity and diversity. The natural communities of the region were formed through glacial, biotic, geologic, and hydrologic change. Industrialization has destroyed many of these sites and fragmented the rest, but those that remain retain a surprising degree of species diversity and community integrity.

The biotic communities of the region formed through the mixing of species from four different habitat types. The tundra stage present after glacial retreat was slowly replaced by boreal forest species. Gradually, deciduous forest or woodland replaced the boreal species in a series of changes based on rates of seed dispersal and mobility. A period of warmer and/or drier climate followed, and grassland and savanna communities became established. The current conditions reflect these changes with relict species still present in areas, but variation has occurred even within historic times. These floras invaded the region in numerous small waves as the glaciers that formed Lake Michigan receded northward. The prime habitats of the current natural landscape are upland savannas, prairie remnants and wetlands. Boreal remnants include bearberry, jack pine, white pine, and paper birch. Some woodland areas are also present. Relicts of other habitats, including tundra and deciduous forest, are located primarily to the north of the Grand Calumet River.

Slow landscape evolution with four major dynamics associated with natural processes resulted in the unique ecosystems present today. First, fluctuations in the level of Lake Michigan and currents in the Lake alternately inundated and drained Lake-associated ecosystems. Fluctuations directed the formation and flow of the Grand Calumet River, making it a sluggish, almost swale-like watershed that drained only a small area of the Calumet region. The wet, hilly dune and swale topography that characterizes the region is the product of slow sediment deposition on the nearshore lake bed and on the shoreline of Lake Michigan. Second, natural succession eventually transformed beach formations into sand savannas and many transitional systems in between. Migration and seed dispersal between areas was the third major process which allowed for disturbed areas to be re-colonized by native species from neighboring areas, and helped to maintain genetic diversity within microhabitats. Finally, periodic fires burned across the lands, clearing dead brush and preventing open areas from becoming overgrown and forested.

Industrialization and human settlement changed the natural systems of the Calumet region dramatically. During the past 100 years, the region's dune and swale topography has been greatly altered by sand mining, by the draining and filling of wetlands, and by the construction of large industrial facilities, roads, and commercial and residential areas on flattened dunes and filled swales. The Grand Calumet River was deepened and channelized. Industries began pumping large quantities of effluent water into the River, so that its flow rate was greatly increased. Contamination made many areas toxic to sensitive native life forms and, in some cases, to more pollution-tolerant organisms as well.

Disturbances to natural areas due to industrialization and human settlement have made them susceptible to invasion by aggressive and exotic species. In some areas, these have formed large monocultures that have choked out many other, more niche-specific species. Processes required for the creation and maintenance of local ecosystems, such as periodic fires and migration, have been suppressed. This interruption has allowed all communities to become overgrown, and some community types have been lost to most of the region. Due to habitat destruction and fragmentation, the gene pools of many niche-specific native species have become dangerously small.

Despite all of the degradation that has taken place, a few high quality natural areas remain. These are small fragments of the former landscape, often isolated both from each other and from the natural processes that formed them, but they have managed to persist largely intact.

The Nature Conservancy, using Natural Heritage Network data, has identified the Greater Calumet Wetlands Site as an area that supports globally and state significant biodiversity. There are 18 natural community types extant within the site. Within these, are found more than 700 species of native plants, of which 85 are globally or state significant; more than 200 species of birds, including 18 species confirmed to nest in the area that are globally or state significant; and 21 species of reptiles and amphibians, eight of which are state significant.

Several federally listed species are known to occur in the study area: Pitcher's thistle (*Cirsium pitcheri*), the Karner blue butterfly (*Lycaeides melissa samuelis*), and the Peregrine falcon (*Falco peregrinus*). Habitat appropriate for Indiana bat (*Myotis sodalis*) is also present, although it has not been demonstrated that the species is there. Numerous state listed species are found throughout the high quality habitats of the study area.

The highest quality natural areas of the study site are Miller Woods, the East and Middle Lagoons of the Grand Calumet Lagoons, Clark and Pine East, and DuPont Dune and Swale. Miller Woods and Clark and Pine are the last and finest dune and swale remnants. It contains habitats that grade from mesic, sheltered forest into prairie and savanna. The Lagoons and adjacent ponds are some of the last local examples of palustrine wetlands, and they show potential as restoration sites. They contain the most diverse macroinvertebrate fauna of any surveyed site in the Grand Calumet River study area. Clark and Pine East includes roughly 50 acres of remnant ridge and swale, which support a diverse range of habitat types, including sand savanna, sand prairie, wet prairie, sedge meadow, emergent marsh, and shrub swamp. DuPont Dune and Swale includes the largest remnant dune and swale area in the region, with 170 acres within the DuPont Property and additional degraded habitat sites in adjacent areas. Franklin's ground squirrels, declining in the state, still occur here.

The river channel itself is highly degraded and contaminated. The macroinvertebrate fauna is poor in all reaches of the study area, and it is entirely absent from many stretches of the river. Fish are too contaminated to be eaten, and diving birds have been observed to lose their ability to fly when the sediments coat their wings with oil. Silt has migrated from the channel onto the banks, and has formed a nutrient-rich, cation-dominated sediment that favors common reed stands over native sedge floodplains. Homes, sewage disposal plants, and industrial facilities and disposal sites line much of the bank, and thick growths of cattail, common reed, and purple loosestrife choke out native plant and animal species in most of the marshes immediately adjacent to the channel. Dissolved oxygen concentrations in the water are often too low to support life, and nutrients released into the water support excess growth of blue-green algae.

