# Structure and Function of Fish Communities in the Southern Lake Michigan Basin with Emphasis on Restoration of Native Fish Communities

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**ABSTRACT:** The southern Lake Michigan basin in northwest Indiana possesses a variety of aquatic habitats including riverine, palustrine, and lacustrine systems. The watershed draining this area is a remnant of glacial Lake Chicago and supports fish communities that are typically low in species richness. Composition of the presettlement Lake Michigan fish community near the Indiana Dunes has been difficult to reconstruct. Existing data indicate that the number of native species in the Lake Michigan watershed, including nearshore Lake Michigan, has declined by 22% since the onset of European settlement. Few remnants of natural fish communities exist, and those occur principally in the ponds of Miller Woods, the Grand Calumet Lagoons, and the Little Calumet River. These communities have maintained a relatively diverse assemblage of fishes despite large-scale anthropogenic disturbances in the area, including channelization, massive river redirection, fragmentation, habitat alteration, exotic species invasions, and the introduction of toxic chemicals. Data that we collected from 1985 to 1996 suggested that the Grand Calumet River has the highest proportion of exotic fish species of any inland wetland in northwest Indiana. Along the Lake Michigan shoreline, another group of exotics (e.g., round goby, alewife, and sea lamprey) have affected the structure of native fish communities, thereby altering lake ecosystem function. Stocking programs contribute to the impairment of native communities. Nonindigenous species have restructured the function of Lake Michigan tributaries, causing disruptions in trophic dynamics, guild structure, and species diversity. Several fish communities have been reduced or eliminated by the alteration and destruction of spawning and nursery areas. Degradation of habitats has caused an increase in numbers and populations of species able to tolerate and flourish when confronted with hydrologic alteration. Fish communities found on public lands in northwest Indiana generally are of lower biological integrity, in terms of structure and function, than those on private lands and are not acting as refugia for native fish populations. Stocking of nonindigenous species should be evaluated to enable the restoration of native fish communities on public lands. Habitat quality will need to be improved and land-use modifications decreased or reversed in order to restore or slow the decline in native fish communities.

*Index terms*: biological integrity, exotic species, fish communities, national park, refugia

## INTRODUCTION

One intention of the U.S. Water Pollution Control Act of 1972 was to restore the biological integrity of the nation's waters (Hocutt 1981). Similarly, one of the main tenets of the National Park Service Organic Act of 1916 was "to conserve . . . the wildlife therein . . . for the enjoyment of future generations." Knowledge of biological diversity in most areas is poor (Allen and Flecker 1993), and our national parks are not an exception (Stohlgren et al. 1995). Karr and Dudley (1981) defined biological integrity as "the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats of the region."
In order to quantify the decline of biological integrity (Hocutt 1981, Karr and Dudley 1981) in a system, reference conditions and multimetric indices must be designed and calibrated for assessment (Davis and Simon 1995). In past eras, the streams and rivers of the Lake Michigan basin were probably coldwater or coolwater streams. Typically, these streams possessed fewer individuals and had lower biomass than warmwater streams of the Central Corn Belt Plain (Mundahl and Simon 1998). Simon (1991) developed expectations for fish community structure and function in the streams and rivers of the Lake Michigan basin of the Central Corn Belt Plain. Simon (1998) also evaluated palustrine wetlands of that region. However, few studies have examined the nearshore of Lake Michigan, precluding the development of an index of biotic integrity for this area (Meek and Hildebrand 1910; T. Simon, unpubl. data).

The health of a stream ecosystem depends on the surrounding watershed (Maughan and Nelson 1980, Menzel et al. 1984, Bain et al. 1988). Land-use practices in the watershed can negatively impact the water body and its resident fish populations. Wetlands in northwest Indiana have been extensively drained, rivers channelized and reversed, river mouths filled, and rivers contaminated (Moore 1959; Simon 1989; T. Simon and P. Moy, unpubl. data). The rivers of the Lake Michigan region have experienced some of the most destructive alterations known in riverine systems.

Extensive restoration work in northwest Indiana has identified and restored plant communities (Choi and Pavlovic 1994, 1995), examined fire effects on Karner blue butterflies (*Lycaeides melissa samuelis* Nabokov; Kwilosz and Knutson 1999, Knutson et al. 1999), and gathered information necessary for restoring wetlands (Stewart et al. 1997). Except for stocking of game fish (including nonindigenous species) for recreational fisheries, none of this restoration activity includes native fish communities. It is necessary to measure the departure of native fish community structure and function from historical conditions if the biological integrity of these communities is to be restored.

Restoration and maintenance of native fish communities in northwest Indiana must overcome significant obstacles (e.g., riparian corridor impact and presence of nonindigenous species). To determine the effectiveness of the state and national parks as refugia, it is essential to examine the fish fauna from several perspectives. (1) Is the fish community at Indiana Dunes and northwest Indiana representative of native fish populations prior to extensive urban and industrial development? (2) Do the Indiana Dunes National Lakeshore and State Park (public lands) fish communities serve as a "least-impacted" area or reference condition for the Lake Michigan drainage compared to communities outside of public lands? (3) What can the present level of fish stocking in the area tell us about ecosystem health? (4) How have exotic or nonindigenous species influenced native fish populations? (5) What additional information needs to be gathered prior to initiating a native fish population restoration effort in northwest Indiana?

