Sylvan Lake

T12N, R12W, Sections 5, 6 & T12N, R13W, Sections 31, 32
Muskegon River

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Environment

Geography
Emerald and Sylvan lakes are located in Newaygo County, in the western portion of the lower peninsula of Michigan (Figure 1). These lakes are part of the Lake Michigan, Muskegon River, and Penoyer Creek watersheds. Emerald and Sylvan lakes, along with Kimball and Pickerel lakes, form the headwaters of Penoyer Creek which discharges into the Muskegon River in the Village of Newaygo. Peck Lake, Ford Lake, Mud Lake, and Ryerson Lake drain into Kimball Lake through Ryerson Lake outlet. Public access to all four of the lakes in this chain is gained through the Michigan Department of Natural Resources (MDNR) boat launch on Pickerel Lake.

Land Use
The area around Emerald and Sylvan lakes was heavily logged during the mid to late 1800s (O'Neal 1997). Historical photos of this area showed few, if any, trees were left standing after the logging operations. A survey of the lake in 1954 indicated the shoreline areas were wooded so some degree of shoreline cover in second growth forest was restored by that time.

Information on dwelling densities along the shoreline was available for Sylvan Lake in 1966 and 2004, and for Emerald Lake in 1947, 1966 and 2004. Dwelling densities for both Sylvan Lake and Emerald Lake in 2004 were similar and relatively high when compared to other lakes in Michigan (Figure 2). Both lakes show an increasing trend in dwelling densities with time.

The percentage of shoreline with artificial armor (rocks and seawall) was determined for Emerald and Sylvan lakes in 2004. Artificial shore armor was moderate to low when compared to other lakes in Michigan (Figure 3).

Submerged tree densities, in the littoral zone, were determined for Emerald and Sylvan lakes in 2004. Submerged tree densities, for both lakes, were very low when compared to other lakes in Michigan (Figure 4).

Lake Morphology
Emerald and Sylvan Lakes are joined through a relatively narrow channel and are managed as a single lake system. The lakes drain into Penoyer Creek through a channel at the southeast end of Emerald Lake. A dam in Penoyer Creek has regulated lake levels in this system since at least the early 1950s. The dam is approximately 4.5 ft in height and the Newaygo County Drain Commissioner presently regulates water levels between the elevations of 760.0 ft during summer and 759.5 ft during winter. The depths of theses two lakes were mapped and general physical features inventoried between 1946 and 1954 (Figures 5 & 6). Sylvan Lake had a maximum depth of 60 ft and a surface area of approximately 113 acres. Emerald Lake had a maximum depth of 49 ft and a surface area of approximately 83 acres.

Water Temperature and Chemical Features

Alkalinity, chlorophyll-a, water transparency, water temperature, and dissolved oxygen measurements were acquired during surveys in 1941, 1947, 1954, and 2004, although not all parameters were acquired during all years. Alkalinity was measured in 1941, 1947, and 1954 in Emerald Lake and none were collected in Sylvan Lake. Alkalinity values were moderate to very high during this period when compared to other lakes in Michigan, indicating relatively good biological productivity in Emerald Lake (Figure 7, Table 1). This is consistent with descriptions of extensive marl deposits in Emerald and Sylvan Lake from the 1954 inventory. The presence of significant marl ($CaCO_3$) tends to reduce biological productivity in lakes due to effects on carbon and nutrient availability.

Chlorophyll-a concentrations were measured in Emerald and Sylvan lakes in 2004. Chlorophyll-a concentrations were similar in both lakes and were relatively low when compared to other lakes in Michigan (Figure 8, Table 1). The levels of Chlorophyll-a indicate borderline mesotrophic-oligotrophic conditions and low biological productivity.

Water transparency (Secchi disc) was measured in Sylvan Lake during 2004 and in Emerald Lake during 1941, 1947, 1954, and 2004. Water transparency was somewhat lower in 2004 than in previous years and about average when compared to other Michigan lakes (Figure 9, Table 1). The lower water transparency values found in recent years may indicate increased nutrient enrichment in these lakes.

Water transparency, chlorophyll-a, and total phosphorous were measured through the Department of Environmental Quality Cooperative Lakes Monitoring Program during 1998, 2004, and 2008 (Table 2). These parameters generally indicated mesotrophic conditions with more oligotrophic conditions indicated by total phosphorous in 2004, and more eutrophic conditions indicated by water transparency in 1998 and total phosphorous in 2008. These results were similar to surveys conducted by the MDNR as slight variations can occur annually or seasonally in Michigan lakes.

Water temperature profiles related to depth were collected in Sylvan Lake during 2004 and in Emerald Lake during 1941, 1947, 1954, and 2004. Water temperature profiles in Emerald and Sylvan lakes in 2004 were similar and exhibited a strong thermocline between depths of 17-35 ft (Figure 10). Similar water temperature profiles were found in Emerald Lake during 1947 and 1954, but a less significant thermocline was found in 1941 (Figure 11).

Dissolved oxygen profiles related to depth were collected in Sylvan Lake during 2004 and in Emerald Lake during 1941, 1947, 1954, and 2004. Dissolved oxygen profiles in Emerald and Sylvan lakes in 2004 were similar and exhibited a strong peak between depths of 18-23 ft (Figure 12). Oxygen levels remained greater than 5 mg/l to a depth of 25 ft in Emerald Lake and 29 ft in Sylvan Lake. Similar dissolved oxygen profiles were found in Emerald Lake during 1941 and 1954, and one measurement at the 30 ft depth in 1947 indicated oxygen levels were probably similar that year (Figure 13).

Both Emerald and Sylvan lakes have a cool (? 69ºF) layer of water with dissolved oxygen levels greater than 5 mg/l. This segment of water exists within the thermocline at depths of about 17 ft to 25-30 ft. The oxygenated thermocline layer was present in all years evaluated.

Biological Features

Zooplankton samples were collected from Emerald and Sylvan lakes in 2004. Mean zooplankton size was very high for both lakes when compared to other lakes in Michigan (Figure 14, Table 1). The mean size of zooplankton was well above the statewide 75th percentile.

Aquatic plants were inventoried in Emerald and Sylvan lakes during 1954. Submerged, floating-leaved, and emergent aquatic plants were found throughout the littoral zone of both lakes (Figures 5 & 6). Species composition and general abundance records were available for Emerald Lake and it is likely similar plants were present in Sylvan Lake (Table 3). The macro-algae Chara spp. was found at moderate to dense levels throughout the lake. Yellow pond-lily and arrowhead were present at medium to sparse abundances. The abundance of the other plants were sparse and included waterweed, native water-milfoil, five species of pondweeds, two species of bulrush, sweet-scented waterlily and buttercup. Bladderwort (Utricularia spp.) and cat-tails (Typha spp.) were other plants reported in a 1926 survey, and coontail (Ceratophyllum demersum) was reported in the 1947 survey.

Chemicals that have consistently been used to kill algae and aquatic macrophytes in Emerald and Sylvan lakes since 1998 include copper products, Reward (diquate dibromide), 2,4-D, and Renovate (triclopyr; Table 4). Renovate is a systemic that is used for controlling Eurasian water-milfoil but also kills native water-milfoil, yellow pond-lily, pickerelweed, sweet-scented waterlily, and watershield. When used at normal levels, the 2,4-D products kill Eurasian water-milfoil, native milfoils and water stargrass. At higher concentrations they can kill bladderwort, sweet scented waterlily, yellow pond-lily, watershield and coontail. Reward is a contact herbicide that is used to target and can kill most macrophytes. Copper products are generally used to control algae (filamentous and planktonic) as well as macroalgae (Chara). Hydrothol 191 (endothall) was proposed for use in 1998 and can also be used to kill algae, as well as coontail, pondweeds, waterweed, milfoil, naiad, and water celery. Aquathol-K (endothall) was proposed for use in 1998 and is similar to Hydrothol 191 except it is generally not used to target algae, waterweed or wild celery. Rodeo was proposed for use in 1998 and was used in 2003. Rodeo is used to kill emergent macrophytes.

Another factor affecting native plants was dredging activities in these lakes, especially in the northwest bay of Emerald Lake where an extensive dredging project was recently proposed. Proper use of 2,4-D and Renovate can achieve relatively selective control of the invasive Eurasian water-milfoil and this can be a beneficial program. However, chemical treatments continue to target removal of native plants in Emerald and Sylvan lakes. Removal of native plants is not recommended because they provide the primary habitat for food, reproduction, and shelter for fish and wildlife in these lakes. Removing native plants also promotes the spread of invasive plants in Michigan lakes.

History

The first surveys of these lakes were conducted by the Michigan Fish Commission and provided notes on surrounding geography, general drawings of the lake, water depth measurements, fish collections, and some observations of invertebrate organisms. Sylvan Lake was surveyed in 1892 and was called Big Marl Lake at that time (Table 5). The gill net survey collected northern pike, largemouth bass, bluegill, and yellow perch. The fish were noted to be in good condition and food was plentiful in the form of larvae, crustaceans, minnows, and crayfish. Bottom materials were noted as mostly clay-marl with some mud (organic material). Emerald Lake was surveyed in 1891 and was called Little Marl

Lake at that time. Bottom materials and food organisms were similar to Sylvan Lake. A net survey was not conducted, although the survey indicated rock bass were also reported in the lake by anglers.

Other surveys were conducted by the Michigan Department of Natural Resources in 1926, 1941, 1947, 1948, 1954, and 2004 (Table 5). Notes from the 1949 survey indicated the lake had heavy marl deposits and a lake level control structure (5 ft high) was present about 1,000 ft downstream of the outlet. The 1954 survey indicated marl had been dredged from the lake in the past. Commercial wiggler harvest was reported on these lakes in 1949. Approximately 90 brush shelters were installed around the lake in 1955, at depths of 10-15 ft. A sewer system was installed in 2002 which provides service to most of the residences on Sylvan, Emerald, Pickerel, and Kimball lakes. A fish kill was reported in 2007 that was determined to be the result of natural winter-spring mortalities due to overwinter and spawning stress.

Fish stocking has been very limited in Emerald and Sylvan lakes (Table 6). In the early 1930s, some bluegill, sunfish, largemouth bass, and yellow perch were stocked. Adult walleye were stocked from the Muskegon River (Newaygo Transfer) for a period in the 1930s and 1940s. Brook trout were stocked in 1965 and one private stocking of fingerling walleye occurred in 1988.

