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DISTRIBUTION OF FISH ASSEMBLAGES IN THE VALPARAISO CHAIN OF LAKES, PORTER COUNTY, INDIANA, WITH EMPHASIS ON LAKE CONDITION ASSESSMENT

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ABSTRACT. The Valparaiso lakes include a moraine chain that separated the high beach ridge of geological Lake Chicago from the Kankakee River of the Illinois River drainage. Only a single historical fish collection was made in any of the Valparaiso lakes prior to 1950, but the Department of Natural Resources has conducted surveys from the mid-1960s until present in Flint, Long, Loomis, Spectacle, and Wauhob lakes. Species diversity in the lakes is relatively low and is comprised of 34 species in 10 families. Three exotic species, including *Carassius auratus*, *Cyprinus carpio*, and *Ctenopharyngodon idella*, have invaded the lakes. The most diverse families in the Valparaiso chain of lakes include the Centrarchidae and Cyprinidae (8 species each). In Mink Lake, which is the only historical lake sampled between 1941 and 2000, species richness increased while biological integrity decreased. The condition of the lakes, based on a lake calibrated index of biotic integrity for northern Indiana, showed that biological integrity ranged between "very poor" and "fair" compared to the reference "least disturbed" condition.

Keywords: Limnology, Porter County, fish assemblages, biological condition, biological diversity

There is limited information concerning the species composition and relative abundance of glacial lake fish available for most areas of North America (Frey 1986). The Indiana Lakes and Streams Survey sampled many lakes in northeastern Indiana (Johnson 1945; Ricker 1945a, b; Ricker 1942a, b; Wohlschlag 1950; Gerking 1950a, b), but the Valparaiso moraine lake chain (Porter County) received limited attention during the last century (Gerking 1945). Few lake collections were made prior to 1950, the only exception being Mink Lake, which was sampled in 1941.

The species diversity and biological condition of the Valparaiso lake chain has declined over the last century as the watershed has developed. Anthropogenic disturbance has resulted in increased eutrophication of the watershed. There is heavy pressure for recreational angling and boating. Increased residential land use around the perimeter of most of the lakes has caused even more distrubance. The available natural habitat has been reduced by the removal and treatment of aquatic plant beds, which are necessary as spawning and nursery habitat for fish. The establishment of seawalls and boat docks to extend residential lands have resulted in the loss of watershed riparian corridors.

Fisheries management studies of the Valparaiso moraine chain of lakes were done between the mid-1960s and 2002 by the Indiana Department of Natural Resources (R. Robertson unpubl. data). Loomis, Spectacle, and Flint lakes are among the three most frequently sampled lakes; however, Long and Wauhob lakes have also been sampled several times. With an increasing need to provide recreational opportunities for sport anglers, management of largemouth bass (*Micropterus salmoides*) and sunfish populations have received increasing attention. These species are dominant members of the fish assemblages of the chain of lakes. Recent sampling intensity has increased the total number of moraine lakes surveyed to 12 (T. Simon unpubl. data). Sampling was conducted between 1997–2000 for two projects, including the Advanced Identification of Wetlands (ADID), a project conducted by U.S. Environmental Protection Agency and the development of biological reference condition derivation for northern Indiana lakes.

The purpose of this study is to document the distribution of the Valparaiso moraine chain of lakes; describe the species richness, structure, and function of fish assemblages; and document invasive species threats. In addition, there are many environmental threats that require further management: sport fishing, water quality, watershed nutrients, and biological pollution of the lakes.

METHODS

Study area.—As the Wisconsian glacier advanced and piled alluvial sediments, it carved and shaped the land to form a series of pockets and depressions that became the Valparaiso chain of lakes. These lakes drained the Valparaiso moraine, an area in northwest Indiana (central Porter County) that contained glacial melt water, into geological Lake Chicago (now Lake Michigan).

