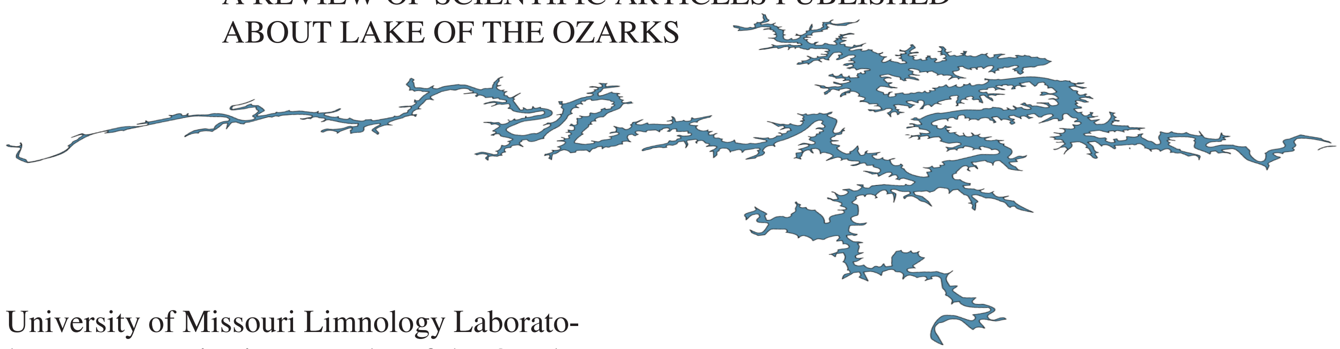
The Water Line

NEWSLETTER OF THE LAKES OF MISSOURI VOLUNTEER PROGRAM

Volume 13 Number 2

Water Quality at “The Lake”

A REVIEW OF SCIENTIFIC ARTICLES PUBLISHED ABOUT LAKE OF THE OZARKS



The University of Missouri Limnology Laboratory’s long-term monitoring on Lake of the Ozarks (LOTO), begun in 1976, resulted in three journal articles, all published in the proceedings of the International Society of Limnology. The first paper, published in 1981, described water quality in LOTO prior to the impoundment of Harry S. Truman Reservoir. In 1988 a second study evaluated changes in water quality associated with the completion of Truman Reservoir. A final paper published in 2000 examined seasonal water quality patterns. A brief summary of these three articles follows.

Limnological characteristics of Lake of the Ozarks, Missouri – 1981. J.R. Jones and J.T. Novak

The purpose of this 1976–1979 study of summer water quality in LOTO was to establish baseline data prior to the impoundment of Truman Reservoir. Three main channel sites, were monitored, one each in the Gravois Mills, Grand Glaize and Niangua arms. Major findings included identification of a strong longitudinal gradient in water quality within the main lake channel. Average phosphorus concentrations at the 59-mile marker were three times higher than values at the dam (92 vs. 31 μg/L), with the 39-mile marker site having intermediate levels of 56 μg/L. Secchi transparency values were lowest up-lake (averaging 0.5 meters), moderate at the mid-lake site (1.2 meters) and deepest near the dam (2.0 meters). Interestingly, chlorophyll levels were similar across the three main lake sites, ranging from 14.2 μg/L at the up-lake site to 10.5 μg/L at the dam.

The chlorophyll concentrations at the 59-mile marker were low relative to phosphorus levels, averaging 0.15 unit of chlorophyll for each unit of phosphorus. In contrast, the ratio of chlorophyll to phosphorus at the dam site averaged 0.34. The inefficient use of phosphorus by algae at the up-lake site was attributed to high levels of inorganic suspended sediment, which reduced the penetration of sunlight into the lake and thus limited algal photosynthesis. While inorganic suspended sediment data were only measured in 1979, elevated turbidity readings and shallow Secchi transparency values at the up-lake site during 1976-1978 support the conclusion that suspended sediments reduced available light and limited algal growth.