Current Status

A fishery survey was conducted on Emerald and Sylvan lakes in 2004. Information from this survey will be used to summarize the current fish community conditions in these lakes and make comparisons to historical fish community composition information.

Thirteen species of fish and five species of turtles were collected during the 2004 survey (Table 7). The prevalent fish species collected, for both biomass and numbers, were bluegill, largemouth bass, northern pike, black crappie, pumpkinseed, rock bass, and yellow perch. These same species were the dominant species of fish collected in the 1954 and 1891-92 surveys. Spottail shiner was the only forage species collected in 2004. Spottail shiners were not collected in 1954, but blacknose shiner, bluntnose minnow, Iowa darter, johnny darter, and western banded killifish were collected. It is uncertain, although possible, that there have been changes in the forage fish in these lakes. Both the 1954 and 2004 surveys appeared to have sufficient effort with seines or electrofishing to sample small fish effectively.

The size distributions of the prevalent fish species collected in the 2004 survey were similar between Emerald and Sylvan lakes (Table 8). Relatively good numbers of large fish were collected for black crappie, largemouth bass, rock bass, and yellow perch. A smaller percentage of larger bluegill, pumpkinseed and northern pike were present in the catch.

Trap net catch rates of northern pike, pumpkinseed, and rock bass were similar between the two lakes, but bluegill catch rates were lower in Sylvan Lake (Figure15). Gill net catch rates of northern pike and yellow perch were similar between the two lakes (Figure 16). Electrofishing catch rates were similar for bluegill and yellow perch between the two lakes, but were lower for largemouth bass in Sylvan Lake (Figure 17). Although catch rates in Sylvan Lake were lower for bluegill in trap nets and largemouth bass in electrofishing, these discrepancies are not likely significant because the catches were relatively high and catch rates were similar for other methods.

The growth rates of fish collected in the 2004 survey were similar for Emerald and Sylvan Lake (Table 9). Black crappie, pumpkinseed, and rock bass had average or slightly above average growth rates compared to state averages. Bluegill and yellow perch had average or slightly below average growth rates compared to state averages. Largemouth bass growth rates were about one inch below state average and northern pike were growing very slowly at over four inches below state average.

Bluegill growth and size structure was used to classify the population in Emerald and Sylvan lakes using methods provided by Schneider (1990). The bluegill populations of both lakes were ranked as poor to acceptable using electrofishing and net collections (Table 10). Even though there were a fair number of bluegills in the 6-8 in size range, smaller bluegill were proportionally very abundant and growth was somewhat low.

Schneider (2002) provided methods for assessing lake habitat quality based on fish, limnological parameters, aquatic plants, and alteration of the shoreline. Emerald and Sylvan lakes scored 41.5 out of a possible 50-53 (Table 11). This score indicates some degradation of habitat in these lakes. Factors indicating degradation of habitat include the presence of the invasive common carp, low dissolved oxygen in the hypolimnion, productivity enrichment, presence of lake-level control, and heavy shoreline development.

Analysis and Discussion

Emerald and Sylvan lakes have similar aquatic habitat conditions, similar fish communities, and have free movement of fish between lakes. These two lakes should be managed as one system.

Bass and panfish dominate the fish community which is typical of warmwater lakes in Michigan. The size structure of the catch indicated favorable fishing conditions for black crappie, pumpkinseed, rock bass, and yellow perch. These fishes also had relatively high growth rates. Largemouth bass growth rates were low, but collections indicated relatively good numbers of large bass present in the population. A few large northern pike were present, but growth rates were very low. The bluegill population was growing below state average and size structure was rated only poor to acceptable. Comparisons of the fish community composition between 1954 and 2004 indicated prevalent game species have not changed, but changes in forage fish composition may have occurred.

Alkalinity levels in these lakes indicate there should be moderate to high biological productivity, but the presence of marl likely is affecting productivity by limiting the availability of carbon and nutrients. Both the chlorophyll-a level and water transparency presently indicate mesotrophic conditions. Water transparency indicates increased nutrient enrichment since the 1940s and 1950s. Both lakes are relatively deep and have a cool, well oxygenated thermocline layer at depths of 17 ft to 25-30 ft. An oxygenated thermocline was present in all surveys conducted in the 1940s, 1950s, and in 2004. An oxygenated hypolimnion was not indicated in any surveys. Overall, Emerald and Sylvan lakes appear to be deep, mesotrophic lakes that have a cool, oxygen rich thermocline during summer.

The lake habitat quality index indicated degraded habitat conditions related to various parameters including lake productivity and heavy shoreline development. This is consistent with high levels of dwelling densities, partially armored shoreline, lake-level control, very low submerged tree densities, chemical killing of plants, and the dredging of the littoral zone one these lakes. These alterations in habitat components can significantly affect fish populations.

Christiansen (1966) found that deadwood was significantly greater in undeveloped than in developed lakes in northern Wisconsin and Michigan. He found that deadwood within the lake was positively correlated with levels of riparian tree density and negatively correlated with dwelling density. This information is consistent with both Emerald and Sylvan lakes that have high dwelling densities and very low submerged wood densities. Saas et al. (2006) found that yellow perch were reduced to extremely low densities and largemouth bass growth rates decreased after wood habitat was removed from a lake. Schindler et al. (2000) found that on average, annual growth rates for bluegill were 2.6 times lower and bluegill populations were approximately 2.3 times less productive in highly developed lakes than in undeveloped lakes. Largemouth bass growth rates are low and bluegill and yellow perch growth rates are moderately low in Sylvan and Emerald lakes. In addition, the presence of large zooplankton generally indicates good growth potential for bluegill in Sylvan and Emerald lakes.
Radomski and Geoman (2001) found that developed shorelines had substantially less emergent and floating-leaf vegetation than undeveloped shorelines in Minnesota lakes. Significant aquatic vegetation losses were visible at dwelling densities of 6.0/km. Bryan and Scarnecchia (1992) found that species richness and total fish abundance were consistently greater in naturally vegetated sites compared to developed sites in both nearshore (0-1m) and intermediate (1-2m) depth zones. Dwelling densities in Emerald and Sylvan lakes are presently greater than 24/km, and both littoral zone dredging and chemical removal of vegetation is occurring in these lakes. It is possible that forage fish composition has changed in these lakes.

Amphibians can also be affected by habitat alterations. Woodford and Meyer (2003) found that adult green frog populations were significantly lower in lakes with developed shorelines (average dwelling densities = 13.1/km) than lakes with little or no development (average dwelling density = 1.8/km). Although amphibian evaluations were not conducted on Emerald and Sylvan lakes, the high dwelling densities indicate that the quality and quantity of amphibian habitat may have declined.

Water transparency indicates that increased nutrient enrichment has occurred in Emerald and Sylvan lakes. Nutrient enrichment can occur from fertilizer applications near shorelines as well as septic tanks. The sewer system installed in 2002 should help alleviate septic tank enrichment. A program to improving natural shoreline buffers and restrict fertilizer use should be implemented on these lakes. Chemical treatments designed to remove aquatic vegetation also increases nutrient cycling in lakes. This is often evident in planktonic and filamentous algal blooms following chemical treatments and the dying of aquatic macrophytes. Permits have been granted to apply copper products for control of algal blooms after chemical treatments in these lakes. Copper also is toxic to invertebrates that support the food chain for fish.

Lake herring (cisco) may be, or have been, present in Emerald and Sylvan lakes. Latta (1995) summarized lakes containing lake herring in Michigan and noted that Pickerel Lake contained this species as late as 1984. Pickerel Lake is connected by a channel to Emerald and Sylvan lakes. Lakes with a cool, oxygen rich thermocline provide favorable habitat for lake herring. Pickerel Lake is similar to Emerald and Sylvan lakes in having this habitat component. Recent evaluations of lake herring in other Michigan inland lakes indicates it will be necessary to conduct a targeted survey during spawning season to determine if lake herring are still present in this chain of lakes. Notes from the last survey conducted on Pickerel Lake in 1995 indicated that residents reported a die-off of lake herring after the 1986 flood. Latta (1995) indicated that reasons for declining lake herring populations in inland lakes included habitat deterioration (especially dissolved oxygen in the thermocline) and competition or predation from introduced fish (i.e., alewife, rainbow smelt, trout, walleye, and muskellunge).

Management Direction

The following management objectives are based on a full historical review of the information available on fisheries and habitat evaluations of Emerald and Sylvan lakes. The habitat objectives are consistent with the Conservation Guidelines for Michigan Lakes (O'Neal and Soulliere 2006) and established Fisheries Division Policies. Generally, individual habitat components should not be altered by more than 25% on a lake-wide scale.

Objective 1. Protect water quality and maintain a cool, oxygen rich thermocline in Emerald and Sylvan lakes. Goals that can help achieve this objective include discontinuing fertilizer use, using non-phosphate fertilizers, maintaining a 35 ft buffer strip along the shoreline, expanding the sewer system where needed, and minimize the destruction of aquatic plants only to control of non-native species when needed.

Objective 2. Restore and protect nearshore aquatic vegetation. Goals that can help accomplish this objective include restore normal lake levels and fluctuations by removing the lake-level control dam, restore hardened shorelines to naturally sloped shorelines, and discontinue removal of native plants from nearshore areas.

Objective 3. Protect native aquatic plant communities. This can be accomplished by providing full protection to native plants in the lake, and controlling non-native plants where necessary and with methods that provide adequate protection for native plants. Dredging within the lake should be minimized as much as possible.

Objective 4. Restore submerged wood habitat in the lake and restore habitat for amphibians, reptiles, and birds. This can be accomplished by establishing and maintaining a natural buffer strip along the shoreline with a minimum width of 35 feet. Short term improvement can be accomplished by installation of trees around the lake within the littoral zone. Discontinue any removal of submerged wood from these lakes.

Objective 5. Reduce the use of copper applications. Minimizing aquatic plant treatments only for necessary control of non-native species will reduce the need for planktonic and filamentous algae treatments. The native macro-algae Chara spp. should not be chemically removed. Swimmers itch treatments using copper should be thoroughly evaluated. If swimmers itch is a significant problem, then alternative methods by treating ducks with drugs (Blankespoor et al. 2001) should be investigated as an option.

