LAKE CLASSIFICATION SYSTEMS – PART 1

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Lake Classification Systems

People have a tendency to classify things. It helps us to visualize relationships and helps us to communicate. We might use a very simple system based on size and say some things are big and other things are small. Then someone will always ask, "how big" or "how small." And we respond that it is "very big" or maybe if it is huge we say it is "really, really big." The point here is that with some classification systems the basis for the system is a relative continuum. In such cases there are no well defined boundaries or lines between what is big or what is small, so we decide that we will draw lines to separate different categories.

Problems arise when someone says the lines are in the wrong place. Often, in scientific circles, papers are published arguing where the lines should be and eventually we reach a rational consensus, at least for communication purposes, as to where the lines should be. But, considerable debate often remains.

Some classification systems are more easily defined; the boundaries are discrete and there is no continuum. For instance, in the classification of plants and animals, a robin is a robin and never a blue jay. Yet in other classification systems, we have situations where the things being classified don't always fit into the same category. So we place it in that category where it fits most of the time. But, enough hedging and enough excuses as to why classification systems don't always work ideally. They are useful for many things.

Thinking about classification of lakes, three systems come to mind; there may be others, but we'll discuss these three. One system is based on the productivity of the lakes or some might say on the relative nutrient richness of the lake. This is the **trophic** basis of classification and the one with which riparian owners are probably most familiar. It is the system that includes oligotrophy and eutrophy and its basis is a continuous scale. A second system is based on the times during the year that the water of a lake becomes mixed and the extent to which the water is mixed. This basis of mixing is a system where a lake may fit a category well most of the time, but not all of the time. And a third system, to keep anglers happy, is based on the fish community of lakes. We say, for instance, that a given lake is a cold-water-fish lake. That tells us that the lake probably has trout in it. There are considerable overlaps in the fish community system, but still enough generalities to make it useful for fish management.

Part One --
The Trophic Concept

Productivity or the nutrient richness of lakes is the basis for the trophic concept of classification. It runs the gamut from nutrient poor, super clear lakes, to those that are nutrient rich and usually have very poor water clarity. As we said, this gamut is a continuum which runs from the oligotrophic lake at one end to the eutrophic lake at the other end. It has become fashionable to place lines and limits along this continuum to separate out other categories. There are even categories that are exceptions to the main continuum. But, to initiate this discussion, let's start at the nutrient poor end.

Oligotrophic lakes contain very low concentrations of those nutrients required for plant growth and thus the overall productivity of these lakes is low. Only a small quantity of organic matter grows in an oligotrophic lake; the phytoplankton, the zooplankton, the attached algae, the macrophytes (aquatic weeds), the bacteria, and the fish are all present as small populations. It's like planting corn in sandy soil, not much growth. There may be many species of plankton and many different types of other organisms, but not very many of each species or type. There may be some big fish but not very many of them. With so little production of organic matter, there is very little accumulation of organic sediment on the bottom of oligotrophic lakes. And thus, with little organic food, we find only small populations of bacteria. Moreover, with only small numbers of plankton and bacteria, we have very little consumption of oxygen, from the deeper waters. One typical measure of an oligotrophic lake is that it has lots of oxygen from surface to bottom. Other measures are good water clarity (a deep Secchi disk reading, averaging about 10 meters or 33 feet), few suspended algae, the phytoplankton, which yield low chlorophyll readings (average about 1.7 mg/m3), and low nutrients, typified by phosphorus (average about 8.0 mg/m3). There are other chemical characteristics, but these are the ones most often mentioned. The bottom of oligotrophic lakes are most often sandy and rocky and usually their watersheds are the same, resulting in few nutrients entering the lake. Oligotrophic lakes have nice clean water, no weed problems and poor fishing. They are often deep with cold water. They are seldom in populated areas -- too many people and heavy use tends to eventually shift them out of the oligotrophic category. They are seldom in good agricultural areas; rich soils needed for agriculture do not allow nutrient poor drainage water needed for the oligotrophic lake. We find most of our oligotrophic lakes in Michigan in the upper peninsula and in the upper third of our lower peninsula.