There has been some improvement, and the macroinvertebrate community reflects early stages in river recovery. There are high densities of a few species tolerant to some level of disturbance. There has been some improvement, with fish communities rebounding during the last decade. Abundance and diversity have improved, and these communities are primarily composed of invasive, tolerant species

RESTORATION PHILOSOPHY AND SYSTEM-WIDE RECOMMENDATIONS

To evaluate the condition and restoration potential of the Grand Calumet River, we must examine each aspect that contributes to the whole ecosystem; however, neither organismal groups nor river sections function individually, but rather interactions among these form a complex association. Contamination of narrow river sections and of specific organisms can have far-reaching effects on the rest of the river and on adjacent wetland areas. Many changes to the Grand Calumet River and to its associated ecosystems, such as an increase in flow rates due to industrial uses of the river, are unlikely to be reversed. For this reason, decisions about restoration need to be made based on present conditions. The first goal in restoration is to achieve natural, integrated community function for river system inhabitants. When possible, certain areas may be enhanced to emulate historic conditions.

Lands adjacent to the Grand Calumet River historically consisted of a series of dunes and swales. For this reason, species of the region are adapted to fill a wide variety of niches, in varied wet and dry habitats. Some species are adapted to move between different habitats in the dune/swale complex. Restoration planners should work to recreate a complex array of contiguous habitat types analogous to the dune/swale system.

One method of enhancement recommended throughout these chapters is the creation of buffers around high quality natural areas. A buffer is a somewhat degraded non-industrialized site adjacent to a high quality area. Although buffers are not sufficiently pristine to support diverse native communities, they can support some native species. The primary purpose of buffers is to prevent contamination from residential and industrial sources from overflowing directly into the most sensitive natural areas. Also, they provide a surrounding habitat that is of higher quality than the polluted areas. Buffers can, and should, also be restored when feasible although they will usually be less diverse than natural areas.

Prescribed burning, exotic species control, and planting of selected native species are highly recommended as management strategies. Burning, a natural ecosystem process, prevents successional processes from eliminating open, grassy habitat-types from the landscape. Fire frequency increased with intentional and accidental fires set by the Native Americans, but fire-suppression efforts began in the nineteenth century. Exotic species control opens areas for colonization by more diverse assemblages of species, and planting helps to ensure that disturbed areas will not simply revert to single-species stands of exotics or of invasive native species. An herbivore assemblage as natural as possible is also needed to maintain natural plant diversity.

Because of the presence of extensive communities of invasive and exotic species, any plans to create a continuous river corridor will need to be carefully considered. A corridor created to facilitate migration of native, conservative plant species might easily become an invasion route for exotic monocultures. Any corridors that are facilitated must be consistently monitored and actively maintained. Establishing diverse native species communities and avoiding exotics should be the goal of restoration efforts.

Reintroduction of extirpated species could play a role in restoration efforts. The river otter was present historically, and could potentially be reintroduced to pond, lake, and river areas if these are sufficiently cleaned and protected to support it. American porcupine (*Erethizon dorsatum*), and perhaps smooth green snake (*Opheodrys vernalis*) could be reintroduced into the Miller Woods area if enough good habitat can be created.

Sediment clean-up has great potential to benefit the Grand Calumet ecosystem by clearing away large quantities of contaminants. These must be disposed of responsibly, with minimal impact on their disposal site environment, to make the moving of contaminants worthwhile. After dredging, provided that all of the contaminated sediments have been removed or effectively capped, macrofauna of the river benthos will again have a non-toxic substrate upon which to grow. Variable banks, depths, and bottoms should be created to provide habitat variation. Fish communities will most likely return to the system though it is unlikely that they will be edible.

Dredging and sediment-replacement methods could also be used to modify topography along the riverbanks. Banks could be dredged to recreate the shallow backwaters and marshy areas that once existed along the river. Dune replacement could be attempted in order to re-create ridged dune and swale topography. Any such drastic alterations would need to be carefully planned, and supplemented by extensive planting and ongoing management. Further study is needed to determine the feasibility of habitat restoration in areas disturbed by these topographic alterations.

The dredging process also poses dangers to ecosystems along the River, and these must be regulated if the benefit of dredging is to outweigh the risk. Contaminants and excess nutrients could, without proper precautions, migrate outward from the channel through aerial, side-channel or groundwater transport of suspended chemicals and sediments. Some chemicals re-suspended by the dredging process may become more toxic when they are exposed to sunlight. Temporary weirs could be built as settling areas for re-suspended sediments. Dredging will create a greatly deepened, U-shaped channel, which will lead to sloughing of the banks and an increase in river flow-rate. This increase in flow may then lead to increased bank erosion. These effects should be minimized with the addition of clean sediments, planting of native species, and construction of anti-erosion structures out of BioLogs™ or other materials. BioLogs™ would also serve as substrate for the growth of native plants and would create calm eddies. Dredged sediments should not be replaced by slag filler, because this can leach contaminants into waters and sediments. Instead, "natural" fillers such as gravel and cobble should be added. This substrate will differ greatly from the current muck sediment, but it should nonetheless be greatly superior to the toxic sediments now present. Micro-habitats for fish will likely be cleared away by dredging, and they will need to be artificially re-created. Lunker boxes, BioLogs™, half logs, and other structures can be used to create artificial undercut banks and riffles for fish.

