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LAKE FISH ASSEMBLAGES IN HOOSIER NATIONAL FOREST, PERRY COUNTY, INDIANA, WITH EMPHASIS ON LAKE CONDITION ASSESSMENT

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ABSTRACT. Three lakes in Hoosier National Forest were created by the impounding of several creeks within the Middle Fork Anderson River watershed. All three lakes were created during the early 1960's to provide recreational opportunities for the public. Only a single study by the Indiana Department of Natural Resources provides data about a decade after the lakes were created on the historical fish assemblage of the lakes prior to reclamation. The current study found that the three reservoirs possess simple fish assemblage structure and are dominated by sunfish species. The lakes do not possess many benthic species or obligate lake species. The index of biotic sustainability classified the lakes as ''poor'' for all three lakes. Scores ranged from 28 to 31, with the mode 29. The majority of the sites in Hoosier National Forest lakes scored between 29 and 30 IBS points. Both Indian and Tipsaw lakes had sustainability scores of 30, while Celina Lake had a mean IBS score of 28.5. Tipsaw Lake ranked the highest with an IBS score of 31.

Keywords: Lacustrine wetlands, reservoirs, community structure, ecosystem function, sustainability

INTRODUCTION

Limited information concerning species composition and relative abundance of small reservoir fish assemblages is 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 1945, 1950a,b), but small reservoirs in southern Indiana were not surveyed. Many of these small reservoir lakes were created during the early- to mid-1960's for recreation, water storage, and drinking water prior to the golden days of the Lake and Stream Survey.

Small reservoirs in Hoosier National Forest have experienced an increasing number of fish kills, affecting species diversity and biological condition. Haas & Boston (1998) did not cite anthropogenic disturbance as the cause for concern; rather, they suggested that water level drawdown has influenced these effects across similar small recreational lakes. Generally, as reservoirs age, changes in the stability and sustainability of the biological assemblages occur. Productivity of reservoirs increases during the first decade as river and lacustrine fish species co-occur in the reservoir (Wetzel 1983). As recruitment of river species fails with time, lacustrine species dominate and increase until the carrying capacity of the reservoir is exceeded and declines are observed.

Fisheries management studies of Hoosier National Forest lakes were done between 1972 and 1987 by the Indiana Department of Natural Resources (Hottell 1977a,b; 1978a,b,c; Glander 1984; Glander & Burch 1988). Celina, Tipsaw, and Indian lakes were surveyed the most frequently; however, Saddle Lake and English Reservoir were also surveyed (Hottell 1977b, 1978c). With an increasing need to provide recreational opportunities for sport anglers, management of black basses, such as largemouth and smallmouth bass (*Micropterus salmoides* and *M. dolomieu*) and sunfish populations have received increasing attention. These species are dominant members of the fish assemblages of small reservoirs in southern Indiana. Recently, sampling intensity has increased providing the opportunity to evaluate trends in water quality and fish assemblage stability. Sampling was conducted between 1970–2005 for several projects, including the monitoring of game species populations by the

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Indiana Department of Natural Resources and the current study.

The purpose of this study is to document the distribution of the fish assemblages in small reservoirs of Hoosier National Forest; 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 such as sport fishing, water quality, watershed nutrients, and biological pollution of the lakes.

METHODS

Study area.—The need for recreation opportunities on public lands provided the impetus for creating reservoir lakes on public lands (Haas & Boston 1998). Lakes in the Hoosier National Forest are found in Perry County and impound a variety of stream tributaries including the Middle Fork Anderson River.

For this manuscript, I describe the fish assemblages of Celina, Tipsaw, and Indian lakes, which are part of the Middle Fork Anderson River watershed (Fig. 1). Many of the smaller ponds and shallow wetlands within the area were not sampled. I recognize that increased sampling in these small ponds and shallow wetland habitat may result in additional fish species being found, but I 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. My 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. Voucher specimens were deposited at the Division of Fishes, Aquatic Research Center, Indiana Biological Survey, Bloomington, Indiana.

