STATE OF MICHIGAN
DEPARTMENT OF NATURAL RESOURCES

Number 2004-2 December 2004

Compilation of Databases on Michigan Lakes

James E. Breck

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FISHERIES DIVISION
TECHNICAL REPORT

MICHIGAN DEPARTMENT OF NATURAL RESOURCES
FISHERIES DIVISION

Fisheries Technical Report 2004-2
December 2004

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Printed under authority of Michigan Department of Natural Resources
Total number of copies printed 165 — Total cost $717.97 — Cost per copy $4.35

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Michigan Department of Natural Resources
Fisheries Technical Report 2004-02, 2004

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Abstract.–In order to do the best job of fisheries management, fisheries biologists need ready access to relevant information. This report describes databases that have recently been compiled and progress in making the information more available to fisheries biologists through development of relational databases and a geographic information system (GIS). The following 14 datasets have been converted to relational database tables: water bodies from the Michigan lake inventory of Humphrys and Green (N = 32,121); Michigan coldwater lakes (N = 1,345); names of Michigan lakes appearing on U.S. Geological Survey topographic maps (N = 6,904); water quality data for lakes with a public access site and a surface area of at least 50 acres (N = 730); Schneider's compilation of lake morphology and water quality (N = 387); Schneider's compilation of Lower Peninsula lakes sampled for fishes with large seines (N = 229); lake characteristics from Fusilier's atlas and gazetteer of Michigan lakes (N = 297); lakes sampled in the Michigamme Project (N = 66); watershed area and perimeter for natural lakes at least 100 acres in area (N = 831 individual lakes and 40 multi-lake groups); names of Michigan lakes sampled as part of the U.S. Environmental Protection Agency's National Acid Precipitation Assessment Program (N = 172); list of reports published by Fisheries Division as research, technical, special, and status of the fishery resource reports (N = 2,404); public boat launch sites on inland lakes (N = 920); Laarman's compilation of fish length at age (N = 26,086 records representing 1,135 lakes and 18 species); and names of inland lakes with angler creel survey data (N = 183 lakes, N = 596 lake-year combinations). Metadata were prepared for these data sets. One critical task in this project was assigning a unique lake code to items in various data sets so that multiple sources of information about particular lakes could be linked. Another critical task was assigning the unique lake code to GIS lake points and polygons so that values from various data sets could be displayed as maps. This compilation of databases also contains a collection of digital images of lake maps. Over 160 lake maps have now been converted for use in GIS analyses and for calculation of lake volume and mean depth. These compiled data sets can now be used in the development of decision-support tools for lake and fisheries management, such as estimation of lake fetch and thermocline depth and estimation of walleye population characteristics from lake variables.

In order to do the best job of fisheries management, fish biologists need ready access to relevant information. Much useful information on Michigan lakes has been collected by various workers under different studies for a variety of purposes, however such information is contained in multiple documents, some of which are not widely available (e.g., Miller and Thompson 1970; Marsh and Borton 1974; Fusilier and Fusilier 1994). Some publications contain only summaries of certain lake data; for example, Hooper (1956) presented a histogram of the methyl orange alkalinities for 241 southern Michigan lakes but did not include the data for individual lakes. Several large data sets (from 66 to >800 lakes) are in electronic form, but are in different formats, making it difficult to extract data from them. Lake maps with depth contours have recently become available in electronic form as images of maps, but the area within each contour interval has not been measured. As used in this report, the term "lake" may include ponds and other types of standing water. This report describes the compilation of multiple lake databases and the progress in making the information more available to fisheries biologists using relational databases and geographic information systems (GIS).

Methods

Unique Lake Code for Linking Data Sets

The first step in the process of compiling databases was to determine the feasibility of linking data sets. Discussions were held with the head of the Information Management Unit in Fisheries Division, Michigan Department of Natural Resources (MDNR), about linking additional data sets to Fisheries Division's central databases. Additional data sets on lakes (or other features) can be added easily if each lake (or item) is assigned a unique identification code. This code can then be related to the code used in the division's central databases. In addition, if such a unique lake code is assigned to items in various data sets, then multiple sources of information about particular lakes can be linked.

At the time this project was started, Fisheries Division had a list of approximately 4,000 lakes in the central database, with a unique code (Water_Body_Key) assigned to each. But the compilation by Humphrys and Green (1962), which had recently been converted to electronic form by Fisheries Division, contained over 35,000 lakes. Therefore, additional lake codes were needed. A protocol was developed for assigning a unique identification code, called "New_Key" in the databases compiled for this project, to each lake and pond in Michigan (Appendix 1). The basic concept was to build on the county lake lists compiled by Humphrys and Green (1962), combining their county code and lake number into a unique code for each lake. For example, Humphrys and Green assigned Vineyard Lake number 503 in the list of lakes in Jackson County (Lake Inventory Bulletin Number 38), so the New_Key for Vineyard Lake is 38-503. The New_Key could then be linked to the Fisheries Division's Water_Body_Key.

Master List of Lakes

The compilation by Humphrys and Green (1962) listed more than 35,000 Michigan lakes and ponds as small as 0.1 acre. Most of these are small unnamed water bodies. An alphabetized list of this compilation contained 8,632 named lakes and ponds (Colby and Humphrys no date; see also Brown 1944a). Lakes on county boundaries had been listed in both counties, with a different lake number assigned in each county, and lakes had been listed on multiple rows if they were found in multiple townships. In order to prepare a master list of lakes, the Humphrys and Green list was edited to remove multiple entries for a single lake and assign a single New_Key. For lakes on county boundaries, the protocol was to base the New_Key code on the county containing the lake outlet, or if there was no outlet, on the county containing the largest portion of the lake (Appendix 1). Lakes created since the 1962 compilation were added to the list. Sometimes one or more small lakes were flooded in the process of creating a new, larger lake; such lost lakes were flagged and not included in counts. Sometimes a lake that was treated as a single unit by Humphrys and Green (1962) is now considered to be two (or more) separate waters. For example, the former Twin Lakes (New_Key = 39-137) in Kalamazoo County has a lower water level and has now formed North Twin Lake (New_Key = 39-367) and South Twin Lake (New_Key = 39-369); in such cases the original record (e.g., for Twin Lakes) was flagged and not included in counts of lakes.

After this project had been going for some time, a new list of Michigan lakes became available in the form of a digital dataset for use in a GIS. This information was acquired from the Spatial Data Library on the State of Michigan's web site (now available from the Michigan Geographic Data Library of the Michigan Center for Geographic Information [MCGI]: http://www.mcgi.state.mi.us/mgdl/). According to the metadata, the original lake dataset was derived from the following sources: U.S. Census Bureau-based TIGER line files, Michigan DNR's Michigan Resource Information System (MIRIS) files (containing features that were digitized from 1:24,000 USGS topographic maps), Michigan Department of Transportation ACT51 maps through 1999, and Qualified Voter File project (QVF) maps begun in 1997. The dataset was further improved through comparisons with 1992 and 1997 Michigan State University aerial photos and 1992-2000 USGS Digital Ortho Quad photos (MCGI 2003). This list of lakes included a unique code ("Unique_id") for each lake polygon, although not all these lake polygons had lake names associated with them. As part of this project, numerous additions of lakes and modification of lake shape and attributes were made using local knowledge and historical records at the Institute for Fisheries Research (IFR). We have edited (and continue to edit) this digital dataset in several ways in the course of preparing a master list of lakes. First, we assigned New_Key codes to all lake polygons at least 10 acres in area. We continue to add New_Key codes to smaller lakes. Second, we split some of the polygons into separate lakes. This was done because some of the original work had continued digitizing along wide inlet or outlet streams where both banks were shown on the map, continuing the polygon to include the next lake. Third, we joined some polygons which actually represented parts of the same lake, as when a bridge across a narrow stretch of water had separated a lake into two polygons on a map. Fourth, we digitized several lakes that had been missed.

Linking Lakes in GIS to Databases

There is another advantage to having a unique lake code, such as New_Key (Appendix 1), for Michigan lakes and ponds. If such a unique code is added to GIS points or polygons representing waters, then the data in the various databases compiled in this project can be linked and displayed on a GIS digital map and spatial analyses can be performed. Therefore, the unique lake code was assigned to corresponding lake polygons (as described above). In addition, a set of GIS points (a point "theme") was created to show the location of each lake for which a unique identification code has been assigned.

Lake points were first created from a list of latitude and longitude values for 6,904 Michigan lakes obtained from U.S. Geological Survey (USGS) Board of Geographic Names. (Similar information can now be obtained via the web from the Geographic Names Information System; USGS 2004.) Points which did not intersect lake polygons were moved to the preferred location: near the lake outlet, or near the center of the lake if there is no outlet. As additional lake polygons are digitized, corresponding lake points will be added.

Lake Databases

Several existing databases on Michigan lakes were identified. Some were already in electronic form, others had to be converted to electronic form. Some sources were in spreadsheets or other formats. These were converted to database tables and unique lake codes were assigned.

Maps of Lake Bathymetry

Maps of lake bathymetry are available for about 2,600 inland lakes in Michigan. The great majority of these maps were made from information collected by field crews operating out of the Institute for Fisheries Research, starting in 1930 (Brown 1938; Brown and Clark 1939; Brown 1943b; Taube et al. 1964). Brown and Clark (1939), Taube et al. (1964), and Taube (2000a) described the methods of mapping. For most of these lakes, the original map contains information on bottom types and aquatic vegetation (Taube et al. 1964). On the original maps, bottom type was indicated by coloring with a wax pencil (Brown 1942). In order to make the maps less expensive to print and distribute, the maps were redrafted by MDNR personnel in Lansing, and the colored areas were replaced by various cartographic patterns of cross-hatching and stippling. It is these redrafted maps of depth contours that were sold to the public for many years by Michigan United Conservation Clubs under an agreement with MDNR. In the course of redrafting the maps, they were photographed to produce a positive transparency, and in the 1990s, Fisheries Division had these film images scanned and converted to digital TIF (Tagged Image File) images. In early 2003 these images were converted by MCGI to PDF (Portable Document Format) format and are now available for viewing and downloading from the MDNR web site (http://www.michigan.gov/dnr, then Publications & Maps | On-Line Maps | Lake Maps).

Maps of lake bathymetry are obviously helpful for finding the locations of deep spots, shallow areas, and other features within a lake. But depth maps can also be used to quantify lake volume, mean depth, area of the littoral zone, and to prepare depth-area (hypsographic) curves (Wetzel 1975). In the past, such quantification was done using a planimeter to measure the area within each contour interval (Taube 2000a), but now such measurements can be done by computer if the contour lines are digitized. As part of this project, we began digitizing the contour lines and other information on MDNR lake maps. Initially, a few lake maps were digitized from the original paper copy on file at IFR using a large digitizing table at the University of Michigan, School of Natural Resources and Environment. More recently, maps are digitized on computer screen using georectified TIF images. A protocol has been developed for digitizing lake maps, including capturing information on depth contours, bottom types, and aquatic vegetation in separate data layers in the digital map, and preparing associated metadata. In this study, priority for digitizing lake maps was given to the largest lakes, lakes where fish population estimates are being conducted by Fisheries Division, lakes being sampled for Fisheries Division's Status and Trends Program, and lakes where special projects are being done.

We tried using special software for converting scanned bitmap images of lake maps into vectors (Adobe Streamline) and then editing the vectors (Adobe Illustrator). This software does automatic line detection, but requires fairly clean bitmap images. It was hoped that this approach would appreciably reduce the effort in creating electronic versions of lake depth contours. However, on our scanned images, the depth-contour lines contain breaks for depth labels, and depth-contour lines overlay cartographic patterns indicating bottom type (e.g., sand, gravel, marl, peat). Both of these features require either editing the bitmap image prior to vectorizing or editing the vectors produced by the software, or both. From our attempts, it appears that a relatively large amount of time (e.g., several hours) must be spent in pre- and post-processing, so it is not clear that this approach saves much time over hand digitizing.

Calculation of Lake Volume and Mean Depth

Lake volume can now be calculated in two ways. The first method sums the volumes within successive depth contours. The volumes of such layers can be calculated from the areas within successive depth contours and the thickness of each contour interval using the formula for a truncated cone given in Taube (2000b).

The second method of calculating lake volume uses GIS software and the digitized depth contours for a lake. A grid is created at the surface of the lake, usually with 1-m spacing between grid lines (a larger spacing is used for very large lakes). The software then computes the distance from each grid intersection to the lake bottom. The sum of these distances (after converting units) represents the lake volume in acre-feet.

Mean depth is calculated by dividing lake volume by lake surface area. Lake volume and mean depth were computed for several lake maps.

