



# Natural Resources Facts

University of Rhode Island • College of Resource Development  
Department of Natural Resources Science • Cooperative Extension



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## *Dissolved Oxygen and Temperature*

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Dissolved oxygen and temperature are two of the fundamental variables in lake and pond ecology. By measuring dissolved oxygen and temperature, scientists can gauge the overall condition of waterbodies. Aquatic organisms need dissolved oxygen for their survival. While water temperature also directly influences aquatic organisms, it regulates dissolved oxygen concentrations within a lake. Dissolved oxygen and temperature are also used to classify lakes. This fact sheet describes why lakes need dissolved oxygen, characterizes daily and seasonal dissolved oxygen concentrations, discusses how temperature affects lakes and dissolved oxygen concentrations, explains methods of classifying lakes using dissolved oxygen and temperature, and specifies how dissolved oxygen and temperature are measured.

### **Why Do Lakes Need Oxygen?**

Dissolved oxygen (DO) is the amount of oxygen in solution. Without oxygen, lakes could not support life. All organisms in a lake, from fish to insects to microscopic zooplankton, need oxygen for **respiration**. During respiration, organisms consume oxygen and give off carbon dioxide while absorbing food molecules to obtain energy for growth and maintenance (Caduto 1990).

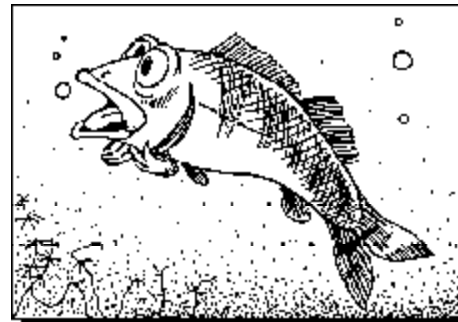
Since different organisms survive at different optimal oxygen levels, the amount of DO determines which organisms a lake can support. High oxygen contents are needed by some species, such as trout. Other species, including carp, catfish, water fleas, and zooplankton, have adapted to survive under low oxygen conditions. Some organisms can even live in environments where oxygen levels fluctuate significantly. Even plants respire at night when lack of sunlight prevents photosynthesis. Decomposition of dead plant and animal material also requires DO. In addition, DO concentration controls important chemical reactions in bottom sediments of lakes.

Oxygen is introduced into lakes in a variety of ways. Wind and wave action bring oxygen into waterbodies. Inflowing streams can also carry DO into

lakes and ponds. In sunlight, aquatic plants and algae produce oxygen within aquatic ecosystems through photosynthesis. Turbulence and currents circulate DO throughout waterbodies.

### **Dissolved Oxygen Fluctuates Daily**

The DO concentration within a waterbody can experience large daily fluctuations. Aquatic plants and algae produce oxygen as a by-product of photosynthesis by day. But at night, they consume oxygen through respiration. **Productive lakes**, lakes with large populations of aquatic plants or algae, are likely to experience the greatest DO fluctuations. In such lakes, the DO concentration is usually lowest just before sunrise, and highest in late afternoon (Caduto 1990). In some highly productive waterbodies, DO is consumed by night-time respiration



respiration faster than it is replaced by oxygen diffusing from the atmosphere. Consequently, fish and other lake

organisms may die from lack of oxygen (Simpson 1991).

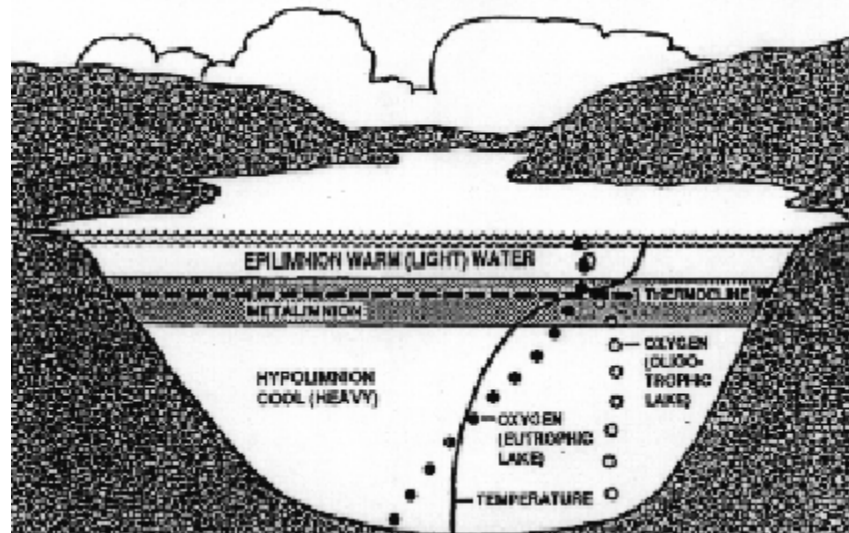
### **What Affects Dissolved Oxygen Levels?**

