Lake Lavine

Branch County, T8S, R6W, S17, 18, and 20
St. Joseph River Watershed, last surveyed in 2013

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Environment

Lake Lavine is an 86-acre natural lake located about 11 miles south of the city of Coldwater and less than one mile north of the Michigan-Indiana border. The lake consists of a single basin with a maximum depth of 71 ft (Figure 1). A wide shoal lines most of the shore, and 30% of the lake (by surface area) is < 5 ft deep. Beyond this shoal, drop-offs generally are steep. Approximately 51% of the lake is deeper than 20 ft. Organic substrates predominate along the southern and western shoreline, whereas sand is the most common substrate along the northern and western shore. Patches of gravel are intermixed with sand on the western edge of the lake. The only inlet is a small unnamed stream that flows through the wetland at the northwest corner of the lake. No streams flow out of Lake Lavine, but there may be subsurface movement of water from the lake into the Prairie River.

Lake Lavine is surrounded by end moraines of coarse-textured till covered by loamy soils of the Riddles-Crosier-Oshtemo series. These materials are relatively porous, and Michigan Department of Conservation maps indicate the presence of groundwater seeps in the northeast corner of the lake. Michigan's Aquatic Habitat Viewer indicates that agriculture (50%) and wetlands (21%) are the most common land uses in the watershed (Figure 2). The land along the northern and eastern shores has been developed for residential and vacation homes, whereas forests and wetlands line most of the southern and western shores. The 2013 habitat survey revealed a total dwelling density of 37.7 dwellings/mile, which is about average for lakes in this region. Abundance of large woody cover is moderate along the undeveloped shorelines. Nearly all woody cover has been removed from the developed areas. Approximately 19% of the shoreline is armored with seawalls or riprap. The Michigan Department of Natural Resources (MDNR) boat launch on the southeast shore provides public access to Lake Lavine.

Limnological sampling was conducted at the deepest point in Lake Lavine on August 20, 2013. As expected, the lake was thermally stratified (Figure 3). The epilimnion extended from the surface to a depth of 15 ft. Water temperatures within the epilimnion were relatively uniform, ranging from 76.4 F to 73.5 F. The metalimnion (zone of thermal change) extended from 15 ft to 43 ft. Water temperatures declined from 73.5 F at the top to 44.8 F at the bottom of the metalimnion. The cold waters of the hypolimnion extended from 43 ft to the bottom of the lake. The oxygen distribution within Lake Lavine followed a clinograde curve, with the highest oxygen concentrations occurring near the surface (Figure 3). Total alkalinity was 80 mg/L, which is indicative of a moderately hardwater lake with medium buffering capacity (Shaw et al. 2004).

The biological productivity of a lake is strongly dependent on its supply of two key nutrients: phosphorus and nitrogen. Nitrogen is the limiting nutrient when the ratio of total nitrogen to total phosphorus is <10:1, and phosphorus is the limiting nutrient when this ratio is >15:1 (Shaw et al. 2004). In Lake Lavine, the ratio of total nitrogen to total phosphorus was 85:1. Thus, phosphorus is the limiting nutrient in this system. The total phosphorus concentration was 0.0061 mg/L. The chlorophyll a concentration, which provides an index of algal biomass, was 0.0031 mg/L. The Secchi disk depth (a measure of water transparency) was 15 ft. Based on these water quality parameters Lake Lavine is considered a mesotrophic or moderately productive lake (Carlson and Simpson 1996).

History

The first fisheries survey of Lake Lavine was conducted in 1927. Largemouth bass, bluegills, pumpkinseeds, yellow perch, grass pickerel, and bullheads were collected during this initial sampling effort. Fall fingerling bluegills, largemouth bass, and yellow perch were stocked in Lake Lavine during 1935-1945 (Table 1). Throughout the state, annual stocking programs for these species were discontinued after research indicated that spawning habitat (i.e., aquatic vegetation for yellow perch, and sand, gravel, or firm mud for bluegills and largemouth bass) was abundant in Michigan lakes and that supplemental stocking had minimal effects on the quality of the fishery (Cooper 1948).

Limnological sampling completed during August 1947 indicated that water temperatures and dissolved oxygen concentrations were suitable for trout survival, and a rainbow trout stocking program was initiated that same year. Rainbow trout have been stocked in Lake Lavine almost every year since 1947 (Table 1). Gill nets were deployed in the lake during June 1968 to assess survival of stocked trout. Eighteen rainbow trout with a mean total length of 11.1 inches were captured in the gill nets. Yellow perch composed the bulk of the catch, and 52% of the perch were 7 inches or larger. Electrofishing also was conducted in July 1968. The catch was low for all species due to survey timing. Bluegills, pumpkinseeds, and largemouth bass were the most abundant species in the sample. Analyses of scale samples indicated that growth was average for bluegills and below average for largemouth bass.

The next gill net survey on Lake Lavine was completed in June 1978. Twenty-two rainbow trout with a mean total length of 10.4 inches were collected. Yellow perch (n = 50) and bluegills (n = 35) were the most abundant game species in the sample. All of the yellow perch were 7 inches or larger and 89% of the bluegills were 6 inches or larger. Catch-per-effort (CPE) of rainbow trout was lower during surveys conducted in 1984 and 1989; however, anglers continued to report good fishing for rainbow trout throughout the 1980s. Scales collected from bluegills and yellow perch during this period revealed that growth was average for these species.

Hook-and-line surveys were conducted during the summer in 1992, 1995, 1996, 1998, and 1999. Thirteen rainbow trout were captured in 148.5 hours of angler effort (CPE = 0.088 fish/angler hour). Limnological surveys completed during 1992-2003 indicated that summer water temperatures and dissolved oxygen concentrations were suitable for trout survival. Anglers reported good fishing for rainbow trout through the early 2000s and declining catch rates during the last five years.

Current Status

A fisheries survey was conducted on Lake Lavine during April 8-9, 2013. The primary objective of this survey was to assess the survival and growth of stocked rainbow trout. A secondary objective was to obtain information on the species composition and size structure of the rest of the fish community in the lake. Fish were captured using three large-mesh fyke nets and three gill nets. Total lengths were recorded for all fish. Dorsal fin ray samples were collected from northern pike for age determination.

In May 2013, fish were captured with fyke nets, gill nets, seines, and nighttime electrofishing gear (Table 2) as part of MDNR's Status and Trends Program (STP). 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, spine or scale samples for age determination were collected from 10 fish per inch group. Weights for all species were calculated using the length-weight regression coefficients compiled by Schneider et al. (2000b). Proportional stock density (PSD) was calculated for largemouth bass using 8 inches for the minimum stock length and 12 inches for the minimum quality length (Anderson 1976; Gabelhouse 1984; Guy and Willis 1990).

No rainbow trout were captured during the April netting effort. The catch consisted of ten different fish species (Table 3). Bluegill (n = 59) was the most numerically abundant species in the sample. Ninety-seven percent of the bluegills were six inches or larger. Northern pike (n = 18) made up 46% of the total fish biomass. Seventy-eight percent of the northern pike were of legal size (i.e., > 24 inches), and the largest fish was 39 inches (Figure 4). Four age classes of northern pike were collected (Figure 5). Age 3 fish dominated the sample, composing > 70% of the total northern pike catch. Length-at-age data revealed rapid growth of pike in this system (Figure 6).

Twenty-one fish species (plus hybrid sunfishes) were collected during the 2013 STP survey (Table 4). Bluegill (n = 1,245) was the most abundant species, composing 60% of the catch by number and 31% of the catch by weight. Thirty-one 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 7). 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 Lake Lavine bluegill population were 6.4 (excellent-superior) based on the large-mesh fyke net sample and 3.0 (acceptable) based on the electrofishing sample.

Nine year classes of bluegills were collected during the STP survey. Yearling and age-2 bluegills composed 67% of the catch (Figure 8). Mean lengths-at-age for juvenile bluegills were similar to statewide averages, whereas mean lengths-at-age for adult bluegills in Lake Lavine were above average (Figure 9).

Redear sunfish (n = 160) made up 8% of the total biomass in the catch. Sixty-eight percent of the redear sunfish were 6 inches or larger (Figure 10) and the maximum length was 9.5 inches. Fish from 10 different year classes were captured during the survey (Figure 11). The mean growth index for redear sunfish was -1.0, which is indicative of below average growth (Figure 12). Redear sunfish often hybridize with bluegills. Hybrid sunfish (n = 114) composed 6% of the total fish biomass during the 2013 survey.

Black crappies (n = 19) and yellow perch (n = 16) were minor components of the catch. Together these two species made up only 3% of the total biomass. The limited length-at-age data available suggest average growth for these species.

Largemouth bass (n = 72) were the most abundant predators in the catch. The PSD was 24, and legal-sized fish (14 inches and larger) composed 8% of the sample (Figure 13). Mean lengths-at-age were similar to statewide averages for fish ages 1-4, and below average for fish ages 5-6 (Figure 14). Fish from the 2010 and 2011 year classes (age 2-3) made up 48% of the largemouth bass catch (Figure 15). Total annual mortality of largemouth bass ages 3-9 was estimated to be 38% (Figure 16).

Four rainbow trout were captured during the STP survey. All of these fish were yearlings that had been stocked in the lake on April 24, 2013. The total length range for rainbow trout was 5-8 inches. Four northern pike with total lengths from 23 inches to 38 inches also were collected during the Status and Trends survey (Figures 4-6).

Analysis and Discussion

Predators (largemouth bass, northern pike, bowfin, and grass pickerel) composed 19% of the total fish biomass during the STP survey. Schneider (2000) observed that predators typically make up 20-50% of the biomass in lakes with desirable fish communities. Based on this standard, it appears that relative abundance of predators in Lake Lavine is slightly below the optimal range.

Catch-per-effort (CPE) with specific gear types provides abundance indices that can be compared to values for lakes sampled as part of the STP during 2002-2007 (K. Wehrly, MDNR - Fisheries Division, unpublished). Nighttime electrofishing generally is the most effective method for capturing adult and sub-adult largemouth bass. The largemouth bass CPE in Lake Lavine was 1.6 fish/minute, which is in the top 25% of values recorded for STP lakes statewide and slightly above the median value of 1.3 fish/minute for lakes in southwest Michigan (K. Wehrly, MDNR - Fisheries Division, unpublished). Largemouth bass smaller than 12 inches are important predators of juvenile bluegills, and lakes with high densities of sub-legal bass often support bluegill populations with high proportions of fish > 7 inches (Gabelhouse 1984; Guy and Willis 1990). To produce quality bluegill fisheries, Guy and Willis (1990) recommended maintaining largemouth PSDs near 20. Lake Lavine fits the description of a lake well-suited for providing a quality bluegill fishery. The population density for largemouth bass is high and the largemouth bass PSD was 24 during the 2013 survey. Thus, although the total biomass of predators in the lake is relatively low, that biomass is skewed toward predators that are critical for preventing stunting in bluegills.

Three factors determine the size structure of largemouth bass 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 Lake Lavine are not available. Based on the catch curve analysis (which assumes consistent recruitment from year-to-year), total annual mortality was estimated to be 38% (Figure 16). This estimate falls near the lower end of the range of total annual mortality values compiled by Allen et al. (2008) for North American largemouth bass populations. Length at age data for Lake Lavine suggest that growth rates are average until age 4 and decline below average for older fish. This growth pattern could be caused by a scarcity of larger prey for adult bass. By age 5, largemouth bass are targeting bluegills with a total length of approximately 3-4 inches (Hoyle and Keast 1987). Bluegills in this size range were abundant in Lake Lavine (Figure 7), so the observed growth pattern does not appear to be due to a lack of forage. An alternative explanation is that fishing mortality is higher for fast-growing bass than for slow-growing bass. Fast-growing individuals reach legal size earlier and likely have a shorter life span than slow-growing individuals.

