Indian Lake
Kalamazoo County, T4S, R10W, 4
St. Joseph River watershed, 2010

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Environment

Indian Lake is a 758-acre natural lake located 3 miles northeast of Vicksburg and about 9 miles southeast of the city of Kalamazoo. The lake consists of two basins. The west basin has a maximum depth of 75 ft, and the northeast basin (locally known as Little Indian Bay) has a maximum depth of 29 ft. Drop-offs generally are steep; however, shoals are relatively wide along the east-central portion of the shoreline. Marl and sand are the predominant substrates along the shoreline in the west basin, but patches of gravel and cobble exist along the eastern shoreline. Organic substrates are common in Little Indian Bay. Two tributaries flow into Little Indian Bay. Dorrance Creek flows into the northeast corner of the bay. The Portage River enters at the northwest corner and exits at the southern end of the bay.

Indian Lake is surrounded by deposits of glacial outwash sand and gravel. These materials are relatively porous, and Michigan Department of Conservation maps indicated the presence of groundwater seeps along the northern shore of Indian Lake. Agriculture is the predominant land use in the watershed (Figure 1). Residential and seasonal homes line most of the shoreline in the west basin. Conversely, nearly all of the shoreline in Little Indian Bay is undeveloped and includes a mixture of wetlands and forest. The 2010 habitat survey revealed a total dwelling density of 35.5 dwellings/mile (22.0 dwellings/km) for Indian Lake. Approximately 54% of the shoreline is armored with seawalls or riprap, which is a high percentage for lakes in southwest Michigan. Large woody structure was common along the east shore of Little Indian Bay and along the forested shoreline at the southeast end of the lake. Logs were scarce along the remainder of the shoreline. Recent quantitative data regarding the abundance and distribution of aquatic plants in this system are not available. There are no public boat launches on Indian Lake.

Limnological sampling was conducted by Fisheries Division staff at the deepest point in Indian Lake on September 1, 2010. As expected, the lake was thermally stratified (Figure 2). The epilimnion extended from the surface to a depth of 15 ft. Water temperatures within the epilimnion were relatively uniform, ranging from 78.4 F to 78.8 F. The metalimnion (zone of thermal change) extended from 15 ft to 50 ft. Water temperatures declined from 78.4 F at the top to 49.9 F at the bottom of the metalimnion. The cold waters of the hypolimnion extended from 50 ft to the bottom of the lake. The oxygen distribution within Indian Lake followed a clinograde curve, with the highest oxygen concentrations occurring near the surface (Figure 2). The dissolved oxygen concentration remained above 3 ppm to a depth of 26 ft.

United States Geological Survey personnel measured various water quality parameters at three depths (3 ft below surface, mid-depth, and 3 ft above the bottom) at the deepest point in Indian Lake on April 22 and September 2, 2010. The total alkalinity (only measured at mid-depth on April 22) was 200 mg/L, which is indicative of a hardwater lake with substantial buffering capacity. The biological productivity of a lake is strongly dependent on its supply of two key nutrients: phosphorus and nitrogen. The ratio of total nitrogen to phosphorus was >45:1 in Indian Lake in 2010, so it appears that

phosphorus is the limiting nutrient in this system (Shaw et al. 2004). Total phosphorus concentrations were low relative to most other lakes in southwest Michigan, ranging from 0.004 mg/L to 0.015 mg/L. The chlorophyll a concentration, which provides an index of algal biomass, was 0.0016 mg/L. Secchi disk depth declined from 24 ft in April to 8 ft in September. Based on these water quality measurements, Indian Lake is considered a borderline oligotrophic-mesotrophic lake (low to moderate productivity; Carlson and Simpson 1996).

History

The first fisheries survey of Indian Lake was completed in 1888. Cisco, black crappie, rock bass, "black bass" (presumably largemouth bass), yellow perch, northern pike, suckers, and bullheads were collected in this initial assessment. During 1933 through 1945, bluegills, largemouth and smallmouth bass, and yellow perch were stocked in Indian Lake (Table 1). Throughout the state, annual stocking programs for these warmwater fish species were discontinued after fisheries managers determined that such programs were unnecessary and could have undesirable effects on the receiving populations (e.g., reduced growth due to increased competition for forage). In addition to the species previously listed, angler reports from 1945 indicated the presence of common carp, bowfin, and gar in Indian Lake.

Rainbow trout were stocked periodically in Indian Lake from 1946 through 1964. This stocking program was discontinued due to poor survival of stocked trout. Fisheries Division files indicate that a local sport fishing group stocked spring fingerling walleyes in the lake during 1965 and 1967. Michigan Department of Conservation personnel sampled with gill nets during the fall of 1965, but failed to capture any walleye. Ciscoes (lake herring) and yellow perch composed the bulk of the catch, and anglers reported good fishing for ciscoes.

A local sport fishing group stocked spring fingerling walleyes in Indian Lake during 1981 through 1984. The stocking density for this program was approximately 4 fish/acre, which is a low stocking density relative to current Michigan Department of Natural Resources (MDNR) stocking guidelines (Dexter and O'Neal 2004). Rainbow trout also were stocked in Indian Lake in 1999.

Current Status

A variety of methods were used to evaluate the fish community in Indian Lake during May 2010. Fish were captured with trap nets, fyke nets, gill nets, seines, and nighttime electrofishing gear as part of the MDNR's Status and Trends Program (Table 2). This program involves standardized sampling in randomly selected lakes to provide information regarding spatial and temporal trends in Michigan's fish communities. Total lengths were recorded for all fish. For game fish species, dorsal spine or scale samples were collected from 10 fish per inch group for age determination.

Twenty-five fish species were collected during the 2010 survey (Table 3). Bluegill (n = 873) was the most abundant game fish species, composing 21% of the catch by number and 23% of the catch by weight. Sixty-eight percent of the bluegills were 6 inches or larger. Size structures of bluegill populations can be challenging to interpret because each gear type exhibits some degree of size selectivity (Figure 3). In an effort to minimize the subjectivity associated with analyses of bluegill catch data, Schneider (1990) developed a standardized scoring system for interpreting length-frequency distributions of bluegills collected with various types of sampling gear. The size scores for

the Indian Lake bluegill population were 5.8 (good-excellent) based on the trap net sample and 3.5 (acceptable-satisfactory) based on the electrofishing sample (Schneider 1990).

The mean growth index for bluegills was +0.2, which is indicative of average growth. Total lengths for age 1-3 bluegills were slightly below average, whereas total lengths for age 4 and older bluegills were slightly above average (Figure 4). Nine year classes of bluegills were collected (Figure 5). Age 4 fish were particularly abundant, composing 41% of the bluegill catch. Annual total mortality was estimated to be 72% for adult bluegills (ages 4-8; Figure 6).

Rock bass (n = 323) composed about 8% of the catch by number and 11% by weight. Growth was average, and 77% of the rock bass captured were 6 inches or larger. Black crappies (n = 62) were less common, but 84% of the crappies were 7 inches or larger. The mean growth index for black crappies was +0.6, which indicates that growth was slightly above average. Few yellow perch and pumpkinseed sunfish were collected during the 2010 survey.

Numerically, largemouth bass (n = 133) were the most abundant predators in the catch. Most of the largemouth bass were in the 9.0-12.9 inch size range (Figure 7). Legal-size fish (14 inches and larger) made up 8% of the catch, and the largest largemouth bass collected was 19 inches. Mean lengths-at-age were near average for age 1-3 fish and below average for age 4 and older fish (Figure 8). Nine year classes were represented in the sample (Figure 9). Annual total mortality of largemouth bass ages 4 to 9 was estimated to be 56% (Figure 10).

Northern pike (n = 32) were the dominant predators in terms of biomass. Sixty-nine percent of the pike collected were larger than the minimum size limit of 24 inches and 13% were > 30 inches (Figure 11). Fish from seven different year classes were captured during the survey (Figure 12). Mean lengths-at-age were substantially above average for northern pike in Michigan (mean growth index = +3.7), indicating rapid growth of northern pike in this system (Figure 13).

Smallmouth bass (n = 11) and channel catfish (n = 5) were minor components of the fish community. Five year classes of smallmouth bass were documented. The limited data available suggest relatively slow growth of smallmouth bass in Indian Lake.