All restoration decisions will need to balance desired benefit to the ecosystem with the possibility that restoration activities will actually harm the system. In many cases, these considerations may require that additional measures be taken in the course of restoration to protect against exotic species and contaminant spread and the erosion of habitat.

Restoring natural systems of the Grand Calumet River should be considered a goal in many steps. Sediment restoration is one step toward cleaning up the ecosystem, but there will be numerous steps in the process, including wetland expansion, habitat creation, bank stabilization, and extermination of exotics. Further pollution from point and non-point sources will need to be assessed and both average and peak pollution rates will need to be reduced. These steps should be occur along with sediment clean-up, but they will be ongoing projects and cannot be performed in any meaningful and lasting way if they are considered only as adjunct to sediment clean-up.

Continuous monitoring of all aspects of the system will be essential to chart restoration progress. Management and partnerships among involved groups will be imperative for making restoration an ongoing, rather than a sporadic and poorly planned endeavor. Ecological considerations will need to be incorporated in a meaningful way at the beginning and in all steps of the land use planning process. Many sites are indirectly affected by the river, including terrestrial systems, and management for these areas must be considered as a step in the entire system restoration. Further, any restoration efforts must be supported by pollution abatement in order to prevent re-contamination of newly restored areas. In some areas it may not be possible to return to historic conditions, but by decreasing pollution impacts and actively preserving and managing lands, progress toward an integrated system of natural areas can be made.

REACH-BY-REACH RECOMMENDATIONS

The Army Corps of Engineers has divided the river into ten reaches that will correspond to discrete dredging projects. The division between reaches is arbitrary from a habitat standpoint, and reach-by-reach recommendations cannot stand alone without incorporation of the ideas detailed above for the entire study system. Recommendations for activities at specific locations can, however, be broken into reach-unit groupings. These, along with brief descriptions of the habitat found in each reach, are described below.

Lagoons reach

The Lagoons area contains two large tracts with high value as natural areas: The Grand Calumet Lagoons and Miller Woods, which border the Lagoons to the north and south.

Grand Calumet Lagoons

The Grand Calumet Lagoons are a series of lagoons located at the eastern end of the Grand Calumet River where the mouth of the river once opened to Lake Michigan. The Lagoons are now at the River's east end. The area immediately to the south of the Lagoons consists of mesic sand savanna, with interspersed marsh and pond communities in swales. The area to the north borders Lake Michigan and includes unusual habitats, such as pannes. The easternmost lagoon provides habitat for the most diverse array of macroinvertebrates in the study area and for a wide variety of submerged aquatic vascular plant species. The ponds that are closely associated with the Lagoons are also valuable as rare remnants of the once-common panne-type community.

The Lagoons are divided into three parts: The West Lagoon, the Middle Lagoon, and the East Lagoon. The West and Middle Lagoon are separated by a shallow stream that usually flows west. A wide channel separates the Middle Lagoon from the East Lagoon. The Middle Lagoon is thought to be the least contaminated of the three areas. The West Lagoon is highly contaminated, and it is currently under enforcement action under the Resource Conservation and

Recovery Act (RCRA). The clean-up mandated under this law will probably involve removal or capping of the contaminated sediments.

The source of contamination in the East Lagoon is unknown. The area receives parking lot drainage. Whether this is the cause of contamination in this Lagoon is unknown. It is recommended that studies be conducted to determine the sources and concentrations of pollutants in this sensitive area, and that management recommendations be developed based on the results. The area should not be dredged until a use for such dredging is demonstrated.

Clean-up or capping of West Lagoon sediments is likely to stir up sediments, and contaminants could be transported into less contaminated areas. To prevent this from occurring, it is recommended that, before cleanup, a weir be built across the West Lagoon near its eastern end, near the boundary of the purchase-defined area. After cleanup, the area should be monitored for water and sediment contamination. The wier should be removed after contaminant levels have stabilized to allow macroinvertebrates, fishes, bullfrogs, and turtles to pass between sections of the Lagoons. This process, and any other restoration activities, should be coordinated with the RCRA process, to assure that clean-up is efficient. If it is likely that contaminants will migrate onto INDU property, dredging and restoration here should also be coordinated with the offices of INDU.

Several smaller ponds are associated with the Grand Calumet Lagoons, and these also should be protected. The two ponds to the north of the Lagoons are appropriate habitat for federally endangered plants. Water and sediment quality should be studied to determine whether the slag piles are causing contamination. Legal issues concerning the "taking" of the resident species of rare organisms should also be considered before any dredging is done in these ponds. Contaminant levels should also be studied in the first row of ponds to the south of the Lagoons. Beyond these, the land rises in elevation, and this has likely prevented contaminants from spreading further to the south.

It is possible that any dredging of the Grand Calumet Lagoons will cause bank sloughing. This sloughing could destroy portions of the valuable Miller Woods tract. Clean sediment should be added to dredged areas, and the banks of dredged Lagoons should be stabilized with native vegetation in order to prevent habitat destruction.

