Deep Creek Lake
Baseline Assessment Report

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Science communication

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EcoCheck is a partnership group between the University of Maryland Center for Environmental Science (UMCES) and the National Oceanic and Atmospheric Administration (NOAA). Comprised of a collection of scientists interested in solving, not just studying environmental problems, EcoCheck has extensive experience in developing similar assessments, including the annual Chesapeake Bay Report Card and numerous report cards for tributaries in the Mid-Atlantic region.

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Executive Summary

Overview of project goals

The ultimate goal for this project, funded by Chesapeake Bay Trust, was to create the first annual ecological health report card for Deep Creek Lake in the style of the Chesapeake Bay report card and other other tributary-specific report cards.

Deep Creek Lake is managed primarily for recreational uses, therefore a unique assessment framework was developed in order to incorporate recreation-based indicators that have not been traditionally incorporated into other ecosystem health assessments. Additionally, rather than focus solely on lake health indicators, watershed indicators were also included in the assessment framework given that land-based activities in the lake's watershed ultimately impact the health of the lake.

After analyzing and integrating data from 2008–2009 for the chosen indicators (Figure i), it became apparent that there was insufficient information for all the indicators and therefore, it would not be possible to produce a comprehensive report card at this time. Instead, the focus of the project shifted from report card production to a rigorous baseline assessment of existing conditions, and identification of work still necessary to produce a future report card.

Development of reporting regions

Based on differences in land use and subwatershed boundaries, three distinct reporting regions were developed for Deep Creek Lake and the surrounding watershed (Figure ii). It was thought that land use differences may lead to variable results in indicator scores among the regions.

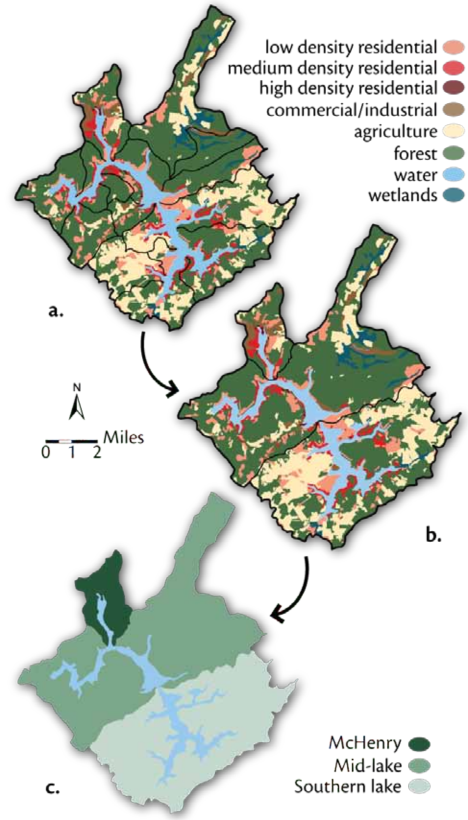


Figure ii. The three reporting regions for Deep Creek Lake (c) were determined by looking at land use patterns in the sub-watershed regions (a & b).

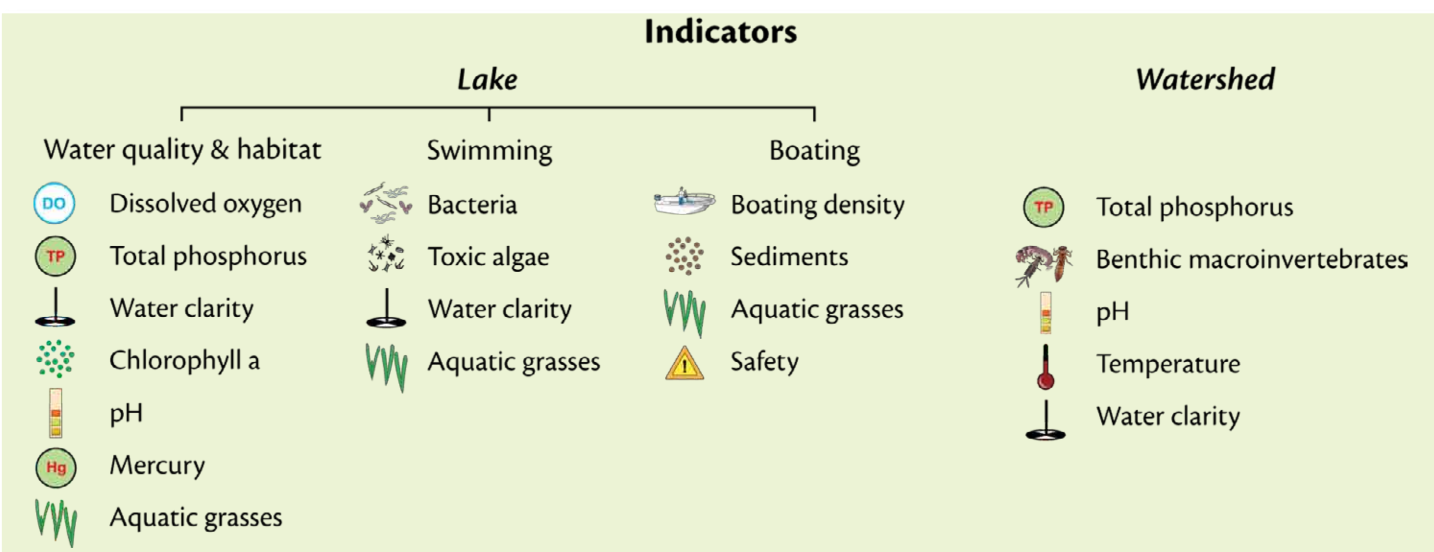


Figure i. Chosen indicators for a comprehensive assessment of the health of Deep Creek Lake and its surrounding watershed.

Lake water quality and habitat scores show slight regional differences

Scores for all water quality parameters were either in the good or very good range, which is in keeping with findings from other annual water quality reports for Deep Creek Lake. Results suggest that there are slight differences in lake water quality between regions (Table i).

McHenry generally had the highest water quality scores, and the Southern lake region had the lowest, although the scores were still in the good to very good range.

Table i. Water quality and habitat scores for lake indicators.

Water quality & habitat indicators	McHenry	Mid-lake	Southern lake	Overall
Dissolved oxygen	93	79	93	87
Total phosphorus	100	95	81	88
Water clarity	67	83	69	74
Chlorophyll *a*	64	73	65	68
pH	100	100	99	100
Mercury	n/a	n/a	n/a	n/a
Aquatic grasses	n/a	n/a	n/a	n/a

Grading scale: 0% very poor – 100% very good; insufficient data

Swimming scores were generally good, but rely solely on bacteria results

In general, the lake appears to be safe for swimming from a bacterial indicator perspective (Table ii). Bacteria sampling stations were relatively evenly distributed throughout each region, and nearly all measurements met safe swimming guidelines for bacteria concentration. Bacteria scores were good in the Southern lake region and very good in the Mid-lake and McHenry regions.

Table ii. Swimming indicator scores.

Swimming indicators	McHenry	Mid-lake	Southern lake	Overall
Bacteria	100	100	98	99
Toxic Algae	n/a	n/a	n/a	n/a
Water clarity	n/a	n/a	n/a	n/a
Aquatic grasses	n/a	n/a	n/a	n/a

Grading scale: 0% very poor – 100% very good; insufficient data

Watershed results are less clear because of inadequate sampling distribution

Generally, indicators in the watershed were more limited than in the lake; care should be exercised when interpreting results. Overall watershed scores are not presented due to the reduced spatial coverage of sampling locations relative to the lake (Table iii).

However, data for benthic macroinvertebrates are relatively robust. Benthic macroinvertebrates are scored differently than other indicators; specific ranges of data values are grouped based on an Index of Biotic Integrity (IBI) which is a measure of the health of the community of invertebrate animals living in the sediments and bottom surfaces of streams. Scores range from very poor to good. The IBI has proven to be a reliable indicator of stream quality because it integrates many of the factors required to maintain a healthy stream ecosystem.

Scores for both the Mid-lake and Southern lake regions were poor, indicating that unhealthy stream conditions exist in both regions. Stream health in the McHenry region was higher, but still only fair.

Table iii. Watershed indicator scores.

Watershed indicators	McHenry	Mid-lake	Southern lake
Total phosphorus	n/a	99	92
Benthic macroinvertebrates	fair	poor	poor
pH	n/a	87	94
Temperature	n/a	96	100
Water clarity	n/a	71	26

Grading scale: 0% very poor – 100% very good; insufficient data

Increased sampling locations are needed

In the future, new monitoring data may be able to provide information at a more detailed scale than is currently available. In particular, data gaps are evident in lake headwater areas where streams enter into the lake. Anecdotal and photographic evidence suggests that these areas may be filling more rapidly with sediments, have high densities of aquatic grasses, and are more prone to potentially toxic algal blooms. All of these issues can have negative impacts on boating access and recreational swimming. Reporting on indicators in these locations will require increasing the density of sampling locations.

Assessment of watershed health and its impacts on lake water quality would also benefit from increased collection of data. Similar to limitations in lake data availability, current watershed sampling programs are not able to provide the amount of information necessary to evaluate all desired watershed parameters. Supplemental sampling by a volunteer-based monitoring program could provide crucial information about the state of the watershed and subsequent effects on lake health.

Deep Creek Lake is generally healthy, but future work should target specific issues

Based on existing water quality data, Deep Creek Lake appears to be generally healthy, but data are limited in the watershed and shallow lake areas. Some issues remain that should be investigated further, including:

- shoreline erosion,
- sedimentation of lake headwater areas,
- restrictions to dock access caused by sedimentation, excessive aquatic grass growth, and lake drawdown, and
- blooms of potentially harmful algae.

Evidence from irregular sampling and photo documentation suggests that these problems are occurring, but their extent and severity are largely unknown because of the current distribution of sampling locations. Assessments of these issues and impacts will require increasing the number and distribution of sampling locations in shallow areas of the lake.

In 2010, MD DNR began measuring sedimentation rates in shallow headwaters areas, and aquatic grasses throughout the lake. This will provide important information about both the ecological health of the lake, and how those issues relate to boating access and recreation.

Additional data analysis will also be required to complete the development of recreational indicators for a future report card, including the missing boating and swimming indicators. For instance, a carrying capacity study scheduled for 2011 will provide boating density information for the entire lake, but more work needs to be done to create measurable indicators from it.

Introduction

This report describes the baseline condition assessment produced by EcoCheck for Friends of Deep Creek Lake in preparation for production of future annual lake ecosystem health report cards. EcoCheck is a partnership group between the University of Maryland Center for Environmental Science and the National Oceanic and Atmospheric Administration.

A new and innovative assessment framework, discussion of the individual indicators, and results of data analysis are all presented, along with suggestions for future monitoring and research needs. This document should be regarded as a baseline report, which future work can be built upon and measured against.

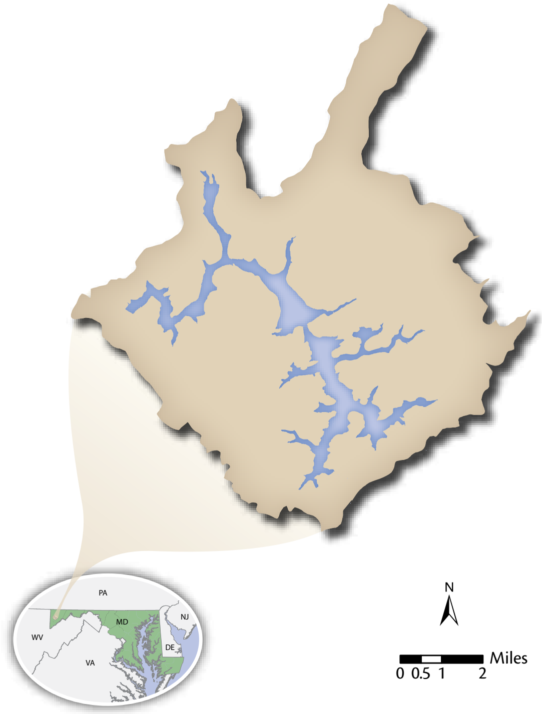


Figure 1.1. Deep Creek Lake and its watershed is located in Garrett County in western Maryland.

Background

Deep Creek Lake, located in the westernmost section of Maryland in Garrett County (Figure 1.1), was created in 1925 to serve as a hydro-electric dam empoundment. The dam continues to operate today, but over time, the lake, which is Maryland's oldest empoundment, has also become a major recreation and vacation destination. The area's combination of lake, mountains, forests, year-round recreational opportunities, and cultural heritage have attracted a wide range of residents and visitors for nearly 90 years.

The Deep Creek Lake area grew slowly and steadily in both population and housing between the 1940s and 1970s. More rapid change began in the 1980s following the completion of I-68, which ended the area's relative isolation and spurred change from a largely Pittsburgh area-oriented resort destination to one increasingly attractive to visitors and investors from both the Washington D.C. and Baltimore areas (ERM 2004).

Today, Deep Creek Lake is the centerpiece of a four-season tourist industry in the region, generating 67% of the property revenue for Garrett County and directly or indirectly impacting about 85% of the local business population (Garrett County Chamber of Commerce 2010).

The lake is nestled in the Appalachian Highlands at 2,500 feet of elevation, and is fed by four major tributaries and over 50 smaller streams.

The lake's watershed (Figure 1.2) covers approximately 180,000 acres and is located west of the eastern continental divide in the Ohio River drainage basin, with its waters ultimately flowing to the Gulf of Mexico via the Mississippi River.

Comprising 3,900 acres, Deep Creek Lake is the largest empoundment in Maryland, with approximately 65 miles of shoreline, a maximum depth of 75 feet, and an average depth of 25 feet (MD DNR Fisheries Service).

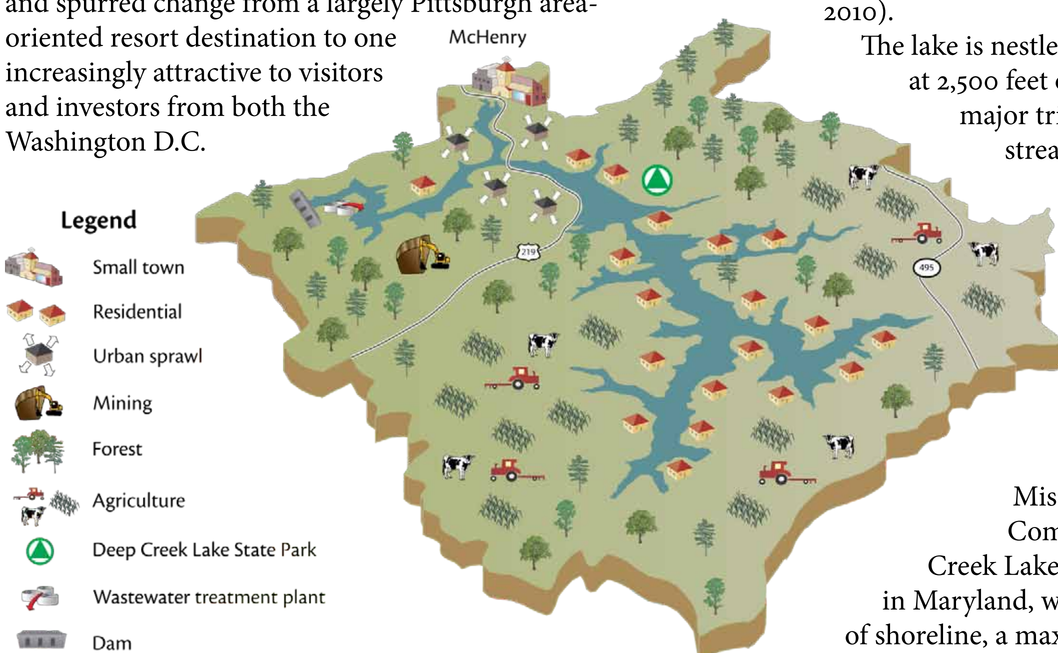


Figure 1.2. Conceptual diagram of Deep Creek Lake and the surrounding watershed.