Analysis and Discussion

Indian Lake supports a well-balanced fish community. Predators (northern pike, bass, gar, bowfin, and grass pickerel) composed 33% of the biomass, planktivore-insectivores (bluegill, black crappie, yellow perch, mimic shiners, and brook silversides) composed 26%, and benthivores made up 31% of the biomass during the 2010 survey. Schneider (2000) observed that predators typically compose 20-50% of the biomass in lakes with desirable fish communities. Based on this standard, Indian Lake appears to have a healthy predator-prey ratio.

Bluegills are the primary game fish in Indian Lake. Catch-per-effort (CPE) with specific gear types provides an index of relative abundance of bluegills. For Indian Lake, the trap net CPE was 41.4 fish/net night. For lakes surveyed as part of the Status and Trends Program during 2002-2007, the statewide average was 48.1 bluegills/net night and the average for lakes in southwestern Michigan was 78.8 bluegills/net night (K. Wehrly, MDNR - Fisheries Division, unpublished). With electrofishing gear, the Indian Lake CPE was 3.2 fish/minute, whereas the statewide average was 4.9 fish/minute and

the southwestern Michigan average was 5.9 fish/minute. Thus, it appears that the population density for bluegills in Indian Lake is fairly low.

Overall, bluegills exhibited a satisfactory to good size structure. Bluegills in the 8-inch size class are common and some 9-inch fish are present. The rapid increase in growth between ages 3 and 4 suggests a change in foraging strategy. Juvenile bluegills typically are confined to vegetation to avoid predators, whereas larger bluegills often forage on Daphnia in open water (Spotte 2007).

Annual total mortality for adult bluegills was estimated to be 72%, which is higher than the median of mortality estimates reported by Schneider (2000). Multiple factors could be responsible for the apparent scarcity of older bluegills in this system. High fishing mortality could have produced the observed population age structure; however, no creel survey data are available to test this hypothesis. High natural mortality would have a similar effect on the population age structure. The overall predator-prey ratio was within the target range for Michigan fish populations, but the ratio of largemouth bass to bluegills was relatively high in Indian Lake. For electrofishing surveys conducted on southwestern Michigan lakes during 2002-2007, the median catch ratio was 3.6 bluegills for each largemouth bass collected (K. Wehrly, MDNR - Fisheries Division, unpublished). During the 2010 electrofishing survey on Indian Lake, only 1.5 bluegills were captured for each largemouth bass collected. Another possible explanation for the observed size structure is that bluegill reproductive success was greater in 2005 and 2006 than in previous years. Such recruitment variability would lead to overestimation of annual total mortality.

Rock bass of harvestable size are common in Indian Lake. No creel survey data are available for Indian Lake, but it is likely that few anglers specifically target or harvest this species. Black crappies are less abundant; however, they probably support a modest targeted fishery during the spring spawning period. Yellow perch and pumpkinseeds are rare in Indian Lake, but add to the overall panfish diversity in this system.

The electrofishing CPE for largemouth bass was 2.1 fish/minute. This catch rate is slightly above the average of 1.6 fish/minute for southwestern Michigan lakes. Thus, it appears that bass abundance is in the normal range for lakes in this region.

The size structure of the largemouth bass population was skewed slightly towards sub-legal fish. Three factors determine the size structure of fish populations:recruitment, annual mortality, and growth. Because sampling only was conducted during a single year, data on year-to-year variation in recruitment of largemouth bass in Indian Lake are not available. Based on the catch curve analysis (which assumes consistent recruitment from year-to-year), annual total mortality in Indian Lake was estimated to be 56% (Figure 10). This estimate is close to the median (58%) of the annual mortality values reported by Allen et al. (2008) for North American largemouth bass populations. Thus, the available data suggest that annual total mortality of largemouth bass in Indian Lake is within the normal range for this species.

The scarcity of large bass in Indian Lake is primarily the result of slow growth. Under average growth conditions, largemouth bass reach the minimum size limit of 14 inches at age 5 (Figure 8). In Indian Lake, largemouth bass do not reach 14 inches until age 6. Given annual total mortality of 56%, this means that 56% fewer bass reach legal size than would attain legal size under average growth

conditions. In Indian Lake, the combination of below average growth and average total annual mortality has resulted in a largemouth bass population with a low percentage of fish larger than 14 inches.

The slow growth of largemouth bass in this system suggests that forage is limited. Although mean lengths-at-age for young bass were near the state average, mean lengths-at-age for adult fish (age 4 and older) were > 1 inch below average. The seine catch indicated that shiners were abundant in Indian Lake. Shiners are suitable forage for juvenile bass, but adult bass require larger prey (e.g., bluegills) for optimal growth. As noted previously, bluegill abundance is relatively low in this system.

Northern pike abundance in Indian Lake is about average for lakes in this region. The gill net CPE for northern pike was 2.7 fish/net night in Indian Lake, compared to the statewide average of 2.6 fish/net night and the average of 2.5 fish/net night for southwestern Michigan lakes (K. Wehrly, MDNR - Fisheries Division, unpublished). Growth of northern pike is excellent. Under average growth conditions, northern pike do not reach 24 inches until age 4. In Indian Lake, most pike reach this size by age 3.With such rapid growth, this lake has the potential to produce trophy-sized northern pike.

Ciscoes currently are classified as a threatened species in Michigan. This species was abundant in Indian Lake during past surveys, but no ciscoes were captured during the 2010 sampling effort. Ciscoes require cool, well-oxygenated water. During the summer, ciscoes are restricted to water layers where the temperature is 68 F or less and the dissolved oxygen concentration is at least 3.0 ppm (Latta 1995). The limnological sampling conducted on September 1, 2010 indicated that such conditions existed in a narrow layer from 23.5 ft to 26 ft in the main basin of Indian Lake. This information suggests that Indian Lake may provide marginal habitat for ciscoes during warm summers. The absence of ciscoes during the 2010 survey does not necessarily indicate that the species has been extirpated from this system, but it is a cause for concern. Additional gill net sampling conducted during the spawning season (late October-early November) is warranted to thoroughly evaluate the status of the cisco population in Indian Lake.

Management Direction

Four fisheries management goals have been developed for Indian Lake. Goal 1: Assess the status of the cisco population. Goal 2: Maintain a healthy predator-prey ratio within the fish community. Goal 3: Protect and rehabilitate habitat for fish and other aquatic organisms. Goal 4: Acquire and develop a public access site on Indian Lake.

To accomplish Goal #1, a cisco survey utilizing gill nets will be conducted during the fall of 2011. Ciscoes move into shallow water for spawning shortly before the formation of ice cover, and this is the period when they are most vulnerable to capture with fisheries assessment gear.

Some anglers have expressed interest in stocking walleyes in Indian Lake. This activity would not be compatible with Goal #2 and is not recommended. Predators currently compose about 33% of the biomass of the fish community, which is in the middle of the target range proposed by Schneider (2000). Adding additional predators to the fish community could skew this balance. The addition of walleyes would be expected to reduce bluegill abundance, decrease growth rates for largemouth bass, and reduce abundance of ciscoes (if a cisco population still exists).

At least three different methods will be used to accomplish Goal #3. Fisheries Division personnel will continue to review Michigan Department of Environmental Quality permit applications for potential effects on aquatic resources. If a proposed project is likely to degrade the aquatic habitat, Fisheries Division staff will object to the proposal and suggest feasible alternatives. Fisheries Division will work with the Indian Lake Association and other organizations to educate riparian landowners on the effects of various practices (e.g., chemical weed treatments and seawall construction) on aquatic ecosystems. As opportunities arise, Fisheries Division also will provide technical assistance to local units of government interested in establishing ordinances that protect aquatic habitats from pollution or unwise development.

Fisheries Division and Parks and Recreation Division will continue to search for opportunities to purchase lakefront property and develop a public boat launch on Indian Lake (Goal #4). Indian Lake is a high priority system for access site development because (1) it is one of the larger lakes in southwest Michigan, (2) it is located near the urban centers of Kalamazoo and Portage, and (3) it supports moderate to strong populations of bluegill, northern pike, largemouth bass, and black crappie. Development of a public access site would be consistent with the mission of Parks and Recreation Division to "provide public recreation and education opportunities" and the mission of Fisheries Division to "promote the optimum use of (aquatic) resources for the benefit of the people of Michigan."

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Table 1.–Fish stocking in Indian Lake (Kalamazoo County), 1933-2010.