Humans have had a devastating effect on the Valparaiso moraine and land use within the watershed. The damming of creeks (e.g., Saeger Lake and Lake of the Four Seasons) and the creation of deepwater wetlands (e.g., Lake Louise) for water storage and recreation have changed the hydrology of the area. Since these dammed watersheds are not natural components of the landscape, we chose not to include those lakes in our list of Valparaiso moraine lakes, although we did sample them. Besides the changes in water storage capacity, residential development along the shoreline, and septic leachate entering the lakes, other anthropogenic disturbance has had some effects on the chain. Instead of draining into Lake Michigan as they formerly did, the lakes now drain into the Kankakee River (F. Veraldi, U.S. Army Corps of Engineers, pers. commun.). In addition, several of the lakes, e.g., Loomis and Long lakes, have been artificially connected by canals to facilitate transport and recreational travel between the lakes.

For this paper, we describe the fish assemblages of 12 natural lakes that are part of the Valparaiso moraine chain of lakes (Fig. 1): Bullseye, Canada, Clear, Deep, Flint, Long, Loomis, Mink, Moss, Round, Spectacle, and Wauhob lakes. Many smaller ponds and shallow wetlands within the area were not sampled. We recognize that increased sampling in these small ponds and shallow wetland habitats may result in additional species, but we believe that the majority of species are documented in our studies from the main lakes.

Sample collection and reach selection.—Fish were collected using a representative sampling approach. Species are sampled in their relative abundance and not true abundance. Most fish sampling approaches are generally incomplete since individual fish cannot be seen, and rather rare species are usually under-sampled. Our sampling approach used boat-mounted electrofishing equipment capable of applying 250–300 v, pulsed DC current, with 2–3 amps into the water. A single netter was positioned on the bow of the boat and, using a long-handled dip net, attempted to collect every individual fish that was seen. Fish were placed into a live-well until completion of the reach. All fish were identified using Gerking (1955), Smith (1979), or Becker (1983). Fish were counted and the maximum and minimum lengths were recorded (mm TL). Batch weights (g) were recorded for each species and each individual was inspected for deformities, eroded fins, lesions, and tumors (DELT) anomalies.

Reach selection was based on natural shoreline features of each water body. For example, intact riparian corridors consisting of wetlands, natural vegetation, or deciduous trees were preferred over boat slips, steel sheet piling, manicured lawns, or rock rip-rap. These natural feature areas were determined to have the greatest diversity and most natural fish assemblage attributes of the water body. The number of lake reaches sampled within a single lake was determined by lake surface area (ha). Each lake reach was 500 m, which in the smallest lakes (e.g., Bullseye Lake) almost covered the entire lake shoreline. The smallest lakes were sampled at a minimum of two reaches. Lakes between 20–100 ha had two natural shoreline sites sampled, those with 100–1000 ha had three sites sampled, and lakes greater than 1000 ha had four sites sampled. This enabled greater sampling intensity in larger lakes without expending too much effort in smaller lakes.