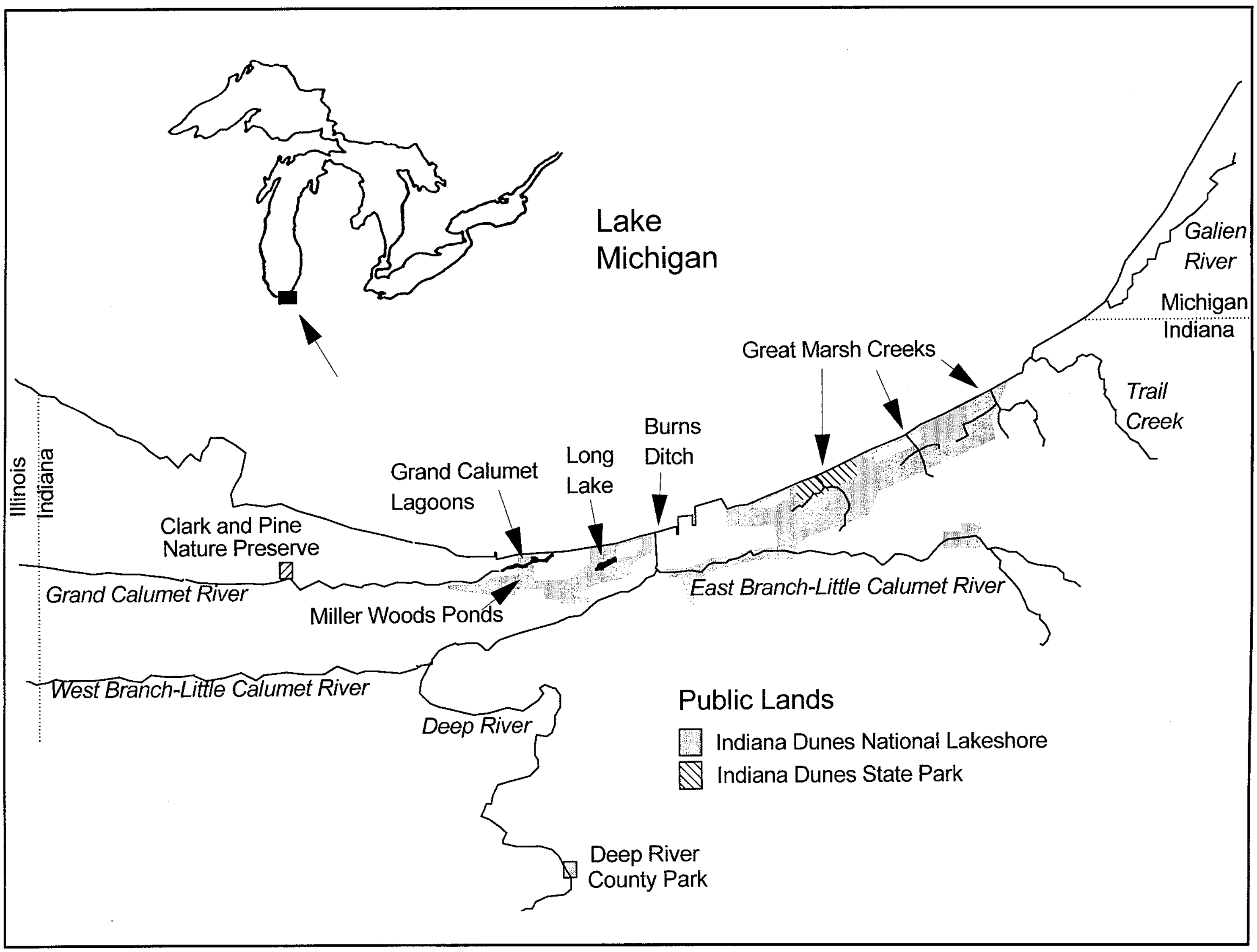


**Figure 1. Location of study area along southern Lake Michigan showing location of streams and land use indicating public holdings.**

## MATERIALS AND METHODS

### Study Area

The southern Lake Michigan drainage (Figure 1) in the Calumet Region of northwest Indiana has a complex geological history (Chrzastowski and Thompson 1992). This includes a series of declines in Lake Michigan water levels that contributed to the build-up of dune and swale topography. This landscape includes rows of ponds that parallel the Lake Michigan shore. Those nearest the present lake shore are the youngest, and pond age increases with increasing distance from the present shoreline. The drainage also contains several large wetlands and water bodies between the rows of dunes (e.g., the ponds of Miller Woods and West Beach, the Great Marsh, and Long Lake). This area also includes riverine systems such as the Grand Calumet and Little Calumet Rivers and tributaries, Trail Creek, and the Galien River. These principal watersheds drain both public and private lands.

Public lands in northwest Indiana include the Indiana Dunes National Lakeshore (INDU), Deep River County Park, Clarke and Pine Nature Preserve, and Indiana Dunes State Park (IDSP), while private lands are those in private ownership. The INDU was established in 1966 to offer recreational opportunities for the public and to serve as an area for protection of native biota. Streams in this area are primarily lowland streams characterized by long, deep pools and short, shallow riffles. These streams lack significant habitat heterogeneity as characterized by a variety of substrates. Available habitat structure is primarily woody debris from fallen deciduous trees. Wetland draining, channelization, and removal of riparian corridors destroyed habitat stability by reducing the amount of the formerly prevalent emergent wetlands.

Major impairments to the structure and function of northwest Indiana's aquatic habitats include channelization, water quality degradation, addition of toxins and agrochemicals, agricultural sedimentation, drainage, deforestation, and the addition of nonindigenous species (U.S. Environmental Protection Agency 1985, Simon 1989, Sly 1991, Hartig and Zarull 1992, Jude et al. 1995). Water quality in the Grand Calumet River has been severely degraded and in certain reaches does not support native fish populations (Simon et al. 1989). Only recently have some fish species returned to the most heavily degraded habitats (Simon et al. 1989).

### Sample Collection

Fish community structure and function in northwest Indiana were determined from daytime inventories conducted between June and October from 1985 to 1996. Complete community sampling was required to characterize sites and determine long-term patterns in fish community dynamics. We evaluated depressional and riverine wetland sites with a variety of collection techniques and methods (Ohio Environmental Protection Agency 1989). For each site, representative samples were collected to document species diversity and relative abundance (Hocutt et al. 1974). All habitats within a sample area were surveyed relative to their frequency.