Bluegills are the primary game fish in Lake Lavine. During the 2013 STP survey the large-mesh fyke net CPE was 41.0 bluegills/net night, which was above the statewide median value and about average for lakes in southwest Michigan. With electrofishing gear, the bluegill CPE for Lake Lavine was in the top 5% statewide and was higher than all the CPEs recorded for southwest Michigan lakes during 2002-2007. The large-mesh fyke net catch consisted almost entirely of adult fish, whereas the electrofishing catch was dominated by juveniles (Figure 7). Thus, the 2013 Status and Trends data indicate that abundance of juveniles was high and abundance of adult bluegills was about average for lakes in this region. The disparity between juvenile and adult bluegill CPE could have been caused by high juvenile mortality (e.g., from predation by largemouth bass). However, abnormally high sampling efficiency during the electrofishing run (e.g., due to excellent water transparency) or recruitment variability could have produced similar results. Roughly equal numbers of age-4, 5, and 6 fish were collected during the STP survey, which is indicative of low annual mortality for adult bluegills.

There was a large discrepancy between the bluegill size score based on the fyke net sample and the size score based on the electrofishing sample. The size score based on the netting effort probably is a more reliable indicator of the quality of the fishery. The nets were fished for three nights, whereas electrofishing only was conducted on a single night. Schneider (1990) noted similar concerns regarding the suitability of one-night electrofishing survey data for calculating size scores.

Redear sunfish are not native to Lake Lavine and no redear sunfish were captured during previous surveys on this system. This species presumably became established in the lake through unauthorized introductions by anglers. In many lakes, it is not uncommon for redear sunfish to attain total lengths greater than 10 inches. In Lake Lavine, none of the sunfish collected were larger than 9.5 inches and the mean length at age for age-6 fish was 2.0 inches below the state average. Snails are an important component of the diet of redear sunfish (Huckins 1997), so a scarcity of snails may be responsible for the poor growth of sunfish in this system.

Yellow perch occupy offshore areas during the period when STP surveys are conducted. Thus, perch typically compose a small percentage of the total fish biomass in the catch. The gill net CPE for yellow perch in Lake Lavine was near the middle of the range reported for STP lakes (K. Wehrly, MDNR - Fisheries Division - unpublished).

Northern pike are not native to Lake Lavine. This lake is not connected to any other waters with northern pike populations. This situation, coupled with anecdotal reports from local residents, suggest that someone illegally introduced northern pike into the lake within the last few years. The wetlands surrounding Lake Lavine are excellent spawning and nursery habitat for northern pike so the population may become self-sustaining.

The poor rainbow trout catch in 2013 probably was the result of several factors. For example, summer water temperatures influence survival and growth of stocked rainbow trout. The optimal temperature range for rainbow trout is 53.6-64.4 F (Raleigh et al. 1984). Zero growth occurs at 73.4 F (Hokanson et al. 1977), and the incipient lethal water temperature for rainbow trout is approximately 77 F (Black 1953; Bidgood and Berst 1969; Hokanson et al. 1977).

Dissolved oxygen concentrations also affect growth and survival of trout. Optimal oxygen concentrations for rainbow trout are 7 mg/L or greater when water temperatures are 59 F or lower and 9 mg/L or greater when water temperatures are > 59 F (Raleigh et al. 1984). "The incipient lethal level of dissolved oxygen for adult and juvenile rainbow trout is approximately 3 mg/L or less, depending on environmental conditions, especially temperature (Gutsell 1929; Burdick et al. 1954; Alabaster et al. 1957; Downing and Merken 1957; Duodoroff and Warren 1962). Although fish can survive at concentrations just above this level, they must make various physiological adaptations to low levels of dissolved oxygen that may jeopardize their health (Randall and Smith 1967; Kutty 1968; Hughes and Saunders 1970; Cameron 1971; Holeton 1971). For example, low levels of dissolved oxygen can result in reduced fecundity and even prevent spawning. Large fluctuations in dissolved oxygen may cause a reduction in food consumption and impaired growth (Duodoroff and Shumway 1970)." [From Raleigh et al. 1984]

Thus, both water temperatures and dissolved oxygen concentrations influence the distribution of rainbow trout within a lake. May (1973) found that lake-dwelling rainbow trout typically occupied depths with water temperatures less than or equal to 70 F and dissolved oxygen concentrations > 3 mg/L. Such conditions existed in a 2 ft deep band within the metalimnion in Lake Lavine on August 20, 2013 (Figure 3). Overall, the temperature and dissolved oxygen profiles indicated that rainbow trout potentially were able to survive in Lake Lavine through the summer of 2013, but the adverse environmental conditions probably had sub-lethal effects on the growth and health of these fish. Environmental conditions probably were worse during the abnormally hot, dry summer of 2012 (Marino 2012).

In recent years various chemicals have been used to control growth of aquatic plants and algae in Lake Lavine (Table 5). For example, copper sulfate and a chelated copper herbicide were applied to a 3-acre plot at the northeast end of the lake in 2012. Copper sulfate is highly toxic to trout and chelated copper products can be toxic to trout under certain conditions (Schrouder et al. 1994; Wisconsin Department of Natural Resources 2012b). The toxicity of copper compounds to fish is influenced by the pH and alkalinity of the lake water, with the greatest risk to fish in waters with low pH and low alkalinity (Lauren and McDonald 1986; Straus and Tucker 1993). Based on the 2013 limnological data, the Lake Lavine rainbow trout population's sensitivity to copper compounds is expected to be low to moderate. Copper treatments can affect trout indirectly through reducing their forage supply as both copper sulfate and chelated copper are toxic to many species of aquatic invertebrates (Wisconsin Department of Natural Resources 2012b). The herbicide 2,4-D also was applied to 6.5 acres of the Lake Lavine shoreline in June 2012 to control Eurasian watermilfoil. The ester formulation used for the Lake Lavine treatment can be toxic to fish and aquatic invertebrates at typical application rates (Jervais et al. 2008; Wisconsin Department of Natural Resources 2012a). Because so many factors affect the toxicity of chemicals to fish, it is difficult to determine if the herbicide and algaecide treatments were important factors limiting trout survival in this system.

Northern pike are voracious predators of rainbow trout (Lepak et al. 2012), so the introduction of northern pike into Lake Lavine presents another major challenge to continued trout management in this system. Four potential management options were identified. The costs and probable outcomes of each option were summarized and this information was presented at a public meeting in Kinderhook on August 26, 2014.

OPTION 1: Continue annual stocking of 4,300 yearling rainbow trout and conduct manual removals of northern pike using gill nets and fyke nets. The nets would be set near suspected spawning sites (i.e., the wetlands at the northwest end of the lake and the submerged vegetation at the south end of the lake) immediately after ice-out. The nets would be checked every day for 10 consecutive days.

Because some natural reproduction of northern pike may already have occurred and juvenile pike are less vulnerable to sampling gear, the manual removal efforts ideally would continue for at least three years. Staff salaries (including wages and benefits), mileage, boat fuel, travel (i.e., meal allowance) costs for three years of manual removals would be approximately $36,600. The cost per Eagle Lake rainbow trout yearling is $1.18. Stocking costs for three years would be $15,222. Thus, the total cost for this option over the next three years would be about $51,820. The manual removals would severely reduce northern pike abundance, but the results of manual removal projects on other lakes indicate a strong possibility that a few pike would survive and potentially recolonize the lake (D. Kramer, MDNR - Fisheries Division, unpublished). This option likely would produce noticeable improvement in trout survival over the next several years. The long-term effects are less certain as they are dependent on the efficiency of the sampling gear at removing northern pike and the presence or absence of any further illegal introductions of northern pike into Lake Lavine. This option is not expected to have any detrimental effects on the largemouth bass and panfish populations in the lake.

OPTION 2: Conduct a rotenone treatment to remove northern pike, resume rainbow trout stocking after the treatment, and re-introduce bluegills and largemouth bass. Rotenone is a naturally occurring fish toxicant that has been used to eliminate undesirable fish species since the 1930s. At the concentrations typically used for fisheries reclamations, rotenone is highly toxic to fish but has little effect on amphibians, reptiles, and aquatic macroinvertebrates. The estimated cost for the rotenone treatment is $42,100. MDNR does not rear bluegills or largemouth bass in state fish hatcheries, so these fish would have to be purchased from a private aquaculture facility. Cost estimates are $11,610 for bluegills (stocking density = 300 fish/acre; size at stocking = 1-3 inches; cost/fish = $0.45) and $4,773 for largemouth bass (stocking density = 30 fish/acre; size at stocking = 4-6 inches; cost/fish = $1.85). Stocking costs for rainbow trout would be the same as in Option 1. Thus, the total cost for implementing Option 2 would be approximately $73,700. This option has the greatest likelihood of eliminating northern pike, but eradication of pike is not a certainty. This option also has the greatest probability of improving the rainbow trout fishery in the lake. However, the rotenone treatment would temporarily eliminate an excellent bluegill fishery. The bluegill population would take several years to recover and the size structure may never be as impressive as it was in 2013. Populations of other native species, such as yellow perch and black crappie, would be temporarily reduced and possibly extirpated by the rotenone treatment.

OPTION 3: Do not remove northern pike and continue stocking rainbow trout. This option would cost $15,222 over the next three years. Although the cost is significantly lower than for options 1 and 2, this option offers little chance of maintaining a productive trout fishery. High mortality of stocked rainbow trout would occur, and few (if any) trout would survive to age 2 (Lepak et al. 2012).

OPTION 4: Discontinue rainbow trout stocking and manage the lake to provide a coolwater-warmwater fishery. There are no costs associated with this option. The rainbow trout fishery would cease to exist and would be replaced by a northern pike fishery. The lake probably would support a naturally reproducing northern pike population of low-moderate population density and above average growth rates. Abundance of lake chubsuckers and yellow perch would decline (Soupir et al. 2000; Paukert and Willis 2003; Paukert et al. 2003). Any changes in abundance and size structure of bluegill likely would be minimal (Mauck and Coble 1971; He and Kitchell 1990; Paukert and Willis 2003; Paukert et al. 2003). Published studies on the effects of introduced northern pike on native largemouth bass populations are lacking. Soupir et al. (2000) summarized the results of largemouth bass introductions in northern Minnesota lakes and found that abundance of largemouth bass was lower in lakes with native northern pike populations. Similarly, Paukert and Willis (2003) studied native fish communities in Nebraska lakes and observed that largemouth bass abundance typically was lower in lakes where northern pike were present. Northern pike can consume juvenile largemouth bass (Mauck and Coble 1971; Soupir et al. 2000), so it is possible that the establishment of a northern pike population in Lake Lavine would result in decreased abundance of largemouth bass.

Only two anglers attended the public meeting in Kinderhook. Those anglers supported Option 4. Additional comments were collected via telephone and an online sport fishing forum. Comments from those anglers led to the development of a fifth option.

OPTION 5: Continue annual stocking of 4,300 yearling rainbow trout, conduct a manual removal of northern pike for one week (Monday-Friday) during late winter 2015, and liberalize northern pike fishing regulations. Northern pike would be captured using gill nets deployed under the ice. The nets would be deployed near suspected spawning sites. This brief effort is not expected to eliminate northern pike from the lake, but it might noticeably reduce the abundance of this species. Stocking costs for three years, staff salaries (including wages and benefits), mileage, and travel (i.e., meal allowance) costs associated with the manual removal are estimated to be $20,393. A Fisheries Order Change Proposal would have to be submitted to eliminate the closed season, minimum size limit, and possession limits for northern pike in Lake Lavine. If the process proceeded as expected, the regulation change would go into effect on April 1, 2016. A sign would be posted at the public access site and at least one news release would be issued to notify anglers of the regulation changes and encourage them to remove pike from this system. It is unlikely that this approach would eliminate northern pike from the lake, but it might reduce pike abundance to such a low level that the rainbow trout fishery could be maintained.

After considering all of the alternatives, Fisheries Division has decided to pursue Option 5. This option was selected for several reasons. (1) This lake has a long history of providing trout fishing opportunities. (2) Trout fishing opportunities are limited in this area. There are only two trout lakes (Lake Lavine and Cary Lake) and one trout stream (Prairie River) in the county. (3) Local anglers have expressed interest in maintaining a trout fishery in the lake. (4) MDNR staff time and stocking commitments associated with this option are feasible. (5) This option allows anglers to actively participate in the management of the fishery.