Eutrophic lakes are the general contrast to the oligotrophic lakes and lie at the other end of the continuum. They are rich in plant nutrients and thus their productivity is high. They produce high numbers of phytoplankton (suspended algae) which often cloud the water so that we have poor Secchi disk readings (average about 2.5 meters or 8.0 feet). These lakes also produce high numbers of zooplankton and minnows and other small fish that feed on the zooplankton. These small fish in turn provide food for the growth of larger fish. All in all, there is a high production of organic matter, like corn planted in rich soil. Much of this organic matter drifts to the bottom and forms a considerable depth of organic sediment. This sediment in turn provides the food for high numbers of bacteria. The descending plankton and the bacteria, through their respiration, can use up much or all of the oxygen from the lower depths of these lakes. Thus, one characteristic of eutrophic lakes is the summertime depletion of oxygen from the lower waters (below the thermocline – usually below about 5.5 meters or 18 feet during the summer months). Because of all of the phytoplankton produced, the eutrophic lake often has chlorophyll concentrations averaging about 14 mg/m3 or higher. The phosphorus concentration averages something over 80 mg/m3. Eutrophic lakes are often relatively shallow and often have weed beds. The weed beds are common because of the availability of nutrients and light to the shallow portions of these lakes, but also because the accumulated organic sediments provide the "soil" for their roots. Fishing is often quite good in eutrophic lakes; the high productivity of plankton and benthic (bottom) organisms in the shallows provide for relatively high numbers of fish with relatively good growth rates. Most of Michigan's eutrophic lakes are in the lower two-thirds of the Lower Peninsula.

So the oligotrophic and eutrophic lakes are contrast ends of the eutrophic continuum. But human nature has stepped in, and we find that often we say a lake is really a little beyond oligotrophic or it isn't quite eutrophic. In other words we rationalize (recognize or create) a transition stage between the oligotrophic and the eutrophic classes. After all, as the oligotrophic lake ages, it gradually accumulates nutrients and sediments, and moves toward and eventually into the eutrophic stage. This natural eutrophication process commonly takes thousands of years and involves both the physical filling of the lake and chemical enrichment of the lake water. Cultural eutrophication, which can occur in a human generation or two, involves chemical enrichment of the lake water by human activity in the lake drainage basin. The transition stage between the oligotrophic and eutrophic conditions has been called a mesotrophic lake.

As you probably suspect, the mesotrophic lake is intermediate in most characteristics between the oligotrophic and eutrophic stages. Production of the plankton is intermediate so we have some organic sediment accumulating and some loss of oxygen in the lower waters. The oxygen may not be entirely depleted except near the bottom (the relative depth of the lake has a bearing on this).

The water is moderately clear with Secchi disk depths and phosphorus and chlorophyll concentrations between those characteristic of oligotrophic and eutrophic lakes. Mesotrophic lakes usually have some scattered weed beds and within these beds the weeds are usually sparse. The fishing is often reasonably good, but mesotrophic lakes cannot handle as much fishing pressure as can eutrophic lakes. The average values and the range of values for phosphorus and chlorophyll concentrations and Secchi disk depth characteristic of oligotrophic, mesotrophic and eutrophic lakes given in Table 1 were taken from Wetzel (1983). It is apparent from Table 1 that there are no fixed values of phosphorus or chlorophyll concentration or of Secchi disk depth which can be used to differentiate mesotrophic lakes from oligotrophic lakes from eutrophic lakes.

PHOSPHORUS AND CHLOROPHYLL CONCENTRATIONS AND SECCHI DISK DEPTHS CHARACTERISTIC OF THE TROPHIC CLASSIFICATION OF LAKES			
MEASURED PARAMETER	Oligotrophic	Mesotrophic	Eutrophic
Total Phosphorus (mg/m3) Average	8	26.7	84.4
Range	3.0 - 17.7	10.9 - 95.6	16 – 386
Chlorophyll *a* (mg/m3) Average	1.7	4.7	14.3
Range	0.3 - 4.5	3 – 11	3 – 78
Secchi Disk Depth (m) Average	9.9	4.2	2.45
Range	5.4 - 28.3	1.5 – 8.1	0.8 – 7.0

Table I – Data from Wetzel, 1983

Moreover, the range of values for phosphorus and chlorophyll concentration and Secchi disk depth overlap for oligotrophic and eutrophic lakes. For example, according to Table 1, a lake with a phosphorus concentration of 17 mg/m3, a chlorophyll concentration of four mg/m3 and a Secchi disk depth of six meters falls within the range typical of oligotrophic, mesotrophic and eutrophic lakes. Given this degree of variability, the best we can say of a mesotrophic lake is that it lies somewhere between an oligotrophic lake and a eutrophic lake.