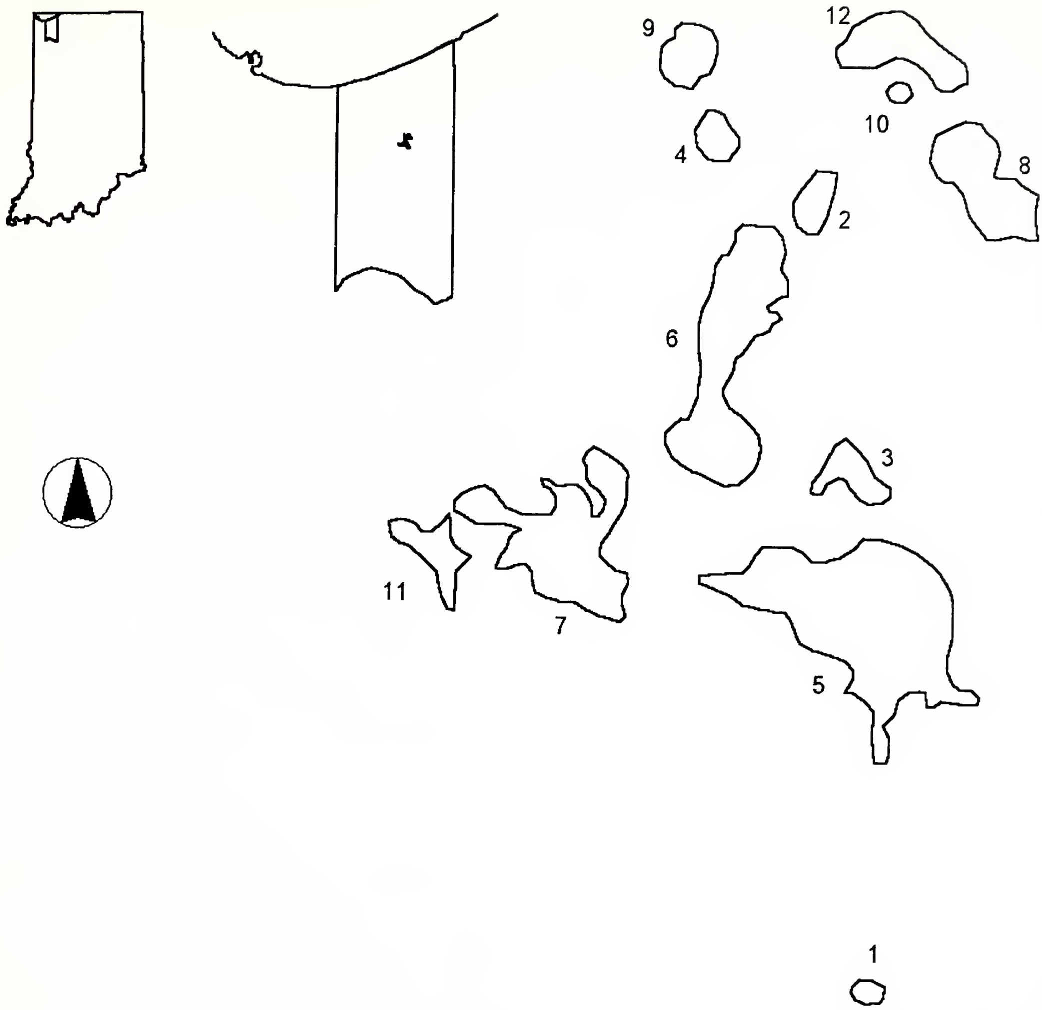

Figure 1.—Distribution of Valparaiso moraine chain of lakes included in this study, from which fish were collected between 1964 and 2001. Lakes identified by number throughout this paper include: Bullseye = 1, Canada = 2, Clear = 3, Deep = 4, Flint = 5, Long = 6, Loomis = 7, Mink = 8, Moss = 9, Round = 10, Spectacle = 11, and Wauhob = 12.

Biological integrity.—Lake management benefits from an estimate of condition, so that a reference or standard can be used to determine the waterbody quality. Karr et al. (1986) developed a quality assessment index for streams and flowing waters that relies on 12 attributes of stream fish assemblages. This same approach was instituted to evaluate the quality of lake-fish assemblages in northern Indiana lakes in the Central and Eastern Corn Belt Plains, Huron-Erie Lake Plain, and Northern Indiana Till Plain Ecoregions (Simon 2001). Twelve attributes of lake fish assemblages were tested to develop a reference condition for lakes greater than 20 ha.

The index attributes for each fish species occurring in northern Indiana lakes were based on published reproductive guilds (Simon 1999), trophic dynamics (Goldstein & Simon 1999), tolerance (Simon 1991), and habitat specialization characteristics. Each species was classified into the respective guild and species associations. These species memberships were then calibrated to formulate the reference or "least impacted" condition.

Table 1.—List of fish species collected between 1941 (Gerking 1945), 1997, and 1998 in Mink Lake, Porter County, Indiana (current study).

Species	Year 1941	1997	1998
Amia calva	X		
Ctenopharyngodon idella			X
Erimyzon sucetta		X	
Umbra limi		X	X
Esox americanus	X	X	X
Esox lucius	X	X	X
Fundulus dispar	X		
Fundulus notatus	X		
Ameiurus nebulosus			X
Lepomis gulosus		X	X
Lepomis macrochirus	X	X	X
Lepomis gibbosus	X	X	
Lepomis microlophus			X
Micropterus salmoides	X	X	X
Pomoxis annularis			X
Pomoxis nigromaculatus		X	
Total species	7	8	10

RESULTS AND DISCUSSION

Historical changes.—Limited information is available to evaluate changes in the species richness of Valparaiso lakes. Gerking (1945) sampled Mink Lake in 1941, at which time 7 fish species were collected (Table 1). Our unpublished sampling of this lake found 8 species in 1997 and 10 species in 1998. The total combined fish list of species for Mink Lake is 16. However, much of the increased number of species is not "natural," but is a result of stocking. The grass carp (*Ctenopharygodon idella*), northern pike (*Esox lucius*), and redear sunfish (*Lepomis microlophus*) have all been stocked in Mink Lake. It is possible that other sunfish species have likewise been stocked, but their native presence in other Valparaiso Lakes would make it difficult to separate introduced from native individuals. The increased number of species as a result of stocking represents 18.8% of the fish diversity in Mink Lake.

