Prepared in cooperation with the Lake Maxinkuckee Environmental Council and the Marshall County Soil and Water Conservation District

Occurrence and Trends of Selected Nutrients, Other Chemical Constituents, Diatoms, and Cyanobacteria in Bottom Sediment, Lake Maxinkuckee, Northern Indiana

Scientific Investigations Report 2014–5199

U.S. Department of the Interior
U.S. Geological Survey

Front cover. Lake Maxinkuckee at sunset [photograph by Chi-sen (Jason) Chan, Culver Military Academy].

Back cover. Lake Maxinkuckee (photograph by Eric Looper, U.S. Geological Survey).

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Conversion Factors

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
foot (ft)	0.3048	meter (m)
inch (in.)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre	0.004047	square kilometer (km^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Mass	
milligram per kilogram (mg/kg)	1.0	part per million (ppm)
percent concentration	10,000	milligram per kilogram (mg/kg)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Occurrence and Trends of Selected Nutrients, Other Chemical Constituents, Diatoms, and Cyanobacteria in Bottom Sediment, Lake Maxinkuckee, Northern Indiana

By Kyle E. Juracek

Abstract

Bottom-sediment cores collected in 2013 were used to investigate the recent and predevelopment (pre-1863) occurrence of selected nutrients (total nitrogen and total phosphorus), carbon, 39 trace elements, diatoms, cyanobacterial akinetes, and 3 radionuclides in the bottom sediment of Lake Maxinkuckee, a kettle lake in northern Indiana. Total nitrogen concentrations in the recent sediment (since about 1970) were variable with no consistent trend indicated. Total phosphorus concentrations in the recent sediment generally were uniform from about 1970 to about 2000 and indicated consistent inputs to the lake during that time. Subsequently, the history of total phosphorus deposition apparently was obscured by postdepositional upward diffusion.

Trace-element concentrations in the bottom sediment of Lake Maxinkuckee generally were not cause for concern. Elevated concentrations of cadmium, copper, lead, mercury, and zinc in the recent sediment, compared to the predevelopment sediment, indicated likely human-related contamination; however, the trace-element concentrations were less than probable-effects guidelines (available for nine trace elements), which represent the concentrations above which toxic aquatic biological effects usually or frequently occur. Arsenic concentrations typically exceeded the threshold-effects guideline, which represents the concentration above which toxic aquatic biological effects occasionally occur, in the recent and predevelopment sediment. The arsenic likely originated from natural sources. Lead concentrations historically exceeded the threshold-effects guideline, but since had decreased below it in the recent sediment at most coring sites. The decreasing trend likely was indicative of the effect of the phase out of leaded gasoline.

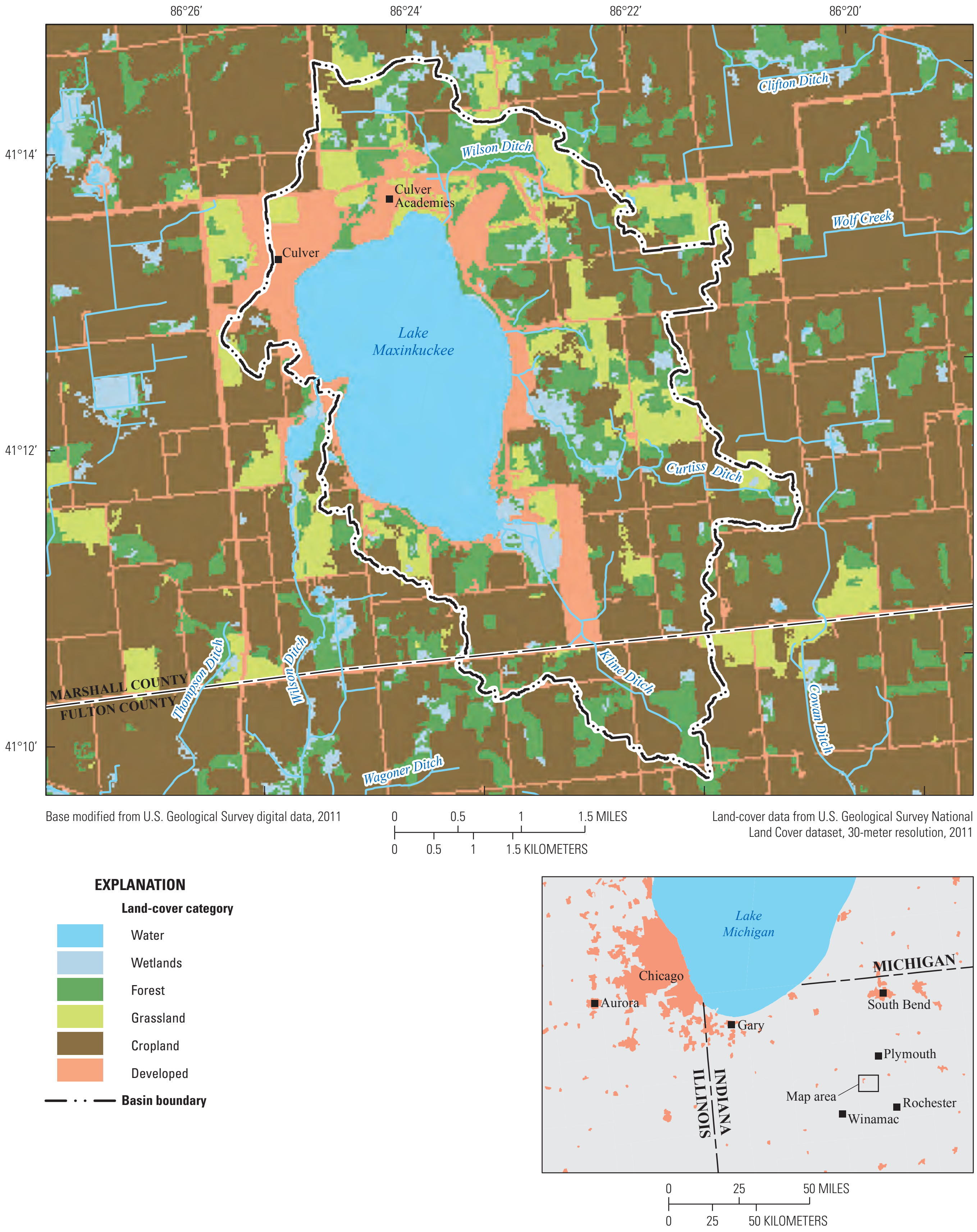
Biological indicators in the bottom sediment provided evidence for an improving, or at least not worsening, lake trophic condition. The occurrence of multiple diatom species, none of which were overwhelmingly dominant, was indicative of a minimally contaminated lake ecosystem. The combined evidence of several diatom species in the recent sediment indicated that the lake had not become more productive in recent decades. The combined evidence provided by akinetes for three cyanobacterial genera in the recent and predevelopment sediment indicated similar nutrient conditions in the lake during the past 40 years and possibly back to at least the mid-1800s.

Introduction

Lake Maxinkuckee is a kettle lake located in Marshall County, northern Indiana (fig. 1). The lake is valued for the recreational and educational opportunities it provides and is of central importance to the economic well-being of the town of Culver (JF New & Associates, 2006), which is located along the northwest shore (fig. 1). Effective management to preserve and protect the lake requires an understanding of past and present lake conditions. Such an understanding is attainable, in part, through an analysis of the sediment deposited on the lakebed. Information obtained from an analysis of bottom-sediment cores can be used to assess current and historical water-quality and sediment-quality conditions, assess habitat quality, help identify constituents of concern in the lake, understand the trophic history of the lake, establish a baseline of lake and basin conditions, and assess the effects of human activity on the condition of the lake.

A 2-year study by the U.S. Geological Survey (USGS), in cooperation with the Lake Maxinkuckee Environmental Council and the Marshall County Soil and Water Conservation District, was begun in 2013 to investigate the past and present condition of Lake Maxinkuckee through an analysis of the lakebed sediment. Specific objectives of the study were to:

1. Determine the occurrence and temporal trends of selected chemical constituents in the bottom sediment;
2. Assess the quality of the bottom sediment with respect to available sediment-quality guidelines; and
3. Determine the occurrence, relative abundance, and trends of diatoms and cyanobacterial akinetes in the bottom sediment as an indication of the trophic history of the lake.



Base modified from U.S. Geological Survey digital data, 2011

Land-cover data from U.S. Geological Survey National Land Cover dataset, 30-meter resolution, 2011

Figure 1. Location of Lake Maxinkuckee and land use (2011) in the Lake Maxinkuckee Basin, northern Indiana.

Purpose and Scope

The purpose of this report is to present the results of the USGS study to assess the condition of Lake Maxinkuckee by an analysis of bottom-sediment cores that were collected at six sites in 2013. A total of nine cores were analyzed for several chemical and biological constituents. Locally, the information provided in this report will help improve the understanding of current and historical lake conditions and allow for better informed decisions regarding the future management of the lake and its basin. Nationally, the methods and results presented in this report provide guidance and perspective for future studies concerned with the issues of sediment quality, contaminant loading, and trophic status as related to the environmental condition of lakes and their ability to meet the needs of wildlife and humans.

Description of Lake Maxinkuckee and its Basin

Lake Maxinkuckee (fig. 1) is a kettle lake that was created about 15,000 years ago when the glaciers of the last Ice Age retreated (Schneider, 1966; Schneider and Johnson, 1966). A kettle lake is formed when an ice block from a retreating glacier is left behind and melts resulting in a depression on the land surface that fills with water (Wetzel, 2001). Lake Maxinkuckee has a surface area of 1,854 acres and measures 2.6 miles (mi) in length and 1.6 mi in width. Water depth in the lake averages 24 feet (ft) with a maximum depth of 88 ft. Primary tributaries to the lake are Curtiss Ditch, Kline Ditch, and Wilson Ditch (fig. 1). Underground springs also feed into the lake (JF New & Associates, 2006). Based on multiple water-quality criteria (for example, transparency, nutrient content, and chlorophyll-*a* content), the lake has been classified as mesotrophic (JF New & Associates, 2006). A mesotrophic lake is characterized by moderate productivity with moderate nutrient concentrations (Wetzel, 2001). Crisman (1986), based on an analysis of algal data (collected periodically from 1899 to 1978), concluded that the lake was moderately productive and the summer algal community was dominated by cyanobacteria since at least 1899. More recently, using multiple water-quality criteria, the lake was classified as oligotrophic (Indiana Department of Environmental Management, 2012). An oligotrophic lake is characterized by low productivity with low nutrient concentrations (Wetzel, 2001).

The Lake Maxinkuckee Basin is an area of about 13.5 mi^2 located in southwest Marshall County and northwest Fulton County, Indiana (fig. 1). Physiographically, the basin is located along the western edge of the Maxinkuckee Moraine, which was formed by the advance and subsequent stagnation of the Saginaw Lobe during the latter part of the Wisconsin Age glaciation (Schneider and Johnson, 1966). Topographically, the land surface in the Maxinkuckee Moraine is a diverse terrain of moderate relief with kames, moraines, outwash plains, and kettles (Wayne, 1966; Gray, 2000). Slopes range from nearly level to strongly sloping. In general, soils in the basin are sandy at the surface and well drained (Smallwood, 1980; Furr, 1987). Bedrock in the basin is shale of Devonian and Mississippian age (Gutschick, 1966).

The climate, as characterized using the Koppen climate classification system (Peel and others, 2007), is moist with warm to hot summers and cold winters. Mean annual precipitation at Plymouth, Indiana, located about 10 mi northeast of Lake Maxinkuckee (fig. 1), is about 40 inches (in.; period of record 1981–2010; National Climatic Data Center, 2013).

Land use (2011) in the basin is diverse (fig. 1). Agricultural land use (cropland and grassland) accounts for about 43 percent of the basin. Wetlands and open water (including Lake Maxinkuckee) cover about 26 percent of the basin. Developed land, which includes the town of Culver, the Culver Academies, and residences along the lakeshore, accounts for about 15 percent of the basin. Most of the developed land is low-intensity residential land use and urban parkland. About 16 percent of the basin is forested (Jin and others, 2013). To reduce sediment and nutrient inputs to the lake, constructed wetlands were completed on Wilson Ditch in 1987, Curtiss Ditch in 1990, and Kline Ditch in 1992 (fig. 1) (Kathy Clark, Lake Maxinkuckee Environmental Council, written commun., 2013).

Wastewater treatment in the basin differs by location. For the town of Culver, including the Culver Academies (fig. 1), wastewater is collected, treated, and discharged downstream from Lake Maxinkuckee. Along the east side of the lake, wastewater is collected and treated in a wetland. Throughout the remainder of the basin, wastewater is treated using septic systems (JF New & Associates, 2006). In 2011, most of the residences along the lakeshore that previously used septic systems were converted to Culver's wastewater treatment system (Kathy Clark, Lake Maxinkuckee Environmental Council, oral commun., 2014).

Methods

The objectives of this study were accomplished by the analysis of bottom-sediment cores collected at six sites in the lake. A description of the core collection and processing and the chemical, biological, and physical analyses completed is provided in the following sections.

Sediment-Core Collection and Processing

In May 2013, bottom-sediment cores were collected at six sites (fig. 2) within Lake Maxinkuckee. The coring sites were selected to provide representative information on conditions throughout the lake and to provide an indication of spatial variability. The specific objectives of the coring were to collect undisturbed cores of the most recently deposited sediment and to collect deeper cores to provide an indication of conditions before substantial human activity in the area. These respective objectives were accomplished using a box corer and a gravity corer. At sites LM–1, LM–2, and LM–3, a box core and a gravity core were collected. At sites LM–4 and LM–5, a box core was collected. A gravity core was collected at site LM–6, which was located in the deepest part of the lake. The latitude and longitude for each site, obtained using global positioning system (GPS) technology, are provided in table 1–1 in the appendix at the back of this report. All cores were collected from a pontoon boat.

The box corer, which has a steel jaw activated by a spring-loaded pin, was slowly lowered by rope to the lakebed at each site. After the corer settled into the bottom sediment, a tug of the rope released the pin causing the steel jaw to shut and capture the core. The inside dimensions of the square transparent acrylic liner used to hold the sample were 14 centimeters (cm) long by 14 cm wide by 50 cm deep.

The gravity corer was lowered by cable to a depth of about 5 ft above the lakebed and then released to penetrate into the bottom sediment. The liner used for the gravity cores was cellulose acetate butyrate transparent tubing with an inside diameter of about 6.7 cm.

When using a gravity corer, a phenomenon referred to as “core shortening” may occur that results in a recovered sediment core the length of which is less than the actual thickness of sediment penetrated (Emery and Hulsemann, 1964). Core shortening is caused by friction of the sediment against the inner wall of the core liner as the corer penetrates the sediment (Emery and Hulsemann, 1964; Hongve and Erlandsen, 1979; Blomqvist, 1985; Blomqvist and Bostrom, 1987). In “normal” lake-bottom sediment, which is characterized by uniform texture with decreasing water content at depth, core shortening results in a core that provides a thinned but complete representation of all of the sediment layers that were penetrated (Emery and Hulsemann, 1964; Hongve and Erlandsen, 1979). In this study, a comparison of the length of core recovered by gravity coring to the thickness of sediment penetrated indicated that core recovery ranged from 31 to 52 percent with an average of 38 percent. The thickness of sediment penetrated was computed as the total depth of corer penetration (as measured from the water surface) minus the water depth.

Following collection, the cores were processed to obtain samples for specific depth intervals. The box cores were processed immediately after collection at the lake. For each box core, the sediment was sampled into plastic jars for successive 2-centimeter (cm) intervals throughout the entire length of the core (that is, 0–2 cm, 2–4 cm, and so on). The 2-cm samples were transported to the USGS laboratory in Lawrence, Kansas,

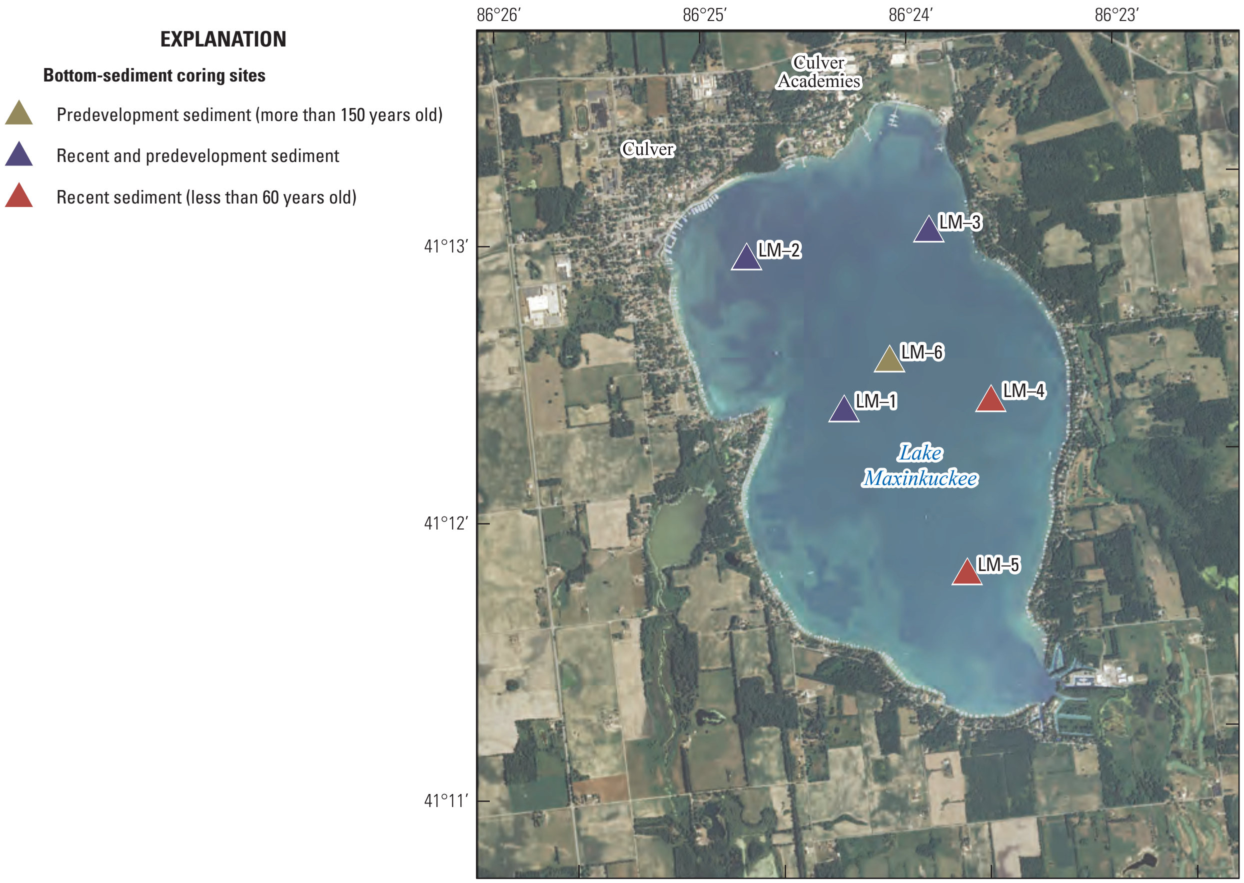


Figure 2. Location of bottom-sediment coring sites in Lake Maxinkuckee, northern Indiana.

Base from U.S. Department of Agriculture, Farm Service Agency-Aerial Photography Field Office, National Agriculture Inventory Program, 2012, 1:12,000 where they were refrigerated (at 5 degrees Celsius [°C]) until final processing.

The gravity cores were transported to the USGS laboratory in Lawrence, Kansas, where they were stored vertically and refrigerated (at 5 °C) until processed (within 1 week of collection). The core liners were cut lengthwise in two places 180 degrees apart. The cuts were completed with a 4-in. hand-held circular saw with the blade set at a depth to minimize penetration of the sediment in the cores. The cores were split in half by pulling a tightly held nylon string through the length of the cores and allowing the halves to separate. Once split, the relatively undisturbed inner parts of the cores were exposed for examination and sampling. To provide sufficient sample material for all of the planned analyses, the sediment was sampled into plastic jars for successive 10-cm intervals throughout the entire length of each core. All samples were refrigerated (at 5 °C) until final processing.

Final processing involved two steps. First, each sample was homogenized using a clean plastic spatula. Second, each sample was subdivided into six subsamples for subsequent shipment to different laboratories for chemical, biological, and physical analyses (see details provided in the following sections).

At coring sites LM–1 to LM–5, water-quality data were collected for the water column using a 7-parameter YSI 6600V2 water-quality monitor (YSI, 2013). The properties measured were pH, temperature, specific conductance, dissolved oxygen, turbidity, chlorophyll (total), and cyanobacteria. These data are provided (see table 1–2 in the appendix) but not discussed.

Chemical Analyses

The bottom-sediment samples were analyzed for nutrients (total nitrogen and total phosphorus), inorganic and total carbon, 39 trace elements, and 3 radionuclides. A complete list of the chemical constituents for which analyses were completed is provided in table 1. With the exception of total nitrogen, 51 samples were analyzed for the various constituents. For total nitrogen, 45 samples were analyzed. Analyses of the samples for total phosphorus, inorganic and total carbon, and 39 trace elements were performed at USGS laboratories in Denver, Colorado, using the methods described by Taggart (2002). Analyses for total nitrogen (that is, the sum of total Kjeldahl nitrogen and nitrate plus nitrite) were performed at TestAmerica Laboratories, Inc. in Denver, Colorado, using the methods described by the U.S. Environmental Protection Agency (1983). Radionuclide analyses were performed at a USGS laboratory in St. Petersburg, Florida, using the methods described by Marot and Smith (2012).

Quality control (QC) for the various chemical constituents was provided by additional analyses. For phosphorus and most of the trace elements, QC included the analysis of 11 reference samples and 2 duplicate analyses of core samples. For phosphorus, analysis of the reference samples indicated that the measured concentrations were, on average, within 9 percent of the most probable value (MPV). Measured concentrations in the reference samples for arsenic, cadmium, chromium, copper, lead, nickel, and zinc were, on average, within about 10 percent (or less) of the MPV. However, for silver, measured concentrations were, on average, within 104 percent of the MPV and indicated the difficulty in detecting concentrations near the method reporting limit. Measured concentrations in four reference samples for mercury and selenium were, on average, within 13 percent and 4 percent of the MPV, respectively. The duplicate analyses (core LM–2,

Table 1. Chemical analyses for bottom-sediment samples collected from Lake Maxinkuckee, northern Indiana, 2013.

[Number in parentheses is the method reporting limit for each constituent. mg/kg, milligrams per kilogram; %, percent dry weight; dpm/g, disintegrations per minute per gram]

Nutrients	
Nitrogen, total Kjeldahl (25 mg/kg)	Phosphorus, total (5 mg/kg)
Nitrogen, nitrate plus nitrite (0.3 mg/kg)	
Carbon	
Carbon, total (0.05%)	Carbon, inorganic (0.01%)
Trace elements	
Aluminum (50 mg/kg)	Mercury (0.01 mg/kg)
Antimony (0.04 mg/kg)	Molybdenum (0.05 mg/kg)
Arsenic (1 mg/kg)	Nickel (0.3 mg/kg)
Barium (0.25 mg/kg)	Niobium (0.1 mg/kg)
Beryllium (0.03 mg/kg)	Potassium (15 mg/kg)
Bismuth (0.06 mg/kg)	Rubidium (0.014 mg/kg)
Cadmium (0.007 mg/kg)	Scandium (0.04 mg/kg)
Calcium (100 mg/kg)	Selenium (0.1 mg/kg)
Cerium (0.1 mg/kg)	Silver (0.01 mg/kg)
Cesium (0.003 mg/kg)	Sodium (25 mg/kg)
Chromium (0.5 mg/kg)	Strontium (0.8 mg/kg)
Cobalt (0.03 mg/kg)	Sulfur (0.05%)
Copper (2 mg/kg)	Thallium (0.08 mg/kg)
Gallium (0.015 mg/kg)	Thorium (0.1 mg/kg)
Iron (50 mg/kg)	Titanium (40 mg/kg)
Lanthanum (0.05 mg/kg)	Uranium (0.02 mg/kg)
Lead (0.4 mg/kg)	Vanadium (0.15 mg/kg)
Lithium (0.3 mg/kg)	Yttrium (0.05 mg/kg)
Magnesium (6 mg/kg)	Zinc (3 mg/kg)
Manganese (0.7 mg/kg)	
Radionuclides	
Cesium-137 (0.05 dpm/g)	Radium-226 (0.05 dpm/g)
Lead-210 (0.05 dpm/g)	

interval 24–26 cm; core LM–4, interval 20–22 cm) typically were within 10 percent of the original analyses.

Quality control for nitrogen was provided by the analysis of reference samples and blank samples. For Kjeldahl nitrogen and nitrate plus nitrite, three reference samples and three blank samples were analyzed. Measured concentrations in the reference samples for Kjeldahl nitrogen and nitrate plus nitrite were, respectively, within 3 percent and 9 percent of the MPV. With one exception, measured concentrations in the blank samples were less than the method reporting limits. For the one exception, a low concentration of nitrate plus nitrite was measured (0.41 milligram per kilogram [mg/kg]).

Quality control for the radionuclides was provided by the duplicate analysis of three samples (core LM–1, interval 8–10 cm; core LM–4, interval 8–10 cm; core LM–5, interval 0–2 cm). On average, the duplicate results for cesium-137 (^{137}Cs), lead-210 (^{210}Pb), and radium-226 (^{226}Ra) were within 9 percent, 2 percent, and 3 percent of the original results, respectively. Results for the duplicate analyses are provided in table 1–3 in the appendix.

Age Dating and Sedimentation Rate

Age dating of the bottom-sediment samples from all six coring sites (fig. 2) was accomplished by determining the activity of ^{137}Cs, ^{210}Pb, and ^{226}Ra. ^{137}Cs is a radionuclide that is a byproduct of aboveground nuclear weapons testing. Measurable activity of ^{137}Cs first appeared in the atmosphere about 1952, peaked during 1963–64, and has since declined (Ritchie and McHenry, 1990). Measurable activity in soils began about 1954 (Wise, 1980). ^{137}Cs is an effective marker for age dating bottom sediment in lakes and reservoirs that existed before 1963–64 (Van Metre and others, 1997). The activity of ^{137}Cs in a sediment core also can be used to demonstrate that the sediment is relatively undisturbed if the 1963–64 peak is well-defined and a generally uniform, exponential decrease in ^{137}Cs activity follows the peak.

Lead-210 is a radionuclide that occurs naturally in the uranium-238 decay series. As ^{226}Ra in soils decays to radon-222 (^{222}Rn), some of the ^{222}Rn escapes to the atmosphere where it quickly decays through two short-lived radionuclides to ^{210}Pb. The fallout of ^{210}Pb from the atmospheric ^{222}Rn results in more ^{210}Pb in surface soil than can be accounted for by the in situ decay of ^{226}Ra in the soil. As surface sediments in a lake are gradually buried and isolated from additional fallout, the “unsupported” ^{210}Pb decays with a half-life of 22.3 years. The relation between unsupported ^{210}Pb and ^{226}Ra in the lakebed sediment can be used to estimate the time since the sediment was deposited and buried (Appleby and Oldfield, 1992). Using this relation, lakebed sediments can be dated as far back as 150 years (Olsson, 1986; Appleby, 2001; Smol, 2008). When the activity of ^{210}Pb and ^{226}Ra in a lakebed sediment sample is equal (allowing for analytical variability), it may be concluded that all of the unsupported ^{210}Pb has decayed, and the sediment is older than 150 years. In this study, a constant initial activity of unsupported ^{210}Pb for each interval of the sediment core was assumed to be equal to the activity of the most recently deposited interval (Appleby and Oldfield, 1983, 1992). The age of each interval was estimated using the following equation:

$$t = (1/k)\ln(Co/Cx), \qquad (1)$$

where

t is the age of the interval (in years),
k is the ^{210}Pb radioactive decay constant (0.03114),
Co is the initial unsupported ^{210}Pb activity, and
Cx is the unsupported ^{210}Pb activity for the interval being dated (Appleby and Oldfield, 1978).