Management Direction

Review of the biological and physical habitat data and conversations with interested stakeholders led to the development of six fisheries management goals for Lake Lavine. Goal 1: Protect and rehabilitate habitat for fish and other aquatic organisms. Goal 2: Reduce the potential for adverse effects of aquatic herbicide treatments on rainbow trout by prohibiting the use of copper compounds. Goal 3: Reduce the abundance of northern pike in the lake. Goal 4: Improve the rainbow trout fishery. Goal 5: Improve the largemouth bass fishery. Goal 6: Maintain the excellent bluegill fishery in Lake Lavine.

GOAL 1: Fisheries Division personnel will continue to review Michigan Department of Environmental Quality (MDEQ) 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. As opportunities arise, Fisheries Division also will work with the lake association, the Michigan Natural Shoreline Partnership, and other organizations to educate riparian landowners on the effects of various practices (e.g., chemical weed treatments, seawall construction, and removal of large woody cover) on aquatic ecosystems.

GOAL 2: Of all the herbicides typically used to control aquatic vegetation growth in Michigan lakes, those that contain copper present the greatest potential for causing mortality of rainbow trout. For this reason, Schrouder et al. (1994) advised against the use of copper sulfate and other copper-based chemicals in trout waters. The Aquatic Nuisance Control Section of MDEQ is responsible for issuing herbicide application permits. Fisheries Division will inform MDEQ of our recommendation to prohibit the use of copper-based chemicals in Lake Lavine.

GOAL 3: As outlined in Option 5 of the previous section, northern pike abundance will be reduced by conducting a manual removal during late winter 2015 and eliminating the closed season, minimum size limit, and possession limits for northern pike on Lake Lavine. The local Law Enforcement Division Lieutenant was informed of this proposal and he did not have any objections to the regulation changes. Fisheries Division personnel will begin the formal regulation review process in December 2014.

GOAL 4: Annual stocking of 4,300 yearling Eagle Lake strain rainbow trout will continue. A recent strain evaluation study conducted in several inland lakes demonstrated that stocking Michigan strain steelhead yielded higher returns to the creel than stocking of Eagle Lake strain fish (Caroffino and Nuhfer 2014). At the present time, no Michigan strain steelhead are available for stocking in inland lakes. If these fish become available, yearling steelhead will be stocked instead of Eagle Lake strain fish. The actions specified under Goals 1-3 also are expected to facilitate attainment of Goal 4.

GOAL 5: Lake Lavine currently supports an average largemouth bass fishery relative to other lakes in southwest Michigan. Northern pike are known to prey on juvenile largemouth bass (Mauck and Coble 1971), and some research has suggested that largemouth bass abundance is lower in lakes with northern pike populations (Soupir et al. 2000; Paukert and Willis 2003). Thus, reducing the population density of northern pike (i.e., Goal 3) may result in increased abundance of largemouth bass in Lake Lavine.

GOAL 6: This lake currently supports one the best bluegill fisheries in southwest Michigan. The bluegill fishery will be maintained by protecting bluegill habitat (i.e., Goal 1) and providing a healthy predator-prey ratio. Sub-legal largemouth bass are key predators on juvenile bluegills and play a vital role in determining the size structure of bluegill populations (Gabelhouse 1984; Guy and Willis 1990). By reducing northern pike abundance, Fisheries Division hopes to protect the sub-legal largemouth bass that have kept the bluegill population at a density that allows rapid growth.

Additional monitoring is necessary to facilitate evaluation of the prescribed management actions. A spring netting survey will be conducted in 2019 to assess abundance of northern pike and survival and growth of rainbow trout in Lake Lavine. Fisheries Division also will solicit comments from anglers regarding catch rates for rainbow trout and harvest of northern pike in this system.

References

Alabaster, J. S., D. W. M. Herbert, and J. Hemens. 1957. The survival of rainbow trout (Salmo gairdneri Richardson) and perch (Perca fluviatilis L.) at various concentrations of dissolved oxygen and carbon dioxide. Annals of Applied Biology 45:177-188.

Allen, M. S., C. J. Walters, and R. Myers. 2008. Temporal trends in largemouth bass mortality, with fishery implications. North American Journal of Fisheries Management 28:418-427.

Anderson, R. O. 1976. Management of small warm water impoundments. Fisheries 1(6):5-7, 26-28.

Bidgood, B. F., and A. H. Berst. 1969. Lethal temperatures for Great Lakes rainbow trout. Journal of the Fisheries Research Board of Canada 26:456-459.

Black, E. C. 1953. Upper lethal temperatures of some British Columbia freshwater fishes. Journal of the Fisheries Research Board of Canada 10:196-210.

Burdick, G. E., M. Lipschuetz, H. F. Dean, and E. F. Harris. 1954. Lethal oxygen concentrations for trout and smallmouth bass. New York Fish and Game Journal 1:84-97.

Cameron, J. N. 1971. Oxygen dissociation characteristics of the blood of rainbow trout, Salmo gairdneri. Comparative Biochemistry and Physiology 38:699-704.

Carlson, R. E., and J. Simpson. 1996. A coordinator's guide to volunteer lake monitoring methods. North American Lake Management Society, Madison, Wisconsin.

Caroffino, D. C., and A. J. Nuhfer. 2014. Evaluation of two strains of rainbow trout stocked into inland lakes in Michigan. Michigan Department of Natural Resources, Fisheries Technical Report 2101, Lansing.

Cooper, G. P. 1948. Fish stocking policies in Michigan. Michigan Department of Natural Resources, Fisheries Research Report 1167, Ann Arbor.

Downing, K. M., and J. C. Merken. 1957. Influence of temperature on survival of several species of fish in low tensions of dissolved oxygen. Annals of Applied Biology 45:261-267

Duodoroff, P., and C. E. Warren. 1962. Dissolved oxygen requirements of fishes. Oregon Agricultural Experiment Station Special Report 141:145-155.

Duodoroff, P., and D. L. Shumway. 1970. Dissolved oxygen requirements of freshwater fishes. Food and Agriculture Organization of the United Nations, Fisheries Technical Paper 86, Rome, Italy.

Gabelhouse, D. W., Jr. 1984. A length-categorization system to assess fish stocks. North American Journal of Fisheries Management 4:273-285.

Gutsell, J. S. 1929. Influence of certain water conditions, especially dissolved gases, on trout. Ecology 10:77-96.

Guy, C. S., and D. W. Willis. 1990. Structural relationships of largemouth bass and bluegill populations in South Dakota ponds. North American Journal of Fisheries Management 10:338-343.

He, X., and J. F. Kitchell. 1990. Direct and indirect effects of predation on a fish community: a whole-lake experiment. Transactions of the American Fisheries Society 119:825-835.

Hokanson, K. E. F., C. F. Kleiner, and T. W. Thorslund. 1977. Effects of constant temperatures and diel temperature fluctuations on specific growth and mortality rates and yield of juvenile rainbow trout, Salmo gairdneri. Journal of the Fisheries Research Board of Canada 34:639-648.

Holeton, G. F. 1971. Respiratory and circulatory responses of rainbow trout larvae to carbon monoxide and to hypoxia. Journal of Experimental Biology 55:683-694.

Hoyle, J. A., and A. Keast. 1987. The effect of prey morphology and size on handling time in a piscivore, the largemouth bass (Micropterus salmoides). Canadian Journal of Zoology 65:1972-1977.

Huckins, C. J. F. 1997. Functional linkages among morphology, feeding performance, diet, and competitive ability in molluscivorous sunfish. Ecology 78:2401-2414.

Hughes, G. M., and R. L. Saunders. 1970. Response of the respiratory pump to hypoxia in the rainbow trout (Salmo gairdneri). Journal of Experimental Biology 53:529-545.

Jervais, G., B. Luukinen, K. Buhl, and D. Stone. 2008. 2,4-D Technical Fact Sheet. National Pesticide Information Center, Oregon State University Extension Services. Available: npic.orst.edu/factsheets/2,4-DTech.pdf.

Kutty, M. N. 1968. Respiratory quotients in goldfish and rainbow trout. Journal of the Fisheries Research Board of Canada 25:1689-1728.

Lauren, D. J., and D. G. McDonald. 1986. Influence of water hardness, pH, and alkalinity on the mechanisms of copper toxicity in juvenile rainbow trout, Salmo gairdneri. Canadian Journal of Fisheries and Aquatic Sciences 43:1488-1496.

Lepak, J. M., E. R. Fetherman, W. M. Pate, C. D. Craft, and E. I. Gardunio. 2012. An experimental approach to determine esocid prey preference in replicated pond systems. Lake and Reservoir Management 28:224-231.

Marino, W. D. 2012. Summer 2012 climate summary for southwest lower Michigan. National Oceanic and Atmospheric Administration, National Weather Service, Grand Rapids.

Mauck, W. L., and D. W. Coble. 1971. Vulnerability of some fishes to northern pike (Esox lucius) predation. Journal of the Fisheries Research Board of Canada 28:957-969.

May, B. E. 1973. Seasonal depth distribution of rainbow trout (Salmo gairdneri) in Lake Powell. Proceedings of the Utah Academy of Sciences, Arts, and Letters 50:64-72.

Paukert, C. P., W. Stancill, T. J. DeBates, and D. W. Willis. 2003. Predatory effects of northern pike and largemouth bass: bioenergetics modeling and ten years of fish community sampling. Journal of Freshwater Ecology 18:13-24.

Paukert, C. P., and D. W. Willis. 2003. Population characteristics and ecological role of northern pike in shallow natural lakes in Nebraska. North American Journal of Fisheries Management 23:313-322.

Raleigh, R. F., T. Hickman, R. C. Solomon, and P. C. Nelson. 1984. Habitat suitability information: rainbow trout. United States Fish and Wildlife Service, Report FWS/OBS-82/10.60, Washington, D.C.

Randall, D. J., and J. C. Smith. 1967. The regulation of cardiac activity in fish in a hypoxic environment. Physiological Zoology 40:104-113.

Schneider, J. C. 1990. Classifying bluegill populations from lake survey data. Michigan Department of Natural Resources, Fisheries Technical Report 90-10, Ann Arbor.

Schneider, J. C. 2000. Interpreting fish population and community indices. Chapter 21 in Schneider, J. C., editor. 2000. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Schneider, J. C., P. W. Laarman, and H. Gowing. 2000a. Age and growth methods and state averages. Chapter 9 in Schneider, J. C., editor. 2000. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Schneider, J. C., P. W. Laarman, and H. Gowing. 2000b. Length-weight relationships. Chapter 17 in Schneider, J. C., editor. 2000. Manual of fisheries survey methods II: with periodic updates. Michigan Department of Natural Resources, Fisheries Special Report 25, Ann Arbor.

Schrouder, J. D., C. M. Smith, P. J. Rusz, R. J. White, D. L. Garling, and G. R. Dudderar. 1994. Managing Michigan ponds for sport fishing, 3rd edition. Michigan State University Extension, Bulletin E-1554, East Lansing.

Shaw, B., C. Mechenich, and L. Klessig. 2004. Understanding lake data. University of Wisconsin-Extension, Publication G3582, Madison.

Soupir, C. A., M. L. Brown, and L. W. Kallemeyn. 2000. Trophic ecology of largemouth bass and northern pike in allopatric and sympatric assemblages in northern boreal lakes. Canadian Journal of Zoology 78:1759-1766.

Straus, D. L., and C. S. Tucker. 1993. Acute toxicity of copper sulfate and chelated copper to channel catfish Ictalurus punctatus. Journal of the World Aquaculture Society 24:390-395.

Wisconsin Department of Natural Resources. 2012a. 2,4-D chemical fact sheet. Wisconsin Department of Natural Resources, Publication WT-964, Madison.

Wisconsin Department of Natural Resources. 2012b. Copper compounds chemical fact sheet. Wisconsin Department of Natural Resources, Publication WT-968, Madison.