Other findings included the relation between flow and lake water quality. Nutrient and turbidity

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levels were elevated and Secchi transparencies shallower in LOTO during years with high inflow. Also, data collected in the three tributary arms indicated water quality in the Gravois Mills and Grand Glaize arms was comparable to the dam site, while the Niangua Arm had slightly higher phosphorus values and shallower Secchi readings.

Limnological characteristics of Lake of the Ozarks, Missouri II: Measurements following formation of a large reservoir upstream – 1988. J.R. Jones and M.S. Kaiser.

The main objective of this study was to determine if water quality in LOTO changed after the completion of Truman Reservoir. The hypothesis was that Truman Reservoir would act as a settling basin, decreasing the amount of inorganic suspended sediment entering LOTO. Lower turbidity would allow more light to penetrate into the water column and lead to more algal growth, especially up-lake.

Data were collected during the summers of 1980-1986, with samples coming from the six previously monitored sites as well as two additional main lake sites (18- and 28-mile markers). Data showed that shifts in water quality were minimal and the strong longitudinal gradient in the main lake was still present during 1980-1986. Because inorganic suspended sediment measurements were limited to only one summer prior to the completion of Truman Dam, changes in suspended sediment concentrations could not be quantified.

Monitoring of surface water near the dam on Truman Reservoir revealed lower phosphorus and inorganic suspended sediment values than measured at the up-lake LOTO site. As expected, Truman Reservoir was acting as a settling basin with outflows containing moderate levels of nutrients and suspended sediment. It was theorized that releases from Truman Reservoir scour the Osage River bed, increasing the phosphorus and inorganic suspended sediment concentrations in water moving down-lake.

Chlorophyll concentrations at the up-lake site increased from 14.2 to 21.1 µg/L (average values for the two studies), even though phosphorus levels decreased from 92 to 78 µg/L. One possible explanation for the increase in chlorophyll relative to phosphorus (ratio increased to 0.27) is that a shift in the algal community might have occurred. Prior to the impounding of Truman Reservoir, the algal community in the up-lake portion of LOTO would have been dominated by species that were best suited for conditions in the Osage River. After 1979, the composition of the algal community in the upper portion of LOTO reflected that found in Truman Reservoir: species better suited for lake conditions.

When water quality data were adjusted to account for differences in seasonal inflow, sites across the lake were determined to have higher chlorophyll concentrations (about 25% higher), even though phosphorus levels had dropped by about 26%. Secchi transparency values across the lake remained relatively unchanged after the completion of Truman Reservoir. Along with potential shifts in the algal community, lower inorganic suspended sediment concentrations in LOTO may account for in-

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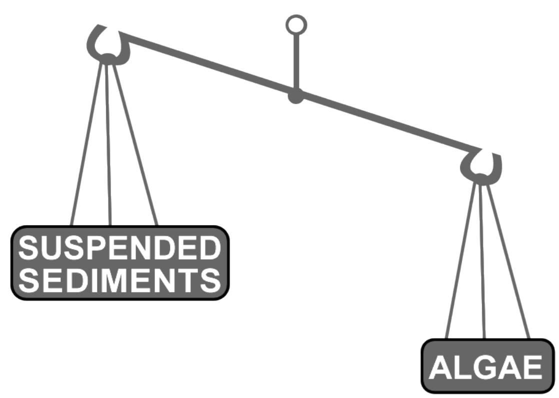

Fewer sediments suspended in the water allowed light to penetrate deeper into the water column, which led to increased algal growth. Water clarity remained constant.

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creased algal production. In Missouri, both inorganic suspended sediment levels and algal biomass determine Secchi transparency. Because algal chlorophyll concentrations increased across the lake during 1980-1986 while Secchi measurements remained unchanged, it seems reasonable to surmise that inorganic suspended sediment levels decreased. In essence, the increased clarity associated with decreased inorganic suspended sediment was countered by increased algal biomass, which was made possible by the more favorable light environment that resulted from lower inorganic suspended sediment levels.