Management

Prior to 2001, Deep Creek Lake was owned by various electric power companies which ran and operated the hydroelectric dam. In 2001, the State of Maryland purchased the lake and adjacent buffer strip, and has since leased the operation of the dam to Brookfield Renewable Power. The Maryland Department of Natural Resources (MD DNR) has a Lake Management Office and is ultimately responsible for lake operations. The Code of Maryland mandates that the "highest" use of the lake is for recreational purposes, with protection of natural resources and ecological balance also of primary concern (Code Of Maryland Regulations (COMAR) 08.08.01.01). To that end, the lake is primarily managed to maintain the lake level for an array of recreational opportunities while continuing to provide water for electric power generation. Garrett County also adopted a Deep Creek Lake watershed zoning ordinance in June 2010 to provide for land use regulations (Garrett County Code 2010).

Current Issues

Deep Creek Lake is reported to be "generally healthy" in annual reporting

According to the 2009 MD DNR Deep Creek Lake Water Monitoring Program Report, the status of Deep Creek Lake is healthy overall (MD DNR 2009A). Deep Creek Lake is typical of moderately-sized deep reservoirs in temperate areas, exhibiting seasonal patterns in many parameters, including dissolved oxygen, pH, temperature, and water clarity. Seasonal temperature stratification is strong in summer, and relatively weak in winter. Water quality parameters generally do not exceed state standards where sampling is performed.Water clarity, pH, temperature, and dissolved oxygen measurements are generally within standards or guidelines for healthy lake systems.

Dissolved oxygen levels fall below standards (five milligrams per liter) in deeper waters during summer, but this is not unusual for a thermally stratified lake system, and is not cause for concern. Similarly, water temperature sometimes exceeds the 20 degree centigrade standard, usually in shallow waters near or in embayments (shoreline areas with shallow waters near stream entrances, or small shallow areas sheltered by land). The lake is considered mesotrophic (moderately affected by nutrient inputs in excess of natural rates for freshwater lakes) (ERM, 2007), but this too is considered expected for a lake created by impoundment of a stream or river system with a dam.

Phytoplankton and fish communities are also considered robust and healthy according to annual state reports (MD DNR 2009A, MD DNR 2009B). Aquatic grass communities also appear to be strong and healthy, supporting extensive habitat for fish and other aquatic organisms (L Karrh, personal communication). Bacteria counts measured at beach and swimming areas were generally good, with bacterial concentrations exceeding swimming guidelines only 2% of the days sampled (Data from Garrett County Department of Health).

Some important issues require further assessment

Although the overall status of Deep Creek Lake is generally good, there remain several issues that require further assessment, including:

- sedimentation of lake headwater areas (shallow areas where streams enter into the lake)
- blooms of potentially harmful algae
- shoreline erosion
- reduced access to boat docks caused by numerous factors

In lake headwaters, some docks are inaccessible during certain times of the year. This appears to be the result of a combination of factors, including sedimentation of shallow areas, increased aquatic grass density, and lake drawdown. (Brookfield Renewable Power is permitted to draw down seven feet of water for electric generation purposes during the summer.)

Friends of Deep Creek Lake

Figure 1.3. Shoreline erosion can contribute to poor water clarity in both lake and stream waters.

Friends of Deep Creek Lake

Figure 1.4. Lake drawdown reduces or elimates access to the lake in shallow areas.

Swimming in some areas of the lake may not be recommended at certain times because of algal blooms of potentially harmful species, such as Microcystis. However, the presence of toxic algae is not measured on a regluar basis and it is difficult to assess the extent or frequency of the problem.

Evidence from impromptu sampling and informal photo documentation suggests that each of these issues is occurring, but are not reflected in annual reporting because of the spatial distribution of current sampling stations.

Watershed health and its impacts on lake water quality also require further assessment. Increased spatial and temporal resolution of stream health data would benefit assessments of the lake, as stream health is directly connected to lake health. Current state sampling programs, while extensive, are simply not able to provide the spatial density of sampling stations that would be necessary to track and rectify all causes of lake degradation.

Report Cards

Integrated assessments can be achieved through annual report cards

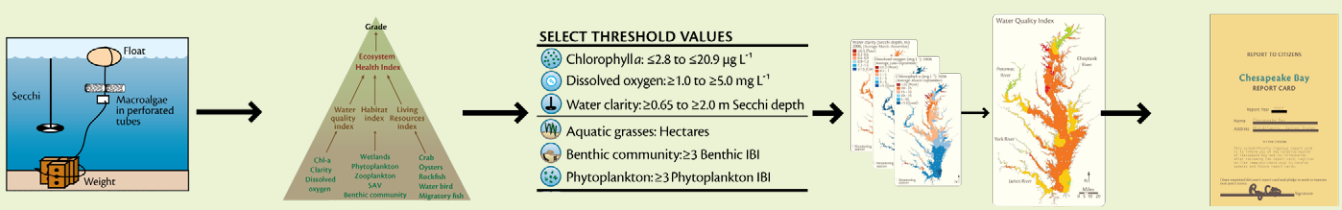
Annual report cards are an excellent way to develop rigorous assessments and communicate results to the public, local decision makers, interest groups, and the scientific community. In order to achieve a regular cycle of report card production, regular measurement of a comprehensive suite of relevant indicators is required. In some cases, additional research and monitoring needs may need to be identified before regular assessments are realistic.

Typically, the process of producing a report card takes five steps, from creating indicators and establishing a monitoring program, to printing and disseminating the report card to the target audience (see below). During the production of a report card, a technical advisory group is often formed to provide a forum for discussing and working through many important issues that arise.

Additional assessment may be identified through baseline reporting

Although the ultimate goal for a report card project is to produce regular assessments annually or semiannually, additional necessary research or monitoring may be identified before such assessments are feasible. In these cases, a baseline report can be generated that develops an assessment of currently known and unknown conditions. Baseline reports usually review the current state of knowledge by integrating data from all relevant and available sources, and present a comprehensive evaluation of the state of the system. These types of assessments can illustrate gaps in data, information, and knowledge, and can also serve as a starting point from which to conduct annual assessments. This report is intended to be a baseline assessment for Deep Creek Lake.

Five Step Process for Developing a Report Card



Step 1—Create new indicators and novel techniques for effective reporting and rigorous spatial analysis. Development of indicators is often based on available data, while recognizing and assessing additional data needs.

Step 2—Select indicators that convey meaningful information and can be measured reliably. Selection is normally based on factors such as spatial and temporal resolution and representativeness of the system. Indicators are grouped and structured to improve clarity to the intended audience.

Step 3—Define thresholds, reporting regions, and method of measuring threshold attainment. Threshold values are often based on values obtained from scientific literature and additional data analysis.

Step 4—Calculate indicator scores and combine into index grades. Where it is appropriate, scores for different regions can be combined into overarching index values and converted to report card letter grades. Detailed maps of index and indicator scores are produced.

Step 5—Communicate results using mass media. Report cards include a variety of visual elements, such as photos, maps, figures, and conceptual diagrams to improve communication of results. These can be presented through press releases, public forums, local interest groups, etc.

Project Objectives

Assessment approach

A new reporting framework for recreation-focused management

Previous assessments of Deep Creek Lake have focused on single aspects of lake health, usually related to water quality. According to COMAR, Deep Creek Lake is to be managed primarily for recreational uses, so an assessment framework was developed for this project that incorporates indicators for water quality and habitat (relevant to fishing), swimming, and boating. Additionally, activities in the surrounding watershed impact the health of the lake, thereby potentially impacting recreational activities, so a number of indicators were also selected to measure overall watershed health.

Ultimately, the goal is to achieve an annual assessment of lake and watershed quality with respect to the recreational quality objectives of lake management. This is different from other ecosystem health assessments, such as the Chesapeake Bay report card, where the indicators are incorporated into a single, overarching index of ecosystem health. Measuring the usability of the lake for recreational uses will require indicators that are not traditionally incorporated into ecosystem health assessments.

Figure 2.1 shows the desired indicators for this assessment. The indicators that are available for assessment in this report are in black, and the indicators that still need to be developed, or for which insufficient information was available to assess, are in gray.

The following sections describe the new assessment framework, focusing on an overview of each indicator.

Water quality and habitat

Measuring the usability of the lake for fishing involves both direct and indirect indicators. Indirect indicators include water quality and habitat-related indicators, and direct measures could include toxicity-related indicators and assessment of fishery status. Indicators for water quality and habitat assessed in this document include dissolved oxygen, total phosphorus, water clarity, chlorophyll *a*, and pH. More information on those indicators is available in the next chapter.

Additional indicators to be assessed in the future include aquatic grasses, mercury in fish tissue, and fish abundance as measured in stock assessments.

Aquatic grasses are an important indicator of habitat quantity and quality for many aquatic species. Fish use aquatic grasses as places of refuge from predators and also as nursery areas. Aquatic grasses are a good indicator of water clarity and nutrient levels because they require both adequate light and nutrients to grow. Once established, they may also help to increase water clarity, by slowing water movement and causing suspended sediments to settle to the bottom (Hutchinson 1975, McRoy and Helfferich 1997, Phillips and McRoy 1980).

Mercury is an indicator of toxicity related to fish consumption. While mercury is a naturally-occuring element, it is commonly released into the environment by human activities, including the burning of coal for power generation, which releases mercury into the air. It eventually settles into water or onto land where it can be washed into waterways. Microorganisms can then transform it into methylmercury, which is highly toxic to

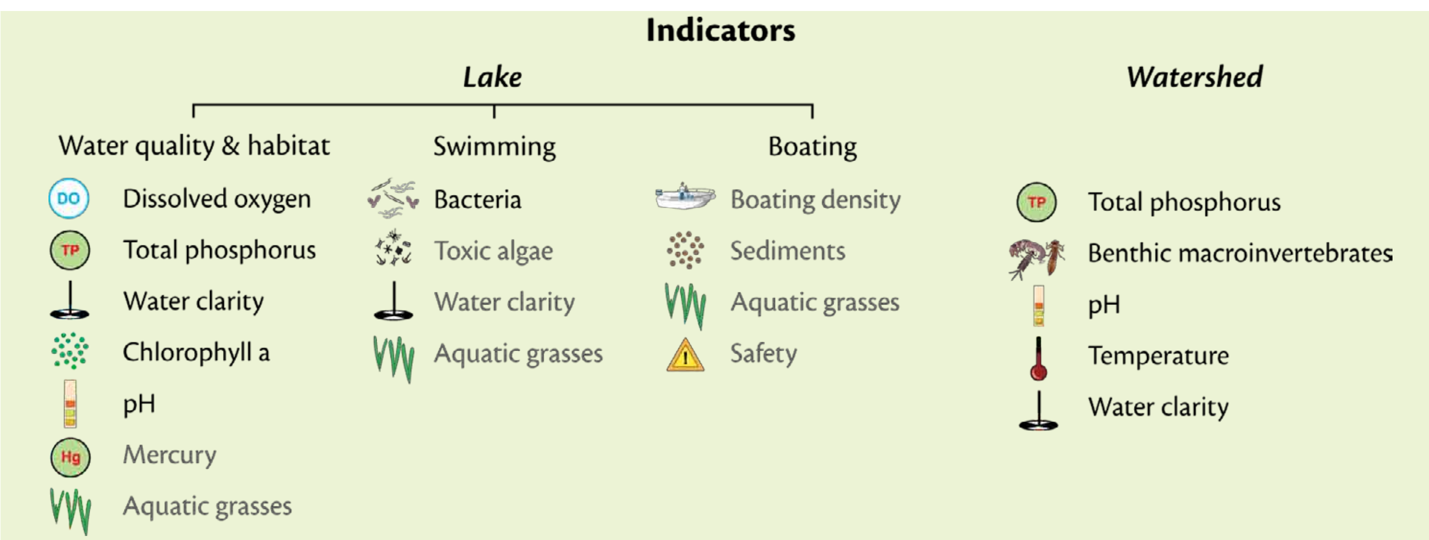


Figure 2.1. Current (black) and desired (gray) indicators for fully assessing the health of Deep Creek Lake and its surrounding watershed.

humans and can accumulate in fish and shellfish tissues.

In Maryland, the major sources of mercury air emissions are:

- power plants (43%)
- municipal waste combustors (31%)
- medical waste incinerators (19%)
- Portland cement plants (6%)
- other (1%) (e.g. landfills, oil-fired power plants, other industries) (MDE Mercury factsheet)

When humans eat fish or shellfish that have methylmercury in their tissues, they ingest mercury. Exposure can affect the human nervous system and harm the brain, heart, kidneys, lungs, and immune system (US EPA 2006). Deep Creek Lake was identified on the State of Maryland's draft 2002 list of Water Quality Limited Segments [303(d) list] as impaired by mercury contamination, based on data for mercury concentrations in fish tissue. Following this report, a Total Maximum Daily Load (TMDL) for mercury in Deep Creek Lake was approved in 2004 (MDE 2002). For this reason, mercury in fish tissues is important to measure when looking at the health of Deep Creek Lake because it is related to fishing activities.

Additional information related to fishing can be obtained from annual assessments of fisheries health conducted by MD DNR (MD DNR 2009B). A healthy fishery reflects a good balance of ecosystem health and fishing regulations.

Swimming

Indicators for recreational swimming quality include bacteria concentration, presence of toxic algae, water clarity, and aquatic grasses. These indicators measure either human health risk and/or user preference aspects of swimming.

Human health risk is evaluated by bacterial indicator concentrations in swimming areas and also by occurrence of potentially toxic algae. Data on the occurrence of toxic algae was not available for this assessment, but bacteria data was available, and more information about this indicator is found in the following chapter.

The term 'algae' is generally used to refer to a wide variety of photosynthetic organisms, generally microscopic in size. They are a natural and essential part of the ecosystem; however, when the number of algae in a waterbody increase suddenly (usually due to the presence of increased levels of nutrients and the occurence of warm and sunny conditions) an algal bloom is said to occur, which can cause foam or scum to accumulate and discolor the water.

Algal blooms are natural, and can occur with regularity depending on weather and water conditions. However, excess inputs of nutrients (especially phosphorus in most freshwater systems) can increase the frequency and severity of algal blooms. Some types of algae produce chemicals

Friends of Deep Creek Lake

Figure 2.2. A kayaker encounters an algal bloom on Deep Creek Lake in an unnamed cove.

that are toxic to aquatic organisms and humans, so a bloom of these algae can have health risks for both humans and wildlife. In humans, the toxins can cause gastrointestinal problems and/or skin or lung irritation (Hoyle et al; Falconer, 1999).