In this study, ages were estimated primarily using ^{210}Pb because (1) with the exception of coring site LM–3, the ^{137}Cs peak was not measured in the sediment cores, and (2) ^{137}Cs activity profiles for natural lakes with low sedimentation rates may be misleading or unusable (Van Metre and others, 2004). The ^{137}Cs, ^{210}Pb, and ^{226}Ra activity profiles for all six coring sites are provided in table 1–3 in the appendix.

Lead-210 dates assigned to individual core intervals were approximate. The uncertainty associated with the dates increases as the years before present increase. In general, the estimated dates were in agreement with ages inferred based on the total lead concentration profile for each core. In this report, “recent” sediment was defined as sediment for which ^{137}Cs activity was detected. The recent sediment was less than 60 years old. “Predevelopment” sediment was defined as sediment for which ^{137}Cs activity was not detected, and ^{210}Pb and ^{226}Ra activity were in secular equilibrium (that is, all of the unsupported ^{210}Pb had decayed). Predevelopment sediment generally was older than 150 years (that is, pre-1863).

Some of the predevelopment sediment samples analyzed may be considerably older than 150 years. For example, assuming a constant sedimentation rate (estimated from the box cores) and accounting for core shortening, sediment samples analyzed from the 50–60 cm depth for the gravity cores collected at sites LM–1 and LM–3 (fig. 2) may be more than 200 years old. Further, sediment samples analyzed from the 70–80 cm depth for the same gravity cores may be more than 300 years old.

Mean annual sedimentation rate was estimated for each box core as the total thickness of the deposited sediment divided by the number of years of deposition. Respectively, for coring sites LM–1, LM–2, LM–3, and LM–4 (fig. 2), the mean annual sedimentation rates were about 0.7, 0.8, 0.6, and 0.7 centimeters per year (cm/yr). For coring site LM–5 (fig. 2), the mean annual sedimentation rate was estimated to be about 1.4 cm/yr. However, the relatively short length of the box core and irregularities in the ^{210}Pb data for this site rendered the sedimentation rate less certain. In comparison, Crisman (1986) estimated the sedimentation rate for 1974–84 at a site in the northern part of Lake Maxinkuckee to be about 0.4 cm/yr.

Biological Analyses

To investigate the trophic condition and history of Lake Maxinkuckee, the same 51 sediment samples used for chemical analyses were analyzed for diatoms and cyanobacterial akinetes. Diatoms are microscopic algae that have a siliceous shell (frustule), consisting of two halves (valves), that may preserve in sediment. Because many diatom species are sensitive to changes in environmental conditions (for example, pH, light, temperature, and concentrations of nutrients and trace elements), changes in diatom species composition and abundance can be used as indicators of environmental changes (Dixit and others, 1992; Smol and Stoermer, 2010). Several diatom species are indicators of eutrophic (nutrient rich, high primary productivity) or oligotrophic (nutrient poor, low primary productivity) conditions (van Dam and others, 1994; Smol and Stoermer, 2010). Analysis of the sediment samples for diatoms was performed by Bio-Limno Research and Consulting, Inc., Halifax, Nova Scotia, Canada. For QC, three sediment samples (core LM–1, interval 0–2 cm; core LM–3G, interval 30–40 cm; core LM–6G, interval 60–70 cm) were counted for dominant species by PhycoTech, Inc., St. Joseph, Michigan, using the same prepared slides. On average, the duplicate counts for dominant species were within 3 percent.

Cyanobacteria (also called blue-green algae) commonly are indicative of eutrophic conditions in lakes and reservoirs (Wetzel, 2001; Smol, 2008). Akinetes are thick-walled, resistant cells that represent the resting stage of cyanobacteria (Adams and Duggan, 1999; Wetzel, 2001). They provide an approximate estimate of past abundance of akinete-producing cyanobacteria (Rasanen and others, 2006a) and can be used to investigate the trophic history of a lake (van Geel and others, 1994; Kling, 1998). Akinetes preserve well in sediment as evidenced by past studies that documented preservation for periods ranging from decades (Livingstone and Jaworski, 1980; Kling, 1998; Rasanen and others, 2006a) to centuries (Cronberg, 1986; van Geel and others, 1994). Analysis of the sediment samples for akinetes was performed by PhycoTech, Inc., St. Joseph, Michigan.

Particle-size Analysis

Particle-size analyses were completed to determine the percentage of sand (particles greater than 63 micrometers [µm] in size), silt (particles 4 to 63 µm in size), and clay (particles less than 4 µm in size) in the bottom sediment. A total of 28 samples were analyzed at the USGS Geosciences and Environmental Change Science Center Soils Laboratory in Denver, Colorado, using a Malvern Mastersizer 2000 laser particle-size analyzer (Malvern, 2013). QC was provided by the duplicate analysis of three samples. On average, the duplicate results were within 9 percent. The particle-size and QC data are provided in table 1–4 in the appendix.

Trend Analysis

Temporal trends in constituent concentrations (as compared to depth in the sediment profile) were assessed for nitrogen, phosphorus, the trace elements for which sediment-quality guidelines were available (table 2), diatoms, and cyanobacteria. A trend was described as “increasing” if constituent concentrations increased from the bottom (oldest) to the top (youngest) part of a sediment core. Conversely, a trend was described as “decreasing” if constituent concentrations decreased from the bottom to the top of a sediment core. For the chemical constituents, a trend was described as “pronounced” if the change in constituent concentrations was beyond the variability that could be explained by analytical variance (defined here as the mean constituent concentration in the sediment core plus or minus 10 percent). A trend was described as “possible” if most or all of the change in constituent concentrations was within the concentration range that could be explained by analytical variance.

Sediment-Quality Guidelines

The U.S. Environmental Protection Agency (EPA) has adopted nonenforceable sediment-quality guidelines (SQGs) in the form of level-of-concern concentrations for several trace elements (U.S. Environmental Protection Agency, 1997). These level-of-concern concentrations were derived from biological-effects correlations made based on paired onsite and laboratory data to relate incidence of adverse biological effects in aquatic organisms to dry-weight sediment concentrations. Two such level-of-concern guidelines adopted by the EPA are referred to as the threshold-effects level (TEL) and the probable-effects level (PEL). The TEL is assumed to represent the concentration below which toxic aquatic biological effects rarely occur. In the range of concentrations between the TEL and PEL, toxic effects occasionally occur. Toxic effects usually or frequently occur at concentrations above the PEL.

The EPA cautions that the TEL and PEL guidelines are intended for use as screening tools for possible hazardous concentrations of chemicals and are not regulatory criteria. This cautionary statement is made because, although biological-effects correlation identifies level-of-concern concentrations associated with the likelihood of adverse organism response, the comparison may not demonstrate that a particular chemical is solely responsible. In fact, biological-effects correlations may not indicate direct cause-and-effect relations because sediments may contain a mixture of chemicals that contribute to the adverse effects to some degree. Thus, for any given site, these guidelines may be over or underprotective (U.S. Environmental Protection Agency, 1997).

MacDonald and others (2000) developed consensus-based SQGs for several trace elements that were computed as the geometric mean of several previously published SQGs. The consensus-based SQGs consist of a threshold-effect concentration (TEC) and a probable-effect concentration (PEC). The TEC represents the concentration below which adverse biological effects are not expected to occur, whereas the PEC represents the concentration above which adverse biological effects are expected to occur more often than not. An evaluation of the reliability of the SQGs indicated that most of the individual TECs and PECs provide an accurate basis for predicting the presence or absence of sediment toxicity (MacDonald and others, 2000). A comparison of the two sets of trace-element SQGs indicated some differences (table 2). The largest difference was for the zinc PEC and PEL. In this case, the PEC (459 mg/kg) was about 69 percent larger than the PEL (271 mg/kg).

For each trace element for which SQGs were available, the larger of the two options for threshold effects and probable effects was selected for the purpose of assessing sediment quality (see shaded values in table 2). The options used to assess sediment quality are hereafter referred to as the threshold-effects guidelines (TEGs), which represent the concentrations above which toxic biological effects occasionally occur, and the probable-effects guidelines (PEGs), which represent the concentrations above which toxic biological effects usually or frequently occur. The guidelines used were selected to provide a less stringent assessment.

Background Information for Selected Chemical Constituents, Diatoms, and Cyanobacteria

Nutrients and Total Organic Carbon

Nutrients, such as nitrogen and phosphorus, are necessary for growth and reproduction of plants. In most freshwater environments, phosphorus is one of the principal limiting factors for primary production (Hakanson and Jansson, 1983; Wetzel, 2001). If phosphorus concentrations are too high, algal growth may become excessive, and possibly result in the production of algal toxins and taste-and-odor compounds. Additionally, excessive algal growth may be detrimental to aquatic life and limit recreational use of a lake. Even small increases in phosphorus can cause increases in algal biomass provided that light limitation is not an issue (Dillon and Rigler, 1974; Jones and Bachmann, 1976; Jones and others, 2008). Primary human-related sources of nutrients include fertilizer application, livestock production, and sewage-treatment plants.

Total organic carbon (TOC), an approximate determination of total organic material in a sediment sample, is important because various organic solutes can form complexes, which in turn affect trace-element solubilities (Hem, 1989). The TOC content of sediment also is important because many contaminants specifically sorb to the organic material in sediment (Karickhoff, 1984; Horowitz, 1991).

Table 2. Sediment-quality guidelines for selected trace elements and associated bioaccumulation index.

[Values in milligrams per kilogram. Shading represents guidelines to which sediment concentrations were compared in this report. EPA, U.S. Environmental Protection Agency; TEL, threshold-effects level; PEL, probable-effects level; TEC, threshold-effect concentration; PEC, probable-effect concentration; --, not available]

Trace element	EPA (1997)		MacDonald and others (2000)		Bioaccumulation index[1]
	TEL	PEL	TEC	PEC	
Arsenic	7.24	41.6	9.79	33.0	moderate
Cadmium	0.676	4.21	0.99	4.98	moderate
Chromium	52.3	160	43.4	111	moderate
Copper	18.7	108	31.6	149	high
Lead	30.2	112	35.8	128	moderate
Mercury	0.13	0.696	0.18	1.06	high
Nickel	15.9	42.8	22.7	48.6	moderate
Silver	0.733	1.77	--	--	moderate
Zinc	124	271	121	459	high

[1] Bioaccumulation index information for trace elements from Pais and Jones (1997).

Trace Elements

Trace elements are important determinants of sediment quality because of their potential toxicity to living organisms (Forstner and Wittmann, 1981; Smol, 2008; Luoma and Rainbow, 2008). Trace elements may be defined as elements that typically are present in the environment in relatively low (less than 0.1 percent) concentrations (Pais and Jones, 1997; Adriano, 2001). Using this definition, most of the elements analyzed in this study may be considered trace elements. Exceptions, which are some of the abundant rock-forming elements, include aluminum and iron (Adriano, 2001).

Trace elements in sediment originate naturally from the rock and soil within a basin. Elevated concentrations of sediment-associated trace elements may be attributable to several human-related sources including fertilizers, liming materials, pesticides, irrigation water, animal and human wastes, coal combustion residues, leaching from landfills, mining, metal-smelting industries, and automobile emissions (Forstner and Wittmann, 1981; Davies, 1983; Adriano, 2001; Luoma and Rainbow, 2008).

The health of living organisms is dependent on a sufficient intake of various trace elements. Many elements, such as cobalt, copper, iron, manganese, and zinc, are essential for plants, animals, and humans. Other elements, such as arsenic and chromium, are required by animals and humans, but are not essential for plants. Nonessential elements for plants, animals, and humans include cadmium, mercury, and lead (Lide, 1993; Pais and Jones, 1997; Adriano, 2001; Marmiroli and Maestri, 2008).

Toxicity is a function of several factors including the type of organism, availability of a trace element in the environment, and its potential to bioaccumulate once in the food chain. The daily intake of trace elements by animals and humans may be classified as deficient, optimal, or toxic. Most, if not all, trace elements may be toxic in animals and humans if the concentrations are sufficiently large (Pais and Jones, 1997; Smol, 2008; Luoma and Rainbow, 2008). Information on the bioaccumulation index (Pais and Jones, 1997) for trace elements with available SQGs is provided in table 2. The bioaccumulation index indicates the relative potential of a trace element to bioaccumulate in organisms.

Diatoms

Diatoms occur in almost all aquatic environments. Generally, in eutrophic water, the diatom community will be dominated by a few abundant species tolerant of nutrient and organic enrichment. In contrast, diatom communities in uncontaminated water (free of sewage or other organic enrichment caused by waste discharge) consist of a greater number of more equally abundant species (U.S. Environmental Protection Agency, 1977; John Smol, Queen's University, Kingston, Ontario, Canada, written commun., 2007). Diatoms respond quickly to the onset of, and recovery from, eutrophication (Hall and Smol, 2010).

Cyanobacteria

Cyanobacteria are common in freshwater ecosystems (Chorus and Bartram, 1999; Wetzel, 2001) and often are associated with eutrophic conditions (Smol, 2008). Abundant growth of cyanobacteria is a concern because it can limit recreational use of a lake, cause taste-and-odor problems for water suppliers, and produce toxins (for example, microcystins) which are a concern for human health (Chorus and Bartram, 1999).

Occurrence and Trends of Selected Chemical Constituents, Diatoms, and Cyanobacteria in Bottom Sediment

This section describes the occurrence and trends of selected chemical and biological constituents in bottom-sediment samples collected from Lake Maxinkuckee. Sediment quality was assessed with reference to available SQGs for selected trace elements (table 2).

Nutrients and Total Organic Carbon

Total nitrogen (TN) concentrations in the recent sediment of Lake Maxinkuckee ranged from 474 to 2,660 mg/kg (tables 1–5, 1–7, 1–9, and 1–11 to 1–13 in the appendix). At coring sites LM–1 and LM–2, pronounced and possible increasing trends in TN concentrations were indicated, respectively. However, at coring sites LM–3, LM–4, and LM–5, an initial increasing trend was followed by a decreasing trend (fig. 3). TN concentrations in the predevelopment sediment (sampled at coring sites LM–1, LM–2, LM–3, and LM–6) exhibited substantial variability within and among sites with an overall range of 615 to 6,190 mg/kg (tables 1–6, 1–8, 1–10, and 1–13 in the appendix).

Total phosphorus (TP) concentrations in the recent sediment of Lake Maxinkuckee ranged from 384 to 735 mg/kg (tables 1–5, 1–7, 1–9, and 1–11 to 1–13). A possible increasing trend in TP concentrations within the past about 6 to 12 years was indicated at coring sites LM–1, LM–2, LM–3, and LM–4 (fig. 4). No pronounced trend was evident at coring site LM–5. However, the largest TP concentration at site LM–5 was measured in the top (most recently deposited) interval of the core (fig. 4). For the predevelopment sediment, TP concentrations ranged from 462 to 1,090 mg/kg (tables 1–6, 1–8, 1–10, and 1–13).

Possible explanations for a recent increasing trend in TP in the bottom sediment of Lake Maxinkuckee include: (1) an increase in the amount of phosphorus available in the basin, (2) an increase in the delivery of phosphorus to the lake, and (3) postdepositional upward diffusion in the sediment (internal loading). Sources of phosphorus to lakes include background contributions from soil and bedrock, atmospheric contributions (wet and dry), fertilizer application (agricultural and urban), livestock production, septic systems, and effluent from wastewater treatment facilities (Wetzel, 2001). In the vicinity of Lake Maxinkuckee, the town of Culver's wastewater treatment facilities are located downstream from the lake.

Available information indicated that a substantial increase in the amount of available phosphorus within the past 10 to 15 years, related to human activity in the basin, was unlikely. Since 1990, the population of Culver generally has been slowly declining (U.S. Census Bureau, 2014). From 1996 to 2012, in Marshall County, corn production fluctuated year to year with no pronounced trend, whereas there was an overall decline in soybean production (fig. 5; U.S. Department of Agriculture, 2014). Corn and soybeans are the two principal crops grown in Marshall County, which is not a primary livestock producing area (Robert Yoder, Marshall County Extension Service, oral commun., 2014).

An increase in precipitation over time could, in part, result in an increase in the delivery of phosphorus to Lake Maxinkuckee through direct atmospheric input and the mobilization and transport of phosphorus from the basin by runoff. To investigate this possibility, daily precipitation data (National Climatic Data Center, 2014) were obtained for Rochester and Winamac, Indiana (fig. 1), for 1960–2013. These two towns were the closest towns to Lake Maxinkuckee for which the desired multidecadal precipitation data were available. Respectively, Rochester and Winamac are located about 14 mi southeast and 15 mi southwest of the lake (fig. 1). The precipitation at these two locations was compared before (1960–86) and after (1993–2013) constructed wetlands were completed (1987–92) on the three primary tributaries to the lake (Curtiss, Kline, and Wilson Ditches; fig. 1).

The comparison indicated that precipitation had increased. Respectively, at Rochester and Winamac, mean

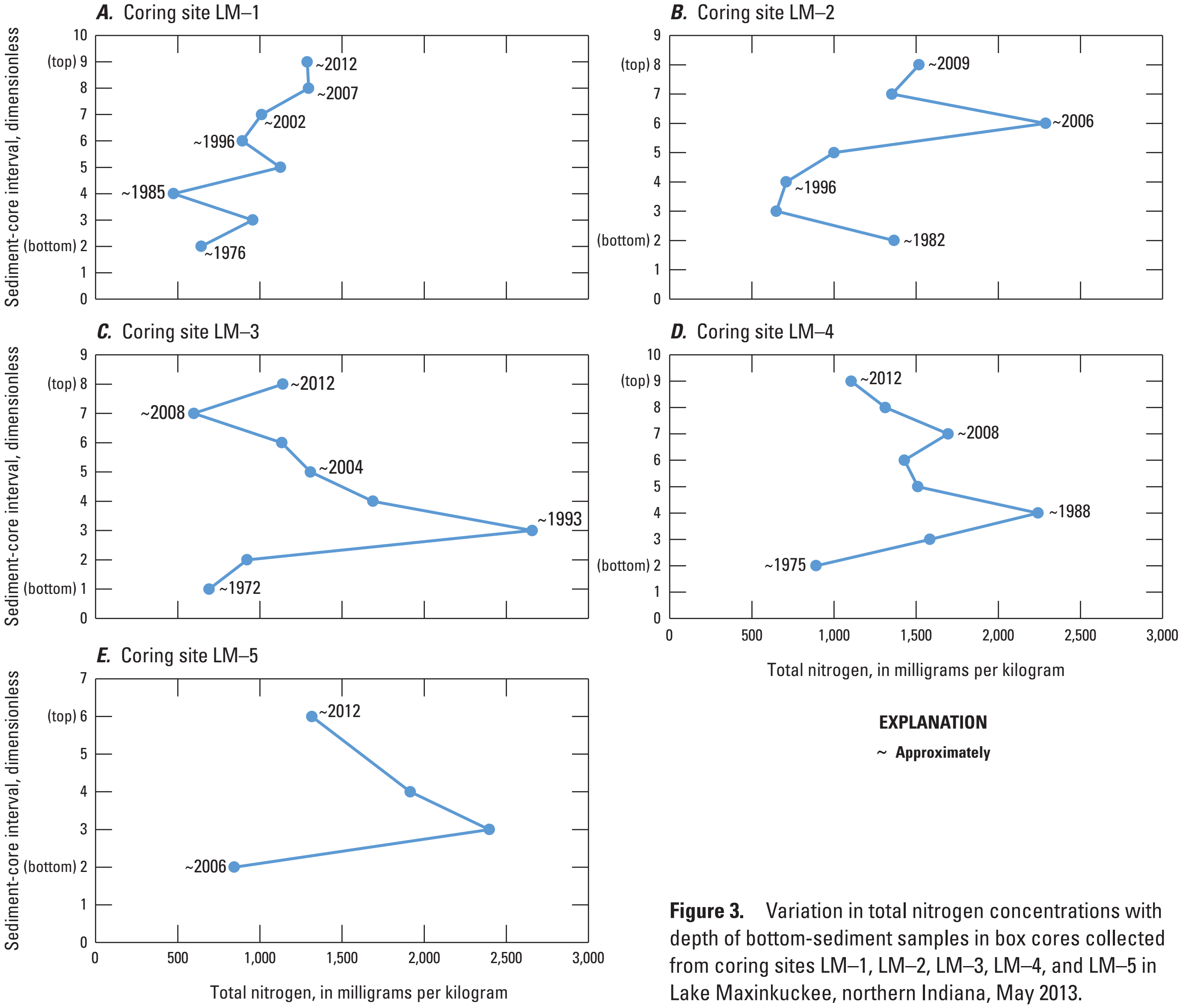


Figure 3. Variation in total nitrogen concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

annual precipitation was 12 and 7 percent greater during the postwetland period (1993–2013) compared to the prewetland period (1960–86). Moreover, the mean annual frequency of large rainfall events (equal to or greater than 1 in.) also increased. At Rochester, the frequency increased from 7.1 to 9.6 events per year (35 percent increase). At Winamac, the frequency increased from 7.2 to 8.9 events per year (24 percent increase). Groisman and others (2001) determined that annual precipitation increased for most of the contiguous United States (including northern Indiana) during the twentieth century. An increasing trend in summer precipitation (1917–2008) was determined for multiple sites throughout Indiana by De Martino and others (2013). Therefore, since 1960, an increase in precipitation for the Lake Maxinkuckee Basin was considered likely, and potentially contributed to an increase in phosphorus mobilization and transport. However, more recently, a comparison of mean annual precipitation and the mean annual frequency of large rainfall events for 1988–99 and 2001–2012 indicated minimal change at Rochester and Winamac. Thus, a precipitation-related explanation to account for the post-2000 increase in TP concentrations in the recent sediment was not supported.

In lakebed sediments, TP concentrations may be affected by postdepositional upward diffusion, which typically is evidenced by an increase in concentrations in the uppermost (most recently deposited) few centimeters of the sediment profile (Engstrom and Wright, 1984; Rydin, 2000; Ostrofsky, 2012). Examination of the TP profiles for Lake Maxinkuckee indicated that such a pattern existed in the recent sediment for coring sites LM–1 through LM–4 and possibly also for coring site LM–5 (fig. 4). In each case, increased TP concentrations were measured in the uppermost few centimeters of the sediment profile. In the lower (older) part of each profile, TP concentrations generally were uniform. An exception to this

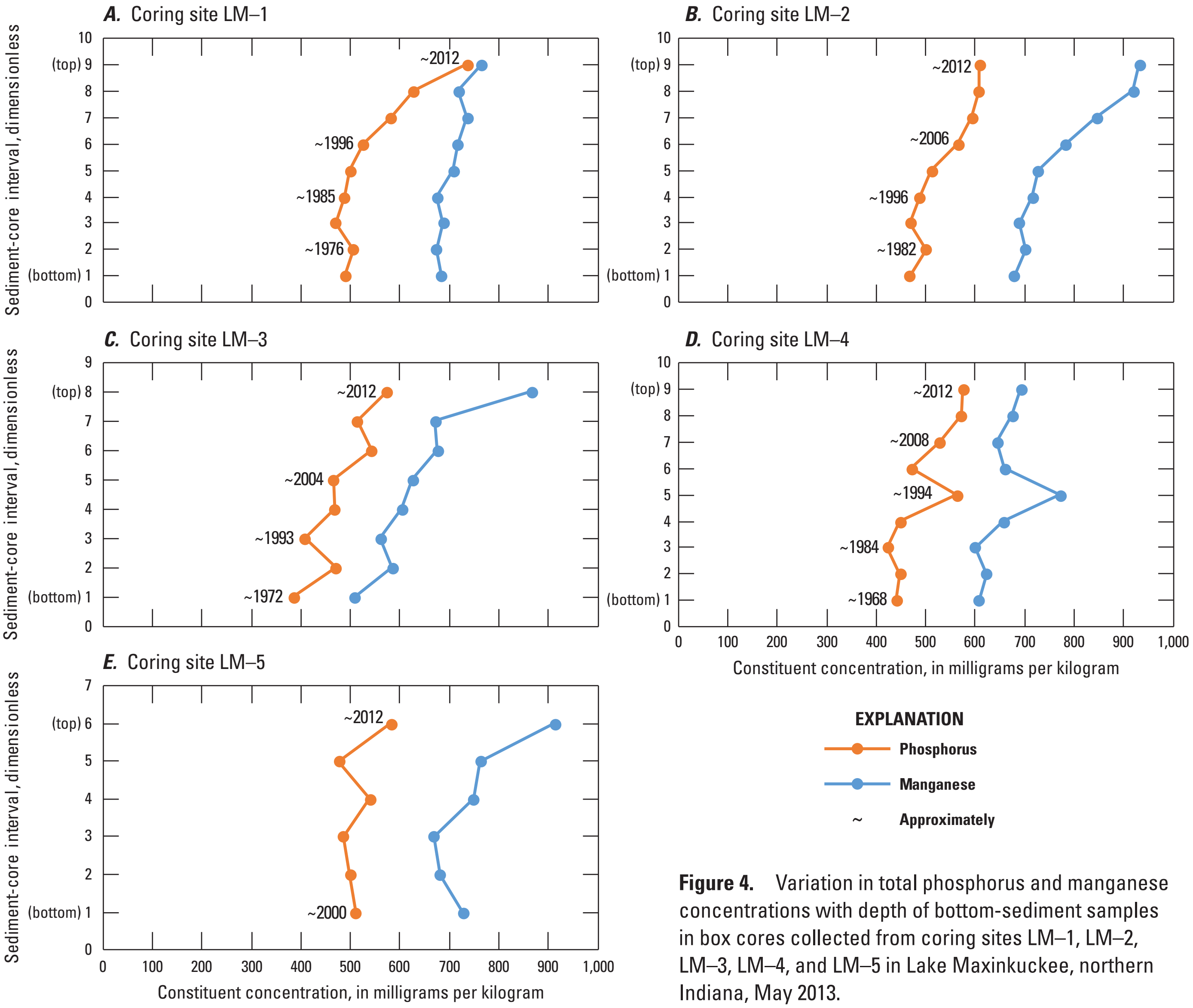


Figure 4. Variation in total phosphorus and manganese concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

pattern was a spike in TP concentration measured for interval 5 of core LM–4. Additional evidence in support of upward diffusion as the explanation was provided by the manganese profiles, which paralleled the TP profiles (fig. 4). Manganese, like phosphorus, may be affected by upward diffusion in lakebed sediments (Engstrom and Wright, 1984; Beutel and others, 2008; White and others, 2008).

In sum, the available evidence indicated that postdepositional upward diffusion was the most likely explanation for the increase in TP concentrations in the uppermost few centimeters of cores LM–1 to LM–4. In the lower (older) section of the recent sediment, TP concentrations generally were uniform. Using the dating results for cores LM–1 to LM–4, it was determined that TP concentrations in the recent sediment generally were uniform from about 1970 to about 2000 and indicated consistent inputs to the lake during that time.

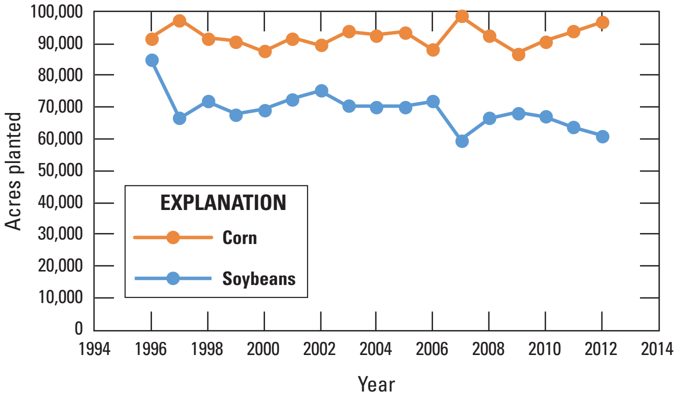


Figure 5. Corn and soybean acres planted in Marshall County, Indiana, 1996–2012.