Year	Species	Life stage	Number	Number/acre	Average length (inches)
1933	Bluegill	Fall fingerling	15,000	20	---
	Largemouth bass	Fall fingerling	2,000	3	---
1934	Bluegill	Fall fingerling	15,000	20	---
	Largemouth bass	Fall fingerling	1,000	1	---
1935	Bluegill	Fall fingerling	25,000	33	---
	Largemouth bass	Fall fingerling	2,500	3	---
	Yellow perch	Fall fingerling	10,000	13	---
1936	Bluegill	Fall fingerling	30,500	40	---
	Largemouth bass	Fall fingerling	2,000	3	---
1937	Bluegill	Fall fingerling	86,400	114	---
	Largemouth bass	Fall fingerling	2,000	3	---
	Yellow perch	Fall fingerling	25,000	33	---
1938	Bluegill	Fall fingerling	115,000	152	---
	Largemouth bass	Fall fingerling	3,000	4	---
	Yellow perch	Fall fingerling	30,000	40	---
1939	Bluegill	Fall fingerling	100,000	132	---
	Largemouth bass	Fall fingerling	3,000	4	---
	Largemouth bass	Yearling	250	0.3	---
	Smallmouth bass	Fall fingerling	4,000	5	---
	Yellow perch	Fall fingerling	10,000	13	---
1940	Bluegill	Fall fingerling	30,000	40	---
	Largemouth bass	Fall fingerling	2,000	3	---
	Largemouth bass	Yearling	3,000	4	---
1941	Bluegill	Fall fingerling	110,000	145	---
	Largemouth bass	Fall fingerling	1,000	1	---
1942	Bluegill	Fall fingerling	50,000	66	---
	Largemouth bass	Fall fingerling	1,000	1	---
	Smallmouth bass	Fall fingerling	3,000	4	---
1943	Bluegill	Fall fingerling	20,000	26	---
	Largemouth bass	Fall fingerling	3,000	4	---
	Smallmouth bass	Fall fingerling	1,500	2	---
1944	Largemouth bass	Fall fingerling	4,000	5	3.9
1945	Bluegill	Fall fingerling	25,000	33	1.5
	Largemouth bass	Fall fingerling	5,000	7	3.5
	Largemouth bass	Fall fingerling	3,000	4	4.0
1946	Rainbow trout	Legal	2,000	3	9.1
1947	Rainbow trout	Yearling	2,000	3	8.0
1948	Rainbow trout	Legal	2,000	3	9.0
1951	Rainbow trout	Legal	2,000	3	8.0

Table 1.–Continued.

Year	Species	Life stage	Number	Number/acre	Average length (inches)
1952	Rainbow trout	Legal	2,000	3	8.0
1953	Rainbow trout	Legal	1,000	1	9.0
1960	Rainbow trout	Legal	1,000	1	---
1964	Rainbow trout	Legal	1,000	1	---
1965	Walleye*	Spring fingerling	---	---	2.0
1967	Walleye*	Spring fingerling	---	---	---
1981	Walleye*	Spring fingerling	3,000	4	---
1982	Walleye*	Spring fingerling	2,700	4	---
1984	Walleye*	Spring fingerling	3,000	4	2.0
1999	Rainbow trout*	Legal	3,233	4	8.0

* Private fish stocking

Table 2.–Sampling effort during the fish community survey on Indian Lake (Kalamazoo County), May 2010. Each net night equals one overnight set of one net.

Sampling period	Gear	Effort
May 3-6	Trap net	8 net nights
May 3-6	Fyke net	9 net nights
May 3-6	Graded-mesh gill net	9 net nights
May 27	Electrofishing	30 minutes
May 27	Seine	5 hauls (25 ft each)

Table 3.–Numbers, weights, lengths, and growth indices for fish species collected during the fish community survey on Indian Lake (Kalamazoo County), May 2010. Fish were captured using trap nets, fyke nets, gill nets, seines, and electrofishing gear.

Species	Number	Percent by number	Weight (lbs)	Percent by weight	Length range (inches)	Percent legal or harvestable[1]	Growth index[2]
Sand shiner	1,522	36.7	2.4	0.3	1-2	---	---
Mimic shiner	933	22.5	1.4	0.2	1-2	---	---
Bluegill	873	21.0	190.1	22.7	1-9	68	+0.2
Rock bass	323	7.8	91.8	10.9	1-10	77	+0.3
Largemouth bass	133	3.2	89.4	10.7	3-19	8	-1.0
Black crappie	62	1.5	21.5	2.6	5-12	84	+0.6
White sucker	43	1.0	128.4	15.3	9-23	---	---
Northern pike	32	0.8	130.7	15.6	15-34	69	+3.7
Yellow bullhead	30	0.7	19.8	2.4	6-13	---	---
Warmouth	28	0.7	8.9	1.1	5-9	71	---
Longnose gar	13	0.3	21.1	2.5	21-29	---	---
Smallmouth bass	11	0.3	6.7	0.8	2-16	9	---
Hybrid sunfish	11	0.3	2.6	0.3	5-7	82	---
Brook silverside	10	0.2	0.0	0.0	2-3	---	---
Common carp	6	0.1	70.1	8.4	19-36	---	---
Bowfin	6	0.1	22.7	2.7	13-26	---	---
Brown bullhead	6	0.1	7.0	0.8	11-15	---	---
Channel catfish	5	0.1	10.4	1.2	16-23	100	---
Pumpkinseed	5	0.1	1.0	0.1	2-7	60	---
Yellow perch	5	0.1	0.7	0.1	2-9	40	---
Blacknose shiner	5	0.1	0.0	0.0	2	---	---
Spotted sucker	4	0.1	10.4	1.2	17-20	---	---
Bluntnose minnow	3	0.1	0.0	0.0	2	---	---
Johnny darter	2	0.0	0.0	0.0	1-2	---	---
Spotted gar	1	0.0	1.4	0.2	22	---	---
Grass pickerel	1	0.0	0.3	0.0	11	---	---
Total	4,073		839				

[1] Harvestable size is 6 inches for bluegill, pumpkinseed, rock bass, hybrid sunfish, and warmouth, and 7 inches for black crappie and yellow perch.

[2] Average deviation from the state average length at age. Mean growth indices <-1 indicate below average growth, indices between -1 and +1 indicate average growth, and indices >+1 indicate growth is faster than the state average.