Objective 6. Improve the growth and size structure of largemouth bass and panfish populations. Actions that can help to improve growth and size structure of fish include maintaining good native aquatic plant communities throughout the lake, and reducing the overall effects of human development on these lakes. Bluegill size structure can sometimes be improved by establishing a walleye population in a lake through stocking. This option should only be considered after adequate plans for habitat restoration and protection are achieved, and after adequate surveys and evaluation of potential affects for lake herring are completed.

Objective 7. Improve the growth and size structure of the northern pike population. This objective will be achieved following establishment of new northern pike regulations for Michigan, which are presently under review. Appropriate regulations will be applied based on biological characteristics of the population.

Objective 8. Conduct targeted evaluations to determine if lake herring are present in Emerald and Sylvan lakes. These evaluations should be conducted using Fisheries Division protocols.

Objective 9. Conduct evaluations of amphibian populations on these lakes. These evaluations should be conducted by Fisheries Division using established protocols.

Objective 10. Conduct a thorough forage fish assessment in these lakes. These evaluations should be conducted using Fisheries Division protocols.

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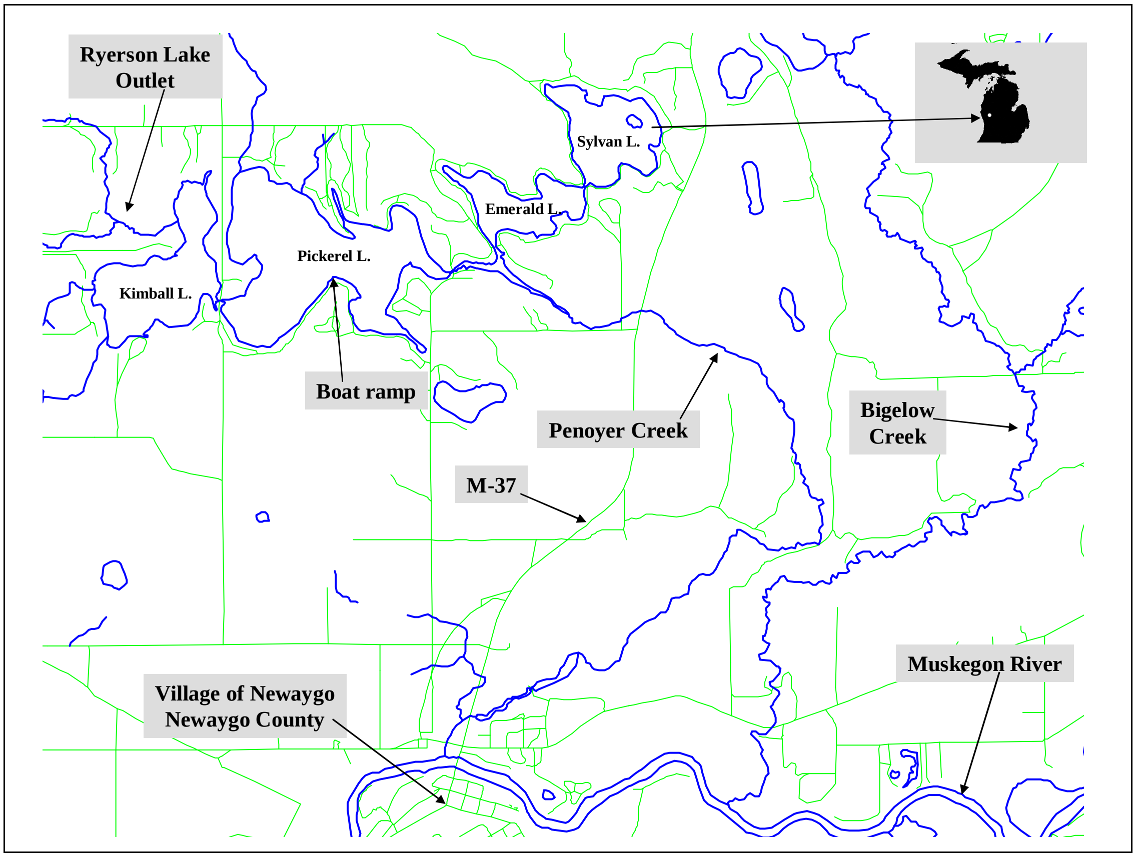

Figure 1. Map of geographic features surrounding Emerald and Sylvan lakes, Newaygo County.

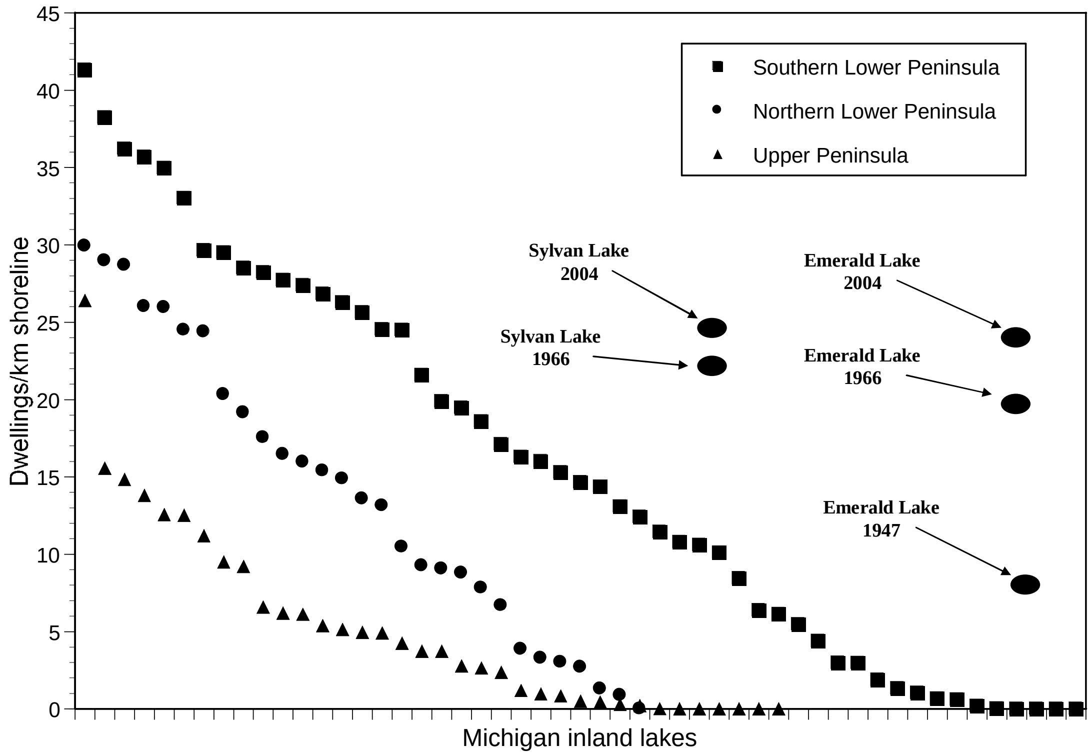

Figure 2. Dwelling densities for three general regions in Michigan, and Emerald Lake and Sylvan Lake in 1947, 1966, and 2004.

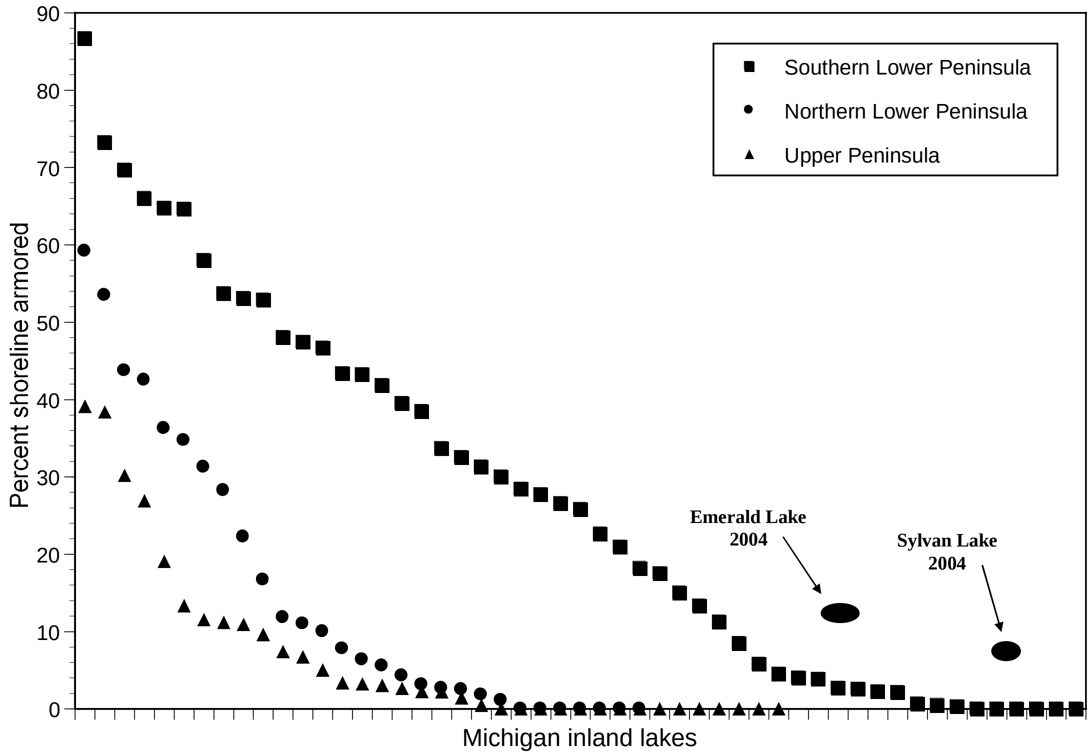

Figure 3. Percentage of shoreline with artificial armor (rocks and seawall) for three general regions in Michigan, and Emerald Lake and Sylvan Lake in 2004.