The amount of oxygen dissolved in a waterbody is affected by salinity, altitude, groundwater inflow, and water temperature. Salinity is how much salt is in the water. Although it is generally not a concern in most freshwater lakes, salinity can greatly affect oxygen solubility in estuaries, brackish waters, bogs, and waterbodies

**Figure 1:**

In summer, deep lakes may undergo thermal stratification. A stratified lake is separated into three thermal layers: the epilimnion (warm surface layer), the metalimnion (transition zone), and the hypolimnion (cool bottom layer).

Adapted from *The Lake and Reservoir Restoration Guidance Manual*, EPA 440/5-88-002



in agricultural areas (Campbell and Wildberger 1992). Higher salinity reduces the amount of oxygen that can dissolve in the water. Due to lower atmospheric pressure, lakes in higher altitudes usually have lower levels of DO. Groundwater, which does not have contact with the atmosphere, typically has lower levels of DO than surface waters. When groundwater enters a lake, DO concentrations are initially reduced near the spring (Caduto 1990). However, groundwater is generally colder than surface waters (Caduto 1990). Colder water holds more oxygen than warmer water. By reducing lake water temperature, groundwater inputs increase the ability of a waterbody to hold oxygen in the long term. Of these variables, temperature most directly effects DO in lakes and ponds.

### How Does Temperature Affect Lakes?

Many factors influence lake and pond water temperature, including seasonal air temperature, water depth, groundwater inflow, stream flow, mixing due to wind and water currents, and the amount of sunlight and shade. Water temperature plays an important role in aquatic ecosystems. It limits the migration, spawning, egg incubation, growth, and metabolism of aquatic organisms. As with DO, each aquatic organism has an optimal temperature range for its metabolism. Warmer water promotes higher metabolism and respiration rates.

Water temperature also affects lakes indirectly by influencing DO concentrations. Warm water holds less oxygen in solution than cold water. **Percent saturation** can be used to describe the DO status of a lake. Percent saturation is calculated as:

$$\frac{\text{DO concentration measured in the lake}}{\text{maximum DO concentration at that temperature}}$$

The bottom half of this equation indicates the importance of temperature in relation to DO capacity of water bodies.

Water temperature can vary within a lake, tremendously influencing lake ecology. **Thermal stratification**, or temperature layering, generally occurs in lakes and ponds greater than 5 meters (16.4 feet) in depth. Stratification occurs because water at different temperatures has different densities. The typical annual cycle of thermal stratification has several phases (Caduto 1990, Kortmann and Henry 1990, Simpson 1991). The first phase, **spring overturn**, occurs in early spring when rising air temperatures warm surface water and melt ice cover. The entire water column stabilizes to a uniform temperature as wind action mixes the water from top to bottom.

As air temperatures increase in spring and summer, lake water also warms up. Surface water warms more rapidly than deeper water. Because the warmer, surface water is lighter than the colder, deeper water, these lakes separate into three distinct thermal layers (Fig. 1). The surface layer, the **epilimnion**, is warmed by sunlight and mixed by wind action. The middle layer, the **metalimnion**, is a transition zone. The bottom layer, the **hypolimnion**, receives minimal sunlight and does not mix with the upper layers. As summer progresses, the depth of the epilimnion increases as the warm temperature water penetrates deeper into lakes.

During autumn, lower air temperatures cool the surface water. When the surface water (epilimnion) cools to the same temperature as the hypolimnion, stratification is broken, and all the water in the lake circulates freely in response to wind action. This process, similar to spring overturn, is called **fall overturn**.

In winter as air temperatures grow colder, lakes may stratify again. As opposed to summer stratification, during winter stratification, the upper zone is colder than the bottom waters. An ice layer may form on the surface of the lake preventing sunlight and oxygen from entering the water.