Calculation of Lake Fetch and Depth to Thermocline

An algorithm was used to estimate lake fetch for all lake polygons. The algorithm determines the longest unobstructed straight line across a lake, and the length and azimuth of this line. The length of this line is one estimate of the fetch (Kalff 2002). These calculations were made in ArcView using a script from Jenness Enterprises (http://www.jennessent.com/arcview/arcview_extensions.htm, specifically Longest Straight Line v1.3).

Ragotzkie (1978) developed an equation to estimate mean depth of the thermocline (D_{th}, in meters) based on lake fetch (F, in kilometers).

$$D_{th} = 4\sqrt{F}$$

This equation is based on measurements of the thermal structure of 18 lakes in Wisconsin and central Canada during spring and summer. Lakes ranged in fetch size from 0.1 to over 20 km; and thermocline depths ranged from about 1 to 19 m (about 3 to 62 ft). No effect of lake orientation was evident, he reported. Ragotzkie (1978, p. 17) said that the estimated depths were accurate "within a meter or so" for deep lakes. This equation was used to estimate the mean depth to thermocline for all 70,000 lake polygons.

Models to Predict Walleye Population Characteristics

Information from several sources was assembled to begin developing models to predict walleye population characteristics. An example application focused on lakes that are at least 50 acres in area and have public access sites, because water quality data were available for these lakes in the database created from MDEQ information downloaded from U.S. EPA STORET (U.S. EPA 2002; See Appendix 5).

As an example of the types of analyses that can now be done using the compiled and linked databases, linear regressions were made to evaluate the influence of average lake alkalinity (mg/L as $CaCO_3$) on walleye mean length in September, by age class. Information on average length of walleyes captured in netting surveys came from Fisheries Division's Fish Collection System and from lake files at IFR (assembled by Nancy Nate, Wisconsin Department of Natural Resources, Madison). This includes data from the compilation by Laarman (1963) (Appendix 14).

Results and Discussion

Unique Lake Code for Linking Data Sets

An edited version of the lake list by Humphrys and Green (1962) is in the database table named "Humphrys 1 record per lake". A unique identification code (New_Key), based on the county and lake number assigned by Humphrys and Green (1962), has been assigned to all 32,121 lakes and ponds. The 32,294 records also include 173 lakes that have, since the 1962 compilation, been drained, or flooded to create a new lake that now has a separate record, or split or joined in the new list. Most of the water bodies in this list are less than 10 acres, some as small as 0.1 acres in surface area.

In the lake polygon dataset, we have assigned New_Key codes to all 6,537 lake polygons at least 10 acres in area. We continue to add New_Key codes to smaller lakes, and so far have added these codes to 2,530 lakes smaller than 10 acres, for a total of 9,067 lakes with this code. Another unique code (Unique_ID) was previously assigned to all 70,542 polygons, including 5,526 islands, 35 streams and 64,980 lakes and ponds down to 0.008 acres (31.4 m^2, 338 ft^2).

Master List of Lakes

There have been several attempts to count or compile a master list of lakes in Michigan. The Michigan Lakes and Streams Directory of 1941 reported that there were 6,454 water bodies "large enough to be lakes" (quoted in Brown 1943a). Brown (1943a) attempted to determine the total number of lakes in Michigan. Before counting the number of lakes one must decide on the definition of the term "lake." Brown (1943a, page 1) wrote that he used "the definition of Forel, the founder of modern limnology, who described a lake as 'a body of standing water occupying a basin and lacking continuity with the sea.' According to this definition all standing waters are lakes regardless of size, depth or origin. Ponds, bogs, swamps, reservoirs, etc. are just special kinds of lakes." Brown used the best available maps of the time: county master-plan maps from the Department of Conservation and the newly available polyconic projection maps from the State Highway Department. Brown (1943a) reported a count of 11,037 lakes, of which over half were less than 10 acres in surface area. This appears to be the source of the widely reported "fact" that Michigan has 11,000 lakes.

Brown (1944b) also used the best available maps of the time to compute the total length of streams in the state. He measured 5,499 miles of main streams and 30,851 miles of tributary streams, for a total of 36,350 miles of streams in Michigan. This appears to be the source of the widely reported "fact" that Michigan has 36,000 miles of rivers and streams.

Humphrys and Green (1962) published a series of lake inventory bulletins, one for each county, in which they assigned a number and measured the surface area for each lake in a county. They included both natural and artificial lakes and ponds as small as 0.1 acre. Humphrys and Veach (no date, Water Bulletin No. 8) developed a classification for Michigan's inland lakes, and Colby and Humphrys (no date, Water Bulletin No. 17) prepared an alphabetical index of named lakes and ponds. Water Bulletin No. 15 (Humphrys and Colby 1962) summarizes the sizes of lakes and ponds by county and for the entire State. Their grand total was 35,068 lakes and ponds in Michigan, with a total of 840,867 acres (Humphrys and Colby 1962). Including lakes and ponds that cross the state boundary, but excluding artificial ponds, they enumerated 20,401 lakes and ponds ≥ 1 acre, 6,474 lakes and ponds ≥ 10 acres, 1,155 lakes ≥ 100 acres, 105 lakes ≥ 1,000 acres, and 9 lakes ≥ 10,000 acres (Humphrys et al. no date, Water Bulletin No. 16).

A different identification key (Water_Body_Key) has been assigned by Fisheries Division's Information Management Unit to 5,335 water bodies, including 3,960 inland lakes and ponds. The table is named FIS_Water_Body. The subset including inland lakes and rearing ponds represents lakes and ponds on which some management activities have been conducted and is not intended to be a complete list of all lakes. The list contains 1,522 lakes and ponds ≥ 1 acre, 1,302 lakes ≥ 10 acres, 590 lakes ≥ 100 acres, 92 lakes ≥ 1,000 acres, and 8 lakes ≥ 10,000 acres.

An edited version of the lake list by Humphrys and Green (1962) is in the database table named "Humphrys 1 record per lake" (Appendix 2). A unique identification code (New_Key), based on the county and lake number assigned by Humphrys and Green (1962), has been assigned to all 32,121 of these lakes, and also to the 173 lakes that have been drained, flooded, split or joined since the 1962 compilation. Most of the lakes in this list are less than 10 acres. This master list contains 21,729 lakes ≥ 1.0 acre (using the field Acres_total), 7,515 lakes ≥ 10.0 acres, 1,182 lakes ≥ 100 acres, 104 lakes ≥ 1,000 acres, and 8 lakes ≥ 10,000 acres.

Probably the best current count of lakes and ponds in Michigan appears in the database table named "Lake polygons shapefile current". It is based on the attribute table of a corresponding GIS lake polygon layer. Editing was done to add, split or join polygons to better represent the lakes. After editing, this theme currently contains 64,980 lakes and ponds down to 0.008 acres (31.4 m^2, 338 ft^2). Because lake areas can be estimated from digitized polygons, area measurements are more precise than earlier estimates. Therefore, the cut-off sizes must be specified with more precision when determining counts of lakes. There are 62,798 lakes ≥ 0.1 acres, 26,266 lakes ≥ 1.0 acres, 6,537 lakes ≥ 10.0 acres, 1,148 lakes ≥ 100 acres, and 98 lakes ≥ 1,000 acres, and 10 lakes ≥ 10,000 acres.

Linking Lakes in GIS to Databases

In the GIS lake polygon file, 9,067 lakes have now been assigned a New_Key code. A point theme has been created in ArcView showing the location of 8,871 named lakes that have unique identification keys assigned. This includes all lake polygons ≥ 10 acres in area. Using this unique code, databases can now be linked to points and lake polygons and displayed spatially.

Lake Databases

The following is a list of lake databases that have been identified, converted to spreadsheets or relational databases, and for which a unique lake identification key has been assigned to all (or almost all) of the lakes:

- Michigan lake inventory (Humphrys and Green 1962); *N* = 32,121 lakes (Appendix 2). This includes lakes from 0.1 to over 10,000 acres in area as well as approximately 57 manmade lakes created after Humphrys and Green's compilation.
- Michigan coldwater lakes (MDNR Fisheries Division 1976); *N* = 1,345 lakes (Appendix 3).
- List of official Michigan lake names, obtained from the U.S. Geological Survey, Board of Geographic Names (USGS 2004); *N* = 6,904 (Appendix 4). (A few of these names are lake groups, e.g., West Branch Lakes in Alger County.)
- Water quality data of lakes with public access sites, at least 50 acres in area [data retrieved from U.S. Environmental Protection Agency STORET database via the web (U.S. EPA 2002); original measurements were made and entered by Michigan Department of Environmental Quality, Land and Water Management Division, Lansing]; *N* = 730 lakes (Appendix 5).
- Compilation of data on lake morphometry and water quality (Schneider 1975); *N* = 387 lakes (Appendix 6).
- Lower Peninsula lakes sampled for fishes with large seines (Schneider 1981); *N* = 229 lakes (Appendix 7).
- Lake characteristics from an atlas and gazetteer of Michigan lakes (Fusilier and Fusilier 1994); *N* = 297 Michigan lakes (Appendix 8).
- Lakes in the Michigamme Project (Evans et al. 1991); *N* = 66 lakes (Appendix 9).
- Watershed area and perimeter, and lake area and perimeter for natural lakes at least 100 acres in area (Marsh and Borton 1974); *N* = 832 individual lakes and 40 multi-lake groups (Appendix 10).
- Names of Michigan lakes sampled as part of the U.S. Environmental Protection Agency's National Acid Precipitation Assessment Program (Kanciruk et al. 1986; Linthurst et al. 1986; Overton et al. 1986); *N* = 172 (Appendix 11).
- List of MDNR Fisheries Division reports, including Fisheries Research Reports, *N* = 2060; Fisheries Technical Reports, *N* = 206; Fisheries Management Reports, *N* = 17; Fisheries Special Reports, *N* = 15; and Status of the Fisheries Resource Reports, *N* = 66 (Appendix 12).
- Public boat launch sites in Michigan (Ray Fahlsing, MDNR Parks and Recreation Bureau, personal communication); *N* = 919 inland lake sites (mostly on lakes 50 acres and larger) (Appendix 13).
- Percy Laarman's (1962) compilation of fish growth rates, used to compute Michigan average growth rates; *N* = 26,086 length-at-age records; *N* = 18 fish species; *N* = 1,135 lakes (Appendix 14).
- Names of inland lakes with creel survey data and a reference to the report containing the data (e.g., Schneider and Lockwood 1979; Ryckman and Lockwood 1985; Lockwood 2000; and references therein); *N* = 183 lakes; *N* = 596 lake-year combinations (Appendix 15).

The following databases have been identified, converted to Excel spreadsheets or Access databases, but lake identification keys have not yet been added:

- Public boat launch sites in Michigan at Great Lakes or river locations (Ray Fahlsing, MDNR Parks and Recreation Bureau, personal communication); *N* = 89 Great Lakes sites, 5 Lake St. Clair sites, 294 river sites. Because these sites are not on inland lakes, lake codes could not be added.
- Lake Survey Summary cards from IFR files; *N* = 549.
- Management Record cards from IFR files; *N* = about 200, with 974 management recommendations.

Formal metadata descriptions have been prepared for most of these databases, following FGDC format (FGDC 2003) (See also Appendices 2-15). Descriptions of the variables have been added to the relational database design for each table.

In the course of assigning unique identification keys to lakes in the atlas of Marsh and Borton (1974), I found that measurements on one lake had been done twice. Muskrat Lake is mostly in Van Buren County, but extends a little into Allegan County, and a separate entry for this lake appears under each of these counties. This provided an opportunity to estimate the measurement error for the values of area and perimeter reported by Marsh and Borton (1974) for this lake and its watershed. I computed percent difference as 100 * (Van Buren value - Allegan value) / (Allegan value). The percent difference in the two values (and the Allegan value) was +12.7% for watershed area (470.9 acres), +6.9% for watershed perimeter (4.47 miles), +0.7% for watershed shape factor (1.47), -4.5% for lake area (138.6 acres), -41.9% for lake perimeter (4.72 miles), -40.6% for lake shape factor (2.86), and +17.9% for the ratio of watershed area to lake area (3.40).

Maps of Lake Bathymetry

As of November 2004, a total of 163 different lake maps had been digitized. This list includes 18 of the 20 largest lakes in Michigan (Laarman 1976); TIF images of lake maps are not available for the other two: Portage Lake, Houghton County, and Michigamme Reservoir, Iron County. This list also includes 74 of the 98 lakes larger than 1,000 acres. About 600 additional lake maps are nearly done being digitized by MCGI. Five lakes have been digitized from both paper and TIF image. For most of the 163 lakes, the original map contained information on bottom types and aquatic vegetation (Taube et al. 1964). In most cases, this information was captured and stored in separate data layers with the digital map.

