

What is Pond “Stratification?”

by Bill Cody & Bob Lusk

This is the first article in a series on water quality and what it means to ponds.

“I’m thinking about turning off my aeration system. How long will it take for my summer-hot pond to stratify?”

That seemingly simple question, posed by R. Larry Mangum, created a flurry of activity on the discussion forum of www.pondboss.com.

Excellent question. It deserves a thoughtful answer.

Long time Pond Boss writer, loyal website moderator and aquatic biologist, Bill Cody, chimed in with his favorite lead sentence.

“It all depends.”

Since water is the foundation of every pond and what lives around and beneath its surface, we should learn more about this wet stuff.

Water Density

Water is an amazing substance. Different temperatures of water have different densities. Cold water is heavier than warm water...to a point...and that point is 39 degrees, F. In your glass of drinking water, the ice is 32 degrees (or colder). It floats because it is less dense than the warmer water beneath it. If the rest of the water in your glass were 32 degrees, it would be ice. Ice is less dense than the water melting it, therefore it floats.

Water is most dense at 39 degrees F. (See Figure 1) As water gets colder than 39 degrees, it becomes less dense again. Amazing.

That’s why ice floats and steam rises. Those forms of water are less dense. Water is truly unique stuff. Weigh a gallon of water at any temperature different than 39 degrees, and it won’t be as heavy as that magic temperature. This factoid sets the stage to learn how water behaves in your pond to form a thermocline.

Because of these facts, some interesting things happen in your pond during summer. The water forms layers, like a big, wet layer cake.

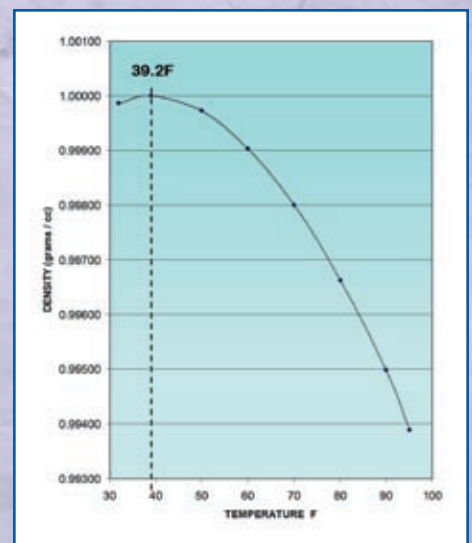
The Epilimnion is the top layer, the area typically most healthy and productive for living things such as fish and plants. This top layer receives heat from the sun and mixing from the wind. The next layer down is the Thermocline, also called Metalimnion, a transitional layer of rapid temperature drop. It can develop even in small bodies of water. The depth and thickness of the thermocline can vary due to pond depth, weather variations, wind, waves, latitude and longitude and localized environments.

In our work, we have found thermoclines as little as six inches thick and some as deep as two pickup trucks end to end. It depends on the size of the water body, its depth and the amount of biological activity happening within. The thermocline tends to be a horizontal fluid layer, extending over the entire body of water at a depth that can change with environmental conditions. The thermocline will move up or down during the summer and sometimes will temporarily disappear during cold rains and strong winds.

When Spring sun’s heat combines with water currents and wave action, your pond or lake begins to warm at the surface. Warm, less dense water will float on top of the cooler, denser water below. Wind pushes warm water downward and waves do their part to mix the heat as deep as possible and water absorbs the warmth...to a depth point. That point becomes the thermocline, the layer with a rapid temperature decline. Clear water absorbs more heat than murky water, so the thermocline in clear ponds will be deeper than in murkier waters. But, alas, the heat from radiation and wave action can only push downward so far.

Whatever that point, a thermocline forms.

The thermocline is the middle layer, keeping the epilimnion separate from the cold bottom layer.



Graph showing how the density of water changes with temperature. Note that water is most dense at 39.2°F (4.0°C). Ice is about 1/12 lighter than water at 32°F (0°C). The change in density of water becomes much greater when water is warm. The change in density between 75.2°F and 77.0°F is 30 times greater than between 39.2°F and 41.0°F.

How Layering Affects Oxygen in Water

What tends to confuse people is talk about oxygen and photosynthesis and all those “chemical and biological” things and how they relate to the thermocline.

It’s not so complicated.

Distribution of dissolved oxygen (DO) and

other chemical concentrations and reactions throughout the water column are influenced by air, temperature and living organisms. Once water separates into layers, these important factors are affected, especially DO. These changes aren't the "cause"...they are the "effect." It is these "effects" that can give pondmeisters serious heartburn.

The upper, warm layer of water is healthy, vibrant and alive. But, what happens over a short period of time in the layers beneath the warmer epilimnion is what can affect the lake in an unhealthy way. As a matter of fact, that lower layer of water is the culprit in almost all fish kills.

If you are primarily concerned with dissolved oxygen, (aren't we all?) then we must understand that stratification affects how oxygen is used in a pond. Dissolved oxygen is responsible for all the beneficial life activities in a pond. Creatures with gills breathe it, plants use it...and manufacture it. DO is almost always quickly depleted in the thermocline and deeper. This oxygen loss is mainly due to biochemical oxygen demand (BOD) in the water column.