Thermal stratification causes extreme DO conditions within a waterbody. Since there is no replenishment of oxygen to the bottom waters, oxygen in these bottom waters may gradually become depleted by **decomposers** that live in, or on bottom sediments. Decomposers are bacteria, fungi, and other organisms that consume oxygen in order to break down **detritus**, dead plant and animal material. If DO concentration drops below 2 milligrams/liter, fish kills may occur. If oxygen levels are reduced below 1 milligram/liter, nutrients once bound to bottom sediments are released into the water through a chemical reaction (Simpson 1991). When stratification breaks down in autumn, algae are able to utilize these nutrients. As a result, an **algal bloom**, a tremendous growth of algae, may occur (See Natural Resources Facts, Fact Sheet No. 96-4, "Algae in Aquatic Ecosystems").

### Classifying Lakes by Temperature

Water temperature is the basis for **thermal classification** of lakes and ponds (Hutchinson and Löffler 1956). Scientists often categorize lakes according to their thermal structure since it is believed that these lakes function similarly. Lakes with the typical thermal stratification scheme described previously would fall under the classification of **holomictic**. Water in holomictic lakes circulates freely throughout the entire water column sometime during the year. Holomictic lakes are further subclassified into monomictic, dimictic, and polymictic. As the name suggests, **monomictic** lakes stratify once per year, usually during summer. **Dimictic** lakes stratify twice during the year with summer and winter stratification and waters that freely circulate in the spring and fall. Most lakes in Rhode Island are monomictic or dimictic. **Polymictic** lakes stratify irregularly throughout the year possibly due to chemically induced density differences. If a lake is not holomictic, it may be **meromictic** which is stratified throughout the entire year often due to chemically induced density differences.

There are many shallow ponds in Rhode Island that do not experience thermal stratification during summer. In these shallow ponds, oxygen usually remains evenly distributed throughout the water column due to

complete mixing of the water by wind and waves. However, lakes on hot, windless days may experience DO depletion, and shallow lakes may experience winter stratification when covered by ice.

### Classifying Lakes by Dissolved Oxygen

DO concentration can also be used as a water quality criterion in order to classify lakes and ponds. The State of Rhode Island uses surface DO as one of the water quality criteria in its five category classification system of lakes and ponds (Table 1).

### What is Trophic Status?

Another way to classify lakes is by trophic status. As lakes age, they gradually fill in with sediment, silt, and organic matter in the natural process of **eutrophication**. This process has been divided into sequential steps, each indicated by a different trophic state. Degree of DO depletion in bottom waters of deep lakes can be an indicator of its trophic state. **Oligotrophic** waters are clear with few aquatic plants and algae. Little oxygen is needed for decomposition, so oxygen remains fairly constant in the hypolimnion. **Eutrophic** waterbodies are cloudy and have an abundance of aquatic plants and algae. In eutrophic lakes, available oxygen will be rapidly consumed by decomposition processes and may become completely depleted, a condition called **anoxia**. Dissolved oxygen concentrations in deep lakes typically progress toward anoxic conditions throughout the summer. **Mesotrophic** waterbodies are in the middle of the trophic status spectrum. Decomposition processes will partially deplete available oxygen supply in mesotrophic lakes. For more information on trophic status, see Natural Resources Facts, Fact Sheet No. 96-2, "Phosphorus and Lake Aging." Dissolved oxygen concentration in the hypolimnion commonly acts as an "early warning" of trophic state changes in a lake because oxygen depletion can occur before other indicators of trophic state change, such as increased algal productivity (Carlson and Simpson 1996).

Class	Designated Uses	Dissolved Oxygen Criteria
A, B	Public water supply with appropriate treatment; agricultural uses; bathing; fish and wildlife habitat (Bacterial levels distinguish these two classes)	75% saturation 16 hours/day, but not < 5 mg/l at any time
C	boating; fish and wildlife habitat; industrial processes and cooling	> or = 5 mg/l at any time
D	migration of fish; good aesthetic value	> or = 2 mg/l at any time
E	nuisance conditions; certain industrial processes	< 2 mg/l at any time

**Table 1:** This five category classification system, based on surface dissolved oxygen concentrations, is used by the State to classify RI lakes and ponds.