Fish in Valparaiso chain of lakes.—Thirty-four fish species in 10 families have been collected from the Valparaiso chain of lakes (Table 2). The dominant families are the sunfish and minnows, each of which is represented by 8 species. Species diversity of the Valparaiso lakes appear to have remained stable.

As the lakes have become more similar as a result of residential development and eutrophication, sensitive species of fish are declining. Attempts to increase recreational angling and the increase of human population have caused anthropogenic disturbances along these lakes. For example, sensitive species occurring in the lake chain are generally only found in Flint, Round, Wahaub, Clear, and Long lakes. These lakes possess a portion of natural shoreline habitat. The remaining lakes have a broad-based community that is ubiquitous, dominated by bluegill (*Lepomis macrochirus*), warmouth (*L. gulosus*), and largemouth bass (*Micropterus salmoides*). These species can be found throughout the entire lake chain, and competition between the species has caused unbalanced community function and fewer native non-game species.

Structure and function of Valparaiso chain of lake fish assemblages.—The altered fish assemblage of the Valparaiso chain of lakes consists of a simple community structure that is designed to enhance top-level carnivore production. With the interest in increasing numbers of larger largemouth bass, the remainder of the fish assemblage has been neglected. This has resulted in a loss of biological diversity, community structure, and biological integrity for these water bodies and has resulted in fewer high-quality lakes. For example, the highest number of species based on a single collection in any of the lakes is 15 species in Flint Lake, followed by 12 species in Wauhob Lake. Compared to regional expectations, the higher diversity of Flint Lake equals an average condition for a lake of similar size, while Wauhob is equal to the highest quality reference lake among those remaining in northern Indiana (Simon 2001).

The anthropogenic changes that have caused decreased stability in community structure are also producing signs of stress on community function. As species are managed towards top level carnivore production, fewer numbers of forage base species are present. Thus, the trophic pyramid is inverted so that instead of a large forage base supporting a small top carnivore base, large numbers of top carnivores are forced to feed on a small forage base. This type of stability can be sustained for short periods of time; however, the performance of such a system cannot produce continued trophy level fish without causing