Biological consumption of oxygen is due to breakdown of organic matter by bacteria and respiration of fish, zooplankton, bacteria and, when in the dark, plants. The chemical part of the oxygen portion of the BOD is the chemicals in water combining with oxygen.

Organic matter is always decomposing in the entire water column. But, in and below the dark thermocline, this isolated deeper water has no way to renew its oxygen and the available dissolved oxygen is quickly consumed. Oxygen has two basic natural methods to absorb into water...surface contact with the atmosphere and photosynthesis by plants.

Translation? Water below the thermocline quickly loses its oxygen. Organic matter, decomposing in water, uses all the valuable oxygen you would rather flow over the gills of your fish. Practically all forms of life must vacate deep water. There's no natural way to replace the oxygen in that lower isolated layer of water, below the thermocline, without some mechanical means of mixing...hence part of the need for bottom aeration in the first place, to circulate the entire pond, bottom to top.

Transparency, or water clarity, is the main factor allowing for oxygen production via photosynthesis of living plants. Sunlight feeds plants, which produces oxygen. The key here? Sunlight. Sunlight often does not reach the thermocline or beyond. Take away those rays of sunshine, and plants reverse their cycles, grabbing oxygen and converting it to carbon dioxide.

Deep, clear water allows more oxygen

production, deeper. Clear water has a lot fewer oxygen-consuming organic things. Fertile, green, productive water has a lot of organic material present and loses oxygen relatively fast without sunlight.

Presence and/or persistence of oxygen in the hypolimnion (deepest coldest zone) is almost always related to productivity and fertility of the pond or lake.

Role of Nutrients

Eutrophic is defined as, "waters rich in mineral and organic nutrients that promote the proliferation of plant life, especially algae, which, when it decomposes, reduces the dissolved oxygen content and leads to the extinction of other organisms." Literally, the Greek word means, "Well nourished." If a thermocline or the deeper hypolimnion develops in most fish ponds it will usually lose its DO in a few hours, days or weeks depending on its level of eutrophy or amount of enrichment.

The degree of nutrient loading is important when discussing eutrophication and productivity. Fertilized ponds with increased productivity are definitely eutrophic or even hyper-eutrophic. That's why most hatchery ponds have emergency aeration on hand. Eutrophic lakes typically have 3-8 feet of visibility. Hyper-eutrophic is a term used for exceptionally enriched ponds/lakes that tend to have nuisance algal blooms and water transparencies usually less than 3 ft. Many fish production ponds are thus, by definition, hyper-eutrophic.

It's Like a Cake

Okay, look at your pond in summer as a layer cake. There are three layers. The epilimnion sits on top because its water is warmer, therefore lighter weight, or less dense. It's the layer we always see. Imagine that layer as alive, teeming with good flavors, a symbol of what we expect to tantalize our fishing taste buds. The second layer, that thermocline thingy, the metalimnion, is the transitional layer, the one which links the two main layers with a rapid drop in temperature. Then, lurking below, squarely on the bottom, sits the cold hypolimnion. Appears great, down there. Cool water. But, alas, it's not so great, because it is almost always void of oxygen. Consequently, it is devoid of all life which needs oxygen. Unless, that is, you aerate your entire pond cake. Then, you have one deep, warm, happy layer, fresh and lively...all epilimnion and well mixed.

Back to the original question...how long does it take? Believe it or not, we have seen ponds begin to stratify within two to three hours after turning off an aeration system. If

you measure temperature and/or oxygen levels, you might be amazed. Oh yes, you might have measurable oxygen all the way to the bottom while your system is on, but when you throw the breaker on that aerator and mechanical water mixing ceases, life at the bottom begins to change. Without a source of water gurgling and roiling in a big vertical circle from pond's top and no oxygen producing plant life at the bottom, organic matter begins to do what it does when the oxygen cuts off. It sucks the oxygen out of the water and anaerobic (without oxygen) conditions take charge.

Exceptions

There are special situations where ponds and lakes are exceptionally clear, with transparencies of 15 to 30 feet or more. Light is able to penetrate far into the depths at, or below, the thermocline. Oxygen can be produced or preserved in these deeper waters; sometimes below the thermocline. When water is exceptionally clear, the biological productivity is extremely low. Consequently, BOD is also exceptionally low and oxygen is consumed much more slowly in the deepest cold layer, even in very low or no light. In these situations it takes a long time to lose dissolved oxygen below the thermocline. In exceptionally clean, clear lakes (oligotrophic), oxygen loss is very slow and DO levels remain high enough to support cold water fish in the deep zone all summer. These are the lakes which support trout fisheries in the mid-depths and warmwater or cool water fish in the top layer.

So, here is the answer to our pondmeister's question. The water will begin to stratify by temperature almost immediately, especially during the hottest summer months. But, the rate of oxygen loss beneath the thermocline when you shut off the aerator will be dependant on water clarity which is usually dependant on the pond's state of eutrophy.

As Cody says, "It all depends."

Next issue, we dive into the "trophics" of water...how water absorbs, dissolves and accumulates its nutrients...and what it means to you.

Additional Reading

Boyd C.E. Water Quality in Ponds for Aquaculture 1990. Birmingham Publishing.

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