Oligotrophic and eutrophic represent the ends and mesotrophic is somewhere in the middle of the trophic continuum of productivity; however, we are never content to leave well enough alone. For instance, as the eutrophic lakes continue to age and accumulate nutrients and sediments, some characteristics reach extremes and the lakes become really bad (as we humans perceive them). So we reach into our bag of modifiers, extend our continuum and say that these lakes are hypereutrophic. Such lakes are often relatively shallow lakes with much accumulated organic sediment. They have extensive, dense weed beds and often accumulations of filamentous algae. Their water clarity is poor with Secchi disk depths usually less than 0.5 meter (about 1.6 feet). The phosphorus concentration is high, often above 100 mg/m3 and the chlorophyll may be over 50 mg/m3. Thus, the hypereutrophic lake represents the extreme ranges for the eutrophic lake shown in Table 1. The fish and other aquatic animals in these lakes are subject to extreme shifts in oxygen concentrations; sometimes very high and at other times very low, even depleted. These lakes are often subject to "winter kill" and even "summer kill" where the depletion of oxygen results in an extensive kill of fish and sometimes other organisms. Needless to say, these are not very desirable lakes for human enjoyment. Hypereutrophic lakes are that way because they have often been impacted by human activities. Such activities are those that add nutrients to the water entering the lake from the watershed. These activities include poorly located and poorly functioning septic systems, industrial effluents, urban runoff and some agricultural practices that fail to control nutrient runoff. Considering these causes, we find most of Michigan's hypereutrophic lakes in the southern one fourth of the state where most of the humans and their activities are located.

Now let's mention additional situations that fail to fit into our continuum of the trophic classification. These are lakes where certain characteristics tend to fit into more than one category. Of particular note is the lake that is morphometrically oligotrophic. Morphometric refers to the shape of the lake basin and these lakes have conflicting characteristics. They are very deep lakes, having a large volume relative to their surface area. They have nutrient concentrations and plankton production in their surface waters that may be much like the eutrophic lake, yet they don't have the depletion of oxygen in their lower waters, and they usually don't have much in the way of weed beds. Their surface waters are often quite clear. So what is going on here? When these lakes mix in the spring and fall their waters become oxygenated (like the others); however, because they have such a relatively large volume of deep water, they have more oxygen available, more than the surface productivity can consume when it settles out during the growing season. Because the plankton does have this great depth for settling, the upper waters are often clear. Little silt accumulates in the shallow areas because wave action causes most of the organic debris to wash down the basin slope into this extensive depth. A good example of the morphometrically oligotrophic lake in Michigan is Higgins Lake. Higgins Lake is located very near Houghton Lake. They have adjoining and very similar watersheds and receive much the same nutrient runoff. Higgins Lake is very deep and Houghton Lake is relatively shallow. Houghton Lake exhibits many of the characteristics of a eutrophic lake while Higgins Lake, because of its depth, appears more like an oligotrophic lake.

