



Natural Resources Facts

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Phosphorus and Lake Aging

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Since the early 20th century, scientists have attempted to classify lakes and ponds into categories in order to describe their condition and thus encourage appropriate lake management. Nutrient levels, especially phosphorus, are particularly important in influencing water quality conditions and hastening lake aging. To be useful, a classification system must recognize that lakes change in response to climatic fluctuations, watershed activities, and nutrient inputs. This fact sheet will describe the process of lake aging in northern temperate ecosystems, such as found in New England; explain trophic status classifications; discuss the role of phosphorus in aquatic ecology; introduce Carlson's Trophic State Index; and offer suggestions for limiting phosphorus inputs to lakes.

Eutrophication

Sediment, silt, and organic matter gradually fill lakes as they age. Nutrients flushed into a lake from its watershed stimulate the growth of aquatic plants and algae, creating a more productive waterbody. **Productivity** is a measure of the amount of plant and algal biomass in a lake or pond. A lake with larger quantities of aquatic plants and algae tends to be more productive than a lake with fewer aquatic plants and algae.

Eutrophication is the natural process that describes increasing lake productivity, nutrient enrichment, and general lake aging. Throughout the eutrophication process the physical, chemical, and biological composition of lakes change (Simpson 1991). In the early 20th century, **limnologists**, scientists who study lakes and freshwater ecosystems, devised a classification system to describe lakes as they proceed through the eutrophication process. Each **trophic state** indicates the lake's general level of water clarity, nutrient enrichment, and algal and aquatic plant abundance. However, trophic state should not be considered a discrete category, but rather part of a continuous spectrum.