Miller Woods

Miller Woods is one of the last and finest remnants of the dune and swale system in the study area. It is located in a transition zone, with mesic, sheltered forest areas common to the east, and more open prairie and savanna dominated sites common in the west. Miller Woods is the only portion of the study area containing large forest trees, and the tract is an important refuge for several species of forest-dwelling mammals including squirrels, voles, shrews, and bats. The area also contains high-quality habitat for amphibians. As a large and well-preserved remnant area, Miller Woods can serve as a model for future restoration efforts. Preservation and management of this site are a top priority.

Some of the areas surrounding Miller Woods may be suitable for restoration of oak savanna/hardwood habitat types, which will be valuable both as buffer areas and as additional habitat for the isolated, high quality oak savanna already present. Restoration efforts will involve initial and ongoing removal of exotics, and possibly revegetation with native species and other management techniques, such as the use of prescribed burning. One element of restoration could include the reintroduction of American porcupine (*Erethizon dorsatum*), and perhaps eventually the river otter (*Lutra canadensis*), into the Miller Woods area. Restoration and management should be carried out in accordance with the advice of local experts and land managers.

In the South Shore portion of the Miller Woods tract, there is extensive illegal dumping of tires and other items. It is recommended that Miller Woods be patrolled and secured from intruders at its southern end.

USX reach

The USX reach of the Grand Calumet River is highly degraded for most of its length. The highest quality natural areas in the reach, both located at the far western end, are the Bongi site and a small portion of the Clark and Pine site that is located mostly in the Gary Sanitary District reach. The Bongi site contains two borrow pits located to the north of the river. The north pit, further from the river, is more contaminated than the south pit perhaps due to fly ash runoff.

Plans for restoration of the USX reach of the River are currently being formulated as part of a RCRA enforcement action against USX Corporation for this area. The plans are currently on hold while the Indiana Department of Environmental Management decides whether or not to issue a water discharge permit for the river dewatering and discharge portion of the USX compliance plan. The plans, which will be paid for by USX Corporation, include dredging within that reach to remove contaminants. Other plans may include the purchase and restoration of natural areas and the control of exotic species.

In addition to these efforts, the U.S. Army Corps of Engineers plans to add deflector logs and submerged gravel weirs in this reach. Deflector logs will help to stabilize the shoreline before and after dredging. Stable shoreline and gravel weirs will provide fish habitat after dredging.

Several concerns remain. Dredging around the sensitive Bongi property at the western end of this reach may cause the banks to erode in this area, thereby destroying portions of this valuable property. Bank sloughing may also cause contamination of the Bongi ponds with sediment-laden waters from the River. The banks here should be stabilized with native vegetation to minimize this impact. The Georgia Pacific Lagoon, located to the south of the river, opposite the Bongi property, is also in danger of contamination due to sediment migration. It has been suggested that a levy be built to protect this area, with tie gates to allow for fish movement in and out of the Lagoon, but these provisions are not included in the current plans for restoration.

Recommendations for the Clark and Pine property are discussed below in the section on the Gary Sanitary District reach.

Possibilities for restoration in this reach of the River have been more extensively studied during the RCRA process than by these authors, so recommendations for this reach are limited. It is highly recommended that any activities in this reach be carefully coordinated between different management agencies. Managers of nearby lands, such as INDU, should be notified in advance of any release of biocontrol organisms, or other activities likely to impact lands beyond the immediate study area.

Gary Sanitary District reach

The majority of the Gary Sanitary District reach is highly degraded, but two high quality sites are found at its eastern and western ends: Clark and Pine mostly within Gary Sanitary District at its eastern end, and DuPont just beyond the reach border to the west.

An emergent marsh runs along the southern side of the Gary Airport for much of the Gary Sanitary District reach. Wetland areas are overgrown with cattails, which greatly limit floral and faunal diversity, and the macroinvertebrate community is highly degraded. Problems with high concentrations of PAHs (polycyclic aromatic hydrocarbons) and PCBs (polycyclic biphenyls) and contaminated sediments plague the Gary Sanitary District area. The presence of a holding area for contaminated sediments likely contributes to this problem.

The Clark and Pine site has one of the highest concentrations of rare and endangered plant and animal species in the state of Indiana. It consists of two main segments, separated only by Clark street. These are Clark and Pine East to the southeast, which runs into the USX reach, and the Clark and Pine Nature Preserve to the northwest. They contain prime examples of dune and swale habitat, including extensive areas of pond, marsh, panne, sand prairie, and open sand savanna. Several smaller natural areas also occur in close proximity to these sites, and they contain many of the same community types, including a jack-pine-dominated sand savanna. Within the Clark and Pine cluster, restoration efforts should focus on exotic species removal, buffer area creation, and, where Clark and Pine East borders the river channel, on bank stabilization.

In the remainder of the reach, dredging should improve conditions by removing large amounts of contaminated sediment, and this may encourage colonization by new species of plants and other organisms. Without ongoing habitat restoration and management, however, the shoreline areas are likely to refill with exotics, and no new habitat diversity or connection with the broader ecosystem will be gained.