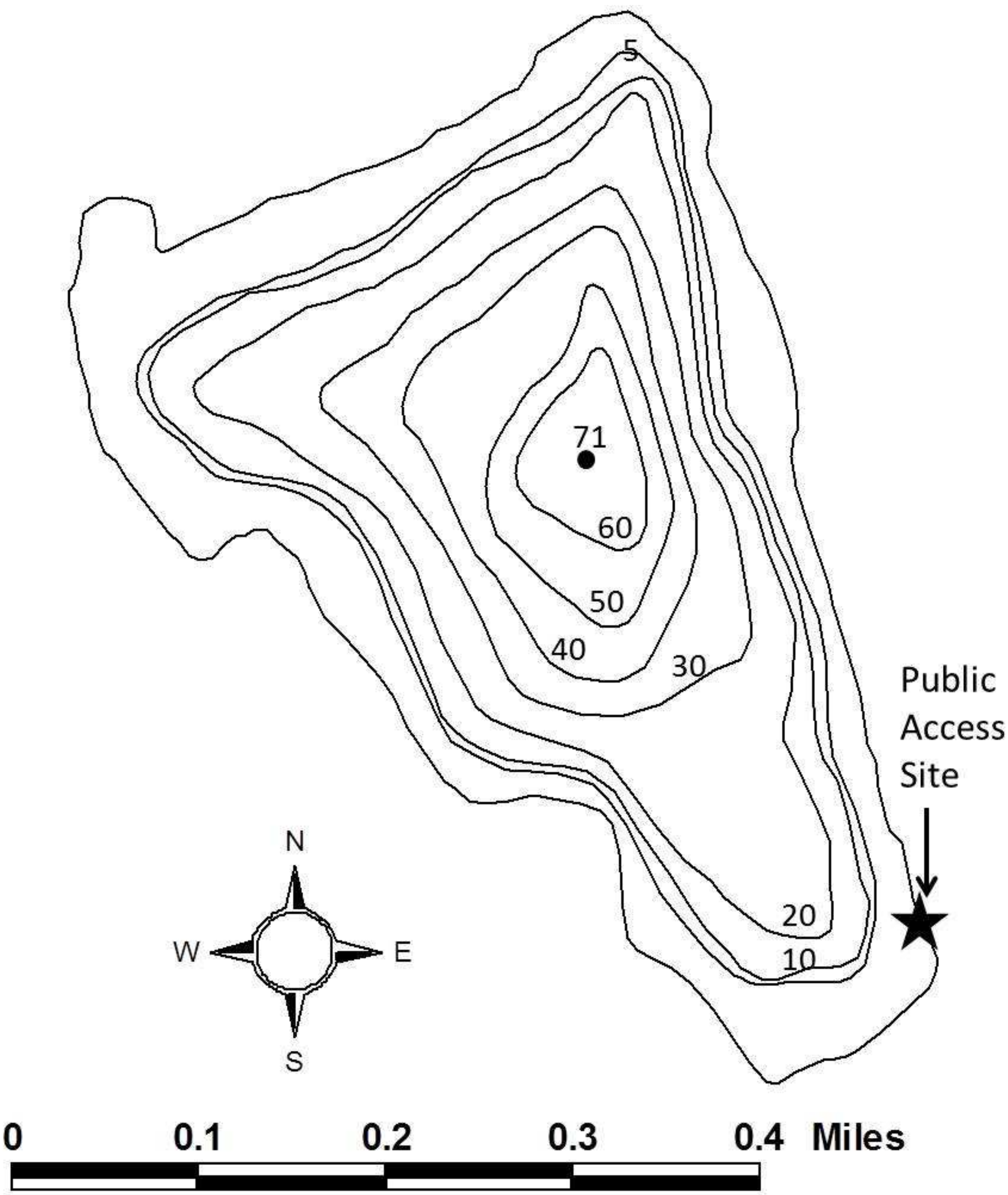

Figure 1.–Bathymetry of Lake Lavine, Branch County. Depths are in feet.

Figure 2.–Aerial view of Lake Lavine and the surrounding area. Image from www.bing.com/maps.

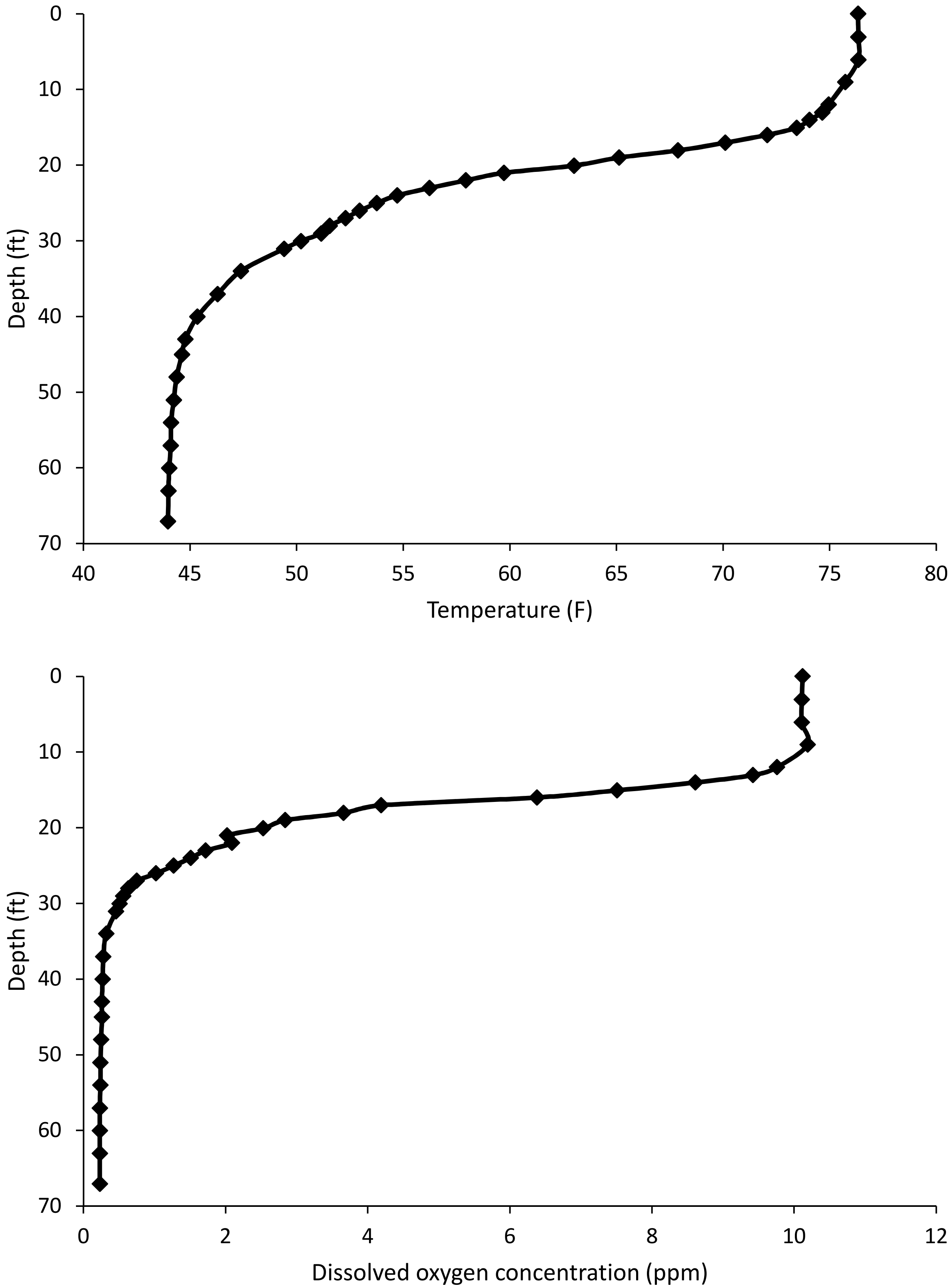

Figure 3.–Temperature and dissolved oxygen profiles for Lake Lavine on August 20, 2013.

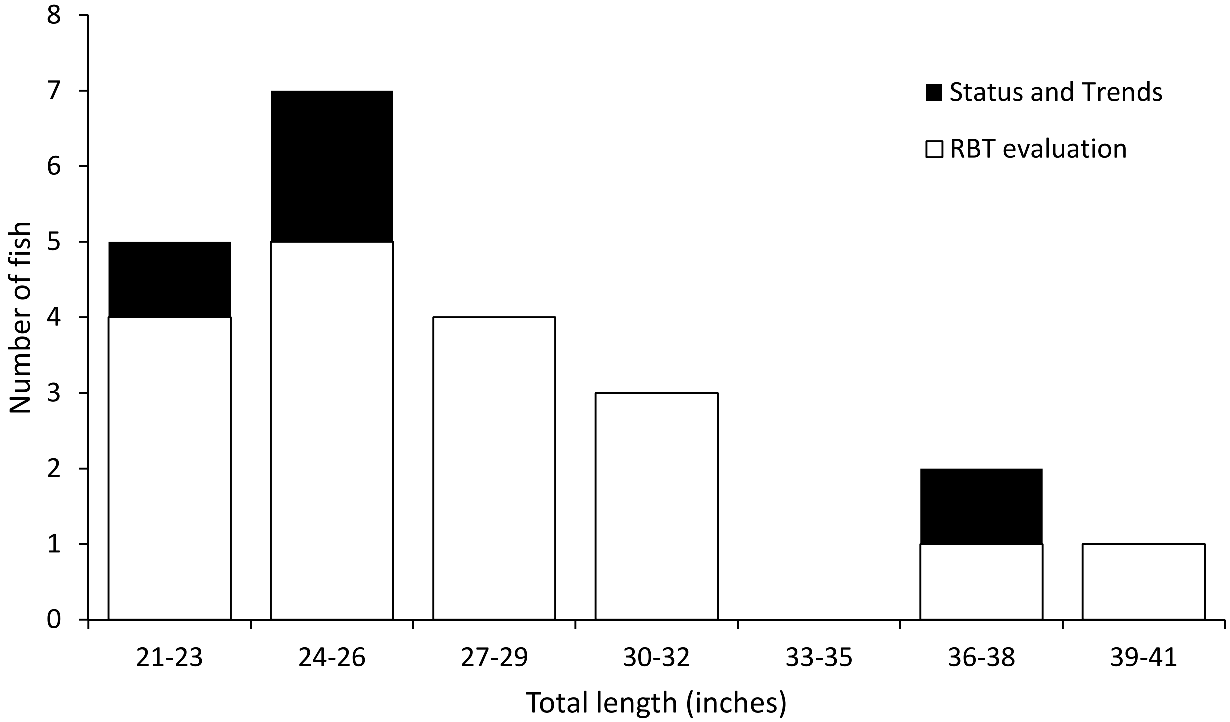

Figure 4.–Length frequency distribution for northern pike captured in Lake Lavine during the rainbow trout evaluation (April 8-9, 2013) and the Status and Trends survey (May 6-9, 2013).