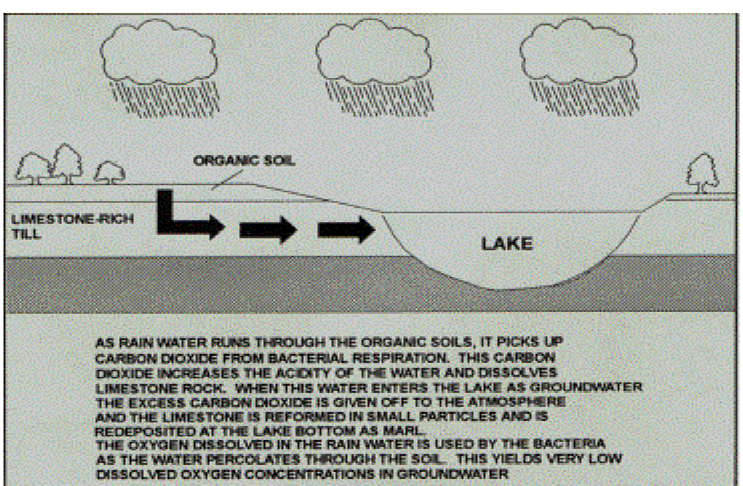

Figure 1 – Base Cause of Marl Lakes

Another type of lake found in Michigan which does not fit the trophic continuum is the marl lake. Marl lakes are different in that they generally are very unproductive; yet they may have summer-time depletion of dissolved oxygen in the bottom waters and very shallow Secchi disk depths, particularly in the late spring and early summer. These lakes gain significant amounts of water from springs which enter at the bottom of the lake. When rainwater percolates through the surface soils of the drainage basin, the leaves, grass and other organic materials incorporated in these soils are attacked by bacteria. These bacteria extract the oxygen dissolved in the percolating rainwater and add carbon dioxide. The resulting concentrations of carbon dioxide can get quite high and when they interact with the water, carbonic acid is formed.

As this acid rich water percolates through the soils, it dissolves limestone. When such groundwater enters a lake through a spring, it contains very low concentrations of dissolved oxygen and is super-saturated with carbon dioxide. The limestone that was dissolved in the water reforms very small particles of solid limestone in the lake as the excess carbon dioxide is given off from the lake to the at-mosphere. These small particles of limestone are marl and, when formed in abundance, cause the water to appear turbid yielding a shallow Secchi disk depth. The low dissolved oxygen in the water entering from the springs produces low dissolved oxygen concentrations at the lake bottom.

This process of marl formation is illustrated in Figure 1. Marl lakes are not very productive and are not very good fishing lakes, but they may give evidence of the shallow Secchi disk depths and low dissolved oxygen concentrations characteristic of a eutrophic lake.

Now for the last type we will mention in this article on the trophic concept of lake classification. This is the **dystrophic** lake. In our general scheme of the trophic concept we see the change from oligotrophic through eutrophic largely as a result of the production and accumulation of organic matter and in this scheme the organic matter is generated within the lake as a result of inorganic nutrients supplied largely from the watershed. The dystrophic lake develops from the accumulation of organic matter from outside of the lake. In this case the watershed is often forested and there is an input of organic acids (e.g. humic acids) from the breakdown of leaves and evergreen needles. There follows a rather complex series of events and processes resulting finally in a lake that is usually low in pH (acid) and often has moderately clear, but colored (yellow/brown) water. This acid and colored water results from the organic acids. These lakes are mostly calcium poor, either being in calcium poor areas or the organic acids depleting the available calcium or both. These lakes are usually small and often develop a thick surrounding of vegetation often containing Sphagnum moss. These lakes are poor in plankton production and have sparse fish populations largely because of the acid conditions and have low nutrient concentrations. They are typified by the bog lakes of northern Michigan.

It is apparent that the characteristics of the trophic continuum are somewhat elastic, that there are exceptions to these classifications and that varying interpretations may be employed. In truth, the category along the eutrophic continuum accepted by any individual is based largely on the use that person plans to make of the lake. The mesotrophic lake of someone who fishes may appear to be a eutrophic lake to a SCUBA diver who prizes clear water. The trophic continuum is a useful generality, but it does not allow for explicit and exact subdivision of intermediate categories.

Literature Cited

Wetzel, R.G. 1983. *Limnology*. Philadelphia, W.B. Saunders Co., 767 pp.

LAKE CLASSIFICATION SYSTEMS (part 2)

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Lake Classification Based On Annual Circulation Patterns

Have you heard the term "Turn-over of your lake" and wondered what it means? When and why does it happen? Are all lakes alike? What makes them differ?

In many lake basins the water has notable patterns of circulation. This circulation is mostly a vertical mixing of the water. It has been called an "over-turn" or "turn-over" of the lake. The circulation or mixing is usually wind driven and is facilitated when the lake has a uniform (or near uniform) temperature from top to bottom. Since we refer to these periods of water exchange as periods of mixing, limnologists have used the noun mixis and the adjective mictic in a classification system.