Lake Volume and Mean Depth

Lake volume and mean depth have been computed for 87 different lakes so far (Table 1). The table indicates for each lake whether the calculations were done using the formula for a series of truncated cones (F) or using a GIS grid (G). Torch Lake, which has the greatest maximum depth of any inland lake in Michigan (285 feet), also has the greatest volume (2,635,927 acre-feet) and mean depth (139.5 feet). (Torch Lake was mapped in 1953 and found to have a maximum depth of 285 feet. A 1931 record from the IFR lake files reports the maximum depth as 297 feet, the same as given by Humphrys and Green in 1962.)

Mean depth values estimated by digitizing the original paper maps were very similar to those estimated by digitizing the TIF image of the map (Table 2). The difference was always less than 0.2 ft, and the average difference in mean depth values was only 0.23%. There was a larger difference in estimated values of lake volume, particularly for Black Lake, one of the first lake maps digitized. But this is attributable to the difficulty in estimating lake area (and hence, volume) from the paper map using the map's printed scale. The TIF images were georeferenced relative to aerial photos before being digitized, so the estimate of lake area (and hence volume) is likely to be more accurate than for the paper maps. Based on this comparison, use of georeferenced and digitized TIF images is recommended over paper maps for calculation of mean depth.

Lake Fetch and Depth to Thermocline

The algorithm used to estimate lake fetch works very rapidly (less than a minute of computer time) on small lake polygons (less than 10 acres), but takes a very long time (many minutes to hours of computer time on a 1.8 GHz Pentium 4 computer) on large lake polygons, greater than 10,000 acres. Longest unobstructed straight line was calculated for all 70,000 lake polygons.

Using the estimate of fetch, Ragotzkie's (1978) equation was employed to predict the mean depth to thermocline for all 70,000 lake polygons. This estimate was added to the database.

Models to Predict Walleye Population Characteristics

Linear regression analysis demonstrated that walleye length in September was related to average alkalinity (Table 3). Figure 1 shows that walleye length is greater in lakes with higher alkalinity. This is an example of the kinds of analyses that are possible from linking multiple data sets, for example length-at-age data and water quality data.

Conclusions

Several datasets formerly available only as paper copies are now accessible electronically. The lake datasets have a unique lake code assigned so that the various datasets can easily be linked with each other and linked to GIS maps, greatly extending their usefulness. The datasets now have associated metadata that describe the source of the original data, the date and location of the original data, the variables and their units, what editing or processing has been done, etc. Multiple datasets are now ready for use in analyses and in development of decision-support tools.

Acknowledgments

Several people helped enter data, check data, assign unique lake codes, digitize lake maps, and otherwise provide assistance. These people include Martin Brown, Kevin Cronk, Christine Diana, Christine Elmore, Cristine Folz, Martha Haab, Christine Hura, Eric Ivanovich, Alexandra Katona, Lidia Szabo Kraft, Jayanthi Madhavan, and Kara Tecco. Nancy Nate entered and checked information on fish growth rates and links to the Fisheries Division central databases.

Special thanks to Shannon Brines, Eric Ivanovich, and Lidia Szabo Kraft for assistance with GIS tasks. Chris Larson, Roger Parsons, and Dennis Burck, current or former members of the Information Management Unit of Fisheries Division, assisted with planning how the division's data design could be expanded to include additional data sets containing information on Michigan's lakes. Jim Schneider provided information he had compiled for several earlier studies as well as general advice. Howard Wandell and Ralph Bednarz of the MDEQ Land and Water Management Division provided information on nutrients and water quality in significant public waters. Ray Fahlsing, MDNR Parks and Recreation Bureau, provided information on lakes with public boat access sites. Lidia Szabo Kraft prepared most of the metadata.

Funding for this project was provided by the Michigan Department of Natural Resources through Federal Aid in Sport Fish Restoration, Project F-80-R, Study 674.

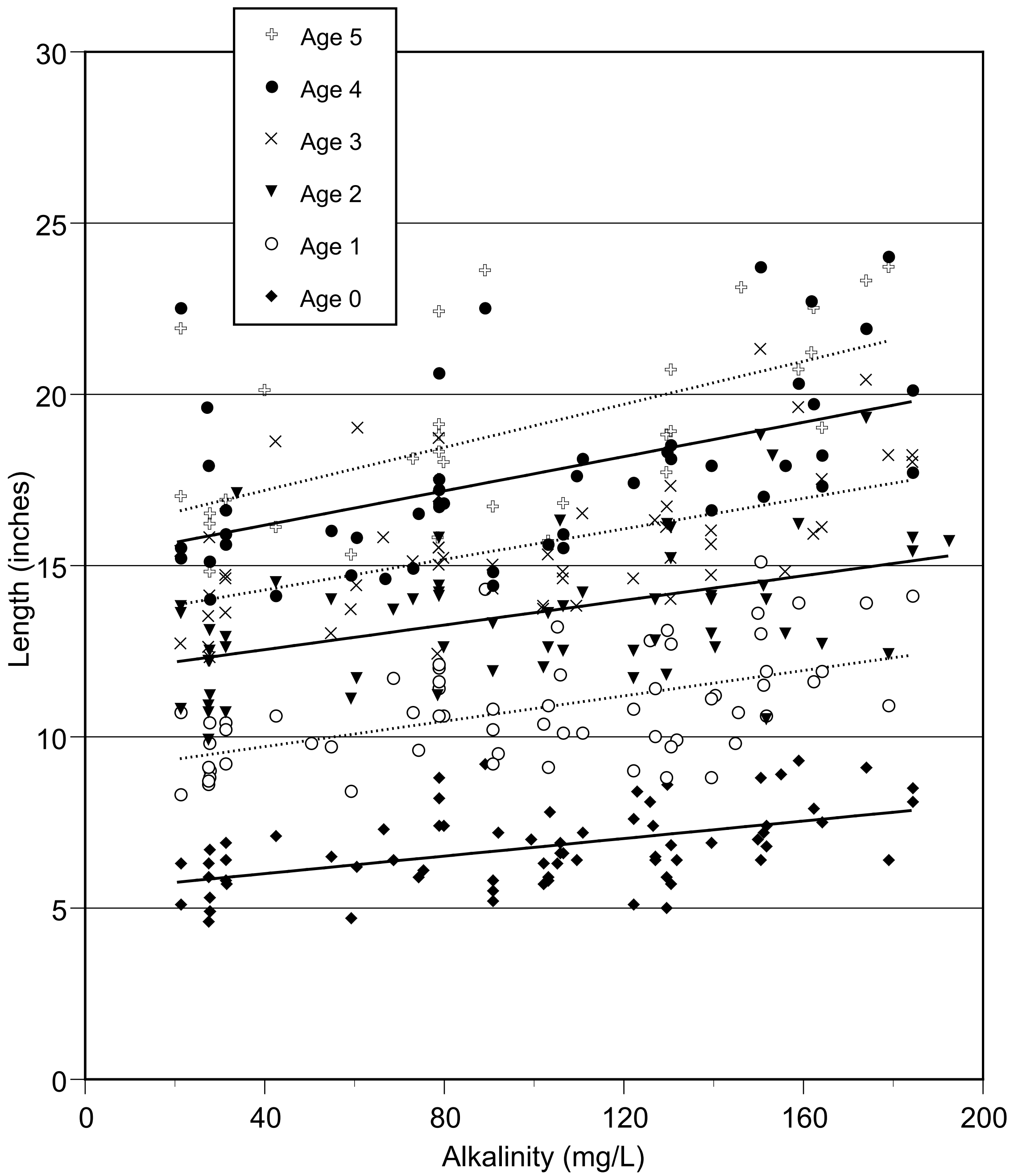

Figure 1.–Mean length (inches) of walleye in September is greater in lakes with higher average alkalinity (mg/L as CaCO3). Each point represents the average length of an age group captured in one fisheries survey on a lake and the corresponding average of alkalinity measurements made by MDEQ for that lake. Regression equations are given in Table 3.

Table 1.–Lakes for which volume and mean depth have been calculated from digitized lake maps. Also shown are the county, surface area from GIS lake polygons and the digitized lake map, volume, mean depth, whether the method (M) used to estimate mean depth was a GIS grid (G) or formula (F) for sections of a truncated cone, maximum depth, whether the source (S) used for digitizing was a paper map (P) or a digital TIF image of the map (T), and unique lake code (New_Key).

Lake	County	Area, GIS (acres)	Area, digitized (acres)	Volume (acre-ft)	Mean depth (ft)	M	Max. depth (ft)	S	New_Key
Allen Lake	Gogebic	78.2	78.0	1,253	16.1	G	40	T	27-111
Ann, Lake	Benzie	501.0	494.0	16,990	34.4	G	75	T	10-111
Antoine, Lake	Dickinson	725.5	746.9	9,294	12.4	F	25	T	22-95
Bay Lake	Gogebic	173.8	173.4	2,447	14.1	G	45	T	27-291
Bellaire, Lake	Antrim	1,788.6	1,814.9	78,587	43.3	F	95	T	5-50
Ben-way Lake	Antrim	127.0	122.1	2,162	17.7	G	42	T	5-94
Birch Lake	Antrim	325.5	322.3	7,011	21.8	G	53	T	5-57
Black Lake	Cheboygan	10,113.5	10,973.2	272,838	24.9	F	50	P	16-144
Black Lake	Cheboygan	10,113.5	10,176.2	253,407	24.9	F	50	T	16-144
Blanch Lake	Newaygo	44.2	42.7	259	6.1	G	30	T	62-33
Burt Lake	Cheboygan	17,394.6	17,477.4	449,792	25.7	G	73	P	16-193
Campau Lake	Kent	82.5	114.1	1,150	10.1	G	42	T	41-45
Center Lake	Jackson	846.9	755.3	2,653	3.5	G	40	T	38-348
Charlevoix, Lake	Charlevoix	17,268.4	17,124.3	978,196	57.1	G	120	T	15-21
Cisco Lake	Gogebic	567.4	573.0	4,745	8.3	G	20	T	27-275
Clark Lake	Gogebic	836.0	875.5	25,416	29.0	G	74	T	27-188
Clear Lake	Barry	186.8	180.0	1,243	6.9	G	16	T	8-57
Clifford Lake	Montcalm	194.8	196.0	3,051	15.6	F	45	T	59-295
Crooked Lake	Emmet	2,351.6	2,452.7	22,070	9.0	G	50	T	24-27
Crystal Lake	Benzie	9,869.0	9,788.6	111,429	56.9	G	162	T	10-42
Culhane Lake	Luce	99.8	98.7	1,521	15.4	G	49	T	48-685
Deep Lake	Lenawee	69.7	64.0	1,587	24.8	G	50	T	46-91
Deer Lake	Charlevoix	462.9	431.1	5,010	11.6	G	22	T	15-15
Dinner Lake	Gogebic	107.7	107.4	1,388	12.9	G	25	T	27-117
Donnell Lake	Cass	246.5	240.6	6,646	27.6	G	63	T	14-224
Duck Lake	Gogebic	612.3	620.6	77,778	12.5	G	25	T	27-108
Duncan Lake	Barry	129.8	132.5	3,672	27.7	G	55	T	8-731
Eagle Lake	Kalamazoo	194.1	230.4	1,120	4.9	G	10	T	39-275
Elk Lake	Antrim	8,194.8	8,020.9	560,932	69.9	F	192	T	5-2
Ellsworth Lake	Antrim	106.5	110.4	1,761	16.0	G	42	T	5-110
Fish Lake	Barry	151.4	158.3	4,800	30.3	G	56	T	8-426
Fish Lake, Big	Lapeer	85.4	108.6	1,816	16.7	G	70	T	44-81
Glen Lake	Leelanau	4,871.2	4,870.6	283,539	58.2	F	130	T	45-9
Glen Lake, Little	Leelanau	1,414.7	1,419.4	8,460	6.0	F	13	T	45-33
Grand Lake	Presque Isle	5,822.5	5,909.2	57,376	9.7	F	25	T	71-87
Grass Lake	Montmorency	631.7	463.6	2,136	4.6	G	6	T	60-226
Gull Lake	Barry	2,046.1	2,043.8	81,890	40.1	G	110	T	39-13
Half-Moon Lake	Muskegon	63.7	62.7	1,804	28.8	G	82	T	61-20
Heart Lake	Otsego	66.7	67.3	2,182	32.4	G	117	T	69-75
Herendeene Lake	Benzie	38.8	36.1	416	11.5	G	37	T	10-95
Higgins Lake	Roscommon	10,185.6	9,923.7	519,137	52.3	F	135	P	72-117
Higgins Lake	Roscommon	10,185.6	9,950.4	519,751	52.2	F	135	T	72-117
Houghton Lake	Roscommon	20,075.1	19,665.8	165,072	8.4	F	21	T	72-78
Houghton Lake	Roscommon	20,075.1	19,726.8	164,959	8.4	F	21	P	72-78
Hubbard Lake	Alcona	8,767.8	8,812.5	314,658	35.7	F	87	T	1-165

Table 1.–Continued.