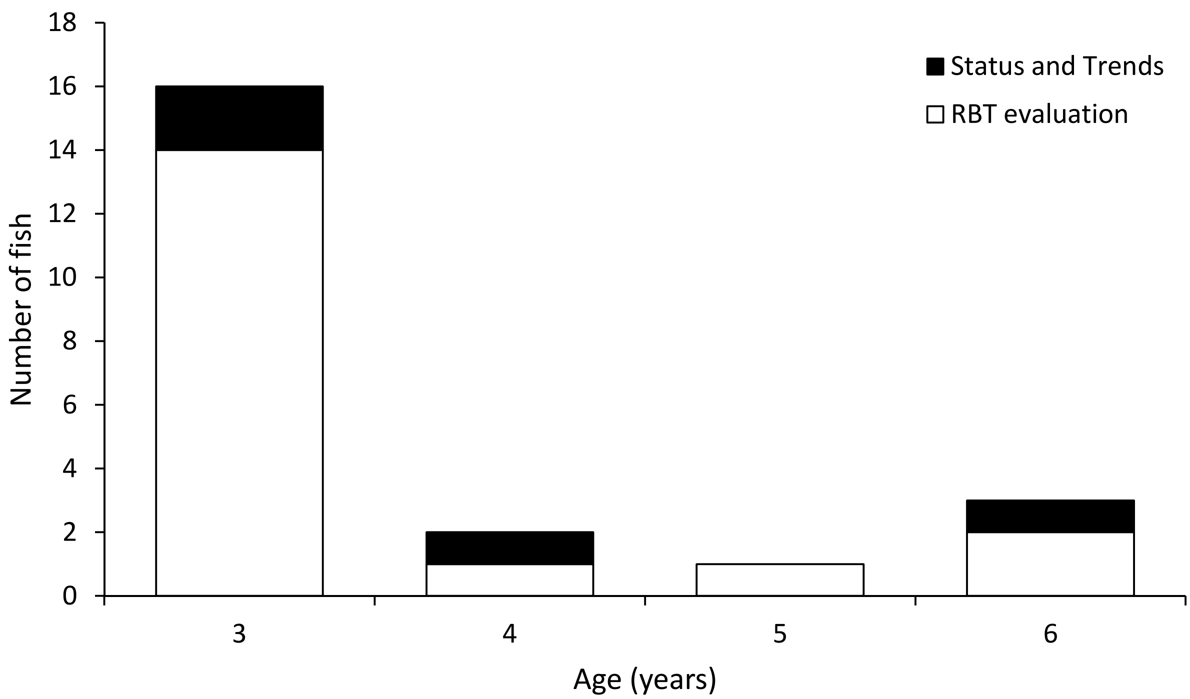

Figure 5.–Age frequency distribution for northern pike captured in Lake Lavine during the rainbow trout evaluation (April 8-9, 2013) and the Status and Trends survey (May 6-9, 2013).

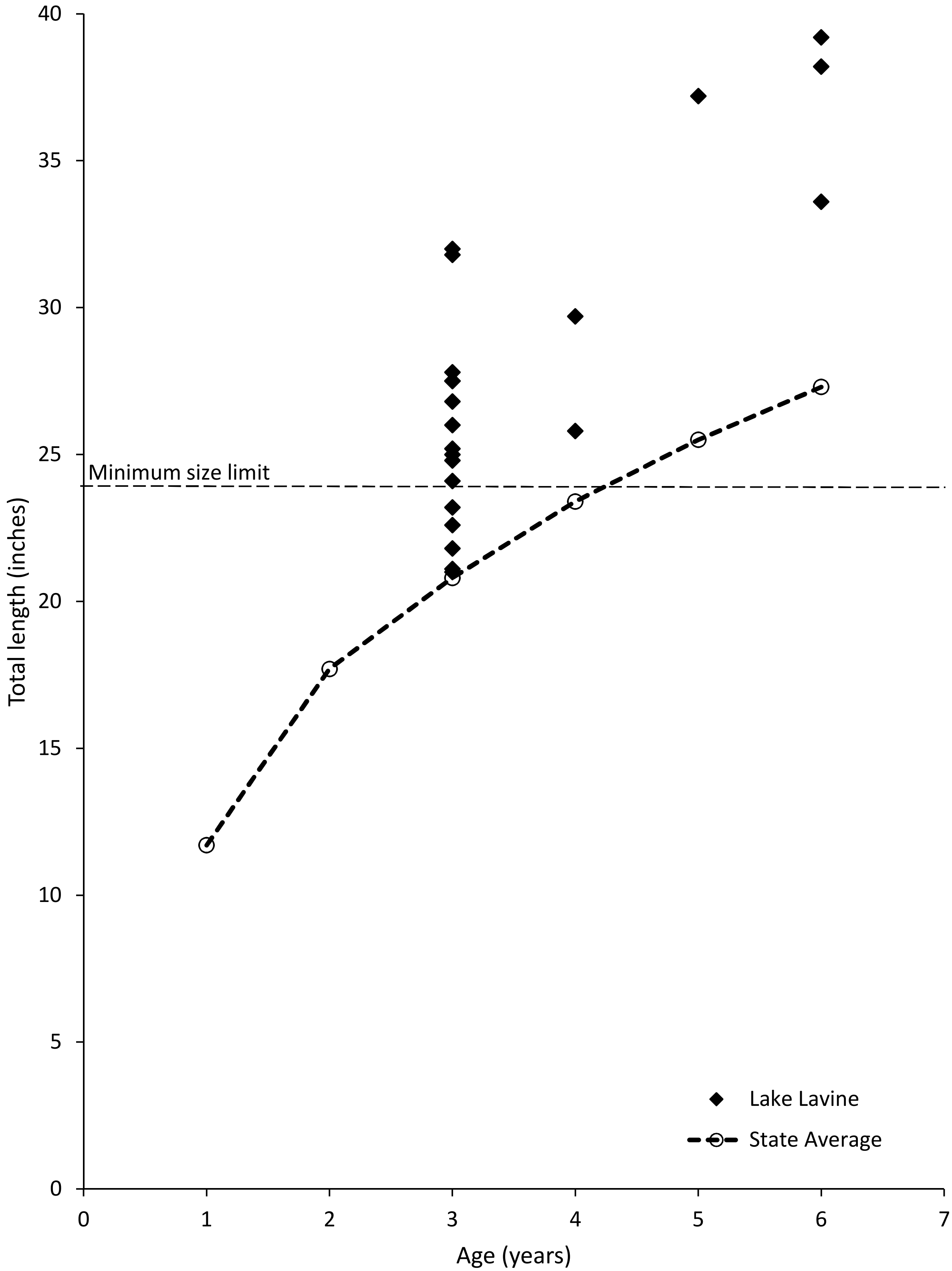

Figure 6.–Growth of northern pike in Lake Lavine, as determined from dorsal fin ray samples collected during April-May 2013. State average lengths from Schneider et al. (2000a).

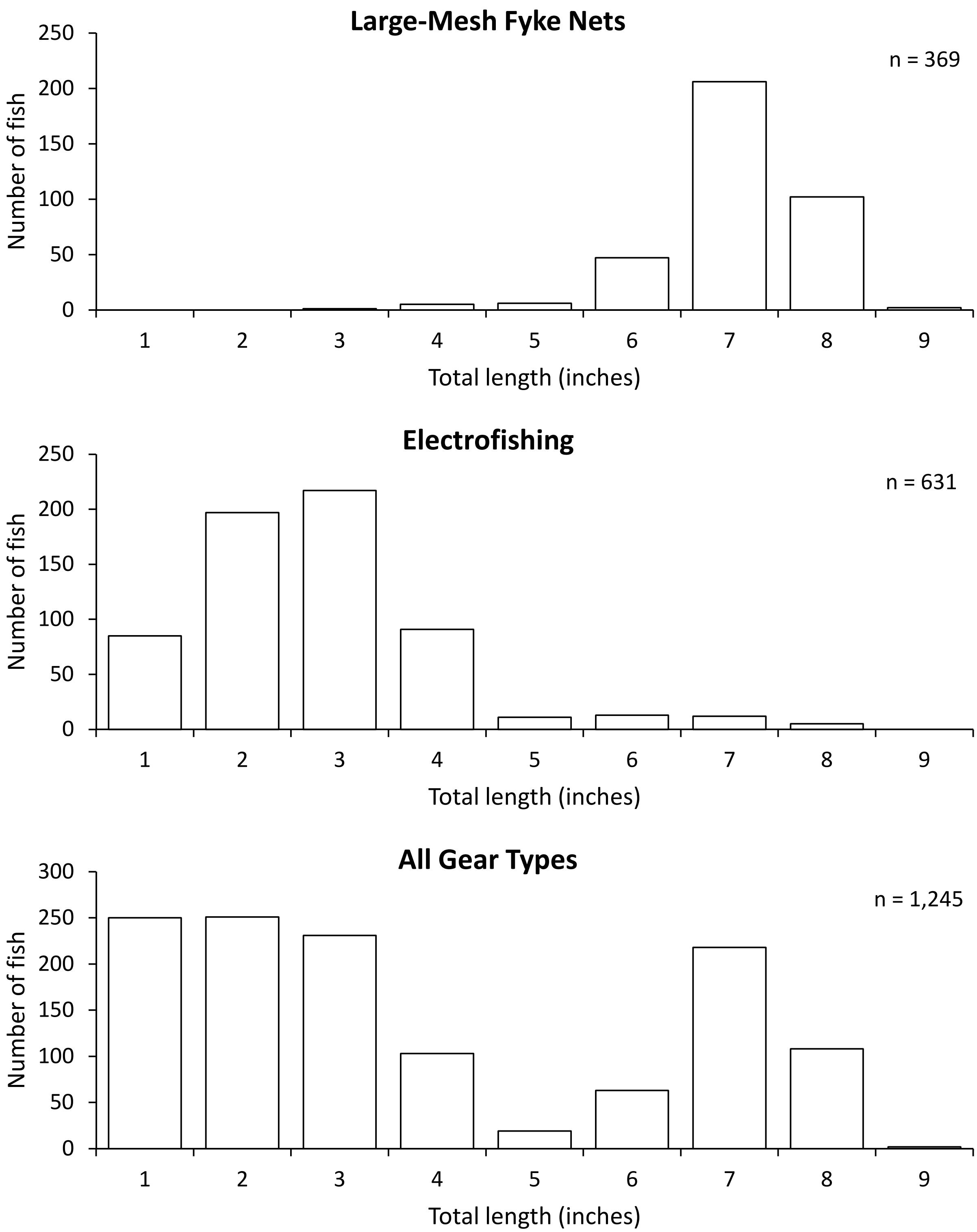

Figure 7.–Length-frequency distributions for bluegills captured in Lake Lavine using large-mesh fyke nets, nighttime electrofishing gear, and all gear types during May 6-9, 2013.

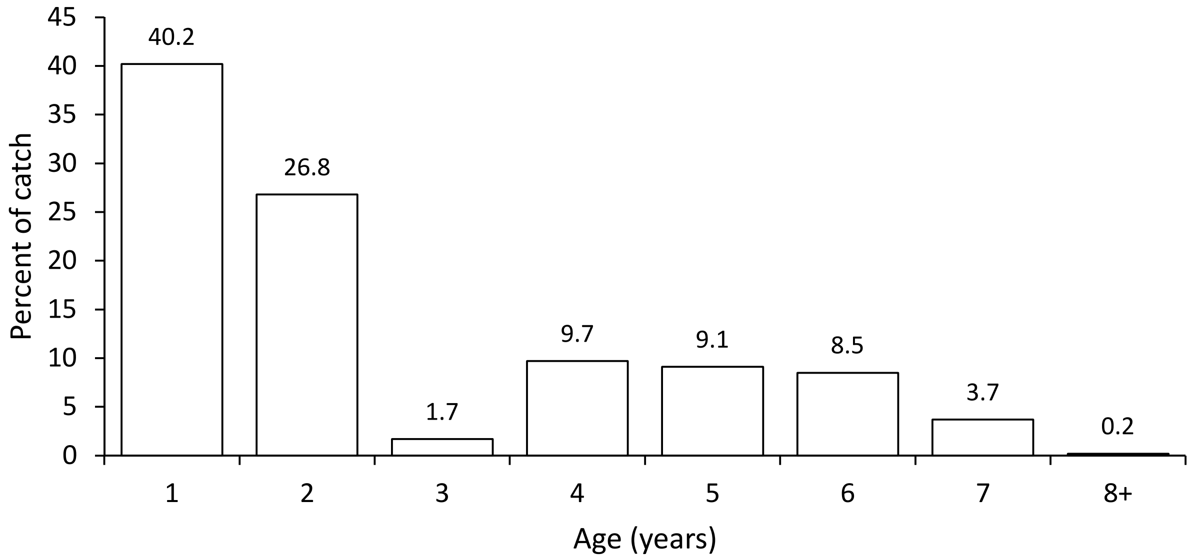

Figure 8.–Age frequency distribution for bluegills captured in Lake Lavine during May 6-9, 2013.