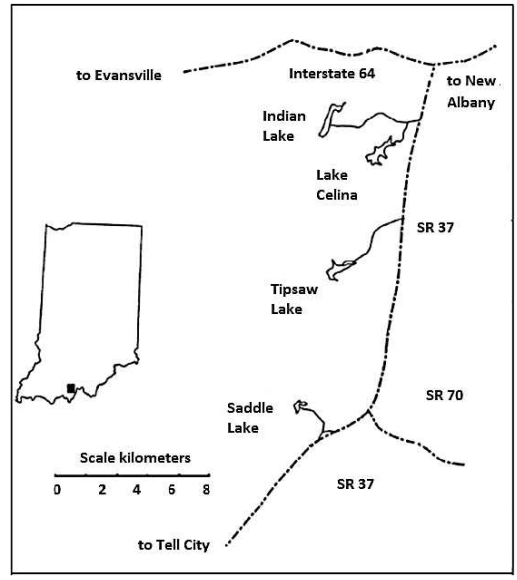

Figure 1.—Location of Celina, Tipsaw, and Indian lakes in Hoosier National Forest, Perry County, Indiana.

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 habitats over anthropogenically modified habitats such as boat slips, steel sheet piling, manicured lawns, or rock rip-rap. A project that developed reference conditions for southern Indiana lakes showed that areas with natural features had the greatest diversity and most natural fish assemblage attributes (Simon 2004). The number of reaches sampled within a single lake was determined by lake surface area (ha). Each lake reach was 500 m, which in the smallest lakes (Indian and Tipsaw) almost covered the entire shoreline. The smallest lakes (20–100 ha) were sampled at a minimum of two reaches.

Habitat parameters were measured using a qualitative measure of habitat that was based on a modified qualitative habitat evaluation index (Rankin 1989). The index is a composite of scores for each category based on a total of 100 points. Measures include substrate quality, instream habitat cover, watershed characteristics, shoreline development, littoral and profundal zone development and quality, depth, and measures of erosion and embeddedness.

Biological sustainability.—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 southern Indiana reservoirs in the Interior River Lowland and Interior Plateau Ecoregions. Ten attributes of lake-fish assemblages were tested to develop a reference condition for lakes greater than 20 ha (Simon 2004); however since reservoirs are not natural systems an index of biological sustainability (IBS) was created consistent with reservoirs on the Tennessee River (McDonough & Hickman 1999).

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 sustainability or "least-impacted" condition.

RESULTS AND DISCUSSION

Historical changes.—Limited information is available to evaluate changes in the species richness of small reservoirs on Hoosier National Forest. The Indiana Department of Natural Resources (Hottell 1977a; Hottell 1978a,b; Glander 1984; Glander & Burch 1988) sampled Tipsaw, Celina, and Indian lakes. They found 14 species in Tipsaw Lake, 9 species in Lake Celina, and 13 species in Indian Lake (Table 1). Our unpublished sampling for Tipsaw Lake found 10 species in 2002 and 8 species in 2005, in Indian Lake 13 species in 2002 and 10 species in 2005, and in Lake Celina 10 species in 2002 and 6 species in 2005. The total combined fish list for Tipsaw Lake includes 15 species, for Lake Celina 14 species, and for Indian Lake 14 species. Upon completion of the dam for each lake, occurring in 1967, all fish in the watershed were eradicated. The Department of Natural Resources stocked largemouth bass, bluegill, redear sunfish (*Lepomis microlophus*), black crappie (*Pomoxis nigromaculatus*), and channel catfish (*Ictalurus punctatus*) in 1968 (Glander 1984).

Fish in Hoosier National Forest Lakes.—Twenty fish species in seven families have been collected from the three lakes in Hoosier National Forest (Table 1). The dominant family was the sunfish family, which was represented by eight species. Species diversity of the Hoosier National Forest has not changed appreciably since the lakes were created in the mid-1960's.

The three reservoirs have become more similar as a result of recreational requirements, patterns in eutrophication (which has caused the decline of former native species resident in the impounded creeks), and the decline of depth in the three lakes. All three lakes have a managed fish assemblage that reflects recreational fishing objectives. All three lakes are dominated by bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*). These two species are found throughout the three lakes.