As we discussed in the previous article (Riparian February 1996) on lake classification schemes, lakes don't always behave in a consistent pattern. Because mixing is a function of temperature and wind, we have large annual variations that dictate when and if the water of a lake mixes. As we will see later, obstacles such as trees and hills also can interfere with the force of the wind that reaches the surface of a given lake. And, if that isn't enough, the area and depth of the lake can also be factors along with a few other things. So, as usual, we are using this classification system based on mixing to describe the general patterns that usually occur. Let's start with the basic terms Amixis, Holomixis and Meromixis. These cover the circulation patterns we are apt to encounter or hear about. They are defined as follows.

Amixis - a lack of mixing: some lakes never circulate. These amictic lakes are usually ice covered throughout the year. Well, they're not around here, you might say, and you are right, thankfully. These lakes are under the polar ice caps (at the North and South Poles of our globe) or high mountain lakes where the temperature is mostly below freezing. Since these are not our usual lakes, we won't say anymore about them.

Holomixis - Entire mixing - a more typical lake situation where the winds mix the "whole" lake once or more annually. We will discuss this category in much more detail since it includes most of the lakes we know.

Meromixis - partial or incomplete mixing - some lakes have one or more periods of annual mixing, but only part of the lake is involved for some notable reasons. There are some of these lakes around so we'll discuss the meromictic lakes later.

Water - An Amazing Substance

Before we discuss this lake mixing business we should talk about how lakes are mixed. First we need to know something about the temperature and density relationship of water. Water is really an amazing substance. It is a rare substance where the solid state is lighter than the liquid state, but it is true for water. Ice floats, luckily for us. As can be seen in the figure, water is most dense (heaviest) at a temperature of 4C or about 39F. So, if we start with ice at 0C, we have a lattice type of structure that is lighter and less dense than water, and the ice floats. When we heat the ice, like the sun does as spring

approaches, it melts, first to water at 0C. This really takes a lot of heat energy. The water is more dense than the ice and it continues to absorb heat and to get warmer. As it gets warmer it gets heavier until it reaches its maximum density at 4C. With additional warming above 4C water becomes lighter (less dense) in the manner illustrated in the figure. At 4C, under normal pressure, water reaches its greatest density. In the winter, under the ice, the water commonly has a temperature that increases with depth, from 0C just under the ice to 4C, at the bottom of the lake. This increase to water's greatest density at 4C occurs within a meter of two of depth (3-5 feet), and then the water temperature stays much the same to the bottom. This is true for most of our inland lakes.
In the spring, the surface water warms until it reaches its maximum density of 4C and the entire lake is about the same temperature (about 4C) -and density- from top to bottom. When it reaches that time of uniform density, there is no density resistance to mixing. Think about the density difference of oil floating on water. You can blow on it and even tilt the container back and forth and the oil and water doesn't mix much - because of the difference in their densities, but a container of water mixes easily. When we eventually reach the uniform density stage in the spring in a lake, there is no density resistance to mixing of the water by the wind. Remember, we usually get some good wind in the spring - that's when we fly kites. The force of the wind mixes the water of the lake. Once uniform density is reached, strong winds can mix the lake from top to bottom in most of our lakes, unless they are unusually deep. This period of mixing is often call the "over-turn" and it is an interesting phenomenon. Nutrients from the lower water are brought to the surface and oxygen from the surface is mixed to the lower depths. After the overturn, for a week or two, we have uniform temperature, oxygen, nutrients etc. from top to bottom. If we wish to take a measure of the spring phosphorus concentration of a lake, it is imperative that we wait until the lake mixes after it reaches a constant temperature from top to bottom. <u>It is better to be a week late in collecting water for phosphorus determination than a day too early.</u> During this mixing period the water will warm and may reach a temperature of 5-7C.