Aquatic grass density and water clarity could also be used to assess swimming preferences—although indicators based on user preference are often qualitative in nature, rather than quantitative, because individual preferences are difficult to quantify. For example, areas with clear water and firm or sandy bottom types that are free of aquatic grasses may be preferable for swimming by some, while others don't mind a rocky bottom type or the presence of some aquatic grasses or cloudiness in the water.

EcoCheck

Figure 2.3. Swimming and boating are popular activities at Deep Creek Lake.

Boating

Boating is recognized as a major recreational use of Deep Creek Lake. One way that has been proposed to evaluate boating at Deep Creek Lake is by looking at indicators related to boating density, accessibility, and safety.

These indicators are either currently unavailable for assessment or are still being evaluated. For example, indicators to assess boating area usability could be developed that incorporate reduced water depth as a result of sediment delivery to lake headwaters, and the occurrence of dense areas of aquatic grass where docks are located. These occurences can reduce boat access to docks.

Safety concerns may also reduce the quality of boating experiences and therefore boating usability. Evaluating the number of boating safety violations on the lake, as well as reported incidents of accidents, complaints, or arrests may be useful in assessing boating safety annually.

Watershed

The Deep Creek Lake watershed is an integral part of the lake system. A comprehensive assessment of lake status must also include measures of watershed health, because activities in the watershed directly affect water quality in the lake.

For example, land development and agricultural and mining practices can increase delivery of sediments, nutrients, toxins, and pet waste into streams. These ultimately empty into the lake, where such pollutants can reduce dissolved oxygen levels, increase chlorophyll *a* levels, bacterial contamination, and the occurence of toxic algal species, and reduce water clarity. Increased sediment delivery to lake headwaters (where the streams feed into the lake) may also reduce the total water depth, decreasing the usability of those areas for recreation.

To measure watershed health, the indicators assessed include total phosphorus, benthic macroinvertebrates, pH, temperature, and water clarity.


Center for Watershed Protection

Figure 2.4. Some agricultural practices can increase the amount of sediments and nutrients entering waterways.

Baseline report

Current assessment is viewed as a baseline condition report

Ultimately, the goal is to achieve an annual assessment of lake quality with a focus on the recreational quality objectives of lake management. In order to develop annual evaluations, information must be developed for several of the required indicators. This report focuses on what can be understood using currently available data, and has acknowledged limitations in scope. This assessment is intended to be viewed as a baseline assessment, to build upon and measure future work against.

Indicators

Water quality and habitat

Current indicators for water quality and habitat are dissolved oxygen, total phosphorus, water clarity, chlorophyll *a*, and pH (Figure 3.1).

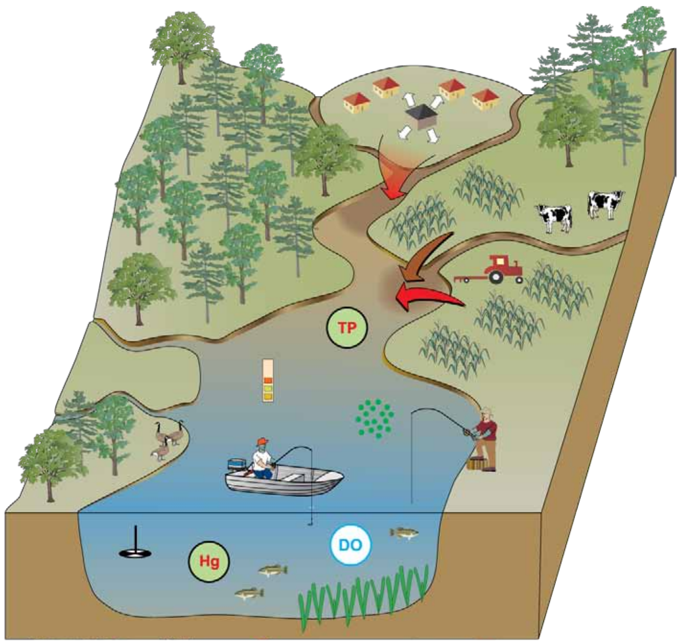


Figure 3.1. Conceptual diagram of water quality and habitat indicators in a section of Deep Creek Lake. Currently assessed indicators are DO, TP, , , and . Potential future indicators include Hg and . Inputs from the watershed that affect these indicators include nutrient and sediment runoff, as well as non-point source (diffuse) runoff.

DO *Dissolved oxygen*

Dissolved oxygen is important for aquatic organisms—most fish and other organisms become stressed with dissolved oxygen concentrations below 5.0 mg·l^{-1}, severely stressed at concentrations below 2.0 mg·l^{-1} (hypoxic conditions), and cannot survive at concentrations below 1.0 mg·l^{-1} (Moore 1942).

Most temperate lake systems experience thermal stratification, which is the separation of warm surface waters from cool deeper waters. This stratification creates a barrier to dissolved oxygen diffusion from the atmosphere into deeper portions of the lake and results in low dissolved oxygen concentrations in deep waters during warmer months (Michaud 1991). Thermal stratification and resulting low dissolved oxygen levels in deep waters are natural phenomena, but can be exacerbated by human activities.

TP *Total phosphorus*

Total phosphorus is a measurement of the amount of all forms of phosphorus, dissolved or particulate, found in a water sample. Phosphorus is a nutrient required by all organisms for basic life processes, and it naturally occurs in rocks, soils, and organic materials. It is used extensively in fertilizers and other chemicals, so it is often found in high concentrations in areas of human activity.

In fact, the primary source of phosphorus entering waterbodies is fertilizers applied to lawns, gardens, and agricultural fields. Normally, phosphorus binds with soil particles and is taken up and used by plants. Problems occur when the fertilizer is washed off before the phosphorus has time to enter the soil (i.e., the fertilizer was applied immediately prior to rainfall), or when the soil erodes into the waterbody (i.e., shoreline erosion). Failing septic systems, wastewater plant effluent, detergents, and animal wastes are also potential sources of phosphorus (Michaud 1991).

In freshwater lakes and rivers, phosphorus is often found to be a growth-limiting nutrient for aquatic plants. This means that excessive amounts of phosphorus entering a waterbody can result in algal blooms and rapid, unsustainable plant growth, which can then lead to decreased water quality.

Water clarity

Water clarity is a measure of how much light penetrates though the water column. Water clarity is dependent upon the amount of particulates (e.g., suspended sediment and plankton) and colored organic matter present. Water clarity plays an important role in determining aquatic grass and phytoplankton distribution and abundance.

Poor water clarity is usually caused by a combination of excess suspended sediments and nutrients that fuel the growth of phytoplankton. The color of the water—

Adrian Jones, IAN Image Library

Figure 3.2. Water clarity is often measured using a secchi disk.

influenced by organic materials—and upstream vegetation can also affect water clarity.

Chlorophyll *a*

Chlorophyll is the green pigment that allows plants to convert sunlight into organic compounds via photosynthesis. There are several types of chlorophyll, but chlorophyll *a* is the predominant type found in microalgae (microscopic plant-like organisms) living in most freshwater ecosystems. Chlorophyll *a* is used as a measure of the amount of microalgae (biomass) present.

Microalgae biomass is controlled by factors such as water temperature and the availability of light and nutrients. Elevated microalgae levels can lead to algal blooms and reduced water clarity, which can have negative impacts on aquatic organisms. Additionally, when an algal bloom dies, the cells sink to deeper water, where they decay and deplete the water of dissolved oxygen.

Lower chlorophyll *a* levels are generally associated with cleaner, clearer water and fewer harmful algal blooms.

pH

pH is an indicator of the acidity of water. pH can influence the chemical composition of a waterbody as well as the ability of different fish species to survive. The pH scale goes from 0–14, with normal lake pH ranging from around 6.5–7.5; 7.0 is neutral.

pH is influenced by watershed characteristics such as soil type and composition and human activities such as mining. Acid rain can also affect pH. pH may not change rapidly, but it is important to track over time. Changes in pH may indicate changes in watershed activities or acid rain deposition and can affect habitat for fish and aquatic grasses.

Swimming

Swimming safety is assessed by measuring bacteria that are indicators of fecal contamination. Additional potential future indicators include two user preference indicators—water clarity and aquatic grass coverage, as well as a measure of toxic algal species (Figure 3.3).

Bacteria

County departments of public health, in cooperation with the state, are responsible for measuring bacteria concentrations at beach areas. The measured bacterium in freshwater recreation areas is *Escherichia coli* (*E. coli*).

E. coli are found naturally in the gastrointestinal tracts of humans and other warm-blooded animals, and are not always pathogenic (i.e., disease-causing). However, *E. coli* is used as an indicator for fecal contamination, which suggests that other pathogenic organisms may also be present.

High indicator bacteria levels are assumed to be related to recent fecal contamination and are an indication of elevated health risk associated with swimming in the water. Swimming advisories may be issued if high *E. coli* concentrations are detected.

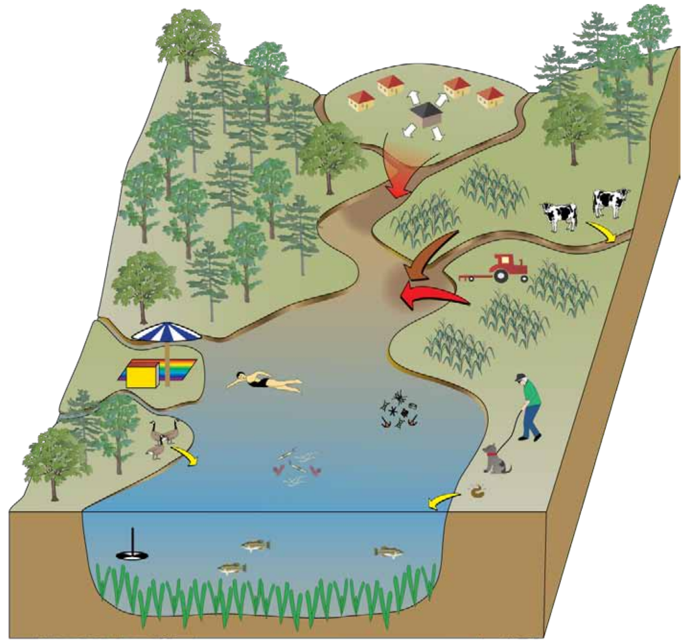


Figure 3.3. Conceptual diagram of swimming safety indicators in a section of Deep Creek Lake. The only currently assessed indicator is . Potential future indicators include , and . Inputs from the watershed that affect these indicators include nutrient and sediment runoff, as well as non-point source (diffuse) runoff and bacterial contamination .

EcoCheck

Figure 3.4. Wildlife can contribute to bacteria loads in the lake.

Watershed

Lake health is influenced by watershed activities and characteristics (Figure 3.5). Current indicators for Deep Creek Lake's watershed assessment are total phosphorus, benthic macroinvertebrates, pH, temperature, and water clarity.

TP Total Phosphorus

Total phosphorus is a measure of the amount of all forms of phosphorus, dissolved or particulate, found in a water sample.

Phosphorus is an important nutrient found naturally in soil and is a common constituent of fertilizers, manure, and organic wastes in sewage and industrial effluent. Soil erosion is a major contributor of phosphorus to streams. Phosphorus can also enter surface waters from ground water. Elevated phosphorus inputs can lead to algal blooms, low dissolved oxygen, and reduced water clarity.

Benthic macroinvertebrates

Benthic macroinvertebrates are freshwater organisms that don't have backbones. They live in and/or on stream and river bottoms. Examples include snails, mussels, crayfish, worms, and immature forms of aquatic insects.

These diverse bottom-dwelling organisms are good indicators of stream health because they respond quickly to environmental stressors, live in the water for all or the majority of their lives, are easy to collect and identify, and differ in their tolerance to different amounts and types of pollution. Additionally, unlike fish, benthic macroinvertebrates have limited mobility, so they are less likely to escape the effects of pollutants introduced by watershed activities such as mining, agriculture, and urban development (Johnson et al. 1993).

The typical sampling and analysis procedure is to collect samples from streams using nets, then to sort and count out how many and what kind of macroinvertebrates are in each sample. Since each species differs in their sensitivity to pollution, the water quality in the area that the sample was taken will be reflected in the macroinvertebrate population found in the sample.

Friends of Deep Creek Lake

Figure 3.6. Stream sampling for benthic macroinvertebrates.

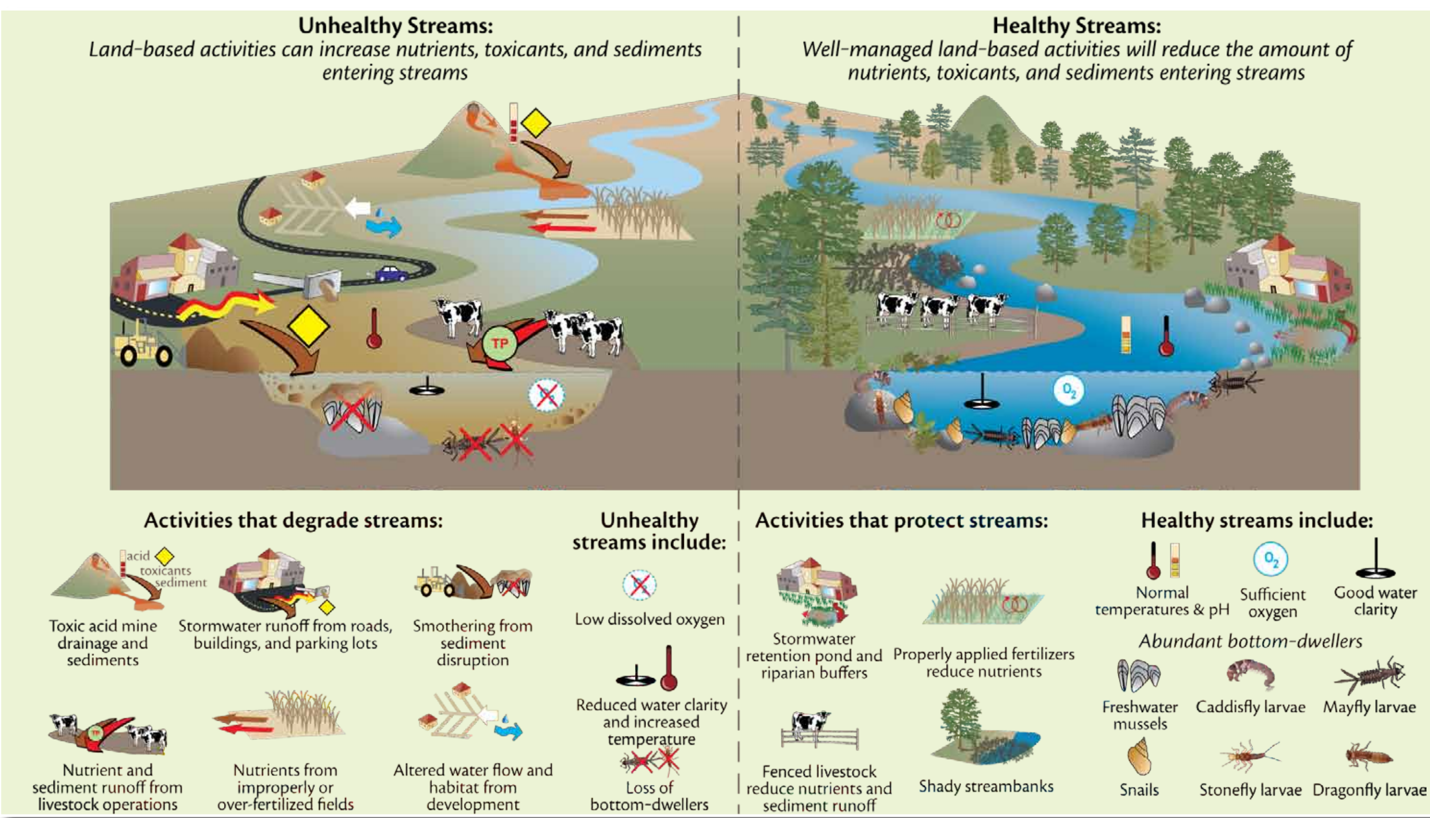


Figure 3.5. Watershed activities impact stream health. Figure adapted from EcoCheck (2009), *New Stream Health Indicator Being Developed* [newsletter].

pH

pH is an indicator of acidity, and can influence the chemical composition of water and the ability of different fish species to survive. The pH scale goes from 0 (acid)–14 (base). The pH of natural waters generally ranges from 6.5–8.5, with 7.0 being neutral.

pH is influenced by watershed characteristics such as soil type and composition and some human activities such as mining. Additional influences on pH are from acid rain.

pH is an indicator that may not change rapidly, but that is important to track over time. Changes in pH may indicate changes in watershed activities or acid rain deposition and can affect habitat for fish and aquatic grasses.