Structure and function of fish assemblages in Hoosier National Forest reservoirs.—The managed fish assemblage of the Hoosier National Forest consists of a simple community structure that is designed to enhance sunfish and top-level carnivore production (Glander 1984). With the goal of increasing the numbers of bluegill, while largemouth bass were often highest in relative abundance, the remainder of the fish assemblage has become stunted. This has resulted in a loss of biological diversity, community structure, and biological sustainability for these water bodies. For example, the highest number of species based on a single collection in any of the lakes is 13 species in Lake Celina. Compared to regional expectations, the highest diversity observed in Lake Celina is equivalent to an average condition for a lake of similar size (Simon 2004).

The management of these three Hoosier National Forest lakes has caused an unstable community structure that is not sustainable. As species are managed towards panfish and top level carnivore production, larger numbers of forage base species and greater competition are needed to enhance growth. However, since carrying capacity restricts that number, the food chain becomes an inverted trophic pyramid. This inverted pyramid, instead of possessing a large forage base supporting a small top carnivore base, has a large number of top carnivores that are forced to feed on a small forage base. This type of stability can be

Table 1.—Listof fishes collected in three lakes in Hoosier National Forest by time periods. IDNR = Indiana Department of Natural Resources, INBS = Indiana Biological Survey. Numbers refer to relative abundance of each species while data in parentheses refer to lake (see below) and year collected. Lake Celina site 1 = 1, Lake Celina site 2 = 2, Tipsaw Lake site 1 = 3, Tipsaw Lake site 2 = 4, Indian Lake site 1 = 5, and Indian Lake site 2 = 6.

	IDNR		INBS	
Scientific name	1970–1976	1983–1987	2002	2005
Esocidae, pickerel & pikes				
Esox americanus, Grass pickerel			2(5)	1(6)
E. lucius, Northern pike	1 (5-1976)			
Cyprinidae, carps, minnows, & shiners				
Notemigonus crysoleucas, Golden shiner	2 (1-1976); 1 (5-1976)		6(3); 3(5)	2(6)
Pimephales notatus, Bluntnose minnow			6(1); 6(2)	
Catostomidae, suckers				
Catostomus commersonii, White sucker	45 (5-1976)		10(5)	
Ictaluridae, bullheads, madtoms, & catfish				
Ameiurus melas, Black bullhead		2(3-1983)	3(1); 1(6)	1(6)
A. natalis, Yellow bullhead	4 (1-1976); 6 (3-1976); 35 (5-1976)	1(3-1983); 4(5-1987); 2(3-1987)	11(5); 6(3)	1(5); 3(6)
A. nebulosus, Brown bullhead	17 (1-1976); 8 (3-1976)		1(2); 3(4)	
Ictalurus punctatus, Channel catfish	10 (1-1970); 19 (1-1972); 10 (1-1976); 10 (3-1972); 9 (3-1976); 2 (5-1976)	102 (3-1983); 1(5-1987)	7(1); 9(2); 2(5); 3(3); 5(4)	
Pylodictis olivaris, Flathead catfish		1(3-1987)		
Fundulidae. Topminnows				
Fundulus notatus, Blackstripe topminnow	1 (3-1976)			18(1); 9(2)

Table 1.—Continued.