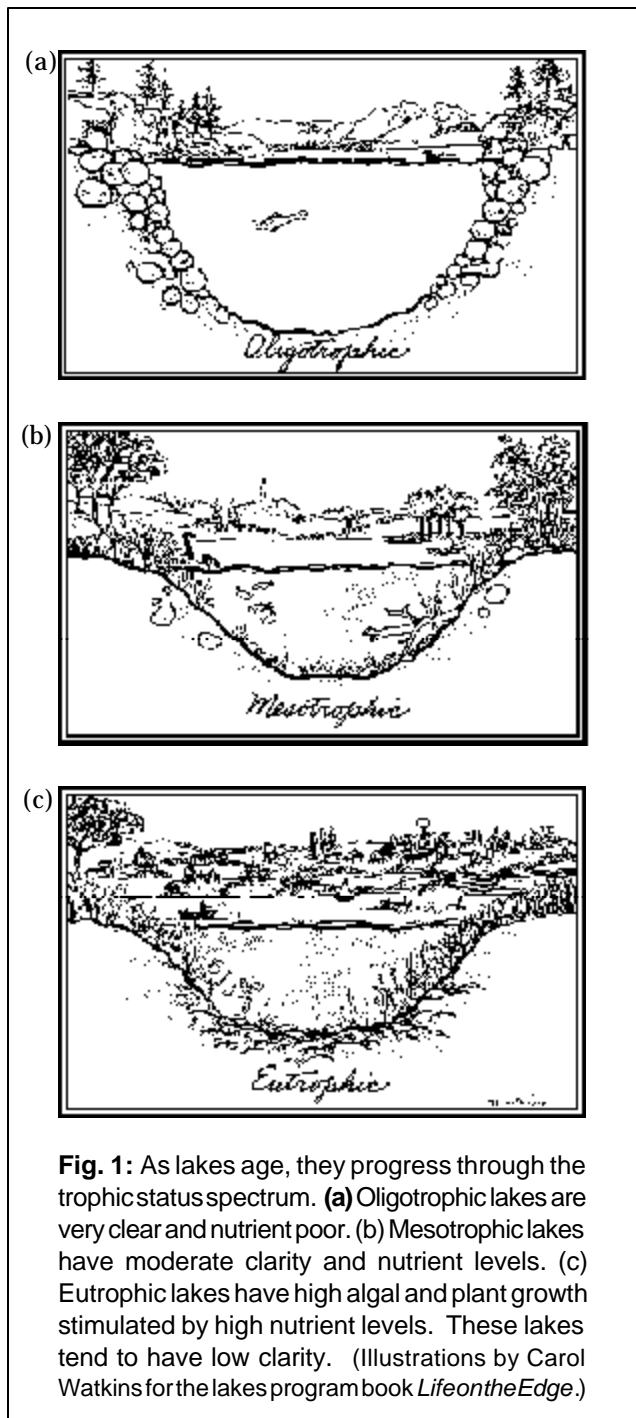


Lakes in early stages of eutrophication are typically characterized by limited algal and plant productivity and low nutrient levels. These **oligotrophic** lakes have very clear water, are nutrient poor, and maintain high dissolved oxygen concentrations throughout the water column and throughout the summer (Fig. 1a) (Simpson 1991, Moore & Thornton 1988). Sand, stones, or other mineral deposits usually line the lake bottom. These lakes may support cold water fisheries, including trout. Organic matter accumulates slowly on the bottom of the lake basin.

Eutrophic lakes are at the opposite end of the trophic status spectrum (Fig. 1c). In these highly productive waterbodies, algal and plant growth is stimulated by high nutrient levels (Simpson 1991, Moore & Thornton 1988). In addition to abundant algae and plants, high sediment inputs contribute to decreased water clarity. Bottom sediments are commonly organic muck. These lakes may also experience severe algal blooms. Deep waters become depleted of dissolved oxygen during the summer (see Natural Resources Facts, Fact Sheet No. 96-3, "Dissolved Oxygen and Temperature"). These lakes typically cannot support cold water fisheries. Extremely eutrophic lakes of "pea-soup quality" are further subclassified as **hypereutrophic** lakes. Eventually, the lake basin may fill in so much with sediment and plants that it becomes a marsh, bog, or other wetland area.

Mesotrophic lakes are in the range between oligotrophic and eutrophic lakes (Fig. 1b). These lakes have intermediate nutrient availability with corresponding intermediate algal and plant growth and intermediate water clarity (Simpson 1991, Moore & Thornton 1988). Many Rhode Island lakes and ponds fall into this mesotrophic range.

Some lakes and ponds are naturally eutrophic. This occurs because trophic state is also a reflection of the lake's physical condition, such as size and shape of the lake, length of time water remains in the waterbody (**residence time**), geology, soils, and size of the watershed (Moore & Thornton



1988, Monson 1992). In addition, man-made reservoirs tend to become eutrophic more rapidly than natural lakes since there is a tendency for these reservoirs to revert back to their original state, typically a stream system or marsh (Moore & Thornton 1988, Monson 1992). Alternatively, some lakes may become more oligotrophic as they age.

Oligotrophic versus eutrophic lakes is not simply "good" versus "bad." Different trophic classes are more suitable for different lake activities (Monson 1992, NYDEC/FOLA 1990). For example, fishermen may desire a more

eutrophic waterbody because abundant aquatic plants provide excellent food and cover for fish. However, swimmers and boaters prefer more oligotrophic lakes with few aquatic plants to tangle legs and boat motors. The goal of lake and fishery managers, biologists, and limnologists is not as simple as oligotrophy, mesotrophy, or eutrophy for all lakes, but to maintain a variety of lake types to satisfy a variety of people (Jones 1995).

Cultural Eutrophication

Natural eutrophication takes place over hundreds, even thousands of years. However, human activities have greatly accelerated the process of eutrophication. **Cultural eutrophication** can take place in as few as ten years. Runoff, especially from urban and agricultural areas, may carry industrial effluent, fertilizers, pesticides, and/or sediment. These by-products of human activity can be discharged into a waterbody and consequently accelerate eutrophication. Most human-oriented land uses, including logging, agriculture, and residential and commercial developments, contribute to cultural eutrophication.

Many water quality monitoring programs, such as URI Watershed Watch, are geared toward monitoring cultural eutrophication in order to provide management information. The good news is that eutrophication is a reversible process, at least to some extent, with sufficient funding (Monson 1992). If problem sources can be identified and land use practices modified, eutrophic lakes can become mesotrophic or even oligotrophic once again.