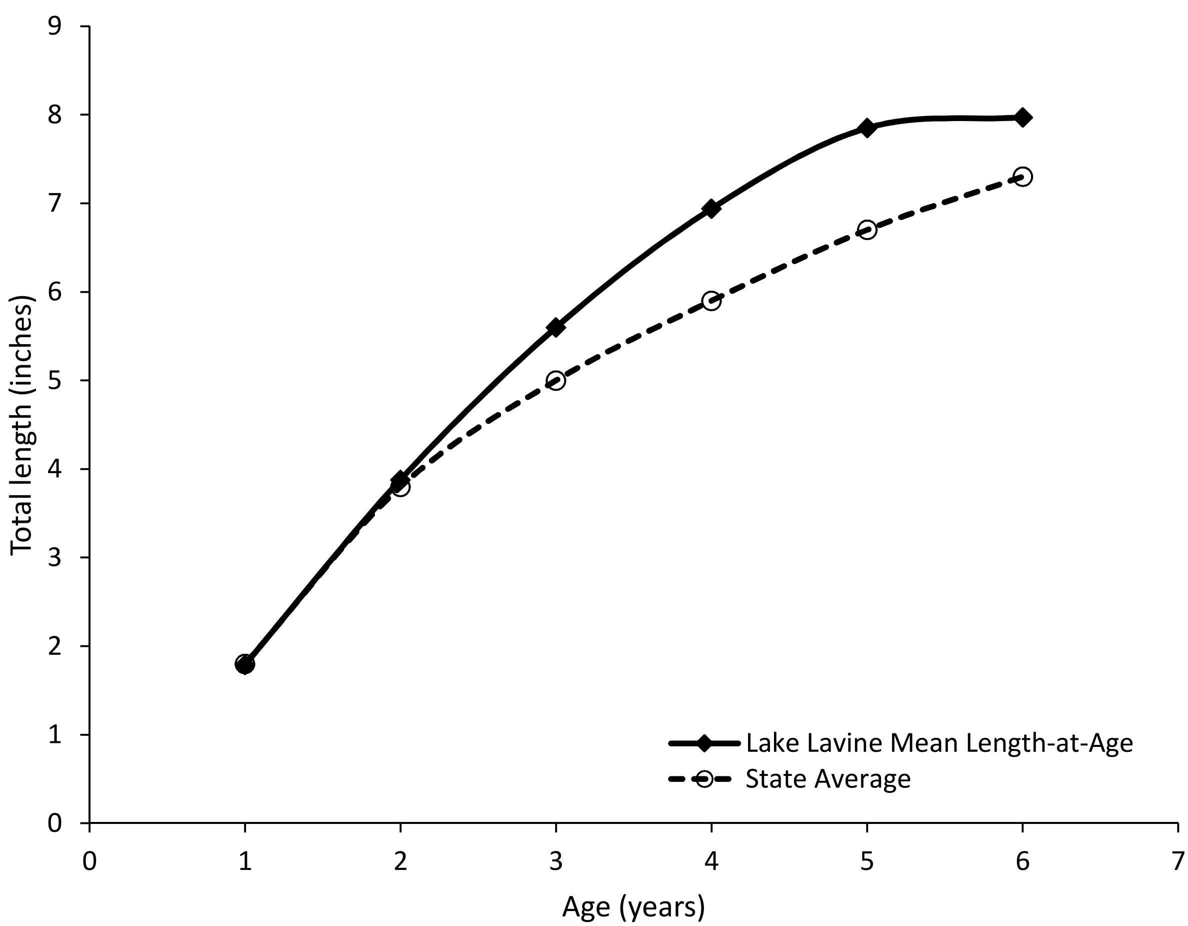

Figure 9.–Growth of bluegills in Lake Lavine, as determined from scale and anal spine samples collected during May 6-9, 2013. State average lengths from Schneider et al. (2000a).

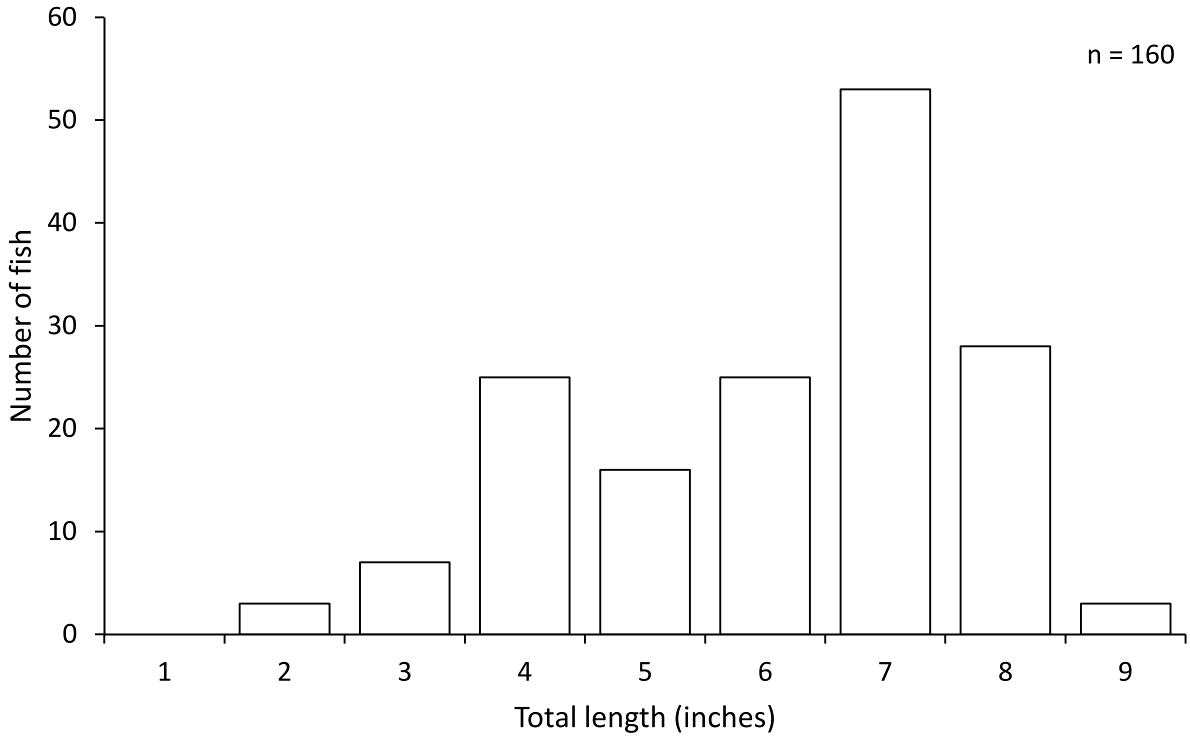

Figure 10.–Length frequency distribution for redear sunfish captured in Lake Lavine during May 6-9, 2013.

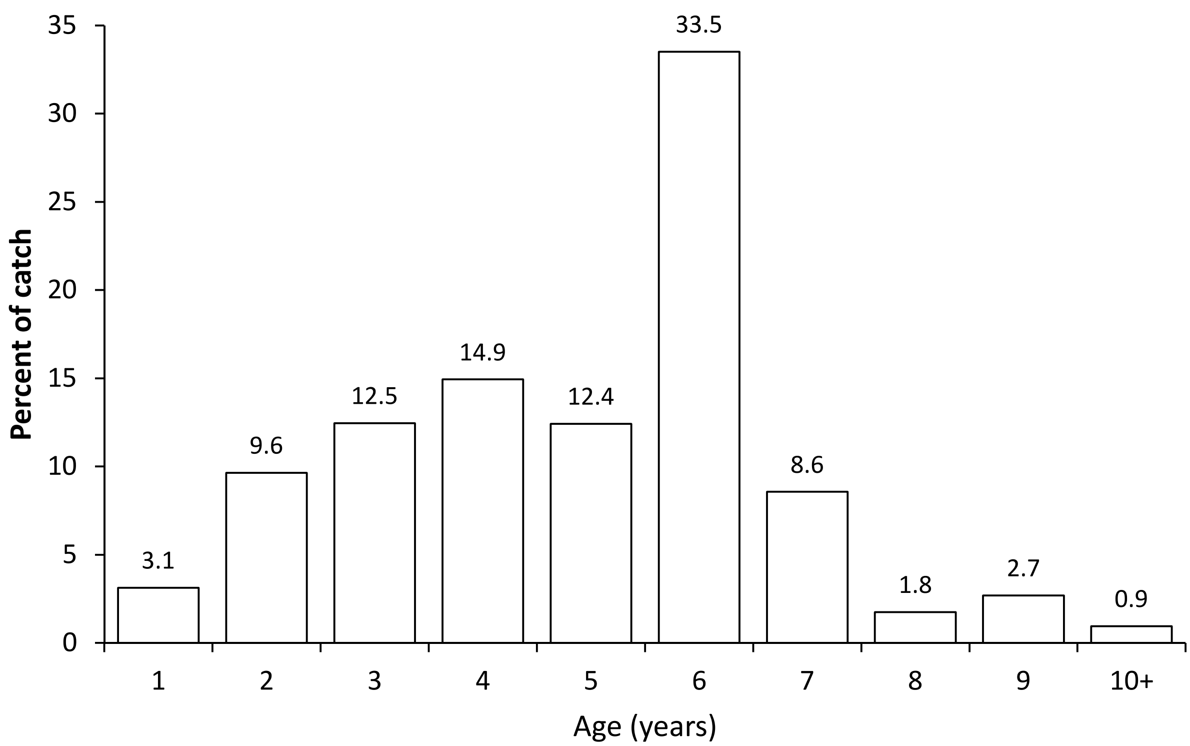

Figure 11.–Age frequency distribution for redear sunfish captured in Lake Lavine during May 6-9, 2013.

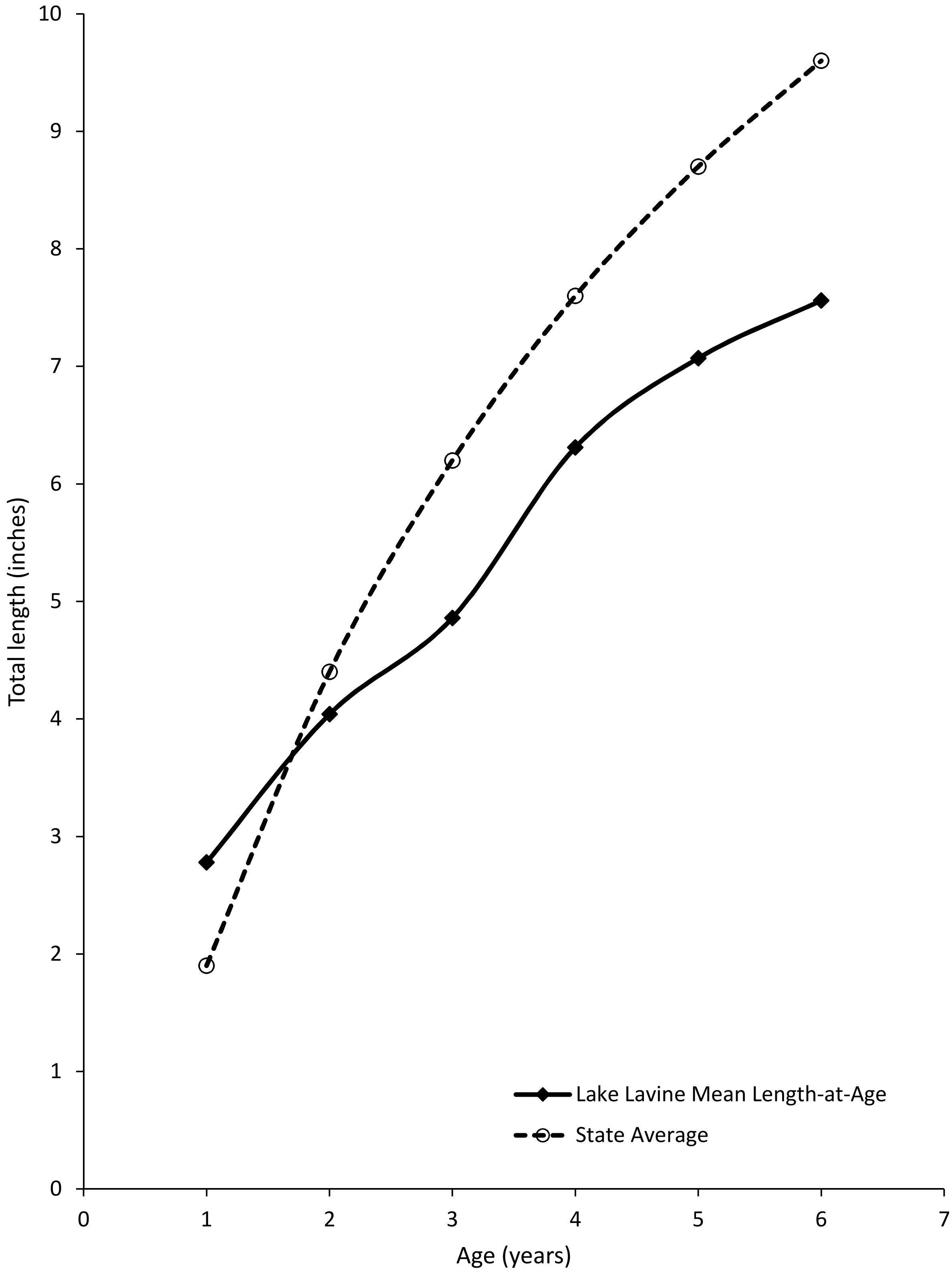

Figure 12.–Growth of redear sunfish in Lake Lavine, as determined from scale and anal spine samples collected during May 6-9, 2013. State average lengths from Schneider et al. (2000a).