Scientific name	IDNR 1970–1976	IDNR 1983–1987	INBS 2002	INBS 2005
Poeciliidae, livebearers				
Gambusia affinis, Eastern mosquitofish	1 (3-1976)			34(1); 15(2); 3(3); 2(4)
Centrarchidae, sunfish & black bass				
Lepomis cyanellus, Green sunfish	28 (1-1976); 9 (3-1976); 10 (5-1976)	16(3-1983)	16(2); 27(3); 8(4); 12(5)	6(3); 17(4); 14(5); 18(6)
L. gulosus, Warmouth	24 (3-1976); 57 (5-1976)	5(3-1983); 29(1-1987); 35(3-1987); 30(5-1987)	3(1); 9(2); 5 (3); 7(4); (5); 14(6)	3(6)
L. macrochirus, Bluegill	184(1-1970); 281(1-1972); 473(1-1976); 235(3-1972); 384(3-1976); 453(5-1976)	174(3-1983); 257(1-1987); 276(3-1987); 486(5-1987)	41(1); 56(2); 38(3); 37(4); 32(5); 78(6)	128(1); 221(2); 207(3); 132(4); 106(5); 59(6)
L. megalotis, Longear sunfish	19 (5-1976)	1(3-1983); 15(5-1987)	11(3); 14(5); 31(6)	2(4)
L. microlophus, Redear sunfish	48 (1-1976); 22 (3-1972); 12 (3-1976); 38 (5-1976)	23(3-1983); 21(1-1987); 65(3-1987); 74(5-1987)	17(1); 12(2); 12(3); 10(4); 17(6)	24(1); 16(2); 6(3); 4(4); 12(5); 18(6)
Micropterus salmoides, Largemouth bass	236(1-1970); 115(1-1972); 523(1-1976); 282(3-1972); 252(3-1976); 302(5-1976)	182(3-1983); 103(1-1987); 228(3-1987); 185(5-1987)	9(1); 17(2); 7 (4); 6(5); 14(6)	16(1); 19(2); 8(3); 11(4); 11(5); 7(6)
M. punctulatus, Spotted bass	2(5-1976)			
Pomoxis nigromaculatus, Black crappie	11(3-1976); 56(5-1976)	1(3-1983)	5(2); 1 (3); 3(4); 4(5)	2(3); 3(4); 1(6)

sustained for short periods of time (<10 years); however, such a system cannot produce continued top-level fish without causing 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. The number of benthic species such as channel catfish (*Ictalurus punctatus*) and bullhead (*Ameiurus* spp.), and obligate lake species such as bowfin (*Amia calva*), has been reduced. As benthic species and obligate lake species decline in relative abundance, a need exists to conserve and recover these species. Promoting the return of biological species richness will assist in the maintenance of biological sustainability.

Local extirpations and new records.—Local extirpations observed in the three Hoosier National Forest lakes were a result of changes that occurred with reservoir aging. Species lost during the first decade were not commonly found and were probably a result of stocking from adjacent lakes or small streams in the area. For example, northern pike (*Esox lucius*) and spotted bass (*Micropterus punctulatus*) were first and last collected in 1976 from Indian Lake. Northern pike is a coolwater species and would not be expected to occur this far south naturally, while spotted bass would be the native black bass occurring in the Anderson River watershed (Simon 1997). The only record is based on a single individual. Flathead catfish (*Pylodictis olivaris*) is another species, typical of large rivers, that was first and last collected in 1987 as a single individual from Tipsaw Lake. As habitat changed from riverine to lacustrine, changes in substrate and dissolved oxygen concentration caused the extirpation of creek species. No new records of species have been recorded from any of the three watersheds since the preliminary study, suggesting that the rotenone treatment of the waterbodies prior to restocking was completely effective.

Condition of Hoosier National Forest lakes.—The condition of the three Hoosier National Forest lakes is based on biological sustainability of these systems. Biological sustainability is different from biological integrity since reservoirs are not natural systems. The index of biotic sustainability classification rated as "poor" for all three lakes (Fig. 2), while the scores ranged from 28 to 31, with the mode 29. The majority of the sites in Hoosier National Forest lakes scored 29 or 30 IBS points (66.7% of IBI scores, n = 6 collection events). Both Indian and Tipsaw lakes had sustainability scores of 30, while Celina Lake had a mean IBS score of 28.5. Tipsaw Lake ranked the highest with an IBS score of 31. The loss of high quality biological conditions among the lakes in the Hoosier National Forest is not a result of littoral habitat loss, but rather a loss of profundal zone due to the loss of depth. All three lakes are experiencing rapid depth loss due to sedimentation of the highly erodible soils in the upper portions of the watersheds. All three lakes have a larger percentage of littoral habitat compared to profundal habitat, which provides increasing area for aquatic plants (Simon et al. submitted, a). Rapid cycling of dissolved oxygen concentrations in these areas, as plants change from photosynthesis to respiration during the night, has caused low dissolved oxygen levels that have resulted in summer kill (Simon et al. submitted, b). All three lakes are dominated by sunfish species and few other species were collected during the 2005 survey.