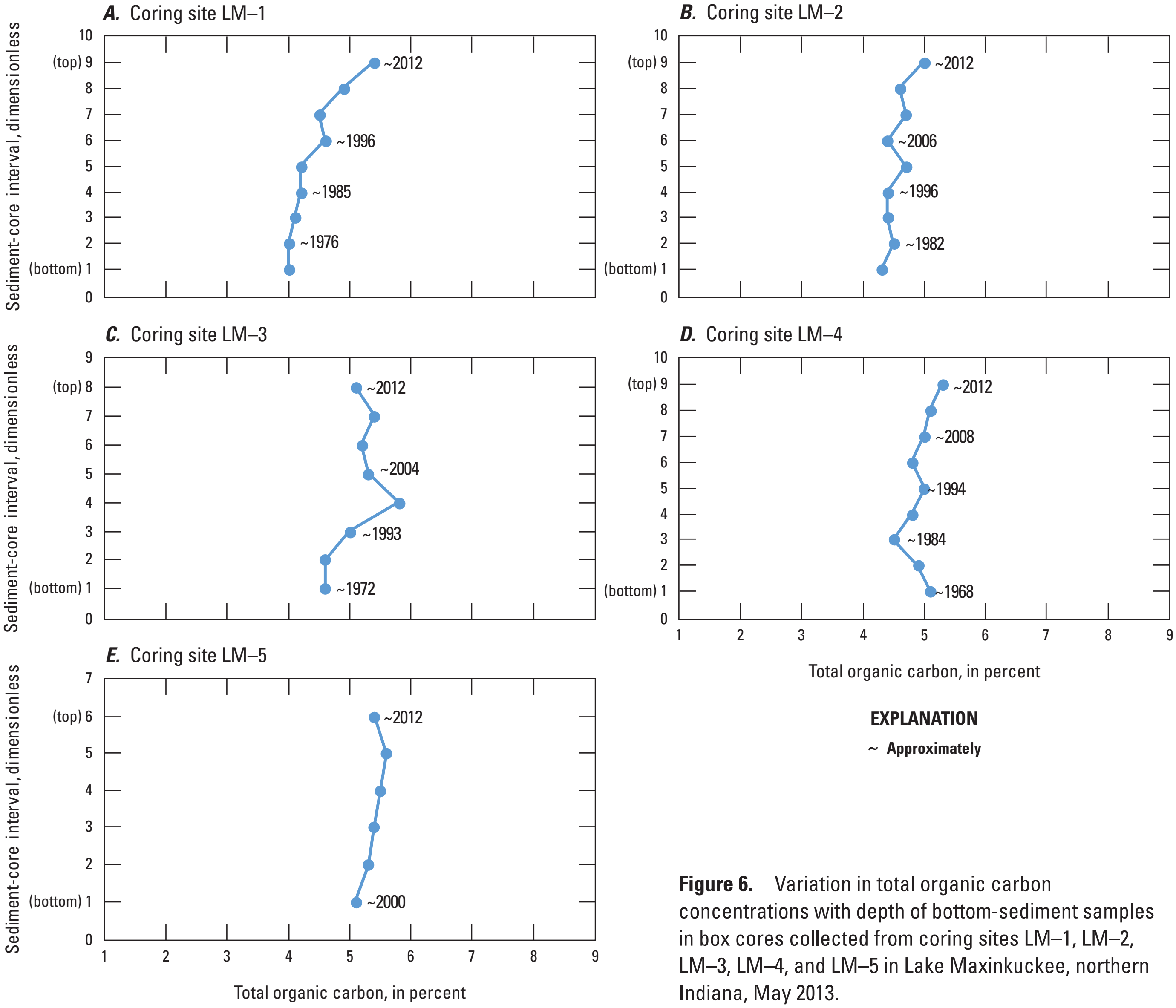


Figure 6. Variation in total organic carbon concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

Subsequently, the history of TP deposition apparently was obscured by upward diffusion.

Total organic carbon, estimated as total carbon minus total inorganic carbon, ranged from 4.0 to 5.9 percent in the recent sediment (tables 1–5, 1–7, 1–9, and 1–11 to 1–13). Overall, a pronounced and consistent trend was not evident for the five coring sites where the recent sediment was sampled (figs. 2 and 6). A possible increasing trend in the upper (most recently deposited) part of core LM–1 was indicated (fig. 6). In the predevelopment sediment, TOC was more variable with a range of 5.4 to 17.9 percent (tables 1–6, 1–8, 1–10, and 1–13).

Trace Elements

In this section, discussion is focused on the trace elements for which SQGs were available (table 2). Complete results for all elements analyzed are provided in tables 1–5 to 1–13 in the appendix. For perspective, national baseline concentrations for selected trace elements in sediment are listed in table 3. The baseline concentrations were compiled using data from more than 400 sites with limited human effects (Horowitz and Stephens, 2008).

Arsenic concentrations in the bottom sediment of Lake Maxinkuckee ranged from about 8 to 32 mg/kg (tables 1–5 to 1–13). At coring sites LM–1 and LM–2, the concentration ranges for the recent and predevelopment samples were similar. At coring site LM–3, the concentration range for the predevelopment samples (about 8 to 10 mg/kg) was notably lower than the range for the recent samples (about 17 to 26 mg/kg). A consistent temporal trend in arsenic concentrations was not indicated for the five coring sites (LM–1 to LM–5) where the recent sediment was sampled (fig. 7). With two exceptions, the arsenic concentrations in the recent and predevelopment sediment exceeded the TEG (9.79 mg/kg), but were less than the PEG (41.6 mg/kg). The two exceptions were predevelopment samples collected at site LM–3, which were less than the TEG. Given that the arsenic concentrations in most of the predevelopment samples were similar to the recent samples, the source of arsenic likely was natural.

Table 3. National baseline concentrations for selected trace elements in sediment.

[Source: Horowitz and Stephens, 2008. mg/kg, milligrams per kilogram]

Trace element	Minimum (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	Median (mg/kg)
Arsenic	0.1	60	8.1	6.6
Cadmium	0.1	2.8	0.5	0.4
Chromium	6.3	270	66	58
Copper	1	150	24	20
Lead	2	200	24	20
Mercury	0.01	3.1	0.08	0.04
Nickel	1	160	28	23
Selenium	0.1	5.6	0.8	0.7
Silver	0.1	4.3	0.3	0.2
Zinc	5.2	430	100	91

Cadmium concentrations ranged between 0.1 and 1.1 mg/kg (tables 1–5 to 1–13). In general, concentrations in the predevelopment samples were lower than the recent samples. With the exception of coring site LM–5, a pronounced or possible decreasing trend in cadmium concentrations was indicated for the recent sediment (fig. 8). The absence of a trend for coring site LM–5 likely was related to the fact that the box core only penetrated back to about the year 2000. Typically, cadmium concentrations in the recent and predevelopment samples were less than the TEG (0.99 mg/kg).

The range in chromium concentrations was about 10 to 24 mg/kg (tables 1–5 to 1–13). In general, concentrations in the predevelopment samples were similar to the recent samples. With the exception of coring site LM–5, a pronounced or possible decreasing trend in chromium concentrations was indicated for the recent sediment (fig. 9). All chromium concentrations in the recent and predevelopment samples were less than the TEG (52.3 mg/kg).

Copper concentrations ranged from 9 to about 21 mg/kg (tables 1–5 to 1–13). Typically, concentrations in the predevelopment samples were lower than the recent samples. A consistent temporal trend in copper concentrations was not indicated for the recent sediment (fig. 10). All copper concentrations in the recent and predevelopment samples were less than the TEG (31.6 mg/kg).

Lead concentrations in the recent samples ranged from 23 to 69 mg/kg. In comparison, the predevelopment samples had lead concentrations that consistently were less than 10 mg/kg (tables 1–5 to 1–13). For all five coring sites where the recent sediment was sampled, a pronounced or possible decreasing trend in lead concentrations was indicated (fig. 11). The decreasing trend likely represents the environmental response to the history of leaded gasoline use in the United States. Leaded gasoline was first introduced in the 1920s and quickly became standard (Davies, 1990). The use of leaded gasoline increased and, during the period of maximum use (that is, the 1940s through the early 1980s), vehicle emissions were the dominant source of lead to the environment (Juracek and Ziegler, 2006). With the phase out of leaded gasoline legislated by the Clean Air Act of 1970, vehicle emissions declined (U.S. Environmental Protection Agency, 2000). At Lake Maxinkuckee, lead concentrations in the recently-deposited sediment have declined but remain higher than the predevelopment (that is, before leaded gasoline) concentrations. Juracek and Ziegler (2006) estimated that, assuming no new sources of lead, the time required for lead concentrations in newly-deposited bottom sediment to return to pre-1920s concentrations may be at least several decades.

With respect to lead, the quality of the recent sediment in Lake Maxinkuckee has improved with time as lead concentrations have decreased. At coring sites LM–1, LM–2, and LM–4, the oldest (deepest) samples had lead concentrations that were higher than the TEG (35.8 mg/kg), whereas the youngest samples had concentrations that were less than the TEG. At coring site LM–3, lead concentrations for all recent samples were higher than the TEG. At coring site LM–5, concentrations for all samples were less than the TEG. For all recent and predevelopment samples, lead concentrations were less than the PEG (128 mg/kg; fig. 11; tables 1–5 to 1–13).

The range in mercury concentrations was 0.02 to 0.12 mg/kg (tables 1–5 to 1–13). The predevelopment samples had concentrations that were lower than the recent samples. In the recent sediment, mercury concentrations exhibited either a decreasing trend or no trend with time (fig. 12). All mercury concentrations in the recent and predevelopment samples were less than the TEG (0.18 mg/kg).

Nickel concentrations ranged from less than 1 to about 15 mg/kg (tables 1–5 to 1–13). Compared to the recent samples, the predevelopment samples had concentrations that were similar and occasionally higher. For the recent sediment,

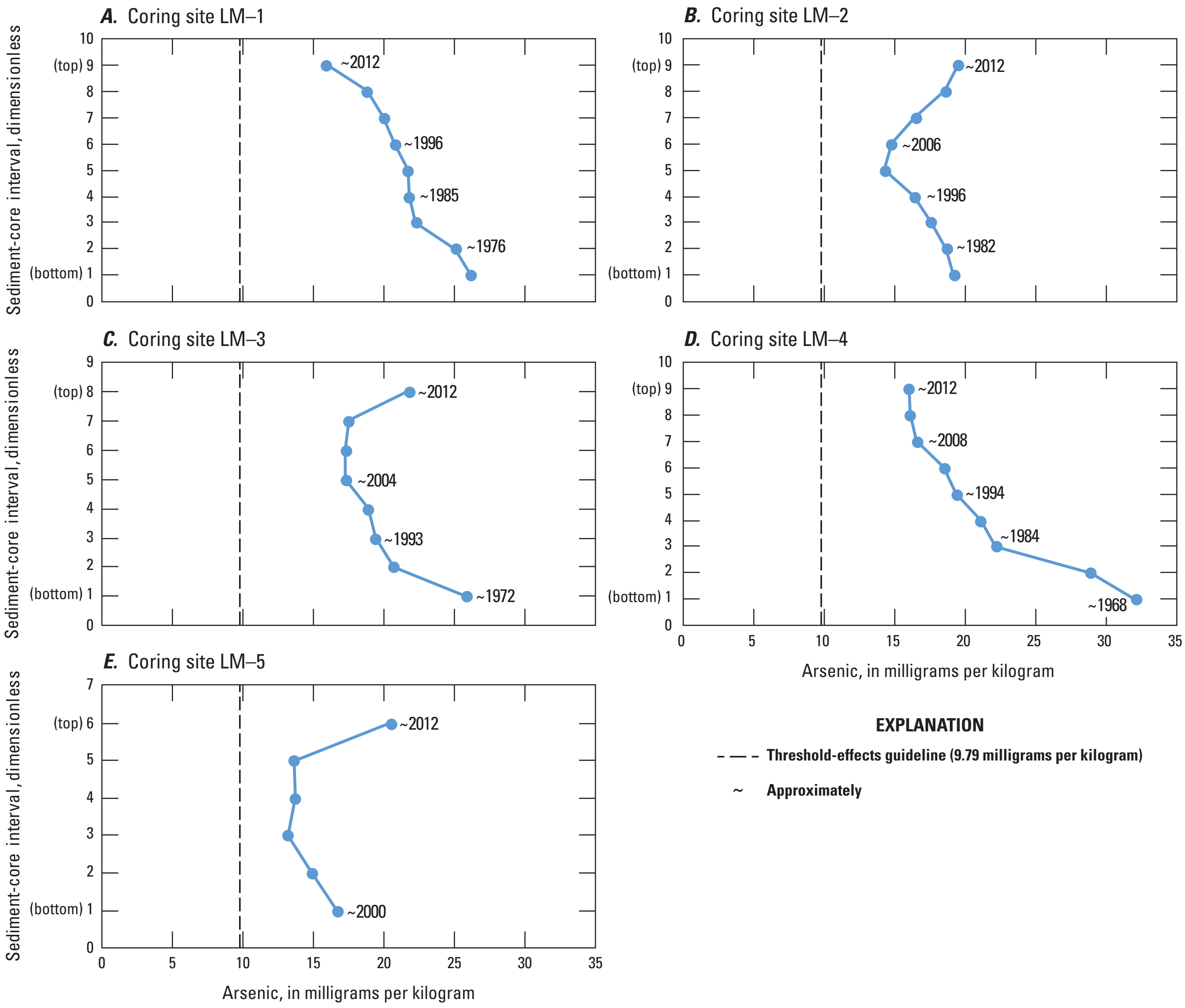


Figure 7. Variation in arsenic concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

a pronounced or possible decreasing trend in nickel concentrations was indicated for coring sites LM–2, LM–3, and LM–4. However, a well-defined trend was not indicated for coring sites LM–1 and LM–5 (fig. 13). All nickel concentrations in the recent and predevelopment samples were less than the TEG (22.7 mg/kg).

Sediment-quality guidelines were not available for selenium. However, Lemly (2002) proposed that a value of 2.0 mg/kg be used as a toxic threshold for selenium concentrations in sediment. In Lake Maxinkuckee, selenium concentrations ranged from about 0.6 to about 3.0 mg/kg and typically were less than 2.0 mg/kg (tables 1–5 to 1–13). In the recent sediment, selenium concentrations exhibited either a possible decreasing trend or no trend with time (fig. 14). The predevelopment samples had concentrations that ranged from lower than to higher than the recent samples.

Concentrations of silver in the recent and predevelopment sediment were less than 0.3 mg/kg (tables 1–5 to 1–13). With the exception of a decreasing trend in the deepest (oldest) one-half of the core collected at coring site LM–4, no trend was indicated for silver concentrations in the recent sediment (fig. 15). All silver concentrations in the

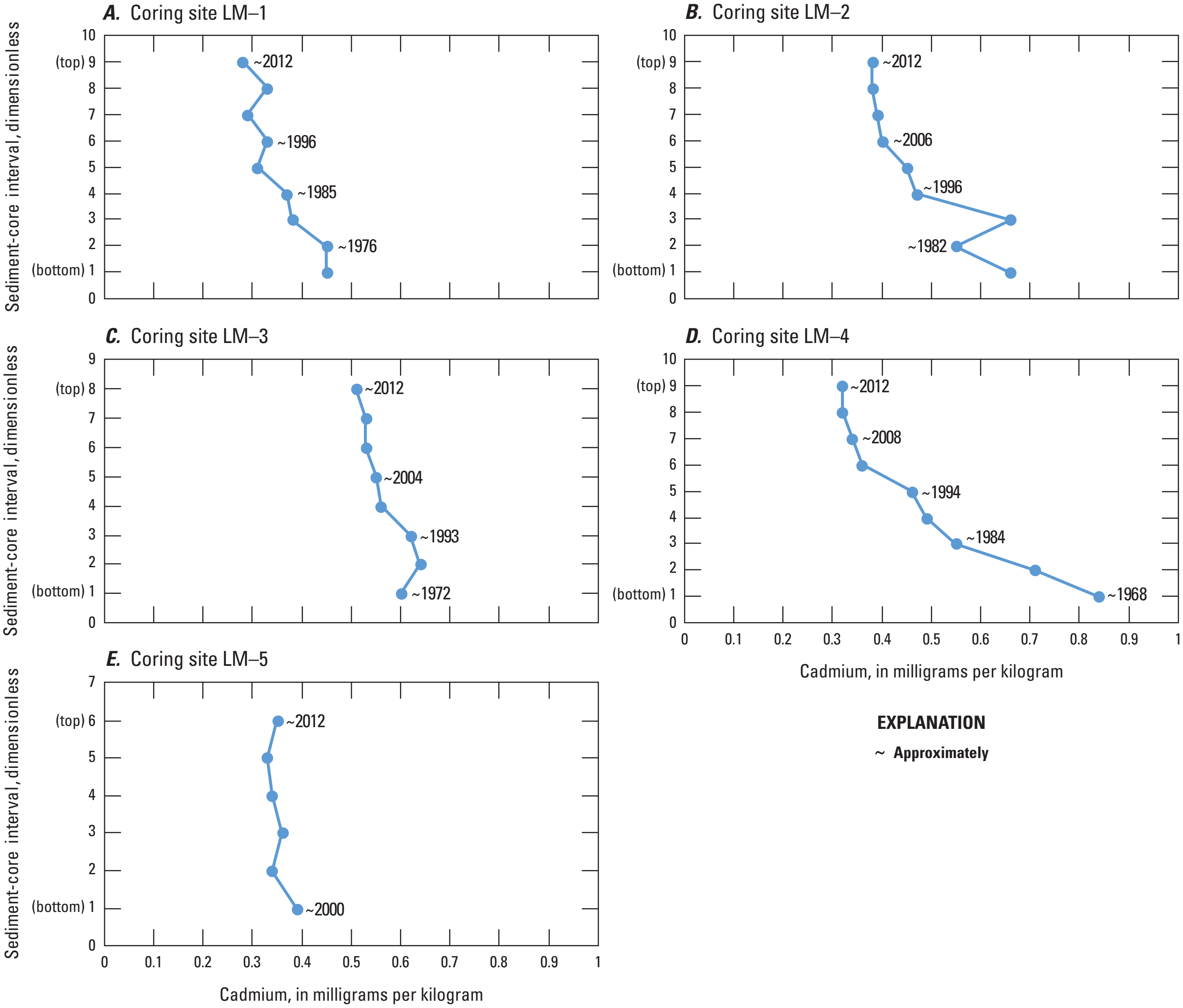


Figure 8. Variation in cadmium concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

recent and predevelopment samples were less than the TEG (0.733 mg/kg).

Zinc concentrations ranged from about 27 to 151 mg/kg (tables 1–5 to 1–13). Typically, the predevelopment samples had concentrations that were lower than the recent samples. For the recent sediment, a pronounced trend in zinc concentrations was not evident at coring sites LM–1, LM–3, and LM–5. However, at coring site LM–4, a pronounced decreasing trend was indicated. At coring site LM–2, zinc concentrations initially decreased then stabilized (fig. 16). With two exceptions, zinc concentrations in the recent and predevelopment samples were less than the TEG (124 mg/kg). The exceptions were individual samples from coring sites LM–3 and LM–6, which exceeded the TEG but were well below the PEG (459 mg/kg; tables 1–5 to 1–13).

Elevated trace element concentrations in recent, compared to predevelopment, sediment deposited in lakes may be indicative of human-related environmental contamination (Forstner and Wittmann, 1981; Baudo and others, 1990; Smol, 2008). In addition to lead, elevated concentrations of cadmium, copper, mercury, and zinc were measured in the recent sediment deposited in Lake Maxinkuckee. Each of these trace elements may originate from human activity. For example, human-related sources of zinc include industrial activity (such as metal production), coal combustion, waste incineration, and vehicular tire wear (Luoma and Rainbow, 2008).

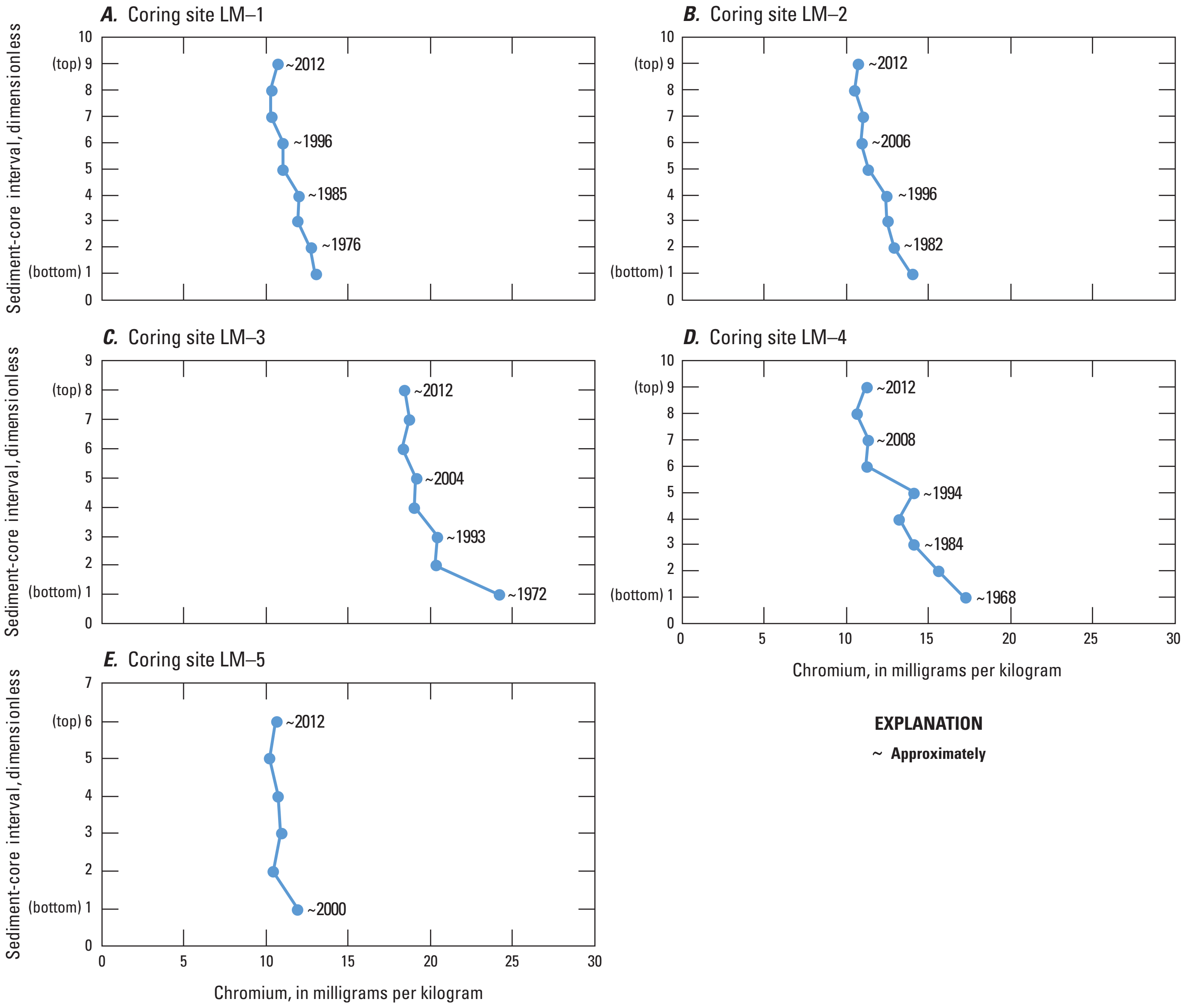


Figure 9. Variation in chromium concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

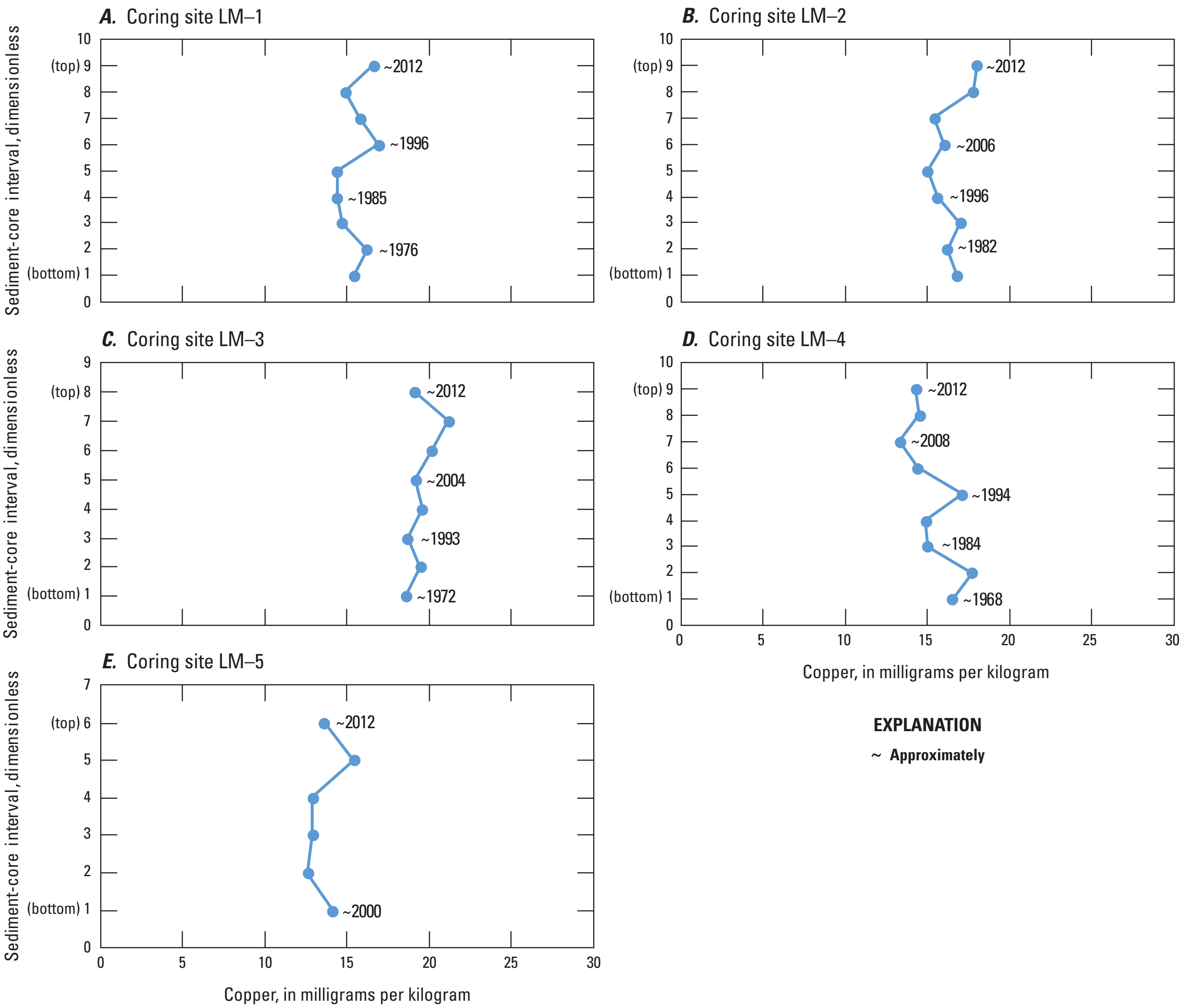


Figure 10. Variation in copper concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