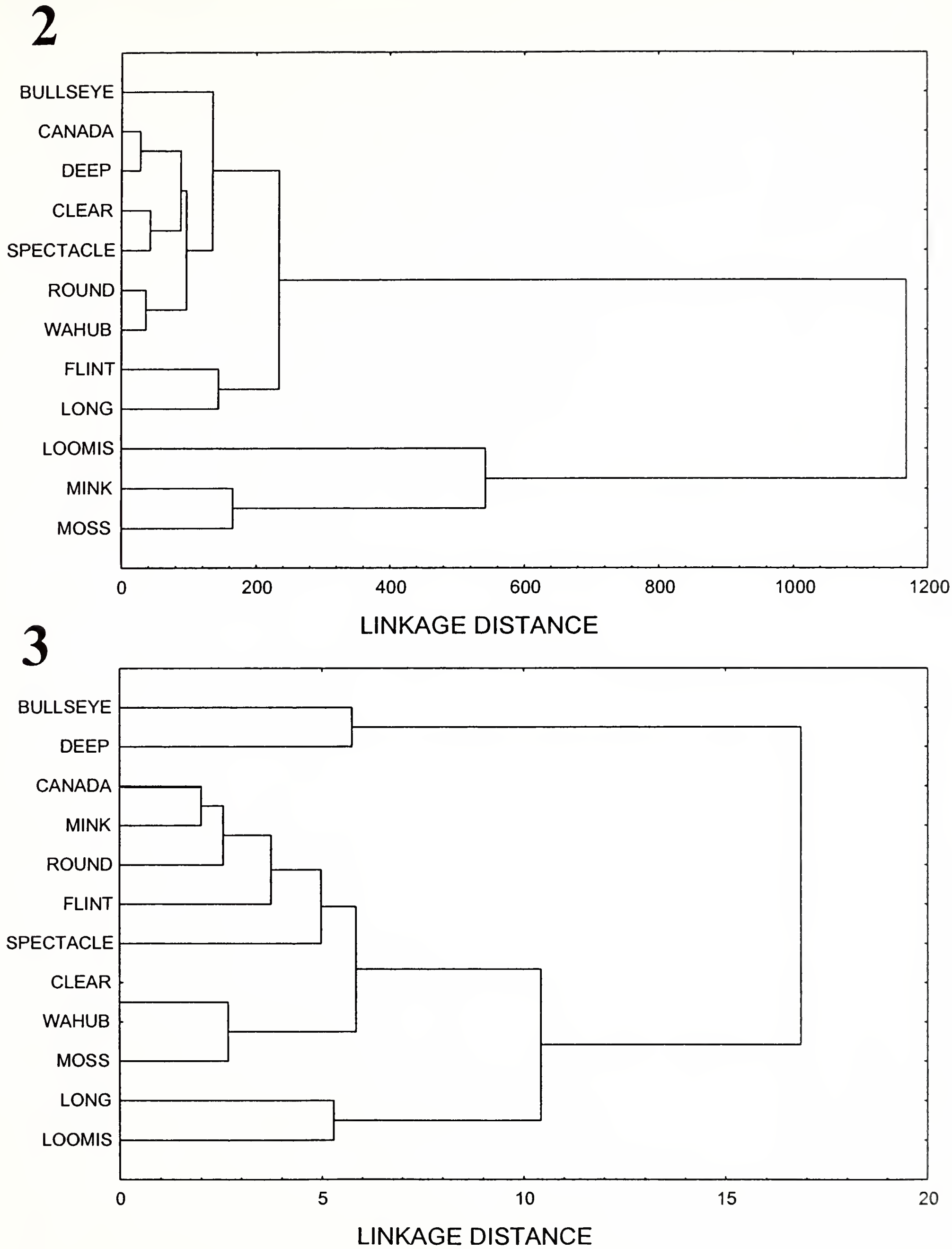

Figure 2, 3.—Results of single linkage, Ward method cluster analysis based on species composition (2) and index of biotic integrity metric score (3) results.

cannibalism of recruits. The pyramid is a simple three-tiered structure with the fish community comprised of insectivores and top-carnivores. The transfer of energy between the various levels of the pyramid is greatly reduced.

Obligate-lake species richness and sensitive species presence in the Valparaiso lake chain

Table 2.—List of fishes collected in Valparaiso lakes by time periods. IDNR = Indiana Department of Natural Resources, INBS = Indiana Biological Survey. Number refers to lake followed by relative abundance of each species in parentheses, with exception of Gerking since data is not available. Bullseye Lake = 1, Canada Lake = 2, Clear Lake = 3, Deep Lake = 4, Flint Lake = 5, Long Lake = 6, Loomis Lake = 7, Mink Lake = 8, Moss Lake = 9, Round Lake = 10, Spectacle Lake = 11, and Wauhob Lake = 12.