Lake	County	Area, GIS (acres)	Area, digitized (acres)	Volume (acre-ft)	Mean depth (ft)	M	Max. depth (ft)	S	New_Key
Indian Lake	Kalkaska	42.3	46.3	296	6.4	G	18	T	40-236
Indian Lake	Schoolcraft	8,647.0	8,434.8	70,131	8.3	F	15	T	75-69
James Lake	Iron	209.3	206.4	1,170	5.7	G	10	T	36-771
Kent Lake	Oakland	1,014.6	957.5	5,855	6.1	G	38	T	63-2
Lac Vieux Desert	Gogebic	4,370.3	4,430.8	51,406	11.6	G	38	T	27-3
Lake of the Woods	Antrim	172.2	174.2	856	4.9	G	14	T	5-27
Leach Lake	Barry	107.3	109.3	2,254	20.6	G	52	T	8-490
Leelanau, North Lake	Leelanau	2,914.3	2,837.7	113,550	40.0	G	121	T	45-64
Leelanau, South Lake	Leelanau	5,693.2	5,641.9	132,387	23.5	G	62	T	45-3
Lincoln Lake	Kent	416.7	409.0	11,432	27.9	G	67	T	41-586
Long Lake	Missaukee	66.4	59.4	401	6.7	G	15	T	57-104
Long Lake	Alpena	5,342.0	5,193.7	59,661	11.5	F	25	T	4-42
Long Lake	Iron	59.8	60.6	2,054	33.9	G	105	T	36-331
Long Lake	Barry	75.4	71.7	1,991	27.8	G	49	T	8-69
Manistique Lake	Luce	10,346.1	10,238.9	93,967	9.2	F	20	T	48-53
Manistique, South Lake	Mackinac	4,132.9	4,091.5	43,452	10.6	G	29	T	49-280
Marble Lake	Branch	741.0	817.4	17,795	21.8	G	60	T	12-50
Michigamme, Lake	Gogebic	4,291.9	4,304.2	120,916	28.1	G	72	T	52-1185
Moosehead Lake	Gogebic	51.1	53.3	825	15.5	G	39	T	27-346
Moraine Lake	Gogebic	89.9	76.4	1,030	13.5	G	22	T	27-930
Murphy Lake	Tuscola	182.5	211.4	1,413	6.7	G	41	T	79-2
Muskegon Lake	Muskegon	4,231.7	4,234.9	101,635	24.0	F	70	T	61-66
Nepessing Lake	Lapeer	427.0	423.9	4,102	9.7	G	25	T	44-159
Nevins Lake	Montcalm	55.2	51.8	1,230	23.7	G	60	T	59-177
Nichols Lake	Newaygo	153.4	152.2	2,435	16.0	G	50	T	62-358
Norway Lake	Iron	51.9	50.4	444	8.8	G	20	T	36-1488
Pickerel Lake	Emmet	1,082.3	1,057.8	10,635	10.1	G	74	T	24-31
Pike Lake	Marquette	90.1	84.7	1,022	12.1	G	37	T	52-297
Pine Island Lake, Big	Kent	194.5	214.4	3,271	15.3	G	45	T	41-278
Pine Lake	Barry	611.2	669.7	6,736	10.1	G	34	T	8-192
Platte Lake, Little	Benzie	896.0	874.4	2,074	2.4	G	8	T	10-140
Pole Creek Lake	Delta	88.9	89.2	459	5.1	F	10	T	21-487
Rifle Lake	Ogemaw	185.2	186.4	4,978	26.7	F	72	T	65-149
Roland, Lake	Houghton	258.4	271.6	3,995	14.7	G	40	T	31-915
Silver Lake	Oceana	672.5	688.7	10,429	15.1	G	25	T	64-188
Sixmile Lake	Charlevoix	368.7	344.3	4,548	13.2	G	31	T	5-89
Skegemog Lake	Antrim	2,766.5	2,748.3	31,649	11.5	F	29	T	5-1
St. Helen, Lake	Roscommon	2,416.0	2,409.1	15,609	6.5	G	25	T	72-95
Tea Lake	Oscoda	204.2	198.2	3,128	15.8	G	70	T	68-142
Tepee Lake	Iron	120.4	123.1	1,104	9.0	G	40	T	36-1936
Thornapple Lake	Barry	415.2	393.7	5,421	13.8	G	31	T	8-481
Thousand Island Lake	Gogebic	1,008.7	1,016.1	13,022	12.8	G	81	T	27-265
Torch Lake	Antrim	18,721.7	18,891.2	2,635,927	139.5	F	285[a]	T	5-51
Townline Lake	Montcalm	288.8	281.9	3,351	11.9	G	49	T	59-426
Turtle Lake	Benzie	40.9	38.9	297	7.6	G	22	T	10-34

[a] Torch Lake was mapped in 1953 and found to have a maximum depth of 285 feet. A 1931 record from the IFR lake files reports the maximum depth as 297 feet, the value reported by Humphrys and Green in 1962.

Table 2.–Comparison of lake area, volume, and mean depth for three lake maps digitized from both the original paper map and the TIF image.

Variable	Source: Paper	Source: TIF	% Difference
	Black Lake, Cheboygan County		
Area (acres)	10,973.17	10,176.15	7.26%
Volume (acre-ft)	272,837.66	253,406.50	7.12%
Mean depth (ft)	24.86	24.90	-0.15%
	Higgins Lake, Roscommon County		
Area (acres)	9,923.71	9,950.36	-0.27%
Volume (acre-ft)	519,136.86	519,750.80	-0.12%
Mean depth (ft)	52.31	52.20	0.22%
	Houghton Lake, Roscommon County		
Area (acres)	19,726.79	19,665.80	0.31%
Volume (acre-ft)	164,959.19	165,071.95	-0.07%
Mean depth (ft)	8.36	8.39	-0.33%

Table 3.–Influence of average alkalinity on mean September length of walleye, by age class, as determined by linear regression. Separate intercepts (±SE) and slopes (±SE) were determined for each age class. The adjusted r^2 is reported. N represents the number of average length values used in the regression. All six regressions are highly significant ($P < 0.001$).

Age class	Intercept	Slope	Adjusted r^2	N
0	5.48±0.29	0.0128±0.003	0.25	70
1	0.90±0.40	0.0185±0.004	0.28	64
2	11.82±0.49	0.0180±0.005	0.20	61
3	13.44±0.53	0.0223±0.005	0.27	53
4	15.17±0.69	0.0250±0.006	0.23	49
5	15.98±0.76	0.0314±0.007	0.34	34

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Appendix 1.–Protocol for assigning“New_Key” unique codes to Michigan lakes and ponds.

The basic concept for assigning a unique lake code (“New_Key”) is to build on the county lake lists compiled by Humphrys and Green (1962), combining their county code and lake number into a unique code for each lake. For example, Humphrys and Green assigned Vineyard Lake number 503 in the list of lakes in Jackson County (bulletin number 38), so the New_Key for Vineyard Lake is 38-503.

Counties (bulletins) were numbered by Humphrys and Green in alphabetical order (Alcona is number 1, Wexford is 83), except that they had St. Clair (bulletin 77) and St. Joseph (bulletin 78) follow Shiawassee (bulletin 76) rather than Saginaw (bulletin 73), the expected alphabetical order. This makes their county numbers different than the county FIPS codes for numbers 74 to 78. The New_Key code uses the county numbering of Humphrys and Green (1962).

For lakes on county boundaries, the protocol is to base the New_Key code on the county containing the lake outlet, or if there is no outlet, on the county containing the largest portion of the lake.

If a lake does not appear in the Humphrys and Green (1962) list, then determine the appropriate county and use the next available lake number for that county. Update the most recently added lake number in the table “Counties” in the Access database.

The following decision tree was developed to handle assignment of codes to lakes that are connected to other lakes.

1. Is the lake part of a group of lakes?
   No - Assign a New_Key as specified above.
   Yes – Go to 2.

2. Is the lake connected to the other lakes in the group to form a single waterbody?
   No –
   - Assign a New_Key.
   - Assign a group-key[1].
   - Enter group-key in the “Lake groups” spreadsheet file with the group name, and an indication of the source of the original grouping or the reason for grouping on the “Lake_Groups” sheet.
   - On the “Group_Parts” sheet of the “Lake groups” spreadsheet file, enter the group-key and the New_Key for each of the New_Key parts.

   Yes – Go to 3.

3. Do the lake parts each have a USGS name on the DRG (the digital version of the topographic map)?
   No – Go to 4.
   Yes –
   - Assign a New_Key to each part.
   - Split the polygon, if not already done, so that each part is a separate polygon
   - Assign a group-key[1].
   - Enter group-key in the “Lake groups” spreadsheet file with the group name, and an indication of the source of the original grouping or the reason for grouping on the “Lake_Groups” sheet.
   - On the “Lake_Groups” sheet of the “Lake groups” spreadsheet file, enter a “1” in the “1w_body_multi_poly” column.
   - On the “Group_Parts” sheet of the “Lake groups” spreadsheet file, enter the group-key and the New_Key for each of the New_Key parts.

[1] The group-key should be assigned as “*new-key*-GRP”, where *new-key* is the New_Key of the most downstream part or the largest part, if one is significantly larger than the rest.

Appendix 1.–Continued.

4. Were the lake parts each assigned a Humphrys-key in Humphrys and Green (1962)?
   No – Stop here. It is not a group of lakes.
   Yes – Go to 5.

5. Is the connection between the two parts "sufficiently wide enough" to prevent the two parts from developing separate physical, chemical, or biological characteristics?
   No –
   - Assign a New_Key to each part.
   - Split the polygon, if not already done, so that each part is a separate polygon.
   - Assign a group-key[1].
   - Enter group-key in the "Lake groups" spreadsheet file with the group name, and an indication of the source of the original grouping or the reason for grouping on the "Lake_Groups" sheet.
   - On the "Lake_Groups" sheet of the "Lake groups" spreadsheet file, enter a "1" in the "1w_body_multi_poly" column.
   - On the "Group_Parts" sheet of the "Lake groups" spreadsheet file, enter the group-key and the New_Key for each of the New_Key parts.

   Yes –
   - Unite the parts to form a single polygon.
   - Assign a group-key[1].
   - Assign the group-key number (no "GRP") as the New_Key in the lakes layer.
   - Enter a "1" in the new "Group" column of the table of the lakes layer.
   - Enter group-key in the "Lake groups" spreadsheet file with the group name, and an indication of the source of the original grouping or the reason for grouping on the "Lake_Groups" sheet.
   - On the "Group_Parts" sheet of the "Lake groups" spreadsheet file, enter the group-key and the New_Key for each of the New_Key parts.

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[1] The group-key should be assigned as "*new-key*-GRP", where *new-key* is the New_Key of the most downstream part or the largest part, if one is significantly larger than the rest.

Appendix 2.–Database: Michigan lake inventory of Humphrys and Green (1962).

Access table name: Humphrys 1 record per lake
Number of records: 32,294.
Number of fields: 50.

Abstract.–This Access table contains information from the Michigan lake inventory bulletins of Humphrys and Green (1962). Each bulletin contains the following introduction: "This inventory of lakes brings together some readily available data from maps, reports, and local sources. It is not presented as a complete or detailed inventory. Eventually, as more accurate information is collected, a more complete survey of Michigan's lakes can be compiled." The first part of each bulletin contains an alphabetical list of all lakes in the county: "Some lakes are known by more than one name; those names appearing on the United States Geological Quadrangles are given highest precedence." Lack of information: "In many instances, the information needed to answer questions under some of the columns was unavailable and no entry was possible." The Access table now contains 32,294 records and 50 fields, with information on water bodies as small as 0.1 acre. The table includes 173 lakes that have, since the 1962 compilation, been drained, or flooded to create a new lake that now has a separate record, or split or joined in the new list.