Temperature

Water temperature is an important measure of stream health because it governs the types of aquatic life that can live in a stream and also because it influences other aspects of water quality—for example, warm waters hold less dissolved oxygen than cool waters, so warm waters may be fully saturated with oxygen but still not contain enough for survival of aquatic organisms (Michaud, 1991).

All aquatic organisms have a preferred temperature range, and if water temperatures stray too far from this range, their ability to survive can be reduced.

Stream temperatures exhibit natural seasonal variation, but the physical characteristics of the stream and surrounding watershed are also important. Wide, shallow, slow-moving streams tend to be warmer than narrow, deep, quickly running streams. Likewise, forested and hilly watersheds will tend to have cooler streams than flat, sparsely vegetated watersheds where water moves more slowly and has more time to absorb heat from sunlight and the ground surface.

The most obvious and easily identified source of thermal pollution is from municipal and industrial discharges—almost half of the water withdrawn from rivers each year in the United States is used as cooling water for power plants. Once the water is passed through the plant, it is returned back to the river at a higher temperature.

Less obvious, but equally as important to consider, is the effect of development within a watershed. Urban and residental development tends to result in less vegetation and increased runoff. This runoff tends to be warmer, especially during the summer months when it flows over hot concrete or asphalt before entering a waterway.

Water clarity

Water clarity is a measure of how much light penetrates though the water column. Water clarity is dependent upon the amount of particles (e.g., suspended sediments) and colored organic matter present.

In streams, high concentrations of suspended sediments can damage both habitats and organisms by filling in rocky stream bottoms and smothering benthic macroinvertebrates and fish larvae. Some sediments can also damage fish gills, prevent proper egg and larval development, and potentially interfere with feeding.

Increased sediment input to streams (decreased water clarity) is also often related to nutrient enrichment because nutrients (such as phosphorus) tend to cling to soil particles. Additionally, high levels of suspended sediments in streams entering into shallow portions of lakes can cause those areas to fill in and become increasingly shallow at an accelerated rate.

Friends of Deep Creek Lake

Figure 3.7. A turbid stream entering Deep Creek Lake.

Data Integration

Land Use

Land use data for the Deep Creek Lake watershed from 2002 was available from the Maryland Department of Planning and provided by Garrett County. Land uses vary geographically within the Deep Creek Lake watershed (Figure 4.1): the southern portion of the watershed has most of the agricultural areas, and mining uses exist mostly in the northernmost portion of the watershed, near Cherry Run Creek. The middle portion of the watershed is mostly forested, while the northern arm of the lake (around McHenry) has a higher concentration of developed land, including commercial and residential uses. The Wisp ski resort is located in this area, on the western shore of the northern arm.

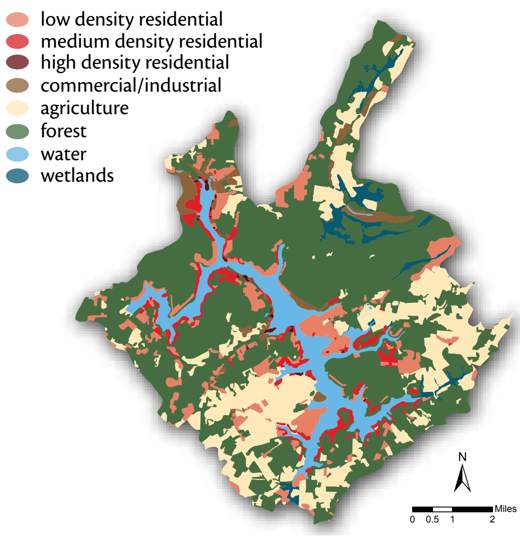


Figure 4.1. Land uses in the Deep Creek Lake watershed are predominantly forest, agriculture, or residential.

Residential areas are relatively uniform and occur throughout the watershed, concentrated near the lake shore. However, residential areas only comprise about 14% of the watershed, with the majority (51%) forest, followed by agriculture (20%; Figure 4.2).

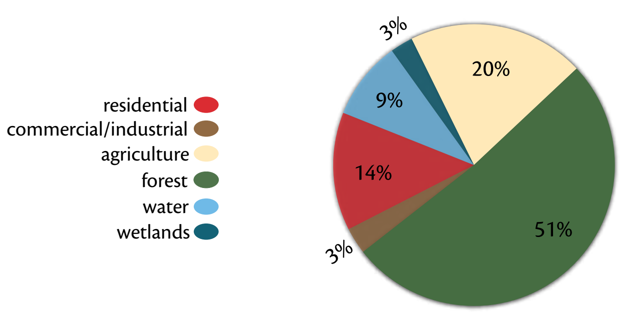


Figure 4.2. Land uses in the Deep Creek Lake watershed classified by percentage of total watershed area.

Reporting Regions

Land uses and watersheds are used to develop reporting regions

The three reporting regions for Deep Creek lake were determined by looking at land use patterns in the lake's sub-watersheds (Figure 4.3). Since activities in the watershed ultimately affect lake water quality, it was thought that variability in land uses might account for differences in scores between the regions.

Specifically, the southern portion of the watershed (south of Glendale Bridge), has a higher concentration of agricultural area, and the northern arm of the lake (McHenry) has a higher concentration of developed and commercial lands, including the Wisp ski resort, marinas, and restaurants. Although other areas of developed lands exist in close proximity to the lake, the McHenry area is unique in that the developed lands are concentrated around a relatively small water area (1 km²; compared to 6 and 8 km² for the Mid-lake and Southern lake regions, respectively), and in a relatively small portion of the lake watershed (12 km² of 166 km²). The middle portion of the watershed has a higher concentration of forested area than McHenry or the southern portion, and also has influences from mining operations that are not present in other regions.

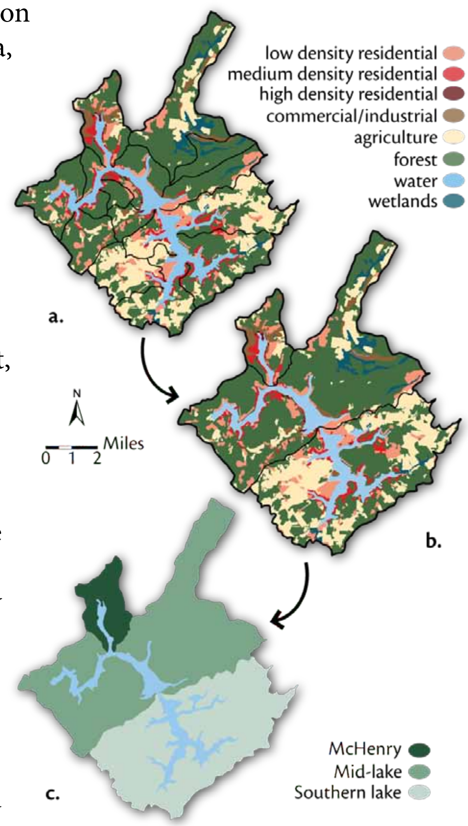


Figure 4.3. The three reporting regions for Deep Creek Lake (b & c) were determined by looking at land use patterns in the sub-watershed regions (a).

Data Availability

Various state agencies collect data in the lake and surrounding watershed

Water quality data for Deep Creek Lake are measured by several different state agencies—MD DNR, the Maryland Department of the Environment (MDE), and Maryland Department of Health and Mental Hygiene (via the Garrett County Health Department). Between the three different agencies, a variety of water quality information is collected at various locations throughout the lake (Table 4.1, Figure 4.4).

Watershed data are also collected by MDE and DNR, as well as by MD DNR's Maryland Biological Stream Survey (MBSS) and Stream Waders programs (Table 4.1, Figure 4.5).

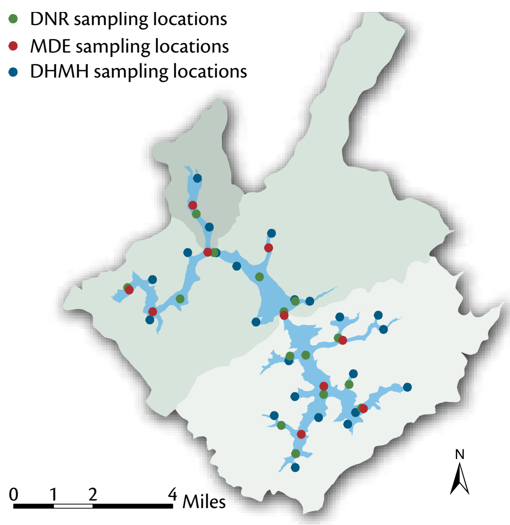


Figure 4.4. Lake data are collected by three different agencies: DNR, MDE, and DHMH.

MBSS collects data on numerous indicators at random, non-tidal stream sites statewide. The Stream Waders program is a component of the MBSS program, where volunteers collect information on benthic macroinvertebrates to increase the number and density of sampling sites to support statewide stream quality assessments.

The watersheds evaluated by these programs, and the sampling locations within the watersheds, are randomly selected each year, so there is no guarantee of having MBSS or Stream Waders sites within the Deep Creek Lake watershed each year. However, for the scope of this project, data from both MBSS and Stream Waders sites within the Deep Creek Lake watershed were available.

Table 4.1. Data for lake and watershed indicators are available from several different state agencies.

Region	Indicator	Sources
Lake	DO	DNR, MDE
Lake	TP	DNR, MDE
Lake		DNR, MDE, DHMH
Lake		DNR, MDE
Lake		DNR, MDE, DHMH
Lake		MDE, DHMH
Watershed	TP	DNR, MDE, MBSS
Watershed		MBSS, Stream Waders
Watershed		DNR, MDE, MBSS
Watershed		DNR, MDE, MBSS
Watershed		MDE, MBSS

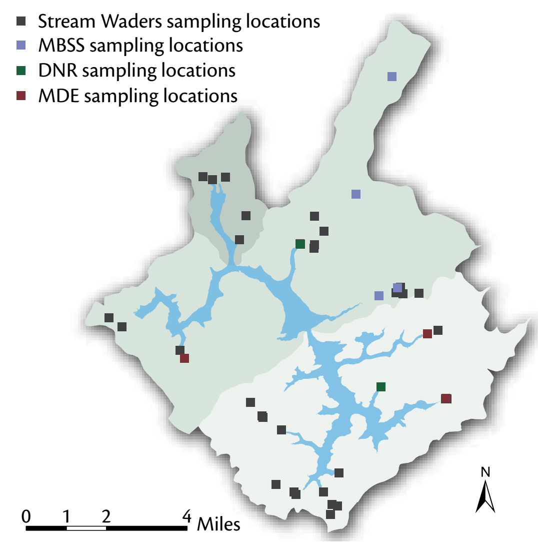


Figure 4.5. Watershed data are collected by DNR and MDE, as well as MBSS and Stream Waders.

Temporal coverage of data

Data from both 2008 and 2009 were used in this baseline assessment to provide a more complete background evaluation of current conditions in the lake and surrounding watershed.

For lake indicators, all MDE data used in this assessment were collected in 2008, and all DNR data were collected in 2009. DHMH data is available for both 2008 and 2009. This means that two years of data were available from at least two different sources for all indicators, except for clarity and pH, which had data from all three sources. Bacteria data were only available from DHMH for this project. MDE collects bacterial data which is why they are listed in Table 4.1. However, there was no MDE data available for the sites pertinent to this assessment in 2008.

For watershed indicators, MDE data is again available from 2008 and DNR data from 2009. MBSS data is available for three sites in 2008, and one site in 2009 (Figure 4.6). Streamwaders data is available for both 2008

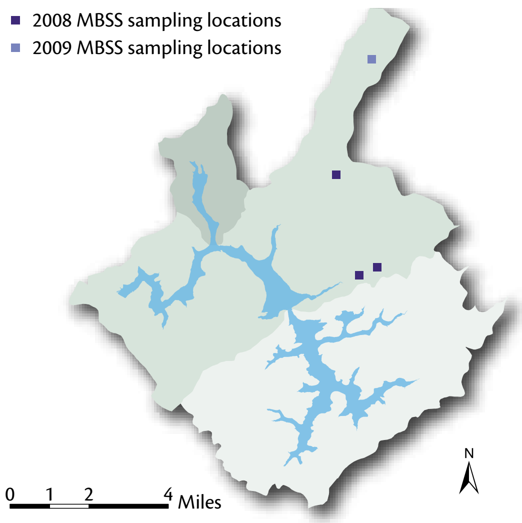


Figure 4.6. There are four MBSS sites in the Deep Creek Lake watershed—three from 2008 and one from 2009.

and 2009, although there were more sites in the Deep Creek Lake watershed in 2009 than 2008 (Figure 4.7). Therefore, like the lake indicators, all watershed indicators are also covered by two years worth of data from at least two different sources.

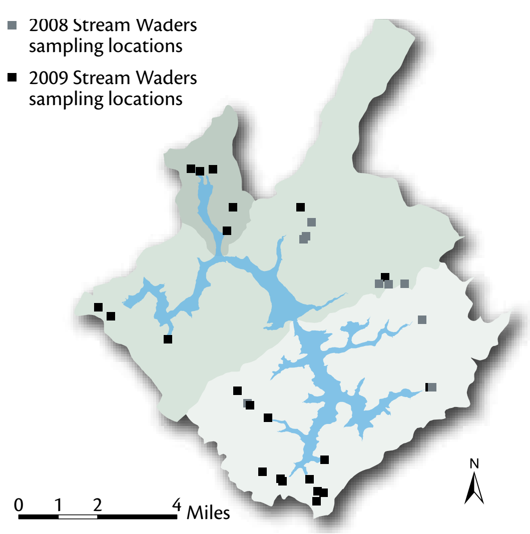


Figure 4.7. There are nine Stream Waders sites in the Deep Creek Lake watershed from 2008 and 22 from 2009.