The marsh property on the south part of the airport has great potential for restoration as wet prairie or emergent marsh. Because the wetlands here are somewhat isolated from the River (and therefore from fish predators and the high contaminant levels present in the river channel waters and sediments), they could serve as habitat for amphibian life. Any wetland creation in this area would need to be coordinated with the Gary Regional Airport, to minimize the possibility of bird strike by planes during takeoff and landing. Because of the presence of an airport in the area, no areas of open water should be created, but the birds in a wet prairie or emergent marsh habitat generally stay low enough to the ground that creation of these habitats should not pose a problem.

A possibility for wetland expansion along the river is the building of side channels. Dredging a channel through the abundant cattails surrounding the River and re-planting around the channel with desired vegetation could create healthy wetland ecosystems. This would establish an area of decreased water flow and shallow habitat ideal for colonization where turtles could live. The braided channels' connections to the River would eventually close, and relatively protected wetlands would remain. Plant species moving into the area would be influenced by water quality as well as by physical topography, so unless all pollutant sources to the river are abated, diversity among plants will probably not be as high as among other colonizing organisms. The ideal result of creating new wetlands in this way would be to establish sedge meadow hydrology and a conservative flora and fauna after the channel has closed. The drastic alteration of the local landscape suggested here would carry with it a high risk of invasion by exotics. Careful planning, and long-term continuous monitoring and exotic species elimination would be essential to achieve the desired results.

Alternatively, areas of the bank could be dredged at a shallower level to create backwaters in the river channel proper. These, like the dredged side channels, could potentially serve as turtle habitat, but they also would need to be actively managed to prevent exotic infestation.

In-stream restoration alternatives include the creation of fish habitat in the river. Lunker boxes are structures built by embedding the ends of log platforms in the river banks and allowing them to backfill with rock. These could provide cover and shallow habitat by creating an artificial undercut bank. This should result in an increase in salmonids, and, because the boxes would be built in the open stream rather than in isolated backwaters and ponds, amphibian species should not be affected by an increase in salmonids. Altering river flow to establish large pool/short riffle sequences would also create new habitat within the river channel. These would help fish and macroinvertebrate communities by encouraging natural aeration. Suckers could spawn in the riffles.

The top priorities for restoration in this reach are to pollution-abate, protect, and manage the Clark and Pine site, and to create buffer areas and migration corridors to protect and connect the Clark and Pine and DuPont natural areas. Possible staging areas include the access road at the end of the Gary Regional airport and either side of the River at the landfill.

DuPont reach

The largest intact dune and swale habitat in this region is in the DuPont reach, and its preservation should be a high priority. The DuPont site, located along the northern bank of the Grand Calumet River between Cline Avenue and Kennedy Avenue, is an example of a smooth transition between flat wetland areas and hilly dune and swale habitat. In some areas, the swales grade down into the River, and the habitat is excellent in the dune and swale systems. DuPont is one of the last areas where natural areas connect directly with the River, and these areas should be preserved. There are also wetlands, including marsh, floodplain forest, and a high quality tract of wet prairie, are immediately adjacent to the river channel. Extensive areas of dry-mesic to wet sand prairie, dry-mesic sand savanna, and swales with sedge meadow and marsh are present as well, a bit inland from the river channel. A cottonwood stand grows at the bend in the River in a pond filled with dredge spoil, and this could be good habitat for Indiana myotis and northern myotis if enough trees are available. To the south of the River, the Tolleston Ridges and Gibson Woods Nature Preserves are worthy of attention as well, but these are isolated from the Grand Calumet River by the Indiana Tollroad. This is an effective barrier to all bit the most mobile terrestrial animals. The habitat types included in this reach range from highly degraded, cattail-infested wetlands to high quality wet prairie. Many areas have been maintained in a relatively open site because of accidental fires that have burned the tract. Amphibian and semi-aquatic mammal communities are quite healthy, and many birds forage here. Of all the reaches of the study area, this is the richest area for bird nesting, and an egret rookery here should be protected. Creating a corridor between DuPont and Clark and Pine East would extend these high quality habitats, but functional limitations due to cultural and land use would limit how successful the corridor could be.

Unfortunately, contaminants are a major problem in the DuPont reach of the Grand Calumet River because concentrations tend to increase further downstream. Fish are greatly affected, and oil-soaked birds are often observed in the area. Contamination affects shoreline plant habitat as well, but it is unknown how deep the contamination reaches into the sediment or how much contamination is present in areas that are not immediately adjacent to the channel. A large stand of cottonwood trees most likely indicates the disposal site of previous dredge spoil. Another major problem in this area is nutrient loading. Nuisance algal blooms have resulted due to deterioration in water quality. Nutrients, including nitrogen and phosphorus, likely enter from inputs upstream, and the resulting blooms do not benefit the ecosystem.

U.S.S. Lead currently has a cleanup program for this area out for public comment. One portion of the cleanup is likely to focus on the channel leading up to the U.S.S. Lead property from the River. Planners of this cleanup should take care to stabilize banks and prevent migration of contaminants into adjacent, highly restorable savanna lands. The U.S.S. Lead property contains extensive marshy habitat which is overgrown with submergent plant species. Pond weed (*Potamogeton), Redekia,* and *Elodea* are among these species, and they serve a useful function by extracting pollutants from the water and concentrating them in their own tissues.