Limnological characteristics of Lake of the Ozarks, Missouri III: seasonal patterns in nutrients, chlorophyll and algal bioassays – 2000. B. D. Perkins and J.R. Jones.

Data collected throughout 1989-1991 and 1993 were examined to determine seasonal trends in water quality. While all sites were monitored, only data from two main lake channel sites (dam and 18 mile marker) were reviewed in the article.

Phosphorus, nitrogen, and inorganic suspended sediment displayed patterns of higher than average values April–June, decreasing concentrations through August, with increasing levels in the fall. The spring peak is associated with elevated inflows into the lake, while increases in fall were related to lake turnover. Decreasing nutrient and suspended sediment concentrations during summer occurred due to reduced inflow (generally) and the sedimentation of suspended materials (both inorganic and organic). Algal chlorophyll concentrations peaked in March and steadily decreased through spring and summer, with no fall peak.

Results from in-lake experiments determined that factors limiting algal growth in LOTO change over the course of the year. Limiting factors were phosphorus during spring, nitrogen during summer, and light in fall and early winter.

Past, Present and Future

One thing that is not in dispute about water quality in Lake of the Ozarks is its variability. These past studies, along with current LMVP monitoring, indicate that water quality (1) changes dramatically across the main channel, (2) varies among tributary arms, (3) differs from one year to the next, and (4) fluctuates within individual seasons. The variable nature of water quality in LOTO can be attributed not only to the vast size of the lake, but also to the influence of its immense watershed. Inputs of nutrients and suspended sediment differ as nonpoint and point sources of pollution vary across the landscape, with rainfall intensity and timing determining the impact. Differences in the timing and quantity of flow from Truman Reservoir also add to the variable nature of water quality in LOTO. Because the factors that influence water quality are many and their interactions complex, attempts to summarize water quality in LOTO require a large amount of data from numerous sites over several years. Continued monitoring by citizen volunteers will aid in evaluating differences in water quality across the lake, identifying trends in water quality over time, and assessing lake function (e.g. how water quality parameters relate to each other). Additional publications are planned to summarize this long-term data set.

The documents discussed in this article are available for download at the LMVP web site:

www.lmvp.org/documents/lake-of-the-ozarks/publications.htm

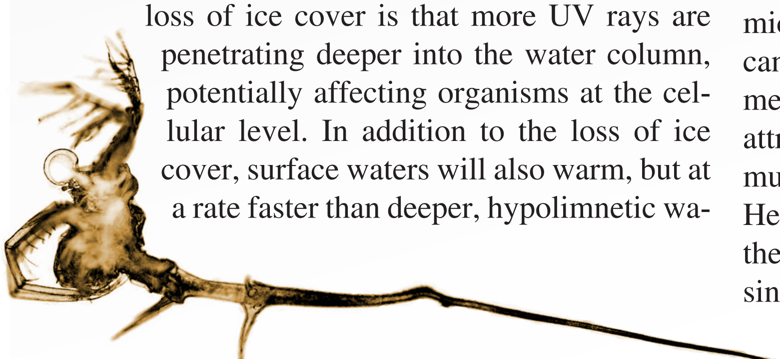
Global Climate Change and Lakes

While some still debate the causes of global climate change, there is strong scientific consensus that the earth's climate is getting warmer. A recent volume of the scientific publication "Limnology and Oceanography" deals specifically with the role that lakes and reservoirs play in climate change. The lakes of the world are not only susceptible to the influences of climate change; they provide a record of and ultimately influence it.

Three themes were prominent throughout the volume. Theme one investigated lakes and reservoirs as sentinels of present climate change and examined which physical, chemical, or biological properties of lakes can help quantify aspects of climate change. Theme two analyzed fossil organisms in lake sediment layers, allowing scientists to speculate on the environmental conditions that existed throughout the past. Finally, theme three considered the role of lakes and reservoirs as regulators of future climate change, which primarily involved tracking the present flow of carbon into and out of lakes and predicting the future flow.