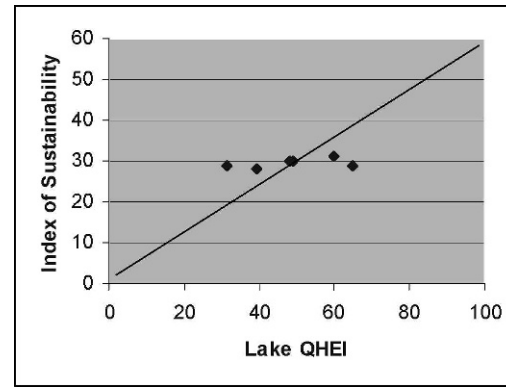

Figure 2.—Hypothesized relationship between index of biological sustainability and lake qualitative habitat evaluation index (QHEI) (black line) and observed scores for three lakes in Hoosier National Forest. The observed relationship between fish diversity and habitat does not follow the expected model.

Trends in lake condition showed that all three lakes have remained stable during the last 35 years (see appendix A–C). Indian Lake had the highest sustainability with scores ranging from 28 to 38, followed by Tipsaw Lake (25–38) and Lake Celina (25–34). Although the sustainability scores are declining for all three

lakes, the decline is not significant from the mean for each lake. This suggests that the variability associated with each lake is sufficient to explain the variability between years.

Relationships with habitat.—Barbour & Stribling (1991) showed that an index of biological integrity was directly related with habitat quality in streams and flowing water. In the absence of pollutants or other anthropogenic disturbance, the quality of fish assemblages should be directly related to habitat. It would not be possible for fish assemblages in lakes to exhibit high quality condition without the presence of natural conditions. The three lakes in Hoosier National Forest showed no relationship with habitat consistent with the model proposed by Barbour & Stribling (1991)(Fig. 2). Habitat and biological sustainability was skewed for the three lakes. Although riparian habitat scored the highest for regionally similar reservoirs in the Interior River Lowland or Interior Plateau Ecoregions, substrates, profundal zone quality, and instream cover were reduced compared to other reservoirs.

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APPENDIX A

Celina Lake metrics for all available years from 1970–2005. DELT = Deformities, Eroded fins, Lesions, and Tumors (DELT), VP = Very Poor, P = Poor.

Metrics	1970	1972	1976	1987	2002	2005		
Total number of species	3 (1)	3 (1)	9 (3)	4 (1)	7 (1)	9 (3)	6 (1)	6 (1)
Number benthic species	1 (1)	1 (1)	3 (3)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Number centrarchid species	2 (1)	2 (1)	4 (3)	2 (1)	4 (3)	5 (3)	4 (3)	4 (3)
Percent tolerant individuals	0 (5)	0 (5)	4.6 (5)	0 (5)	11 (5)	17 (5)	0 (5)	0 (5)
Percent omnivore individual	0 (5)	0 (5)	0 (5)	0 (5)	7 (5)	5 (5)	0 (5)	0 (5)
Percent insectivore individual	45 (3)	72 (5)	53 (3)	75 (5)	90 (5)	87 (5)	94 (5)	92 (5)
Percent carnivore individuals	55 (1)	28 (5)	47 (1)	25 (5)	10 (2)	13 (3)	6.7 (1)	6.6 (1)
Relative abundance	430(3)	415(3)	1105(5)	410(3)	86 (1)	131 (1)	229 (2)	288 (3)
Percent lake obligate individuals	0 (0)	0 (0)	1.6 (1)	7.1 (1)	3.5 (1)	7.6 (1)	3.9 (1)	2.8 (1)
Percent DELT	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
TOTAL Sustainability score	**25**	**31**	**34**	**31**	**29**	**31**	**28**	**29**
Classification	**P-VP**	**P**	**P**	**P**	**P**	**P**	**P**	**P**

APPENDIX B

Tipsaw Lake metrics for all available years from 1970–2005. DELT = Deformities, Eroded fins, Lesions, and Tumors (DELT), VP = Very Poor, P = Poor, F = Fair.