Because it is relatively inaccessible to scientists, this area has not been studied as much as other high quality sites in the region. More study is recommended to determine the extent and impact of contamination in the high quality areas of the site. Whatever is found, there may be difficult choices to be made in this reach between cleaning contaminants and preserving current plant communities; complete removal of contamination could mean complete destruction of current habitat, so preventing destruction through creative engineering should be a high priority in this area.

We recommend that disturbance be minimized adjacent to the high quality areas (including dune/swale habitat) in this reach, and that special care be taken not to disturb the wet prairie remnants that extend to the shores of the River. Contamination along the remainder of the shoreline should be removed to the sand - deep enough to take out the seed bank. This should remove the exotics, but the banks will also need to be stabilized with new vegetation and re-grading. The strategy of creating artificial wetlands through dredging of side-channels, already discussed for Gary Sanitary District reach, could also be beneficial here provided that the natural River connection is not harmed.

In choosing a staging area for dredging equipment, designers should avoid high quality wet prairie. The boats might possibly launch from a location near the DuPont plant where the river bends close to the plant. Alternatively, they might use areas beside Kennedy Avenue where gas containers border the river. This strategy would require that two staging areas be used, one on each side of Kennedy Avenue, because the train trestle would block boat travel between them.

River water nutrient status must also be considered in designing pollution abatement strategies. Excess nutrients in River waters currently fuel growth of thick algal mats, which shade out other plant life. Nutrient loads in the waters of the Grand Calumet River could possibly be reduced by bank flooding, which would allow shoreline plants to take up nutrients from floodwaters. Historically, before the river was deepened and channelized, such flooding occurred quite often. The danger in this strategy is that contaminants from floodwaters could be deposited in shoreline soils. For this reason, water quality should be monitored intensively and deemed safe before any decisive plans for riverbank flooding are made or implemented.

Removal of exotics will be important not only along the dredge channel, but also within the high quality natural areas. In many locations of the DuPont Property, micro-habitat areas exist that are small enough, and exotic populations are limited enough, that manual control could realistically clear exotics from the sites. Ongoing plans for such removal activities are highly recommended.

A highly aggressive approach should be taken in dredging the channel here, in order to clean this particularly polluted reach, but much care should be taken to protect sensitive habitats along the banks. Further study should determine the extent of contamination in areas associated with the river by hydrology, but too far away from the channel to be included in the dredge process.

East Chicago Sanitary District reach

This section of the River contains several small remnant areas of dune and swale, as well as several very polluted areas. An area of upland meadow is present to the south of the river, between the Indiana Harbor Canal and the Roxanna Substation, which is located to the east of Indianapolis Boulevard on the north side of the river.

The upland meadow at the Roxanna Substation shows great promise as a site for restoration activities because of its connection with the high quality DuPont reach; restoration efforts could upgrade the site from a degraded remnant tract into a productive habitat.

Roxanna Marsh reach

The Roxanna Marsh reach of the River contains an open, shallow pond that was once a stopover area for shorebirds migrating between the Arctic Tundra and South America. The water level has risen during the past ten years, making the area unsuitable as a staging area for these birds. The area is now a large mudflat with very little vegetation growing on it. The area also contains several sites, dominated by a flora of large cottonwood trees, that were previously filled with dredged materials. These are each approximately 30-40 acres in size. One is located neat the Harbison-Walker property and the other is near the U.S.S. Lead. These may support bat populations, which are rare in the study area. Dredging should increase the macroinvertebrate community which will in turn provide an insect food source to bats inhabiting the area.

One option for restoration of Roxanna Pond is to manage water and vegetation levels in the spring and fall so that the area can again be used as a landing and foraging area for migrating shorebirds. There is currently no such area in the entire Midwest, and such an area is needed by the many species of birds that make long-range annual migrations. This option would require that sediments from the Pond be dredged and replaced; capping of sediments probably would not work as a substitute, because the added sediment would raise the sediment level near or above the water level, making the pond unsuitable for bird landing and foraging. A dike or berm, with gates at the inlet to Roxanna Pond should be built and regulated. Appropriate vegetation and infauna would be able to grow there, and so that the area would appeal to migrating birds. There is some concern that regulation of water levels in Roxanna Pond would impair salmonid migration in the River, but these concerns could probably be addressed within the context of the suggested plan; a control structure around Roxanna Pond probably would not provide any impediment to migration within the river channel itself, and if there were any negative impacts, water levels could be regulated in the spring and fall for shorebirds, and then left at their natural levels in fall through winter to allow for unimpeded salmonid migration. Monitoring and management would be required to enhance food and shelter conditions for migrating birds. The recommendation for a staging area should be further investigated before a final decision is made on its feasibility.

Two potential options are proposed for the cottonwood areas: The area may serve as habitat for several bat species, in which case it could be managed for use as bat habitat. Alternatively, the areas could be cut and dredged, and managed as mud flats in the same way as was proposed for Roxanna Pond. These areas should be surveyed for bat populations and for general ecosystem function, and strategies should be formulated based on the results of these surveys. Many potential staging areas are present in this reach including the old East Chicago dump.