Riverine wetlands included headwater streams, ditches, and moderate-sized rivers. Longitudinal sampling distances were 15 times the average stream wetted width, with a minimum sampling distance of 50 m and a maximum of 500 m. Sampling was conducted with a 3.3-m common sense minnow seine (3.1-mm mesh) in small headwater streams (less than 3 m across). For stream widths of 1–5 m (e.g., Trail Creek) a long-line electrofishing technique using a T&J 1750-watt generator capable of 240-v DC output with 6–8 amps was used in an upstream, serpentine manner. The decision of whether to use a seine or long-line system depended on depth and habitat complexity. Streams with a high degree of habitat complexity were sampled using the electrofishing gear. Streams wider than 5 m (e.g., East Branch Little Calumet River) were sampled with a tote-barge configuration using the T&J generator and were generally sampled along both banks. Sampling upstream was conducted along one bank and downstream along the other bank. In nonwadable streams (e.g., mouth of Salt Creek), we used a DC canoe-mounted electrofishing unit consisting of a T&J 1,750-watt generator configuration with the net serving as the anode. In the largest river sizes (e.g., Grand Calumet River and Burns Ditch), either a canoe or an 18-foot Coffelt electrofishing unit was used. The boat electroshocker included a 5,000-watt Honda generator with a VVP-15 unit with pulsed DC output and a bow-mounted electrosphere. In canoe and boat-mounted collections, both shorelines were inventoried for a minimum of 2,300 seconds for distances of 500 to 1,000 m.

Three techniques were used for Lake Michigan sampling: beach seining, visual transect surveys by SCUBA, and boat-mounted electrofishing. Lake Michigan beach seining was done with a 50-foot bag seine with 1.6-mm mesh. Seines were waded to depths of 2 m and then pulled into shore along 500 m of shoreline. Visual transects by SCUBA estimates involved two divers swimming a perpendicular transect for 1000 m from shore, then proceeding every 50 m along a serpentine series of transects parallel to shore. All fish encountered were visually identified and counted.

Electrofishing in Lake Michigan was done by fishing parallel to shore for minimum distances of 500 m for at least 2,300 seconds. All habitats encountered were sampled including depressions, rip-rapped sea walls and breakwaters, and beaches. Surf and littoral zones of beaches were sampled by dragging the electrosphere in the water along the shoreline. Stunned fish were netted and placed into a live well for identification, enumeration, and batch weighing. Fish were inspected for gross external deformities, eroded fins, lesions, and tumors (DELT) and released. Smaller species such as minnows, darters, madtoms, and sculpins were preserved in 10% formalin. Preserved specimens were identified in the laboratory using standard taxonomic references (Gerking 1955, Smith 1979, and Becker 1983); scientific and common names follow Simon et al. (1992).

### Reference Conditions

Simon (1991) developed reference condition expectations for the Lake Michigan drainage of northwest Indiana. Pristine sites (i.e., those that could represent reference sites) do not exist in northwest Indiana. Therefore, we sampled a range of habitats and streams draining the watershed in order to characterize the "least-impacted" conditions for the drainage—in other words, the best of the remaining areas (Simon 1991). Unfortunately, very few least-impacted areas remain. Subtle patterns of the reference condition did emerge from the cumulative data, which allowed the reconstruction of fish community characteristics (Davis and Simon 1995). These reference conditions were used to calibrate an index of biotic integrity (after Karr et al. 1986) for the southern Lake Michigan basin (Simon 1991).

Simon (1991) defined species that are considered tolerant and intolerant, assigned trophic and reproductive guild designations, and listed pioneer and headwater species. Tolerant species are those that increase under degraded conditions (Simon 1991), while intolerant species are those that are sensitive to changes in water quality and habitat modification. The percentage of pioneer species functions as a measure of the permanence of a perennial stream; an increase in the proportion of pioneer species indicates hydrologic alteration (Simon 1991). Reproductive guilds were alternative metrics proposed by the Ohio Environmental Protection Agency for streams and rivers (Ohio Environmental Protection Agency 1989). This characteristic of lotic fish communities replaced the percentage of hybrid species (Karr et al. 1986). Destruction of reproductive habitat causes the loss of species that need clean sand and gravel substrates. The loss of riverine wetland function for fish habitat and reproduction was directly measured by the percentage of simple lithophils. Catch-per-unit-effort (CPUE) is commonly used as an estimate of abundance in an area. Although CPUE is a poor abundance index when data are combined across species (Richards and Schnute 1986), we believed it was adequate for relative abundance comparisons between our sites. The percentage of deformities, eroded fins, lesions, and tumors (DELT) increases at the lowest extreme of biological integrity (Karr et al. 1986). The health of fish possessing DELT anomalies is poor and is associated with degraded water and habitat quality.

### Statistical Analysis

Statistical analyses were carried out on structural (e.g., total number of species; percentage of headwater species; number of minnow species; number of darter species; number of sunfish species; number of darter, madtom, and sculpin species [DMS]; number of salmon species; percentage of tolerant species; and number of intolerant species) and functional (e.g., percentage of omnivores, insectivores, and carnivores; percentage of pioneer species; percentage of simple lithophils; CPUE; and percentage of DELT) attributes of fish communities by standard methods (Zar 1984). Differences between public and private sites for each fish community characteristic were examined by performing a Student *t*-test for unequal observations. Significant differences in variance were determined using an F-test. Results are reported at a significance level of $P < 0.05$.

## RESULTS AND DISCUSSION

### Historical Fish Communities

Since only a few studies describing fish community composition were conducted prior to 1950 (Table 1), the presettlement fish community of northwest Indiana has been difficult to reconstruct. Past studies covered riverine wetland community characterization (Meek and Hildebrand 1910, Shelford 1911), palustrine wetland structure and function (Meek and Hildebrand 1910), and nearshore Lake Michigan fish communities (Meek and Hildebrand 1910). Although recent collections (Ledet 1978, 1979, 1980; Spacie 1988; Simon 1991; Simon and Stewart 1998) have found greater numbers of fish species for riverine and palustrine locations, a large decline in native fish species has been observed in Lake Michigan. Often, increasing biodiversity has been a result of exotic or nonindigenous species introductions and colonization (Morman 1979, Edsall et al. 1995). Better sampling methods and more intensive collection efforts led to the collection of a greater number of species during recent periods (Table 1).