Metrics	1972	1976	1983	1987	2002	2005		
Total number of species	4 (1)	10 (3)	9 (3)	6 (1)	10 (3)	8 (3)	7 (2)	8 (3)
Number benthic species	1 (1)	3 (3)	3 (3)	1 (1)	2 (1)	2 (1)	0 (0)	0 (0)
Number centrarchid species	3 (1)	7 (5)	7 (5)	3 (1)	5 (3)	5 (3)	6 (3)	7 (5)
Percent tolerant individuals	0 (5)	2.5 (5)	6.7 (5)	0.4 (5)	39 (1)	7.3 (5)	2.5 (5)	9.6 (5)
Percent omnivore individuals	0 (5)	0 (5)	0 (5)	7 (5)	5 (5)	0 (5)	0 (5)	0 (5)
Percent insectivore individuals	49 (3)	63 (3)	41 (3)	58 (3)	100 (5)	90 (5)	97 (5)	94 (5)
Percent carnivore individuals	51 (1)	37 (3)	59 (1)	42 (1)	0 (0)	10 (1)	3.4 (1)	6.2 (1)
Relative abundance	549(5)	685(5)	310(3)	541 (5)	100 (1)	67 (1)	236 (2)	177 (1)
Percent lake obligate individuals	0 (0)	0.8 (1)	1.6 (1)	6.5 (1)	5 (1)	15 (3)	1.7 (1)	3.4 (1)
Percent DELT	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
TOTAL Sustainability score	**27**	**38**	**34**	**28**	**25**	**32**	**29**	**31**
Classification	**P-VP**	**P-F**	**P**	**P**	**P-VP**	**P**	**P**	**P**

APPENDIX C

Indian Lake metrics for all available years from 1970–2005. DELT = Deformities, Eroded fins, Lesions, and Tumors (DELT), F= Fair, P = Poor, VP = Very poor.

Metrics	1976	1987	2002		2005	
Total number of species	12 (3)	7 (3)	12 (3)	6 (1)	8 (3)	10 (3)
Number benthic species	3 (3)	2 (1)	4 (3)	1 (1)	1 (1)	2 (1)
Number centrarchid species	8 (5)	2 (1)	4 (3)	5 (3)	6 (3)	6 (3)
Percent tolerant individuals	1 (5)	0 (5)	13 (5)	0 (5)	9 (5)	18 (5)
Percent omnivore individuals	4.4 (5)	0 (5)	10.8(5)	0 (5)	0 (5)	1.7 (5)
Percent insectivore individuals	66 (3)	77 (5)	81 (5)	91 (5)	93 (5)	92 (5)
Percent carnivore individuals	30 (3)	23 (5)	10 (3)	9 (1)	6.5 (1)	6.7 (1)
Relative abundance	1021(5)	795(5)	115 (1)	155 (1)	169 (1)	120 (1)
Percent lake obligate individuals	5.6 (1)	3.8 (1)	7.8 (1)	9.0 (1)	5.3 (1)	2.5 (1)
Percent DELT	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)	0 (5)
TOTAL Sustainability score	**38**	**36**	**34**	**28**	**30**	**30**
Classification	**F-P**	**F-P**	**P**	**P**	**P**	**P**

LITERATURE CITED

Barbour, M.T. & J.B. Stribling. 1991. Use of habitat assessment in evaluating the biological integrity of stream communities. Pp. 25–38. *In* Biological criteria: Research and Regulation, Proceedings of a Symposium, 12–13 December, 1990, Arlington, Virginia (G. Gibson, ed.). Office of Water, U.S. Environmental Protection Agency, Washington, D.C. EPA 440-5-91-005.

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison, Wisconsin.

Frey, D.G. 1986. Limnology of North America. John Wiley and Sons, New York, New York.

Gerking, S.D. 1945. Distribution of the fishes of Indiana. Investigations of Indiana Lakes and Streams 3:1–137.

Gerking, S.D. 1950a. A carp removal experiment at Oliver Lake, Indiana. Investigations of Indiana Lakes and Streams 3:373–392.

Gerking, S.D. 1950b. Populations and exploitation of fishes in a marl lake. Investigations of Indiana Lakes and Streams 3:393–434.

Gerking, S.D. 1955. A key to the fishes of Indiana. Investigations of Indiana Lakes and Streams 4:49–86.