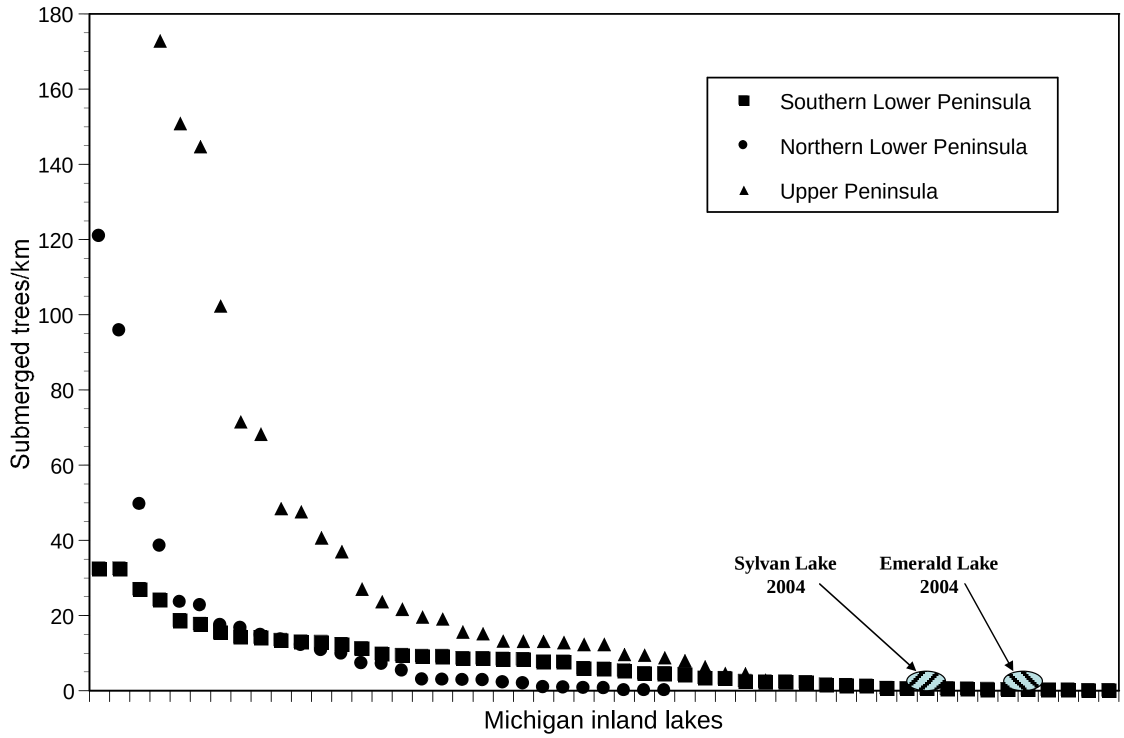

Figure 4. Submerged tree densities for three general regions in Michigan, and Emerald Lake and Sylvan Lake in 2004.

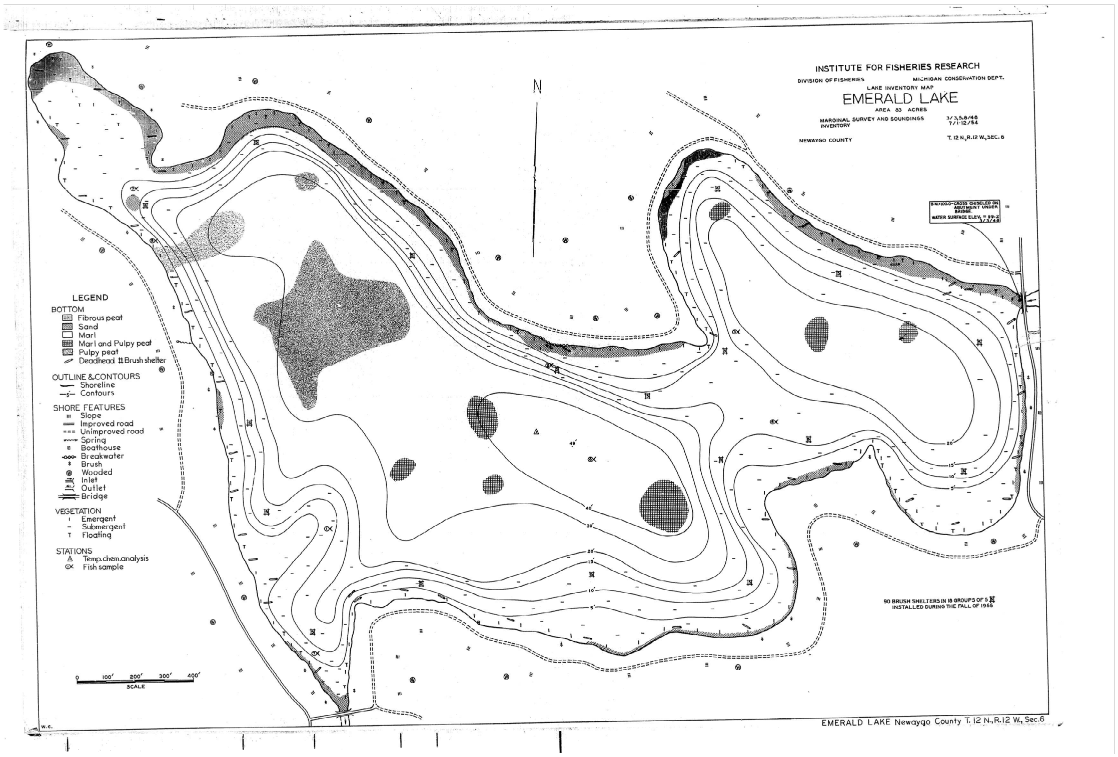

Figure 5. Inventory map of Emerald Lake, Newaygo County, 1946 and 1954. Emerald Lake has a surface area of approximately 83 acres and shoreline length of 2.2 miles.

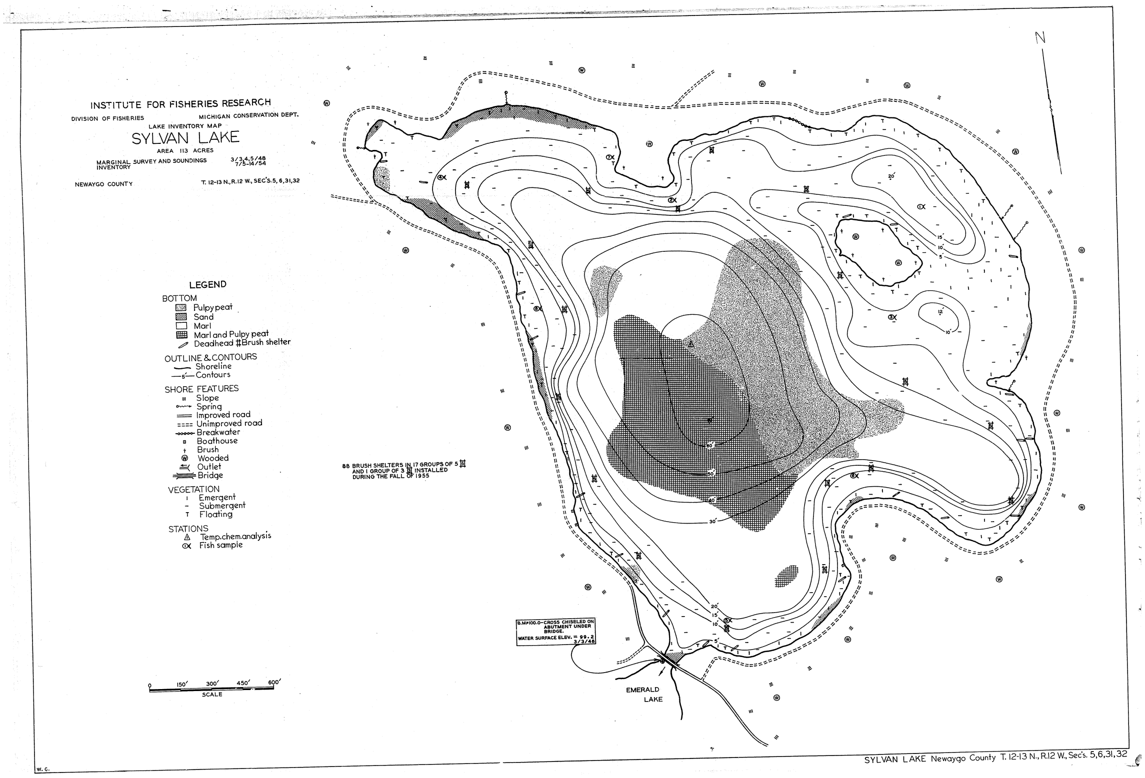

Figure 6. Inventory map of Sylvan Lake, Newaygo County, 1948 and 1954. Sylvan Lake has an approximate surface area of 113 acres and a shoreline distance of 2.3 miles.

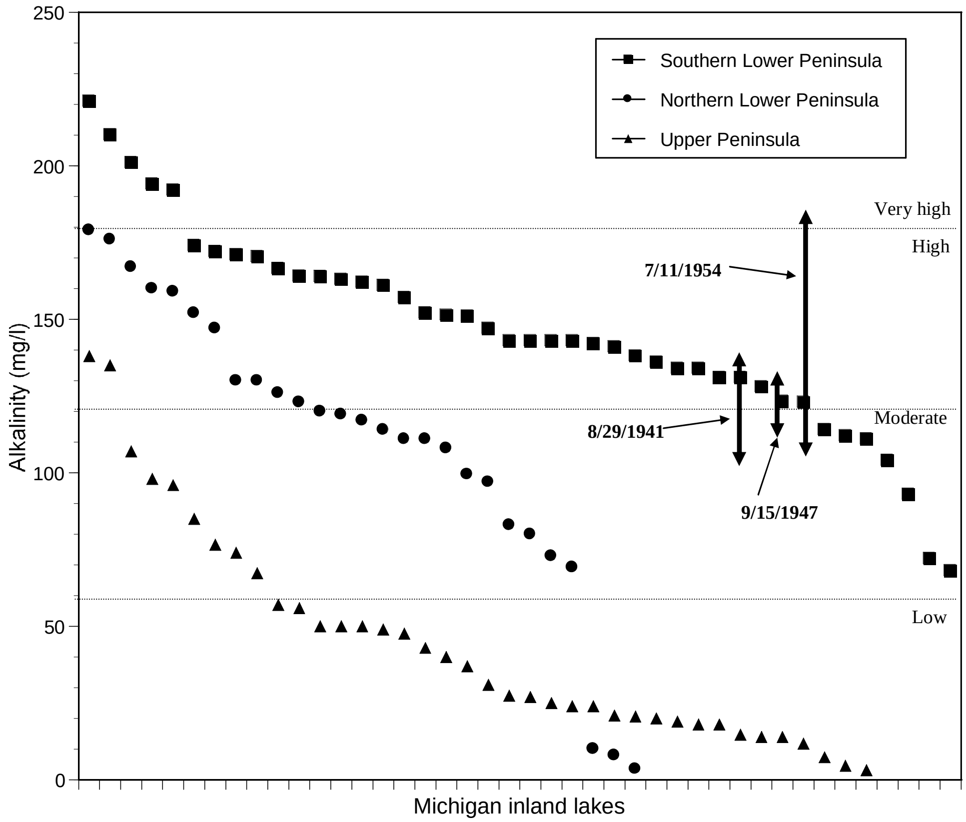

Figure 7. Alkalinity values for three general regions in Michigan and Emerald Lake. Dotted lines indicate low, moderate, high, and very high alkalinity values for Michigan. Arrows indicate range of multiple annual samples reported in Table 1.