The number of native species in the Lake Michigan watershed, including nearshore Lake Michigan, has declined by 22% since the onset of European settlement (Table 2). Taxa, including the blackfin cisco (*Coregonus nigripinnis*) and shortnose cisco (*C. reighardi*), have been declared extinct (Miller et al. 1989, Sommers et al. 1981). During 1994 we found the Iowa darter (*Etheostoma exile*) in the Grand Calumet Lagoons (Simon and Stewart 1998). Based on historical distribution patterns, we believe this species once had a wider range than at present, suggesting that it has been extirpated from much of its former range (Lee and Gilbert 1980). The longnose dace (*Rhinichthys cataractae*; Gilbert and Shute 1980), trout perch (*Percopsis omiscomaycus*; Gilbert and Lee 1980), and lake chub (*Couesius plumbeus*; Wells 1980) were also once more common in the nearshore of Lake Michigan (Gilbert and Lee 1980, Gilbert and Shute 1980, Wells 1980). Lake-dwelling coregonid species have also declined substantially; only the lake herring (*Coregonus artedii*) and bloater (*C. hoyi*) have either increased or maintained their distributions (Smith and Todd 1992). Keystone predators, such as lake trout (*Salvelinus namaycush*), lake whitefish (*Coregonus clupeaformis*), muskellunge (*Esox masquinongy*), and northern pike (*E. lucius*), have been either eliminated or drastically reduced in the nearshore of Lake Michigan (Table 2). Bowfin (*Amia calva*), Iowa darter, and burbot (*Lota lota*) have been reduced or eliminated by the alteration and destruction of spawning and nursery areas.

### Structural Characteristics of Fish Communities

To compare structural characteristics of fish communities between public and private lands in northwest Indiana we divided the stream sampling effort into headwater (< 50 $km^2$) streams and mid-sized streams (drainage area of 50–1,300 $km^2$). Several fish community structural characteristics in similarly sized watersheds were significantly different between private and public sites (Table 3). A number of sites on park property had either few or none of the expected structural characteristics of a "least-impacted fish community" (Simon 1991). For example, lower species richness ($t_{33.7} = 2.145$, $P = 0.039$), lower percentage of headwater species ($t_{33.7} = 2.111$, $P = 0.046$), lower number of minnow species ($t_{34} = 3.421$, $P =$

Table 1. Historical records of fish collections from the Lake Michigan drainage in Northwest Indiana. Common and scientific names follow Simon et al. (1992).

| Common/Scientific Name | Riverine | | | | | | Palustrine | | | Lake Michigan | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Meek & Hildebrand | Ledet | | | Spacie | Simon | Meek & Hildebrand | Shelford | Simon & Stewart | Meek & Hildebrand | Simon |
| | 1910 | 1978 | 1979 | 1980 | 1988 | 1990-1993[a] | 1910 | 1911 | 1994-1995[a] | 1910 | 1995-1996[a] |
| PETROMYZONTIDAE | | | | | | | | | | | |
| Least brook lamprey *Lampetra aepyptera* | | | | | | X | | | | | |
| American brook lamprey *L. appendix* | | | | | | X | | | | | |
| Silver lamprey *Ichthyomyzon unicuspis* | | | | | | | | | | X | |
| Sea lamprey *Petromyzon marinus* | | | | | | X | | | | | |
| ACIPENSERIDAE | | | | | | | | | | | |
| Lake sturgeon *Acipenser fulvescens* | | | | | | | | | | X | |
| LEPISOSTEIDAE | | | | | | | | | | | |
| Longnose gar *Lepisosteus osseus* | | | | | | | | | X | | |
| AMIIDAE | | | | | | | | | | | |
| Bowfin *Amia calva* | X | | | | | X | | X | X | | |
| CLUPEIDAE | | | | | | | | | | | |
| Alewife *Alosa pseudoharengus* | | X | | | | X | | | | | |
| Gizzard shad *Dorosoma cepedianum* | | | | X | | X | | | | | |
| SALMONIDAE | | | | | | | | | | | |
| Coho salmon *Oncorhynchus kisutch* | | X | | | | X | | | | | |
| Rainbow trout *O. mykiss* | | X | | | X | X | | | | X | X |
| Chinook salmon *O. tshawytscha* | | | | | X | | | | | X | |
| Brown trout *Salmo trutta* | | X | X | | X | X | | | | | X |
| Lake trout *Salvelinus namaycush* | | | | | | | | | X | X | |
| Lake cisco *Coregonus artedii* | | | | | | | | | | X | |
| Lake whitefish *C. clupeaformis* | | | | | | | | | | X | |
| Blackfin cisco *C. nigripinnis* | | | | | | | | | | X | |
| Kiyi *C. kiyi* | | | | | | | | | | X | |
| CYPRINIDAE | | | | | | | | | | | |
| Carp *Cyprinus carpio* | X | X | X | X | X | | | X | X | X | |
| Goldfish *Carassius auratus* | | | X | X | X | X | | | X | | |
| Grass carp *Ctenopharyngodon idella* | | | | | X | | | X | | | |
| Common shiner *Luxilus cornutus* | X | X | | | X | | | | | | |
| Hornyhead chub *Nocomis biguttatus* | | X | | | | X | | | | | |
| Golden shiner *Notemigonus crysoleucas* | X | | | X | X | X | X | X | X | | X |
| Emerald shiner *Notropis atherinoides* | | | | | X | | | | | | X |
| River shiner *N. blennius* | | | | | | | | | | X | X |
| Spottail shiner *N. hudsonius* | | X | | | X | | | | | X | X |
| Sand shiner *N. ludibundus* | | | | | | | | | | | X |
| Mimic shiner *N. volucellus* | | | | | | | | | | | X |
| Southern redbelly dace *Phoxinus erythrogaster* | | | | | | | X | | | | |