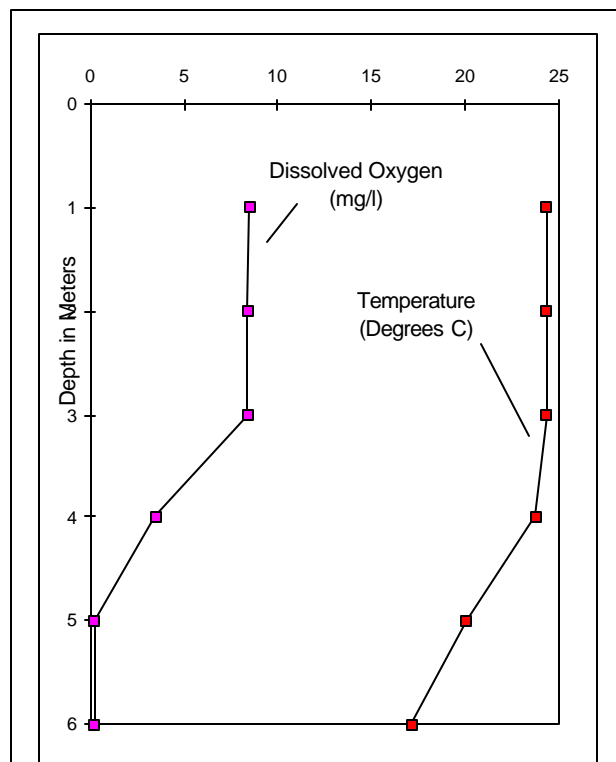
## How are Temperature and Dissolved Oxygen Measured?

Temperature is perhaps the easiest water quality measurement that can be made on a lake. All that is needed is an accurate thermometer and a little patience while the thermometer equilibrates to the water temperature. Care must be taken to ensure that the temperature reading does not change due to contact with air. It is best to read the thermometer while it is still in the water. Thermometers are commonly attached to water sampling devices. Electronic thermistor thermometers are also available.

The Winkler titration method is the standard method for measuring DO content and has been adapted for use in field kits. The kits are widely available, ranging in price from \$30 - \$50. The first step of the Winkler titration is to "fix" the water sample. Once a sample is fixed, the monitor need not be concerned about oxygen diffusing into or out of the sample. The sample is fixed by adding manganous sulfate solution, alkaline potassium iodide azide solution, and a strong acid. During these steps, for each molecule of oxygen in the water, a molecule of free iodide is released into the water. The remainder of the titration is concerned with the iodide concentration, which is equivalent to oxygen concentration but cannot diffuse out of the sample as readily as oxygen. The final stages of the procedure includes a drop by drop addition of sodium thiosulfate. When all of the iodide has reacted, the solution becomes clear. The concentration of DO is related to the amount of sodium thiosulfate added to the sample to produce a clear solution.

Dissolved oxygen samplers are used to collect samples. A principle feature if these samplers is that they have a mechanism to allow sample collection at specific depths, after first purging the sampler of air. Dissolved oxygen and temperature measurements from the lake surface to the bottom are compiled into a DO profile (Fig. 2). These measurements can be made using samplers, DO kits and thermometers. However, it is easier to make multiple DO measurements using a dissolved oxygen meter. Unfortunately, the cost of meters, ranging from hundreds to thousands of dollars, is often prohibitive for volunteer monitoring groups (Simpson 1991).

Analysis of DO and temperature measurements give an indication of a lake or pond's general condition. Volunteers in the URI Watershed Watch program make DO measurements every other week using DO samplers and field kits. These measurements are made at the deepest spot of lakes and ponds with a maximum depth greater than or equal to five meters (16.4 feet). Water samples from depths of one meter from the surface and one meter from the bottom are routinely collected and tested.



**Figure 2:**

### Dissolved Oxygen and Temperature Profile

Dissolved oxygen and temperature can be taken at every meter in a lake's water column. As typical with most thermally stratified deep lakes, this profile shows that both temperature and dissolved oxygen concentrations decreased with depth.

### For more information:

- Caduto, M.J. 1990. *Pond and Brook: a guide to nature in freshwater environments*. Prentice-Hall, Inc. Englewood Cliffs, NJ.
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- RI Water Quality Standards. 1981. *Water quality regulations for water pollution control*. RIDEM.
- Simpson, J.T. 1991. *Volunteer Lake Monitoring: A Methods Manual*. EPA 440/4-91-002. pp. 16-21,70-72. Phone # (202) 260-7018.