Back to the unique character of water. As water warms above 4C, it becomes less dense again. Remember, water is most dense at 4C, and at temperatures either above or below it becomes less dense. So as the sun continues to warm the surface of the water and the winds begin to lessen in intensity, most of heat is absorbed in the first few centimeters, the surface water temperature increases and becomes lighter (less dense) and "floats" on the more dense water below. This heating of the surface water continues and eventually forms an upper layer of warm water. It acts as a layer of insulation, absorbing the heat from the sun and preventing the lower water from getting any heat. This upper layer is eventually warmed and mixed to a depth of about 5-6 meters (15 to 20 feet). We call this layer of water the epilimnion (epi - on top, limnion - layer). Below the epilimnion, the temperature of the water drops rapidly for about 2 meters (6-7 feet) and then remains about the same to the bottom. So we have a bottom layer of water that is cold, usually about 4-7C, and a middle transition layer. Remember, the upper layer has been warmed to a temperature of 25-30C (depending on how warm the summer happens to be or where our lake happens to be). By early summer, our lake is layered - or stratified. Our epilimnion 5-6 meters deep, is warm (25-30C) and much less dense than the lower waters.

Our middle layer is called the metalimnion (meta - middle, limnion - layer) and it is about two meters thick with rapidly decreasing temperature and increasing density. The epilimnion continues to mix when we get strong winds in the summer, but, the increase in water density in the metalimnion prevents this summer mixing from going any lower.
Below the metalimnion we have the cold, much more dense hypolimnion (hypo - below, limnio - layer).

In a deep lake, the hypolimnion can be a very large volume, a large percent of the lake, and the reverse is true in a shallow lake. Given a top layer of 5-6 meters and a middle layer of 2-3 meters, if our lake is only 6 meters deep (about 19-20 feet) we would not have any middle or bottom layer. Thus, some of our shallow lakes can mix entirely during the summer whenever we get strong winds. These lakes behave quite differently from those lakes that are stratified into three layers.
But, we're off here of a bit on a tangent. We need to get back to this classification based on mixing. So, when the water is uniform temperature (and thus density) from top to bottom and we add wind, we usually get mixing. Lets look at holomictic lakes, those lakes that mix entirely at least during one period a year.

We have four types of holomictic lakes

1. Oligomictic lakes. These lakes are usually located in the tropics and have poor (oligo) mixing. The mixing is irregular, or sporadic and usually of short duration. These lakes are usually warm throughout, but the surface waters are even warmer, creating some stratification. Only occasional, and maybe rare, cooling of the surface waters allow any chance of mixing.
2. Polymictic lakes. Poly means many and the lakes have many mixing periods even to the extent that they are mixed nearly continuously throughout the year. These lakes are often small, shallow and in tropical or at least warmer climates or at higher altitudes. The temperature changes are often influenced more by cooling of the surface at night and warming during the day rather than by distinctive seasonal changes. In some of these lakes circulation occurs mostly at night by convection currents rather than by the wind. We'll talk a little more about convection currents later.
3. Monomictic lakes Mono means one, so these lakes have one regular period of mixing during the year. To complicate the situation, conditions that allow mixing in monomictic lakes can occur either under cold or warm climates. So we have cold monomixis and warm monomixis. The cold monomixis lakes are usually near the polar areas. They freeze over during the long winter months and are ice-free during the summer. However, the summer temperatures never are warm enough to heat the water much above 4C. So these lakes could mix often during a relatively short summer. In some years they may not be ice-free and then would be amictic for that year. Warm monomictic lakes are usually those sub-tropical lakes that have a long summer and a short winter. They are stratified most of the year and then for a short period in the winter the stratification breaks down and the lakes can mix. When the Great Lakes don't freeze over, they commonly mix throughout the winter and have only one extended mixing period from Fall to Spring and can be classified as warm monomictic lakes.
4. Dimictic lakes. Di means two. Finally we come to our average temperate zone lake that is the type we have (mostly) here in Michigan. These lakes normally have two periods of mixing, one in the spring and one in the fall. We have already discussed how the dimictic lake warms in the spring until the entire water mass is uniform both in temperature and density; and how summer stratification develops. Now we can discuss how the summer stratification breaks down and the fall overturn occurs. As summer wanes in September (in Michigan) we begin to have cooler nights (and shorter days) and less solar heating during the day. The surface water of the lake cools and becomes more dense (heavier) than the warmer water below. Thus, the surface water sinks. The sinking of more dense water develops slight vertical currents that we call convection currents. This process continues, the days and nights get cooler, and the surface water continues cooling and sinking. In September and October when night air is cooler than the lake water we often see morning fog over the lake. The warmer surface water is evaporating into the cool air and condensing, forming the fog. This process continues until the lake once again