Lakes as sentinels

As air temperatures continue to rise, arctic and alpine lakes may be the hardest hit. Currently, some lakes that were perennially covered in ice are experiencing only seasonal ice cover. One result of the loss of ice cover is that more UV rays are penetrating deeper into the water column, potentially affecting organisms at the cellular level. In addition to the loss of ice cover, surface waters will also warm, but at a rate faster than deeper, hypolimnetic waters. As a result of warming, the temperature differential between the two layers intensifies, hastening the onset of stratification and increasing its stability. The subsequent changes in the rates of nutrient cycling and food web dynamics can be dramatic. In one example, the mean surface temperature in Italian Lake Maggiore rose by about 6 °F over the last 25 years. This warming increased the depth of the epilimnion, thus providing deeper and darker waters with oxygen. The dark, oxygenated water provided the spiny water flea (Bythotrephes longimanus) daytime refuge from sight-feeding predators. The spiny water flea continued to migrate to the surface at night (with the rest of the zooplankton community) to feed on other zooplankton. Numbers of the spiny water flea have increased 10-fold in the lake, and the population of its preferred prey species have declined significantly as a direct result of the increased epilimnion depth caused by the warming water.



Bythotrephes longimanus
(aka Spiny Water Flea)

Lakes as integrators

Paleolimnology is a subset of limnology (study of inland waters) focused on uncovering the past by examining the sediment record. The layers of lake sediments are arranged annually, much like tree rings, and age can be determined by counting (in some cases) or via isotopes (e.g., carbon dating). By examining sections microscopically for fossils of microorganisms and their eggs, paleolimnologists can infer the chemical and environmental requirements of certain organisms (using current data) and attribute those conditions to the past. A synthesis of multiple studies spanning more than 200 Northern Hemisphere lakes shows a distinct restructuring of the diatom community (a group of algae) since the 19th century due to

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increasing temperatures. Interestingly, changes were apparent in Arctic lakes up to 100 years before appearing in temperate lakes around 1970. By comparing the relative abundance of other micro-organisms in the sediments, scientists concluded that an increase in sun energy to the lake was directly linked to the shift in diatom community composition, and not landscape changes or pollution in the watershed. Using these methods, paleolimnologists can look tens of thousands of years into the past. The greatest obstacle of these methods is separating the overwhelming effects of human activities in the watershed from the larger scale climate effects.

Unit Name	Grams
femtogram (fg)	0.000000000000001
picogram (pg)	0.000000000001
nanogram (ng)	0.000000001
microgram (µg)	0.000001
milligram (mg)	0.001
gram (g)	1
kilogram (kg)	1000
megagram (Mg)	1000000
gigagram (Gg)	1000000000
teragram (Tg)	1000000000000
petagram (Pg)	1000000000000000

Metric Units of measure
1 kilogram = 2.2 pounds

Lake as regulators

The two major greenhouse gases (CO_2 and methane) can be produced within lakes, and carbon is a central element of both. Carbon enters lakes in either particulate or dissolved form and comes from vegetation and geologic sources (e.g., limestone). Once in the lake, carbon is either buried in the sediments, passed through the out-flowing stream or dam, incorporated into living material (plants, algae, bacteria), or out-gassed to the atmosphere as CO_2 or methane.

Globally, lakes and reservoirs bury four times more carbon in their sediments than the oceans do. Because of their hydrology and their placement in the landscape near carbon-contributing human populations, reservoirs are particularly good at receiving and holding carbon. For example, small eutrophic (productive) reservoirs store carbon at a rate that is one to two orders of magnitude higher than natural lakes, based on surface area. While overall more carbon is stored in lakes and reservoirs than is emitted by them, this is not the case in every instance. New reservoirs contribute greenhouse gases to the atmosphere for roughly their first decade due to the decomposition of flooded