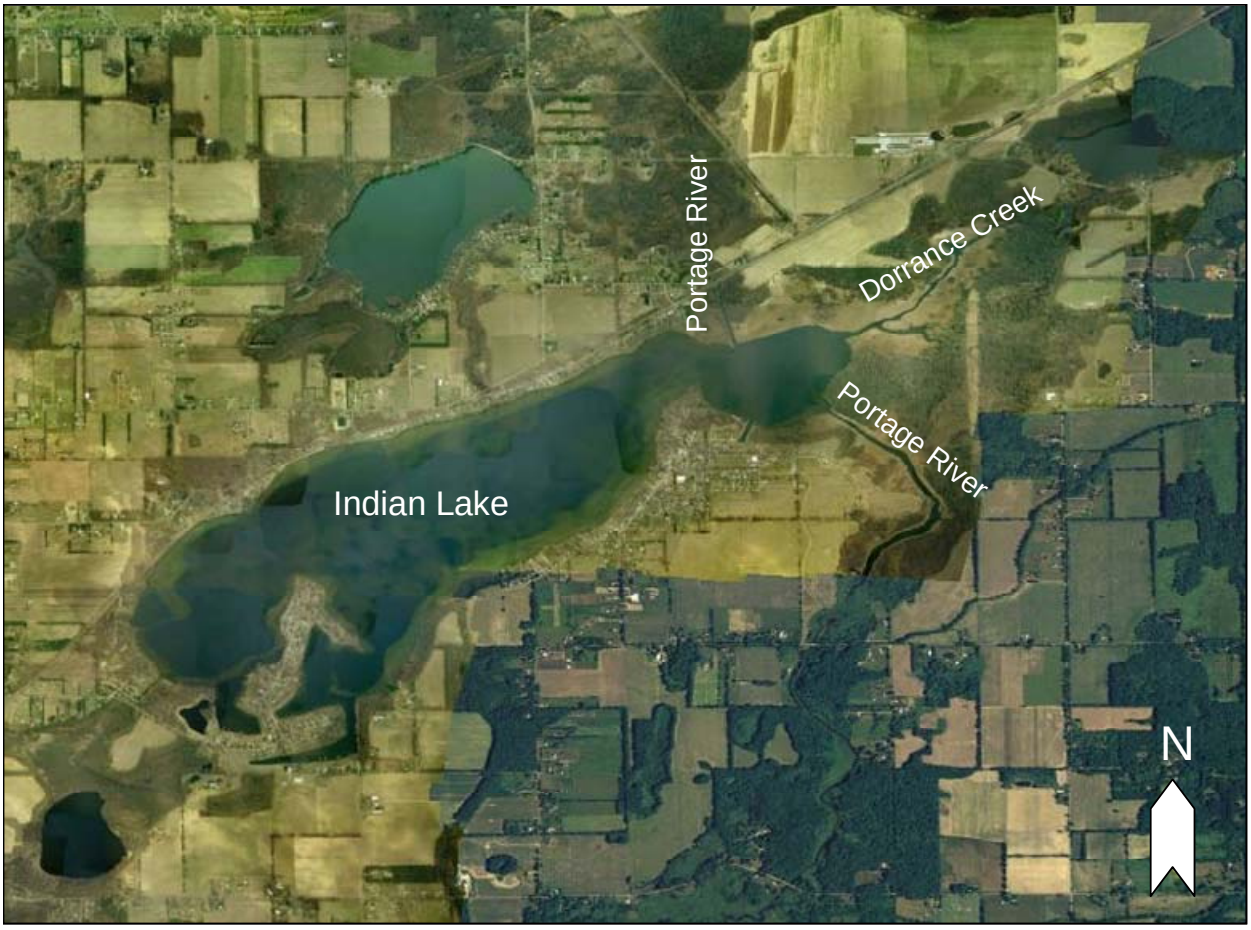
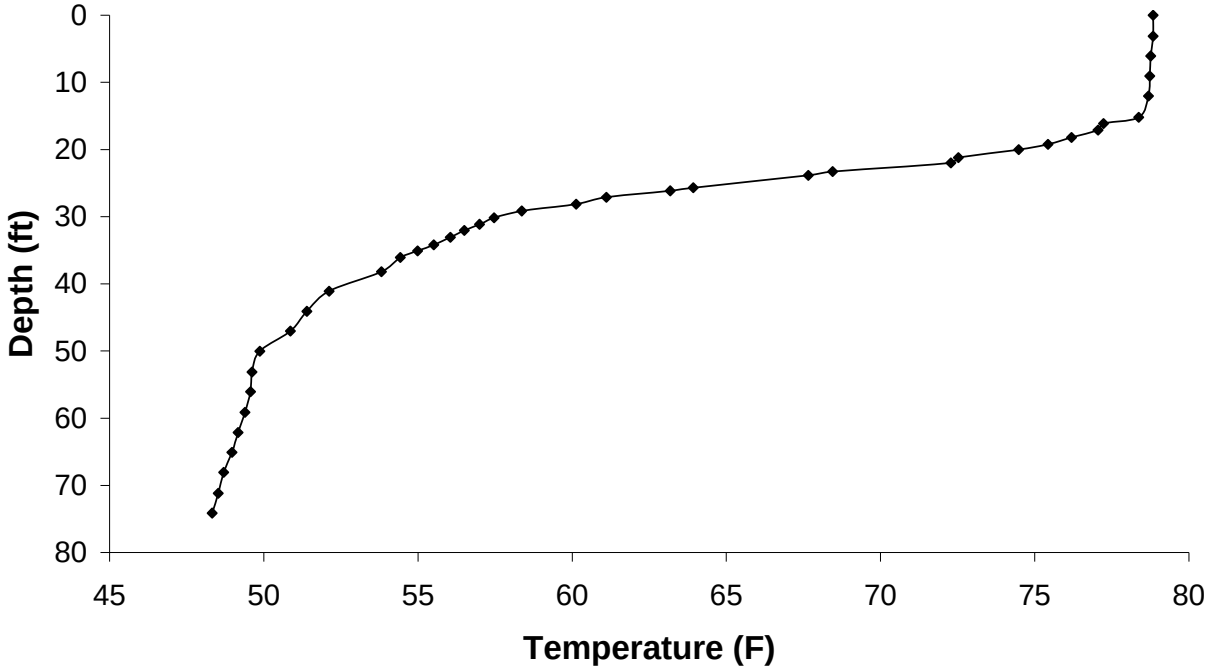


Figure 1.–Aerial view of Indian Lake (Kalamazoo County) and the surrounding area. Image from www.bing.com/maps.



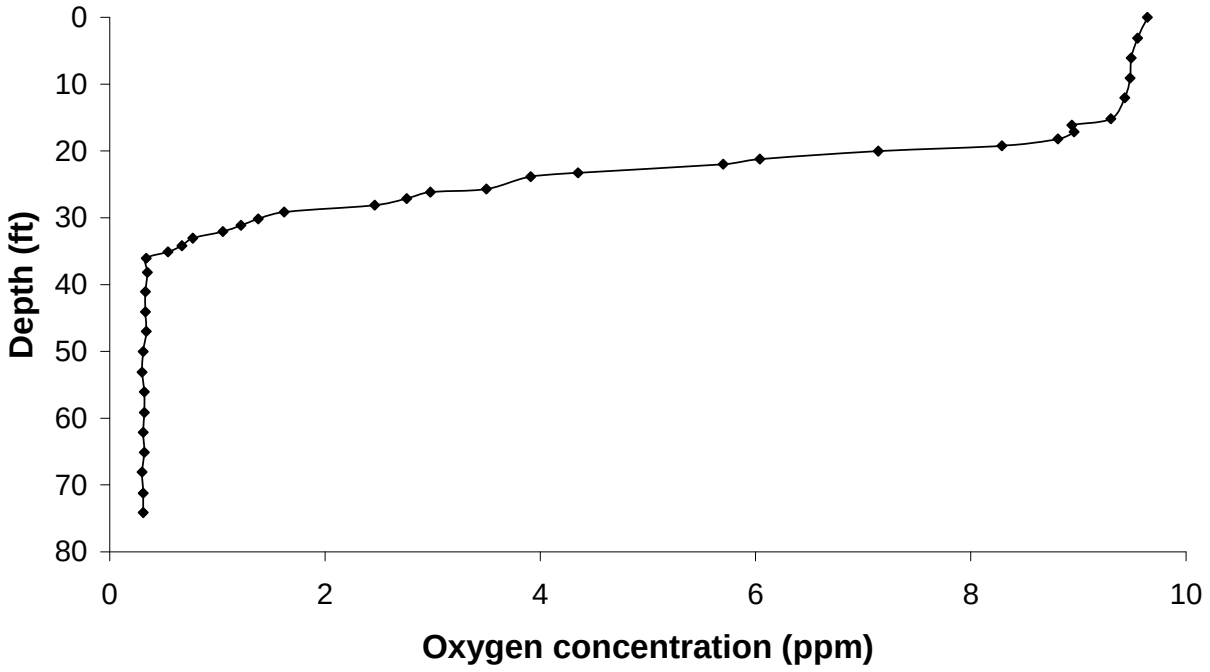


Figure 2.–Temperature and dissolved oxygen profiles for Indian Lake (Kalamazoo County) on September 1, 2010.