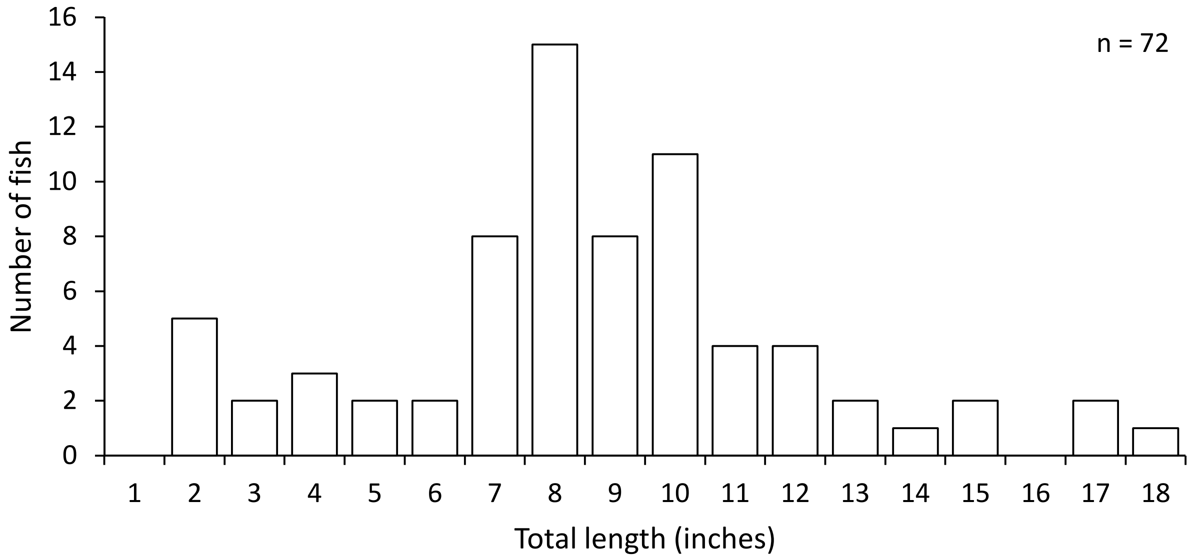

Figure 13.–Length frequency distribution for largemouth bass captured in Lake Lavine during May 6-9, 2013.

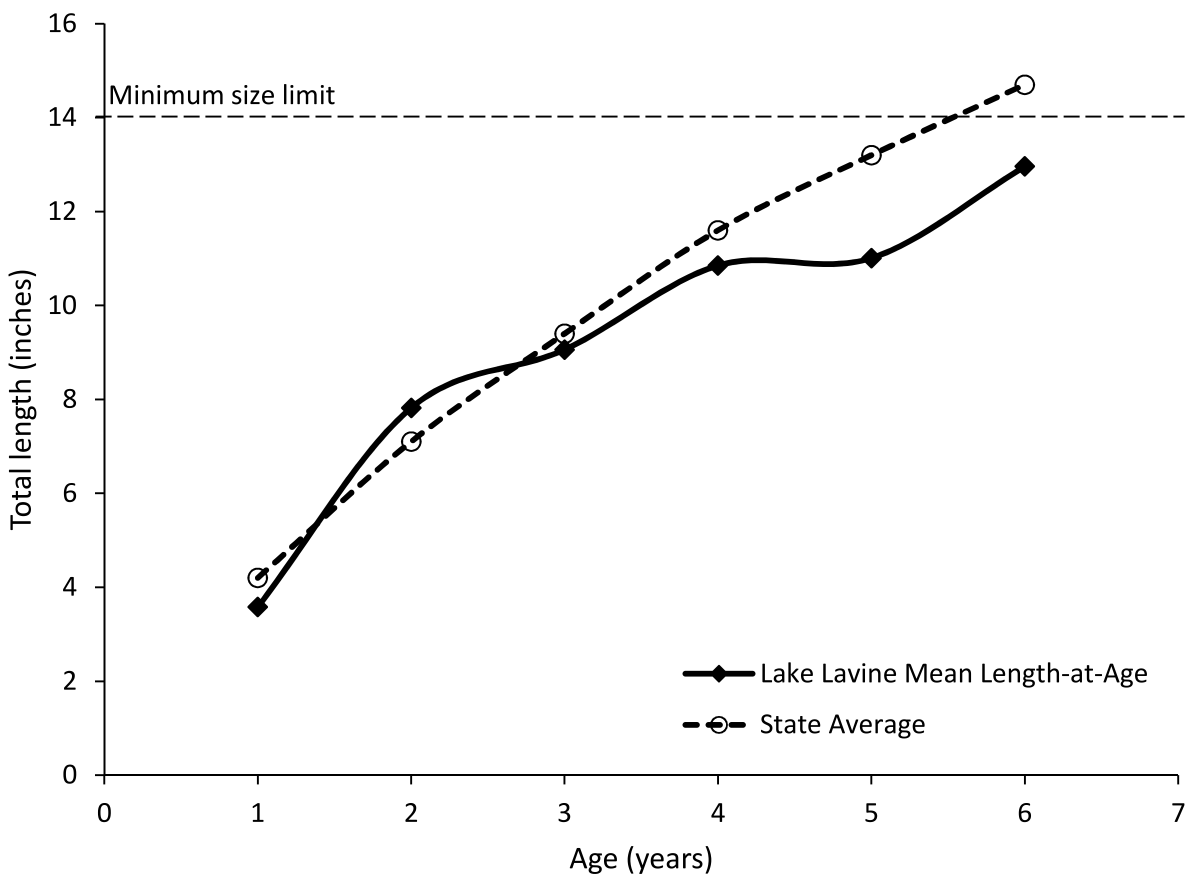

Figure 14.–Growth of largemouth bass in Lake Lavine, as determined from scale and anal spine samples collected during May 6-9, 2013. State average lengths from Schneider et al. (2000a).

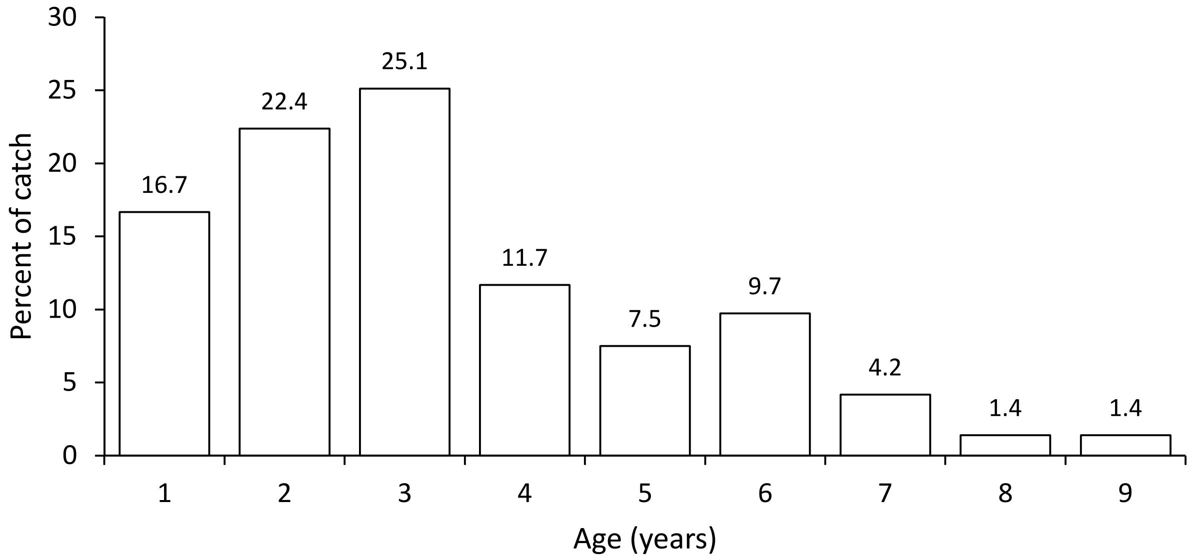

Figure 15.–Age frequency distribution for largemouth bass captured in Lake Lavine during May 6-9, 2013.

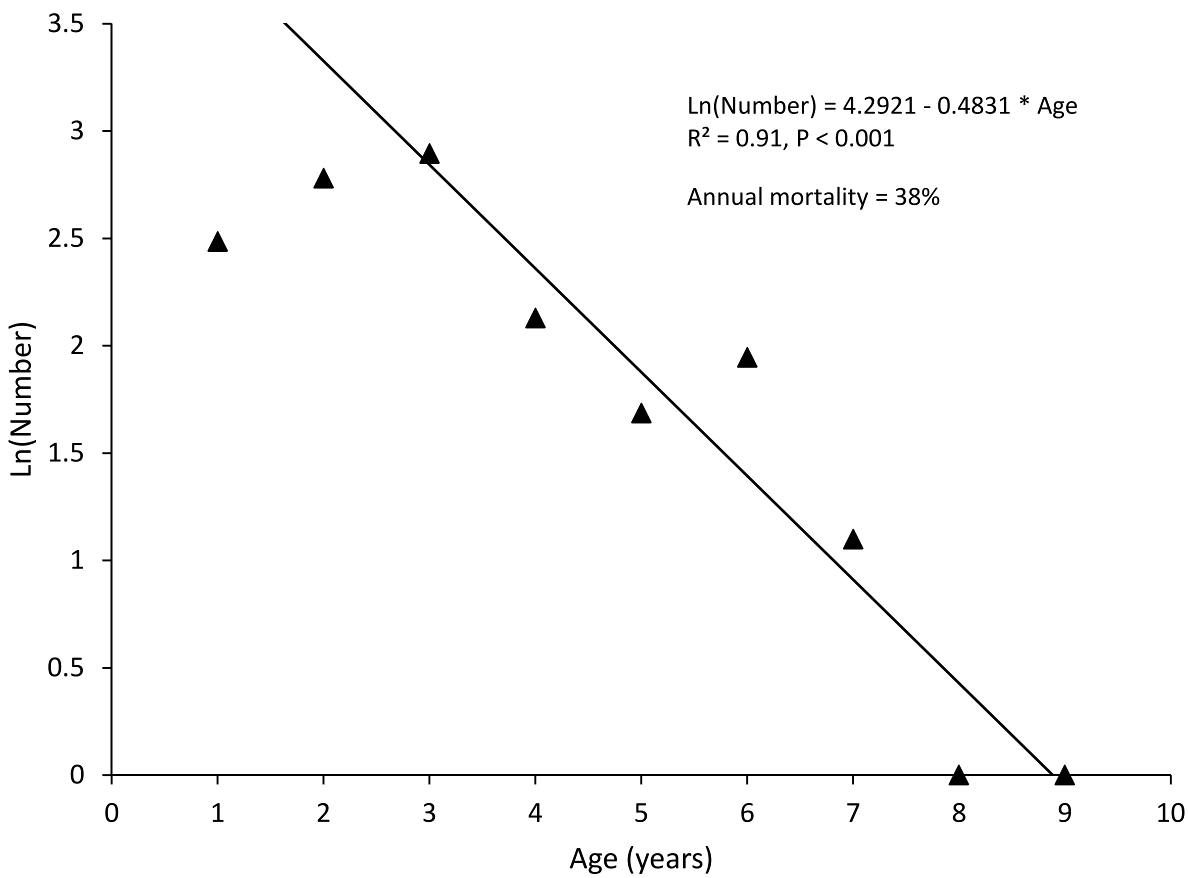

Figure 16.–Natural log of observed numbers of fish versus age for largemouth bass captured in Lake Lavine during May 6-9, 2013.