Description of changes.–This lake information, originally in a series of bulletins, one per county, was keypunched by a contractor under the direction of Chris Larson, Michigan Department of Natural Resources (MDNR), Fisheries Division, Lansing office. The resulting table was edited at the Institute for Fisheries Research by workers under the direction of James E. Breck, MDNR Fisheries Research Biologist. The main editing was to prepare a version of the table containing only one record per lake. The original bulletins and keypunched table had a total of approximately 35,000 records on water bodies as small as 0.1 acres. There was a separate record for each lake-township combination. For example, if a lake occurred in two townships, there were two records for that lake. The first major editing task was, for each county, to delete records to allow only one record per lake. The procedure was to keep the record containing the township, range, and section (TRS) of the lake outlet. The second major editing task was to find lakes that crossed county lines, to allow only one record per lake. In the original bulletins, lakes were listed by TRS, with lakes in the lowest township and range listed first. County lake numbers were then assigned to each lake by Humphrys and Green. This meant that lakes that crossed county lines were assigned different numbers for the portion in each county. We edited the list to delete all but one record for lakes that crossed county lines. A new unique lake code (New_Key) was assigned to all water bodies by combining the county code and lake code assigned by Humphrys and Green. For example, the portion of Higgins Lake in Crawford County (county number 20) had been assigned lake number 13 in that county list, whereas the portion in Roscommon County (county number 72) had been assigned lake number 117. Because the outlet for Higgins Lake is in Roscommon County, we assigned New_Key the value 72-117. At the same time we updated the lake area field. In the original bulletin, the field AREA contained the lake's area in that county. For example, in the record for Crawford County, the area of Higgins Lake was given as 22.5 acres (with a note that 9577.5 acres was in Roscommon County for a total of 9600.0 acres), whereas the record for Roscommon County gave the area as 9900.0 acres, a difference of 300 acres. We created a new field (Acres_total) for the total area of the lake, combining portions from all counties. Similarly, lakes on the State border had been assigned the lake area inside Michigan. When the information was given in the notes, we updated the Acres_total field. As information became available, we added lakes not already on the list, assigning a New_Key according to the outlet county and using the next higher county lake number. Several new lakes have been created by flooding one or more smaller lakes. When this situation was identified, a record was added for the new lake and the flooded lakes were assigned an Origin value of minus one. With editing, the total number of records changed from about 35,000 to 32,294, including the 173 lakes that have, since the 1962 compilation, been drained, or flooded to create a new lake that now has a separate record, or split or joined in the new list.

Appendix 2.–Continued.

Original Fields.–The field names in the Access table are given first, with the original field names given in parentheses in capital letters. The following field descriptions that contain quotation marks are quoted directly from Humphrys and Green (1962), from Bulletin No. 1, for Alcona County.

Lake_No (LAKE NUMBER): "Each lake has been assigned a county lake number. This system is based upon the General Land Office township, range, and section number survey. Lakes in the lowest township and range are listed first."

Lake_Name (LAKE NAME): "Some lakes are known by more than one name; those names appearing on the United States Geological Quadrangles are given highest precedence."

Origin (ORIGIN): "All bodies of surface water have been arbitrarily classified as to their origin on the basis of available information." Classes of surface water recognized are given in another table.

Acres (AREA): "Some lakes have been carefully surveyed by civil engineers for platting of lots or for lake level determination reports. These acreages have been accepted as being most accurate."

Town (TOWNSHIP): Tier number of the township north or south of the base line for Michigan, assigned by the General Land Office. (The township and range numbering system is explained in the book by R. G. Wetzel and G. E. Likens [1979].)

Range (RANGE): Range number of the township east or west of the principal meridian for Michigan, assigned by the General Land Office.

Section1 (SECTION) to Section22: In the original bulletins, this field contained a list of all sections in the specified township containing some portion of the lake. In the keypunched version, these section numbers were individually entered into successive fields: Section1, Section2, Section3, up to Section22. The intention now is to have Section1 list the section number containing the lake outlet, but not all lake records have been checked yet. For lakes with no outlet, Section1 is intended to contain the section number of the center of the lake.

Inlet (INLET): "These terms [INLET and OUTLET] refer to any channels, natural or cultural, permanent or intermittent, that permit the flow of water into or out of the lake basin."

Outlet (OUTLET): "These terms [INLET and OUTLET] refer to any channels, natural or cultural, permanent or intermittent, that permit the flow of water into or out of the lake basin."

Max_Depth (MAXIMUM DEPTH): Given in feet. "The maximum depth of many lakes has been investigated. These figures have been listed but must be considered subject to change when more detailed surveys have been complete or when the lake level fluctuates."

Shoretype (% MINERAL): "Except for those lakes that have been surveyed, the source of shore-type information consists of available soil survey maps." Humphrys and Green (1962) had another column indicating percent organic (% ORGANIC = 100 - % MINERAL).

Panfish (PANFISH): X means panfish are present. "FISH SPECIES: The limnological aspects of lakes are extremely complex and subject to considerable change due to management practices, natural changes or pollution. Only three groups have been indicated – trout, pike, and panfish. These designations are general and do not cover the quantitative or qualitative aspects of the fish population present."

Pike (PIKE): X means pike are present. "FISH SPECIES: The limnological aspects of lakes are extremely complex and subject to considerable change due to management practices, natural changes or pollution. Only three groups have been indicated – trout, pike, and panfish. These designations are general and do not cover the quantitative or qualitative aspects of the fish population present."

Appendix 2.–Continued.

Trout (TROUT): X means trout are present. "FISH SPECIES: The limnological aspects of lakes are extremely complex and subject to considerable change due to management practices, natural changes or pollution. Only three groups have been indicated – trout, pike, and panfish. These designations are general and do not cover the quantitative or qualitative aspects of the fish population present."

Public_Access (PUBLIC ACCESS): X means there is public access. "Lakes indicated as having public access are limited to those having fishing access points, parks or boat rentals open to the public. Numerous lakes have unimproved public frontage that may eventually become public access points.

"The information presented does not represent an attempt to classify lakes as being public or private in nature. This determination must be left to the discretion of Michigan courts."

Added Fields.–The following fields were added by James E. Breck to the columns of information in Humphrys and Green (1962).

GLB: Great Lakes Basin: E, H, M, or S, for Erie, Huron, Michigan, or Superior, respectively.

MU: MDNR Fisheries Management Unit (MU): LE, LHN, LHS, LMC, LMN, LMS, LSE, or LSW, for Lake Erie MU, Northern Lake Huron MU, Southern Lake Huron MU, Central Lake Michigan MU, Northern Lake Michigan MU, Southern Lake Michigan MU, Eastern Lake Superior MU, Western Lake Superior MU, respectively.

Humphry_Key: Bulletin number and lake number (e.g., 20-13). A separate Humphry_Key is given for portions of lakes in different counties.

New_Key: Unique code for a given water (e.g., 72-117), based on the county numbers and lake numbers assigned by Humphrys and Green (1962). Portions of a lake in different counties have the same New_Key.

Bulletin: Numeric code for county, based on the number assigned by Humphrys and Green (1962). They numbered counties in standard alphabetical order from Alcona (1) through Saginaw (73), but then used non-standard alphabetical order for Sanilac (74), Schoolcraft (75), Shiawassee (76), St. Clair (77), and St. Joseph (78). Tuscola (79) through Wexford (83) are again in standard alphabetical order.

Acres_GIS: Lake area (acres, to three decimal places) as determined by GIS information.

Acres_total: Lake area (acres) from Humphrys and Green (1962), combining portions in different counties or states. In some cases, this number has been updated to the value in Acres_GIS.

Co_Reg_N_Laarman: A unique lake code (County-Region-Lake number) assigned by Percy Laarman (1963) for his study of fish average length.

Comment: Text field for comments.

Lk_listN: Field contains a 1 if this lake was on the list sent to each Fisheries Division MU in December 2000 for designation of lake ownership and access for planning lake surveys.

Owner_Code: 1 = public lake; 2 = private lake where Fisheries Division could probably get permission to sample; 3 = private lake where Fisheries Division probably could NOT get permission to sample; 4 = not sure about ownership; 5 = no MU file on this lake. These codes were assigned by Fisheries Division based on readily available information in order to assist in planning lake surveys. Official determination of lake ownership must be left to the discretion of Michigan courts.

Appendix 2.–Continued.

Access_Code: 1 = with launch site; 2 = without launch site, but easy access; 3 = without launch site, but difficult access; 4 = not sure about accessibility. These codes were assigned by Fisheries Division based on readily available information in order to assist in planning lake surveys.

Note: Text field for comments.

TRS: Town, Range, Section code, with no spaces, no hyphens, and no preceding zeros (e.g., T23NR4WS10).

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

Laarman, P. W. 1963. Average growth rates of fishes in Michigan. Michigan Department of Conservation, Report 1675, Ann Arbor.

Wetzel, R. G., and G. E. Likens. 1979. Limnological analyses. W. B. Saunders Company, Philadelphia.

Appendix 3.–Database: Michigan coldwater lakes.

Access table name.–Coldwater_lakes
Number of records.–1345.
Number of fields.–10.

Abstract.–This Access table lists the lakes designated as coldwater lakes (probably capable of supporting stocked trout) by the Fisheries Division of the Michigan Department of Natural Resources in a 1976 document.

Description of changes.–The list was entered into a spreadsheet, checked, then imported into Access. A few errors were noted in the original list; these were noted in the "Problems" field.

Original Fields.–The field names in the Access table are given, then the description of the field.

CWLN: Coldwater lake code on the original list. This is a six-digit code based on the county numbers (2 digits) and lake numbers (4 digits) assigned by Humphrys and Green (1962). For example, in Alcona County (county number 1), Hubbard Lake is number 165, so the CWLN is 010165.

Lake_Name: Lake name.

CWL_Acres: Surface area (acres) given in the original list.

Twp: Town (e.g., N45).

Rng: Range (e.g., W10).

Sect: Section (e.g., 36).

Added Fields.–The following fields were added by James E. Breck.

New_Key: Unique code for a given water (e.g., 72-117), based on the county numbers and lake numbers assigned by Humphrys and Green (1962).

Coldwater_Lake: Code = 1 if lake name appears on the list of designated coldwater lakes; 7 = lake now identified was "NO NAME" on Fisheries Division's list.

Tot_Acres: Surface acres based on the compilation by Humphrys and Green (1962).

Problems: Description of problems encountered, if any.

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

Michigan Department of Natural Resources (MDNR), Fisheries Division. 1976. Coldwater lakes of Michigan. Michigan Department of Natural Resources, Fisheries Division (unpublished report), Lansing.

Appendix 4.–Database: List of official Michigan lake names.

Access table name.–MILAKE names from BGN
Number of records.–6,904.
Number of fields.–20.

Abstract.–This Access table contains a list of official names of Michigan inland lakes obtained from the U.S. Geological Survey (USGS), Board of Geographic Names (USGS 2004). These names appear on USGS topographic maps. Similar information can now be obtained via the web from the Geographic Names Information System (http://geonames.usgs.gov/).

Description of changes.–The original list gave lake location in degrees, minutes, and seconds of latitude and longitude. These were converted to decimal degrees. Several errors were corrected for designated county. Great Lakes were removed from the list. Unique lake codes were added.

Original Fields.–The field names in the Access table are given, then the description of the field.

Lake_Name: Lake name. A few of these names are lake groups, e.g., West Branch Lakes in Alger County.

Type: Type of water body, either lake or reservoir.

County: County in which the lake is located.

DegN: Degrees north latitude.

MinN: Minutes north latitude.

SecN: Seconds north latitude.

NLat: "N" indicates north latitude.

DegW: Degrees west longitude.

MinW: Minutes west longitude.

SecW: Seconds west longitude.

WLong: "W" indicates west longitude.

USGS_Map: Name of the USGS topographic quadrangle map on which the lake name appears.

NameDate: Date on which the official lake name was designated.

NameYr2: Second year on which the official lake name was changed.

Added Fields.–The following fields were added by James E. Breck.

New_Key: Unique code for a given water (e.g., 72-117), based on the county numbers and lake numbers assigned by Humphrys and Green (1962).

DecDegN: Decimal degrees north latitude, created from degrees, minutes, seconds.

DecDegW: Decimal degrees west longitude, created from degrees, minutes, seconds.

JB_added: Flag to indicate a lake was added to the list by James Breck.

Note: Note about the lake.

ID: This field was automatically added by Access; it is an AutoNumber field.

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

U.S. Geological Survey (USGS). 2004. Geographic Names Information System (GNIS). Available: http://geonames.usgs.gov/).

Appendix 5.–Database: Water quality data for significant public lakes.

Access table name.–EPA_STORET_WQ_DATA
Number of records.–128,244
Number of fields.–26

Abstract.–This Access table contains water quality information for 730 lakes that have public access and are 50 acres or larger. The data was retrieved from U.S. Environmental Protection Agency STORET database via the web. The original measurements were made and entered by Michigan Department of Environmental Quality, Land and Water Management Division, Lansing. There is a separate record for each measurement of each parameter in a lake, making this a very large table. Codes are used to indicate the parameter measured, name of the sampling station, etc. Companion tables explain the codes and link the sampling station code to our unique lake code.