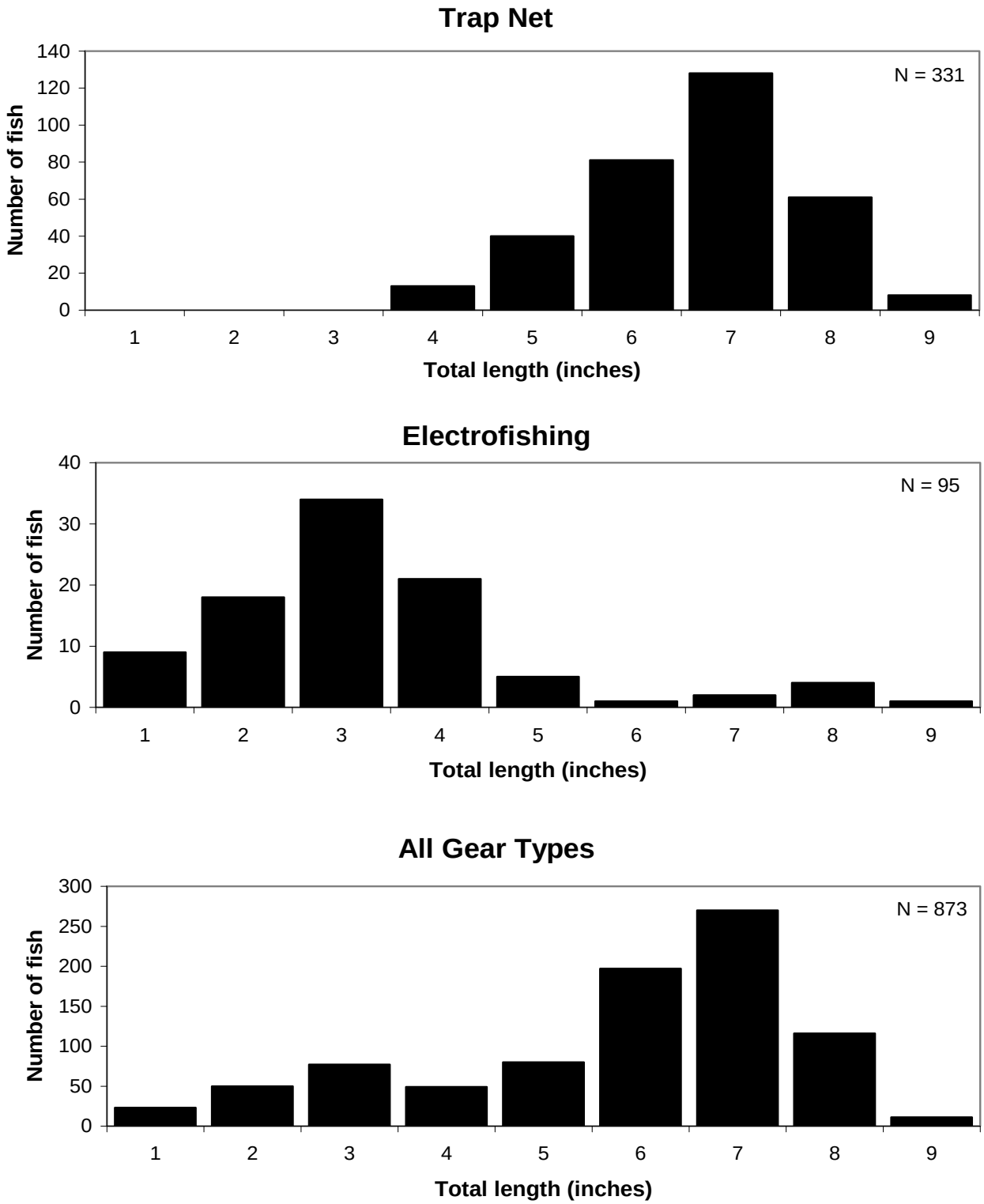


Figure 3.–Length frequency distributions for bluegills captured in Indian Lake (Kalamazoo County) using trap nets, electrofishing gear, and all gear types, May 2010.

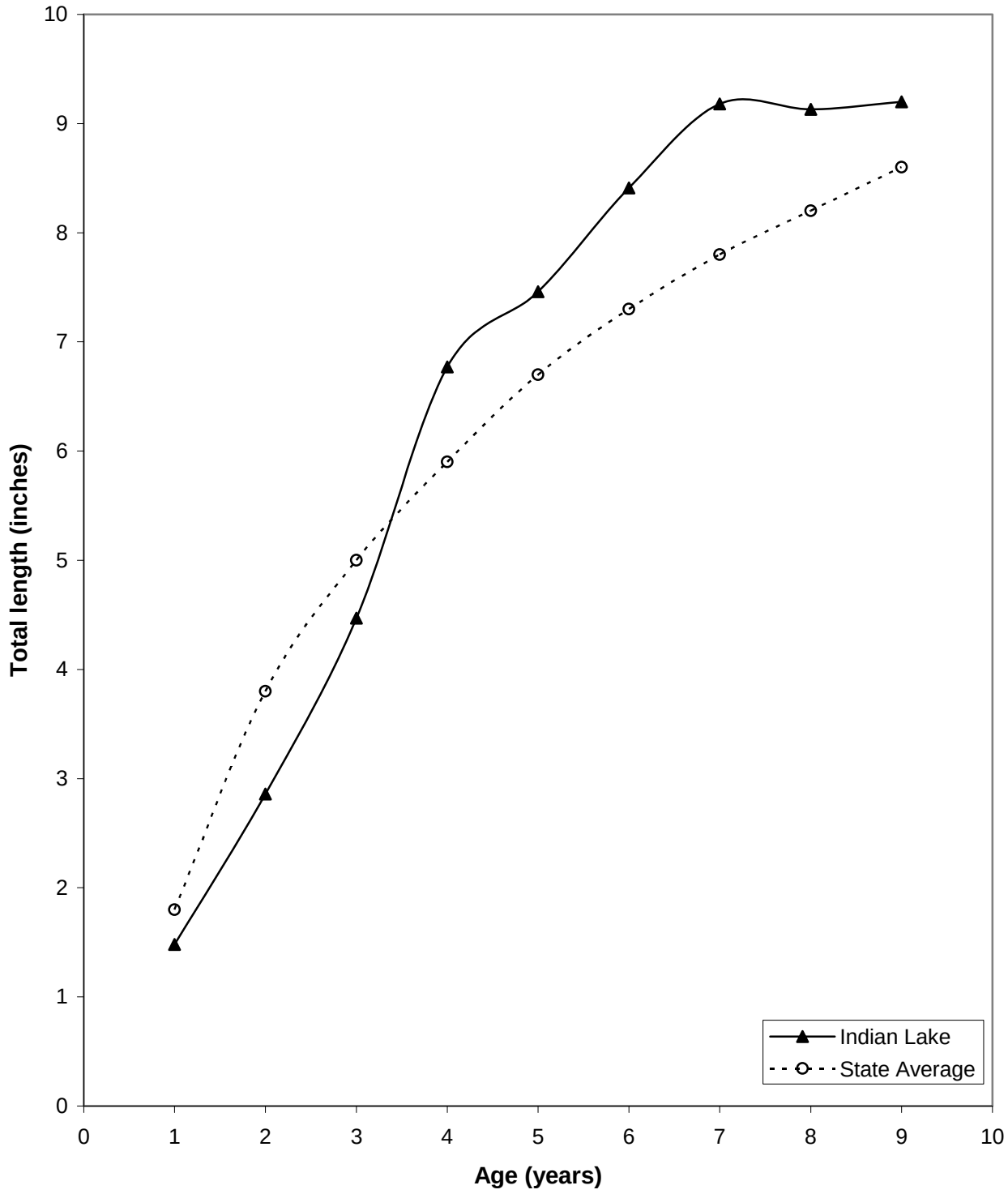


Figure 4.–Growth of bluegill in Indian Lake (Kalamazoo County), as determined from scale and spine samples collected during May 2010. State average lengths from Schneider et al. (2000).

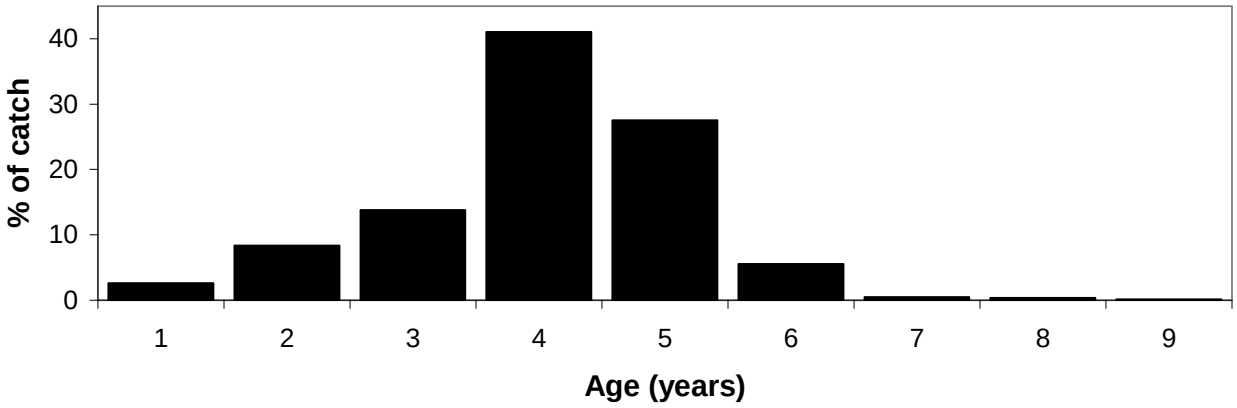


Figure 5.–Age frequency distribution for bluegill captured in Indian Lake (Kalamazoo County) during May 2010.