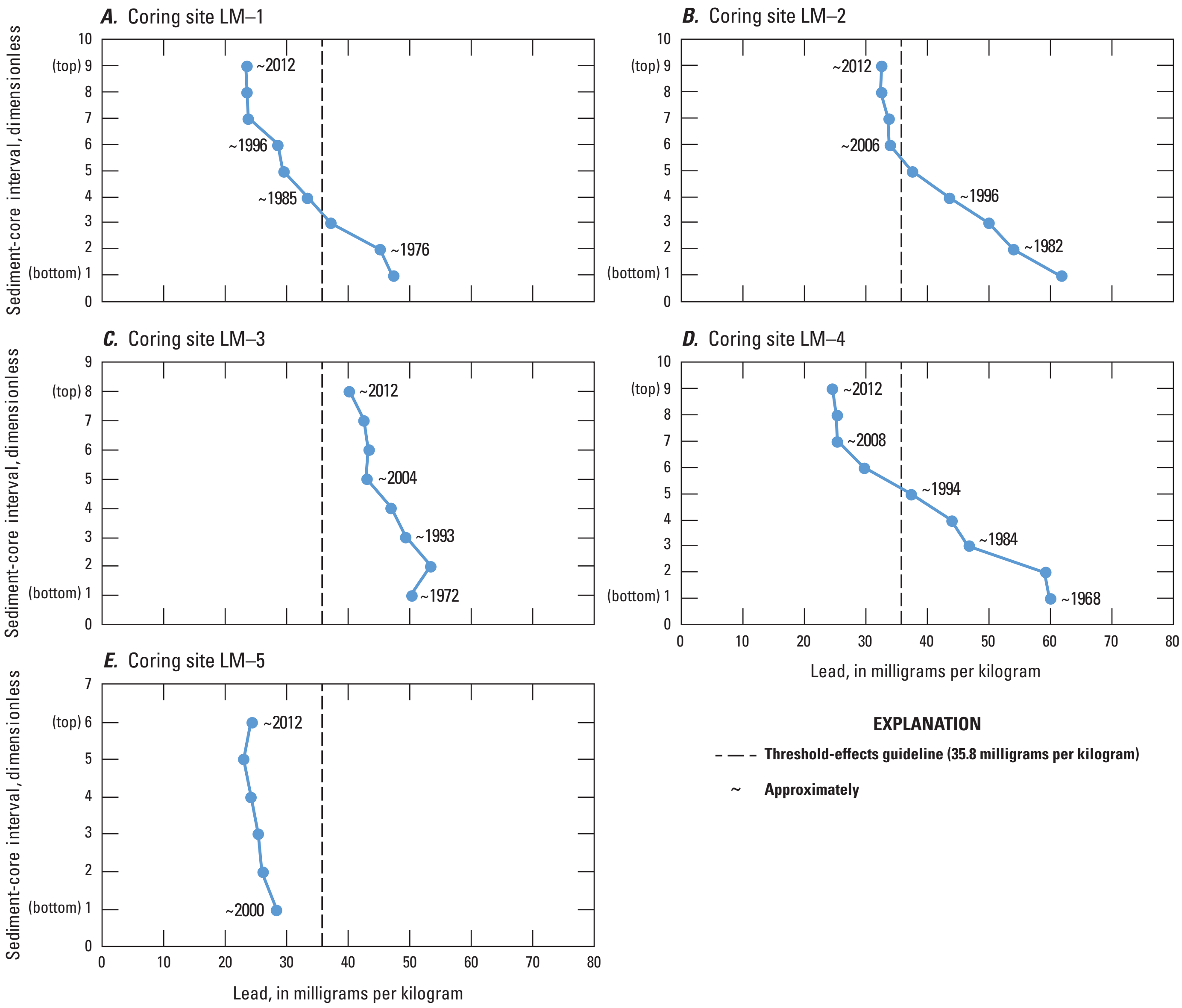


Figure 11. Variation in lead concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

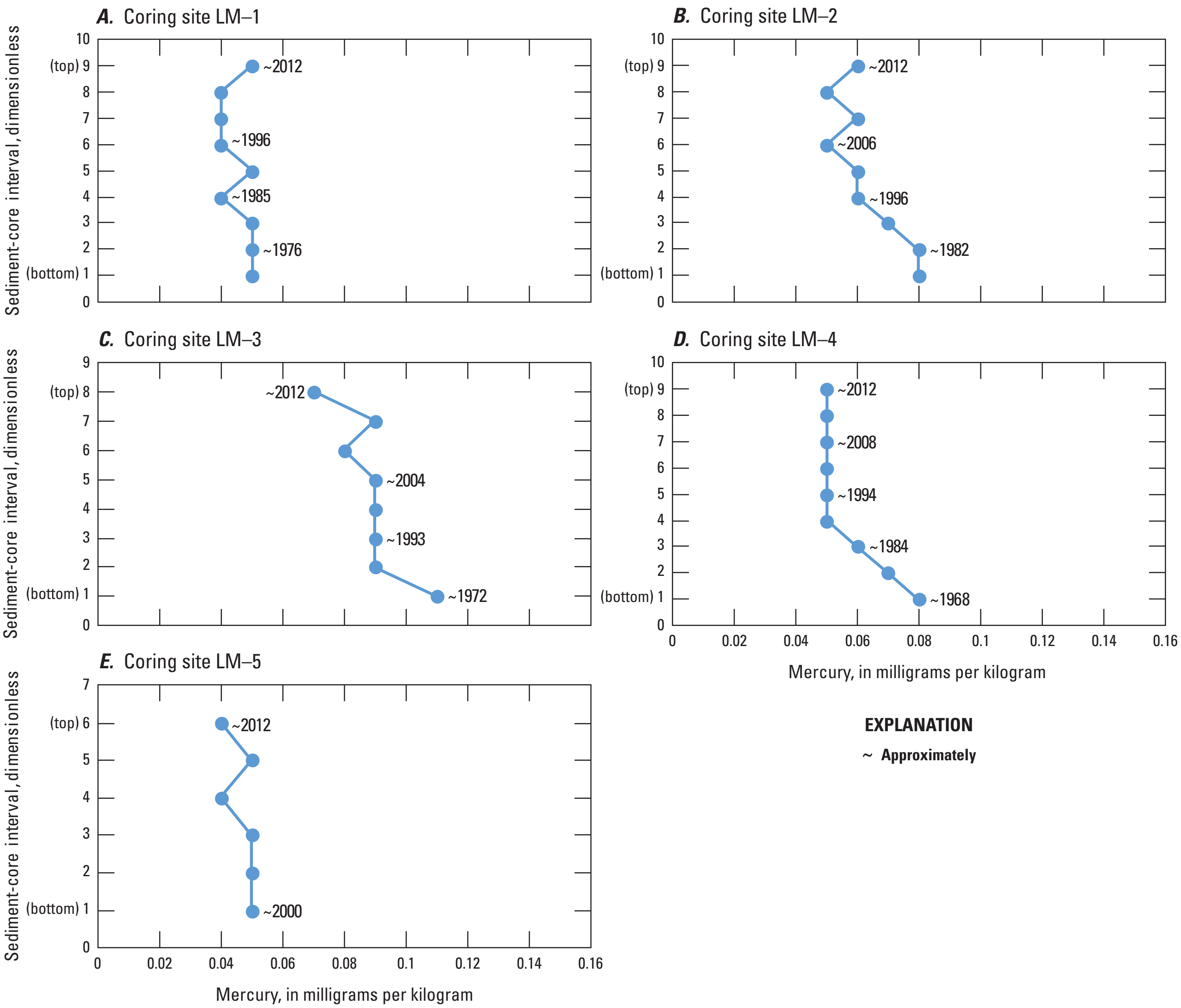


Figure 12. Variation in mercury concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

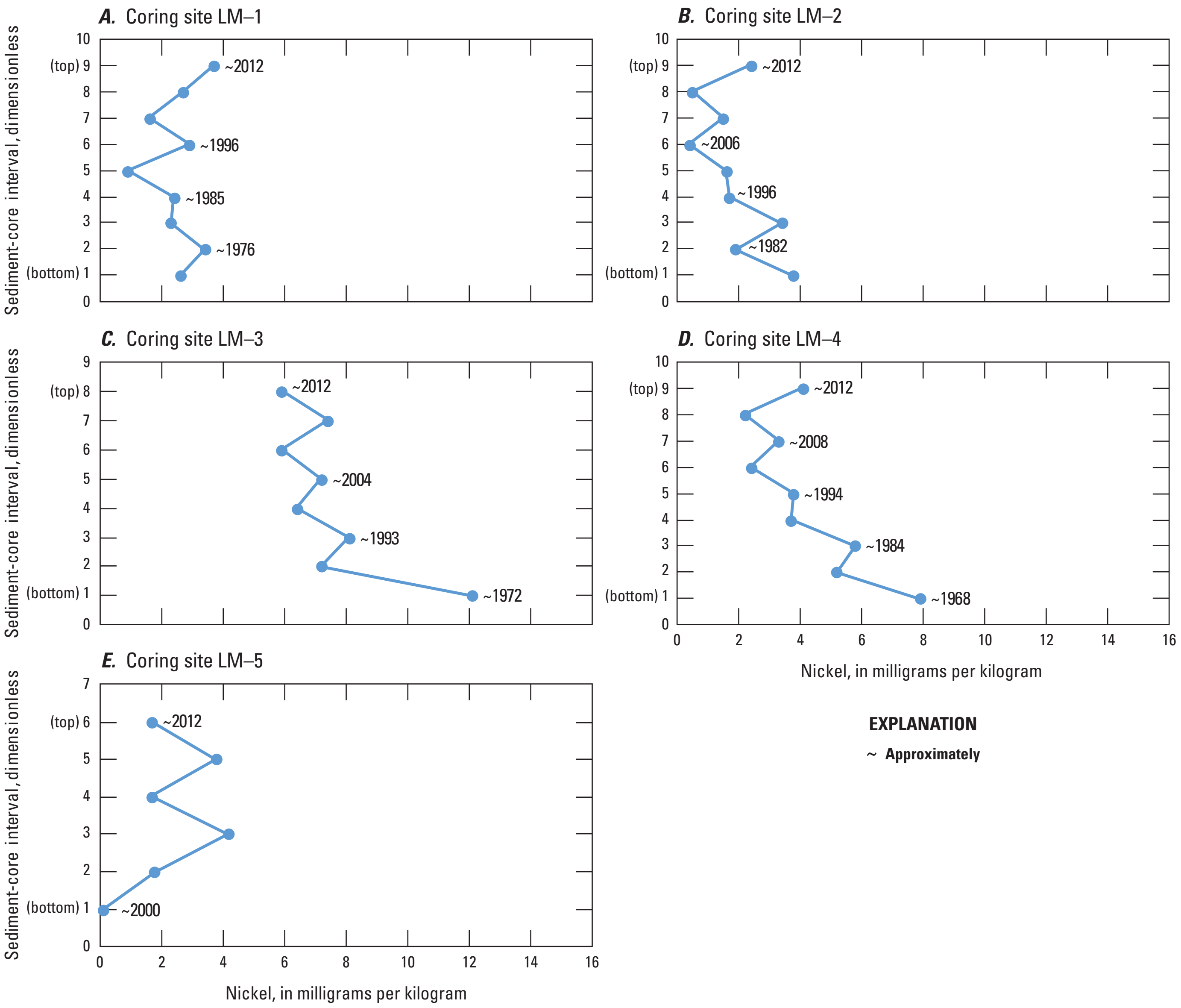


Figure 13. Variation in nickel concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

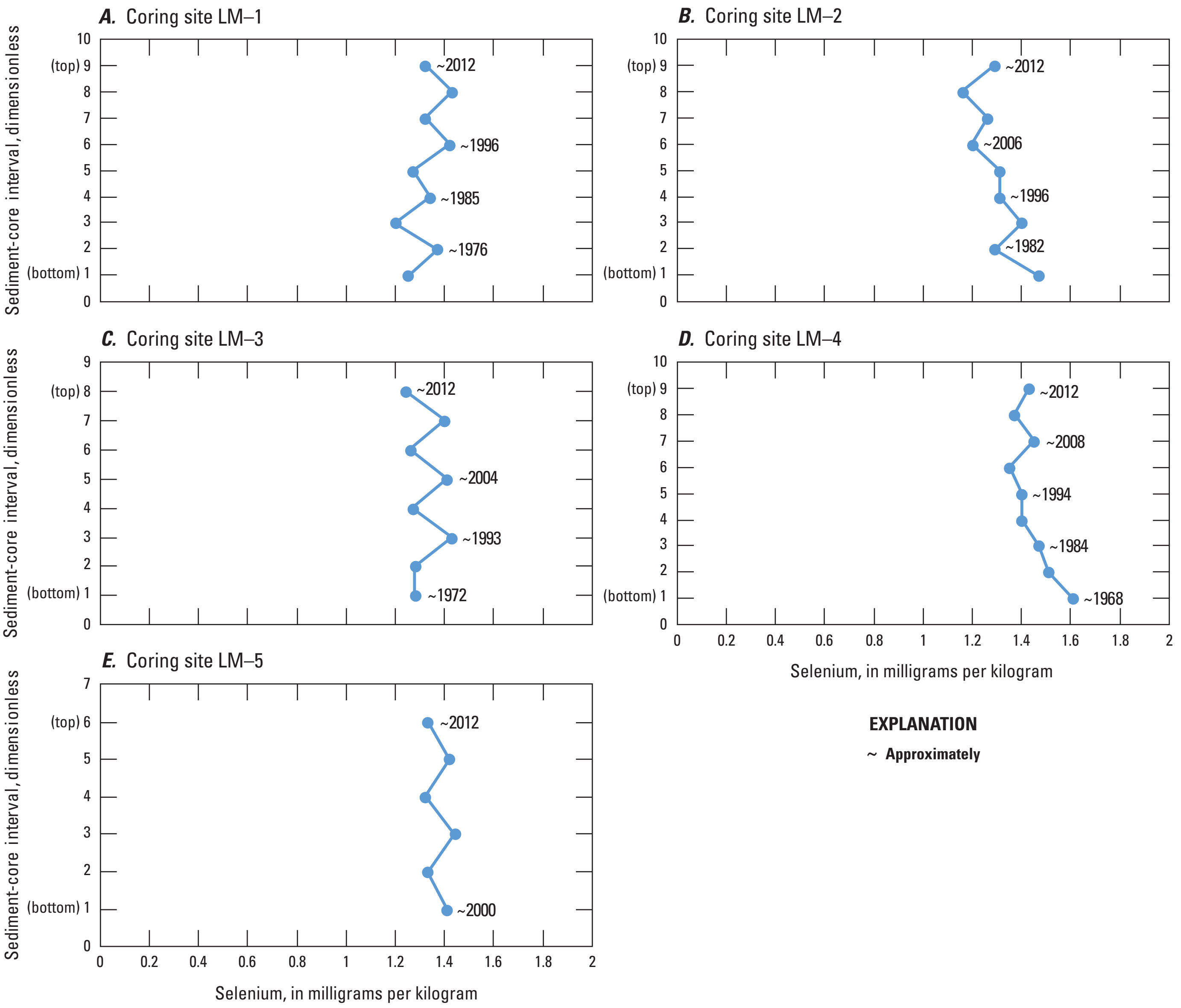


Figure 14. Variation in selenium concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

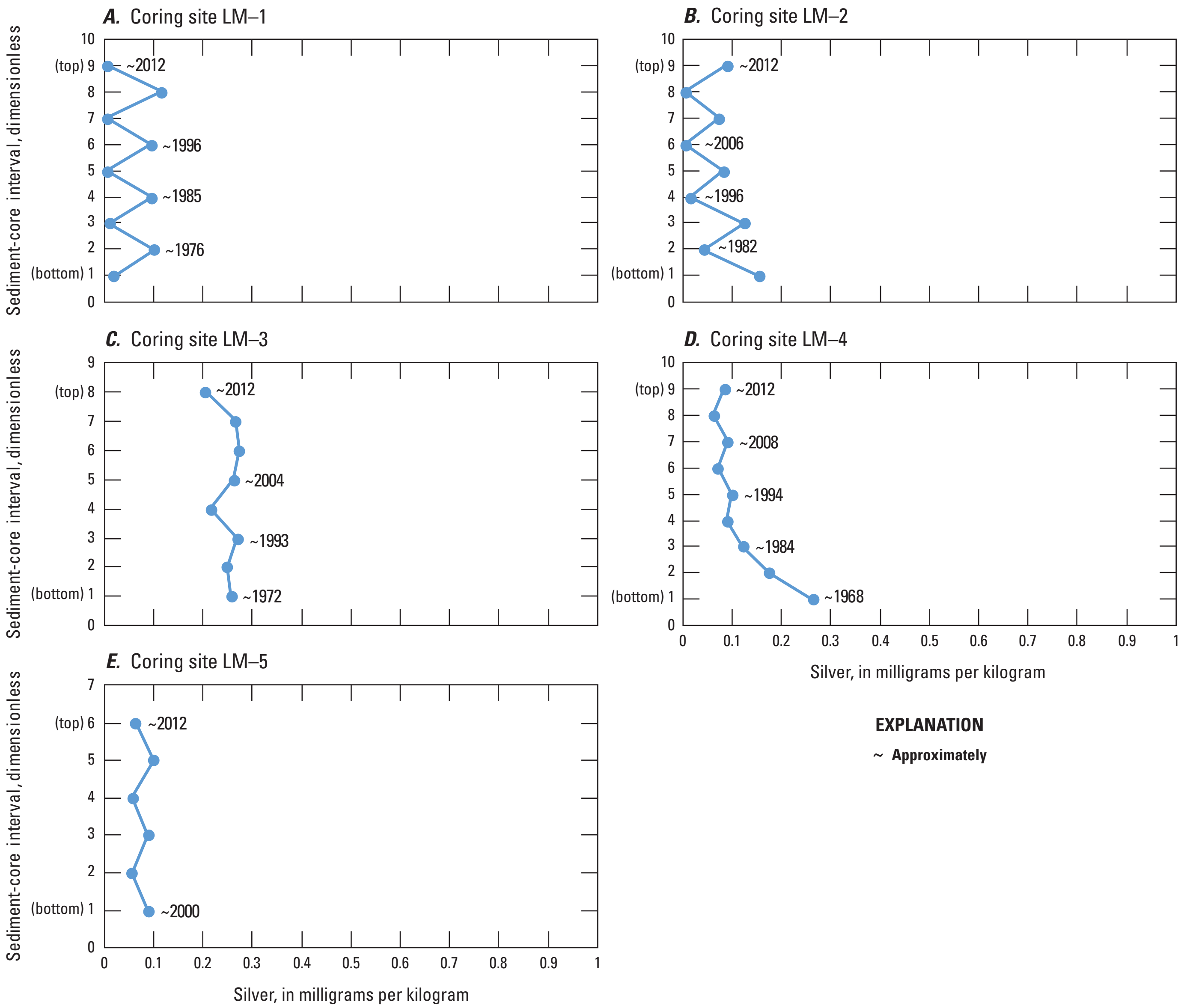


Figure 15. Variation in silver concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

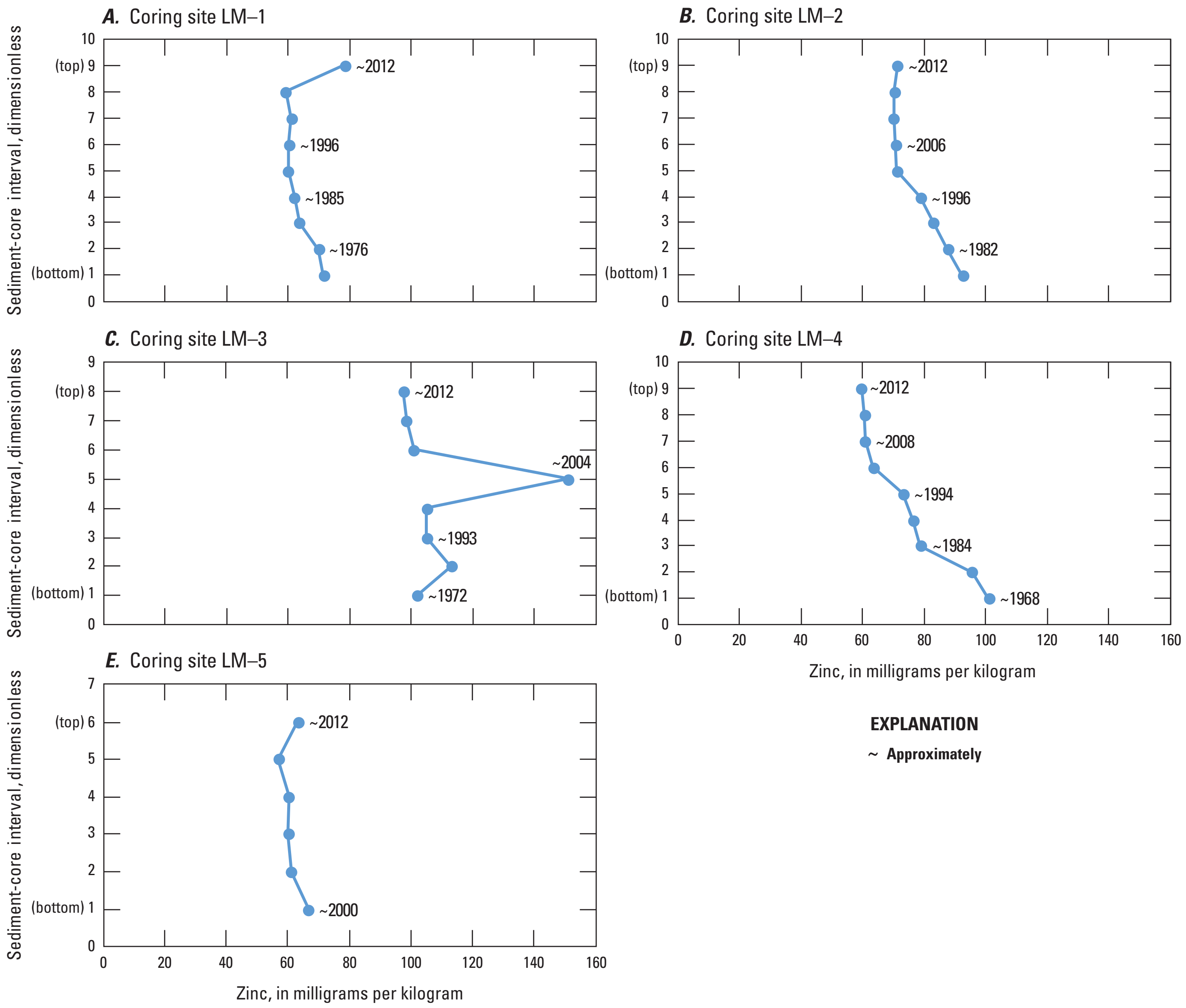


Figure 16. Variation in zinc concentrations with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

Diatoms

A total of 188 different diatom species were identified in the bottom-sediment samples collected from Lake Maxinkuckee. Most of the species occurred rarely with a relative abundance of less than 1 percent. There were 13 species that had a relative abundance greater than 1 percent and together accounted for about 83 percent of the total abundance (table 4). The occurrence of multiple species, none of which were overwhelmingly dominant, was indicative of a minimally contaminated lake ecosystem (John Smol, Queen's University, Kingston, Ontario, Canada, written commun., 2007). The 13 relatively abundant species are the focus of the following discussion. Complete information on the occurrence of the 13 species in each sediment sample is provided in tables 1–14 to 1–22 in the appendix. A complete list of the rare diatom species identified is provided in table 1–23 in the appendix.

For *Achnanthidium minutissimum* (formerly *Achnanthes minutissima*), an overall increasing trend in abundance in the recent sediment was indicated (fig. 17). However, this species is not considered a good indicator of eutrophic or oligotrophic conditions because it is cosmopolitan (van Dam and others, 1994; Rasanen and others, 2006b; Bigler and others, 2007; Bennion and others, 2011). In other words, it is known to tolerate a wide range of environmental conditions including nutrient concentrations. In the predevelopment sediment, *Achnanthidium minutissimum* was less abundant or absent (tables 1–15, 1–17, 1–19, and 1–22).

Table 4. Relative abundance of the most frequently encountered diatom species in bottom-sediment samples collected from Lake Maxinkuckee, northern Indiana, May 2013.

Diatom species	Relative abundance (percent)
Achnanthidium minutissimum	7.8
Amphora ovalis	3.1
Asterionella formosa	5.5
Aulacoseira ambigua	7.9
Cyclotella bodanica	8.7
Cyclotella ocellata	11.2
Cyclotella pseudostelligera	1.7
Fragilaria crotonensis	7.1
Pseudostaurosira brevistriata	12.9
Staurosira construens	3.0
Staurosira construens var. *venter*	8.9
Staurosirella pinnata	3.5
Synedra demerarae	1.3
All other species	17.4

Amphora ovalis is an indicator of eutrophic conditions (van Dam and others, 1994; Jasprica and Hafner, 2005; Hadley and others, 2010). In the recent sediment, there was an overall decreasing trend in abundance (fig. 18), which indicated that the lake possibly became less productive in recent decades. *Amphora ovalis* typically was less abundant in the predevelopment sediment, if not absent (tables 1–15, 1–17, 1–19, and 1–22). Two explanations may account for the lower abundance of *Amphora ovalis* in the predevelopment sediment. One possibility is that the lake was less productive during predevelopment times. A second possibility is that the abundance was reduced by dissolution of the diatoms in the water column or postdepositional dissolution and breakage of diatoms in the sediment, or both (Fritz and others, 1993).

Asterionella formosa generally is considered an indicator of eutrophic conditions (Bradshaw and others, 2005; Pienitz and others, 2006; Battarbee and others, 2012). However, Yilmaz and Aykulu (2010), citing Rawson (1956) and Patrick and Reimer (1966), noted that it may be abundant in eutrophic, mesotrophic, or oligotrophic waters. In the recent sediment, there was a pronounced increase in the abundance of *Asterionella formosa* in the uppermost section of each core (fig. 19). Given the apparent ability of this species to thrive in a range of conditions, interpretation of the increase was not attempted. The abundance of *Asterionella formosa* in the predevelopment sediment, compared to the recent sediment, typically was either lower or absent (tables 1–15, 1–17, 1–19, and 1–22).

Aulacoseira ambigua may be an indicator of eutrophic (van Dam and others, 1994; Heinsalu and others, 2008) or mesotrophic (Pienitz and others, 2006; Poister and others, 2012) conditions. Rasanen and others (2006b) concluded that, given its tolerance to a wide range of environmental conditions, it may not be a good indicator for any lake type. In the recent sediment, the overall pattern for *Aulacoseira ambigua* was a decrease in abundance followed by relative uniformity (fig. 20). A possible interpretation, that the lake became less productive in recent decades, would be consistent with the evidence provided by *Amphora ovalis*. However, the accuracy of this interpretation is debatable given the uncertainty as to what conditions are indicated by the changing presence of *Aulacoseira ambigua*. In the predevelopment sediment, *Aulacoseira ambigua* ranged from absent to moderately abundant (tables 1–15, 1–17, 1–19, and 1–22).

Cyclotella bodanica is an indicator of oligotrophic conditions (van Dam and others, 1994; Smol, 2008; Genkal and others, 2013). At coring sites LM–1 and LM–4, there was an increase in abundance of *Cyclotella bodanica* that indicated the lake had become more oligotrophic in recent decades. However, no such trend was evident at the other three coring sites (LM–2, LM–3, and LM–5; fig. 21). Thus, overall, the best interpretation of the evidence provided by *Cyclotella bodanica* may be that the lake had not become more productive in recent decades. *Cyclotella bodanica* in the predevelopment sediment, compared to the recent sediment, ranged from less abundant to much more abundant (tables 1–15, 1–17, 1–19, and 1–22).

Cyclotella ocellata was the second-most abundant species in the bottom sediment of Lake Maxinkuckee (table 4). There was a lack of consensus as to what conditions this species represents. It has been labelled as a mesotrophic to eutrophic indicator (van Dam and others, 1994), an oligotrophic indicator (Battarbee and others, 2012), and as a controversial or cosmopolitan species (Cremer and Wagner, 2003; Reed and others, 2010). In the recent sediment, a pronounced multidecadal increase in the abundance of *Cyclotella ocellata* was followed by a decrease in abundance in the most recently deposited sediment. This pattern was consistent at all five coring sites where the recent sediment was sampled (fig. 22). Given the uncertainty as to what conditions are represented, interpretation of the pattern was not attempted. *Cyclotella ocellata* was absent in the predevelopment sediment (tables 1–15, 1–17, 1–19, and 1–22). It is worth noting that Schlegel and Scheffler (1999) proposed that *Cyclotella ocellata* abundance may be affected more by loss factors (for example, sinking and grazing) than growth-related factors (for example, light, temperature, and nutrients).