*continued*

Table 1, *continued.*

| Common/Scientific Name | Riverine: Meek & Hildebrand 1910 | Riverine: Ledet 1978 | Riverine: Ledet 1979 | Riverine: Ledet 1980 | Riverine: Spacie 1988 | Riverine: Simon 1990-1993[a] | Palustrine: Meek & Hildebrand 1910 | Palustrine: Shelford 1911 | Palustrine: Simon & Stewart 1994-1995[a] | Lake Michigan: Meek & Hildebrand 1910 | Lake Michigan: Simon 1995-1996[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bluntnose minnow *Pimephales notatus* | | X | | | | X | | | X | X | X |
| Fathead minnow *P. promelas* | | | | | X | X | | | X | | |
| Blacknose dace *Rhinichthys atratulus* | | X | | | | X | | | | | X |
| Longnose dace *R. cataractae* | | | | | | X | | | | | X |
| Rudd *Scardinius erythrophthalmus* | | | | | | X | | | | | |
| Creek chub *Semotilus atromaculatus* | | X | X | X | X | X | | | | | |
| CATOSTOMIDAE | | | | | | | | | | | |
| Longnose sucker *Catostomus catostomus* | | | | | | | | | | X | X |
| White sucker *C. commersoni* | X | X | X | | X | X | X | | X | X | X |
| Lake chubsucker *Erimyzon sucetta* | | X | | | X | X | X | X | X | | |
| Northern hogsucker *Hypentelium nigricans* | X | | | | | | | | | | |
| Bigmouth buffalo *Ictiobus cyprinellus* | | | | | | X | | | | | |
| Spotted sucker *Minytrema melanops* | | X | | | | | | | | | |
| ICTALURIDAE | | | | | | | | | | | |
| Black bullhead *Ameiurus melas* | X | X | | X | X | X | X | X | | | |
| Yellow bullhead *A. natalis* | X | X | | X | X | X | X | X | | | |
| Brown bullhead *A. nebulosus* | X | X | | X | X | X | | X | X | | |
| Channel catfish *Ictalurus punctatus* | X | | | | | X | | | X | | |
| Tadpole madtom *Noturus gyrinus* | | | | | | X | X | | X | | |
| UMBRIDAE | | | | | | | | | | | |
| Central mudminnow *Umbra limi* | X | X | X | X | X | X | X | X | | | |
| ESOCIDAE | | | | | | | | | | | |
| Grass pickerel *Esox americanus* | X | X | X | X | X | X | X | X | X | | |
| Northern pike *E. lucius* | X | X | | | | | | | | | |
| Muskellunge *E. masquinongy* | | | | | | | | | | X | |
| ANGUILLIDAE | | | | | | | | | | | |
| American eel *Anguilla rostrata* | | | | | | | | | | X | |
| GADIDAE | | | | | | | | | | | |
| Burbot *Lota lota* | | | | | X | | | | | X | |
| APHREDODERIDAE | | | | | | | | | | | |
| Pirate perch *Aphredoderus sayanus* | X | | | | | X | | | | | |
| PERCOPSIDAE | | | | | | | | | | | |
| Trout perch *Percopsis omiscomaycus* | | | | | | | | | | X | X |
| FUNDULIDAE | | | | | | | | | | | |
| Starhead topminnow *Fundulus dispar* | | | | | | | X | | | | |
| Banded killifish *Fundulus diaphanus* | | | | | | | | | | X | |

*continued*

**Table 1, *continued.***

| | Riverine | | | | | | | | Palustrine | Lake Michigan | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Meek & Hildebrand | Ledet | | | Spacie | Simon | Meek & Hildebrand | Shelford | Simon & Stewart | Meek & Hildebrand | Simon |
| Common/Scientific Name | 1910 | 1978 | 1979 | 1980 | 1988 | 1990-1993[a] | 1910 | 1911 | 1994-1995[a] | 1910 | 1995-1996[a] |
| GASTEROSTEIDAE | | | | | | | | | | | |
| Brook stickleback *Culaea inconstans* | | | | | | X | | | | | |
| Ninespine stickleback *Pungitius pungitius* | | | | | | | | | | | X |
| Threespine stickleback *Gasterosteus aculeatus* | | | | | | | | | | | X |
| ATHERINIDAE | | | | | | | | | | | |
| Brook silverside *Labidesthes sicculus* | | | | | | X | X | | X | | |
| MORONIDAE | | | | | | | | | | | |
| White perch *Morone americana* | | | | | X | | | | | X | |
| Striped bass hybrid *M. saxatilis x chrysops* | | | | | | | | | | X | |
| CENTRARCHIDAE | | | | | | | | | | | |
| Rock bass *Ambloplites rupestris* | X | | | | | | | | X | | |
| Green sunfish *Lepomis cyanellus* | X | X | X | X | X | X | X | X | X | X | |
| Orangespotted sunfish *L. humilis* | | | X | | X | | | X | | | |
| Pumpkinseed *L. gibbosus* | X | | | | X | X | X | X | X | X | X |
| Warmouth *L. gulosus* | | | | | X | X | | X | | | |
| Bluegill *L. macrochirus* | X | X | X | X | X | X | X | X | X | | X |
| Smallmouth bass *Micropterus dolomieu* | X | | | | | X | | | | | X |
| Largemouth bass *M. salmoides* | X | X | | X | | X | X | X | X | | X |
| White crappie *Pomoxis annularis* | | | | | X | X | | X | | | |
| Black crappie *P. nigromaculatus* | X | | X | | X | | | X | | X | |
| PERCIDAE | | | | | | | | | | | |
| Yellow perch *Perca flavescens* | X | | X | | | X | X | | X | X | X |
| Iowa darter *Etheostoma exile* | | | | | | | | | X | | |
| Johnny darter *E. nigrum* | X | | | | X | X | X | | X | | X |
| Logperch *Percina caprodes* | | | | | | | | | | X | |
| Blackside darter *P. maculata* | | X | | | X | X | | | | | |
| Walleye *Stizostedion vitreum* | | | | | | X | | | | | |
| COTTIDAE | | | | | | | | | | | |
| Mottled sculpin *Cottus bairdi* | | | | | | X | | | | X | X |
| GOBIIDAE | | | | | | | | | | | |
| Round goby *Neogobius melanostomus* | | | | | | | | | | | X |
| SCIAENIDAE | | | | | | | | | | | |
| Freshwater drum *Aplodinotus grunniens* | X | | | | | | | | | X | |