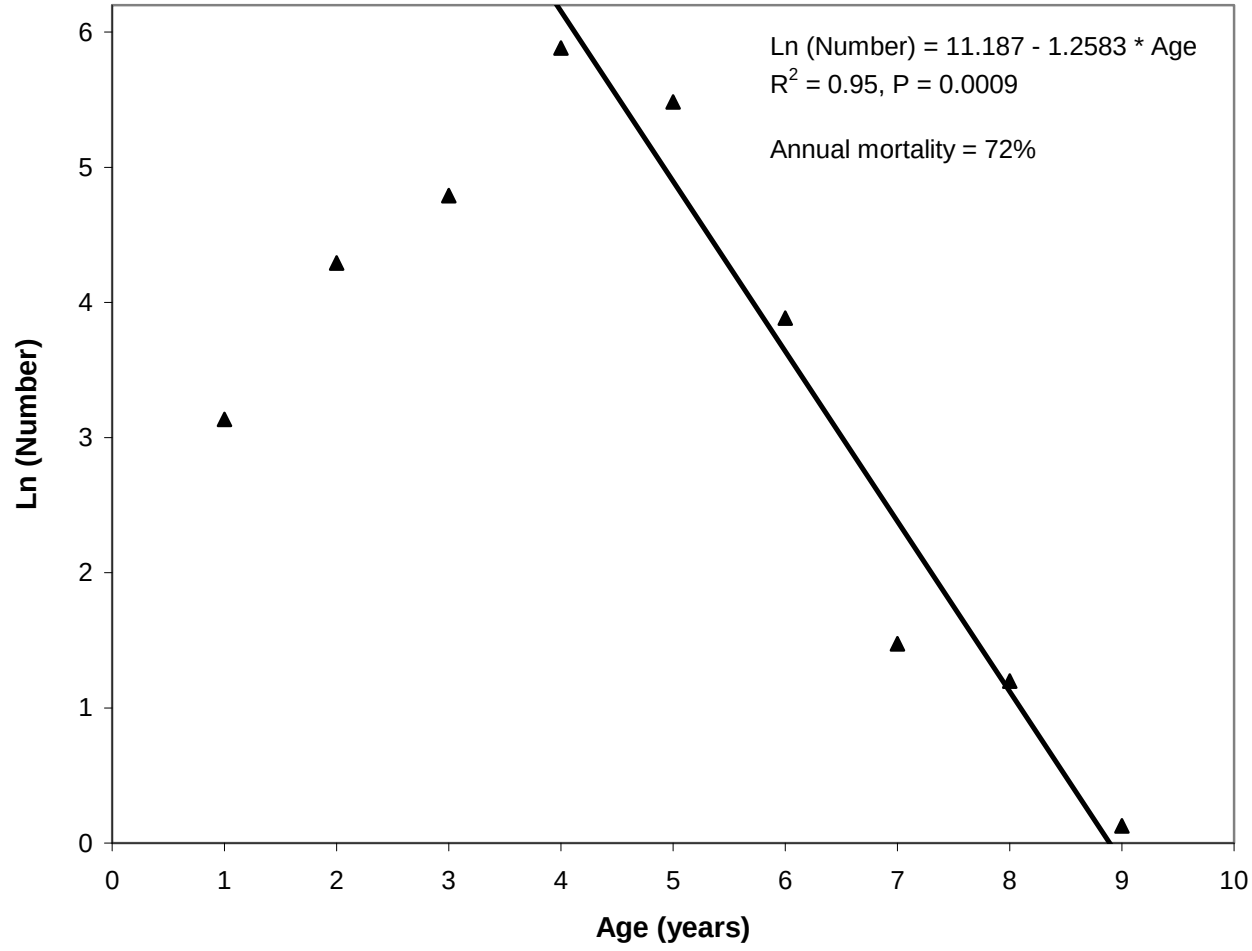


Figure 6.–Observed ln(number) versus age for bluegill captured in Indian Lake (Kalamazoo County) during May 2010.

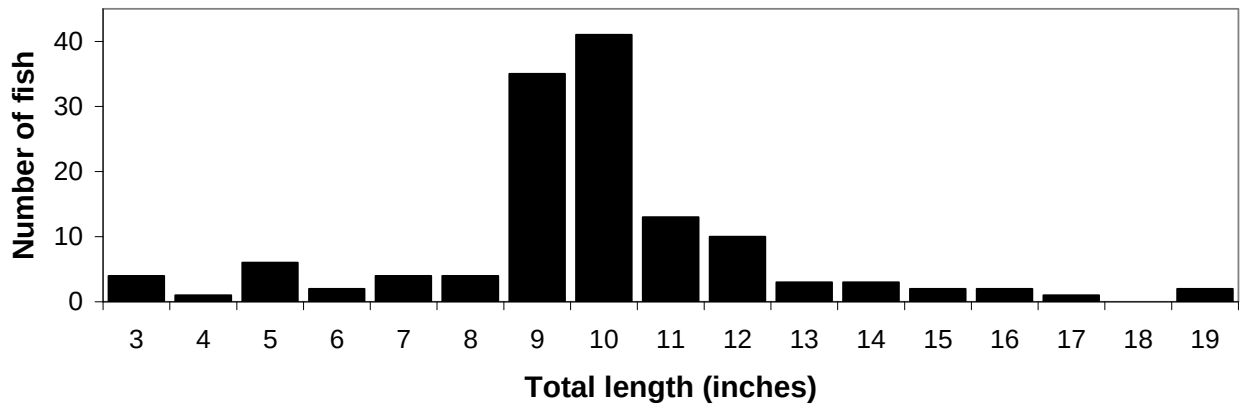


Figure 7.–Length frequency distribution for largemouth bass captured in Indian Lake (Kalamazoo County) during May 2010.

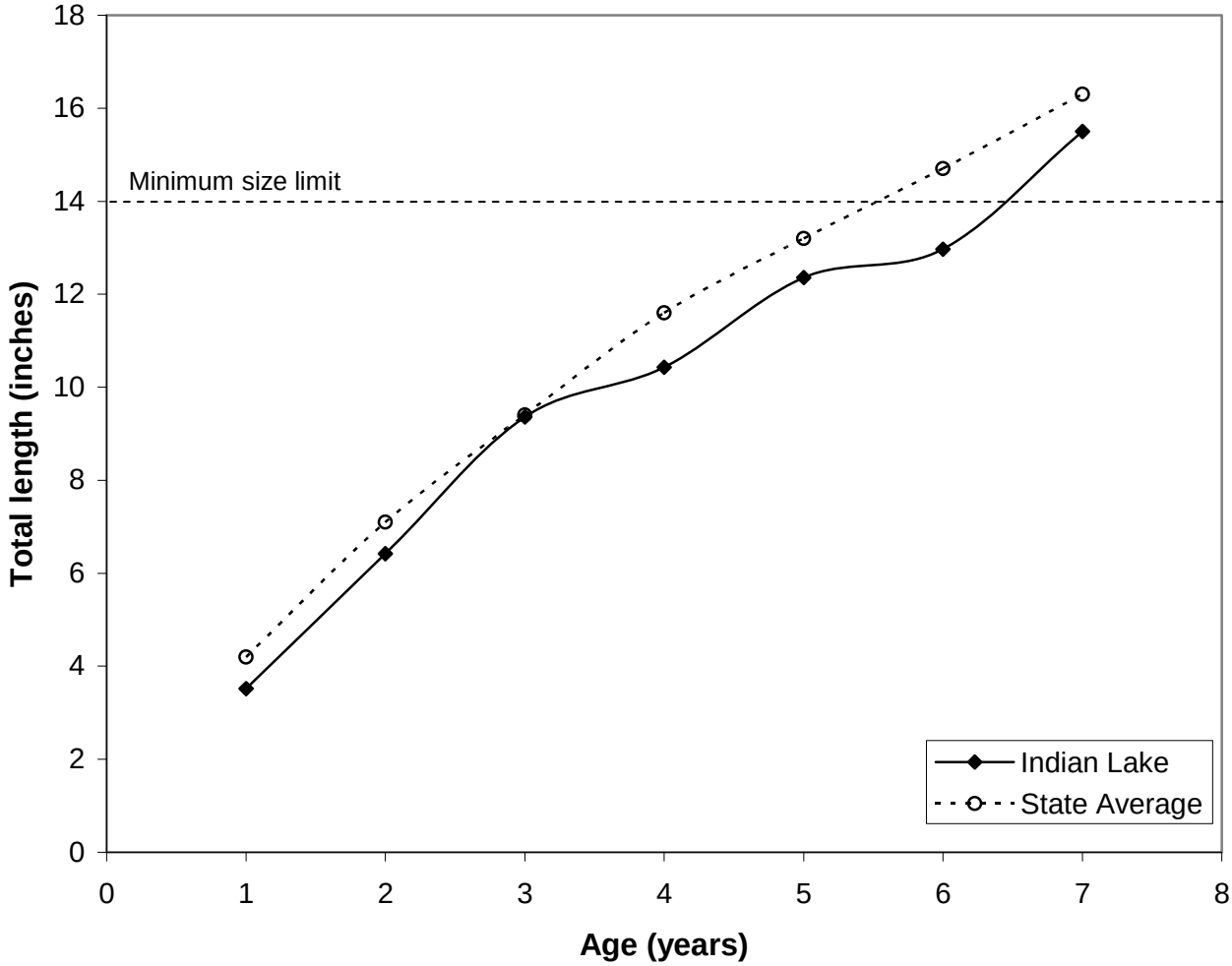


Figure 8.–Growth of largemouth bass in Indian Lake (Kalamazoo County), as determined from scale and spine samples collected during May 2010. State average lengths from Schneider et al. (2000).