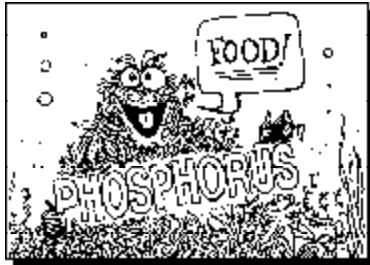
Role of Phosphorus in Eutrophication

The phosphorus content of increased inputs to a lake frequently stimulate cultural eutrophication. Just as you need nutrients to grow and survive, aquatic plants and algae require certain nutrients for growth. Phosphorus is the **limiting nutrient** of most freshwater lakes, ponds, and streams. This means that the amount of phosphorus in a lake determines or limits aquatic plant and algal productivity. Without phosphorus, few aquatic plants and algae would be able to grow. However, even minute amounts of phosphorus, parts per billion levels, can cause tremendous increases in growth. The presence of phosphorus in lakes also enables plants to use other nutrients more efficiently, further increasing productivity.

As aquatic plant and algal biomass increases, there is a corresponding increase in the amount of biomass to be decomposed after these plants die. Decomposition by bacteria and fungi consumes dissolved oxygen. Plants and algae undergo night-time respiration which also consumes oxygen. If a lake's dissolved oxygen content decreases significantly, fish kills may occur or fish species composition may shift to those with lower oxygen needs. If lakes lose oxygen faster than it can be replaced by photosynthesis and

atmospheric exchange, the lake may become **anoxic**, without oxygen. When anoxia occurs, a chemical reaction takes place in bottom sediments which releases sediment-bound phosphorus into the water column. This additional supply of phosphorus perpetuates the cycle of more and more plant and algal growth and decreased water clarity. Nuisance algal blooms may occur more and more frequently.

Typically, any form of land use development contributes more phosphorus to a waterbody than undeveloped forested land. Some significant contributors of phosphorus are: phosphate-based detergents, lawn and garden fertilizers,



improperly sited and maintained septic systems, waterfowl, agricultural drainage, urban storm runoff, wastewater treatment effluent, animal wastes, road deicers, and atmospheric deposition.

Total phosphorus in northern lakes typically ranges from 14-17 ppb under natural conditions (Monson 1992). In 1976, the EPA recommended phosphorus limits of 50 ppb for streams where they enter a lake and 25 ppb within the lake to prevent or control eutrophication. Many monitoring programs measure total phosphorus concentrations to detect trends in water quality of lakes and ponds. URI Watershed Watch evaluates total phosphorus concentrations in its lakes and incoming streams on at least a tri-season basis, in May, July, and November.

In coastal ponds, nitrogen often replaces phosphorus as the limiting nutrient. In these waterbodies, total nitrogen concentrations can be measured as an indicator of eutrophication. Similar to freshwater responses to phosphorus, increased nitrogen loads to a coastal pond may shift the pond toward the eutrophic end of the trophic status spectrum.

Carlson's Trophic State Index

Water clarity is a widely accepted indicator of lake trophic status. The Secchi disk is the typical tool used to measure water clarity. The common assumption is that the deeper the Secchi disk is visible from the surface of the

water, the clearer and more oligotrophic the lake (see Natural Resources Facts, Fact Sheet No. 96-1, "Measuring Water Clarity"). Using Secchi depth measurement data, Dr. Robert Carlson (1977) developed the **Carlson's Trophic State Index** (TSI). The index was developed to alleviate difficulties in communicating with the public using the traditional oligotrophic, mesotrophic, eutrophic classification system.

Since all lakes classified into the same trophic status are not identical, TSI quantitatively describes the trophic status of a lake within a numerical range of 0-110 (Table 1). Shallow Secchi depth measurements, indicative of low water clarity, correspond to higher TSI numbers. Higher TSI numbers indicate more eutrophic waterbodies. An increase by 10 on the TSI scale correlates to a doubling of lake algal biomass and halving of water clarity (Carlson 1977, Monson 1992).