Data Gaps

Data gaps exist in any assessment

In an ideal situation, data for all desirable indicators would be available and ready for use in an assessment of Deep Creek Lake health. Unfortunately, ideal situations rarely arise, and the current assessment must rely on currently available data.

For this assessment, data were available for water quality and habitat (dissolved oxygen, water clarity, total phosphorus, pH, and chlorophyll *a*), swimming (indicator bacteria), and watershed health indicators (total phosphorus, benthic macroinvertebrates, pH, temperature, and water clarity). These indicators enable us to develop a snapshot baseline assessment which can be built on in future years by adding additional sampling locations and parameters, as well as developing new and innovative ways to integrate existing data.

For example, information currently exists for complaints, arrests, and boating incidents on the lake, and a boat carrying capacity has been previously developed (C. Matthews, personal communication). Integrating these data into an assessment will require additional thought on how best to convert them into meaningful indicators and scores.

Sampling sites are not evenly distributed throughout reporting regions

For both lake and watershed regions, there is much greater data coverage in the Mid-lake and Southern lake regions than in the McHenry region. There are a total of four lake data points in the McHenry reporting region—two DHMH sites, and one from each DNR and MDE—and five watershed data points—all from Stream Waders.

In contrast, there are 19 lake and 18 watershed sites in the Mid-lake region, and 25 lake and 18 watershed sites in the Southern lake region. While McHenry is a smaller region than the other two, both in terms of lake and watershed area, the low number of sampling locations still does not allow for a comprehensive assessment of the region. In particular, the watershed data available for McHenry only comes from Stream Waders, and therefore does not encompass all the desired indicators.

Watershed data are sparse except for benthic macroinvertebrates

Looking at Figure 4.5, data availability and coverage throughout the watershed appears to be quite good. However, the majority of the sites are from Stream Waders, which only collect benthic macroinvertebrate data.

All other watershed indicators (total phosphorus, pH, temperature, and water clarity) are only sampled at DNR, MDE, and MBSS locations, which are much reduced in number and spatial coverage. If the Stream Waders sites are disregarded, there are zero watershed sites in the McHenry region, seven in the Mid-lake region, and only three in the Southern lake region (Figure 4.8).

This means that assessing watershed indicators other than benthic macroinvertebrates, while possible, does not give a complete picture of the health of Deep Creek Lake's watershed.

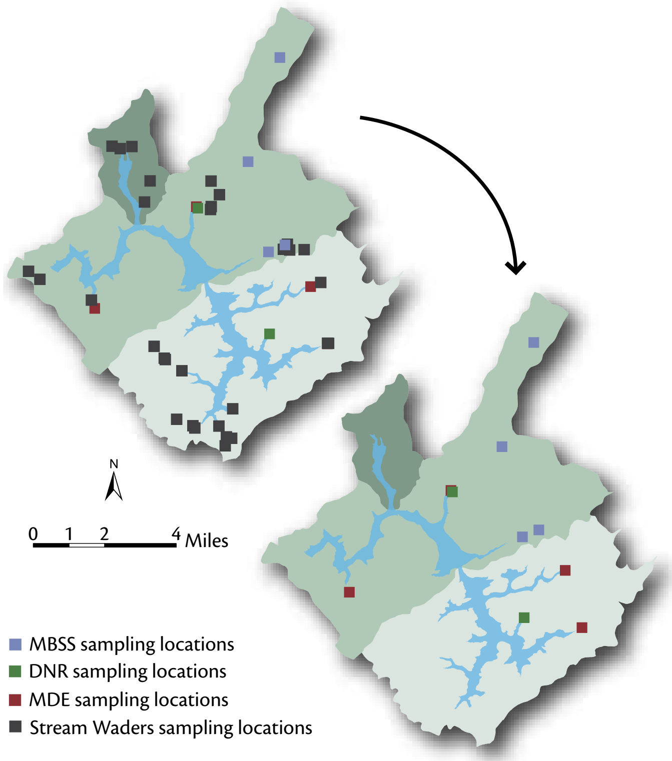


Figure 4.8. Without the Stream Waders sites, spatial coverage of watershed data locations is very low.

Shallow water areas require additional sampling

Some of the issues at Deep Creek Lake are particular to areas which are not sampled by existing programs. The limitations of state and county programs must be recognized—it is simply beyond the scope of these programs to develop long-term sampling programs that include sampling at all desired locations.

In particular, it appears that there are issues related to boating and swimming access that should be assessed separately in shallow lake headwater areas (areas where streams enter the lake and where water depth is less than 10 feet at full pool depth). Anecdotal and photographic evidence suggests that these areas may be filling more rapidly with sediments and have high densities of aquatic grasses, both of which may reduce accessibility of boats to docks at the shoreline.

Additionally, swimming in these areas may be affected by the high densities of aquatic grasses and algal blooms that have been documented in recent years.

Reporting on indicators in these locations will require increasing the density of sampling locations. Some work by the Maryland Department of Natural Resources beginning in 2011 will develop new data for sedimentation rates and aquatic grass coverage in many of these shallow water areas. Additional sampling might be considered in conjunction with these efforts or could be supplemented by volunteer monitoring programs.

Thresholds

Assessment thresholds were determined using information from reports and local expertise

The reporting framework used in this project is similar to other assessments done by EcoCheck, and requires that data values be assessed in relation to specific thresholds of significance. The thresholds are significant because they represent the point where prolonged exposure to unhealthy conditions leads to a negative response (Longstaff et al. 2010). Thresholds for this project were derived from research and reporting on lake ecosystems, in particular from work done by MD DNR (Tables 5.1 and 5.2, MD DNR 2009A).

Table 5.1.Thresholds for lake indicators.

Indicator	Threshold	Score
Dissolved oxygen	5.0 mg·l^{-1}	p/f
	Range (µg·l^{-1})	
Total phosphorus	< 12.0	3
	12.0 to < 24.0	2
	24.0 to < 96.0	1
	≥ 96.0	0
	Range (meters)	
Water clarity	≥ 4.0	3
	2.0 to < 4. 0	2
	0.5 to < 2. 0	1
	< 0.5	0
	Range (µg·l^{-1})	
Chlorophyll *a*	< 2.6	3
	2.6 to < 7.3	2
	7.3 to < 56	1
	≥ 56	0
pH	6.5 ≤ value ≤ 8.5	p/f
Bacteria (*E. coli*)	count ≤ 235·100 mL^{-1}	p/f

Scoring of data

In addition to data threshold values, appropriate temporal periods over which to assess the data must also be established. It is not informative to include data from periods when data values are consistently below threshold values, for example. Including these data may skew results toward unrealistically high scores; it is more informative to evaluate data when there is the potential for exceedances of thresholds, or during periods when the exceedances would have significant ecological consequences. To determine the appropriate temporal periods for data assessment, evaluation of time series data in relation to specific thresholds can be useful (Figure 5.1).

Table 5.2. Thresholds for watershed indicators.

Indicator	Threshold	Score
	Range (mg·l^{-1})	
Total phosphorus	< 0.05	4
	0.05 to < 0.075	3
	0.075 to < 0.10	2
	0.10 to ≤ 0.20	1
	> 0.20	0
	Range	
Benthic macroinvertebrates	1 to 1.9	very poor
	2 to 2.9	poor
	3 to 3.9	fair
	4 to 5	good
pH	6.5 ≤ value ≤ 8.5	p/f
Temperature	≤ 20 °C	p/f
Water clarity	≤ 10 NTU	p/f

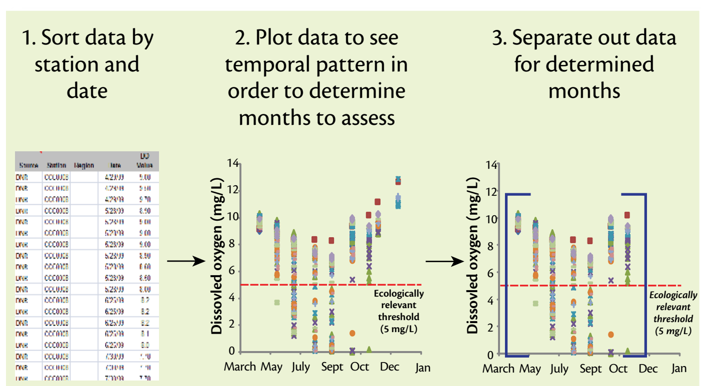


Figure 5.1. Examining data over time in relation to relevant thresholds helps determine the appropriate temporal period for evaluation.

Once thresholds and relevant assessment time periods have been identified, data are scored using either a pass/fail or multiple threshold method. Ideally, multiple thresholds are used to provide some gradation of results from poor to excellent, rather than just pass or fail, but this may not be appropriate for all indicators.

Pass/Fail scoring method

A pass/fail scoring method is used to calculate the scores for three of the six lake indicators (dissolved oxygen, pH, and bacteria) and three of the five watershed indicators (pH, temperature, and water clarity). The process is outlined in Figure 5.2 below, and results in a score on a scale of 0 to 100%, where the higher percentage values represent more healthy conditions (Williams et al. 2008).

One disadvantage of using a pass/fail method is that there is no way to know how close a failing value is to passing. In other words, if a dissolved oxygen measurement is 4.9 $mg \cdot l^{-1}$, it fails because the threshold is 5.0 $mg \cdot l^{-1}$. However, it is much closer to passing than a value of 1.0 $mg \cdot l^{-1}$. Therefore, using a pass/fail method does not allow for any knowledge of how close or far values are from the threshold criteria.

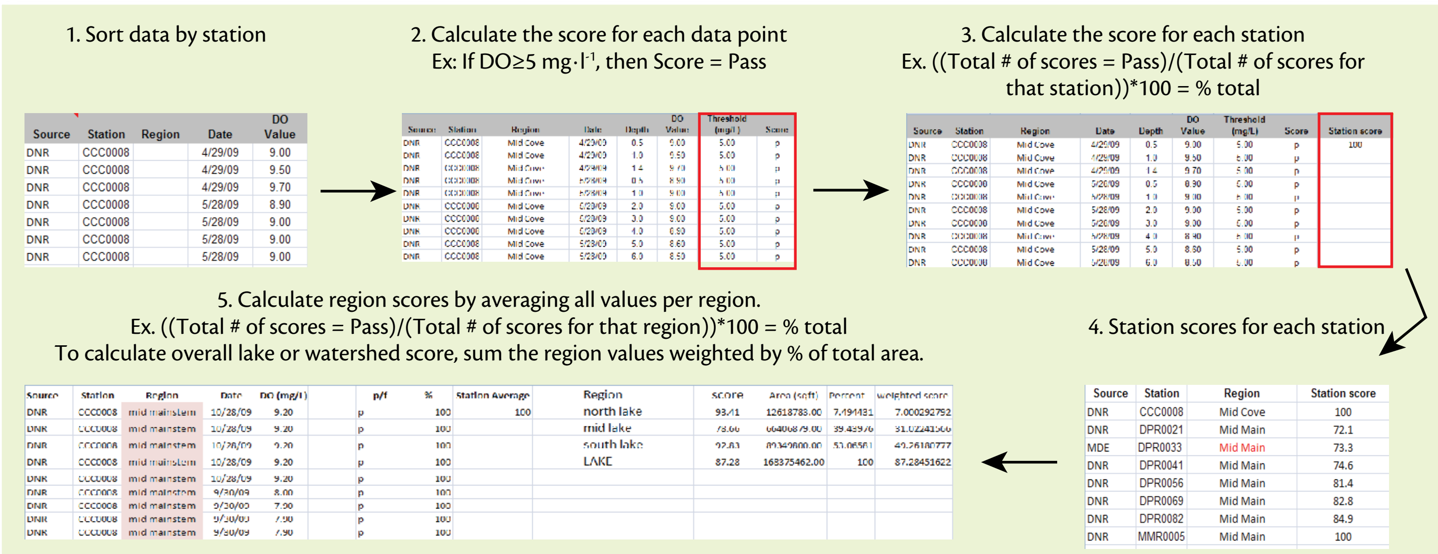


Figure 5.2. A pass/fail scoring method is a simple way to score some indicators.

Multiple thresholds

Multiple thresholds are used to score indicators based on a gradient of healthy to unhealthy conditions. For example, total phosphorus is an indicator of the amount of phosphorus in the water system. However, the amount of phosphorus, from low, acceptable levels, to just a little bit too much, to a truly excessive amount, can have different effects on the ecosystem. Therefore, when the measured value of total phosphorus is compared to multiple thresholds, it can score low, medium, or high. This is similar to a grading scale, in which an A is excellent, a B is good, and a C is average. In this way, indicators can be assessed with greater precision than using a pass/fail method (Figure 5.3).

Indicators	Multiple Thresholds	% Passing	Description
Total phosphorus	Pristine	80–100	Good
		60–80	Fair
Water clarity		40–60	Moderate
Chlorophyll *a*		20–40	Poor
Benthic macroinvertebrates	Impaired	<20	Very Poor

Figure 5.3. Multiple thresholds allow for greater precision in assessing indicators than using a pass/fail method.

Applications of multiple thresholds work well if divided into several categories, corresponding to specific percentiles in the frequency distribution of the data (Figure 5.4). This creates a scoring scheme based on intervals within the frequency distribution such that the lowest and highest 5% of measurements represent the very worst and best scores.

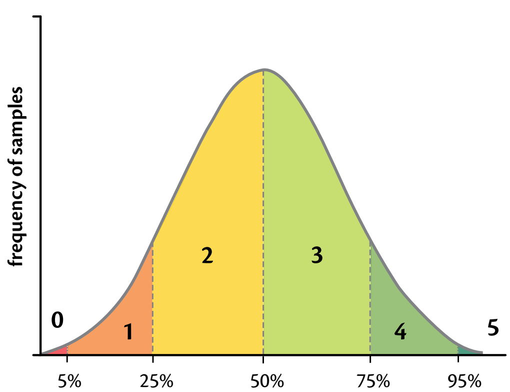


Figure 5.4. Example frequency distribution—scores are divided equally among percentiles.

Scores between the highest and lowest 5% are divided into regular intervals. If a particular value is identified as standard or ecologically significant criterion, this value can be used to "anchor" the distribution of scores (Figure 5.5). Previous applications of these types of thresholds have used the preferred or goal value as the next-to-highest score so that this value scores very high, but values that are within the top 5% of the distribution receives the best score (EcoCheck 2011).

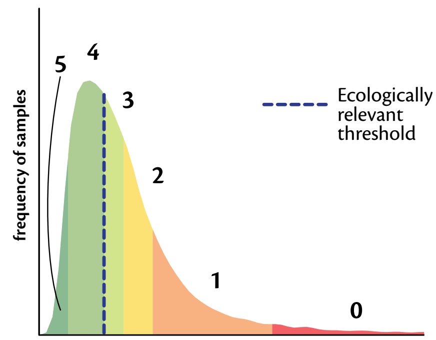


Figure 5.5. Example frequency distribution—scores are anchored by an ecologically relevant threshold, then divided equally among percentiles.