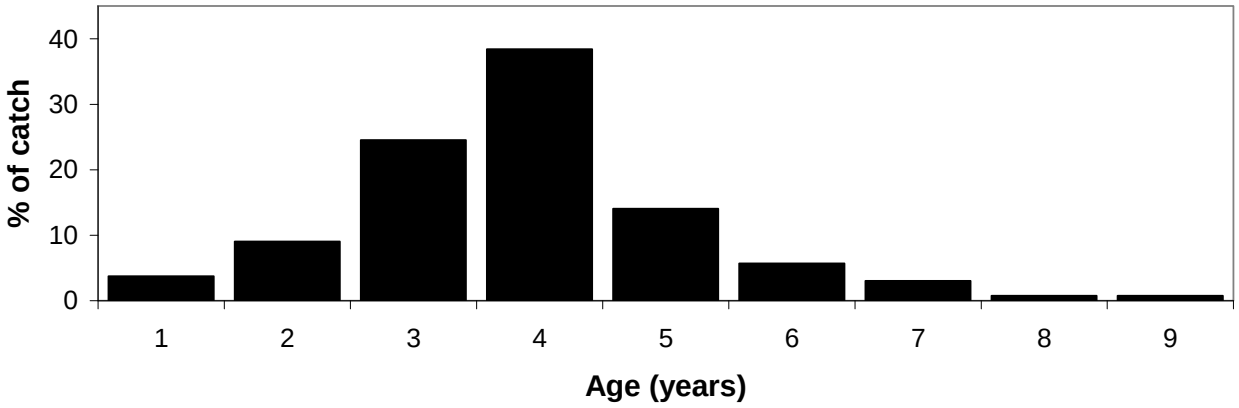


Figure 9.–Age frequency distribution for largemouth bass captured in Indian Lake (Kalamazoo County) during May 2010.

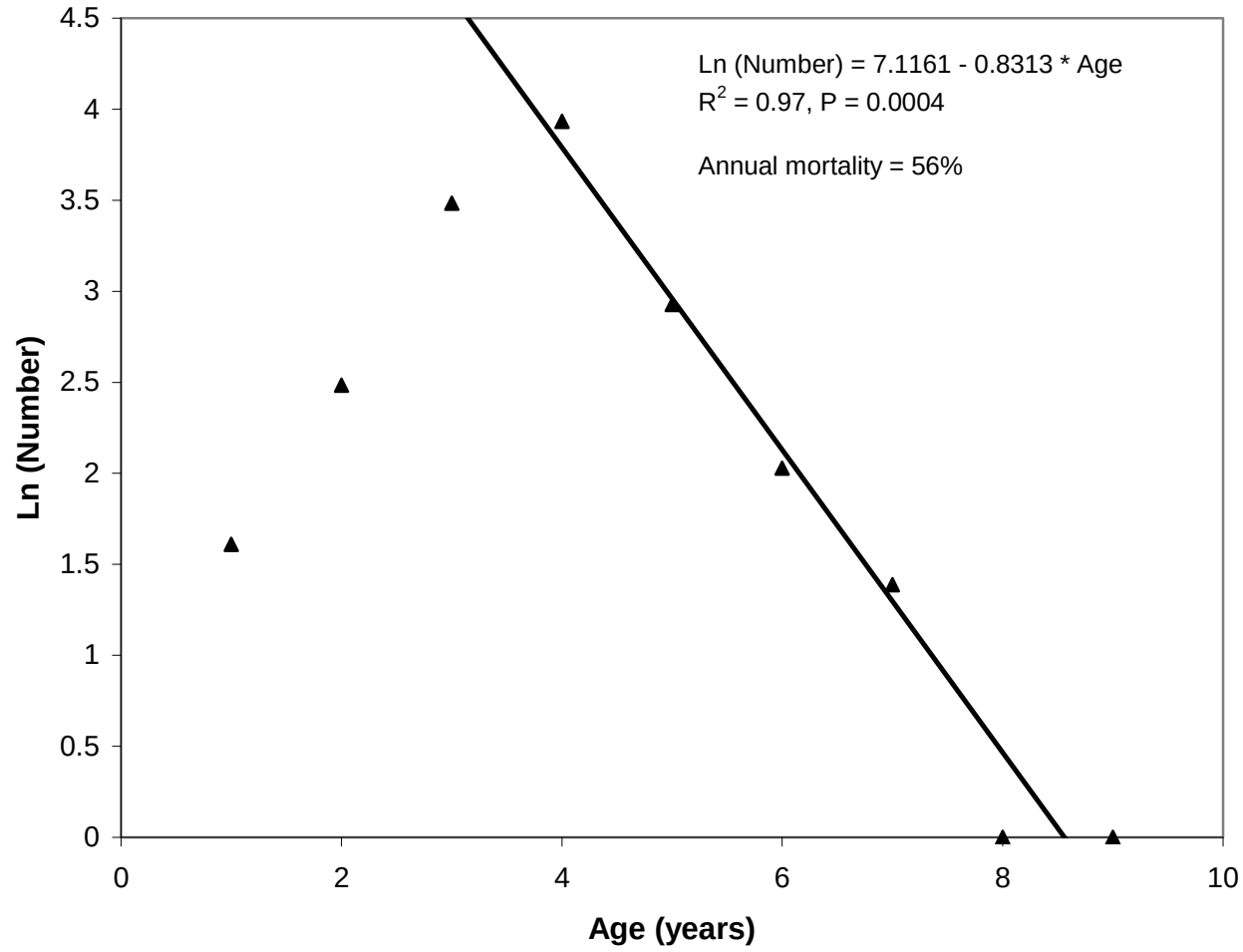


Figure 10.–Observed ln(number) versus age for largemouth bass captured in Indian Lake (Kalamazoo County) during May 2010.