Hammond Sanitary District reach

This reach is clogged with sewage refuse, and its waters are practically devoid of oxygen, making them toxic to fish. Areas adjacent to the river channel are overgrown with exotic plant species. Extensive dredging of both the immediate channel and the adjacent soft-side marshes will be required if any restoration is to take place in this area. Such extensive dredging will also reduce the stench that currently pervades this highly residential district. It will also be important to prevent further pollution of this area because currents here change directions with the seasons. Instead of flowing away from their source, pollutants are flushed back, and they concentrate along the banks and riverbed.

One risk in the dredging procedure here is that alterations to the riverbed may alter the hydrology of the area. The area is underlain by a bowl-shaped basin, bordered by a brim from the expressway, that causes the aforementioned reversals in current direction. If this area were leveled, it is likely that there would be an increase in the amount of water flowing to Illinois through the Grand Calumet River. This might negatively impact salmonid migration. Engineers planning the dredging for this reach should carefully examine the current riverbed formation so that this change in hydrology can be prevented.

Culverts reach

This area is highly degraded by an abundance of sewage material. The river is practically impassable due to the depth of raw sewage. Residences nearby are subjected to unpleasant odors and an unsightly river. The water is anoxic and surrounded by cattail wetlands. Removing most of the material in the channel during dredging will be an improvement, but contamination problems will persist if large portions of the riverbanks, which are also highly contaminated, are not removed as well. Any removal activity will improve conditions, but re-contamination is expected unless there is a change in sewage treatment capacity.

Far West reach

The Illinois section of the Grand Calumet River is not part of the study area, but, as a connected river reach, it merits mention in any paper concerned with the River's ecologic functioning. Burnham Prairie is a site located approximately 2 km to the west of the Illinois-Indiana state line. Unlike the Indiana sites, that are on beach or nearshore sand deposits, Burnham Prairie is on silt-loam soils deposited in somewhat deeper water. It is one of the last remaining black-soil prairies in the region. The area contains marsh, wet-mesic and dry-mesic prairie, and a small dry-mesic savanna grove with burr oak. Northern leopard frogs and plains garter snakes, rare throughout the Indiana study area, are common at this site.

Canal reach

The area around the Canal reach is primarily industrial with a few scattered residences. Surrounding the river is a great deal of sheet piling, cement, and slag. Water flow in the river is faster here than in the other reaches, and the channel is deeper. A steel wall crosses the river to control water flow. This reach represents the only connection to Lake Michigan for migrating fishes, and therefore a channel for fish passage must be maintained. There is a wetland complex near the canal, and at the place where the canal meets the Grand Calumet River there is a dune and swale remnant. This dune/swale area should be avoided as a staging area for dredging.

Lake George reach

The Lake George reach was previously dredged to Calumet Avenue. After the Federal Channel is dredged, recommendations on whether it should be connected to the Canal reach will be made.

IMPAIRED USES

The following list of "impaired uses" of the Grand Calumet River were developed by the Indiana Department of Environmental Management as part of the first Remedial Action Plan report (RAP I), and they serve as justification for planned dredging activities. The paragraphs below discuss how these impairments to river system use will be reduced by dredging, and by the implementation of recommendations made in this document.

I) Restriction on fish and wildlife consumption

Removing the contamination in the Grand Calumet River should improve fish and wildlife communities over several generations. After dredging, the best that can be hoped for in the river is to reach Lake Michigan levels of fish contamination. At that point, the same restrictions for fish consumption would apply to both water bodies. Achieving Lake Michigan levels is possible for migratory species, but catfish and carp should not be eaten, and they will probably never be safe for consumption. Continuous monitoring of contamination levels will provide an estimate of when river fish are safe under Lake Michigan guidelines. There is no appreciable hunting in the area.

ii) Tainting of fish and wildlife flavor

Assuming that dredging removes contamination, tainting should be reduced.
See *I) Restriction on fish and wildlife consumption*

iii) Degradation of fish and wildlife populations

Fish and wildlife populations will be improved only with habitat improvement following contamination removal. Dredging removes a great deal of allochthonous material and destroys areas of shallow water habitat. Fish and wildlife habitat, including shallow water areas and riffles, must be artificially created in order to encourage re-colonization. Fragmentation of habitat must also be minimized by the creation of corridors between natural areas, to prevent degradation of populations due to shrinkage of the gene pool for rare species.

iv) Fish tumors and other deformities

Fish deformities should be greatly reduced, if not eliminated, with contamination removal. See *I) Restriction on fish and wildlife consumption*

v) Bird or animal deformities or reproduction problems

Removing contaminants from the river will improve the quality of the fish, over several generations, that the birds are consuming. Therefore, there should be long-term improvement, but immediate results are not likely. There is a risk of harming bird and animal populations far from the River because many organisms that feed in the area are migratory, and this might be eliminated with contamination removal. Pollution abatement is essential to prevent re-contamination. Another potential threat is the area where dredge spoil is stored. Birds and other animals that land, live, or feed in this area will be at risk of contamination, so measures should be taken for the construction of suitable storage facilities.

vi) Degradation of benthos

Dredging should eliminate a majority of the contaminated sediment that is limiting species diversity in the benthos. Pollution abatement is imperative since most contamination accumulates in the sediment. Also, re-contamination from bank sloughing is a possibility if all of the contamination is not removed. Addition of clean sediment should promote colonization by tolerant species, provided that the appropriate sediment type is used and that water quality is improved.