Scores are standardized to 0-100% scale

In order to integrate individual indicator scores into a more encompassing index (e.g., aquatic habitat or swimming quality), scores are standardized to a 0–100% range. This allows indicators with different score classes to be easily combined. For instance, one indicator may have three appropriate thresholds that are useful, while others may have five. By converting each to 0–100%, the results can be combined into an overall index. Scores for individual indicators and combined indexes are calculated for each reporting region. A score for a reporting region is calculated by averaging all individual scores within the region and standardizing to the 0–100% scale. An overall score (e.g., lake-wide aquatic habitat score) can be calculated as the area weighted average of regional scores.

Results

Overview of lake scores

Scores for all water quality and swimming indicators were either in the good or very good range.

Water quality and habitat scores ranged from fair to very good

Chlorophyll *a* and water clarity scores were 68 and 74%, respectively, while dissolved oxygen and total phosphorus scores were 87 and 88%, respectively. pH scored 100% or very good.

Table 6.1 Scores for lake water quality & habitat indicators.

Water quality & habitat indicators	*McHenry*	*Mid-lake*	*Southern lake*	*Overall*
Dissolved oxygen	93	79	93	87
Total phosphorus	100	95	81	88
Water clarity	67	83	69	74
Chlorophyll *a*	64	73	65	68
pH	100	100	99	100
Mercury	n/a	n/a	n/a	n/a
Aquatic grasses	n/a	n/a	n/a	n/a

Dissolved oxygen

Dissolved oxygen scores were good in McHenry and the Southern lake regions (93% in each), but were fair in the Mid-lake region (79%). This may be a result of deeper stations in the Mid-lake region that have measurements below the upper, well-mixed portions of the lake. The lower scores in the Mid-lake region may be misleading.

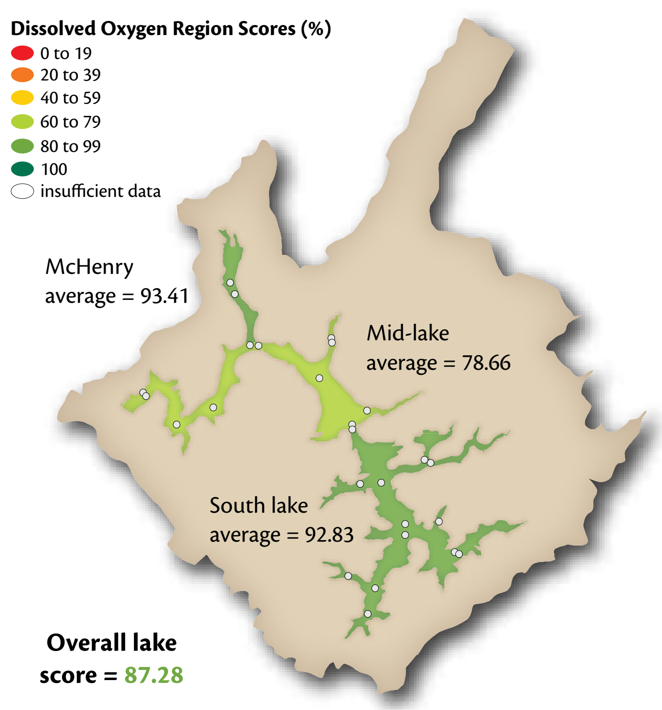


Figure 6.1. Lake region scores for dissolved oxygen were good.

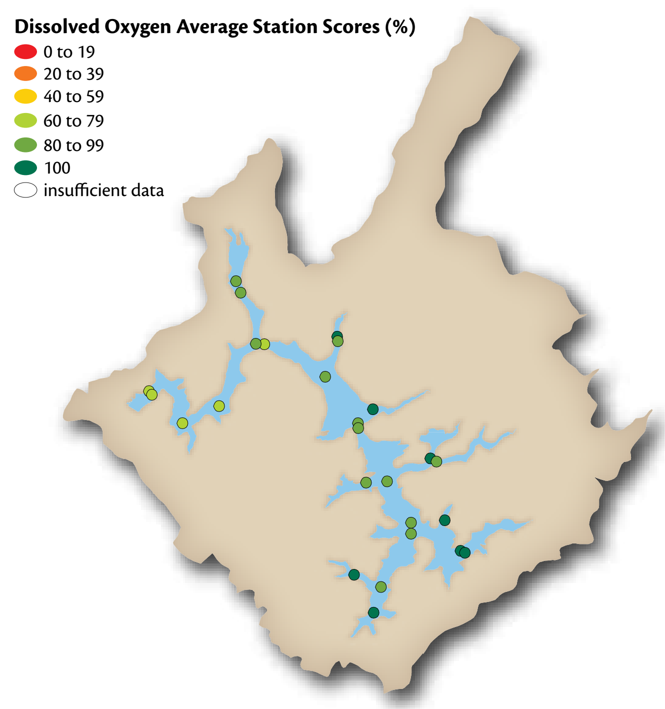


Figure 6.2. Average station scores for lake dissolved oxygen.

Water clarity

Water clarity did not score quite as well as other indicators in the lake. McHenry scored 67%, Mid-lake 83%, and Southern lake 69%. Overall, lake water clarity scored 74%, which is in the fair range.

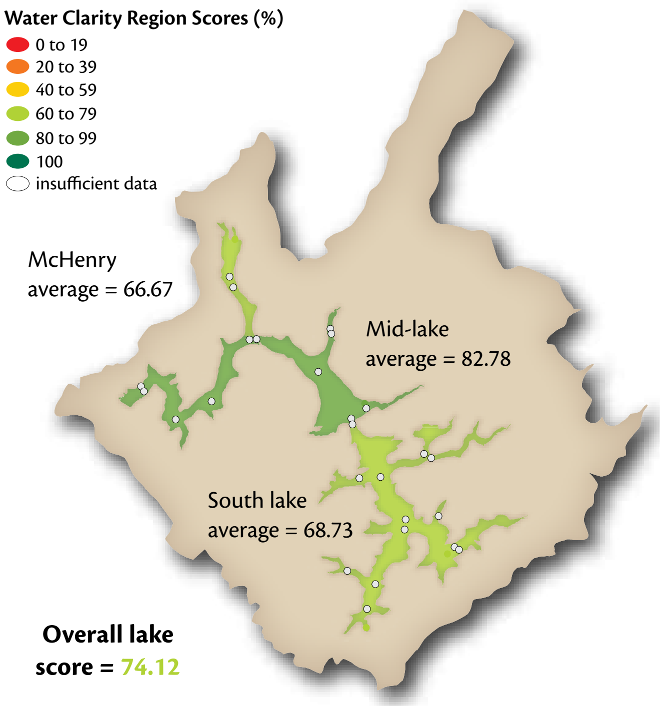


Figure 6.3. Lake region scores for water clarity were fair.

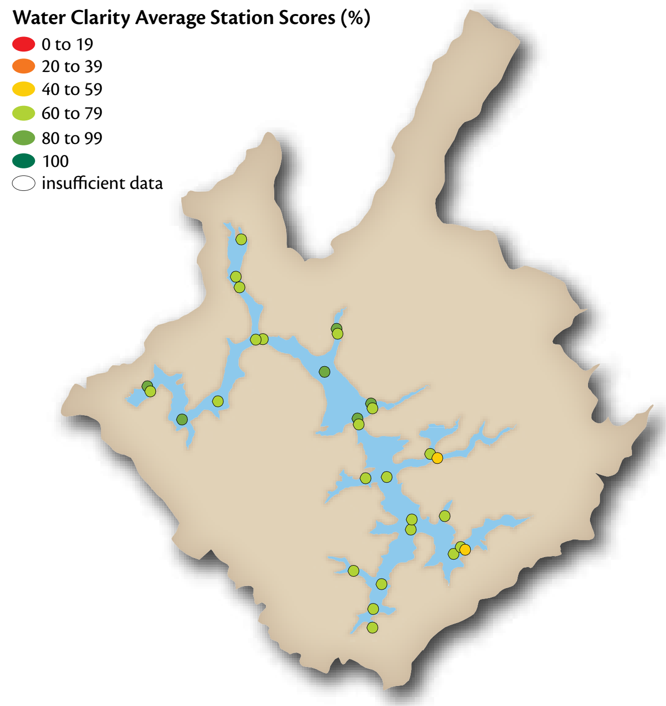


Figure 6.4. Average station scores for lake water clarity.

Chlorophyll *a*

Chlorophyll *a* scores were generally fair. McHenry and Southern lake chlorophyll *a* scores were 64 and 65%, respectively. The Mid-lake region scored slightly better at 73%. The overall score for the lake is 68%, again in the fair range.

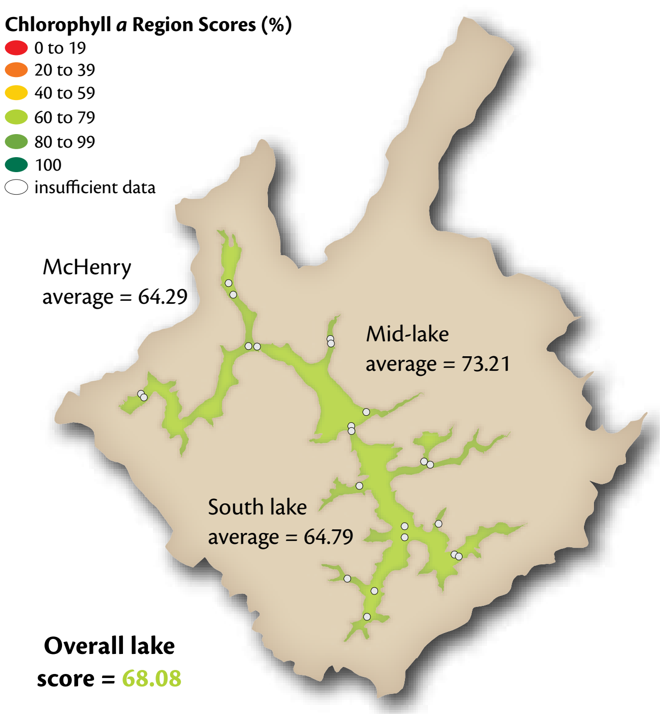


Figure 6.5. Lake region scores for chlorophyll *a* were fair.

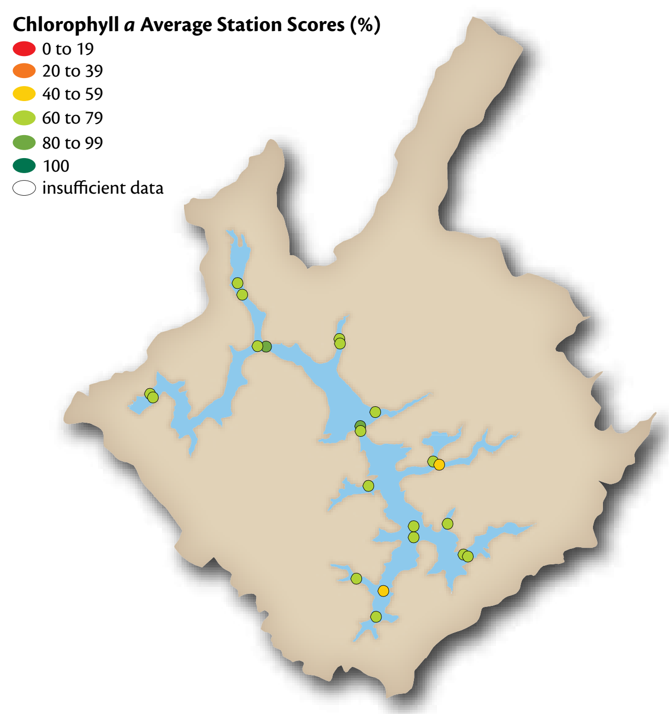


Figure 6.6. Average station scores for lake chlorophyll *a*.

Total phosphorus

Total phosphorus scores were very good in the McHenry region and good in the Mid-lake and Southern lake regions. McHenry scored 100%, Mid-lake 95%, and Southern lake 81%. The overall score for total phosphorus was 88%, which is good.

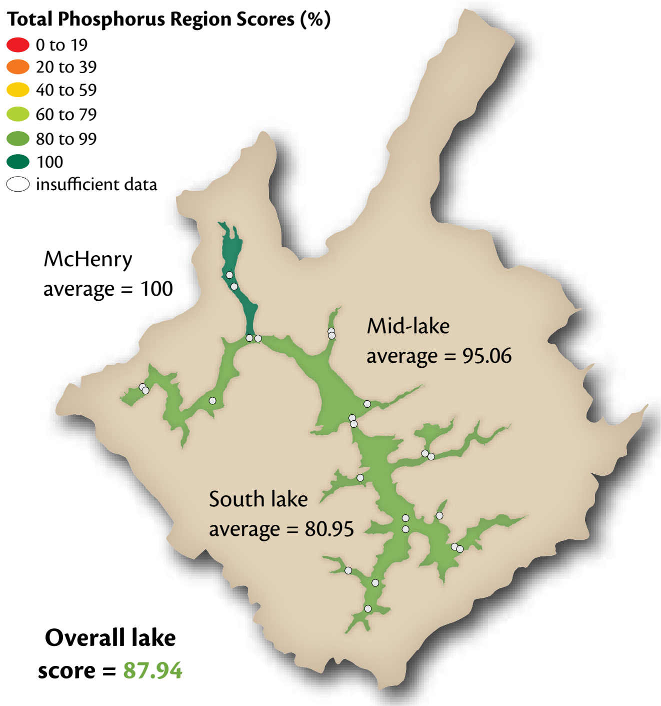


Figure 6.7. Lake region scores for total phosphorus were good.