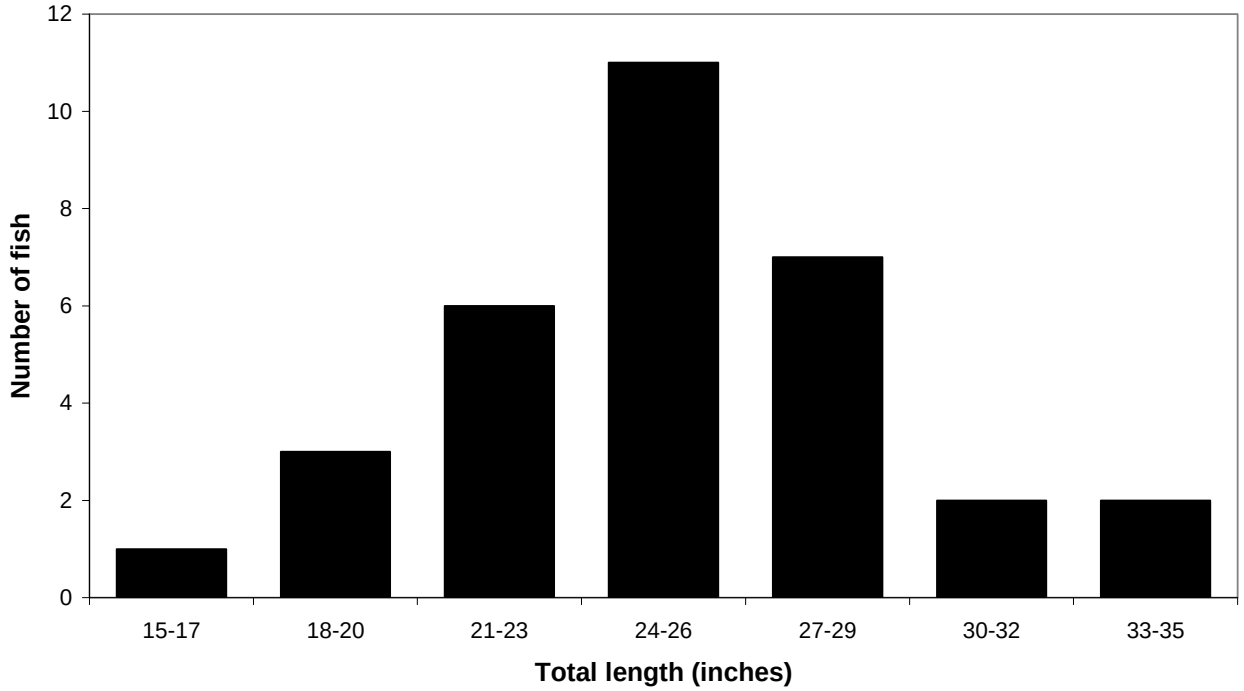


Figure 11.–Length frequency distribution for northern pike captured in Indian Lake (Kalamazoo County) during May 2010.

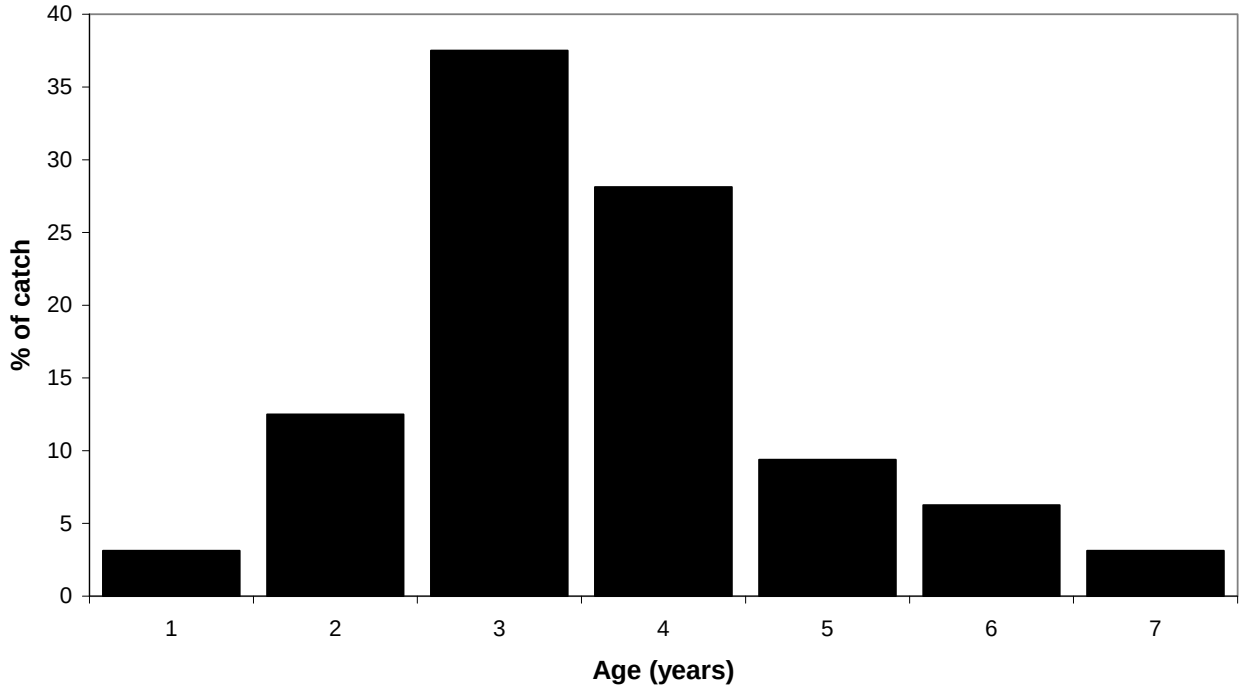


Figure 12.–Age frequency distribution for northern pike captured in Indian Lake (Kalamazoo County) during May 2010.

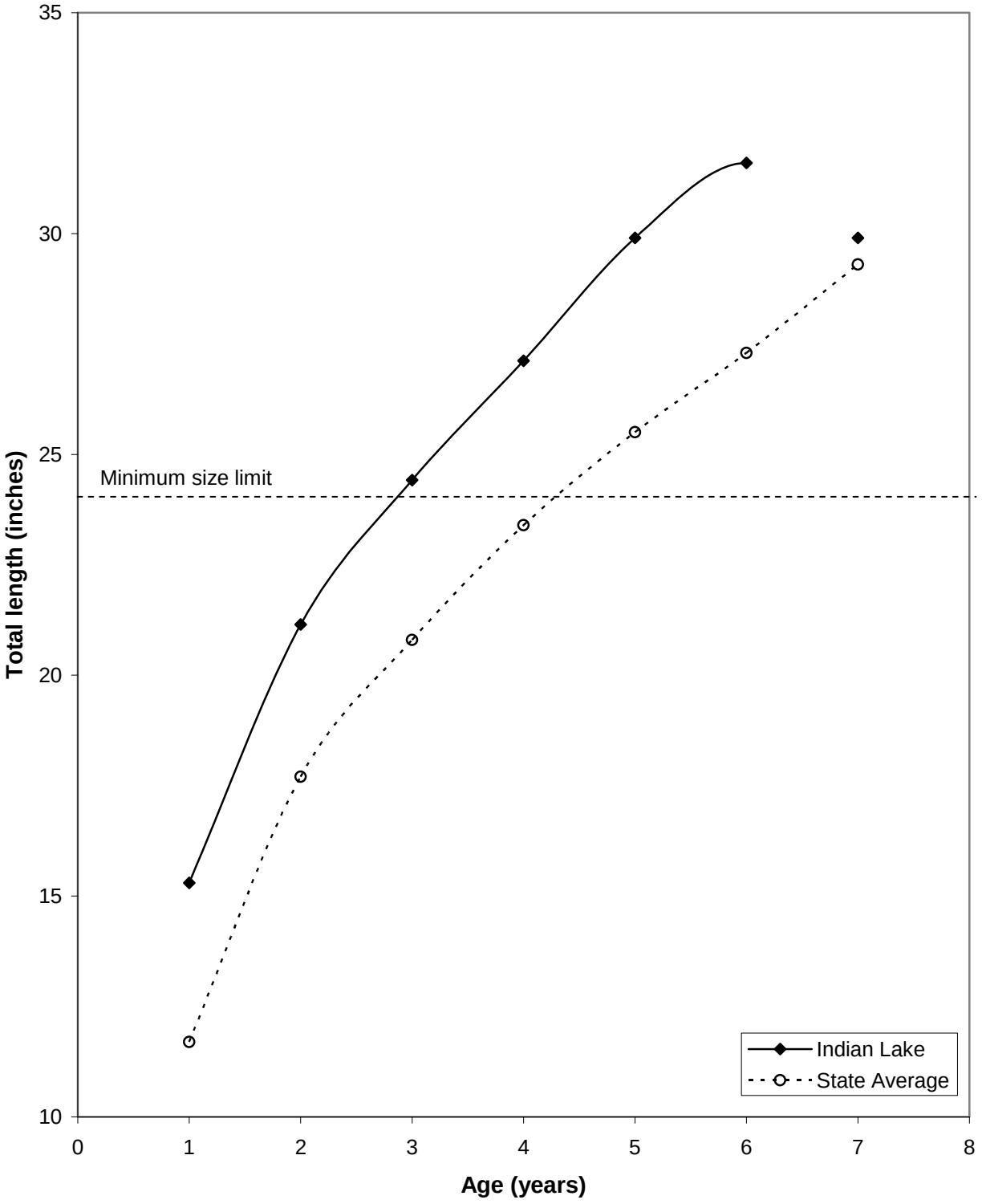


Figure 13.–Growth of northern pike in Indian Lake (Kalamazoo County), as determined from dorsal fin ray samples collected during May 2010. Only one age 7 fish was captured. State average lengths from Schneider et al. (2000).