Practical Limnology: Further Properties of Water and Lakes

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Chapter 3

Introduction: In the second installment of this series, I introduced the importance of energy to water and lakes. In this section I will explain how other properties of water interact with the energy to form the pattern of 'stratification' that we know for our lakes.

By the time you read this, many of you already will have experienced your first sunburn for this season and the growing season will be well underway. Things are warming up. This is true for the lakes as well and the way this happens is the result of the increased energy of the sun (our seasonal cycle) and the way water reacts to that energy.

Everyone knows that in the summer the surface of the lake is warmer than deeper waters. This is another property of water that I have depicted in figure 1.

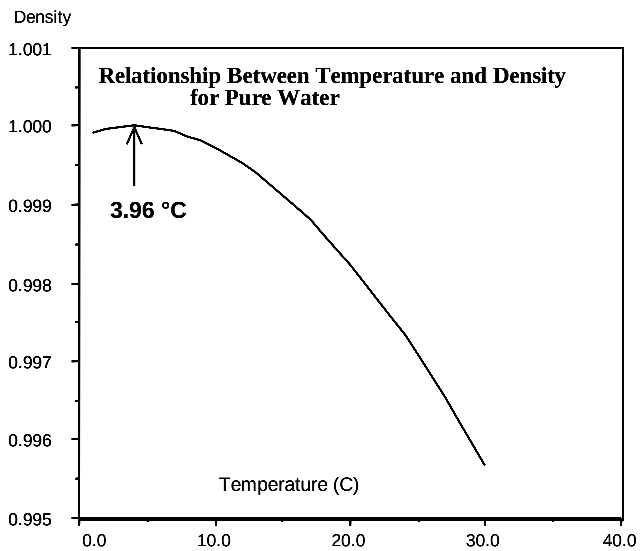

Figure 1. Plot of density versus temperature for temperatures above freezing.

In figure 1, the important trends are that for temperatures normally occurring for Lake Keowee, density decreases as temperature increases. This means that warm water floats over cooler water. Also, the density changes with temperature in a non-linear manner. This is very important for lakes in very warm climates because a small difference in temperature can have an important difference in density.

Another property of water is viscosity. Viscosity is the internal friction of the liquid and we can think of this in terms of liquids we know that are more or less viscous. For example, pancake syrup is more viscous than water – water pours more easily. Honey is so viscous that we nearly have to dip it rather than pour it (mechanics might think about differential lubricant here, or an oil additive such as STP, very viscous). Viscosity is important because warm water is less viscous than cooler water. And this means that warmer water has different flow characteristics from cooler water.

Density and viscosity are both affected by temperature and temperature is mostly affected by the sun's energy. From the second installment of this series, we know that the energy of the sun is absorbed rapidly near the surface of the lake. This is due to the basic property of water but also due to any additional materials that are dissolved or suspended in the lake water. Absorbance of light (energy) tends to increase the temperature of the water. And because most of the energy is absorbed near the surface, most of the increase in temperature occurs near the surface as well. This works well because this warmer water is more buoyant and naturally ‘floats’ above the cooler waters that have not absorbed as much light (energy). However, this tendency for water to form density layers that are different temperatures has another effect. It tends to ‘stratify’ the lake into different limnological layers or zones.

Figure 2 depicts the hypothetical relationship between temperature distribution in a stratified lake as well as the exponential extinction of light in that lake. The temperature distribution is important because the density of water associated with each temperature is different. The less dense water near the surface tends not to mix with waters of greater density at greater depth.

Based on temperature, the stratified lake may be divided into three regions: the Epilimnion or surface layer of the lake, the Hypolimnion or deepest layer of the lake, and the Metalimnion forming the region of transition between the other two layers. These regions are defined by temperature only. And although these layers or zones are often associated with certain chemical trends (especially for oxygen), they are nevertheless strictly defined by temperature.

The epilimnion is the zone in which the warmest (least dense) water resides. Because of convection or wind mixing, the epilimnion often has a minimal temperature (density) gradient associated with it. It is sometimes referred to as the ‘surface mixed layer’.

The metalimnion begins where a strong temperature gradient begins. The term for the strong temperature gradient is the ‘thermocline’. In some views the definition of the thermocline is any temperature gradient that changes at least one degree Celsius in one meter of depth. The depth at which the thermocline is diminished marks the bottom of the metalimnion.

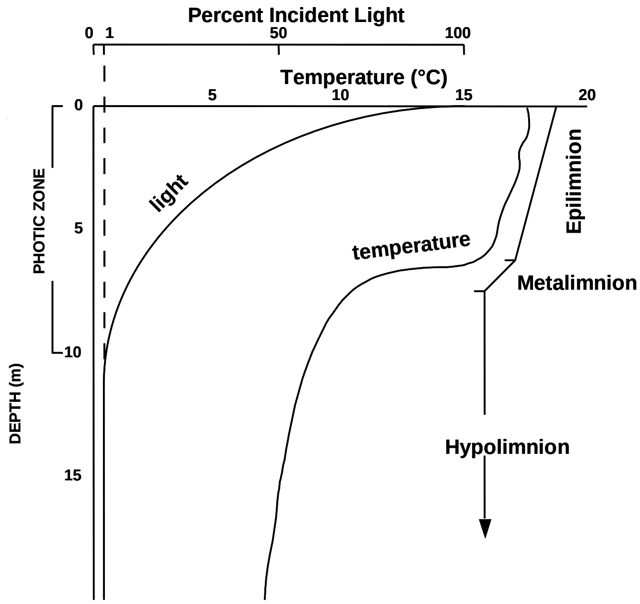

Figure 2. Temperature and light in a stratified lake.

The hypolimnion forms the deepest, coolest (densest) water of the lake. This water is often water that existed during winter and has been isolated from sunlight and the atmosphere by the formation of the less dense, shallower layers. This is very important because the lack of mixing between these layers or zones means that very different water quality can exist or develop during the period of stratification.

Large reservoirs in our region typically have one period of stratification and one season of mixing each year. Such lakes are termed, ‘monomictic’. In northern regions lakes (such as Lake Michigan) experience two seasons of mixing, one in the fall and one in the spring. Such lakes are termed, ‘dimictic’. And there are a few lakes that never completely mix (Carter’s Lake in Georgia is an example) and these are termed, ‘meromictic’. More about this another time.

Mixing is important because any type of water movement also requires energy and such movement results in energy exchange. Lake Keowee has several complicating energetic factors that affect the formation of the stratified layers as well as the motions of the water (hydrodynamics) in the lake. These complicating factors include: the operation of hydroelectric facilities at Keowee Dam and Jocassee Dam, the pumping action of Oconee Nuclear Station, and the shape of the basins forming the lakes.

The actions of the hydroelectric facilities and the nuclear station are complex but to understand them, we must first understand the way the shape of the basins affects water movement in the absence of other factors. That will be the subject of the next installment.