[a] From unpublished data

0.002), and lower number of sunfish species ($t_{30.5}$ = 2.569, $P$ = 0.015) were found at public sites than at private sites in headwater streams. The percentage of headwater species ranged from 0% to 95% at public sites, which contrasted with 12% to 28% for private sites. Most public sites had lower numbers of darter, madtom, and sculpin (DMS) and of minnows and intolerant species. These results suggest that public sites in northwest Indiana are not serving as least-impacted or reference sites for fish communities of streams; furthermore, they reflect lower biological integrity than privately owned sites in this size class. None of the characteristics of mid-sized streams were significantly different between publicly owned and privately owned lands (Table 3).

The percentage of tolerant species was highest in the Grand Calumet River (96%) followed by the Little Calumet River, the Galien River, and the Lake Michigan nearshore (Table 4). Only the Trail Creek watershed had fewer than 50% tolerant species. This watershed also had the highest percentage of intolerant species, composing 32% of the fish community. The Little and Grand Calumet river watersheds had no intolerant species, and the Lake Michigan basin (2.3%) and Galien River (1.2%) watershed had few intolerant species. The large number of tolerant species in streams on the publicly owned land was unexpected because privately owned lands would be expected to suffer higher degradation due to a greater likelihood of suffering anthropogenic impacts.

**Functional Characteristics of Fish Communities**

Functional characteristics of southern Lake Michigan fish communities are influenced by trophic guild interactions, reproductive habitat needs, and water permanence of streams draining the dune and swale areas. In our data, the mean percentage of insectivores ($t_{39.3}$ = 2.345, $P$ = 0.023) was significantly greater outside the park than inside the park, when sites for the Grand Calumet River were removed; but the percentage of omnivores ($t_{47.9}$ = 0.979, $P$ = 0.332) and percentage of carnivores ($t_{42.3}$ = -0.286, $P$ = 0.776) were not significantly different between the two areas. Fish communities sampled from public lands had wider ranges for all three trophic guilds than did those from private lands (Table 5). The percentage of omnivores from public lands ranged up to 95%, while the percentage of carnivores ranged from zero to 74%. The percentage of pioneer species was not significantly different between public and privately owned sites ($t_{49.6}$ = -0.074, $P$ = 0.942) and ranged from zero to more than 70% pioneer species. While many sites on public lands had no simple lithophils and these ranged up to 34% on privately owned sites, there was no significant difference ($t_{43.1}$ = 0.589, $P$ = 0.559) between public and privately owned lands (Table 5). Degradation of habitats probably caused the disruption of trophic and reproductive guilds, and increased populations of those species able to tolerate and flourish when confronted with hydrologic alteration.

**Table 2. Distribution and status of native fish species among habitat types in the northwest Indiana drainage of Lake Michigan. RR = range reductions, EP = extirpated from study area, and EX = extinctions.**

| | | Habitat Types | | |
|---|---|---|---|---|
| Species | Status | Lake Michigan | Riverine | Palustrine |
| Lake sturgeon | RR | X | | |
| Bowfin | RR | | X | |
| Lake whitefish | RR | X | | |
| Blackfin cisco | EX | X | | |
| Kiyi | RR | X | | |
| Shortnose cisco | EX | X | | |
| Lake trout | RR | X | | |
| Lake chub | EP | X | | |
| Longnose dace | RR | X | X | |
| Longnose sucker | RR | X | | |
| Northern pike | EP | X | X | |
| Muskellunge | EP | X | | |
| Burbot | RR | X | X | |
| Trout perch | RR | X | | |
| Iowa darter | RR | | | X |
| Deepwater sculpin | RR | X | | |

**Abundance and Individual Health of Fish Communities**

Abundance and individual health are measures of site environmental conditions. Declining environmental quality typically results in lower abundance and increased DELT. The CPUE at public sites was significantly lower, in most cases about half, than that at private sites ($t_{39.3}$ = 2.547, $P$ = 0.015). Private lands had significantly greater percentages of DELT anomalies ($t_{33.7}$ = 2.145, $P$ = 0.039) than did public lands (Table 5). Fish collected outside the park possessed greater DELT anomalies—up to 1.3% in the Lake Michigan drainage. Most of these DELT anomalies were lesions. Few fish collected on public lands had DELT anomalies. No fish collected from 1990 to 1995 in riverine wetland sampling showed any DELT anomalies. However, several fish collected from palustrine wetlands during the summer of 1996 from the Grand Calumet Lagoons had physical problems. These included a single goldfish (*Carassius auratus*) with an internal abdominal tumor that burst when dissected and expelled a clear liquid (P.M. Stewart, pers. obs.).

**Fish Stocking**

The Indiana Department of Natural Resources (IDNR) maintains a fish stocking program in northwest Indiana supporting a popular sport fishery (Table 6). The effects of fish stocking on native fish communities in northwest Indiana and on public lands have not been examined. However, the addition of keystone predator species such as coho and chinook salmon and rainbow trout can change the abundance and community composition of other trophic levels (Hambright et al. 1986, Schofield et al. 1988). A decline in biological integrity may result from fish either being stocked directly into national park waters or swimming into public areas (e.g., Little Calumet River and Grand Calumet Lagoons; J. Francis, Indiana Department of Natural Resources, Indianapolis, pers. com.).