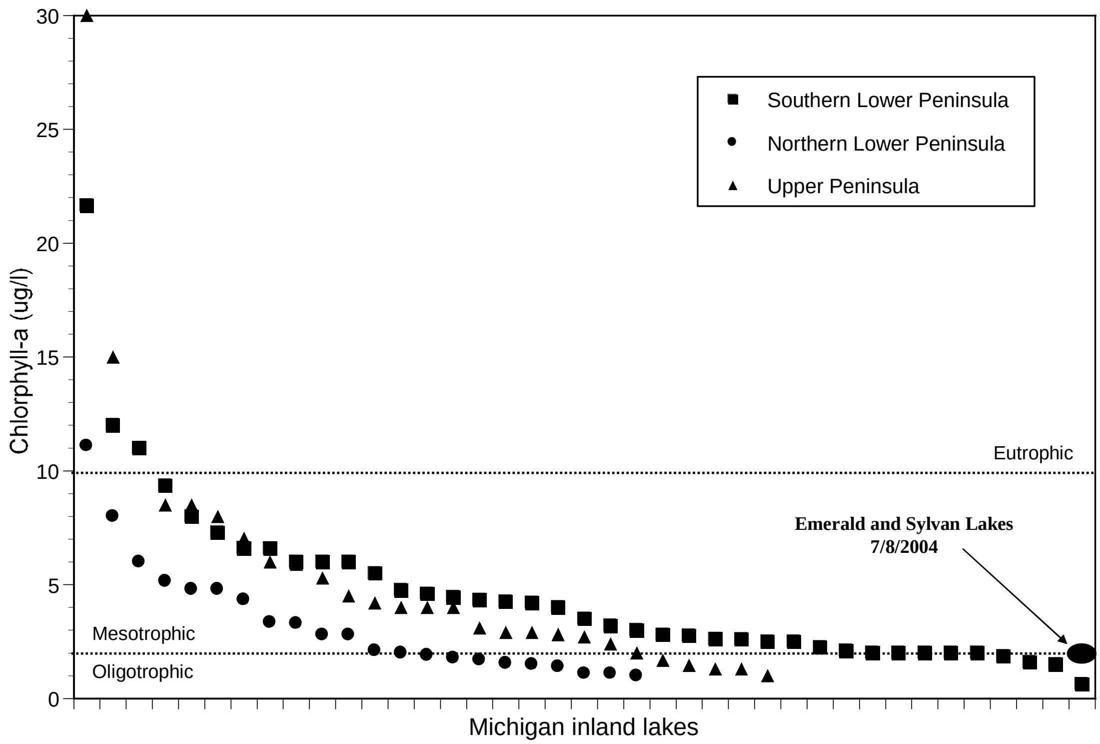

Figure 8. Chlorophyll-*a* concentration values for three general regions in Michigan, Emerald Lake, and Sylvan Lake. Dotted lines indicate general trophic ranges for Michigan lakes.

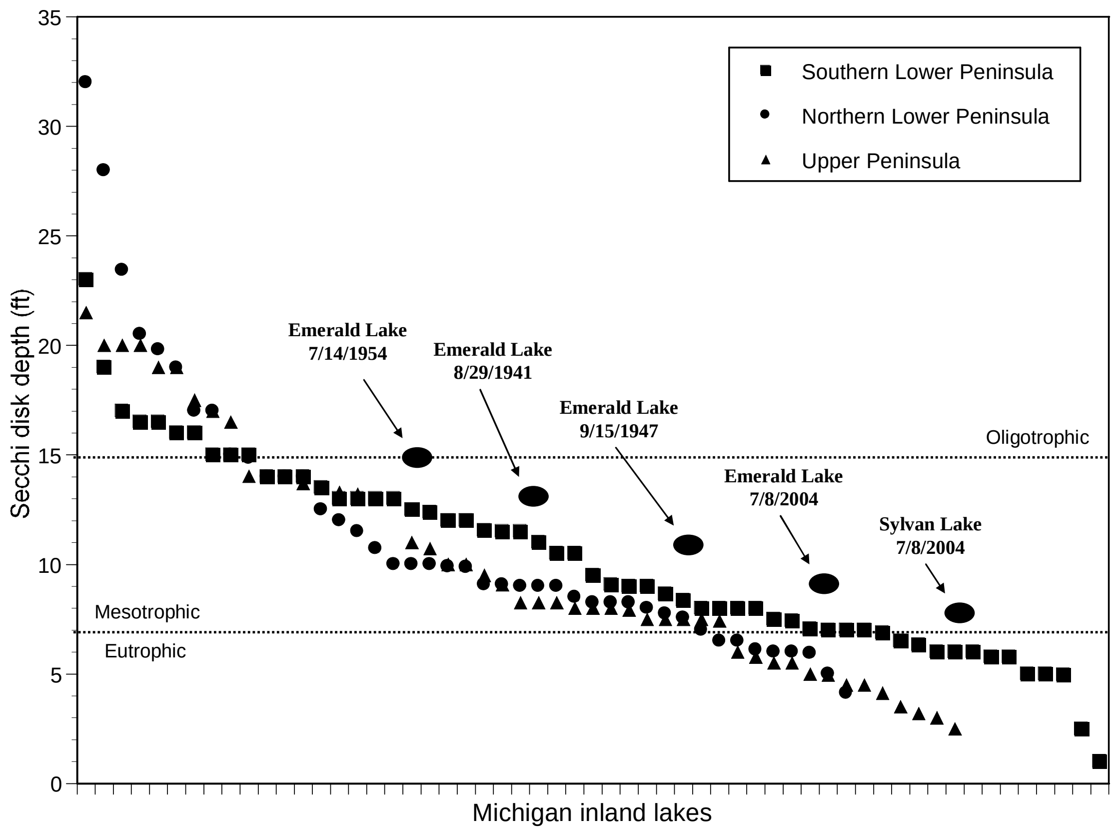

Figure 9. Water transparency values for three general regions in Michigan, Emerald Lake, and Sylvan Lake. Dotted lines indicate general trophic ranges for Michigan lakes.

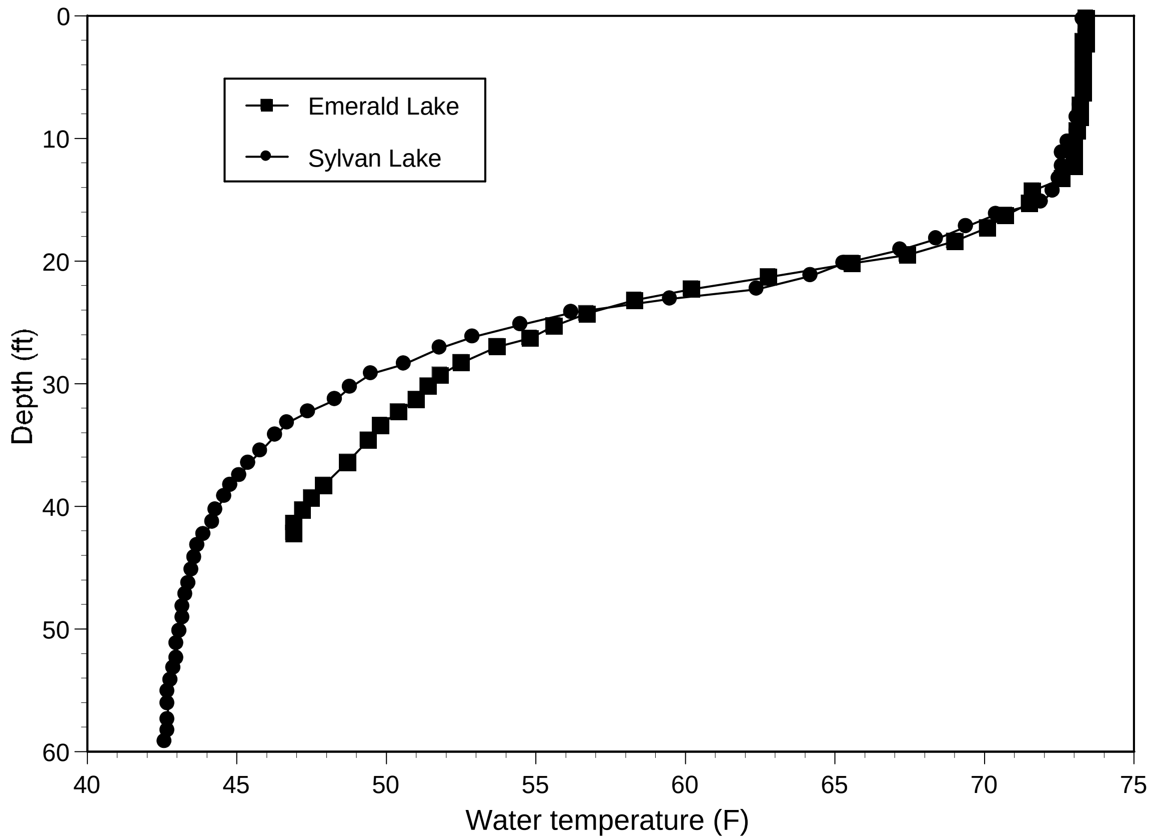

Figure 10. Water temperature profile of Emerald Lake and Sylvan Lake collected on 2/8/2004.