Description of changes.–Records for each lake were downloaded separately from STORET and then combined into a single table. To reduce the size of the table, several companion tables were created for the long names and other details for various codes, include codes for parameter, organization, station name, primary station information, composite method, primary activity category, secondary activity category, and remark.

Original Fields.–The field names in the Access table are given, then the description of the field.

Organization Code: Agency responsible for samples.

Primary Station ID: This is the main identifier for the station at which a measurement is made.

Secondary ID #1: A secondary identifier.

Surface Water Indicator: Denotes if water is considered surface water.

Ground Water Indicator: Denotes if water is considered ground water.

Pipe Indicator: Denotes if water is considered to be coming from a pipe.

Sample Code: Code for the sample.

Start Date: The date on which a grab sample was taken or the start of a composite sample.

End Date: The date on which the final composite sample was taken. Not present for a grab sample if the UMK is present.

UMK: User Multi-purpose Key. This free text is not present if End Date is not null.

Composite Method Code: Method for collecting samples, see: http://www.epa.gov/storpubl/legacy/compmeth.htm

Composite/Grab Number: A numeric value representing the total number of grab samples in a composite sample.

Sample Depth: Distance from the water surface at which a sample was taken.

Start Time: The time at which a grab sample was taken or the start time of the composite sample, based upon a 24-hour clock.

End Time: The composite sample end time based upon a 24-hour clock.

Effluent Monitoring Code: Codes that segregate data collected from different monitoring activities, but collected under the same agency code.

Replicate Number: BIOS sample replicate number.

Pipe ID: Pipe Identifier for an effluent sample.

Appendix 5.–Continued.

Primary Activity Category: Codes used to define a sample type and categories based on the media number in legacy STORET.

Secondary Activity Category: Codes used to define a sample type that is based on the media code found in the legacy STORET.

Parameter Code: Numeric code uniquely identifying a STORET parameter.

Result Value: The data: this is the numeric value (result) of the parameter measurement.

Remark Code: Character code and definition used to further quantify a result.

Composite Statistic Code: Code for statistics and performance types.

Added Fields.–The following fields were added by James E. Breck.

ID: This field was automatically added by Access; it is an AutoNumber field.

Text_Value: Text data: some records had text values for "Result Value", so we moved these to this "Text_Value" field.

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

U.S. Environmental Protection Agency (EPA). 2002. STORET Legacy Data Center. Available: http://oaspub.epa.gov/storpubl/legacy/proc_advanced_query (accessed April 2002, where Station Type = Surface Water, Organization Code for Michigan Department of Environmental Quality = 21MICH, State = Michigan).

Appendix 6.–Database: Schneider's compilation of data on lake morphology and water quality.

Access table name.–Schneider_1975_WQ
Number of records.–387
Number of fields.–22

Abstract.–This Access table contains information on morphology and water quality for 387 Michigan inland lakes. This information was compiled by James C. Schneider and is described in his 1975 paper, "Typology and fisheries potential of Michigan lakes." Data includes lake area, mean and maximum depth, alkalinity, Secchi depth, depth to the thermocline, pH, and codes for vegetation abundance, drainage type, and oxygen concentration in the hypolimnion.

Description of changes.–This information was obtained from James Schneider in a spreadsheet, then converted to an Access table. The unique lake code was assigned to each lake.

Original Fields.–The field names in the Access table are given, then the description of the field.

County_Code: County code of Humphrys and Green (1962).

Lake_HCode: Lake code of Humphrys and Green (1962).

Lake_Name: Lake name used by Schneider.

Area: Lake surface area (acres).

Mean_Depth: Mean depth (feet).

Max_Depth: Maximum depth (feet).

Alk_surface: Alkalinity at the lake surface (ppm as $CaCO_3$).

Top_Thermo: Depth (feet) to the top of the thermocline.

Bot_Thermo: Depth (feet) to the bottom of the thermocline.

Epi/Tot: Ratio of volume of epilimnion to total volume.

Secchi: Secchi depth (feet).

Color: Color.

Veg_Code: Vegetation code: ranks 1-5 (sparse to abundant).

Drain_Code: Drainage code.

O2_Code: Oxygen code [see: Code_O2_JCS]: 1, 2, 3, and 4 = stratified lakes; 1 = ≥ 2 ppm DO at all depths; 2 = DO falls to 2 ppm in hypolimnion; 3 = DO falls to 2 ppm between 5-ft level of thermocline and top of hypolimnion; 4 = DO falls to 2 ppm between bottom of epilimnion and 5-foot level of thermocline; 5 = unstratified lakes; 6 = lakes subject to frequent, severe, fish kills (DO falls to near zero throughout the lake).

O2_year: Year in which oxygen was measured.

pH_low: Low value of pH.

pH_high: High value of pH.

Unstratified: Is the lake unstratified? 1 = yes.

Appendix 6.–Continued.

Added Fields.–The following fields were added by James E. Breck.

New_Key: Unique code for a given water (e.g., 72-117), based on the county numbers and lake numbers assigned by Humphrys and Green (1962).

Note: Note about modifications of Schneider's original values.

JCS_order: Numerical order originally used by Schneider.

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

Schneider, J. C. 1975. Typology and fisheries potential of Michigan lakes. Michigan Academician 8:59-84.

Appendix 7.–Database: Lower Peninsula lakes sampled for fishes with large seines.

Access table name: large-seine data
Number of records: 229.
Number of fields: 105.

Abstract.–This Access table contains summary information on 229 Lower Peninsula lakes sampled for fishes with very large seines from 1957 to 1964. Details are given by Schneider (1981). The sampling used seines 800 to 1600 feet long and 15 to 30 feet deep. From 4 to 19 fish species were caught per lake, but only data on 17 species are included in this summary table.

Description of changes.–This file was converted from an Excel spreadsheet to an Access table. Some field names were modified. Two new fields were added, one to indicate the order of records in the original spreadsheet. A second field was a unique code for each lake, based on the numbering system for counties and lakes used by Humphrys and Green (1962).

Original Fields.–The field names in the Access table and their descriptions are given below. They are very similar to the original column names in the original Excel spreadsheet. Information from cell notes is given in the field description.

Lake_name: Lake name.

County: County.

Twp: Township.

Range: Range.

Section: Section.

Lake_area: Lake surface area (acres).

Max_depth: Maximum depth (feet).

Mean_depth: Mean depth (feet).

Alkalinity: Alkalinity (ppm).

Veg_rank: Vegetation rank; 1 = sparse; 3 = common; 5 = abundant.

Secchi: Water transparency as measured by Secchi disk (feet).

Climate: Growing degree days above a base of 55°F; per Van Den Brink et al. (1971; see Schneider 1975).

O2_type: Mid summer stratification and DO (see Schneider 1975): 1, 2, 3, and 4 = stratified lakes; 1 = ≥ 2 ppm DO at all depths; 2 = DO falls to 2 ppm in hypolimnion; 3 = DO falls to 2 ppm between 5-ft level of thermocline and top of hypolimnion; 4 = DO falls to 2 ppm between bottom of epilimnion and 5-foot level of thermocline; 5 = unstratified lakes; 6 = lakes subject to frequent, severe, fish kills (DO falls to near zero throughout the lake).

Fishing: Fishing quality; 1 = poor; 2 = fair; 3 = good; 4 = poor panfish; 5 = poor game fish.

Problem: 1 = none; 2 = stunted bluegill; 3 = stunted yellow perch; 4 = common carp; 5 = sucker.

Seine_mon: Month in which seining occurred.

Seine_yr: Last two digits of year in which seining occurred.

Seine_len: Seine length (feet).

Small_mesh: Mesh size (stretch measure) of the seine.

Material: Seine material; 1 = cotton; 2 = nylon.

Water_T: Water temperature (degrees F) at seining.

Wind: Wind conditions; 1 = calm; 2 = moderate; 3 = calm.

Appendix 7.–Continued.

Sun: Weather conditions; 1 = clear; 2 = partly cloudy; 3 = overcast; 4 = rain.

A_seined: Acres seined.

Seine_eff: Seine efficiency; 1 = poor; 2 = fair; 3 = good.

Tot_n_all: Total number, all fish species.

Tot_lb_all: Total weight of all fish species (pounds).

Lb_ac_all: Pounds per acre, all species combined.

Pred_pct_wt: Total weight of predators as a percentage of total fish weight; predator weight includes the following strongly piscivorous species: largemouth and smallmouth bass, northern pike, walleye, grass pickerel, gar, and bowfin.

BG_n_per_lb: Number of bluegill per pound of bluegill; (number of bluegill / pounds of bluegill).

BG_number: Number of bluegill.

BG_pounds: Pounds of bluegill.

BG_pct_wt: Bluegill as percent by weight of all species.

BG_pct_gt6: Percent of bluegill greater than 6 inches.

BG_pct_gt8: Percent of bluegill greater than 8 inches.

BG_lb_acre: Pounds of bluegill per acre.

BG_ngt6ac: Number per acre of bluegill greater than 6 inches.

BG_grow_in: Growth index of bluegill.

PSD_n: Number of pumpkinseed.

PSD_lbs: Pounds of pumpkinseed.

PSD_pct_wt: Pumpkinseed as percent by weight of all species.

PSD_pct_gt6: Percent of pumpkinseed greater than 6 inches.

PSD_grow_in: Growth index of pumpkinseed.

YP_number: Number of yellow perch.

YP_lbs: Pounds of yellow perch.

YP_pct_wt: Yellow perch as percent by weight of all species.

YP_pct_gt7: Percent of yellow perch greater than 7 inches.

YP_grow_in: Growth index of yellow perch.

Crappie_n: Number of black crappie.

Crappie_lb: Pounds of black crappie.

Crap_pct_w: Black crappie as percent by weight of all species.

Crappctgt7: Percent of black crappie greater than 7 inches.

Crap_gro_in: Black crappie growth index.

Rockb_n: Number of rock bass.

Rockb_lbs: Pounds of rock bass.

Rockpct_wt: Rock bass as percent by weight of all species.

Rbass %?6”: Percent of rock bass greater than 6 inches.

LMB_n: Number of largemouth bass.

LMB_lbs: Pounds of largemouth bass.

LMB_pct_wt: Largemouth bass as percent by weight of all species.

Appendix 7.–Continued.

LMB_p_gt10: Percent of largemouth bass greater than 10 inches.

LMB_p_gt15: Percent of largemouth bass greater than 15 inches.

LMB_gro_in: Growth index of largemouth bass.

SMB_n: Number of smallmouth bass.

SMB_lbs: Pounds of smallmouth bass.

SMB_pct_wt: Smallmouth bass as percent by weight of all species.

SMB_p_gt10: Percent of smallmouth bass greater than 10 inches.

SMB_p_gt15: Percent of smallmouth bass greater than 15 inches.

SMB_gro_in: Growth index of smallmouth bass.

Pike_n: Number of northern pike.

Pike_lbs: Pounds of northern pike.

Pike_pct_w: Northern pike as percent by weight of all species.

Pike_p_gt20: Percent of northern pike greater than 20 inches.

Pike Growth index: Growth index of northern pike.

WAE_n: Number of walleye.

WAE_lbs: Pounds of walleye.

WAE_pct_w: Walleye as percent by weight of all species.

WAE_pct_gt13: Percent of walleye greater than 13 inches.

WAE_gro_in: Growth index of walleye.

Pickerel_n: Number of grass pickerel.

Pickrl_lbs: Pounds of grass pickerel.

Pickrl_p_w: Grass pickerel as percent by weight of all species.

Bullh_n: Number of bullheads (not distinguished in the seine reports as to yellow, brown or black).

Bullh_lbs: Pounds of bullheads (not distinguished in the seine reports as to yellow, brown or black).

Bullh_p_wt: Bullheads as percent by weight of all species (not distinguished in the seine reports as to yellow, brown or black).

Minnow_n: Number of minnows.

Minnow_lbs: Pounds of minnows.

Minnow_p_w: Minnows as percent by weight of all species.

Carp_n: Number of common carp.

Carp_lbs: Pounds of common carp.

Carp_pct_w: Carp as percent by weight of all species.

Warmouth_n: Number of warmouth.

Warmouth_lbs: Pounds of warmouth.

Warmth_p_w: Warmouth as percent by weight of all species.

Chubsk_n: Number of lake chubsucker.

Chubsk_lbs: Pounds of lake chubsucker.

Chubsk_p_w: Lake chubsucker as percent by weight of all species.

Wsuck_n: Number of white sucker.