## Influence of Nonindigenous Species

Large-scale disturbance enables exotic species to colonize and disperse into areas impaired or heavily modified by anthropogenic activities (Fox and Fox 1986, Orians 1986, Mills et al. 1993). The presence of exotic species results in changes to the structure and function of fish communities, further impairing biological integrity (Elton 1958, Mooney and Drake 1986, Vitousek 1986, Meng et al. 1994, Krueger et al. 1995, Moyle and Light 1996). We found sixteen nonindigenous and exotic species in Lake Michigan and its tributaries (Table 7). Exotic species composed the highest percentages of fish found in the Grand Calumet and Lake Michigan collections—more than 50% in each area (Table 4). In contrast, the Little Calumet River and Trail Creek samples had about 12–14% exotic species. The Galien River was the only tributary watershed of southern Lake Michigan where exotic or nonindigenous species were not collected.

**Table 3. Structural metric means and ranges for fish communities in headwater and mid-sized streams in the Lake Michigan drainage on public lands, and in the remainder of northwest Indiana. Headwater streams have a drainage area <50 km$^2$ and mid-sized streams are >50–1300 km$^2$ (Simon 1991).**

| Attribute | Private (mean±SD) | Public (mean±SD) | *P*-value[a] |
|---|---|---|---|
| HEADWATER STREAMS | (N = 20) | (N = 16) | |
| Total number of species | 6.85±3.51<br>5–11 | 4.50±3.06<br>2–13 | 0.039 |
| Number DMS spp. | 0.5±0.68<br>1–2 | 0.38±0.50<br>0–1 | 0.533 |
| % Headwater species | 18.4±6.75<br>12–28 | 6.7±10.88<br>0–95 | 0.046 |
| Number minnow spp. | 2.4±1.60<br>1–3 | 0.75±1.29<br>0–3 | 0.002 |
| Number intolerant spp. | 1.15±1.694<br>0–4 | 0.69±1.58<br>0–1 | 0.404 |
| Number sunfish spp. | 1.85±1.73<br>2–4 | 0.69±0.95<br>1–4 | 0.015 |
| MID-SIZED STREAMS | (N = 11) | (N = 6) | |
| Total number of species | 9.46±4.66<br>6–15 | 9.17±6.46<br>8–22 | 0.926 |
| Number darter species | 0.36±0.51<br>0–2 | 0.83±1.17<br>0–2 | 0.384 |
| Number sunfish species | 3.09±1.92<br>2–3 | 3.17±1.47<br>2–5 | 0.929 |
| Number salmon species | 0.36±0.81<br>0–2 | 1.0±1.1<br>1–2 | 0.247 |
| Number intolerant species | 1.18±1.47<br>0–6 | 1.33±2.34<br>0–4 | 0.889 |
| % Tolerant species | 64.9±32.89<br>25–50 | 62.27±28.44<br>39–70 | 0.866 |

[a] *P*-value refers to *t*-test comparison of means.

## Information Needs for Restoration

The negative impacts of natural and anthropogenic disturbances on fish community structure and function are well-documented (Matthews and Styron 1981, Ross et al. 1985, Pearsons et al. 1992, Allen and Flecker 1993). Yet little information exists, with the exception of the study by Simon et al. (1989), on the effects of such disturbances on native fish communities in northwest Indiana. Reference data are needed to address fish restoration options, categorize imperiled habitats, and evaluate patterns in fish community response. Limiting factors in northwest Indiana include habitat loss, sediment contaminant burdens and sinks, and degraded water quality. The interactions between impact and pattern of community response need to be assessed prior to restoration. Also needed are inventories that evaluate recolonization sources for species. Stocking of nonindigenous species should be studied to determine the relationship of that practice to long-term spatial and temporal disruptions to communities of native species.

Once reference conditions for physical habitat are known, there will be a model for restoration goals. Mitigation and restoration goals and initiatives for native species should be directed toward the return of habitat to its historic condition. For example, the greatest number of species we observed in the southern Lake Michigan drainage was on public lands (Table 3). If these watersheds were truly coldwater or coolwater streams, high species richness would not be expected. There were fewer darter species and a greater range in the number of intolerant species at the

Table 4. Comparison of fish community attributes of Lake Michigan tributaries, 1985 to 1996. N = number of collections in each watershed.

| Watershed | N | Percent exotic | Percent tolerant | Percent intolerant |
|---|---|---|---|---|
| Lake Michigan | 27 | 52.6 | 55.7 | 2.3 |
| Little Calumet | 14 | 11.8 | 66.3 | 0 |
| Grand Calumet River | 38 | 59.3 | 95.6 | 0 |
| Trail Creek River | 5 | 13.6 | 38.5 | 32.0 |
| Galien River | 12 | 0 | 65.9 | 1.2 |

Table 5. Functional characteristics, abundance, and individual health attributes of fish communities of the Lake Michigan drainage on public lands, and in the remainder of the watershed.

| Attribute | Private (N = 29) | Public (N = 23) | *P*-value |
|---|---|---|---|
| % Omnivores | 36.01±34.9 | 26.62±33.94 | |
| | 19–39 | 6–95 | 0.332 |
| % Insectivores | 44.00±30.6 | 31.91±34.38 | |
| | 25–50 | 3–96 | 0.193 |
| % Carnivores | 6.65±13.62 | 7.88±16.58 | |
| | 0–5 | 0–74 | 0.776 |
| % Pioneer spp. | 17.02±28.69 | 17.66±33.84 | |
| | 25–49 | 0–73 | 0.942 |
| Catch-per-unit-effort | 99.38±102.28 | 45.91±42.92 | |
| | 50–150 | 18–180 | 0.015 |
| % Simple lithophils | 4.05±8.454 | 2.82±5.65 | |
| | 0–34 | 0–20 | 0.559 |
| % DELT[a] | 0.01±1.2 | 0.0±0 | |
| | 0–1.3 | 0 | 0.039 |

[a] Deformities, eroded fins, lesions, and tumors.