Glander, P.A. 1984. Tipsaw Lake, 1983 Fish Management Report. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

Glander, P.A. & M.E. Burch. 1988. Slot size limit evaluation: Indian, Celina, and Tipsaw Lakes, 1987 Interim Fisheries Management Report. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

Goldstein, R.M. & T.P. Simon. 1999. Toward a united definition of guild structure for feeding ecology of North American freshwater fishes. Pp. 123–202. *In* Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities (T.P. Simon, ed.). CRC Press, Boca Raton, Florida.

Haas, G.E. & C. Boston. 1998. The impacts from increased recreation use on the non-recreational purposes and benefits of federally managed man-made lakes/reservoirs. National Park Service, Moscow, Idaho.

Hottell, H. 1977a. Lake Celina resurvey 1976. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

Hottell, H. 1977b. Saddle Lake resurvey 1976. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

Hottell, H. 1978a. Tipsaw Lake resurvey 1976. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

Hottell, H. 1978b. Indian Lake resurvey 1976. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

Hottell, H. 1978c. English Reservoir resurvey 1976. Indiana Department of Natural Resources, Division of Fish and Wildlife, Indianapolis, Indiana.

Johnson, W.L. 1945. Age and growth of the black and white crappies of Greenwood lake, Indiana. Investigations of Indiana Lakes and Streams 3:297–324.

Karr, J.R., K.D. Fausch, P.L. Angermeier, P.R. Yant & I.J. Schlosser. 1986. Assessing Biological Integrity in Running Waters: A Method and its Rationale. Illinois Natural History Survey Special Publication 5, Champaign, Illinois.

McDonough, T.A. & G.D. Hickman. 1999. Reservoir fishery assessment index: A tool for assessing ecological health in Tennessee Valley Authority impoundments. Pp. 523–540. In (T.P. Simon, ed.). *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities*. CRC Press, Boca Raton, FL. 671 pp.

Rankin, E.T. 1989. The Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods, and Applications. Ohio Environmental Protection Agency, Division of Water Quality Planning and Assessment, Ecological Analysis Section, Columbus, Ohio.

Ricker, W.L. 1942a. The rate of growth of bluegill sunfish in lakes of northern Indiana. Investigations of Indiana Lakes and Streams 2:161–214.

Ricker, W.L. 1942b. Creel census, population estimates and rate of exploitation of game fish in Shoe Lake, Indiana. Investigations of Indiana Lakes and Streams 2:215–265.

Ricker, W.E. 1945a. Fish catches in three Indiana lakes. Investigations of Indiana Lakes and Streams 2(16):325–344.

Ricker, W.E. 1945b. Abundance, exploitation, and mortality of the fishes in two lakes. Investigations of Indiana Lakes and Streams 2:345–448.

Simon, T.P. 1991. Development of an index of biotic integrity expectations for the Ecoregions of Indiana. I. Central Corn Belt Plain. EPA 905/9-91/025. U.S. Environmental Protection Agency, Region 5, Chicago, Illinois.

Simon, T.P. 1997. Biological characterization of the Middle Fork Anderson River, Perry County, Indiana. EPA 905-R-96-007. U.S. Environmental Protection Agency, Chicago, Illinois.

Simon, T.P. 1999. Assessment of Balon's Reproductive Guilds with Application to Midwestern North American freshwater fishes. Pp. 97–122. *In* Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities (T.P. Simon, ed.). CRC Press, Boca Raton, Florida.

Simon, T.P. 2004. Development of Environmental Indicators based on probability –based design sampling of Indiana lakes: Southern Oxbow Lakes and Reservoirs. Indiana Department of Environmental Management. ARN 305-2-01-382.

Simon, T.P., S.L. Worden & R. Morehouse. submitted(a). Physical and chemical limnology of three lakes in Hoosier National Forest. Proceedings of the Indiana Academy of Science.

Simon, T.P., S.L. Worden & R. Morehouse. submitted(b). Diel patterns in dissolved oxygen and select chemical parameters in three lakes in Hoosier National Forest. Proceedings of the Indiana Academy of Science.

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

Wetzel, R. 1983. Limnology. W.B. Saunders, Philadelphia, Pennsylvania.

Wohlschlag, D.E. 1950. Vegetation and invertebrate life in a marl lake. Investigations of Indiana Lakes and Streams 3:321–372.

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