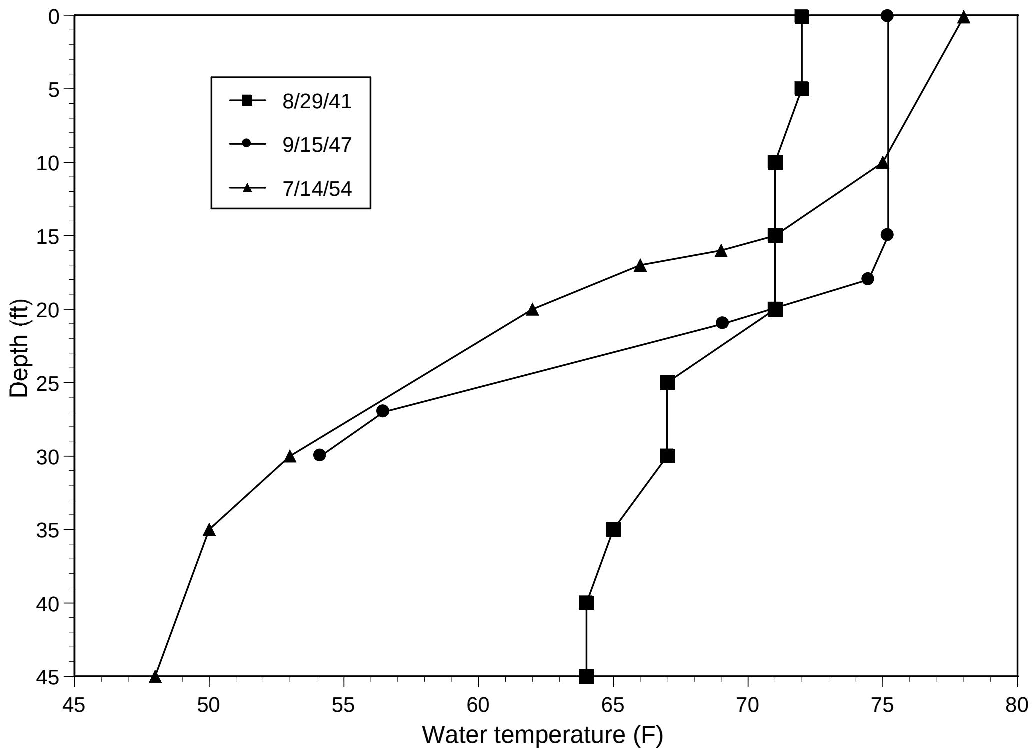

Figure 11. Water temperature profiles collected in Emerald Lake in 1941, 1947, and 1954.

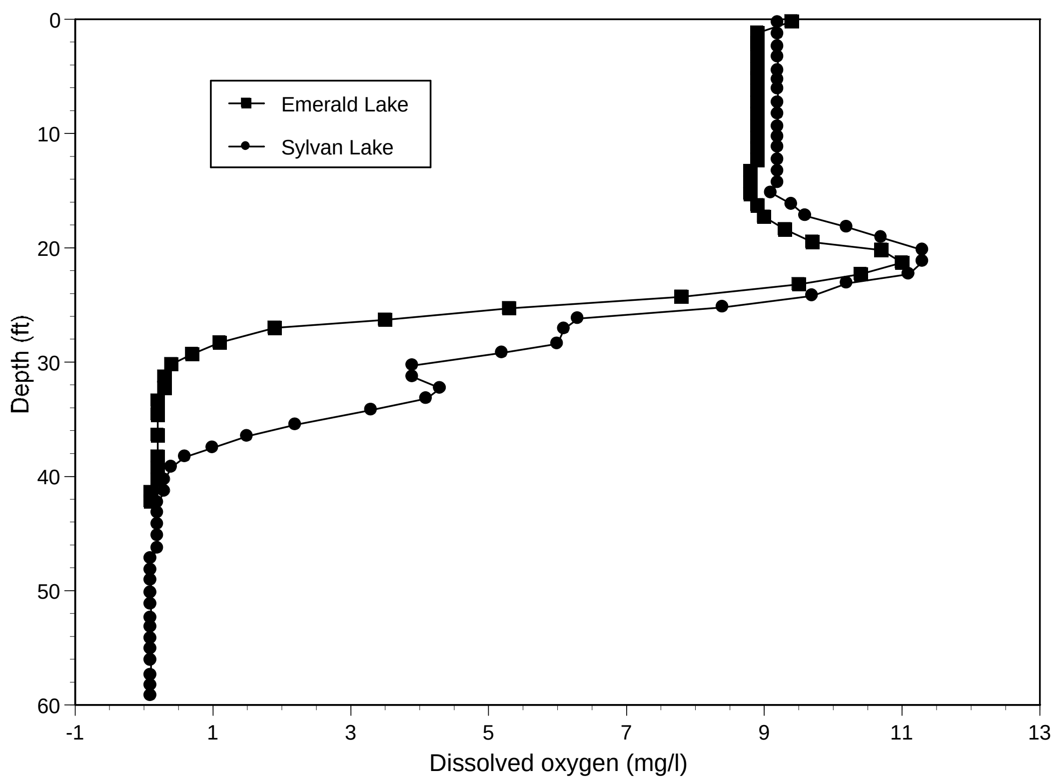

Figure 12. Dissolved oxygen profiles collected in Emerald Lake and Sylvan Lake on 7/8/2004.

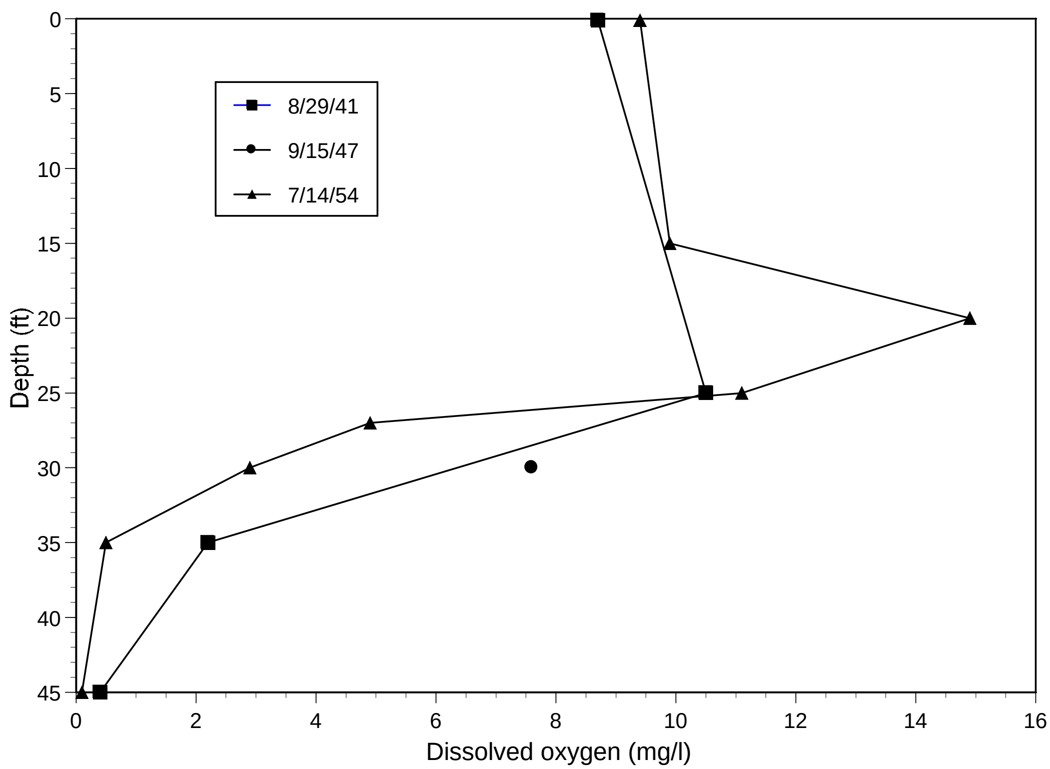

Figure 13. Dissolved oxygen profiles collected in Emerald Lake in 1941, 1947, and 1954.

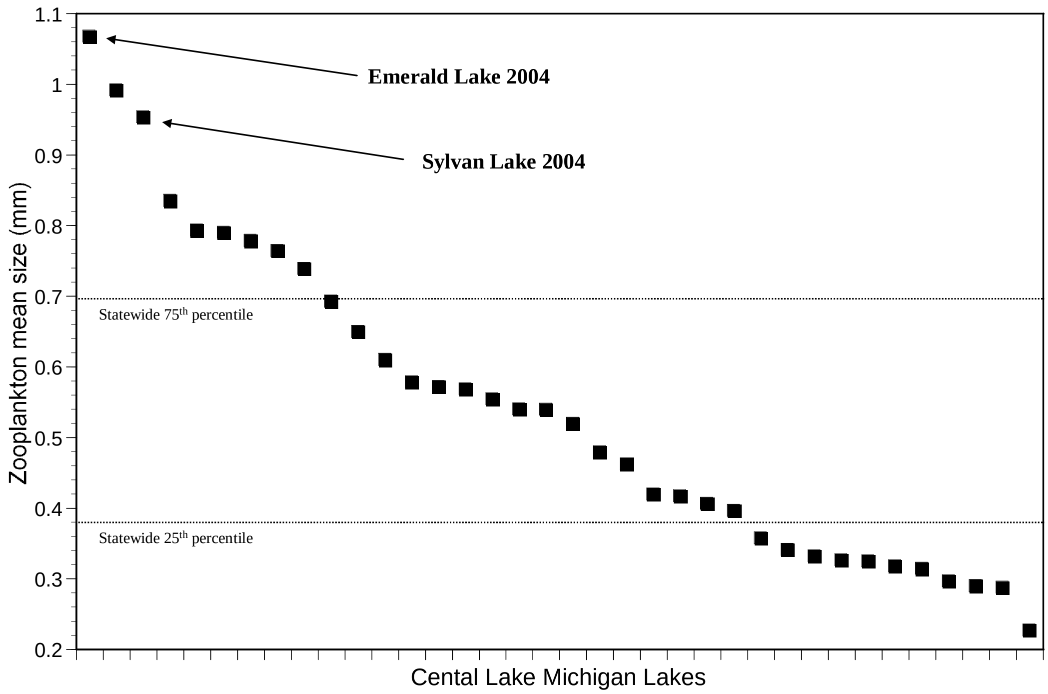

Figure 14. Zooplankton mean size for Central Lake Michigan Lakes sampled from 2003 through 2008. The dotted lines represent the 25th and 75th percentiles for all waters of the state.