reaches the same temperature and density from surface to bottom. We have already had some mixing by the convection currents. While the lake can turn over in the Fall without wind, strong winds can accelerate this mixing of the water. This Fall "overturn", which usually happens in Michigan in October, re-mixes dissolved oxygen and nutrients throughout the lake. As the daily temperatures continue to cool below 4C, we eventually reach freezing, usually at night, and we awaken one morning to find a skim of ice over the shallower parts of the lake. Finally, the skim of ice covers the lake and any further mixing is stopped and we enter the winter stagnation period.

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So the typical dimictic lake has two periods of mixing each year under normal conditions. Let's talk about those situations when the conditions aren't normal or typical. We mentioned earlier about the shallow lakes less than 6-7 meters (about 20 feet) deep that don't stratify very well and thus might mix anytime during the summer when there are strong winds. There are also times when there is not enough wind to force the overturn. thus, it is possible to have a spring, or time, when the water density is uniform from top to bottom, but there is no overturn because there is no wind. And we can have all degrees of climate conditions from no wind to very strong wind. Mild or moderate winds can cause incomplete or partial overturns. Consider a very deep lake, especially with a relatively small surface area. The force of the wind doesn't have much distance to work on and the deep water needs more force to drive currents all the way to the bottom. So, only the upper waters are mixed. Likewise, some of our lakes have steep shorelines with the surface of the water being sheltered by the land and/or by tall trees. These barriers prevent the winds from exerting their full force on the surface of the water, especially when the high land or trees are on the windward side of the lake. The result can be no overturn or a partial mixing. So this classification is like most others and is generally, but not always, accurate. There is another factor that can cause density differences in water besides temperature differences, and that leads to our final category.

6. Meromixus lakes. Meromictic lakes in our area would probably be typical dimictic lakes; however, their periods of mixing usually are incomplete. These lakes, over time, have developed a deep layer of water that has a much greater amount of material in solution than does the upper waters. These solutes, substances in solution, cause these lower waters to have a greater density that resists mixing the same as density differences caused by temperature. Thus when temperature of the water is uniform from top to bottom, we still have a density gradient that limits the normal mixing only to the depth where the currents encounter this dense lower layer. The concentration of substances in the lower depths accumulate usually over an extended time. The meromictic situation usually develops in deeper waters. This allows the substances that settle or precipitate to the bottom annually to accumulate along with substances that come into solution from the bottom due to bacterial breakdown of organic debris. Thus, this layer of increased density due to substances in solution becomes thicker over the years, eventually occupying a significant volume of the deep waters of the lake. There are not a lot of meromictic lakes in Michigan, but perhaps there are a few more than we realize. A common cause of meromixis in Michigan is associated with the runoff of road salt. There are not enough lake surveys to allow us to have a good idea of the number or percentage of our lakes that may be meromictic.

So lets review this classification based on periods of mixing. Our scheme looks like the following:

- Amictic - never mixing, usually ice covered year around, in the polar regions.
- Meromictic - lakes that may mix once or more annually, but do not mix completely.
- Holomictic - mixing of the entire lake.
- Oligomictic - mixing is unusual, irregular and of short duration, these lakes are relative few in number and are mostly tropical.
- Polymictic - these lakes have many periods of mixing annually, even ap- proaching continuous mixing and are influenced more by daily temperature changes than seasonal.
- Monomictic - one period of mixing annually, the cold monomictic lakes are ice covered most of the year and mix during a brief summer, while the warm monomictic lakes are the opposite with a brief ice-free winter period of mixing.
- Dimictic - lakes that usually mix twice annually in the spring and in the fall. This category covers the lakes in the temperate zones of our globe and includes the majority of our lakes.

There you have another lake classification scheme, one based on the pattern of water mixing peculiar to each lake.

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