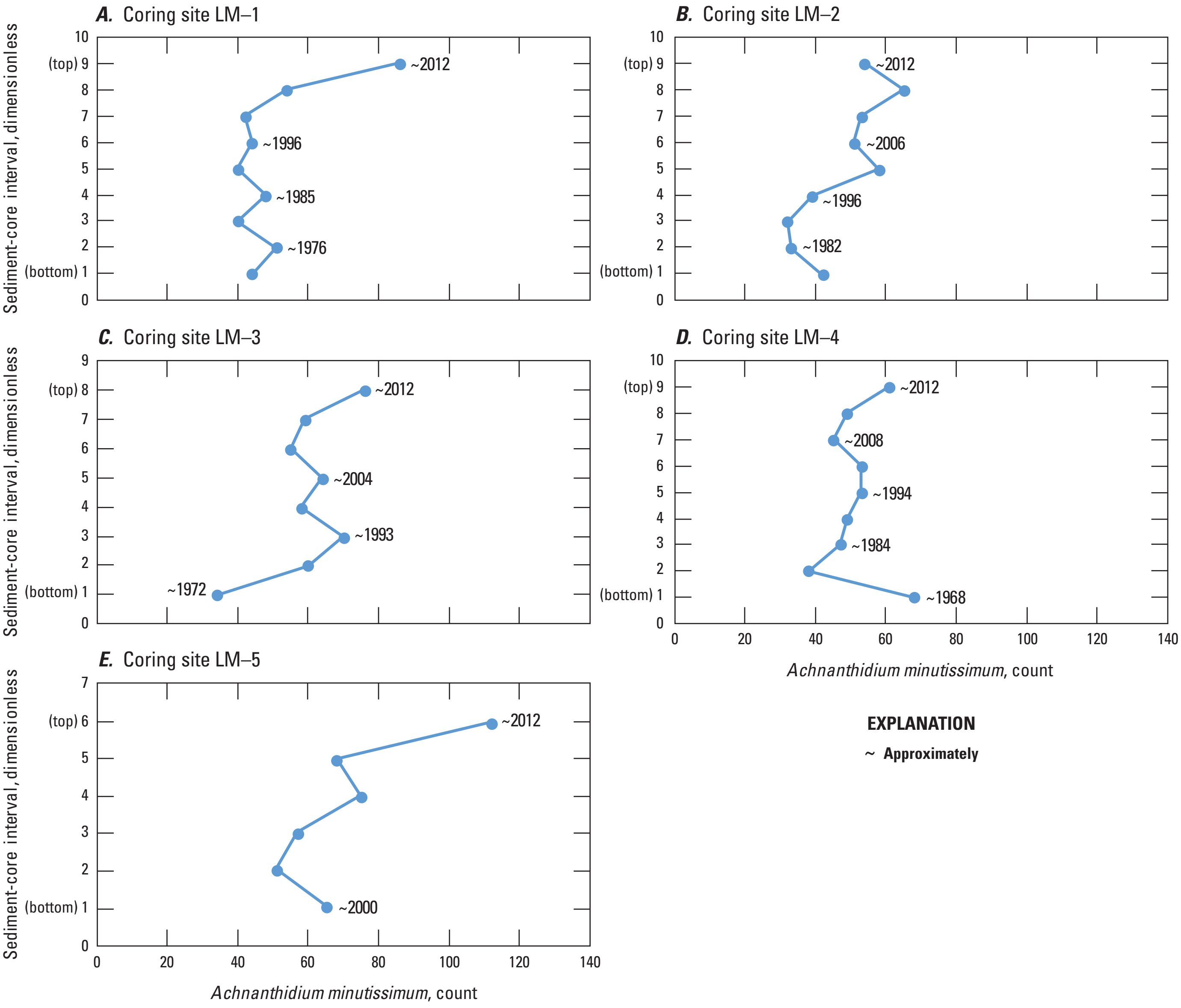


Figure 17. Variation in occurrence of *Achnanthidium minutissimum* with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

Cyclotella pseudostelligera typically is an indicator of eutrophic conditions (van Dam and others, 1994; Battarbee and others, 2012; Bennion and others, 2012). At coring sites LM–1 and LM–4, there was an overall decrease in abundance of *Cyclotella pseudostelligera* that indicated the lake had become less productive in recent decades (fig. 23). This interpretation was consistent with the evidence provided by *Cyclotella bodanica* for these two coring sites. Insufficient abundance of *Cyclotella pseudostelligera* at coring sites LM–2, LM–3, and LM–5 precluded an assessment of trends at these sites (tables 1–15, 1–17, 1–19, and 1–22). *Cyclotella pseudostelligera* in the predevelopment sediment, compared to the recent sediment, ranged from similar abundance (coring site LM–1) to rare (coring sites LM–2 and LM–3; tables 1–15, 1–17, 1–19, and 1–22).

Certain *Fragilaria* species (some of which have been renamed) generally are not considered to be reliable indicators of lake trophic status because they can tolerate a wide range of ecological conditions including nutrient concentrations (Bennion and others, 2001; Ampel and others, 2008; Fluin and others, 2010; Smol and Stoermer, 2010). In the recent sediment of Lake Maxinkuckee, such species present in relative abundance (with an occurrence greater than 1 percent of the total diatom abundance) included *Pseudostaurosira brevistriata* (formerly *Fragilaria brevistriata*), *Staurosira construens* (formerly *Fragilaria construens*), *Staurosira construens* var. *venter*

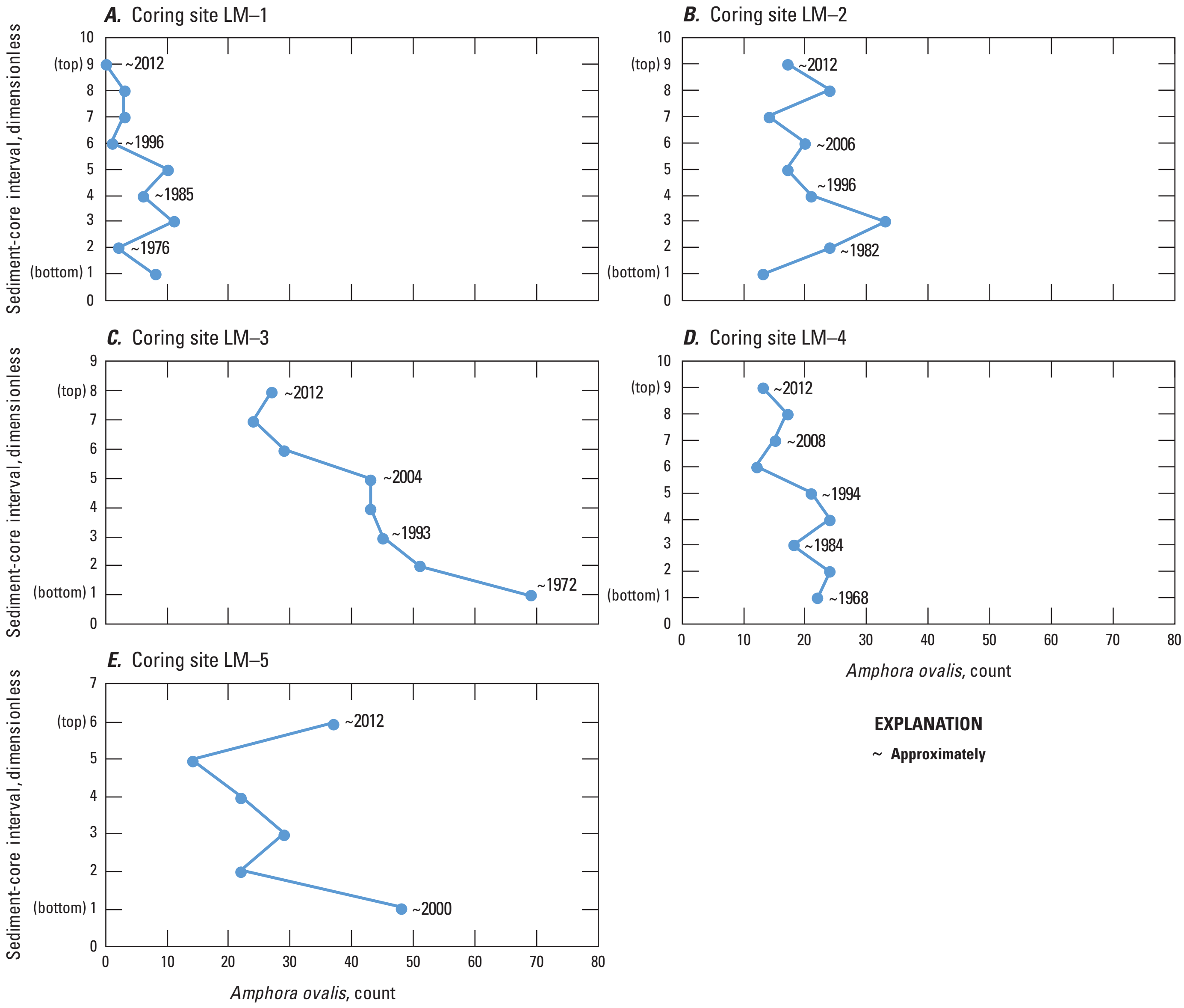


Figure 18. Variation in occurrence of *Amphora ovalis* with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

(formerly *Fragilaria construens* var. *venter*), and *Staurosirella pinnata* (formerly *Fragilaria pinnata*). *Pseudostaurosira brevistriata* was the most abundant species in the recent sediment (tables 1–14, 1–16, 1–18, 1–20, and 1–21).

Fragilaria crotonensis may be an indicator of mesotrophic or eutrophic conditions (van Dam and others, 1994; Negro and de Hoyos, 2005; Pienitz and others, 2006; Bennion and others, 2011; Battarbee and others, 2012). At coring sites LM–1 and LM–4, there was a pronounced decrease in abundance of *Fragilaria crotonensis* that indicated the lake had become less productive in recent decades (fig. 24). This interpretation was consistent with the evidence provided by *Cyclotella bodanica* and *Cyclotella pseudostelligera* for these two coring sites. However, no such trend was evident at the other three coring sites (LM–2, LM–3, and LM–5; fig. 24). *Fragilaria crotonensis* in the predevelopment sediment, compared to the recent sediment, ranged from similar or lower abundance (coring sites LM–1 and LM–6) to absent (coring sites LM–2 and LM–3; tables 1–15, 1–17, 1–19, and 1–22).

The final relatively abundant species identified in the bottom sediment of Lake Maxinkuckee was *Synedra demerarae* (table 4). Because a search of the literature uncovered no information regarding the utility of this species as an indicator of lake trophic status, it was not discussed further in this report.

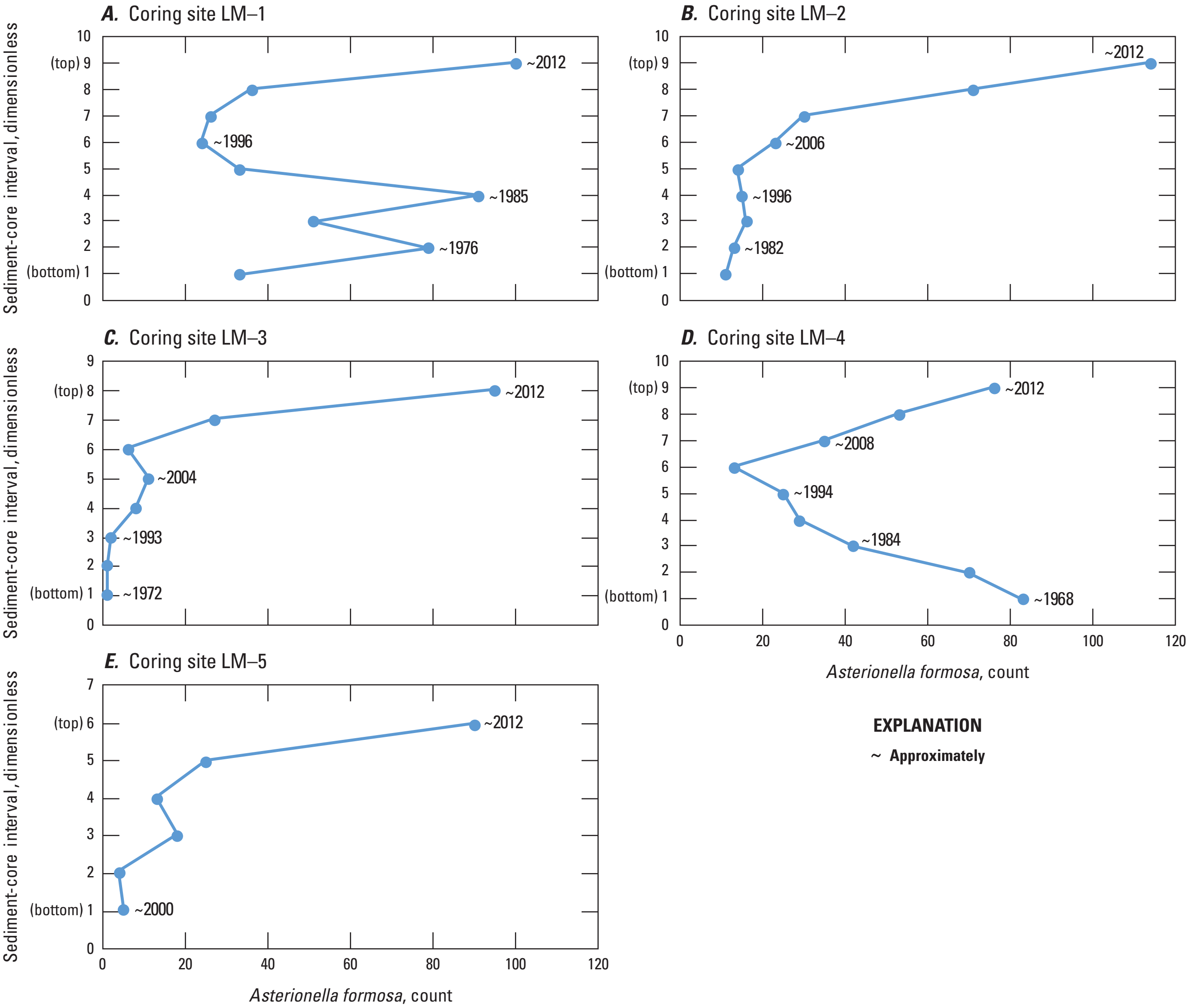


Figure 19. Variation in occurrence of *Asterionella formosa* with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

In sum, the diversity of diatom species, and the relative abundance of multiple species, in the bottom sediment indicated that Lake Maxinkuckee was not substantially affected by nutrient enrichment. Moreover, the combined evidence provided by multiple species indicated that Lake Maxinkuckee had not become more productive in recent decades. This conclusion was based on the evidence provided by the following species: *Amphora ovalis*, *Aulacoseira ambigua*, *Cyclotella bodanica*, *Cyclotella pseudostelligera*, and *Fragilaria crotonensis*.

Water-quality evidence for a stable, low-productivity lake condition was provided by the Indiana Clean Lakes Program. From 2000 to 2012, 33 water samples collected during the late spring or summer had very low chlorophyll-*a* concentrations that ranged from 0.15 to 4.60 micrograms per liter (µg/L) with a median of 2.06 µg/L (Indiana Clean Lakes Program, 2014). Chlorophyll-*a* concentrations less than 4 µg/L are indicative of oligotrophic conditions (Wetzel, 2001).

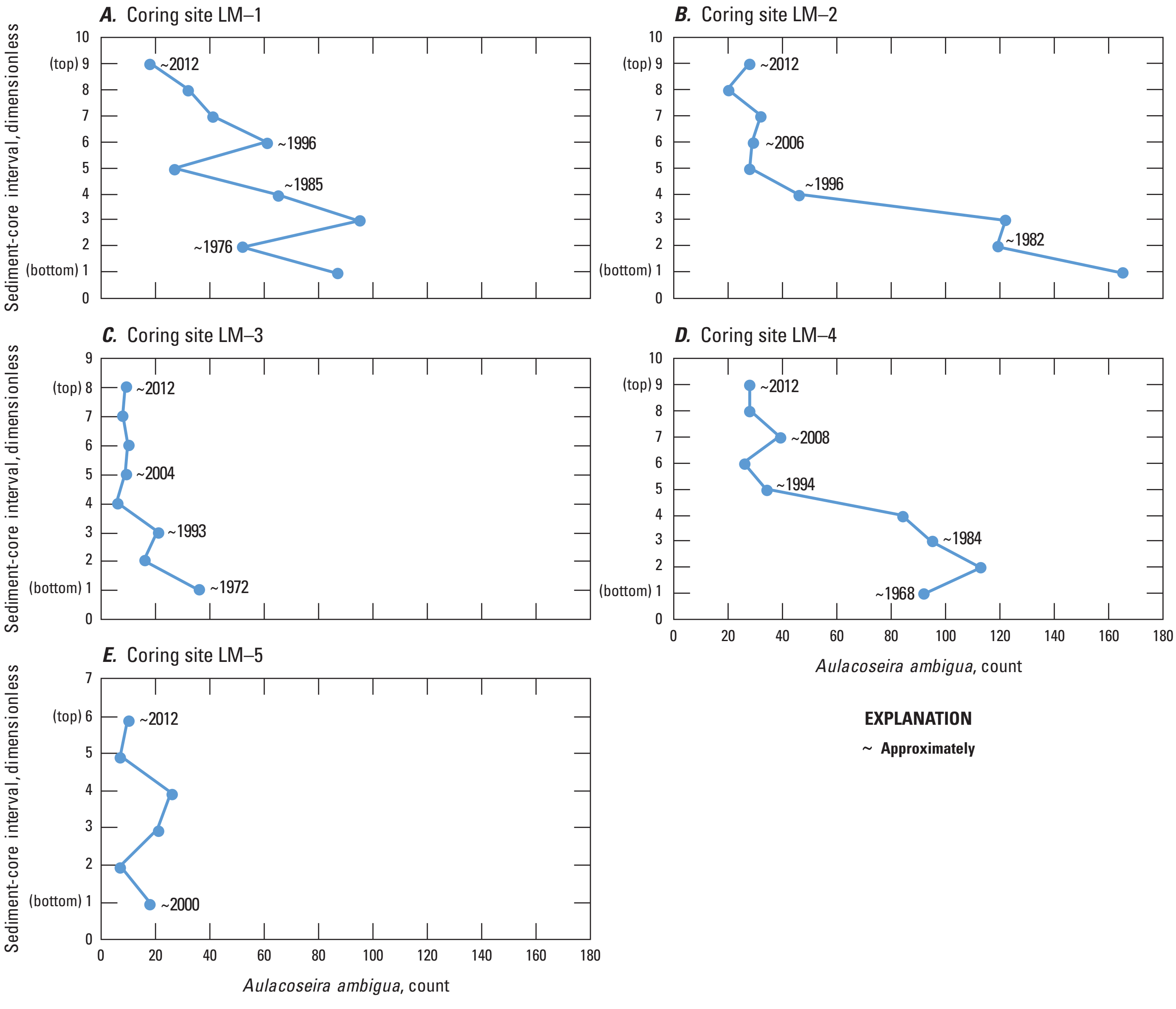


Figure 20. Variation in occurrence of *Aulacoseira ambigua* with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

Cyanobacteria

In the bottom sediment of Lake Maxinkuckee, the preserved algal community was dominated by akinete-producing cyanobacteria. Thus, the akinete-producing cyanobacteria either were more abundant or better preserved than the diatoms. Cyanobacterial akinetes from the genera *Anabaena*, *Aphanizomenon*, and *Gloeotrichia* (species *echinulata*) (hereafter *G. echinulata*) were present. Among the three akinete-producing cyanobacteria, *G. echinulata* was dominant in the recent and predevelopment sediment. In the recent sediment, the relative abundance ranged from 68 to 97 percent with a mean of 88 percent (fig. 25). Similarly, in the predevelopment sediment, the relative abundance ranged from 79 to 96 percent with a mean of 93 percent. Complete information on the occurrence and abundance of cyanobacterial akinetes in each sediment sample is provided in table 1–24 in the appendix.

G. echinulata is a species of cyanobacteria that has a unique life cycle. Unlike other species that primarily obtain phosphorus from the water column, *G. echinulata* acquires most of its phosphorus from the bottom sediment where it spends the first stage of its life before migrating up into the water column (Barbiero and Welch, 1992; Istvanovics and others, 1993; Karlsson, 2003). It is for this reason that

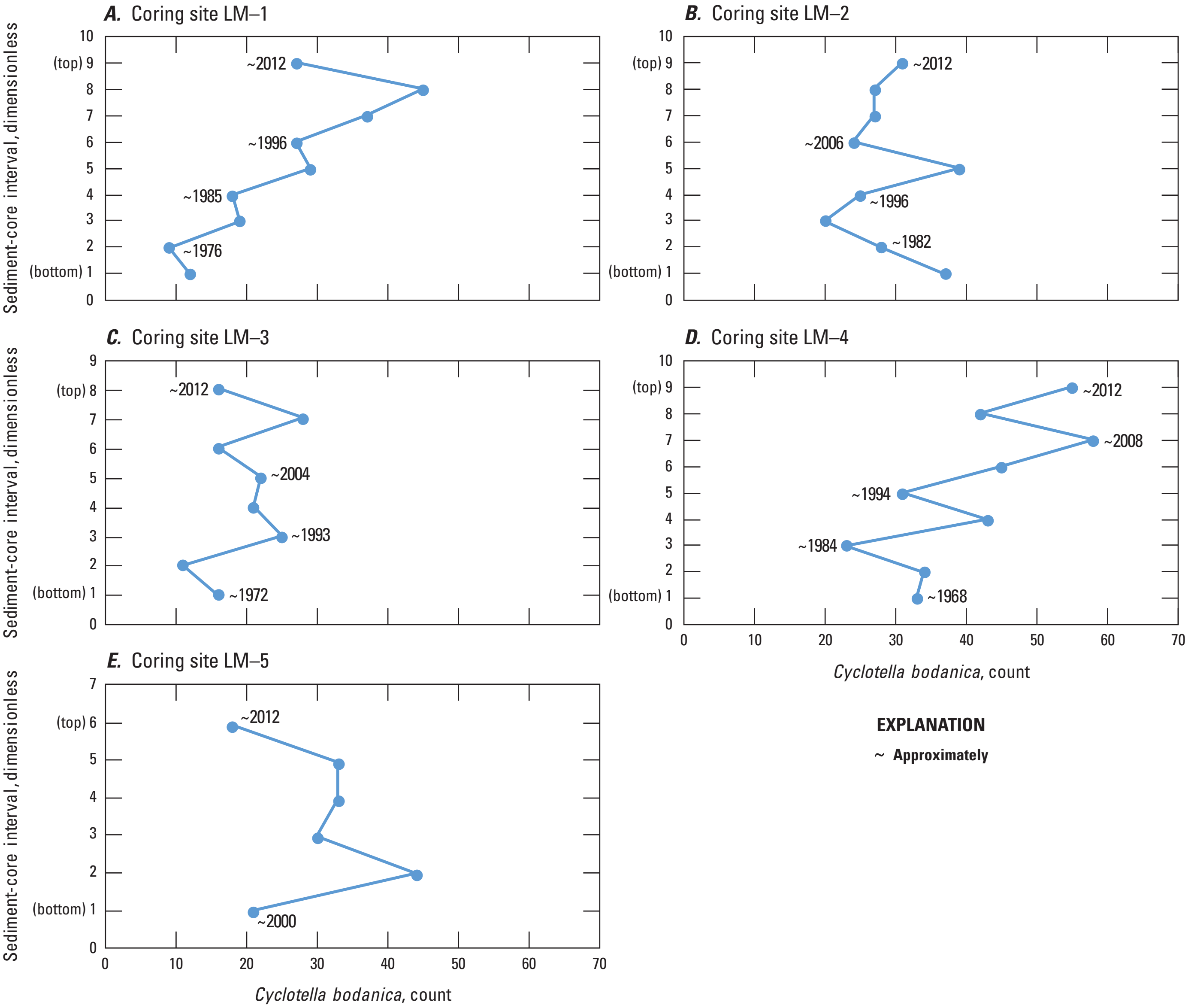


Figure 21. Variation in occurrence of *Cyclotella bodanica* with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

G. echinulata can thrive in oligotrophic or mesotrophic lakes (Carey and others, 2008). In addition, there is evidence to indicate that the presence of *G. echinulata* in the water column can stimulate the growth of other phytoplankton (Carey and Rengefors, 2010; Carey and others, 2014). One possible explanation is the fact that the upward migration of *G. echinulata* can provide a substantial source of internal phosphorus loading (Barbiero and Welch, 1992; Istvanovics and others, 1993). Because *G. echinulata* is potentially toxic (it is known to produce the cyanotoxin microcystin), it represents a possible health risk for aquatic organisms and humans (Carey and others, 2012).

The consistency in the relative abundance of the three akinete-producing cyanobacteria genera in the recent and predevelopment sediment indicated that lake conditions may not have changed appreciably in recent decades and possibly have been similar dating back to at least the mid-1800s. If phosphorus concentrations in the lake had increased substantially in recent decades, a pronounced increase in the abundance of *Anabaena* or *Aphanizomenon*, or both, would be expected (van Geel and others, 1994; Kling, 1998). Such an increase was not indicated in the recent sediment (fig. 25).