Scientific name	Gerking (1941)	IDNR (1960–1969)	IDNR (1970–1979)	IDNR (1980–1990)	INBS (1990–1999)	IDNR (2000–2003)
Amiidae						
Amia calva	8(−)		5(4), 6(9)	5(3), 6(9)	2(11), 4(3), 5(2), 6(1), 9(3), 10(1), 12(3)	6(2)
Umbridae						
Umbra limi					1(79), 3(3), 8(6), 10(11), 12(2)	11(2)
Esocidae						
Esox americanus	8(−)	6(18), 7(17)	6(6), 7(5)	6(23), 7(4)	2(8), 3(2), 4(10), 5(15), 6(10), 7(5), 8(3), 10(4), 12(4)	6(1), 12(2)
Esox lucius			5(17), 6(3), 7(4)	5(9), 6(6), 7(8),	8(3), 9(4), 10(4), 12(11)	6(9), 12(2)
Cyprinidae						
Carassius auratus					11(14)	
Cyprinus carpio		7(14)	5(3)	5(5)	5(2), 6(22)	
Ctenopharyngodon idella					8(1)	
Luxilus cornutus		7(8)				
Notemigonus cryscleucas		7(36), 11(2)	5(1), 6(51), 7(10)	5(6), 6(42), 7(41)	2(9), 5(10), 6(45), 10(17), 12(10)	6(20), 7(11), 12(9)
Pimephales notatus					5(1)	
Pimephales promelas					6(5)	
Rhinichthys obtusus						12(1)
Catostomidae						
Catostomus commersonii		7(2)	7(3)			
Erimyzon sucetta		6(39), 7(39), 11(64)	5(19), 6(36), 7(15), 11(17)	5(15), 6(101)	2(4), 3(2), 6(9), 8(13), 9(1), 10(33), 12(21)	6(57), 12(10)
Ictaluridae						
Ameiurus melas		6(3), 7(5)	5(2), 7(9)	5(34), 6(8), 7(14)	5(19), 6(33)	
Ameiurus natalis		6(4), 7(2)	5(1), 6(5), 7(33)	6(6), 7(27)	5(63), 7(5), 9(1), 10(1), 11(1)	6(1), 11(2)
Ameiurus nebulosus		7(2)	5(46), 6(6), 7(21)	5(14), 6(21), 7(11)	2(2), 3(1), 6(66), 7(1), 8(1)	6(21), 7(32), 11(2), 12(2)

Table 2.—Continued.

Scientific name	Gerking (1941)	IDNR (1960–1969)	IDNR (1970–1979)	IDNR (1980–1990)	INBS (1990–1999)	IDNR (2000–2003)
Ictalurus punctatus		7(3)	7(10)	7(9)		
Noturus gyrtinus					5(4), 7(3), 12(1)	
Fundulidae						
Fundulus diaphanus		7(1)			3(4)	
Fundulus dispar	8(−)				1(1), 3(28), 5(28), 6(22), 7(31), 9(6), 10(46), 12(54)	
Fundulus notatus	8(−)				5(6), 6(3)	
Moronidae						
Morone chrysops				5(2)		
Centrarchidae						
Lepomis cyanellus		6(32), 7(1)	7(3)		2(1), 5(14), 6(86), 7(1)	11(2)
Lepomis gibbosus	8(−)	6(16), 7(118), 11(22)	5(1), 7(17), 11(26)	7(9)	3(5), 5(3), 7(15), 8(7), 12(6)	
Lepomis gulosus		6(38), 7(82), 11(1)	5(10), 6(11), 7(37), 11(14)	5(19), 6(44), 7(26)	1(1), 2(2), 3(5), 5(9), 6(11), 7(48), 8(24), 10(1), 11(15), 12(4)	6(11), 7(20), 11(3)
Lepomis macrochirus	8(−)	6(318), 7(1622), 11(31)	5(64), 6(109), 7(1401), 11(65)	5(16), 6(175), 7(576)	1(2), 2(20), 3(53), 5(83), 6(112), 7(753), 8(388), 9(228), 10(12), 11(71), 12(39)	6(126), 7(291), 11(1), 12(56)
Lepomis microlophus		6(256), 7(72)	5(23)	5(11), 6(28),	2(3), 6(2), 8(2), 12(1)	6(43), 7(9), 12(31)
Micropterus salmoides	8(−)	6(66), 7(105), 11(8)	5(8), 6(13), 7(138), 11(40)	5(50), 6(98), 7(96),	1(1), 2(15), 3(19), 5(59), 6(23), 7(15), 8(31), 9(6), 10(17), 11(7), 12(8)	6(82), 7(86), 12(27)
Pomoxis annularis					1(39), 8(2)	
Pomoxis nigromaculatus		6(1), 7(176)	5(47), 6(65), 7(40)	5(39), 6(27), 7(106)	1(9), 2(6), 5(16), 6(2), 7(8), 8(7), 9(1), 12(2)	6(8), 7(9), 12(1)
Percidae						
Etheostoma axile					5(10), 6(1), 9(8), 10(1), 12(8)	
Etheostoma nigrum					5(4)	
Perca flavescens		6(30), 7(37)	5(41), 6(24), 7(1)	5(15), 6(47)	3(13), 5(59), 6(6), 10(1)	6(53), 12(4)