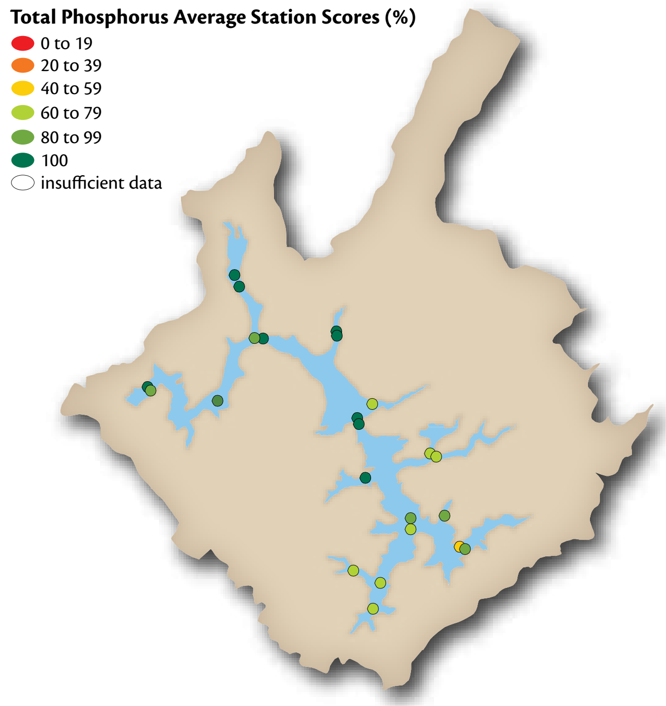


Figure 6.8. Average station scores for lake total phosphorus.

pH

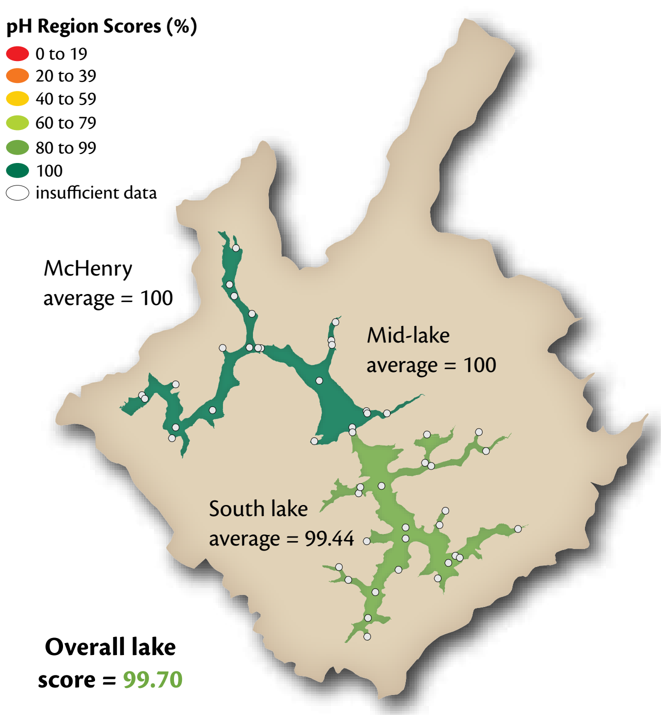


Figure 6.9. Lake region scores for pH were very good.

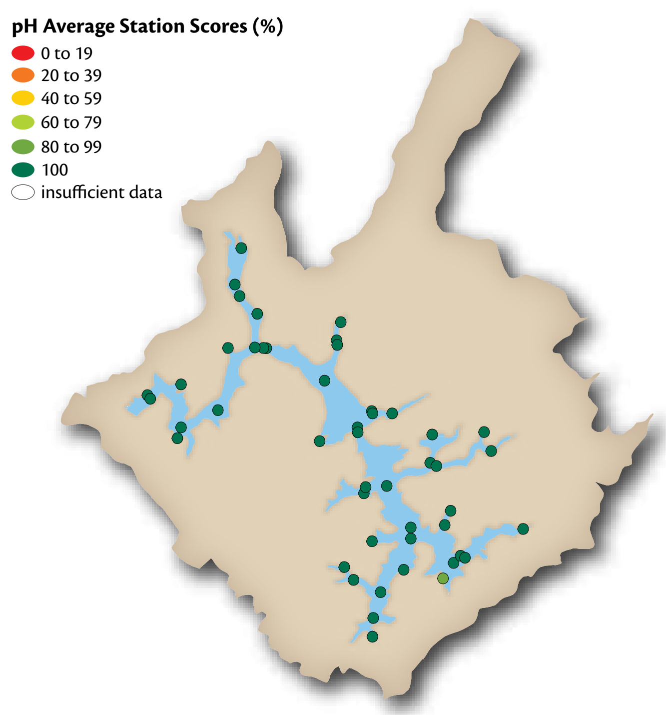


Figure 6.10. Average station scores for lake pH.

Swimming scores were generally good

Table 6.2. Scores for swimming indicators.

Swimming indicators	*McHenry*	*Mid-lake*	*Southern lake*	*Overall*
Bacteria	100	100	98	99
Toxic Algae	n/a	n/a	n/a	n/a
Water clarity	n/a	n/a	n/a	n/a
Aquatic grasses	n/a	n/a	n/a	n/a

Bacteria

Bacteria scores were good in the Southern lake and very good in the Mid-lake and McHenry regions. Two sites in the Southern lake region had less than 100% of samples meeting the safe swimming bacteria concentration guideline of 235 counts 100·ml^{-1}. In May 2009, the site at Sky Valley had a bacterial concentration of 2419 counts·100 ml^{-1}, and the site at Hazlehurst had 411 count 100·ml^{-1}. Overall, the lake scored 99%, which is the highest good score attainable.

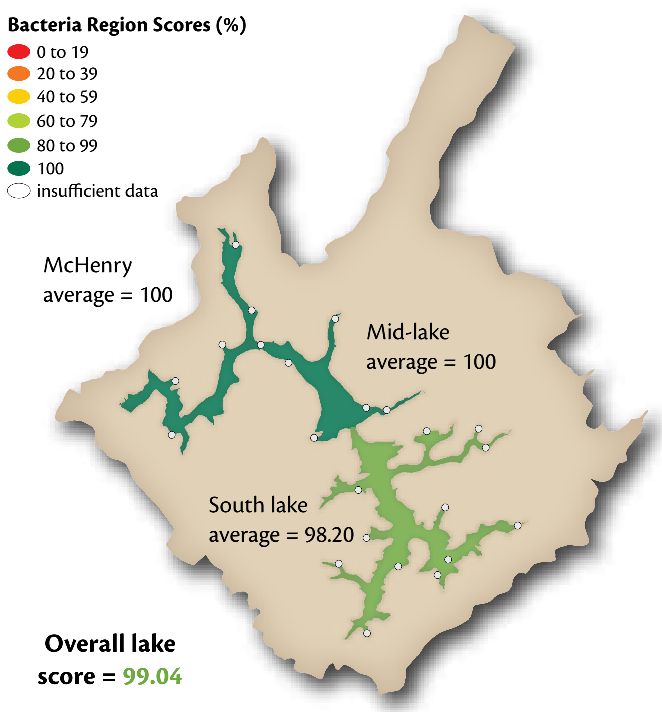


Figure 6.11. Lake region scores for bacteria were very good.

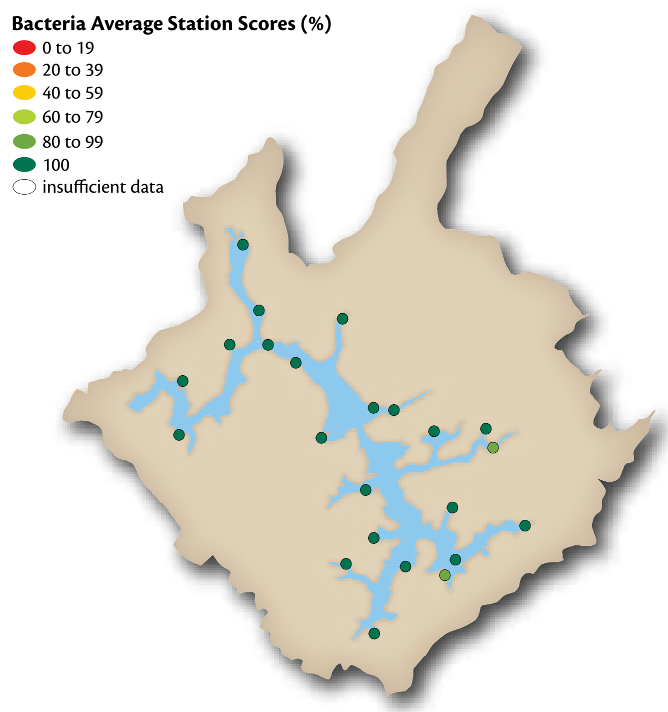


Figure 6.12. Average station scores for lake bacteria.

Overview of watershed scores

Scores for watershed indicators ranged from very good to poor (Table 6.3).

Table 6.3. Scores for all watershed indicators.

Watershed indicators	*McHenry*	*Mid-lake*	*Southern lake*
Total phosphorus	n/a	99	92
Benthic macroinvertebrates	fair	poor	poor
pH	n/a	87	94
Temperature	n/a	96	100
Water clarity	n/a	71	26

Watershed indicator results were mixed and had limited data

Indicators in the watershed were more limited than in the lake; care should be exercised when interpreting results due to the reduced spatial coverage of sampling locations relative to lake sampling stations. See data maps for sampling site locations for each indicator.

Benthic Macroinvertebrates

Benthic macroinvertebrates are scored slightly differently than other indicators; specific ranges of data values are grouped based on an Index of Benthic Integrity (IBI) and range from very poor (IBI values from 1 to 1.9), poor (2 to 2.9), fair (3 to 3.9) and good (4 to 5). IBI scores for McHenry were fair with an average value of 3.34, and Mid-lake and Southern lake were poor with average values of 2.39 and 2.50, respectively.

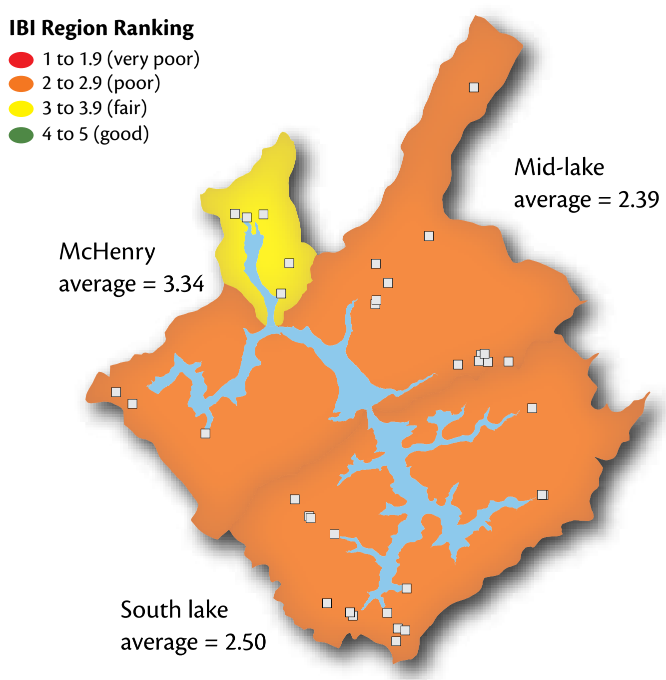


Figure 6.13. Watershed region scores for benthic macroinvertebrates ranged from poor to fair.

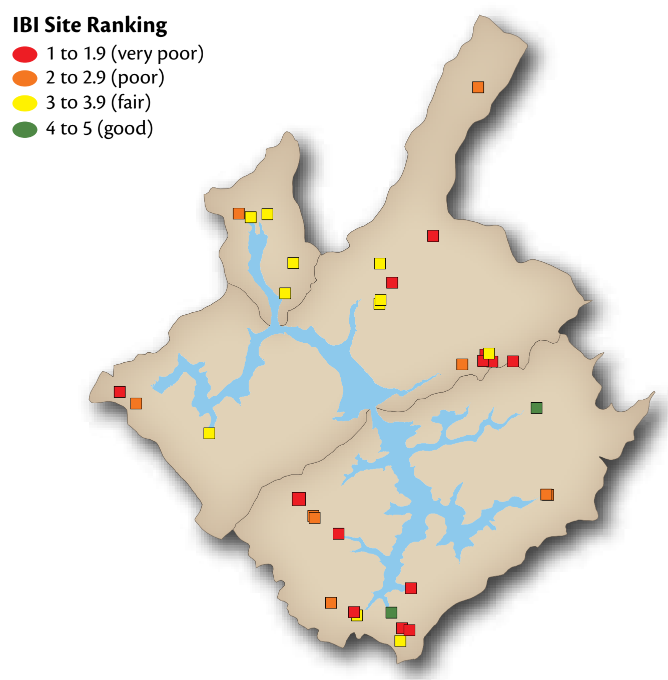


Figure 6.14. Average station scores for benthic macroinvertebrates were mostly poor.

Total phosphorus

Total phosphorus scores were 99% in the Mid-lake and 92% in the Southern lake regions. There were no sites where total phosphorus was measured in the McHenry region.

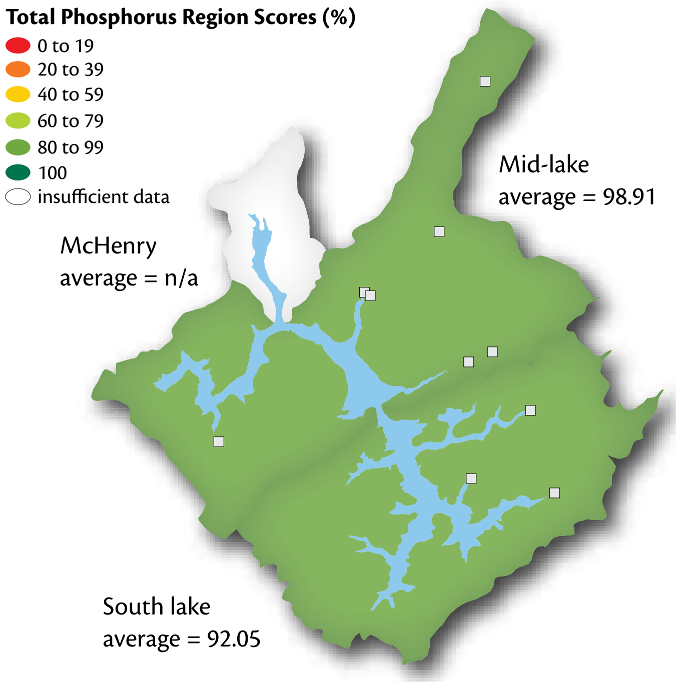


Figure 6.15. Watershed region scores for total phosphorus.

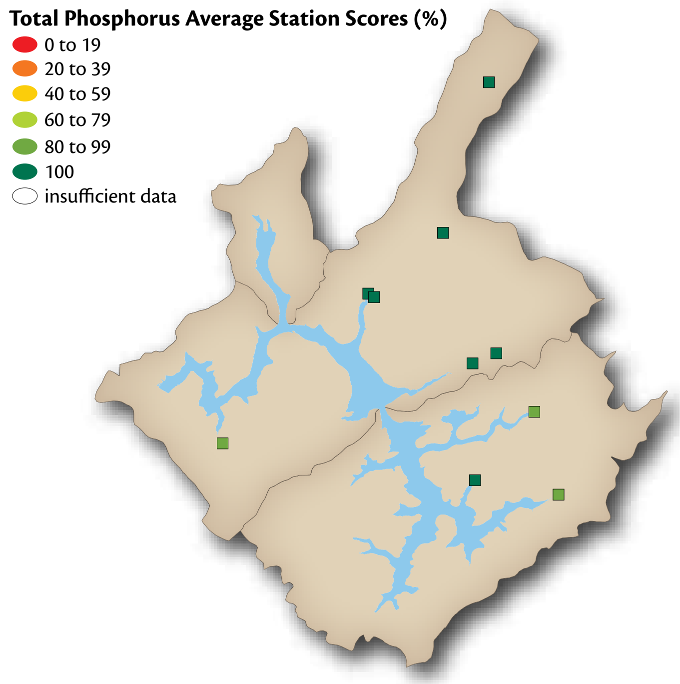


Figure 6.16. Station scores for watershed total phosphorus.

pH

pH scores were 87% in the Mid-lake and 94% in the Southern lake regions. There were no sites where pH was measured in the McHenry region.