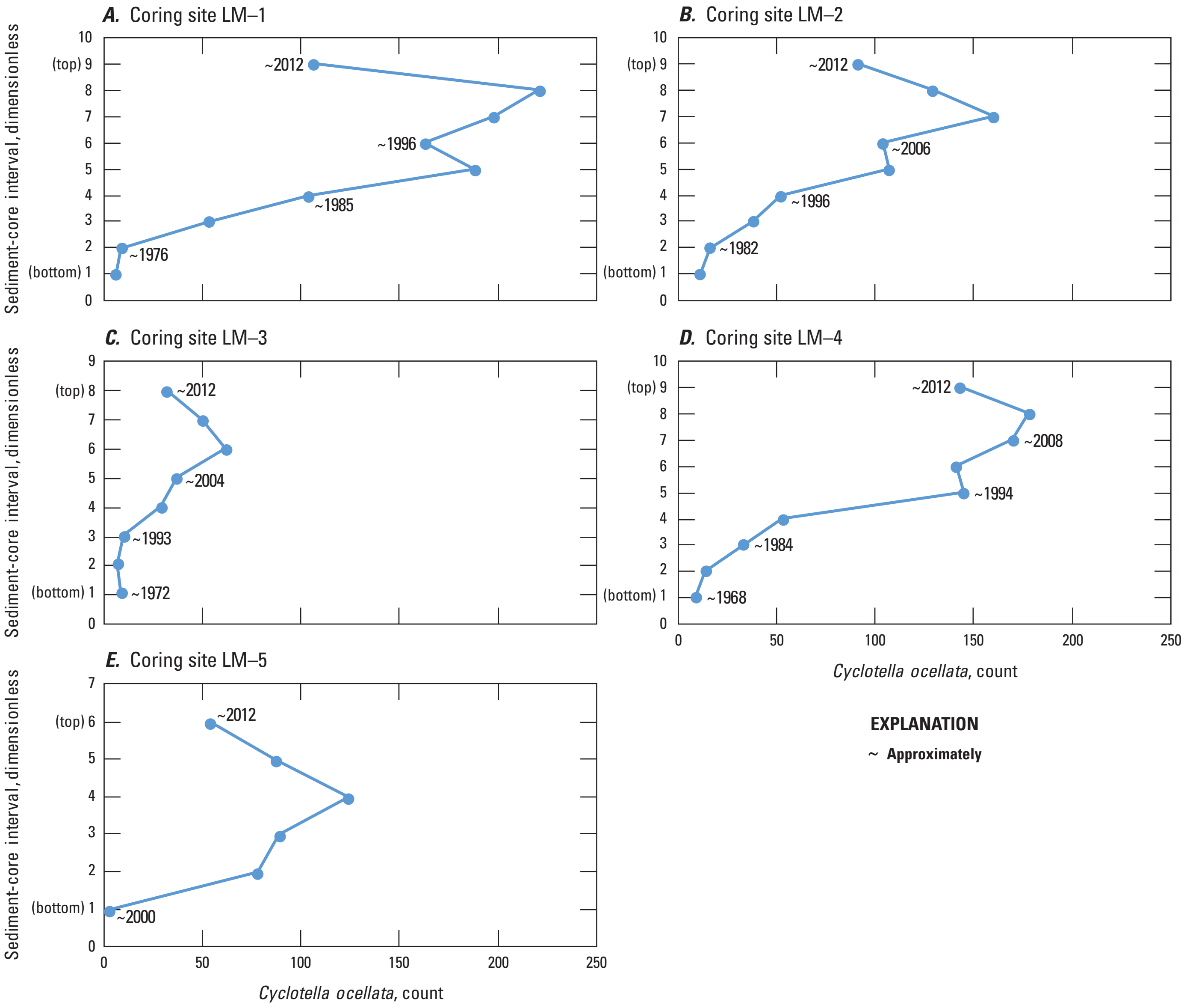


Figure 22. Variation in occurrence of *Cyclotella ocellata* with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

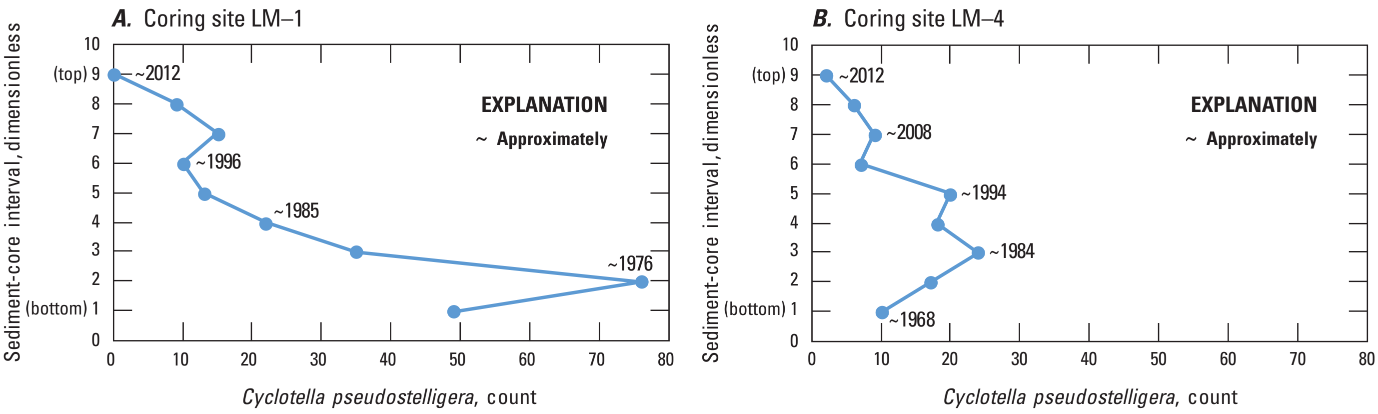


Figure 23. Variation in occurrence of *Cyclotella pseudostelligera* with depth of bottom-sediment samples in box cores collected from coring sites LM–1 and LM–4 in Lake Maxinkuckee, northern Indiana, May 2013.

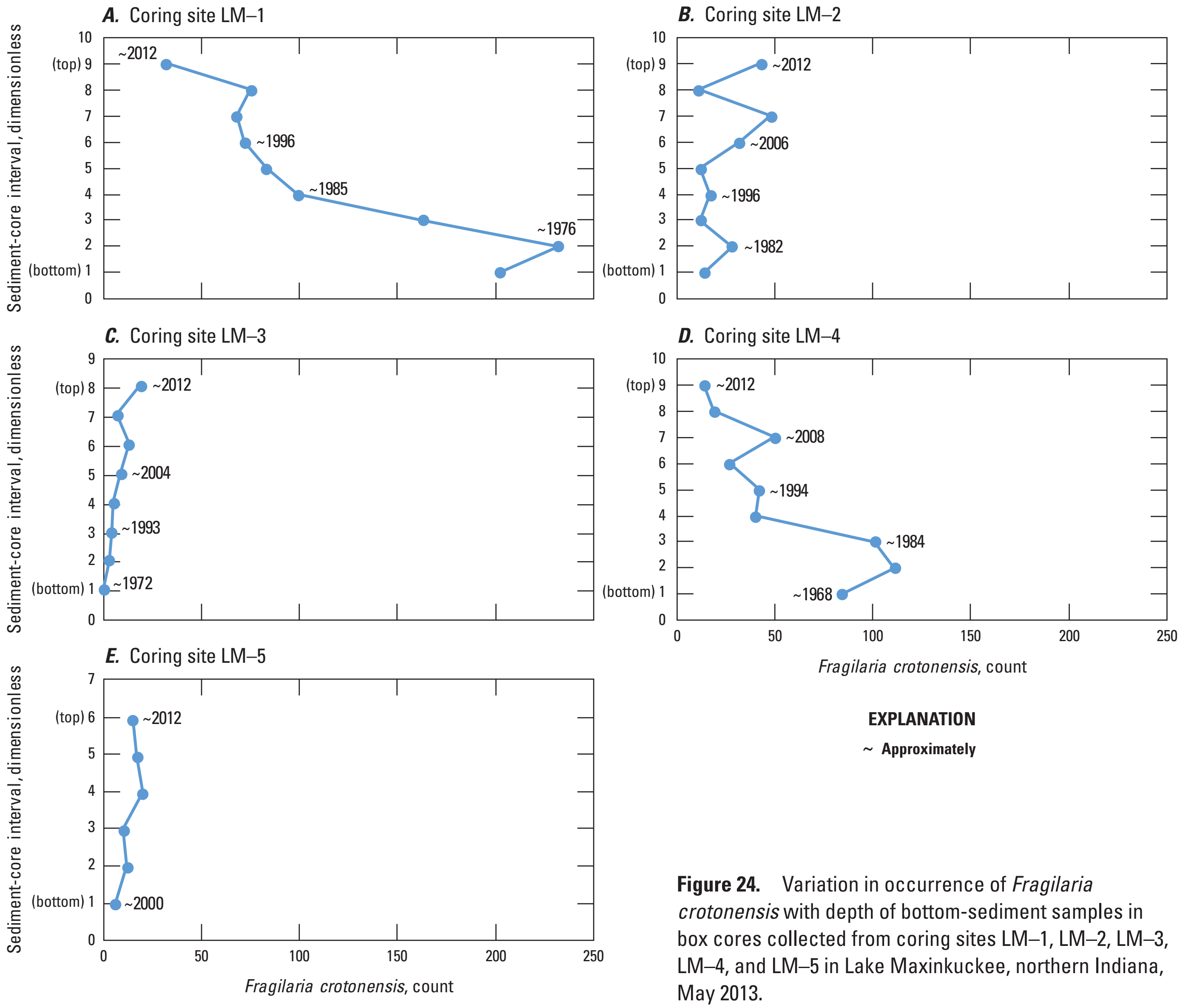


Figure 24. Variation in occurrence of *Fragilaria crotonensis* with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

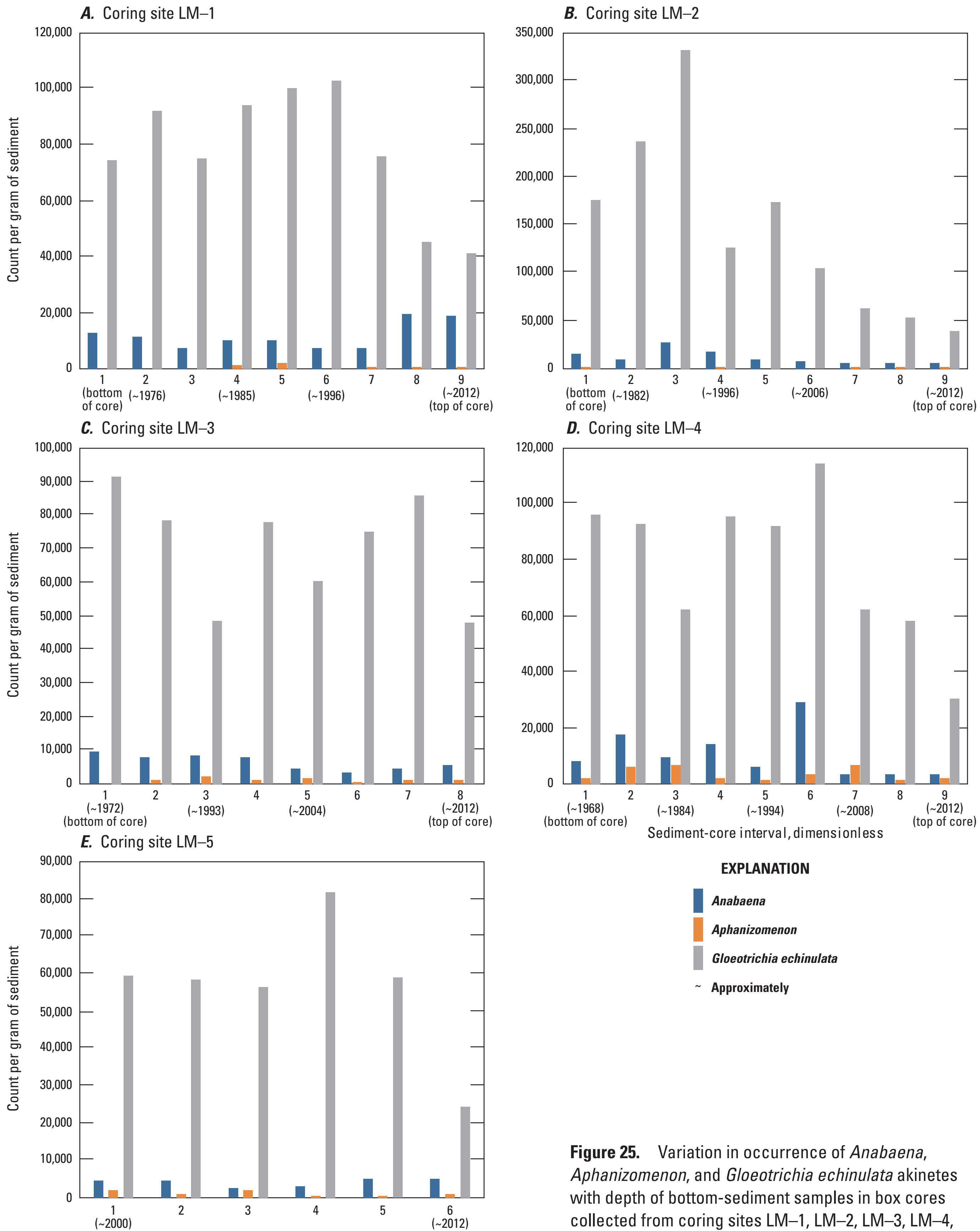


Figure 25. Variation in occurrence of *Anabaena*, *Aphanizomenon*, and *Gloeotrichia echinulata* akinetes with depth of bottom-sediment samples in box cores collected from coring sites LM–1, LM–2, LM–3, LM–4, and LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

Summary and Conclusions

A 2-year study by the U.S. Geological Survey, in cooperation with the Lake Maxinkuckee Environmental Council and the Marshall County Soil and Water Conservation District, was begun in 2013 to investigate the past and present condition of Lake Maxinkuckee through an analysis of the lakebed sediment. The study was based on an analysis of bottom-sediment cores that were collected from six sites in 2013. The cores were analyzed for total nitrogen, total phosphorus, carbon, 39 trace elements, diatoms, cyanobacterial akinetes, and 3 radionuclides. The primary results of this study are listed below:

1. Total nitrogen concentrations in the recent sediment (since about 1970) were variable with no consistent trend indicated.
2. Total phosphorus concentrations in the recent sediment generally were uniform from about 1970 to about 2000 and indicated consistent inputs to the lake during that time. Subsequently, the history of total phosphorus deposition apparently was obscured by postdepositional upward diffusion.
3. Elevated concentrations of cadmium, copper, lead, mercury, and zinc in the recent sediment, compared to the predevelopment (pre-1863) sediment, indicated likely human-related contamination.
4. Trace element concentrations were less than probable-effects guidelines (available for nine trace elements), which represent the concentrations above which toxic aquatic biological effects usually or frequently occur.
5. Arsenic concentrations typically exceeded the threshold-effects guideline, which represents the concentration above which toxic aquatic biological effects occasionally occur, in the recent and predevelopment sediment. The arsenic likely originated from natural sources.
6. Lead concentrations historically exceeded the threshold-effects guideline but since had decreased below it in the recent sediment at most coring sites. The decreasing trend likely was indicative of the effect of the phase out of leaded gasoline.
7. The occurrence of multiple diatom species, none of which were overwhelmingly dominant, was indicative of a minimally contaminated lake ecosystem.
8. The combined evidence of several diatom species in the recent sediment indicated that the lake had not become more productive in recent decades.
9. The combined evidence provided by akinetes for three cyanobacterial genera in the recent and predevelopment sediment indicated similar nutrient conditions in the lake during the past 40 years and possibly back to at least the mid-1800s.

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Appendix

Table 1–1. Latitude and longitude coordinates and water depth for bottom-sediment coring sites at Lake Maxinkuckee, northern Indiana, May 2013.

Coring site number (fig. 2)	Date cored (month/day/year)	Latitude (decimal degrees)	Longitude (decimal degrees)	Water depth[1] (feet)
LM–1	05/15/13	41.20472	86.40806	72
LM–2	05/15/13	41.21444	86.41472	45
LM–3	05/16/13	41.21500	86.39972	35
LM–4	05/16/13	41.20444	86.39611	54
LM–5	05/14/13	41.19417	86.39944	45
LM–6	05/16/13	41.20744	86.40397	88

[1] Water depth is rounded to the nearest foot.

Table 1–2. Vertical profiles of water-quality parameters measured at bottom-sediment coring sites LM–1 through LM–5, Lake Maxinkuckee, northern Indiana, May 14, 2013.

[Location of coring sites shown in figure 2. µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; FNU, formazin nephelometric units; µg/L, micrograms per liter; cells/mL, cells per milliliter]

Depth (feet)	pH	Temperature, in degrees Celsius	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Turbidity (FNU)	Chlorophyll, total (µg/L)	Cyanobacteria (cells/mL)
Coring site LM–1							
0	8.26	14.86	390	11.55	1.8	3.9	680
6	8.20	14.81	390	11.62	1.5	9.6	1,160
12	8.18	14.72	390	11.61	1.6	14.7	1,280
18	8.18	14.57	391	11.62	1.9	16.0	1,350
24	8.04	12.56	396	10.96	1.9	12.8	1,210
30	7.85	12.20	399	10.58	1.0	11.0	1,180
36	7.60	10.06	403	9.93	0.3	6.0	1,000
42	7.51	9.50	403	9.53	0.2	4.4	800
48	7.41	9.09	405	9.01	0.2	3.0	740
54	7.34	8.87	407	8.56	0.2	3.3	720
60	7.35	8.84	408	8.28	0.4	3.2	720
66	7.44	8.76	409	8.09	0.3	3.0	720
Coring site LM–2							
0	7.87	15.11	389	11.61	1.5	3.7	490
4	7.85	15.05	390	11.63	1.3	5.1	800
8	7.85	14.98	390	11.61	1.5	11.0	1,150
12	7.87	14.95	390	11.71	1.6	13.4	1,200
16	7.89	14.96	390	11.62	1.5	14.1	1,320
20	7.93	14.87	390	11.50	1.7	14.9	1,400
24	7.98	14.40	390	11.59	1.5	15.4	1,250
28	7.94	11.31	400	10.04	1.4	13.3	1,150
32	7.49	10.24	402	9.60	0.7	6.4	980
36	7.48	10.12	404	9.56	0.5	6.0	1,150
40	7.40	9.70	405	8.90	0.5	5.1	810

Table 1–2. Vertical profiles of water-quality parameters measured at bottom-sediment coring sites LM–1 through LM–5, Lake Maxinkuckee, northern Indiana, May 14, 2013.—Continued

[Location of coring sites shown in figure 2. µS/cm, microsiemens per centimeter at 25 degrees Celsius; mg/L, milligrams per liter; FNU, formazin nephelometric units; µg/L, micrograms per liter; cells/mL, cells per milliliter]

Depth (feet)	pH	Temperature, in degrees Celsius	Specific conductance (µS/cm)	Dissolved oxygen (mg/L)	Turbidity (FNU)	Chlorophyll, total (µg/L)	Cyanobacteria (cells/mL)
			Coring site LM–3				
0	7.62	15.42	389	11.56	1.9	4.3	800
3	7.70	15.38	389	11.56	1.7	3.9	650
6	7.74	15.29	389	11.63	1.7	5.0	690
9	7.86	15.24	389	11.58	1.7	6.0	980
12	7.95	15.10	390	11.58	2.1	12.4	1,290
15	7.99	14.97	390	11.67	1.7	15.0	1,390
18	8.04	14.95	390	11.58	1.8	15.8	1,360
21	8.07	14.92	390	11.57	1.8	16.1	1,270
24	8.11	14.96	390	11.57	1.8	15.5	1,300
27	8.13	14.91	390	11.62	1.8	15.8	1,480
30	8.14	14.93	390	11.57	1.8	15.2	1,460
33	8.16	14.85	389	11.52	2.0	15.5	1,240
			Coring site LM–4				
0	8.37	15.27	390	11.63	1.7	5.0	800
5	8.32	15.21	390	11.61	1.6	10.2	950
10	8.31	15.00	390	11.70	1.6	12.5	1,200
15	8.29	14.89	390	11.63	1.7	14.8	1,280
20	8.30	14.87	390	11.66	1.6	15.5	1,300
25	8.30	14.87	390	10.62	1.6	15.1	1,280
30	7.81	9.79	401	10.50	0.5	5.3	800
35	7.62	9.63	403	9.77	0.1	3.8	750
40	7.58	9.46	404	9.56	0.2	3.3	700
45	7.52	9.17	406	9.22	0.4	3.1	610
50	7.51	9.06	407	9.05	0.1	2.4	680
			Coring site LM–5				
0	8.22	14.04	386	11.31	1.4	5.0	960
4	8.21	14.02	386	11.30	1.3	6.1	970
8	8.22	14.02	386	11.33	1.3	9.7	1,020
12	8.22	13.95	386	11.35	1.2	12.8	1,100
16	7.85	10.94	397	10.32	0.5	8.0	1,160
20	7.77	10.72	399	9.98	0.6	6.9	1,010
24	7.66	9.80	401	9.52	0.3	5.2	880
28	7.61	9.71	402	9.20	0.2	4.0	820
32	7.58	9.46	403	9.04	0.3	4.1	820
36	7.59	9.43	403	8.93	0.2	3.9	960
40	7.60	9.42	403	8.90	0.5	4.0	670

Table 1–3. Activity of cesium-137, lead-210, and radium-226 in bottom-sediment samples collected from Lake Maxinkuckee, northern Indiana, May 2013.

[The parenthetical values are the analytical variability for each sample. cm, centimeters; dup, duplicate analysis; dpm/g, disintegrations per minute per gram; ±, plus or minus error; R, recent; ND, not detected; --, not applicable; P, predevelopment]

Coring site number[1] (fig. 2)	Depth interval (cm)	Radionuclide activity (dpm/g)			Relative age of sediment
		Cesium-137	Lead-210	Radium-226	
LM–1	0–2	0.69 (± 0.12)	22.67 (± 0.78)	1.07 (± 0.15)	R
	2–4	0.77 (± 0.10)	19.53 (± 0.58)	0.93 (± 0.10)	R
	4–6	0.73 (± 0.07)	17.01 (± 0.44)	0.86 (± 0.08)	R
	8–10	0.86 (± 0.08)	13.98 (± 0.48)	0.81 (± 0.08)	R
	8–10dup	0.88 (± 0.11)	14.40 (± 0.58)	0.81 (± 0.10)	R
	12–14	1.03 (± 0.09)	11.64 (± 0.46)	0.96 (± 0.09)	R
	16–18	1.18 (± 0.11)	10.19 (± 0.50)	0.96 (± 0.11)	R
	20–22	1.38 (± 0.11)	9.22 (± 0.47)	0.92 (± 0.10)	R
	24–26	1.59 (± 0.13)	8.11 (± 0.47)	0.93 (± 0.11)	R
	28–30	1.95 (± 0.18)	8.21 (± 0.61)	1.15 (± 0.15)	R
LM–1G	50–60	ND (--)	1.61 (± 0.35)	1.14 (± 0.13)	P
	70–80	ND (--)	1.77 (± 0.38)	1.30 (± 0.14)	P
LM–2	0–2	1.08 (± 0.13)	13.77 (± 0.58)	1.01 (± 0.13)	R
	2–4	0.96 (± 0.10)	12.72 (± 0.50)	1.09 (± 0.11)	R
	4–6	1.04 (± 0.12)	12.09 (± 0.55)	0.88 (± 0.11)	R
	8–10	1.05 (± 0.12)	11.48 (± 0.53)	1.02 (± 0.12)	R
	12–14	1.21 (± 0.11)	10.26 (± 0.45)	0.88 (± 0.10)	R
	16–18	1.33 (± 0.14)	8.71 (± 0.49)	1.05 (± 0.16)	R
	20–22	1.84 (± 0.15)	7.08 (± 0.46)	1.05 (± 0.12)	R
	24–26	1.97 (± 0.13)	6.06 (± 0.38)	1.00 (± 0.10)	R
	28–30	2.38 (± 0.15)	6.31 (± 0.40)	1.25 (± 0.13)	R
LM–2G	40–50	ND (--)	1.39 (± 0.40)	1.12 (± 0.17)	P
	60–70	ND (--)	1.85 (± 0.37)	1.14 (± 0.15)	P
LM–3	0–2	1.48 (± 0.13)	12.82 (± 0.51)	1.19 (± 0.16)	R
	2–4	1.52 (± 0.14)	11.44 (± 0.54)	1.19 (± 0.16)	R
	4–6	1.55 (± 0.14)	10.67 (± 0.52)	1.09 (± 0.16)	R
	8–10	1.58 (± 0.14)	10.16 (± 0.52)	1.34 (± 0.18)	R
	12–14	1.85 (± 0.15)	9.21 (± 0.50)	1.32 (± 0.17)	R
	16–18	1.95 (± 0.11)	7.60 (± 0.34)	1.37 (± 0.12)	R
	20–22	2.22 (± 0.13)	6.78 (± 0.37)	1.40 (± 0.14)	R
	24–26	1.71 (± 0.12)	4.58 (± 0.32)	1.52 (± 0.15)	R
LM–3G	30–40	ND (--)	1.25 (± 0.20)	1.40 (± 0.12)	P
	50–60	ND (--)	1.63 (± 0.27)	1.46 (± 0.15)	P
	70–80	ND (--)	1.59 (± 0.26)	1.07 (± 0.13)	P

Table 1–3. Activity of cesium-137, lead-210, and radium-226 in bottom-sediment samples collected from Lake Maxinkuckee, northern Indiana, May 2013.—Continued

[The parenthetical values are the analytical variability for each sample. cm, centimeters; dup, duplicate analysis; dpm/g, disintegrations per minute per gram; ±, plus or minus error; R, recent; ND, not detected; --, not applicable; P, predevelopment]

Coring site number[1] (fig. 2)	Depth interval (cm)	Radionuclide activity (dpm/g)			Relative age of sediment
		Cesium-137	Lead-210	Radium-226	
LM–4	0–2	0.97 (± 0.12)	16.36 (± 0.59)	1.14 (± 0.13)	R
	2–4	1.04 (± 0.14)	16.52 (± 0.67)	1.05 (± 0.14)	R
	4–6	1.02 (± 0.13)	14.76 (± 0.60)	0.91 (± 0.11)	R
	8–10	1.16 (± 0.09)	12.52 (± 0.42)	1.01 (± 0.09)	R
	8–10dup	0.98 (± 0.13)	12.48 (± 0.54)	0.97 (± 0.12)	R
	12–14	1.45 (± 0.14)	9.76 (± 0.49)	1.13 (± 0.12)	R
	16–18	1.73 (± 0.15)	8.22 (± 0.47)	1.05 (± 0.13)	R
	20–22	2.31 (± 0.15)	7.41 (± 0.41)	1.18 (± 0.11)	R
	24–26	3.07 (± 0.18)	5.87 (± 0.41)	1.20 (± 0.12)	R
	28–30	3.24 (± 0.14)	5.01 (± 0.32)	1.30 (± 0.10)	R
LM–5	0–2	1.67 (± 0.13)	13.57 (± 0.70)	1.28 (± 0.14)	R
	0–2dup	1.82 (± 0.14)	13.22 (± 0.72)	1.22 (± 0.14)	R
	2–4	1.71 (± 0.12)	12.85 (± 0.61)	1.20 (± 0.12)	R
	4–6	1.81 (± 0.13)	13.17 (± 0.72)	1.08 (± 0.13)	R
	8–10	1.99 (± 0.14)	12.98 (± 0.71)	1.14 (± 0.13)	R
	12–14	2.04 (± 0.12)	11.29 (± 0.59)	1.06 (± 0.12)	R
	16–18	2.28 (± 0.14)	9.72 (± 0.67)	1.16 (± 0.13)	R
LM–6G	40–50	1.28 (± 0.13)	6.03 (± 0.68)	2.53 (± 0.23)	R
	60–70	ND (--)	1.71 (± 0.45)	2.04 (± 0.19)	P
	80–90	ND (--)	2.34 (± 0.53)	2.56 (± 0.22)	P

[1] Coring site numbers ending in “G” indicate a gravity core. Other coring site numbers indicate a box core.

Table 1–4. Percentage of sand, silt, and clay in bottom-sediment samples collected from Lake Maxinkuckee, northern Indiana, May 2013.

[cm, centimeters; R, recent sediment; P, predevelopment sediment; dup, duplicate analysis]

Coring site number[1] (fig. 2)	Depth interval in core, below sediment-water interface (cm)	Percentage of sand[2]	Percentage of silt[2]	Percentage of clay[2]
LM–1	8–10 (R)	4.54	65.42	30.04
	12–14 (R)	2.42	65.61	31.96
	16–18 (R)	2.67	66.70	30.63
	20–22 (R)	2.57	67.26	30.17
	24–26 (R)	1.97	65.94	32.09
LM–2	4–6 (R)	5.09	55.64	39.27
	8–10 (R)	3.95	62.94	33.11
	12–14 (R)	3.96	59.32	36.72
	16–18 (R)	3.08	65.30	31.62
	20–22 (R)	2.81	57.58	39.61
	24–26 (R)	4.96	64.61	30.43
LM–3	4–6 (R)	9.17	60.06	30.77
	8–10 (R)	8.27	61.03	30.71
	12–14 (R)	10.82	56.36	32.82
	16–18 (R)	10.97	61.26	27.77
	20–22 (R)	12.82	58.25	28.93
	24–26 (R)	7.82	61.12	31.06
LM–3G	70–80 (P)	4.02	62.56	33.43
	70–80dup (P)	3.91	63.34	32.75
LM–4	4–6 (R)	3.84	59.38	36.79
	8–10 (R)	4.11	60.37	35.53
	8–10dup (R)	5.66	63.92	30.42
	12–14 (R)	3.43	60.27	36.30
	12–14dup (R)	3.14	61.89	34.97
	16–18 (R)	7.14	67.42	25.44
	20–22 (R)	4.97	55.92	39.11
	24–26 (R)	3.15	62.85	34.00
LM–5	0–2 (R)	8.91	57.39	33.70
	8–10 (R)	9.00	55.00	36.00
	12–14 (R)	5.77	61.50	32.73
LM–6G	80–90 (P)	5.97	74.54	19.49

[1] Coring site numbers ending in "G" indicate a gravity core. Other coring site numbers indicate a box core.

[2] Sand was defined as particles greater than 63 micrometers (µm) in size. Silt was defined as particles 4 to 63 µm in size. Clay was defined as particles less than 4 µm in size.