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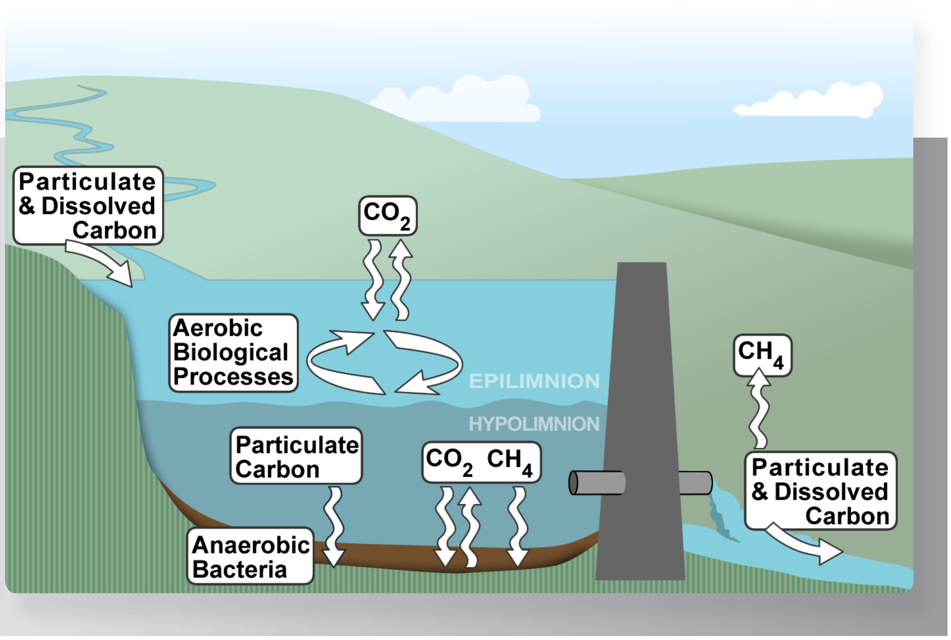
Carbon enters lakes from from the atmosphere (as CO_2) and from streams and runoff in both particulate and dissolved forms.

Aerobic biological processes incorporate carbon into living organisms where it is either stored or respired (as CO_2)

In lake sediments, particulate carbon (including dead organisms) is decomposed by bacteria, producing CO_2 and methane (CH_4).

Reservoirs that pull water from the hypolimnion release methane as well as particulate and dissolved carbon.



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terrestrial vegetation. Because of methane gas discharge from the hypolimnion, some hydroelectric reservoirs in the tropics may release more greenhouse gases than would be released by the fossil fuels that were offset by hydroelectricity.

The Future

Rainfall in temperate regions is expected to decrease as the climate changes, meaning there will be less runoff flowing into Missouri's lakes. Water use will increase as our water supplies are used to grow food and biofuels for an ever-expanding population. To address the water shortages humans will build more impoundments, and by 2050 the total global surface area of impoundments is estimated to increase 250%. At present, lakes and reservoirs bury an average of 0.6 Pg of carbon in their sediments each year, the equivalent of 1.3 million pounds TIMES one million (1 Pg = 1015 grams). That amount should increase significantly as the number of impoundments increases.

It seems certain that climate changes will have an effect on lakes, but those changes will vary from region to region or even lake to lake. Prolonged stratification will increase the amount of time deep sediments are without oxygen, thus increasing nutrient cycling from sediments. With less runoff entering lakes, residence times will increase, allowing suspended sediment particles to settle out. As a direct result of increased light penetration, higher nutrient concentrations, and higher temperature, Missouri lakes, particularly in the northern plains region, are likely to grow more algae in the summer than they do now. Community structures will change as differently adapted predator, prey, and forage species inhabit our lakes. The new reservoirs we build will store more carbon than they emit, but not for a number of years, and not enough to offset population growth. Ultimately, we will have to adapt to our new climate and our lakes' new character.

The journal volume referenced can be found online: http://aslo.org/lo/toc/vol_54/issue_6_part_2/index.html

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MISSOURI DEPARTMENT OF NATURAL RESOURCES