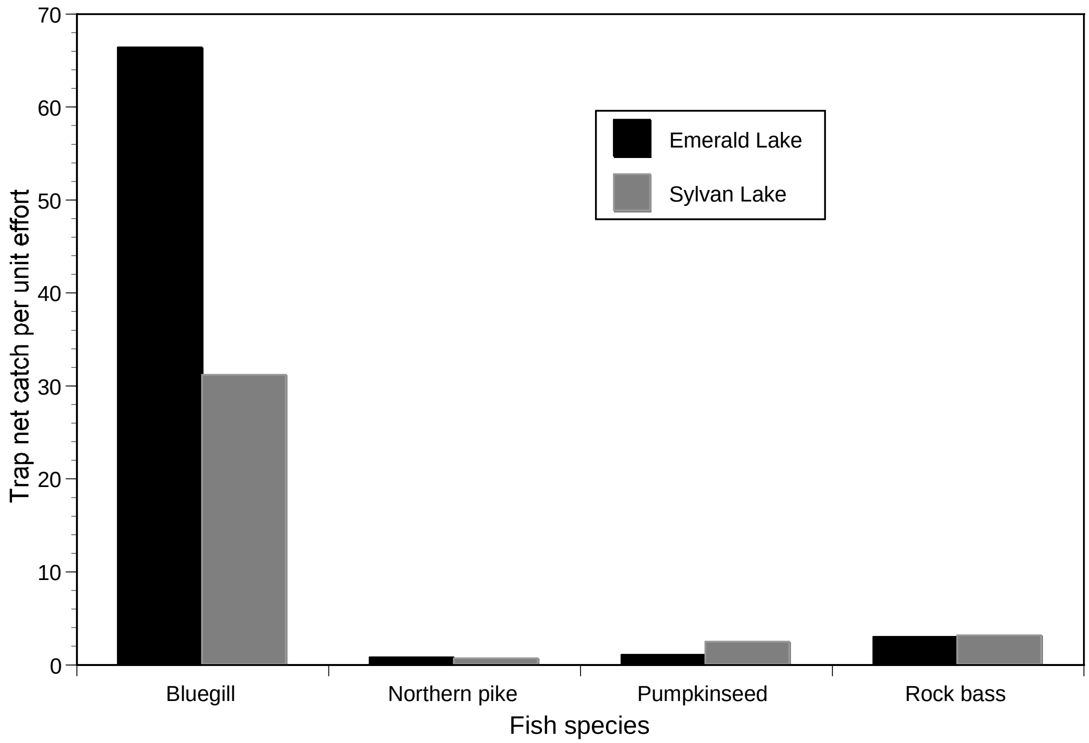

Figure 15. Trap net catch per unit effort of fish collected in Emerald and Sylvan lakes during 2004.

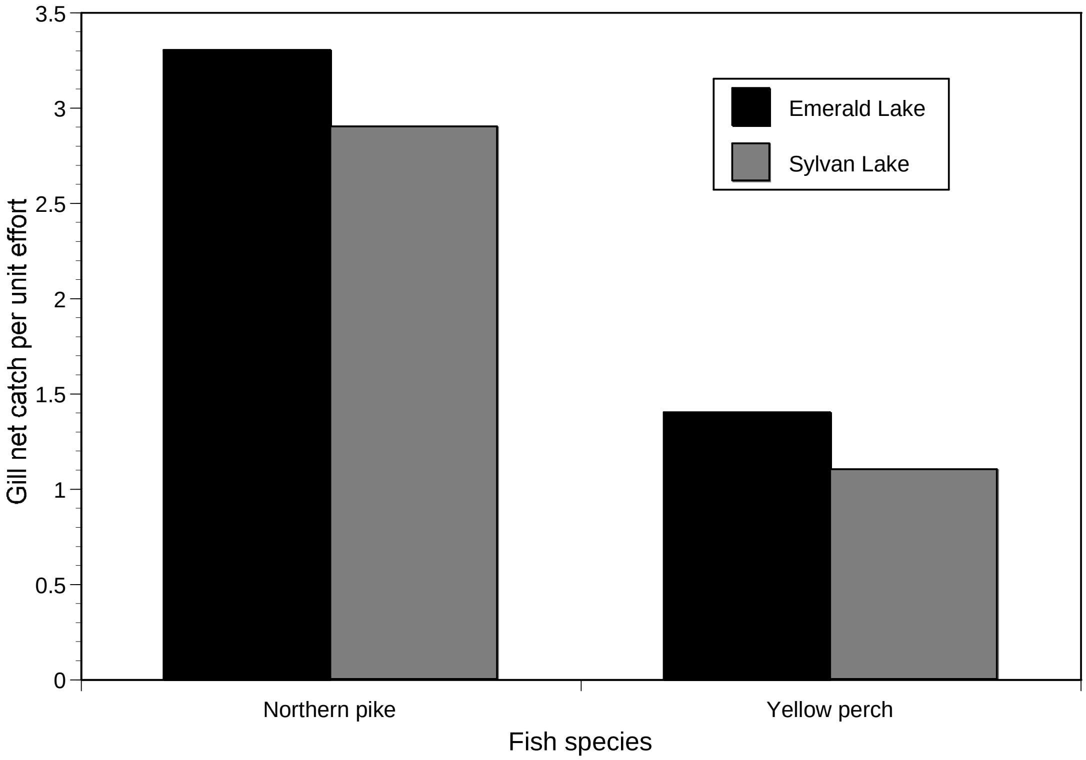

Figure 16. Gill net catch per unit effort of fish collected in Emerald and Sylvan lakes during 2004.

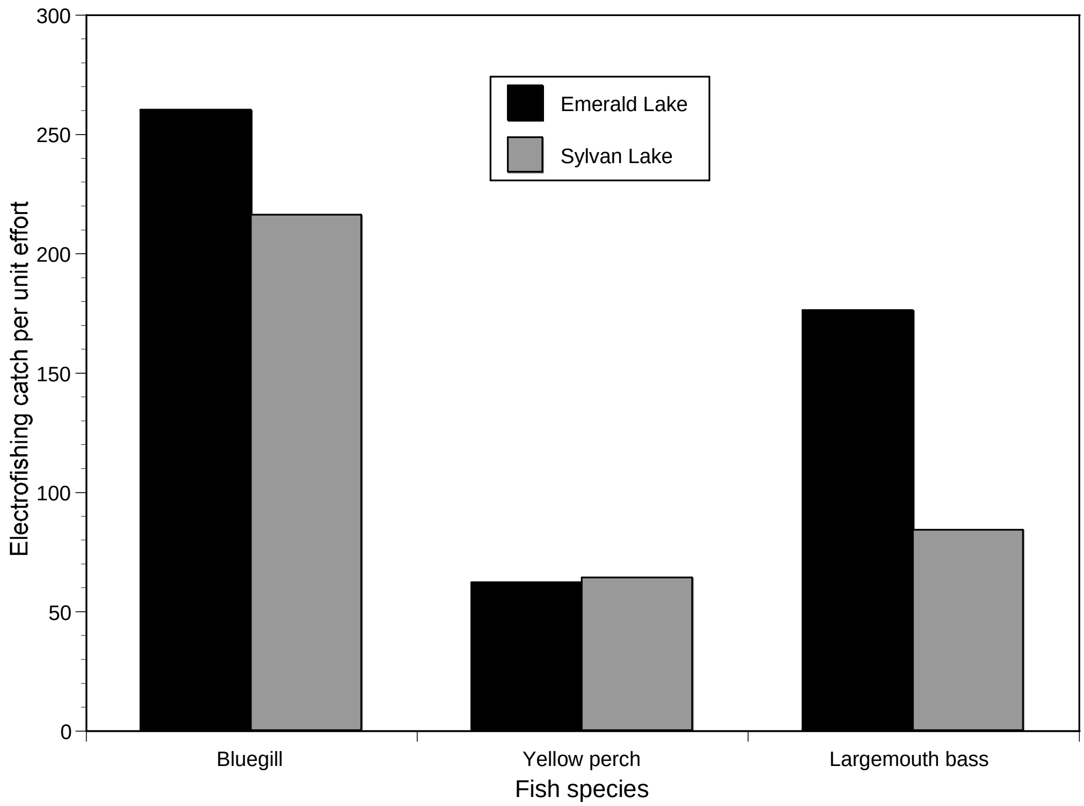

Figure 17. Electrofishing catch per unit effort of fish collected in Emerald and Sylvan lakes during 2004.

Table 1. Limnological parameters evaluated in Emerald and Sylvan lakes, Newaygo County, in 1941, 1947, 1954, and 2004. Alkalinity ranges represent multiple samples each year; 1941- six samples collected at two stations and four depths; 1947 – two samples collected at one station and two depths; 1954 – two samples collected at one station and two depths.

Date	**8/29/1941**	**9/15/1947**	**7/11/1954**	**7/8/2004**	**7/8/2004**
Basin	**Emerald**	**Emerald**	**Emerald**	**Emerald**	**Sylvan**
Secchi disk (ft)	13	11	14-16	9.1	8.2
Alkalinity (mg/l)	108-146	113-139	109-187		
Chlorophyll-*a* (ug/l)				1.9	2.0
Trophic status					
Secchi disk	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic	Mesotrophic
Chlorophyll-*a*				Oligotrophic-Mesotrophic	Mesotrophic
Zooplankton					
Mean body length (mm)				1.07	0.95

Table 2. Limnological parameters evaluated in Emerald and Sylvan lakes, Newaygo County, in 1998, 2004, and 2008 through the Michigan Department of Environmental Quality Cooperative Lakes Monitoring Program (http://www.michigan.gov/deq/0,1607,7-135-3313_3686_3731-195536--,00.html). Note: M indicates mesotrophic, O indicates oligotrophic, and E indicates eutrophic.

Year	**1998**		**2004**		**2008**	
Basin	**Emerald**	**Sylvan**	**Emerald**	**Sylvan**	**Emerald**	**Sylvan**
Secchi disk (ft)	8.9	6.7	11.6	12.3	14.6	12.0
Chlorophyll-*a* (mg/l)					2.9	
Total phosphorous (ug/l)			10	8	9	11
Trophic status						
Secchi disk (ft)	M	M-E	M	M	M	M
Chlorophyll-*a* (mg/l)					M	
Total phosphorous (ug/l)			M	O	M	E

Table 3. Aquatic plants found in Emerald Lake on July 2, 1954. For shore locations N is north, S is south, E is east, and W is west.