Table 1–5. Concentrations of nutrients, carbon, and trace elements for bottom-sediment samples collected from coring site LM–1 in Lake Maxinkuckee, northern Indiana, May 2013.

[Shading indicates concentration greater than threshold-effects guideline listed in table 2. cm, centimeters; R, recent sediment; mg/kg, milligrams per kilogram; --, not available; %, percent dry weight; <, less than]

Constituent and unit of measurement	Constituent concentration								
	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
	28–30 cm, R (bottom of core)	24–26 cm, R	20–22 cm, R	16–18 cm, R	12–14 cm, R	8–10 cm, R	4–6 cm, R	2–4 cm, R	0–2 cm, R (top of core)
					Nutrients				
Total nitrogen, mg/kg	--	642	956	474	1,130	893	1,010	1,300	1,290
Total phosphorus, mg/kg	489	505	469	488	499	525	582	628	735
					Carbon				
Carbon (total organic), %	4	4	4.1	4.2	4.2	4.6	4.5	4.9	5.4
Carbon (total), %	11.7	11.8	11.9	12.1	12.3	12.6	12.6	12.7	12.7
					Trace elements				
Aluminum, mg/kg	13,400	12,900	11,800	11,800	10,900	10,500	9,960	10,100	10,000
Antimony, mg/kg	0.49	0.48	0.41	0.38	0.36	0.39	0.34	0.4	0.38
Arsenic, mg/kg	26.2	25.1	22.3	21.8	21.7	20.8	20	18.8	15.9
Barium, mg/kg	333	334	315	328	326	331	318	318	324
Beryllium, mg/kg	0.42	0.35	0.35	0.35	0.35	0.33	0.25	0.34	0.3
Bismuth, mg/kg	0.09	0.11	0.07	0.09	<0.06	0.09	<0.06	0.12	<0.06
Cadmium, mg/kg	0.45	0.45	0.38	0.37	0.31	0.33	0.28	0.33	0.28
Calcium, mg/kg	256,000	242,000	248,000	245,000	264,000	253,000	260,000	247,000	255,000
Cerium, mg/kg	13.5	13.4	12.3	12.3	11.6	11.2	10.3	10.7	10.8
Cesium, mg/kg	1.1	1.1	0.91	0.94	0.86	0.86	0.77	0.86	0.81
Chromium, mg/kg	13	12.7	11.9	12	11	11	10.3	10.3	10.7
Cobalt, mg/kg	2.6	2.7	2.3	2.4	2.2	2.2	2.1	2.2	2.1
Copper, mg/kg	15.4	16.2	14.7	14.4	14.4	16.9	15.8	14.9	16.6
Gallium, mg/kg	3.3	3.2	2.9	2.9	2.8	2.6	2.4	2.4	2.4
Iron, mg/kg	11,800	11,400	10,800	10,700	10,700	10,500	10,300	10,100	9,730
Lanthanum, mg/kg	6.6	6.5	6.3	6	5.7	5.5	5	5.3	5.2
Lead, mg/kg	47.3	45.2	37.2	33.4	29.5	28.6	23.8	23.6	23.5
Lithium, mg/kg	9.1	6.4	8.9	7.1	7	4.4	6.8	5.1	6
Magnesium, mg/kg	9,250	9,030	9,060	9,100	9,320	9,330	9,270	9,210	9,080
Manganese, mg/kg	683	673	687	674	707	717	735	718	765
Mercury, mg/kg	0.05	0.05	0.05	0.04	0.05	0.04	0.04	0.04	0.05
Molybdenum, mg/kg	6	6.1	5.7	5.1	5.4	5.4	4.9	4.8	3.1
Nickel, mg/kg	2.6	3.4	2.3	2.4	0.9	2.9	1.6	2.7	3.7
Niobium, mg/kg	1.9	1.8	1.6	1.7	1.5	1.7	1.5	1.7	1.6
Potassium, mg/kg	4,510	4,330	4,010	3,990	3,780	3,650	3,530	3,500	3,520
Rubidium, mg/kg	21.7	20.2	19	18.3	17.5	16.6	16	15.6	16.5
Scandium, mg/kg	1.7	2.3	1.4	2	1.3	1.9	1.2	1.8	1.2
Selenium, mg/kg	1.25	1.37	1.2	1.34	1.27	1.42	1.32	1.43	1.32
Silver, mg/kg	0.019	0.101	0.01	0.096	<0.01	0.094	<0.01	0.116	<0.01
Sodium, mg/kg	1,240	1,180	1,150	1,160	1,120	1,050	1,030	1,020	1,070
Strontium, mg/kg	328	323	329	325	346	340	353	330	343
Sulfur, %	0.92	0.81	0.87	0.72	0.76	0.82	0.81	0.78	0.66
Thallium, mg/kg	0.22	0.21	0.2	0.18	0.16	0.16	0.15	0.19	0.15
Thorium, mg/kg	1.83	1.89	1.71	1.69	1.51	1.53	1.37	1.46	1.45
Titanium, mg/kg	567	521	480	501	436	469	413	427	434
Uranium, mg/kg	1.5	1.67	1.47	1.61	1.5	1.61	1.34	1.53	1.21
Vanadium, mg/kg	21	20.6	17.4	18.1	17.9	17.1	16.3	16.4	16.3
Yttrium, mg/kg	4.3	4.2	3.9	3.8	3.7	3.7	3.4	3.4	3.5
Zinc, mg/kg	71.5	70	63.7	62	60	60.3	61.1	59.3	78.3

Table 1–6. Concentrations of nutrients, carbon, and trace elements for bottom-sediment samples collected from coring site LM–1G in Lake Maxinkuckee, northern Indiana, May 2013.

[Shading indicates concentration greater than threshold-effects guideline listed in table 2. cm, centimeters; P, pre-development sediment; mg/kg, milligrams per kilogram; %, percent dry weight; <, less than]

Constituent and unit of measurement	Constituent concentration	
	Interval 1 70–80 cm, P	Interval 2 50–60 cm, P
Nutrients		
Total nitrogen, mg/kg	615	3,640
Total phosphorus, mg/kg	927	684
Carbon		
Carbon (total organic), %	11.5	7.8
Carbon (total), %	15.6	14.7
Trace elements		
Aluminum, mg/kg	14,400	10,400
Antimony, mg/kg	0.23	0.1
Arsenic, mg/kg	27.2	17.6
Barium, mg/kg	253	296
Beryllium, mg/kg	0.47	0.26
Bismuth, mg/kg	<0.06	<0.06
Cadmium, mg/kg	0.25	0.16
Calcium, mg/kg	136,000	217,000
Cerium, mg/kg	16.3	11.9
Cesium, mg/kg	1.3	0.92
Chromium, mg/kg	14.2	10.6
Cobalt, mg/kg	4	2.8
Copper, mg/kg	13.5	9.7
Gallium, mg/kg	3.6	2.6
Iron, mg/kg	39,100	23,200
Lanthanum, mg/kg	8.1	5.8
Lead, mg/kg	7.03	5.78
Lithium, mg/kg	12.2	6.2
Magnesium, mg/kg	8,440	8,950
Manganese, mg/kg	619	666
Mercury, mg/kg	0.03	0.02
Molybdenum, mg/kg	9.3	4.7
Nickel, mg/kg	8.2	3.6
Niobium, mg/kg	1.8	1.5
Potassium, mg/kg	5,310	3,860
Rubidium, mg/kg	24.2	17.3
Scandium, mg/kg	2	2
Selenium, mg/kg	1.77	1.16
Silver, mg/kg	<0.01	<0.01
Sodium, mg/kg	1,330	1,060
Strontium, mg/kg	190	258
Sulfur, %	0.63	0.26
Thallium, mg/kg	0.21	0.14
Thorium, mg/kg	2.22	1.6
Titanium, mg/kg	584	455
Uranium, mg/kg	1.59	1.02
Vanadium, mg/kg	25	17.8
Yttrium, mg/kg	5.3	3.9
Zinc, mg/kg	48.7	31.3

Table 1–7. Concentrations of nutrients, carbon, and trace elements for bottom-sediment samples collected from coring site LM–2 in Lake Maxinkuckee, northern Indiana, May 2013.

[Shading indicates concentration greater than threshold-effects guideline listed in table 2. cm, centimeters; R, recent sediment; mg/kg, milligrams per kilogram; --, not available; %, percent dry weight; <, less than]

Constituent and unit of measurement	Constituent concentration								
	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
	28–30 cm, R (bottom of core)	24–26 cm, R	20–22 cm, R	16–18 cm, R	12–14 cm, R	8–10 cm, R	4–6 cm, R	2–4 cm, R	0–2 cm, R (top of core)
Nutrients									
Total nitrogen, mg/kg	--	1,370	649	709	1,000	2,290	1,350	1,520	--
Total phosphorus, mg/kg	467	500	468	488	512	565	593	607	608
Carbon									
Carbon (total organic), %	4.3	4.5	4.4	4.4	4.7	4.4	4.7	4.6	5
Carbon (total), %	12.6	12.8	12.8	12.9	13.3	13	13.3	13.1	13.5
Trace elements									
Aluminum, mg/kg	13,200	12,000	11,800	11,100	9,970	9,590	9,480	9,500	9,670
Antimony, mg/kg	0.69	0.55	0.54	0.51	0.4	0.41	0.38	0.37	0.34
Arsenic, mg/kg	19.2	18.7	17.6	16.4	14.3	14.8	16.5	18.6	19.5
Barium, mg/kg	349	327	339	329	334	321	338	332	346
Beryllium, mg/kg	0.45	0.37	0.41	0.35	0.33	0.27	0.29	0.31	0.35
Bismuth, mg/kg	0.13	0.09	0.11	0.07	0.09	0.06	0.08	0.07	0.08
Cadmium, mg/kg	0.66	0.55	0.66	0.47	0.45	0.4	0.39	0.38	0.38
Calcium, mg/kg	263,000	272,000	261,000	275,000	266,000	279,000	264,000	275,000	266,000
Cerium, mg/kg	15.9	13.3	13.1	12.1	11.7	10.9	11	10.5	10.9
Cesium, mg/kg	1.1	0.98	0.96	0.85	0.82	0.76	0.78	0.75	0.79
Chromium, mg/kg	14	12.9	12.5	12.4	11.3	10.9	11	10.5	10.7
Cobalt, mg/kg	2.7	2.5	2.5	2.3	2.2	2.1	2.1	2	2.2
Copper, mg/kg	16.8	16.2	17	15.6	15	16	15.4	17.8	18
Gallium, mg/kg	3.2	3.1	3	2.7	2.6	2.4	2.5	2.5	2.5
Iron, mg/kg	9,750	9,450	9,230	9,350	8,860	8,800	9,150	9,280	9,410
Lanthanum, mg/kg	7	6.6	6.4	6	5.7	5.3	5.4	5.2	5.4
Lead, mg/kg	61.8	54	50	43.5	37.5	33.9	33.7	32.5	32.6
Lithium, mg/kg	8.2	11.4	7.2	11.3	7.1	9.1	4.6	8.9	5.8
Magnesium, mg/kg	9,500	9,810	9,540	9,930	9,380	9,760	9,270	9,520	9,370
Manganese, mg/kg	678	701	688	715	726	783	845	919	932
Mercury, mg/kg	0.08	0.08	0.07	0.06	0.06	0.05	0.06	0.05	0.06
Molybdenum, mg/kg	2.8	2.4	2.4	2.3	1.7	1.2	0.97	0.89	0.9
Nickel, mg/kg	3.8	1.9	3.4	1.7	1.6	0.4	1.5	0.5	2.4
Niobium, mg/kg	1.9	2	1.7	1.8	1.6	1.4	1.5	1.6	1.6
Potassium, mg/kg	4,390	4,170	3,860	3,760	3,500	3,370	3,330	3,290	3,300
Rubidium, mg/kg	21.1	20.4	18.7	18.4	16.2	16.1	15.6	15.7	15.4
Scandium, mg/kg	2.4	1.6	2.1	1.3	1.8	1.1	1.8	2	1.8
Selenium, mg/kg	1.47	1.29	1.4	1.31	1.31	1.2	1.26	1.16	1.29
Silver, mg/kg	0.156	0.042	0.125	0.015	0.082	<0.01	0.073	<0.01	0.09
Sodium, mg/kg	1,200	1,180	1,080	1,070	979	970	944	980	958
Strontium, mg/kg	338	351	340	363	347	365	353	359	352
Sulfur, %	0.31	0.37	0.29	0.31	0.3	0.24	0.13	0.18	0.13
Thallium, mg/kg	0.23	0.22	0.2	0.19	0.17	0.16	0.15	0.16	0.16
Thorium, mg/kg	2	1.79	1.78	1.58	1.56	1.41	1.49	1.38	1.49
Titanium, mg/kg	562	535	528	499	448	427	429	439	440
Uranium, mg/kg	1.74	1.47	1.52	1.44	1.3	1.12	1.01	0.84	0.83
Vanadium, mg/kg	21.5	19.7	19.1	18.2	16.9	16.6	15.6	16.1	15.5
Yttrium, mg/kg	4.5	4.4	4.1	4	3.6	3.5	3.5	3.4	3.5
Zinc, mg/kg	92.6	87.7	83.1	78.8	71.2	70.8	70.1	70.4	71.4

Table 1–8. Concentrations of nutrients, carbon, and trace elements for bottom-sediment samples collected from coring site LM–2G in Lake Maxinkuckee, northern Indiana, May 2013.

[Shading indicates concentration greater than threshold-effects guideline listed in table 2. cm, centimeters; P, pre-development sediment; mg/kg, milligrams per kilogram; %, percent dry weight; <, less than]

Constituent and unit of measurement	Constituent concentration	
	Interval 1 60–70 cm, P	Interval 2 40–50 cm, P
Nutrients		
Total nitrogen, mg/kg	6,190	4,670
Total phosphorus, mg/kg	714	535
Carbon		
Carbon (total organic), %	17.9	9.3
Carbon (total), %	21.6	16.9
Trace elements		
Aluminum, mg/kg	17,600	8,520
Antimony, mg/kg	0.38	0.1
Arsenic, mg/kg	25.5	13
Barium, mg/kg	264	287
Beryllium, mg/kg	0.53	0.26
Bismuth, mg/kg	0.09	<0.06
Cadmium, mg/kg	0.44	0.16
Calcium, mg/kg	117,000	237,000
Cerium, mg/kg	19.4	10.7
Cesium, mg/kg	1.8	0.82
Chromium, mg/kg	19.6	9.6
Cobalt, mg/kg	5.9	2.5
Copper, mg/kg	17.5	9
Gallium, mg/kg	4.7	2.4
Iron, mg/kg	21,400	12,700
Lanthanum, mg/kg	9.6	5.4
Lead, mg/kg	8.67	4.65
Lithium, mg/kg	6.7	3.5
Magnesium, mg/kg	8,380	7,880
Manganese, mg/kg	354	588
Mercury, mg/kg	0.04	0.02
Molybdenum, mg/kg	16.1	5.8
Nickel, mg/kg	14.9	2
Niobium, mg/kg	2.6	1.5
Potassium, mg/kg	7,090	3,120
Rubidium, mg/kg	32.5	15.5
Scandium, mg/kg	3.5	1.7
Selenium, mg/kg	2.97	1.06
Silver, mg/kg	0.082	0.011
Sodium, mg/kg	1,460	806
Strontium, mg/kg	200	300
Sulfur, %	0.75	0.27
Thallium, mg/kg	0.29	0.13
Thorium, mg/kg	3.05	1.55
Titanium, mg/kg	746	403
Uranium, mg/kg	2.71	1.15
Vanadium, mg/kg	32.5	15.8
Yttrium, mg/kg	6.7	3.6
Zinc, mg/kg	62	26.6

Table 1–9. Concentrations of nutrients, carbon, and trace elements for bottom-sediment samples collected from coring site LM–3 in Lake Maxinkuckee, northern Indiana, May 2013.

[Shading indicates concentration greater than threshold-effects guideline listed in table 2. cm, centimeters; R, recent sediment; mg/kg, milligrams per kilogram; %, percent dry weight]

Constituent and unit of measurement	Constituent concentration							
	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8
	24–26 cm, R (bottom of core)	20–22 cm, R	16–18 cm, R	12–14 cm, R	8–10 cm, R	4–6 cm, R	2–4 cm, R	0–2 cm, R (top of core)
	Nutrients							
Total nitrogen, mg/kg	691	922	2,660	1,690	1,310	1,130	598	1,140
Total phosphorus, mg/kg	384	469	407	467	465	542	513	573
	Carbon							
Carbon (total organic), %	4.6	4.6	5	5.8	5.3	5.2	5.4	5.1
Carbon (total), %	9.82	11	11.2	11.3	11.9	11.8	12	11.7
	Trace elements							
Aluminum, mg/kg	24,900	20,900	18,800	18,800	17,800	17,600	17,600	17,200
Antimony, mg/kg	1.5	0.68	0.67	0.56	0.57	0.49	0.49	0.4
Arsenic, mg/kg	25.9	20.7	19.4	18.9	17.3	17.3	17.5	21.8
Barium, mg/kg	370	357	353	348	348	340	344	347
Beryllium, mg/kg	0.63	0.65	0.48	0.57	0.44	0.5	0.43	0.49
Bismuth, mg/kg	0.14	0.14	0.14	0.12	0.12	0.11	0.13	0.11
Cadmium, mg/kg	0.6	0.64	0.62	0.56	0.55	0.53	0.53	0.51
Calcium, mg/kg	149,000	195,000	185,000	203,000	193,000	206,000	193,000	208,000
Cerium, mg/kg	28.1	23.3	21.3	21.4	19.4	20.7	20.2	20.5
Cesium, mg/kg	2	1.6	1.5	1.5	1.4	1.4	1.4	1.3
Chromium, mg/kg	24.2	20.3	20.4	19	19.1	18.3	18.7	18.4
Cobalt, mg/kg	5.4	4.8	4.5	4.4	4.2	4.1	4.2	4.1
Copper, mg/kg	18.6	19.5	18.7	19.6	19.2	20.2	21.2	19.1
Gallium, mg/kg	6	5.1	4.8	4.7	4.4	4.4	4.3	4.4
Iron, mg/kg	16,500	13,900	12,800	13,300	12,300	12,700	12,200	13,100
Lanthanum, mg/kg	13.5	11.1	10.1	10.2	9.2	10	9.5	9.9
Lead, mg/kg	50.2	53.4	49.3	46.9	42.9	43.3	42.5	40.1
Lithium, mg/kg	9.6	9.9	6	9.9	4.2	9.5	6	8
Magnesium, mg/kg	10,300	11,100	10,400	11,000	10,300	10,800	10,100	10,600
Manganese, mg/kg	508	584	560	603	624	675	670	865
Mercury, mg/kg	0.11	0.09	0.09	0.09	0.09	0.08	0.09	0.07
Molybdenum, mg/kg	3.4	2.2	2.3	2.2	1.5	1.3	1.2	1
Nickel, mg/kg	12.1	7.2	8.1	6.4	7.2	5.9	7.4	5.9
Niobium, mg/kg	4	3.1	3	3.1	2.9	3	3.1	2.9
Potassium, mg/kg	10,100	7,610	7,660	6,970	7,130	6,530	7,020	6,460
Rubidium, mg/kg	41.6	34.1	31.8	31.6	30	30	29.5	29.4
Scandium, mg/kg	4.2	3.5	3.2	3.2	3	3.1	3	3
Selenium, mg/kg	1.28	1.28	1.43	1.27	1.41	1.26	1.4	1.24
Silver, mg/kg	0.258	0.249	0.27	0.216	0.262	0.274	0.266	0.205
Sodium, mg/kg	3,200	2,750	2,510	2,490	2,300	2,210	2,210	2,210
Strontium, mg/kg	226	269	269	279	276	285	280	293
Sulfur, %	0.55	0.48	0.53	0.48	0.34	0.38	0.26	0.24
Thallium, mg/kg	0.4	0.34	0.33	0.31	0.29	0.29	0.3	0.28
Thorium, mg/kg	3.93	3.11	2.97	2.83	2.66	2.75	2.8	2.66
Titanium, mg/kg	1,220	1,010	897	930	872	896	860	893
Uranium, mg/kg	1.99	1.77	1.71	1.74	1.59	1.49	1.36	1.16
Vanadium, mg/kg	35.8	30.2	29.3	28.3	27.2	26.1	27	26.3
Yttrium, mg/kg	8.4	7.2	6.8	6.7	6.4	6.4	6.4	6.3
Zinc, mg/kg	102	113	105	105	151	101	98.6	97.6

Table 1–10. Concentrations of nutrients, carbon, and trace elements for bottom-sediment samples collected from coring site LM–3G in Lake Maxinkuckee, northern Indiana, May 2013.

[Shading indicates concentration greater than threshold-effects guideline listed in table 2. cm, centimeters; P, predevelopment sediment; mg/kg, milligrams per kilogram; %, percent dry weight; <, less than]

Constituent and unit of measurement	Constituent concentration		
	Interval 1 70–80 cm, P	Interval 2 50–60 cm, P	Interval 3 30–40 cm, P
Nutrients			
Total nitrogen, mg/kg	2,640	2,730	2,160
Total phosphorus, mg/kg	555	486	462
Carbon			
Carbon (total organic), %	7.8	7	5.4
Carbon (total), %	13.5	12.8	12.3
Trace elements			
Aluminum, mg/kg	20,200	20,300	16,400
Antimony, mg/kg	0.2	0.2	0.1
Arsenic, mg/kg	10.3	8.9	8.3
Barium, mg/kg	329	332	325
Beryllium, mg/kg	0.54	0.49	0.42
Bismuth, mg/kg	<0.06	<0.06	<0.06
Cadmium, mg/kg	0.19	0.17	0.12
Calcium, mg/kg	175,000	159,000	208,000
Cerium, mg/kg	24.4	23.9	20.2
Cesium, mg/kg	1.7	1.6	1.3
Chromium, mg/kg	19.6	19.1	15.3
Cobalt, mg/kg	4.7	4.4	3.6
Copper, mg/kg	10.7	10.6	10.1
Gallium, mg/kg	4.8	4.7	4
Iron, mg/kg	12,400	11,700	10,600
Lanthanum, mg/kg	11.8	11.4	9.5
Lead, mg/kg	8.89	9.4	8.01
Lithium, mg/kg	10	5.9	7.7
Magnesium, mg/kg	12,400	11,900	12,400
Manganese, mg/kg	444	446	553
Mercury, mg/kg	0.02	0.02	0.02
Molybdenum, mg/kg	6.5	5.8	3.8
Nickel, mg/kg	8.1	8.6	4.4
Niobium, mg/kg	3.1	3.1	2.5
Potassium, mg/kg	8,210	8,870	6,630
Rubidium, mg/kg	34.7	33.8	28.2
Scandium, mg/kg	3.6	3.6	3
Selenium, mg/kg	1.02	0.86	0.62
Silver, mg/kg	0.042	0.093	0.039
Sodium, mg/kg	2,560	2,810	2,290
Strontium, mg/kg	247	226	265
Sulfur, %	0.35	0.31	0.21
Thallium, mg/kg	0.25	0.26	0.2
Thorium, mg/kg	3.31	3.38	2.63
Titanium, mg/kg	946	948	782
Uranium, mg/kg	1.88	1.44	1.18
Vanadium, mg/kg	27.9	27.7	22.3
Yttrium, mg/kg	7.2	7.4	6.1
Zinc, mg/kg	45.9	43.6	36.6

Table 1–11. Concentrations of nutrients, carbon, and trace elements for bottom-sediment samples collected from coring site LM–4 in Lake Maxinkuckee, northern Indiana, May 2013.

[Shading indicates concentration greater than threshold-effects guideline listed in table 2. cm, centimeters; R, recent sediment; mg/kg, milligrams per kilogram; --, not available; %, percent dry weight; <, less than]

Constituent and unit of measurement	Constituent concentration								
	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
	28–30 cm, R (bottom of core)	24–26 cm, R	20–22 cm, R	16–18 cm, R	12–14 cm, R	8–10 cm, R	4–6 cm, R	2–4 cm, R	0–2 cm, R (top of core)
Nutrients									
Total nitrogen, mg/kg	--	891	1,580	2,240	1,510	1,430	1,690	1,310	1,100
Total phosphorus, mg/kg	440	448	422	448	563	471	528	571	575
Carbon									
Carbon (total organic), %	5.1	4.9	4.6	4.8	5	4.8	5	5.1	5.3
Carbon (total), %	12.3	12.4	12.5	12.8	13	12.9	13.2	13.3	13.3
Trace elements									
Aluminum, mg/kg	15,600	14,800	12,500	11,900	13,700	9,820	9,350	9,310	9,550
Antimony, mg/kg	1.2	0.99	0.71	0.52	0.65	0.31	0.39	0.56	0.4
Arsenic, mg/kg	32.1	28.9	22.2	21.1	19.4	18.5	16.6	16.1	16
Barium, mg/kg	345	340	337	332	368	324	321	320	331
Beryllium, mg/kg	0.52	0.55	0.4	0.39	0.44	0.33	0.25	0.29	0.23
Bismuth, mg/kg	0.26	0.18	0.13	0.11	0.12	0.09	0.09	0.08	0.09
Cadmium, mg/kg	0.84	0.71	0.55	0.49	0.46	0.36	0.34	0.32	0.32
Calcium, mg/kg	215,000	233,000	230,000	252,000	308,000	255,000	240,000	247,000	240,000
Cerium, mg/kg	17	18.2	14.8	14.4	13.6	12.1	11.1	11.5	10.7
Cesium, mg/kg	1.4	1.3	1.2	1.1	1	0.89	0.82	0.83	0.86
Chromium, mg/kg	17.2	15.6	14.1	13.2	14.1	11.2	11.3	10.6	11.2
Cobalt, mg/kg	3.7	3.3	3	2.9	2.9	2.4	2.3	2.4	2.4
Copper, mg/kg	16.5	17.7	15	14.9	17.1	14.4	13.3	14.5	14.3
Gallium, mg/kg	4.2	3.9	3.3	3.2	3.2	2.7	2.6	2.6	2.5
Iron, mg/kg	13,300	12,500	11,100	10,800	11,900	9,770	9,300	9,570	9,360
Lanthanum, mg/kg	8.2	8.3	6.8	7	6.7	6	5.3	5.6	5.2
Lead, mg/kg	60	59.1	46.7	43.9	37.3	29.7	25.4	25.3	24.6
Lithium, mg/kg	4.6	9.5	3.3	7.5	7.8	7	1.2	4.8	<0.3
Magnesium, mg/kg	8,430	8,940	8,380	8,870	11,000	8,970	8,370	8,740	8,430
Manganese, mg/kg	607	622	599	656	771	659	644	675	692
Mercury, mg/kg	0.08	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.05
Molybdenum, mg/kg	5.3	5.1	4.3	4	3.5	4.1	3.7	3.4	2.8
Nickel, mg/kg	7.9	5.2	5.8	3.7	3.8	2.4	3.3	2.2	4.1
Niobium, mg/kg	2.5	3.4	2	2	1.8	1.6	1.5	1.6	1.5
Potassium, mg/kg	5,590	4,870	4,640	4,100	4,680	3,450	3,680	3,260	3,680
Rubidium, mg/kg	26.6	25.3	21.9	21.2	20	17.4	16.5	16.4	16.3
Scandium, mg/kg	2.9	2.7	2.4	2.3	2.1	1.8	1.8	1.8	1.8
Selenium, mg/kg	1.61	1.51	1.47	1.4	1.4	1.35	1.45	1.37	1.43
Silver, mg/kg	0.264	0.175	0.122	0.09	0.099	0.071	0.091	0.062	0.084
Sodium, mg/kg	1,330	1,300	1,120	1,090	1,230	979	916	967	960
Strontium, mg/kg	302	312	320	346	373	365	347	362	351
Sulfur, %	0.82	0.59	0.6	0.53	0.58	0.6	0.57	0.54	0.53
Thallium, mg/kg	0.4	0.34	0.24	0.21	0.2	0.18	0.18	0.15	0.17
Thorium, mg/kg	2.6	2.4	2.02	1.85	1.84	1.58	1.59	1.5	1.52
Titanium, mg/kg	680	723	566	569	590	471	427	455	425
Uranium, mg/kg	1.98	2.03	1.66	1.64	1.46	1.43	1.4	1.35	1.27
Vanadium, mg/kg	27.2	25.8	22.7	21.6	21.8	17.6	17.3	16.9	17.2
Yttrium, mg/kg	5.5	5.1	4.6	4.4	4.1	3.8	3.6	3.6	3.6
Zinc, mg/kg	101	95.6	78.7	76.4	73.2	63.5	60.9	60.7	59.6