Two other types of measurements, chlorophyll a concentration and total phosphorus concentration, may also be used to calculate TSI. These two measurements can be used to estimate lake productivity. Higher chlorophyll a and total phosphorus concentrations translate into higher TSI numbers. Natural log transformations of Secchi disk values, chlorophyll a concentrations, or total phosphorus concentrations are calculated to determine TSI values as such:

$$TSI = 60 - 14.41 \ln \text{ Secchi depth (meters)}$$

$$TSI = 9.81 \ln \text{ Chlorophyll a (ppb)} + 30.6$$

$$TSI = 14.42 \ln \text{ Total Phosphorus (ppb)} + 4.15$$

If one of these measurements is known, the other measurements can be predicted from these equations (Carlson 1977, Monson 1992). TSI was developed for use on lakes with few rooted aquatic plants and little non-algal cloudiness, therefore, TSI should only be used on lakes with these characteristics. Scientists associate ranges on the TSI scale with the classic oligotrophic, mesotrophic, and eutrophic trophic status classifications (Table 1).

As TSI suggests, total phosphorus, chlorophyll a, and water clarity are inter-related components. When additional phosphorus enters a waterbody, aquatic plant and algal growth is stimulated. Chlorophyll a concentrations, indicative of algal levels, subsequently increase (see Natural Resources Facts, Fact Sheet No. 96-4, "Algae in Aquatic Ecosystems"). With greater algal and plant growth, water clarity decreases, progressing the lake toward the eutrophic end of the trophic status scale.

Table 1:

The Carlson's Trophic State Index describes the trophic state of lakes quantitatively. Scientists associate ranges of the TSI scale with the classic oligotrophic, mesotrophic, eutrophic classifications.

	TSI Value	Secchi Depth Measurement	Chlorophyll a	Total Phosphorus
Oligotroph	< 3.9	>4 m (>13 ft)	<2.6 ppb	<12 ppb
Mesotroph	4.0 - 5.0	2-4 m (6.5-13 ft)	2.6-7.2 ppb	12-24 ppb
Eutroph	5.0 - 11.0	<2 m (6.5 ft)	>7.2 ppb	>24 ppb

**What YOU Can Do
to Limit Phosphorus Inputs to Lakes
(for more information see *Diet for a Small Lake...*)**

- * Maintain your septic system.
 - Have it inspected every year or two
 - Have it pumped regularly, usually every 1-3 years.
 - Old systems should be replaced to meet new standards.
 - Avoid using garbage disposals which add excessive solids and grease to septic systems.
- * Don't pour chemicals (pesticides, disinfectants, acids, medicines, paint thinner, etc.) down the drain. These chemicals harm septic system bacteria and can contaminate groundwater.
- * Manage lawn and garden fertilizer use. (Most fertilizers contain phosphorus)
 - Have your soil tested to determine exactly how much fertilizer your lawn needs.
 - Use a mulching lawnmower; grass clippings recycle nutrients to your lawn.
 - Avoid fertilizer application just before a heavy rain.
 - Use slow-release fertilizers.
 - Do not rinse spilled fertilizer off paved surfaces, but sweep excess up or onto lawn.
 - Use native and adapted plants with lower fertilizer needs.
 - Store fertilizer in a location with a concrete floor.
- * Plant a buffer strip of plants or shrubs (a greenbelt) between your lawn and lake; this zone will absorb excess phosphorus before it can enter the lake. (Fig. 2)
- * Rake and remove leaves from lakeside property in the fall (leaves contain phosphorus). Do not dispose of them in the lake.
- * Use no-phosphate detergents (check labels). Most liquid laundry detergents do not contain phosphorus, but some powdered laundry detergents and dishwasher detergents still do.
- * Support maintaining wetlands in their natural states. Wetland areas help to filter nutrients and many other pollutants.
- * Do NOT feed the waterfowl. Waterfowl, along with all animals and humans, excrete phosphorus in their wastes. Feeding waterfowl encourages them to congregate in your lake.
- * Direct roof downspouts to broad, grassy areas so the rain water has a chance to seep into the ground rather than run off, carrying sediments and nutrients with it.
- * Conserve water. For example, use low-flow shower heads or place a brick in the toilet tank.
- * Correct soil erosion problems immediately! Steep, sloping banks and exposed soil should be seeded or terraced to prevent erosion.
- * Join your local lake, pond, or watershed association.



Fig. 2: A buffer zone of plants, shrubs, or trees between your property and your lake will help prevent phosphorus from entering the lake. This is just one way that **you** can help prevent cultural eutrophication in your lake.

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For more information:

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For more information on URI Watershed Watch:

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