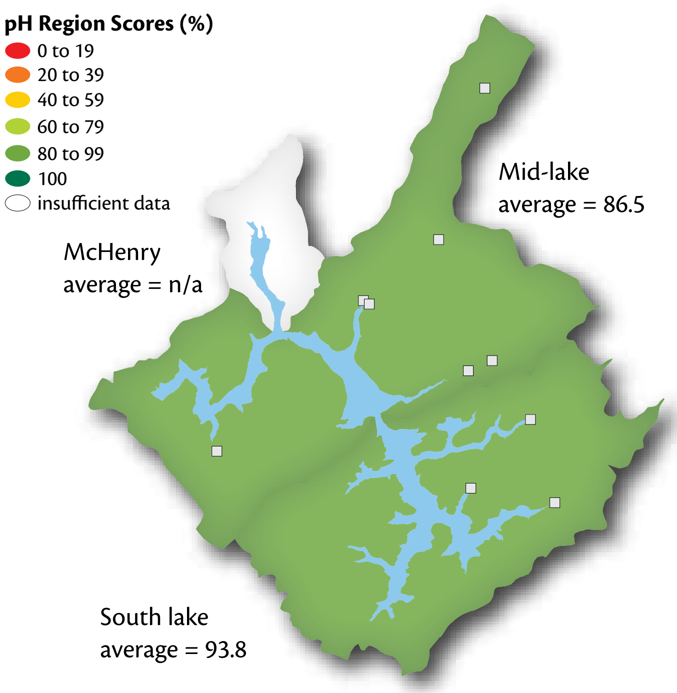


Figure 6.17. Watershed region scores for pH.

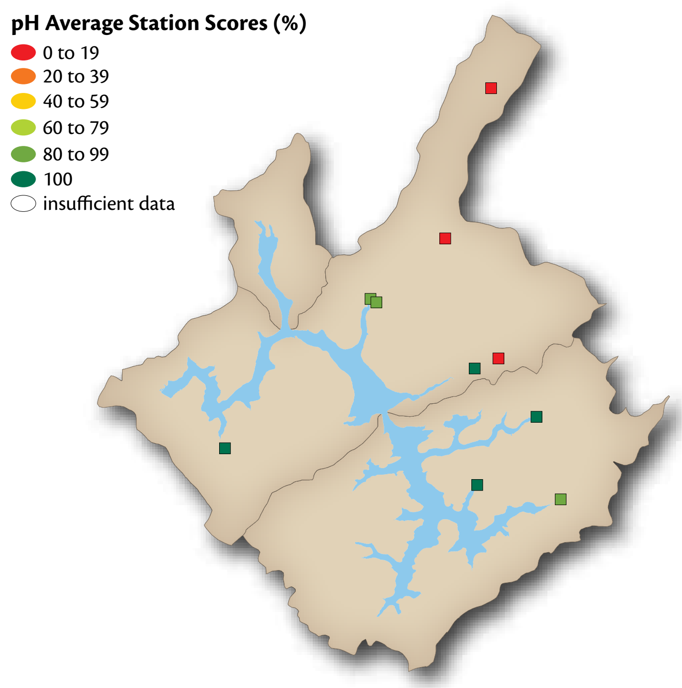


Figure 6.18. Station scores for watershed pH.

Temperature

Temperature scores were 96% in the Mid-Lake and 100% in the Southern lake regions. There were no sites where temperature was measured in the McHenry region.

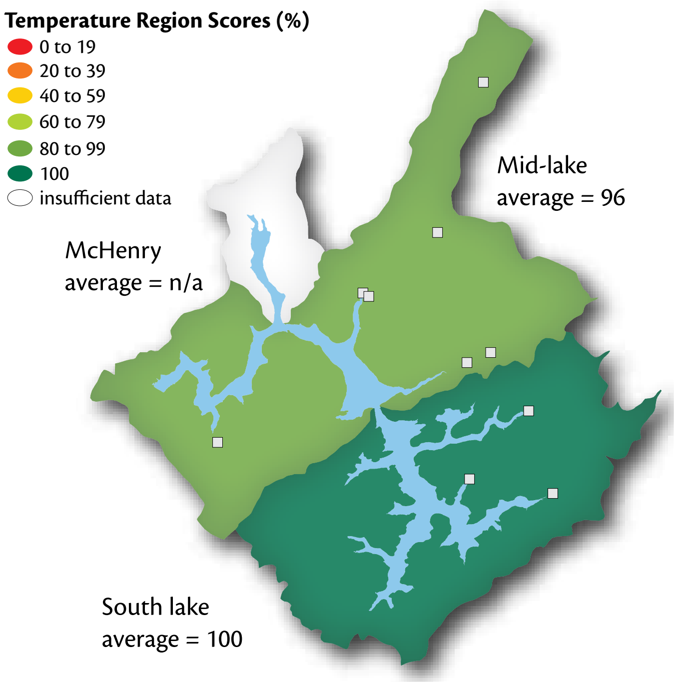


Figure 6.19. Watershed region scores for temperature.

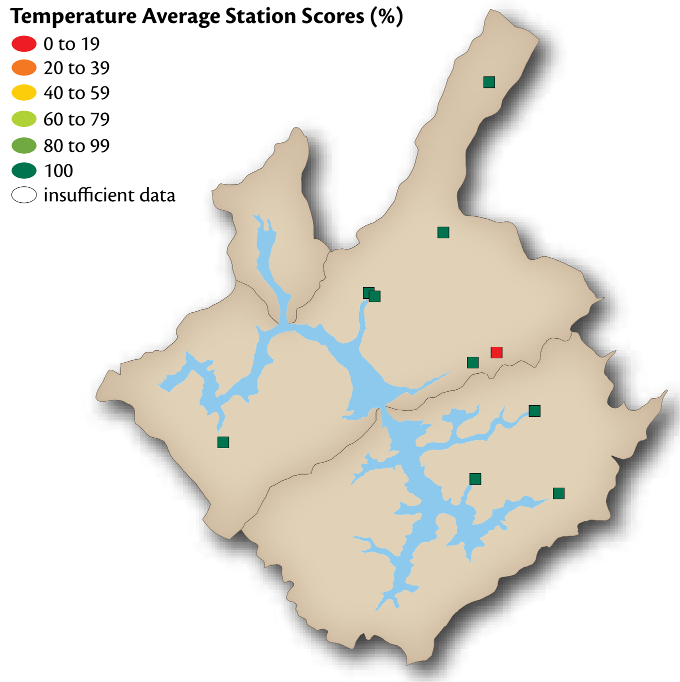


Figure 6.20. Station scores for watershed temperature.

Water clarity

Water clarity scores were 71% in the Mid-Lake and 26% in the Southern lake regions. There were no sites where water clarity was measured in the McHenry region, the Mid-lake region had six sampling locations, and the South lake region had two. Therefore, water clarity results are not representative of the entire watershed, and limited inference can be made regarding water clarity status in any of the reporting regions.

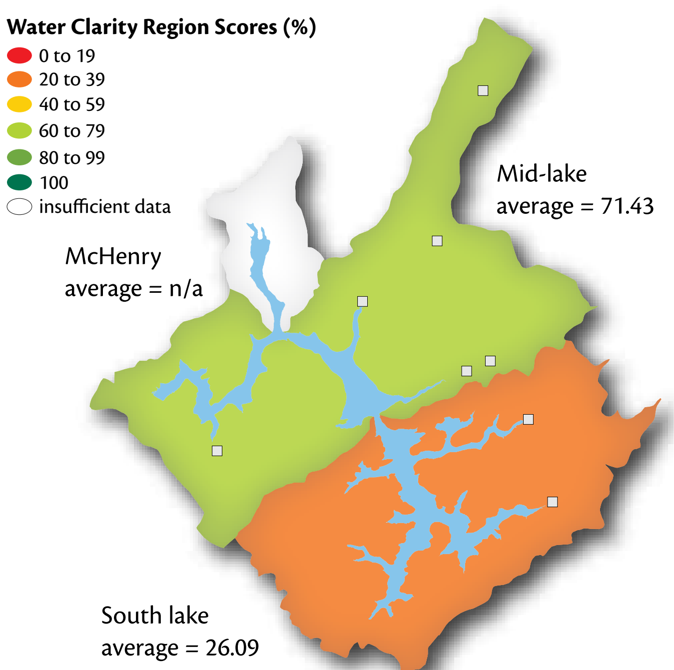


Figure 6.21. Watershed region scores for water clarity.

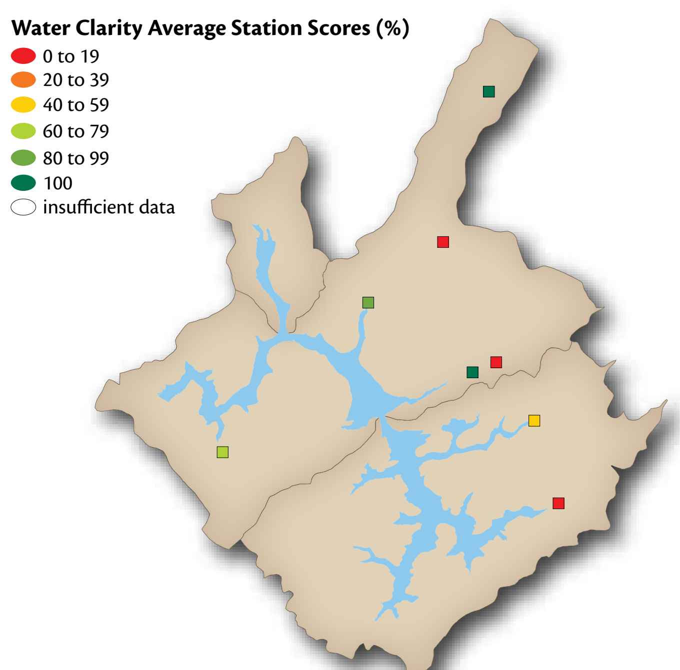


Figure 6.22. Station scores for watershed water clarity.

Discussion

Implications

Lake water quality and habitat scores show slight regional differences

Scores for lake water quality and habitat indicators were either in the good or very good range, which is in keeping with findings from other annual water quality reports (MD DNR 2009A). Taken as a whole, however, results suggest that there are differences in lake water quality between regions.

McHenry generally had the best water quality scores, and the Southern lake region had the worst. In particular, the Southern lake region had the worst scores for total phosphorus and pH.

Chlorophyll *a* and water clarity scored poorly overall, suggesting that eutrophication may be a problem in the McHenry and Southern lake regions. Both regions had chlorophyll *a* and water clarity scores that were lower (approximately 9 and 15% lower, respectively) than the Mid-lake region scores.

Swimming scores were good, but rely solely on bacteria results

Bacteria sampling stations were relatively evenly distributed throughout the lake, and scores for all regions were either 100 or 99%. In general, the lake appears to be safe for swimming from a bacterial health perspective.

There are several other parameters that were identified that could be useful in assessing swimming status, but for which data was not available. These parameters include aquatic grasses, water clarity, and toxic alage. Anecdotal evidence suggests that aquatic grasses and water clarity may affect the quality of the swimming experience, but that preferences are variable among individuals. The presence of toxic algae has public health implications. Specific thresholds for each of these parameters must be further developed, and they must be regularly sampled at swimming and recreational areas in order to incorporate these parameters into an annual ecosystem health assessment.

Watershed results are less clear because of inadequate sampling distribution

Scores for watershed data show that most indicators receive a passing grade, however, sampling sites are not well distributed throughout the watershed regions.

Of the 31 sites in the watershed, only 10 sites measure total phosphorus, pH, temperature, and water clarity, and these are unevenly distributed—seven are in the Mid-lake region, three are in the Southern region, and zero are in the McHenry region. This uneven distribution means that definitive conclusions about the status of these indicators cannot be made.

However, sampling locations for benthic macroinvertebrates (organisms that live on the stream bottom and are good indicators of overall stream health) were well distributed and the scores (both Mid-lake and Southern lake regions were poor and the McHenry region was fair) suggest reason for concern about stream health, especially in the Mid-lake and Southern watershed regions.

Future work

Although the water quality of Deep Creek Lake appears to be generally good, several issues remain, particularly in shallow water areas. Those that should be investigated further include:

- shoreline erosion and sedimentation of lake headwater areas,
- restrictions to dock access from sedimentation, excessive growth of aquatic grasses, and lake drawdown, and
- blooms of potentially harmful algae.

Evidence from periodic but irregular sampling and photo documentation suggests that these problems are occurring, but their extent and severity is largely unknown because of the current distribution of sampling locations in the lake. It is simply beyond the scope of state and county sampling efforts to include long-term sampling at the density that would be required to evaluate these issues.

Making more definitive assessments of these issues and impacts in shallow water areas will require increasing the density of sampling locations and the types of data collected. New and important work by MD DNR on sedimentation rates and aquatic grasses will provide useful information on processes in these areas. Additional sampling might be considered in conjunction with these efforts and could be supplemented by a volunteer monitoring program.

Assessment of watershed health and its impacts on lake water quality would also benefit from increased collection of data. Similar to limitations in lake data availability, watershed sampling programs are not able to provide the amount of information necessary to evaluate all desired watershed parameters. Supplemental sampling by a volunteer-based monitoring program could provide crucial information about the state of the watershed and subsequent effects on lake health.

Conclusions

As a result of data limitations, Friends of Deep Creek Lake and EcoCheck were unable to produce a report card, which was the original goal of this project. Instead, the goal was adjusted to production of a detailed baseline assessment designed to be the foundation for future annual report cards. This baseline assessment has produced the following benefits:

- All relevant data sets were assembled and reviewed in an integrated fashion, a task which had not been done previously,
- Data were reviewed and assessment indicators evaluated,
- Needs for expanded data collection and analysis were identified and defined, and
- Indicators necessary for a comprehensive reporting framework which incorporates recreation in Deep Creek Lake condition were identified.

Currently available indicators of Deep Creek Lake water quality suggest that the lake is in generally good condition. However, it is important to note the data primarily represent water quality conditions in the middle portions of the lake, and watershed stream data show that many tributaries are in poor health. In order to obtain a comprehensive assessment of the lake and watershed, there is a need to expand the distribution and number of sampling locations in the lake and watershed.

Future research and monitoring of the lake and watershed should include:

- Lake and tributary shoreline erosion and resulting sediment accumulation,
- Near-shore sampling (i.e., the area from the shoreline to 100 feet out in the lake),
- Conditions of shallow water areas,
- Recreational use barriers caused by sedimentation, excessive growth of aquatic grasses, and lake draw down,
- Algal blooms, and
- More even distribution of sampling sites.

Several water monitoring initiatives have begun within the past several years by agencies researching the health of Deep Creek Lake and the lake watershed. In 2010, MD DNR launched a study of aquatic grasses in the lake, and in 2011 began a multi-year sedimentation study. Volunteer Streamwader sampling coordinated by MD DNR will continue for the forseeable future, and a carrying capacity study on boating has been scheduled. These various efforts will generate additional and important data for future assessment work.

This baseline assessment presents a detailed assessment of the current state of knowledge regarding the health of Deep Creek Lake and its watershed. This report has illustrated several information gaps, which will need to be addressed before an annual report card can be produced. Although several of the data gaps will be partly addressed by planned monitoring efforts, other gaps will remain and will need to be addressed through additional efforts, either by expanding existing sampling programs, or through volunteer based monitoring efforts.

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