vii) Restrictions on dredging activities

Contaminated sediment brought up from dredging should not pose a threat if a proper disposal plan is in place. Because of the nature of the contaminants, phototoxicity is a possibility, but if proper precautions are taken, risks can be avoided. Disposal areas should be lined and capped so that neither groundwater nor air becomes contaminated.

viii) Eutrophication or undesirable algae

Eutrophication is a result of poor water quality. To address this problem, nutrient inputs must be eliminated. Dredging will not impact the persistence of undesirable algae. Diversity will probably increase when algal species re-colonize, but blue-green algae will dominate regardless of sediment condition.

ix) Restrictions on drinking water consumption or taste and odor problems

Long-term effects on drinking water are not at issue since the public drinking supply comes from Lake Michigan. However, dredging may affect the quality of drinking water temporarily during the actual process due to the transfer of contaminated materials from the river into the lake. Drinking water sources should be tested during this process, and perhaps a water source further from the Indiana Harbor outlet should be utilized for a short time while disturbed sediments settle.

x) Beach closings

Dredging the Grand Calumet River will facilitate flow, and it will, therefore, increase the number of downstream beach closings. Bacterial contamination is a real problem due to heavy sewage input. Unless there is a change in treatment capacity, the same amount of sewage combined with faster water flow will increase the transfer of bacteria to the beaches. With restoration of some of the marsh areas along the river (Roxanna Marsh), there is the potential for a natural filtering system that might remove some of the bacterial contamination.

xi) Degradation of aesthetics

Debris scattered along the river shore and debris in the channel will be removed in the dredging process. Dredging will release a great deal of oily sediment, and therefore the oily sheen on the river will increase temporarily. Over time however, there should be a noticeable improvement in the oily appearance.

xii) Added cost to agriculture or industry

Shipping capacity and cost should improve with a decrease in sediment volume after dredging.

xiii) Degradation of phytoplankton and zooplankton

The ecosystem for phytoplankton and zooplankton is toxic now, and removing contamination can only improve conditions. Phytoplankton community structure depends on nutrients and flow rate. A decrease in nutrient loading is essential for improving the phytoplankton populations. Zooplankton are greatly affected by the toxic sediment, so dredging should be an improvement. However, more information on resident planktonic communities is needed for a thorough estimation.

xiv) Loss of fish and wildlife habitat

Fish habitat availability will decrease because of the smooth, U-shaped channel that results from dredging. Contamination should decrease and dissolved oxygen should increase, but fish populations will not be attracted to the area unless artificial habitats are created. For this reason, habitat enhancement in the river channel is an essential part of post-dredging restoration. Other animals should benefit from less contamination, but again, habitat must be created. Dredging along the banks to create shallow backwaters or to eliminate exotic seedbeds could, combined with active ongoing management, create some of this habitat. See *iii) Degradation of fish and wildlife populations.*

CONCLUSIONS

Preservation and restoration in the Calumet region are necessary to re-create viable natural systems in the wake of contamination and fragmentation from human settlement and industry. The historic habitats of the region were diverse and formed from floras of several different regions of the country. Despite extensive degradation, several rare and highly valuable natural areas remain, as fragments of the native landscape. For these to persist as viable, functioning ecosystems, extensive restoration measures must be taken. Dredging and replacement of sediments in the Grand Calumet River are first steps in the process, but they will need to be accompanied by preservation and management activities to be successful.

Dredging will remove many contaminants from the River, but it probably will not fully clean the river system and may have some negative effects. To minimize the negative effects of dredging, banks should be stabilized and fish micro-habitat should be artificially re-constructed. Pollutant concentrations in the waters and sediments of the River should be monitored after dredging to assure that they stabilize at low levels. For dredging to be effective in the long term, re-contamination of the River from point and non-point sources will have to be stopped.

Habitats of the Grand Calumet River system have been degraded not only by contamination, but by fragmentation, invasion of aggressive species, and suppression of natural processes. These problems will also need to be addressed. Buffer areas are needed to prevent further contamination of high quality areas. Corridors of semi-native habitat should be created between high quality areas, to allow for migration of species between them. Populations of invasive species should be eliminated to the greatest extent possible, and replaced with assemblages of native species. Habitats that require fire to persist should be burned on an ongoing basis. Extirpated species should, when appropriate, be re-introduced to the region. Areas should be managed to create a variety of different habitat types, and habitat for rare species should be given priority in restoration. Restoration plans will need to take current conditions, such as the unprecedented rapid flow of the present-day River, into account. It may not be possible to return to presettlement conditions, but efforts should be made to create a diverse set of ecologic conditions and habitats in today's landscape that have the potential to persist over time and, to some extent, to mimic presettlement conditions.

To accomplish the goal of an integrated, viable landscape, a new land-use ethic will have to be established. Diverse groups will need to cooperate to make restoration a consistent, long-term project. All aspects of the system will require ongoing monitoring, and plans for preservation and restoration will need to be integrated at every stage of the land-use planning process. By acknowledging that the ecologic systems of the region must be understood and maintained, we will move toward the goal of an integrated, functioning landscape where human inhabitants and native communities can successfully coexist.