Wsuck_lbs: Pounds of white sucker.

Appendix 7.–Continued.

Wsuck_pct_w: White sucker as percent by weight of all species.

Bowfin_n: Number of bowfin.

Bowfin_lbs: Pounds of bowfin.

Bowfin_p_w: Bowfin as percent by weight of all species.

Added Fields.–The following fields were added by James E. Breck to the columns of information in the table from Schneider.

New_Key: Unique code for a given water (e.g., 72-117), based on the county numbers and lake numbers assigned by Humphrys and Green (1962).

JCS_Lake_n: Order in the list provided by Schneider.

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

Schneider, J. C. 1975. Typology and fisheries potential of Michigan lakes. Michigan Academician 8:59-84.

Schneider, J. C. 1981. Fish communities in warmwater lakes. Michigan Department of Natural Resources, Fisheries Research Report 1890, Ann Arbor.

Van Den Brink, C., N. D. Strommen, and A. L. Kenworthy. 1971. Growing degree days in Michigan. Michigan State University Agricultural Experiment Station Research Report 131. 48 pp.

Appendix 8.–Database: Lake characteristics from Fusilier's atlas and gazetteer of Michigan lakes.

Access table name.–Fusilier lakes
Number of records.–299, of which 297 are Michigan lakes; the others are Lake Baikal in Russia and Lake Nyos in Cameroon, Africa.
Number of fields.–27.

Abstract.–This Access table contains information from the atlas and gazetteer of Michigan lakes by Fusilier and Fusilier (1994). W. Fusilier of Water Quality Investigators provided the original dataset and Jim Breck added the field, "New-Key". This database contains information on 299 lakes, including lake area and volume, maximum and mean depth, drainage area, flushing rate, spring and summer water-quality indices developed by Wally Fusilier, and other information.

Description of changes.–Jim Breck added the field, "New-Key". The ID field was added automatically by Access.

Original Fields.–The field names in the Access table are given, then the description of the field.

Lake: Lake name.

County: County in which the lake is located.

USGS map: U.S. Geological Survey topographic quadrangle map on which the lake is located.

Lake type: Lake types include Natural; Man-made; Natural with a dam; Fosse; Reservoir; Fault; Clay pit; Artificial; Drowned river mouth; Gravel pit; Pond; Canal.

River basin: River basin in which the lake occurs.

Area: Surface area (acres).

Max depth: Maximum depth (feet).

Mean depth: Mean depth (feet). This was calculated by dividing total lake volume (acre-feet) by lake surface area (acres).

Volume (acre feet): Lake volume (acre-feet). This was determined by scanning a photocopy of the corresponding DNR lake map (if available), determining the area within each contour line, and computing total lake volume (acre-feet).

Shoreline length (ft): Length of shoreline (feet).

Watershed area (ac): Area of the watershed (acres); does not include lake surface area.

Drainage area (ac): Drainage area (acres); includes lake surface area.

Watershed to lake ratio: Ratio of watershed area to lake area.

Flushing rate (y): Flushing rate (years), or hydrologic turnover time.

Elevation: Elevation of lake surface (feet above mean sea level).

Longest dimension (ft): Longest dimension (feet). This is one method to estimate lake fetch.

Ice out date: Ice out date.

Date lake mixed: Date lake mixed.

Official lake monitor: Name of individual who is the official lake monitor.

2nd Official lake monitor: Name of individual who is the second official lake monitor.

Spring L WQ Index: Spring lake water quality index, developed by Wally Fusilier; field may include values calculated for successive years, e.g. 95 89 90.

Summer L WQ Index: Summer lake water quality index, developed by Wally Fusilier; field may include values calculated for successive years, e.g. 95 89 90.

Appendix 8.–Continued.

Bottom Sediment (Percent mineral): Bottom sediment (percent mineral); field may include several values, e.g. 83 89 77 79.

Latitude: Latitude, given as degrees, followed by decimal minutes; e.g., 44° 23.764N.

Longitude: Longitude, given as degrees, followed by decimal minutes; e.g., 83° 45.684W.

Added Fields.–The following fields were added by James E. Breck.

New_Key: Unique code for a given water (e.g., 72-117), based on the county numbers and lake numbers assigned by Humphrys and Green (1962).

ID: AutoNumber field in Access.

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

Fusilier, W. E., and B. Fusilier. 1994. Fusilier's atlas and gazetteer of Michigan lakes participating in the Secchi disk, water quality testing and bottom sediment testing offered by Water Quality Investigators. Volume IV. Water Quality Investigators, Dexter, Michigan

Appendix 9.–Database: Lakes in the Michigamme Project.

Access table name.–Michigamme-Lakes
Number of records.–66.
Number of fields.–15.

Abstract.–This Access table contains information on 66 lakes sampled for the Michigamme Project (Evans et al. 1991). The lake information in this table includes location (county, town, range, and section), surface area, volume, maximum and mean depth, area of the basin, lake alkalinity, and color. These lakes were sampled to obtain sediment cores. Additional information is available on the heavy metals and selected organic contaminants in the sediment. For several lakes there are also measurements of mercury in the feathers of eagles nesting nearby.

Description of changes.–The original information was obtained from Red Evans as a spreadsheet, which was converted to an Access table. A unique lake code (New_Key) was added for each lake.

Original Fields.–The field names in the Access table are given, then the description of the field.

Code: Evan's lake code.

Lake: Lake name.

County: County name.

Twp: Township(s) in which the lake is located.

Range: Range(s) in which the lake is located.

Sect: Section(s) in which the lake is located.

Vol_m3: Lake volume (cubic meters).

Basin_A_km2: Basin area (square kilometers).

Acres_calc: Lake surface area (acres), calculated.

Surface_A_ha: Lake surface area (hectares).

Max_D_m: Maximum depth (m).

Ave_D_m: Mean depth (m).

Alk_mgL: Alkalinity (mg/L as $CaCO_3$).

Color: Lake color (Color units).

Added Fields.–The following fields were added by James E. Breck.

New_Key: Unique code for a given water (e.g., 72-117), based on the county numbers and lake numbers assigned by Humphrys and Green (1962).

References

Evans, E., M. Wilson, and W. Creal. 1991. Assessment of mercury contamination in selected Michigan lakes, 1987-90: historical trends, environmental correlates, and potential sources. Michigan Department of Natural Resources, Surface Water Quality Division, Staff Report No. MI/DNR/SWQ-91/106.

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

Appendix 10.–Database: Watershed area of natural lakes in Michigan.

Access table name.–Lake_watersheds_MB74
Number of records.–872.
Number of fields.–23.

Abstract.–This Access table contains information from the atlas of Michigan lakes and their watersheds by Marsh and Borton (1974). They summarize watershed and lake information on over 800 natural lakes that are at least 100 acres in surface area. This includes 832 individual lakes and 40 multi-lake groups. Their measurements of watershed area refer only to the portion of the basin that drains to the lake by direct overland flow or by small streams; they exclude both lake surface area and the land area drained by large streams and rivers that enter the lake. Basin delineations and measurements were made from U.S.G.S. topographic maps; the name, year, and scale of the map are reported. Given their definition of watershed, they report watershed area, perimeter, and shape factor (watershed perimeter divided by the perimeter of a circle of the same area). They also report lake area, perimeter, and shape factor. For each measurement of area, they reported values with units of square miles, acres, and square kilometers. For each measurement of length, they reported values with units of miles and kilometers.

Description of changes.–The information for each lake was first entered into a spreadsheet, and checked. The spreadsheet was converted to an Access table. A unique lake code (New_Key) was added for each lake.

Original Fields.–The field names in the Access table are given, then the description of the field.

Bull_num: County number, based on Bulletin Number of Humphrys and Green (1962).

County: County name.

Lake_name: Lake name.

Twp: Town.

Range: Range.

USGS_topo: Name of the U.S. Geological Survey topographic quadrangle map on which the lake is found.

Map_year: Year of the U.S.G.S. topographic map.

Map_scale: Scale of the U.S.G.S. topographic map (either 1:24,000 or 1:62,500).

w_a_sqmi: Watershed area (square miles) drained by overland flow directly or by small streams (not by large streams or rivers); excludes lake area.

w_a_acre: Watershed area (acres) drained by overland flow directly or by small streams (not by large streams or rivers); excludes lake area.

w_a_sqkm: Watershed area (square kilometers) drained by overland flow directly or by small streams (not by large streams or rivers); excludes lake area.

w_p_mi: Watershed perimeter (miles).

w_p_km: Watershed perimeter (kilometers).

shape_w: Watershed shape factor: watershed perimeter divided by perimeter of a circle of same area.

l_a_sqmi: Lake surface area (square miles).

l_a_acre: Lake surface area (acres).

l_a_sqkm: Lake surface area (square kilometers).

l_p_mi: Lake perimeter (miles).

Appendix 10.–Continued.

l_p_km: Lake perimeter (kilometers).

shape_l: Lake shape factor: lake perimeter divided by perimeter of a circle of same area.

Ratio_l_w: Watershed to lake ratio: watershed area divided by lake area, where watershed excludes lake area and watershed of large streams and rivers.

Added Fields.–The following fields were added by James E. Breck.

New_Key: Unique code for a given water (e.g., 72-117), based on the county numbers and lake numbers assigned by Humphrys and Green (1962).

N_inflow_rivers: Number of rivers flowing into the lake that drain watershed not included in their measurement of watershed area. This field was created, but the information was not compiled.

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

Marsh, W. M., and T. E. Borton. 1974. Michigan inland lakes and their watersheds: an atlas. Prepared for Inland Lake Management Group, Water Quality Appraisal Section, Bureau of Water Management. Michigan Department of Natural Resources, Water Resources Commission, Lansing.

Appendix 11.–Database: Michigan lakes sampled for the U.S. EPA National Acid Precipitation Assessment Program.

Access table name.–EPA-NAPAP-lakes
Number of records.–172.
Number of fields.–14.

Abstract.–This Access table contains information on the name, location, and sampling date of 172 Michigan lakes sampled October 9 through November 6, 1984, as part of the U.S. Environmental Protection Agency's National Acid Precipitation Assessment Program (NAPAP) (Kanciruk et al. 1986). Sixteen of these lakes have no name, probably because they are very small. The NAPAP report contains the results of chemical analyses of water samples collected from these lakes; this table identifies lakes for which these chemical analyses are available. The data have also now been entered into a companion table; these variables include elevation, surface temperature, stratification status at time of sampling, lake area, watershed area, hydrologic type (drainage or seepage), Secchi depth, turbidity, color, pH, acid neutralizing capacity, dissolved organic carbon concentration, dissolved inorganic carbon, conductivity, concentrations of several cations (Ca, Mg, Na, K, NH_4) and anions (SO_4, HCO_3, Cl, NO_3, F), total phosphorus, total aluminum, iron, manganese, and silicate. Two companion reports (Linthurst et al. 1986; Overton et al. 1986) contain additional information on the NAPAP sampling program to determine characteristics of lakes in the eastern United States.

Description of changes.–The information on lake name, location, and sampling date of Michigan lakes was located in the report by Kanciruk et al. (1986) and entered into a spreadsheet. Geographic location originally reported in degrees, minutes, and seconds was converted to decimal degrees. The spreadsheet was converted to an Access database. A unique identification code (New_Key) was assigned to each lake, based on the county numbers and lake numbers assigned by Humphrys and Green (1962).

Original Fields.–The field names in the Access table are given, then the description of the field.

LakeName: Lake name.

Lake_ID: Unique lake identification code assigned by the National Acid Precipitation Assessment Program.

Lat-Deg: Degrees north latitude.

Lat-Min: Minutes north latitude.

Lat-Sec: Seconds north latitude.

Long-Deg: Degrees west longitude.

Long-Min: Minutes west longitude.

Long-Sec: Seconds west longitude.

Date_Samp: Date lake was sampled.

Added Fields.–The following fields were added by James E. Breck.

New_Key: Unique code for a given water (e.g., 72-117), based on the county numbers and lake numbers assigned by Humphrys and Green (1962).

ID: AutoNumber field automatically added by Access.

Lat_Dec_Deg: Decimal degrees north latitude, computed from degrees, minutes and seconds.

Long_Dec_Deg: Decimal degrees west longitude, computed from degrees, minutes and seconds.

Note: Note.

Appendix 11.–Continued.

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

Kanciruk, P., J. M. Eilers, R. A. McCord, D. H. Landers, D. F. Brakke, and R. A. Linthurst. 1986. Characteristics of lakes in the Eastern United States. Volume III: Data compendium of site characteristics and chemical variables. EPA/600/4-86/007c. U. S. Environmental Protection Agency, Washington, D. C. 439 pp.