Common name	Scientific name	Abundance	Depth (ft)	Shore location
Chara (macroalgae)	*Chara spp.*	Medium-Dense	Variable	All areas
Waterweed	*Elodea canadensis*	Sparse	6	SW
Native water-milfoil	*Myriophyllum spp.*	Sparse	4-10	NW bay
Robbins' pondweed	*Potamogeton robbinsii*	Sparse	2-5	NW bay
Sago pondweed	*Potamogeton pectinatus*	Sparse	2-10	W
Large-leaf pondweed	*Potamogeton amplifolius*	Sparse	6	SW
Flat-stemmed pondweed	*Potamogeton zosteriformis*	Sparse	10	SW
Floating pondweed	*Potamogeton natans*	Sparse	3-6	W
Softstem (Round) bulrush	*Schoenoplectus tabernaemontani*	Sparse	0-2	SW
Three-square bulrush	*Schoenoplectus pugens*	Sparse	0-3	W
Sweet-scented waterlily	*Nymphea spp.*	Sparse	2-5	S & SW
Yellow pond-lily	*Nuphar spp.*	Sparse-Medium	2-6	SW
Arrowhead	*Sagittaria latifolia*	Sparse-Medium	0-2	SW
Buttercup	*Ranunculus spp.*	Sparse	2-3	S

Table 4. Summary of known chemical treatment applications for aquatic vegetation removal in Emerald and Sylvan lakes, 1998-2008.

Year	Comment
1998	Permit application requested the use of, Hydrothol-191, Aquatholl-K, Rodeo, 2,4-D and copper products, amounts used were unknown
1999	Chemicals used were Reward and copper products
2000	Chemicals used were Reward, 2,4-D and copper products
2001	Chemicals used were Reward and copper products
2002	Chemicals used were Reward, 2,4-D and copper products
2003	Chemicals used were Reward, Rodeo and copper products
2004	Chemicals used were Reward, Renovate and copper products
2005	Chemicals used were Reward, Renovate and copper products
2006	Chemicals used were Reward, Renovate, 2,4-D and copper products
2007	Chemicals used were Reward, Renovate and copper products
2008	Chemicals used were Reward, Renovate, 2,4-D and copper products

Table 5. File summary for Emerald Lake (E) and Sylvan Lake (S), Newaygo County.

Lake	Date	Comments
S	7/11/1892	Michigan Fish Commission survey of fish and depths
E	7/11/1892	Michigan Fish Commission survey of fish and depths
E	8/26/1926	Lake survey
E	8/29/1941	Limnology survey
E	9/15/1947	Lake survey - notes indicate the lake had a dam 1,000 ft downstream, vegetation sparse, encrusted with marl, with heavy deposits of marl everywhere
E	3/1948	Lake mapped - notes indicate a marl bottom with some pulpy peat and sand. Fishing reported as good
E, S	1949	Note that commercial wiggler harvest was occurring on both lakes
E, S	9/53	Stocking of adult walleye from the Muskegon River (Newaygo transfer), which occurred in the 1940s, was discontinued in 1953
E	7/1/1954	Lake survey – note that steep slopes were present and the result of marl dredging that had occurred in the past
E	10/1955	Installed 18 groups (5) of brush shelters at even intervals around the lake at the 10’-12’ contours
E, S	2002	Approximate date of sewer system construction that serves the majority of residences on this chain of lakes (including Pickerel and Kimball lakes)
E, S	2004	Lake survey
S	2007	Fish kill report - investigation indicated normal winter/spring mortalities

Table 6. Numbers of fish stocked into Emerald Lake, Newaygo County, 1930-2008. Stocked fish were fingerlings unless indicated as fry (F) or adult (A). A “P” indicates stocking by a private (non-MDNR) entity.

Year	Species					
	Bluegill	Brook trout	Largemouth bass	Sunfish	Walleye	Yellow perch
1930	3,200			800		170,000 F
1931	2,400		375	3,200		
1939					221 A	
1940					110 A	
1944			500			
1947					207 A	
1948					75 A	
1954					2,000	
1965		3,000				
1988					800 P	

Table 7. Fish and turtle species collected in Emerald (E) and Sylvan (S) lakes in 1892, 1954, and 2004. The presence of turtles was not recorded in the 1892 and 1954 surveys. Note that GN = gill net, TN = trap net, SE = seine, and EL = electrofishing.

Common name	Scientific name	S-1892	E-1954	S-2004	E-2004
Method		GN	GN, SE	TN,GN,SE,EL	TN,GN,SE,EL
Fish					
Black bullhead	*Ameiurus melas*			X	
Black crappie	*Pomoxis nigromaculatus*		X	X	X
Blacknose shiner	*Notropis heterolepis*		X		
Bluegill	*Lepomis macrochirus*	X	X	X	X
Bluntnose minnow	*Pimephales notatus*		X		
Common carp	*Cyprinus carpio*				X
Green sunfish	*Lepomis cyanellus*		X	X	X
Iowa darter	*Etheostoma exile*		X		
Johnny darter	*Etheostoma nigrum*		X		
Largemouth bass	*Micropterus salmoides*	X	X	X	X
Northern pike	*Esox lucius*	X		X	X
Pumpkinseed	*Lepomis gibbosus*		X	X	X
Rock bass	*Ambloplites rupestris*		X	X	X
Spottail shiner	*Notropis hudsonius*			X	X
Walleye	*Sander vitreus*		X	X	
Western banded killifish	*Fundulus diaphanous menona*		X		
White sucker	*Catostomus commersonii*		X		
Yellow bullhead	*Ameiurus natalis*				X
Yellow perch	*Perca flavescens*	X	X	X	X
Turtles					
Common musk turtle	*Sternotherus odoratus*			X	X
Common map turtle	*Graptemys geographica*				X
Painted turtle	*Chrysemys picta*			X	
Snapping turtle	*Chelydra serpentine*			X	
Spiny softshell turtle	*Apalone (-Trionyx) spinifera*				X

Table 8. Length distributions of fish collected in Emerald and Sylvan lakes in 2004.

Length	Black crappie		Bluegill		Largemouth bass		Northern pike		Pumpkinseed		Rock bass		Yellow perch	
(in)	Emerald	Sylvan	Emerald	Sylvan	Emerald	Sylvan	Emerald	Sylvan	Emerald	Sylvan	Emerald	Sylvan	Emerald	Sylvan
1			1		7									
2			23	29								1		
3	1		78	82	5	2				5	2	2	6	10
4	1		323	162	31	15			2	9	6	5	13	13
5			167	48	2	5			3	5	5	6	8	7
6	9		104	41	10	9			5	5	9	10	7	5
7	8		66	37	7	3			2	3	10	6	4	2
8	2		7	9	7	10					6	13	3	
9	4	1		1	5	5					13	3	1	1
10	5	2			5	3					8	5	1	4
11	1				8	1					11	8		
12					6	4					2	2	1	
13		1			3	5						1		1
14					13	8								
15					7	6	1							
16					3	2	1	1						
17					1	1	4	2						
18							2							
19					1		3	4						
20							6	2						
21							4	4						
22							4	3						
23							5	3						
24							4	4						
25								1						
26							1	2						
27								4						
28							1							
36								1						
Total	31	4	769	409	121	79	36	31	12	27	72	62	44	43

Table 9. Growth rates of fish, relative to state averages, for fish collected in Emerald and Sylvan lakes during 2004.

Species	Emerald Lake	Sylvan Lake
Black crappie	0.7	-
Bluegill	-0.3	-0.7
Largemouth bass	-0.6	-1.5
Northern pike	-5.4	-4.0
Pumpkinseed	0.7	0.1
Rock bass	0.7	0.5
Yellow perch	-0.1	-0.5

Table 10. Bluegill growth and size structure classification for Emerald and Sylvan lakes in 2004. Refer to Schneider (1990) for methods[1].

Sample method	Average length (in)	%>6	%>7	%>8	Average score	Rank	Growth index
Emerald Lake							
Electrofishing data	4	6.9	2.3				-0.3
Electrofishing score	2	2	3		2.3	Poor	Acceptable
Net data	5.3	24.6	9.7	0.8			-0.3
Net score	2	3	4	4	3.2	Acceptable	Acceptable
Sylvan Lake							
Electrofishing data	3.6	4.6	0.9				-0.7
Electrofishing score	1	2	2		1.7	Poor	Poor
Net data	5.3	25.7	15.2	3.2			-0.7
Net score	2	3	4	5	3.5	Acceptable	Poor

1. Scores and ranks are as follows: 1=very poor, 2=poor, 3=acceptable, 4=satisfactory, 5=good, 6=excellent, and 7=superior.

Table 11. Habitat quality scores for Emerald and Sylvan lakes based on fish community composition[1]. Several other variables were used to determine scores including limnological parameters, aquatic plant abundance, and alteration of the shoreline (Schneider 2002).

Metric	Description	Possible score	Score	Comments
1	Native fish fauna	1-5	3.5	Demote a point for introduction of common carp and ½ point for walleye.
2	Winterkill	1-5	5	Winterkill intolerant species = 62% by number of sample
3	Acidity	1,2,3,5	3	pH>5, acid tolerant and other species present
4	Thermocline/hypolimnion DO	1-5	3	No indicator species present
5	Productivity/enrichment	1-5	4	Black crappie, bullhead, and carp low percentage
6	Turbidity	1-4	3	No turbidity intolerant species present
7	Silt	1-4	4	Silt intolerant walleye and northern pike present
8	Macrophytes	1,2,3,5	4	Four macrophyte dependent species present (northern pike, bluegill, largemouth bass, yellow bullhead)
9	Edge modification	1-5	3	One edge modification intolerant species present (northern pike), and heavy shoreline development with low submerged trees.
10	Level stabilization	1-5	4	Northern pike abundant
11	Predation/competition	2,3,5	5	Natural dominant species present
	Total		41.5	

1. The range of possible scores is 12-53. A maximum score would be achieved in a deep, oligotrophic, non-acidic lake with moderate densities of aquatic macrophytes, which was unaffected by species introductions, low DO (dissolved oxygen), eutrophication, or modifications of edge or water levels. Typical shallow, mesotrophic, Michigan lakes with no DO below the thermocline would score a maximum of 50. Natural Michigan lakes that are shallow, productive and have fish kills due to low DO in winter would score a maximum of 31. Most lakes in Michigan presently will not have maximum scores due to human alterations.