Table 1. – Fish stocking in Lake Lavine, 1935-2013.

Year	Species	Strain	Life stage	Number	Number/acre	Average length (inches)
1935	Bluegill	---	Fall fingerling	20,000	233	---
1936	Bluegill	---	Fall fingerling	3,000	35	---
		---	Yearling	1,000	12	---
1937	Bluegill	---	Fall fingerling	10,000	116	---
1938	Bluegill	---	Fall fingerling	10,000	116	---
	Yellow perch	---	Fall fingerling	5,000	58	---
1939	Bluegill	---	Fall fingerling	10,000	116	---
	Yellow perch	---	Fall fingerling	5,000	58	---
1940	Bluegill	---	Fall fingerling	25,000	291	---
1941	Bluegill	---	Fall fingerling	50,000	581	---
1942	Bluegill	---	Fall fingerling	12,500	145	---
1944	Bluegill	---	Fall fingerling	5,000	58	2.00
	Largemouth bass	---	Fall fingerling	1,000	12	3.00
1945	Bluegill	---	Fall fingerling	3,500	41	1.50
	Largemouth bass	---	Fall fingerling	1,500	17	3.50
1947	Rainbow trout	---	Adult	2,000	23	8.00
1948	Rainbow trout	---	Adult	2,000	23	8.80
1950	Rainbow trout	---	Adult	2,000	23	10.00
1951	Rainbow trout	---	Adult	2,000	23	8.00
1952	Rainbow trout	---	Adult	2,000	23	8.00
1953	Rainbow trout	---	Adult	2,000	23	9.00
1954	Rainbow trout	---	Adult	2,000	23	8.00
1955	Rainbow trout	---	Legal	2,000	23	---
1956	Rainbow trout	---	Legal	2,000	23	---
1958	Rainbow trout	---	Legal	2,000	23	---
1959	Rainbow trout	---	Legal	2,500	29	---
1960	Rainbow trout	---	Legal	1,165	14	---
1961	Rainbow trout	---	Legal	2,000	23	---
1962	Rainbow trout	---	Legal	1,500	17	---
1963	Rainbow trout	---	Legal	2,250	26	---
1964	Rainbow trout	---	Legal	4,500	52	---
		---	Sub-legal	1,500	17	---
1965	Rainbow trout	---	Sub-legal	3,375	39	---
1966	Rainbow trout	---	Fall fingerling	3,600	42	---
1967	Rainbow trout	---	Yearling	2,000	23	---
1968	Rainbow trout	---	Yearling	3,044	35	---
1969	Rainbow trout	---	Yearling	3,460	40	---
1973	Rainbow trout	---	Yearling	2,200	26	---
1974	Rainbow trout	---	Yearling	2,200	26	---
1975	Rainbow trout	---	Yearling	2,200	26	---

Table 1.–Continued.

Year	Species	Strain	Life stage	Number	Number/acre	Average length (inches)
1976	Rainbow trout	---	Yearling	2,200	26	---
1977	Rainbow trout	---	Yearling	2,200	26	---
1978	Rainbow trout	---	Yearling	2,200	26	---
1979	Rainbow trout	---	Yearling	2,200	26	6.20
1980	Rainbow trout	---	Yearling	2,200	26	7.64
1981	Rainbow trout	*Harrietta*	Yearling	2,200	26	6.12
1982	Rainbow trout	*Harrietta*	Yearling	3,000	35	5.60
1983	Rainbow trout	*Harrietta*	Yearling	4,300	50	6.80
1984	Rainbow trout	*Harrietta*	Yearling	4,200	49	6.56
1985	Rainbow trout	*Shasta*	Yearling	4,300	50	7.44
1986	Rainbow trout	*Shasta*	Yearling	4,300	50	6.52
		Michigan	Adult	516	6	11.44
1987	Rainbow trout	*Shasta*	Yearling	4,300	50	6.64
1988	Rainbow trout	*Shasta*	Yearling	4,300	50	6.16
1989	Rainbow trout	*Shasta*	Yearling	4,300	50	6.68
1990	Rainbow trout	*Arlee*	Yearling	4,294	50	6.88
1991	Rainbow trout	*Arlee*	Yearling	4,180	49	7.08
1992	Rainbow trout	*Shasta*	Yearling	4,300	50	6.84
1993	Rainbow trout	*Shasta*	Yearling	4,100	48	6.52
1994	Rainbow trout	*Shasta*	Yearling	4,297	50	6.92
1995	Rainbow trout	*Harrison Lake*	Yearling	4,298	50	5.44
1996	Rainbow trout	*Gerrard Kamloops*	Yearling	4,299	50	5.92
1997	Rainbow trout	*Shasta*	Yearling	4,298	50	6.28
1998	Rainbow trout	*Shasta*	Yearling	4,260	49	5.96
1999	Rainbow trout	*Shasta*	Yearling	4,240	50	6.88
2000	Rainbow trout	*Shasta*	Yearling	4,288	50	5.64
2001	Rainbow trout	*Shasta*	Yearling	4,300	50	6.04
2002	Rainbow trout	*Eagle Lake*	Yearling	4,300	50	6
2003	Rainbow trout	*Eagle Lake*	Yearling	4,300	50	5.90
2004	Rainbow trout	*Eagle Lake*	Yearling	4,300	50	7.26
2005	Rainbow trout	*Eagle Lake*	Yearling	4,730	55	7.26
2006	Rainbow trout	*Eagle Lake*	Yearling	4,300	50	6.50
2007	Rainbow trout	*Eagle Lake*	Yearling	4,300	50	6.23
2008	Rainbow trout	*Eagle Lake*	Yearling	4,300	50	6.56
2009	Rainbow trout	*Eagle Lake*	Yearling	4,300	50	6.55
2010	Rainbow trout	*Eagle Lake*	Yearling	4,300	50	6.93
2011	Rainbow trout	*Eagle Lake*	Yearling	4,300	50	6.16
2012	Rainbow trout	*Eagle Lake*	Yearling	4,300	50	6.66
2013	Rainbow trout	*Eagle Lake*	Yearling	4,300	50	7.00

Table 2.–Sampling effort during the Status and Trends Program survey on Lake Lavine, May 6-9, 2013. Each net night equals one overnight set of one net.

Sampling period	Gear	Effort
May 6-9	Large-mesh fyke net	9 net nights
May 6-8	Small-mesh fyke net	4 net nights
May 6-8	Graded-mesh gill net	4 net nights
May 9	Seine	3 hauls (25 ft each)
May 9	Nighttime electrofishing	30 minutes

Table 3.–Numbers, weights, and lengths for fish species collected during the rainbow trout evaluation on Lake Lavine, April 8-9, 2013. Fish were captured using gill nets and large-mesh fyke nets.

Species	Number	Percent by number	Weight (lbs)	Percent by weight	Length range (inches)	Percent legal or harvestable*
Bluegill	59	31.4	17.5	8.3	4-8	97
Yellow bullhead	39	20.7	19.9	9.5	8-12	---
Yellow perch	22	11.7	6.1	2.9	5-10	82
Northern pike	18	9.6	96.7	46.2	21-39	78
Brown bullhead	12	6.4	11.0	5.2	11-14	---
Bowfin	9	4.8	24.4	11.6	15-27	---
Black crappie	9	4.8	5.1	2.4	7-13	100
Largemouth bass	8	4.3	24.7	11.8	10-22	63
Lake chubsucker	6	3.2	2.2	1.0	7-9	---
Redear sunfish	6	3.2	2.0	0.9	7-8	100
Total	188		209.5			

* Harvestable size is 6 inches for bluegill and redear sunfish, and 7 inches for black crappie and yellow perch.

Table 4.–Numbers, weights, lengths, and growth indices for fish species collected during the Status and Trends Program survey on Lake Lavine, May 6-9, 2013. Fish were captured using fyke nets, gill nets, seines and nighttime electrofishing gear.

Species	Number	Percent by number	Weight (lbs)	Percent by weight	Length range (inches)	Percent legal or harvestable[1]	Growth index[2]
Bluegill	1,245	60.3	142.8	31.2	1-9	31	+0.7
Lake chubsucker	175	8.5	44.1	9.6	2-10	---	---
Redear sunfish	160	7.8	38.6	8.4	2-9	68	-1.0
Yellow bullhead	139	6.7	78.6	17.2	2-13	---	---
Hybrid sunfish	114	5.5	25.8	5.6	1-8	66	---
Largemouth bass	72	3.5	40.7	8.9	2-18	8	---
Blackchin shiner	44	2.1	0.1	0.0	1-2	---	---
Brown bullhead	21	1.0	26.8	5.9	9-16	---	---
Black crappie	19	0.9	8.3	1.8	7-12	100	+0.6
Yellow perch	16	0.8	4.7	1.0	4-10	94	+0.2
Bluntnose minnow	14	0.7	0.0	0.0	1-2	---	---
Central mudminnow	10	0.5	0.0	0.0	1-2	---	---
Bowfin	9	0.4	23.2	5.1	2-25	---	---
Blacknose shiner	5	0.2	0.0	0.0	1-2	---	---
Northern pike	4	0.2	23.2	5.1	23-38	75	+4.7[3]
Rainbow trout	4	0.2	0.6	0.1	5-8	0	---
Spotfin shiner	3	0.1	0.0	0.0	1-2	---	---
Grass pickerel	2	0.1	0.2	0.0	7-8	---	---
Green sunfish	2	0.1	0.2	0.0	2-6	50	---
Iowa darter	2	0.1	0.0	0.0	2-2	---	---
Banded killifish	2	0.1	0.0	0.0	1-1	---	---
Starhead topminnow	1	0.0	0.0	0.0	1	---	---
Total	2,063		458.2				

[1] Harvestable size is 6 inches for bluegill, pumpkinseed, rock bass, and hybrid sunfish, 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.

[3] Growth index was calculated from length-at-age data for northern pike collected during the rainbow trout evaluation in April 2013 and the Status and Trends Program survey in May 2013.

Table 5.–Aquatic herbicide treatments in Lake Lavine, 2010-2013. Data from treatment reports provided to the Michigan Department of Environmental Quality by the permittees.

Date	Herbicide	Rate of application	Total amount	Target species
Jun 2010	Reward® (diquat dibromide)	1 gal/acre	4 gal	Eurasian watermilfoil
	Navigate® (2,4-D)	100 lb/acre	650 lb	Eurasian watermilfoil
Jun 2011	Navigate® (2,4-D)	100 lb/acre	650 lb	Eurasian watermilfoil
	Reward® (diquat dibromide)	1 gal/acre	4 gal	Eurasian watermilfoil
Aug 2011	Reward® (diquat dibromide)	1 gal/acre	1.5 gal	Eurasian watermilfoil
Jun 2012	Navigate® (2,4-D)	100 lb/acre	650 lb	Eurasian watermilfoil
	Reward® (diquat dibromide)	2 gal/acre	8 gal	Eurasian watermilfoil
	Copper sulfate	22 lb/acre	66 lb	Starry stonewort
	Cygnet Plus	12.5 pts/acre	37.5 pts	Starry stonewort
Jul 2012	Nautique® (chelated copper)	3 gal/acre-ft	25 gal	Starry stonewort
Jun 2013	Tribune™ (diquat dibromide)	2 gal/acre	6 gal	Starry stonewort
	Nautique® (chelated copper)	3 gal/acre	50 gal	Starry stonewort