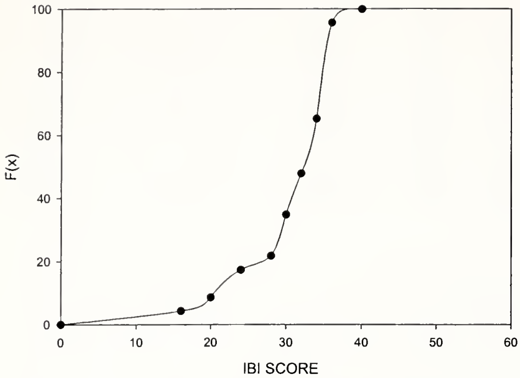

Figure 4.—Cumulative frequency distribution of index of biotic integrity scores for 23 sampling events conducted in the Valparaiso moraine chain of lakes.

have also declined (Simon 1998). Species such as bowfin (*Amia calva*), lake chubsucker (*Erimyzon sucetta*), warmouth (*Lepomis gulosus*), banded killifish (*Fundulus diaphanous*), starhead topminnow (*Fundulus dispar*) have declined in numbers, i.e., relative abundance, and presence in a number of lakes. As obligate lake species and sensitive species decline in relative abundance, recovery of these species and improvements in biological integrity within the lakes will be more difficult to attain.

Local extirpations and new records.—Local extirpation of several species has occurred in the Valparaiso lake chain (Table 2). The common shiner (*Luxilus cornutus*), white sucker (*Catostomus commersonii*), and channel catfish (*Ictalurus punctatus*) were collected from Loomis Lake during the mid-1960s and mid-1970s. The common shiner has not been collected since 1969, the white sucker has not been collected since 1976, and the channel catfish was last collected in 1982 from any of the chain of lakes. The white bass (*Morone chrysops*), found in Flint Lake during the mid-1980s, was last collected in 1986. The only new species record since the millennium was the single blacknose dace (*Rhinichthys obtusus*) in Wauhob Lake.

Cluster analysis.—Cluster analysis of species composition and IBI metric scores showed two clusters (Fig. 2). Species composition clustered Loomis, Mink, and Moss lakes as a single unit (Fig. 2). These lakes were dominated by stunted bluegill. Within the second cluster, Bullseye Lake was separated from three other lake pairs. Bullseye Lake was deep relative to surface area and is dominated by central mudminnow (*Umbra limi*), black crappie (*Pomoxis nigromaculatus*), and bowfin (*Amia calva*). Round Lake and Wauhob Lake differed from other Valparaiso lakes by the presence of lake chubsucker (*Erimyzon sucetta*), golden shiner (*Notemigonus crysoleucus*), northern pike (*Esox lucius*), and starhead topminnow (*Fundulus dispar*). Long Lake with 18 species and Flint Lake with 19 species were the most diverse lakes.

Cluster analysis of IBI metric scores showed two clusters which did not possess substantial linkage distances (Fig. 3). Bullseye Lake and Deep Lake were separate from the remainder of the lakes. These two lakes consistently scored "very poor." Within the second cluster Long Lake and Loomis Lake were consistently classified as "fair," which was only a 5% linkage difference from the rest of the lakes in the second unit.

Condition of lake chain.—The condition of Valparaiso lakes compared to other northern Indiana lake reference conditions (Simon 2001) showed that these lakes ranged from "very poor" to "fair" (Fig. 4). The IBI scores ranged between 16–40, with the mode 36. The majority of the Valparaiso lakes scored between 30 and 36 IBI points (73.9% of IBI scores, n = 23 collection events). Flint lake ranked the highest with an IBI score of 40 (mean = 38, n = 4). The loss of high quality biological conditions among the lakes in the chain is not a result of habitat loss, but rather a change in the trophic status of this chain (Morris unpubl. data). Several lakes (i.e., Flint, Spectacle, and Loomis lakes) have experienced high shoreline modifications, which may indicate that lake recovery to higher categories of quality may not be possible. The fish community reflects the condition of the watersheds, with only a few lakes possessing any sensitive fish species such as lake chubsucker (*Erimyzon sucetta*), starhead topminnow (*Fundulus dispar*), and Iowa darter (*Etheostoma exile*). These lakes are dominated by sunfish species and black bass, with accompanying loss of native minnow species.

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