Table 1–12. Concentrations of nutrients, carbon, and trace elements for bottom-sediment samples collected from coring site LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

[Shading indicates concentration greater than threshold-effects guideline listed in table 2. cm, centimeters; R, recent sediment; mg/kg, milligrams per kilogram; --, not available; %, percent dry weight; <, less than]

Constituent and unit of measurement	Constituent concentration					
	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6
	16–18 cm, R (bottom of core)	12–14 cm, R	8–10 cm, R	4–6 cm, R	2–4 cm, R	0–2 cm, R (top of core)
Nutrients						
Total nitrogen, mg/kg	--	844	2,400	1,920	--	1,320
Total phosphorus, mg/kg	510	499	485	539	477	582
Carbon						
Carbon (total organic), %	5.1	5.3	5.4	5.5	5.6	5.4
Carbon (total), %	13.4	13.6	13.7	13.8	14	13.7
Trace elements						
Aluminum, mg/kg	10,800	9,540	9,410	9,250	8,590	9,350
Antimony, mg/kg	0.39	0.36	0.4	0.32	0.39	0.33
Arsenic, mg/kg	16.7	14.9	13.2	13.7	13.6	20.5
Barium, mg/kg	339	319	326	324	311	336
Beryllium, mg/kg	0.27	0.28	0.26	0.29	0.21	0.29
Bismuth, mg/kg	0.09	0.07	0.08	0.07	0.08	0.09
Cadmium, mg/kg	0.39	0.34	0.36	0.34	0.33	0.35
Calcium, mg/kg	305,000	258,000	246,000	259,000	234,000	262,000
Cerium, mg/kg	11.4	11.5	10.5	10.7	10.2	11.2
Cesium, mg/kg	0.86	0.8	0.86	0.78	0.77	0.82
Chromium, mg/kg	11.9	10.4	10.9	10.7	10.2	10.6
Cobalt, mg/kg	2.3	2.2	2.3	2.1	2.1	2.3
Copper, mg/kg	14.1	12.6	12.9	12.9	15.4	13.6
Gallium, mg/kg	2.5	2.4	2.4	2.4	2.1	2.4
Iron, mg/kg	9,170	8,680	8,820	8,680	8,230	9,410
Lanthanum, mg/kg	5.6	5.5	5.2	5.4	5	5.4
Lead, mg/kg	28.4	26.1	25.4	24.2	23	24.3
Lithium, mg/kg	7.4	6.5	1.8	5.7	1.8	5.7
Magnesium, mg/kg	9,590	9,060	8,450	8,890	7,970	9,070
Manganese, mg/kg	727	681	668	748	762	912
Mercury, mg/kg	0.05	0.05	0.05	0.04	0.05	0.04
Molybdenum, mg/kg	2.7	2.1	1.6	1.5	1.1	1.1
Nickel, mg/kg	<0.3	1.8	4.2	1.7	3.8	1.7
Niobium, mg/kg	1.6	1.6	1.6	1.6	1.5	1.6
Potassium, mg/kg	3,760	3,360	3,590	3,300	3,310	3,340
Rubidium, mg/kg	16.8	16.1	15.8	15.7	14.5	15.9
Scandium, mg/kg	2	1.7	1.8	1.7	1.6	1.8
Selenium, mg/kg	1.41	1.33	1.44	1.32	1.42	1.33
Silver, mg/kg	0.088	0.055	0.089	0.056	0.099	0.063
Sodium, mg/kg	1,080	1,030	1,000	1,020	913	1,070
Strontium, mg/kg	363	347	333	338	315	354
Sulfur, %	0.54	0.44	0.35	0.41	0.37	0.22
Thallium, mg/kg	0.18	0.17	0.17	0.17	0.16	0.17
Thorium, mg/kg	1.57	1.57	1.52	1.39	1.44	1.53
Titanium, mg/kg	547	455	423	446	415	485
Uranium, mg/kg	1.35	1.33	1.08	1.07	0.84	0.85
Vanadium, mg/kg	18	15.9	16.2	15	14.9	15.9
Yttrium, mg/kg	3.7	3.6	3.6	3.5	3.3	3.6
Zinc, mg/kg	66.7	61.1	60.2	60.4	57	63.3

Table 1–13. Concentrations of nutrients, carbon, and trace elements for bottom-sediment samples collected from coring site LM–6G in Lake Maxinkuckee, northern Indiana, May 2013.

[Shading indicates concentration greater than threshold-effects guideline listed in table 2. cm, centimeters; P, predevelopment sediment; R, recent sediment; mg/kg, milligrams per kilogram; %, percent dry weight; <, less than]

Constituent and unit of measurement	Constituent concentration		
	Interval 1 80–90 cm, P	Interval 2 60–70 cm, P	Interval 3 40–50 cm, R
Nutrients			
Total nitrogen, mg/kg	1,590	1,010	1,460
Total phosphorus, mg/kg	1,090	734	585
Carbon			
Carbon (total organic), %	11.6	7.7	5.9
Carbon (total), %	15.5	14.2	11.1
Trace elements			
Aluminum, mg/kg	13,600	12,200	22,700
Antimony, mg/kg	0.22	0.2	1.4
Arsenic, mg/kg	28.8	18.4	29.9
Barium, mg/kg	262	306	362
Beryllium, mg/kg	0.42	0.38	0.72
Bismuth, mg/kg	0.06	<0.06	0.21
Cadmium, mg/kg	0.19	0.19	1.1
Calcium, mg/kg	124,000	204,000	151,000
Cerium, mg/kg	15.2	14.3	24.3
Cesium, mg/kg	1.3	1.1	2
Chromium, mg/kg	14.3	12.1	22.5
Cobalt, mg/kg	4.1	3.4	5.1
Copper, mg/kg	13.2	10.7	20.6
Gallium, mg/kg	3.5	3.1	5.7
Iron, mg/kg	60,600	28,200	19,500
Lanthanum, mg/kg	7.4	7	11.3
Lead, mg/kg	7.06	8.7	68.6
Lithium, mg/kg	4.1	6.9	10.2
Magnesium, mg/kg	7,280	8,820	8,200
Manganese, mg/kg	823	697	537
Mercury, mg/kg	0.03	0.03	0.12
Molybdenum, mg/kg	8.1	4.7	8.1
Nickel, mg/kg	9	4.9	11.8
Niobium, mg/kg	1.9	1.8	3.4
Potassium, mg/kg	5,300	4,260	7,960
Rubidium, mg/kg	23.2	20.6	36.7
Scandium, mg/kg	2.6	2.3	4
Selenium, mg/kg	1.66	1.19	2
Silver, mg/kg	0.059	0.018	0.236
Sodium, mg/kg	1,200	1,180	1,910
Strontium, mg/kg	176	257	232
Sulfur, %	0.6	0.38	1.22
Thallium, mg/kg	0.22	0.18	0.48
Thorium, mg/kg	2.23	1.9	3.53
Titanium, mg/kg	545	536	977
Uranium, mg/kg	1.51	1.23	2.31
Vanadium, mg/kg	24.5	20.9	36.3
Yttrium, mg/kg	5.1	4.5	7
Zinc, mg/kg	49.3	37.2	130

Table 1–14. Abundant diatom species in bottom-sediment samples collected from coring site LM–1 in Lake Maxinkuckee, northern Indiana, May 2013.

[cm, centimeters; R, recent sediment]

Diatom species	Diatom count								
	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
	28–30 cm, R (bottom of core)	24–26 cm, R	20–22 cm, R	16–18 cm, R	12–14 cm, R	8–10 cm, R	4–6 cm, R	2–4 cm, R	0–2 cm, R (top of core)
Achnanthidium minutissimum	44	51	40	48	40	44	42	54	86
Amphora ovalis	8	2	11	6	10	1	3	3	0
Asterionella formosa	33	79	51	91	33	24	26	36	100
Aulacoseira ambigua	87	52	95	65	27	61	41	32	18
Cyclotella bodanica	12	9	19	18	29	27	37	45	27
Cyclotella ocellata	6	9	53	104	188	163	198	221	106
Cyclotella pseudostelligera	49	76	35	22	13	10	15	9	0
Fragilaria crotonensis	202	232	163	99	83	72	68	75	32
Pseudostaurosira brevistriata	25	48	28	24	24	29	49	23	18
Staurosira construens	0	1	0	3	2	1	3	7	0
Staurosira construens var. *venter*	11	4	8	19	16	30	26	21	3
Staurosirella pinnata	27	12	14	7	22	4	20	7	14
Synedra demerarae	0	10	5	6	7	9	9	28	16

Table 1–15. Abundant diatom species in bottom-sediment samples collected from coring site LM–1G in Lake Maxinkuckee, northern Indiana, May 2013.

[cm, centimeters; P, predevelopment sediment]

Diatom species	Diatom count	
	Interval 1 70–80 cm, P	Interval 2 50–60 cm, P
Achnanthidium minutissimum	12	7
Amphora ovalis	1	6
Asterionella formosa	13	15
Aulacoseira ambigua	0	58
Cyclotella bodanica	251	341
Cyclotella ocellata	0	0
Cyclotella pseudostelligera	58	11
Fragilaria crotonensis	52	22
Pseudostaurosira brevistriata	1	3
Staurosira construens	5	0
Staurosira construens var. *venter*	5	1
Staurosirella pinnata	5	7
Synedra demerarae	1	2

Table 1–16. Abundant diatom species in bottom-sediment samples collected from coring site LM–2 in Lake Maxinkuckee, northern Indiana, May 2013.

[cm, centimeters; R, recent sediment]

Diatom species	Diatom count								
	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
	28–30 cm, R (bottom of core)	24–26 cm, R	20–22 cm, R	16–18 cm, R	12–14 cm, R	8–10 cm, R	4–6 cm, R	2–4 cm, R	0–2 cm, R (top of core)
Achnanthidium minutissimum	42	33	32	39	58	51	53	65	54
Amphora ovalis	13	24	33	21	17	20	14	24	17
Asterionella formosa	11	13	16	15	14	23	30	71	114
Aulacoseira ambigua	165	119	122	46	28	29	32	20	28
Cyclotella bodanica	37	28	20	25	39	24	27	27	31
Cyclotella ocellata	11	16	38	52	107	104	160	129	91
Cyclotella pseudostelligera	2	15	0	6	5	3	1	7	2
Fragilaria crotonensis	14	28	12	17	12	32	48	11	43
Pseudostaurosira brevistriata	143	116	117	124	89	86	68	72	37
Staurosira construens	17	29	12	18	35	20	22	0	7
Staurosira construens var. *venter*	43	79	110	119	69	83	62	59	62
Staurosirella pinnata	36	69	18	23	20	21	50	27	9
Synedra demerarae	0	13	3	1	23	24	18	24	21

Table 1–17. Abundant diatom species in bottom-sediment samples collected from coring site LM–2G in Lake Maxinkuckee, northern Indiana, May 2013.

[cm, centimeters; P, predevelopment sediment]

Diatom species	Diatom count	
	Interval 1 60–70 cm, P	Interval 2 40–50 cm, P
Achnanthidium minutissimum	0	0
Amphora ovalis	0	0
Asterionella formosa	0	0
Aulacoseira ambigua	0	1
Cyclotella bodanica	213	9
Cyclotella ocellata	0	0
Cyclotella pseudostelligera	0	1
Fragilaria crotonensis	0	0
Pseudostaurosira brevistriata	8	1
Staurosira construens	0	0
Staurosira construens var. *venter*	0	0
Staurosirella pinnata	3	0
Synedra demerarae	0	0

Table 1–18. Abundant diatom species in bottom-sediment samples collected from coring site LM–3 in Lake Maxinkuckee, northern Indiana, May 2013.

[cm, centimeters; R, recent sediment]

Diatom species	Diatom count							
	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8
	24–26 cm, R (bottom of core)	20–22 cm, R	16–18 cm, R	12–14 cm, R	8–10 cm, R	4–6 cm, R	2–4 cm, R	0–2 cm, R (top of core)
Achnanthidium minutissimum	34	60	70	58	64	55	59	76
Amphora ovalis	69	51	45	43	43	29	24	27
Asterionella formosa	1	1	2	8	11	6	27	95
Aulacoseira ambigua	36	16	21	6	9	10	8	9
Cyclotella bodanica	16	11	25	21	22	16	28	16
Cyclotella ocellata	9	7	10	29	37	62	50	32
Cyclotella pseudostelligera	1	0	3	1	2	1	0	0
Fragilaria crotonensis	0	3	4	5	9	13	7	19
Pseudostaurosira brevistriata	190	177	174	177	125	144	141	101
Staurosira construens	41	47	55	36	76	78	51	21
Staurosira construens var. *venter*	109	122	110	109	129	97	98	42
Staurosirella pinnata	34	55	47	43	33	51	25	28
Synedra demerarae	5	4	0	1	4	4	4	7

Table 1–19. Abundant diatom species in bottom-sediment samples collected from coring site LM–3G in Lake Maxinkuckee, northern Indiana, May 2013.

[cm, centimeters; P, predevelopment sediment]

Diatom species	Diatom count		
	Interval 1 70–80 cm, P	Interval 2 50–60 cm, P	Interval 3 30–40 cm, P
Achnanthidium minutissimum	0	0	0
Amphora ovalis	0	0	2
Asterionella formosa	0	0	0
Aulacoseira ambigua	0	0	0
Cyclotella bodanica	13	5	9
Cyclotella ocellata	0	0	0
Cyclotella pseudostelligera	0	1	0
Fragilaria crotonensis	0	0	0
Pseudostaurosira brevistriata	0	0	1
Staurosira construens	0	0	2
Staurosira construens var. *venter*	0	0	4
Staurosirella pinnata	2	0	5
Synedra demerarae	0	0	1

Table 1–20. Abundant diatom species in bottom-sediment samples collected from coring site LM–4 in Lake Maxinkuckee, northern Indiana, May 2013.

[cm, centimeters; R, recent sediment]

Diatom species	Diatom count								
	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6	Interval 7	Interval 8	Interval 9
	28–30 cm, R (bottom of core)	24–26 cm, R	20–22 cm, R	16–18 cm, R	12–14 cm, R	8–10 cm, R	4–6 cm, R	2–4 cm, R	0–2 cm, R (top of core)
Achnanthidium minutissimum	68	38	47	49	53	53	45	49	61
Amphora ovalis	22	24	18	24	21	12	15	17	13
Asterionella formosa	83	70	42	29	25	13	35	53	76
Aulacoseira ambigua	92	113	95	84	34	26	39	28	28
Cyclotella bodanica	33	34	23	43	31	45	58	42	55
Cyclotella ocellata	9	14	33	53	145	141	170	178	143
Cyclotella pseudostelligera	10	17	24	18	20	7	9	6	2
Fragilaria crotonensis	84	111	101	40	42	27	50	19	14
Pseudostaurosira brevistriata	31	59	63	101	78	108	113	73	98
Staurosira construens	19	16	33	20	4	44	37	11	9
Staurosira construens var. *venter*	18	40	56	67	74	63	17	47	24
Staurosirella pinnata	18	14	14	13	28	11	19	22	20
Synedra demerarae	4	8	11	11	4	0	13	16	4

Table 1–21. Abundant diatom species in bottom-sediment samples collected from coring site LM–5 in Lake Maxinkuckee, northern Indiana, May 2013.

[cm, centimeters; R, recent sediment]

Diatom species	Diatom count					
	Interval 1	Interval 2	Interval 3	Interval 4	Interval 5	Interval 6
	16–18 cm, R (bottom of core)	12–14 cm, R	8–10 cm, R	4–6 cm, R	2–4 cm, R	0–2 cm, R (top of core)
Achnanthidium minutissimum	65	51	57	75	68	112
Amphora ovalis	48	22	29	22	14	37
Asterionella formosa	5	4	18	13	25	90
Aulacoseira ambigua	18	7	21	26	7	10
Cyclotella bodanica	21	44	30	33	33	18
Cyclotella ocellata	3	78	89	124	87	54
Cyclotella pseudostelligera	5	2	4	1	5	7
Fragilaria crotonensis	6	12	10	20	17	15
Pseudostaurosira brevistriata	93	156	123	132	127	123
Staurosira construens	12	32	21	17	23	7
Staurosira construens var. *venter*	100	122	126	70	81	86
Staurosirella pinnata	46	23	14	19	34	15
Synedra demerarae	7	9	10	15	4	15

Table 1–22. Abundant diatom species in bottom-sediment samples collected from coring site LM–6G in Lake Maxinkuckee, northern Indiana, May 2013.

[cm, centimeters; P, predevelopment sediment; R, recent sediment]

Diatom species	Diatom count		
	Interval 1 80–90 cm, P	Interval 2 60–70 cm, P	Interval 3 40–50 cm, R
Achnanthidium minutissimum	13	12	31
Amphora ovalis	0	13	9
Asterionella formosa	8	13	78
Aulacoseira ambigua	27	24	246
Cyclotella bodanica	293	265	24
Cyclotella ocellata	0	0	9
Cyclotella pseudostelligera	7	4	10
Fragilaria crotonensis	66	14	102
Pseudostaurosira brevistriata	1	2	6
Staurosira construens	0	6	0
Staurosira construens var. *venter*	0	4	4
Staurosirella pinnata	2	2	2
Synedra demerarae	1	0	3

Table 1–23. Rare diatom species in bottom-sediment samples collected from Lake Maxinkuckee, northern Indiana, May 2013.

Achnanthes laevis
Achnanthes lemmermannii
Achnanthes rosenstockii
Achnanthes suchlandtii
Achnanthidium exiguum
Achnanthidium microcephalum
Adlafia miniscula
Amphipleura pellucida
Amphora pediculus
Amphora thumensis
Amphora sp.
Aneumastus tusculus
Aulacoseira distans
Aulacoseira distans var. *nivaloides*
Aulacoseira granulata
Brachysira styriaca
Brachysira vitrea
Caloneis bacillum
Caloneis ventricosa
Caloneis sp.
Cavinula scutelloides
Cocconeis neothumensis
Cocconeis pediculus
Cocconeis placentula var. *lineata*
Craticula cuspidata
Ctenophora pulchella
Cyclostephanos dubius
Cyclotella comensis
Cyclotella hakanssoniae
Cyclotella meneghiniana
Cyclotella michiganiana
Cyclotella stelligera
Cymatopleura solea
Cymbella affinis
Cymbella amphicephala
Cymbella aspera
Cymbella cistula
Cymbella cuspidata
Cymbella cymbiformis
Cymbella delicatula
Cymbella descripta
Cymbella ehrenbergii
Cymbella gaeumannii
Cymbella heteropleura
Cymbella microcephala
Cymbella perpusilla
Cymbella subaequalis
Cymbella tumidula
Cymbella sp.
Cymbopleura naviculiformis
Denticula kuetzingii
Denticula subtilis
Diatoma ehrenbergii
Diatoma tenuis var. *elongatum*
Diatoma vulgare
Diploneis minuta
Diploneis petersenii
Diploneis puella
Encyonema caespitosum
Encyonema silesiacum
Encyonopsis cesatii
Entomoneis ornata
Eolimna minima
Epithemia adnata
Epithemia argus
Epithemia sorex
Eucocconeis flexella
Eucocconeis flexella var. *alpestris*
Eunotia arcus
Eunotia bilunaris
Eunotia monodontiforma
Eunotia pectinalis
Fragilaria capucina
Fragilaria capucina var. *mesolepta*
Fragilaria vaucheriae
Fragilariforma virescens
Frustulia rhomboides
Geissleria decussis
Gomphoneis olivacea
Gomphonema acuminatum
Gomphonema angustatum
Gomphonema clavatum
Gomphonema gracile
Gomphonema minutum
Gomphonema parvulum
Gomphonema pumilum
Gomphonema truncatum
Gomphonema sp.
Gyrosigma acuminatum
Hantzschia amphioxys
Hippodonta capitata
Karayevia clevei
Kobayasia subtilissima
Mastogloia smithii
Melosira varians
Navicula agrestis
Navicula angusta
Navicula capitatoradiata
Navicula cincta
Navicula cryptocephala
Navicula cryptotenella
Navicula goeppertiana
Navicula gregaria
Navicula humerosa
Navicula lenzii
Navicula menisculus
Navicula oblonga
Navicula porifera
Navicula pseudanglica
Navicula pseudolanceolata
Navicula pseudotuscula
Navicula radiosa
Navicula rhynchocephala
Navicula schadei
Navicula stroemii
Navicula cf. *sublucidula*
Navicula subplacentula
Navicula tridentula
Navicula trivialis
Navicula veneta
Navicula viridula
Navicula sp.
Navicymbula pusilla
Neidium ampliatum
Neidium iridis
Nitzschia acicularis
Nitzschia amphibia
Nitzschia clausii
Nitzschia dissipata
Nitzschia fonticola
Nitzschia frustulum
Nitzschia gracilis
Nitzschia heufleriana
Nitzschia linearis
Nitzschia palea
Nitzschia paleacae
Nitzschia perminuta
Nitzschia recta
Nitzschia subacicularis
Pinnularia maior
Pinnularia microstauron
Pinnularia microstauron var. *adirondackensis*
Pinnularia viridis
Pinnularia sp.
Placoneis clementioides
Placoneis clementis
Planothidium delicatulum
Planothidium lanceolatum
Psammothidium bioretti
Pseudostaurosira construens var. *binodis*
Reimeria sinuata
Rhoicosphenia abbreviata
Rhopalodia gibba
Sellaphora mutata
Stauroneis smithii
Staurosirella lapponica
Staurosirella leptostauron
Stephanodiscus alpinus
Stephanodiscus minutulus
Stephanodiscus niagarae
Stephanodiscus parvus
Striatella flocculosa
Surirella angusta
Surirella biseriata var. *bifrons f. amphioxys*
Surirella patella
Surirella sp.
Synedra filiformis
Synedra filiformis var. *exilis*
Synedra ostenfeldii
Synedra parasitica
Synedra radians
Synedra rumpens
Synedra ulna
Synedra ulna var. *biceps*
Tryblionella angustata

Table 1–24. Cyanobacterial akinetes in bottom-sediment samples collected from Lake Maxinkuckee, northern Indiana, May 2013.

[cm, centimeters; R, recent sediment; %, percent; P, predevelopment sediment]

Coring site number[1] (fig. 2)	Depth interval (cm)	Number (relative percentage abundance) of cyanobacterial akinetes[2]		
		Gloeotrichia echinulata	***Anabaena***	***Aphanizomenon***
LM–1	0–2 (R)	40,700 (68%)	18,700 (31%)	550 (1%)
	2–4 (R)	45,000 (69%)	19,200 (30%)	437 (1%)
	4–6 (R)	75,900 (90%)	7,370 (9%)	567 (1%)
	8–10 (R)	103,000 (94%)	6,840 (6%)	0 (0%)
	12–14 (R)	100,000 (89%)	10,100 (9%)	1,840 (2%)
	16–18 (R)	93,800 (90%)	10,000 (9%)	910 (1%)
	20–22 (R)	74,800 (91%)	7,090 (9%)	0 (0%)
	24–26 (R)	92,000 (89%)	11,300 (11%)	0 (0%)
	28–30 (R)	74,200 (85%)	12,800 (15%)	0 (0%)
LM–1G	50–60 (P)	113,000 (91%)	11,600 (9%)	0 (0%)
	70–80 (P)	118,000 (93%)	8,810 (7%)	0 (0%)
LM–2	0–2 (R)	38,700 (87%)	5,180 (12%)	345 (1%)
	2–4 (R)	51,600 (91%)	4,300 (8%)	614 (1%)
	4–6 (R)	62,000 (91%)	5,240 (8%)	437 (1%)
	8–10 (R)	104,000 (94%)	6,110 (6%)	0 (0%)
	12–14 (R)	173,000 (95%)	8,960 (5%)	0 (0%)
	16–18 (R)	125,000 (87%)	17,300 (12%)	825 (1%)
	20–22 (R)	332,000 (92%)	27,000 (8%)	0 (0%)
	24–26 (R)	236,000 (97%)	8,130 (3%)	0 (0%)
	28–30 (R)	175,000 (92%)	14,000 (7%)	1,080 (1%)
LM–2G	40–50 (P)	146,000 (95%)	7,520 (5%)	0 (0%)
	60–70 (P)	126,000 (95%)	4,580 (3%)	2,290 (2%)
LM–3	0–2 (R)	47,500 (88%)	5,130 (10%)	1,030 (2%)
	2–4 (R)	85,800 (94%)	4,210 (5%)	1,050 (1%)
	4–6 (R)	75,000 (95%)	3,260 (4%)	466 (1%)
	8–10 (R)	60,200 (92%)	4,330 (6%)	1,180 (2%)
	12–14 (R)	77,600 (90%)	7,810 (9%)	1,040 (1%)
	16–18 (R)	48,400 (83%)	8,000 (14%)	1,910 (3%)
	20–22 (R)	78,300 (90%)	7,460 (9%)	1,060 (1%)
	24–26 (R)	91,400 (91%)	9,410 (9%)	0 (0%)
LM–3G	30–40 (P)	114,000 (96%)	1,380 (1%)	3,450 (3%)
	50–60 (P)	137,000 (96%)	5,850 (4%)	0 (0%)
	70–80 (P)	197,000 (96%)	6,340 (3%)	1,270 (1%)

Table 1–24. Cyanobacterial akinetes in bottom-sediment samples collected from Lake Maxinkuckee, northern Indiana, May 2013.—Continued

[cm, centimeters; R, recent sediment; %, percent; P, predevelopment sediment]

Coring site number[1] (fig. 2)	**Depth interval (cm)**	**Number (relative percentage abundance) of cyanobacterial akinetes[2]**		
		Gloeotrichia echinulata	***Anabaena***	***Aphanizomenon***
LM–4	0–2 (R)	30,000 (87%)	3,220 (9%)	1,490 (4%)
	2–4 (R)	57,900 (94%)	2,910 (5%)	728 (1%)
	4–6 (R)	62,000 (87%)	3,190 (4%)	6,380 (9%)
	8–10 (R)	114,000 (78%)	29,000 (20%)	3,310 (2%)
	12–14 (R)	91,900 (93%)	5,590 (6%)	1,240 (1%)
	16–18 (R)	95,500 (86%)	13,900 (13%)	1,460 (1%)
	20–22 (R)	62,100 (80%)	8,870 (12%)	6,500 (8%)
	24–26 (R)	92,800 (80%)	17,100 (15%)	5,940 (5%)
	28–30 (R)	95,800 (91%)	7,590 (7%)	1,900 (2%)
LM–5	0–2 (R)	24,100 (81%)	4,960 (17%)	709 (2%)
	2–4 (R)	58,900 (91%)	5,030 (8%)	457 (1%)
	4–6 (R)	81,400 (96%)	2,940 (3%)	490 (1%)
	8–10 (R)	56,200 (93%)	2,250 (4%)	1,690 (3%)
	12–14 (R)	58,400 (92%)	4,170 (7%)	596 (1%)
	16–18 (R)	59,100 (90%)	4,400 (7%)	1,890 (3%)
LM–6G	40–50 (R)	88,400 (83%)	12,600 (12%)	5,200 (5%)
	60–70 (P)	88,200 (79%)	19,600 (17%)	4,200 (4%)
	80–90 (P)	91,300 (94%)	4,800 (5%)	1,370 (1%)

[1] Coring site numbers ending in “G” indicate a gravity core. Other coring site numbers indicate a box core.

[2] For each depth interval, the relative percentage abundances were rounded to sum to 100 percent.

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