Linthurst, R. A., D. H. Landers, J. M. Eilers, D. F. Brakke, W. S. Overton, E. P. Meier, and R. E. Crowe. 1986. Characteristics of lakes in the eastern United States. Volume I: Population descriptions and physico-chemical relationships. EPA/600/4-86/007a. U. S. Environmental Protection Agency, Washington, D. C. 136 pp.

Overton, W. S., P. Kanciruk, L. A. Hook, J. M. Eilers, D. H. Landers, D. F. Brakke, D. J. Blick, Jr., R. A. Linthurst, M. D. DeHaan, and J. M. Omernik. 1986. Characteristics of lakes in the eastern United States. Volume II: Lakes sampled and descriptive statistics for physical and chemical variables. EPA/600/4-86/007b. U. S. Environmental Protection Agency, Washington, D. C. 374 pp.

Appendix 12.–Database: Reports published by the Fisheries Division of the Michigan Department of Natural Resources.

Access table name.–Reports
Number of records.–2,404.
Number of fields.–12.

Abstract.–This Access table contains information on the authors, title, and report number of publications by the Fisheries Division of the Michigan Department of Natural Resources. The table lists all reports (up to September 2003) in the following report series: Fisheries Research Reports, Fisheries Technical Reports, Fisheries Management Reports, Fisheries Special Reports, and Status of the Fisheries Resource Reports. Companion tables contain full names of the report series, key words, and authors. Another companion table (named link-reports) contains the unique lake code (New_Key, based on the county numbers and lake numbers assigned by Humphrys and Green 1962) and report code for lakes mentioned in research, technical, and status reports.

Description of changes.–This is a new table. Some of the information was obtained from the bibliographic database maintained at the Fisheries Division Library located at the Institute for Fisheries Research in Ann Arbor.

Original Fields.–Because this is a new table, there were no previous fields.

Added Fields.–The following fields were added by James E. Breck.

Report_No: Code for report number.

Authors: Authors, as listed in the report.

Year: Year of publication.

Title: Title of report.

Report_Type: Code for type of report; e.g., FRR is Fisheries Research Report, FTR is Fisheries Technical Report, FSR is Fisheries Special Report, SFR is Status of the Fishery Resource Report.

Report_Type_lump: Code for type of report; lumps several types of Fisheries Research Reports together, including FRR with UMIFRR (University of Michigan, Institute for Fisheries Research Report) and DCIFRR (Department of Conservation, Institute for Fisheries Research Report). This lumping allows selection and searching of reports that continue the same series, even though there were changes in the name of the publishing organization.

RDR_num: Research and Development Report Number. At one time, State personnel at the Institute for Fisheries Research (IFR) were associated with the Research and Development Division of the Department of Conservation. Research and Development numbers were assigned to research reports from about 1964 through 1972. As part of a reorganization and name change in 1973, IFR researchers became part of Fisheries Division of the Department of Natural Resources, and Research and Development numbers were discontinued.

Number: Report number as text (old version).

Num_num: Report number as an integer. This allow sorting in numeric order.

Num_txt: Report number as text. This allows sorting in dictionary order.

File_name: File name of the associated abstract (html format) or full document (pdf document).

Path_file_name: Includes additional parts of the path name for the file, e.g., the relative file path of Fisheries Division reports available on the DNR website (see http://www.michigan.gov/dnr).

Appendix 12.–Continued.

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

Appendix 13.–Database: Public boat launch sites on Michigan lakes.

Access table name.–Boat_DNR
Number of records.–920.
Number of fields.–29.

Abstract.–This Access table contains information on inland lakes with public boat launch sites. The information originally came in a spreadsheet from Ray Fahlsing, MDNR Parks and Recreation Bureau (PRB). The main purpose of this table is to link the unique lake codes (New_Key) with corresponding launch site codes assigned by PRB. Addition information about the boat launch sites was carried along.

Description of changes.–Ray Fahlsing, MDNR Parks and Recreation Bureau, supplied the original information in the form of a spreadsheet. The boat launch sites on inland lakes were extracted from that list, which also included sites on rivers and Great Lakes. Unique lake codes (New_Key) were assigned.

Original Fields.–The field names in the Access table are given, then the description of the field.

SITE_ID: Identification number for the boat launch site, as assigned by PRB.

SITE_NO: Site number, as assigned by PRB.

DISTRICT: Number of the former DNR District in which the site is located.

WATER_ID: Code for the water body, assigned by PRB.

SITE_NAME: Site name.

LOC_DESC1: Description of the location, such as "West Campground", or "Hubbard Lake".

LOC_DESC2: Description of the location, such as "Alcona Dam Pond".

_ACC_WATER: Code for water body that can be accessed.

LAKE_ACRES: Lake surface area (acres).

MAP: Map number, as assigned by Michigan United Conservation Clubs, the distributor of lake maps for many years.

TWP: Town.

RNG: Range.

SEC: Section.

MAP_LOC_2: Nearby city on a road map.

RAMP: Code for type of ramp.

ADA: ADA compliant?

PIER: If pier present, then "YES".

TOILETS: If toilets present, then "YES".

CFT_CTRLS: not known.

_BAS_RULES: Code for rules.

_PARK: Park number.

OWNER_CODE: Code for owner of the site.

OWNER_NAME: Name of owner of the site, e.g., city name or agency.

ADM: Code for agency that administers the site.

ADM_NAME: Name of agency that administers the site, e.g., city name or agency.

OPER_CODE: Code for agency that operates the site.

OPER_NAME: Name of agency that operates the site, e.g., city name or agency.

Appendix 13.–Continued.

Added Fields.–The following fields were added by James E. Breck.

NEW_KEY: Unique code for a given water (e.g., 72-117), based on the county numbers and lake numbers assigned by Humphrys and Green (1962).

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

Appendix 14.–Database: Compilation of growth rates of Michigan fishes.

Access table name.–Laarman_Growth
Number of records.–26,086.
Number of fields.–18.

Abstract.–This Access table contains information from Percy Laarman's (1963) compilation of growth data for Michigan fishes. The Access table contains 26,086 records, with length-at-age information on individuals or groups of individuals from 18 fish species: bluegill, pumpkinseed, green sunfish, longear sunfish, black crappie, rock bass, warmouth, largemouth bass, smallmouth bass, yellow perch, walleye, muskellunge, northern pike, grass pickerel, rainbow smelt, lake trout, cisco, and white sucker. Fish were obtained from 1,135 lakes and streams sampled from 1921 to 1964. Each length-age record also contains information on species, number of individuals, sex (if determined), weight (if measured), capture gear, date, and categories for lake size, depth, alkalinity, and Secchi depth.

Description of changes.–This data was originally keypunched on computer cards for Laarman's study and stored on magnetic tape. Data from the magnetic tape was downloaded to ASCII files, with a separate file for each fish species. For the current project, these ASCII files were converted to a single Access database table. The Laarman records contain his code for the lake in which particular fish were sampled. This Laarman code was translated to the corresponding New_Key code using information in a 3-ring binder prepared by Laarman and located at the Institute for Fisheries Research.

Original Fields.–The field names in the Access table are given, then the description of the field.

LaarCode: Code used by Percy Laarman to identify lakes; it is based on county-region-lake number.

Type: Type of water: 1 = lakes, 1 to 5 acres; 2 = lakes, 6 to 14 acres; 3 = lakes, 15 to 49 acres; 4 = lakes, 50 to 99 acres; 5 = lakes, 100 to 299 acres; 6 = lakes, 300 to 999 acres; 7 = lakes over 1000 acres; 8 = streams, ≤ 24 ft wide; 9 = streams, ≥ 25 ft wide; & = Great Lakes.

Depth_class: Lake mean depth class: 1 = 1 to 4 ft; 2 = 5 to 10 ft; 3 = 11 to 15 ft; 4 = 16 to 20 ft; 5 = 21 to 29 ft; 6 = over 30 ft.

Alk_class: Surface alkalinity class: 1 = 0 to 20 ppm; 2 = 21 to 40 ppm; 3 = 41 to 105 ppm; 4 = 106 to 200 ppm; 5 = 201 ppm and greater.

Secchi_class: Secchi disk reading class: 1 = 0 to 3 ft; 2 = 4 to 8 ft; 3 = 9 to 13 ft; 4 = 11 to 19 ft; 5 = 20 ft and greater.

Species: Fish species: 1 = brook trout; 2 = brown trout; 3 = rainbow trout; 4 = lake trout; 5 = bluegill; 6 = yellow perch; 7 = pumpkinseed; 8 = black crappie; 9 = rock bass; 10 = largemouth bass; 11 = smallmouth bass; 12 = walleye; 13 = muskellunge; 14 = northern pike; 15 = grass pickerel; 16 = warmouth; 17 = green sunfish; 18 = longear sunfish; 19 = rainbow smelt; 20 = cisco; 21 = white sucker.

hMon_coll: Half month of collection: 0 = not given; 1 = days 1 to 15; 2 = days 16 to 31.

Mon_coll: Month of collection: 1 = January; … 12 = December.

Yr_coll: Last two digits of year of collection: 19xx.

Gear: Gear used in sampling: 0 = unknown; 1 = gill net; 2 = trap net; 3 = seine; 4 = hook and line; 5 = poisoning; 6 = electroshocker; 9 = others.

Sex: Sex of individual fish: 0 = unknown; 1 = male; 2 = female; 3 = combined.

Age_group: Age group.

N : Number of specimens.

Appendix 14.–Continued.

Ave_Len_tenths: Average length (tenths of inches).

Ave_Len: Average length (inches).

Ave_Wt: Average weight (grams).

Added Fields.–The following fields were added by James E. Breck.

New_Key: Unique code for a given water (e.g., 72-117), based on the county numbers and lake numbers assigned by Humphrys and Green (1962).

ID: AutoNumber field automatically added by Access.

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

Laarman, P. W. 1963. Average growth rates of fishes in Michigan. Michigan Department of Conservation, Report 1675, Ann Arbor.

Appendix 15.–Database: Michigan lakes with creel surveys.

Access table name.–Creel_Survey lakes
Number of records.–596.
Number of fields.–7.

Abstract.–This Access table lists the lakes and years in which an angler creel survey was performed and the report in which the results can be found. For winter surveys that extend into a second calendar year (e.g., winter of 1983-84), a separate record was made for each year. The table includes 596 lake-year combinations from 183 different lakes. Most records refer to a designed angler survey, but some refer to results from the General Creel Census conducted by Conservation Officers.

Description of changes.–Several reports were searched for creel survey results (e.g., Ryckman and Alward 1976; Schneider and Lockwood 1979; Ryckman and Lockwood 1985; Miller 1992; Lockwood 2000, and references therein). Information on the lake, year, and report number were tabulated. If the results were from the General Creel Census, this was noted along with the years over which summarized data was reported. For each lake, the unique lake code (New_Key) was added to the table.

Original Fields.–Because this is a new table, there were no previous fields.

Added Fields.–The following fields were added by James E. Breck.

ID: AutoNumber field automatically added by Access.

New_Key: Unique code for a given water (e.g., 72-117), based on the county numbers and lake numbers assigned by Humphrys and Green (1962).

Lake_Name: Lake name.

Cr_Survey_Yr: Year of creel survey. For surveys that extend into a second calendar year (e.g., 1983-84), a separate data record was made for each year.

Report_No: Code for the number of the report that contains the details of the creel survey.

Summary_Yrs: Years over which summarized data is reported (e.g., 1940-45).

Gen_CC: Are these data from the General Creel Census conducted by Conservation Officers? (yes/no).

References

Humphrys, C. R., and R. F. Green. 1962. Michigan lake inventory bulletins 1-83. Michigan State University, Department of Resource Development, East Lansing.

Lockwood, R. N. 2000. Sportfishing angler surveys on Michigan inland waters, 1993-99. Michigan Department of Natural Resources, Fisheries Technical Report 2000-3, Ann Arbor.

Miller, B. R. 1992. Results of the 1989 and 1991 catch survey on Sylvania lakes. Michigan Department of Natural Resources, Fisheries Technical Report 92-7, Ann Arbor.

Ryckman, J. R., and W. Alward. 1976. An estimate of winter fishing pressure for eleven Oakland County lakes. Michigan Department of Natural Resources, Surveys and Statistical Services Report 157, Lansing.

Ryckman, J. R., and R. N. Lockwood. 1985. On-site creel surveys in Michigan 1975-82. Michigan Department of Natural Resources, Fisheries Research Report 1922, Ann Arbor.

Schneider, J. C., and R. N. Lockwood. 1979. Effects of regulations on the fisheries of Michigan lakes, 1946-65. Michigan Department of Natural Resources, Fisheries Research Report 1872, Ann Arbor.