Table 6. Annual stocking (in thousands) of predator species in northwest Indiana in Lake Michigan and tributary streams (J. Francis and R. Robertson, Indiana Department of Natural Resources, Indianapolis, pers. com.).

| Species | Lake Michigan | Trail Creek | INDU |
|---|---|---|---|
| Channel catfish | | | 1.3[a] |
| Chinook salmon | 150 | 100 | 100[b] |
| Coho salmon | | 60 | 90[b] |
| Rainbow trout (2 strains) | | | |
| Skamania (spring) | 65 | 65[b] | |
| (fall) | | ~25 | ~25[b] |
| Michigan | | 60 | 60[b] |

[a] Fish stocked in East Grand Calumet Lagoons, Marquette Park, Gary.
[b] Fish stocked north of Route 20 at Howe Road (at Little Calumet River km 12.2).

private sites. The percentage of tolerant species was not significantly higher at public sites than in the rest of the southern Lake Michigan drainage (Table 3). Fish zoogeography must be considered when setting biological goals and determining reference condition expectations (Hocutt and Wiley 1986, Simon 1991).

Even though public lands currently are not functioning as refugia for fish communities, areas of high biological integrity with least-impacted biological diversity do exist. The highest quality palustrine wetland in our study was the middle Grand Calumet Lagoon. At this site, intolerant, lake-obligate species were collected including lake chubsucker (*Erimyzon sucetta*), Iowa darter, and grass pickerel (*Esox americanus*). The highest quality riverine wetlands included Reynolds Creek (headwaters of the East Branch of the Little Calumet River) and the Little Calumet River upstream of Mineral Springs Road. Although nonindigenous species are present at both sites, native species dominate the community. Both areas are located in the upper Little Calumet River drainage. These sites can serve as a species source pool for enhancing recolonization efforts and as models for water quality and habitat restoration.

## CONCLUSIONS

An examination of the U.S. government list of threatened and endangered fish species from 1979 to 1989 showed that 26 species were removed from the list (Williams et al. 1989). Specific changes in the list were the result of taxonomic changes (11 species), discovery of additional populations (5 species), and extinction (10 species). Not a single species was removed from the list due to successful recovery (Allen and Flecker 1993). Extinctions of 27 fish species have been documented for the past 100 years in the United States. The Great Lakes were among those regions that suffered the greatest loss of fish species (Miller et al. 1989).

The Lake Michigan drainage once possessed important wetland habitats that served as spawning and nursery areas to resident and transient fish communities (Goodyear et al. 1982). Native fish populations in adjacent watersheds have declined by 67% in the

Table 7. Nonindigenous and exotic species of the Lake Michigan drainage and public holdings.

| Species | Lake Michigan | Tributaries | Public |
|---|---|---|---|
| Sea lamprey | X | X | |
| Alewife | X | X | X |
| Coho salmon | X | X | X |
| Chinook salmon | X | X | X |
| Rainbow trout | X | X | X |
| Atlantic salmon | X | | |
| Brown trout | X | X | |
| Carp | X | X | X |
| Goldfish | X | X | X |
| Grass carp | X | X | |
| Rudd | X | X | |
| Threespine stickleback | X | | |
| Ninespine stickleback | X | | |
| White perch | X | X | |
| Striped bass hybrid | X | | |
| Round goby | X | | |

Illinois River and by 44% in the Maumee River (Karr et al. 1985). Fish communities have been altered due to anthropogenic changes in the landscape, including drainage of wetlands, channelization, introduction of toxins, and the addition of nonindigenous species (Simon 1991). These threats along with over-fishing have led to historical changes in Great Lakes fish communities (Hartman 1988).

Our comparison of historic and current studies suggested that the number of native fish species in the Lake Michigan watershed of northwest Indiana has declined by 22% since the onset of European settlement. We believe that population densities have also been altered; however, little background data exist to support such a conclusion. Few areas in northwest Indiana, including most sites on public lands, qualify as "least-impacted." We found that in terms of the structure and function of fish communities, public lands generally possessed lower biological integrity than private lands. Public lands in the southern Lake Michigan region are not serving as refugia for native fish populations in northwest Indiana.

Stocking programs exist for channel catfish in the Grand Calumet Lagoons and for nonindigenous salmonids in the Little Calumet River and Lake Michigan. To restore the native fish communities on public lands, stocking of nonindigenous species needs to be evaluated to ensure that native fish communities are not adversely affected.

Recent estimates suggested that 139 nonindigenous species occur in the Great Lakes Basin, including 25 fish species (Mills et al. 1993, Edsall et al. 1995). The increase of exotic species has contributed to the decline of native species. Our study demonstrated that greater numbers of exotic species exist on private lands than on public lands; however, dispersal into aquatic habitats on public lands has not been restricted, nor have attempts to reduce migration been explored. The percentage of exotic species found in our study was highest in the Grand Calumet River and nearshore Lake Michigan (over 50%) and lowest in the Galien River, Little Calumet River, and Trail Creek.

Improvements in native species richness and biological integrity will require extensive habitat restoration to achieve a goal of "no net loss of species." The public lands that we sampled, with the exception of the Middle Grand Calumet Lagoon and two sites in the upper Little Calumet River, are experiencing heavy impacts from large-scale anthropogenic disturbances and are not functioning as fish refugia. The ecological integrity of these sites needs to be further evaluated to permit the development of models for restoration efforts. Habitat quality needs to be improved and land-use modifications decreased to restore or slow the decline in native fish communities. In addition, natural systems must be protected against introductions of exotic and nonindigenous species. Without a commitment to native species restoration, continued decline in the native fish communities of the Lake Michigan drainage is inevitable.


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