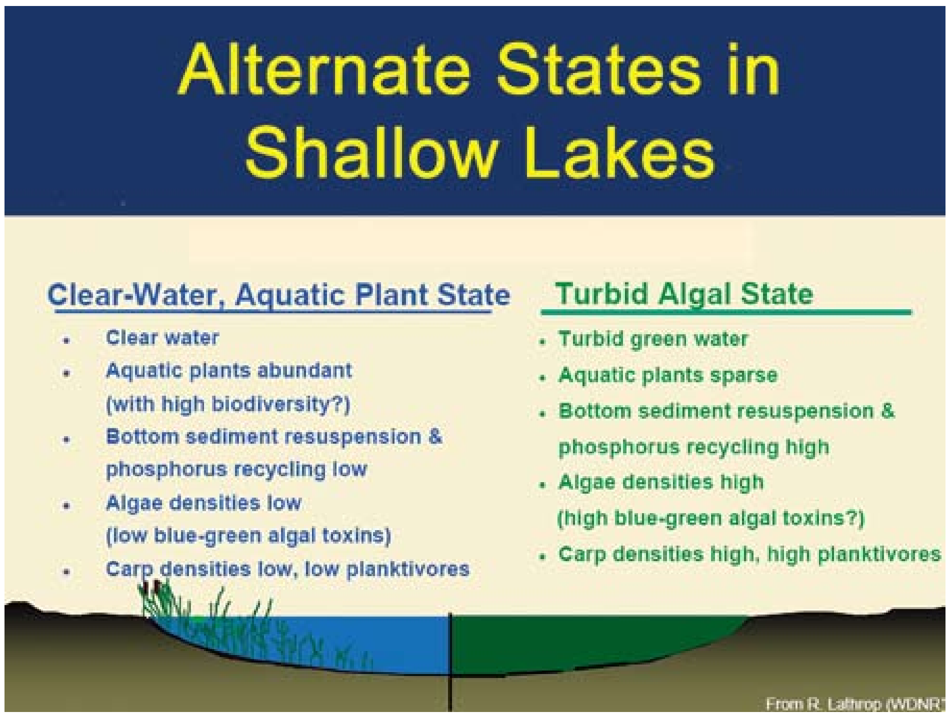
The Lake Connection

An overview of shallow lakes ecology & management techniques

by Dwight Osmon, CLM, Water Resources Planner, Hey and Associates, Inc.

A working definition for shallow lakes is a lake with a maximum depth less than 20 feet and/or an average depth of less than 10 feet. Shallow lakes may be thought of as a lake composed entirely of a littoral zone—the area where aquatic plants can grown because sunlight can penetrate to the lake bottom—or as large, deep wetlands. Some other characteristics typical of shallow lakes include a high watershed area to lake area ratio, resulting in nutrient richness and high productivity and internal loading from lake sediments due to physical or abiotic factors (wind or biological processes) or biotic factors (such as bottom feeding organisms like carp that can stir up lake sediment). Internal loading is the recycling of existing nutrients like phosphorus from lake sediments into the water column, which fuels additional plant and animal growth.

The physical nature of shallow lakes promotes intense interactions between the water column and the lake sediments because there is a relatively low water volume to lake bottom ratio. This interaction may or may not be mediated by the presence of aquatic macrophytes



(plants). Aquatic plants affect overall lake ecology in a number of ways. They stabilize bottom sediments, preventing sediment resuspension and limiting nutrients and turbidity. Aquatic plants also provide daytime refuges for zooplankton, which consume algae, causing an increase in water clarity. Aquatic plants also compete directly with algae for nutrients and light, which temper algal blooms. Without aquatic plants, algae dominate.

In contrast, in deeper lakes, stratification isolates much of the lake bottom from interactions with the water column, and the littoral zone comprises a relatively small portion of the overall lake area. As a result, the majority of the key ecological reactions occur in the open water zone and others are related to seasonal stratification events and lake turnover. Typically deeper lakes are more responsive to external nutrient loading (especially its reduction), turnover in the spring and fall, support fewer fish per unit volume, and experience less intense zooplankton predation by fish than shallow lakes. These key differences in the fundamental ecological interactions in deep versus shallow lakes require different management actions and ecological models to understand the complex relationships affecting lake condition.

The “Alternate Stable States” refers to a model often used to explain the ecology of shallow lakes. Shallow lakes generally exist in one of two conditions, or stable states, known as the “clear water state” or the “turbid water state.” Characteristics of the clear water state include abundant aquatic plant growth, a diverse and productive gamefish community, and numerous zooplankton, while the turbid state is free of aquatic plants, produces dense algae populations, and supports an undesirable bottom feeding fish community. Typically there is no intermediate state of existence for shallow lakes. They will either be full of algae or full of plants.

Because the entire lake bottom is exposed to sufficient sunlight, shallow lakes are able to support an incredible density and array of life. As Figure 1 shows, the clear or turbid water state depends on the amount of nutrients and turbidity. It is clear from this graphical representation that it is unlikely for a hyper-eutrophic lake (dark red) to persist in the clear water state with or without management while lakes in the intermediate range (mesotrophic to eutrophic) may exist as either clear or turbid. It is our goal as managers to find ways to scale the hill.

Trophic structure is the relationship of organisms to each other. Figure 2 illustrates the trophic structure for clear and turbid shallow lakes. A trophic cascade is the name for a model to describe the complex biological interactions occurring across a food chain.

We can use an example to illustrate how a trophic cascade generally occurs in shallow lakes. In this example we’ll explore factors that would promote a shift from clear to turbid conditions. Top predators (piscivores), such as Northern pike, walleye, and largemouth bass are lost from a lake through over-fishing, lack of reproduction, or reduced stocking efforts. The loss of piscivores means that there are no longer predators feeding on panfish (planktivores), and carp. These populations increase and become abundant, yet the average panfish size decreases or becomes stunted. Carp begin to disturb the bottom sediments at a higher rate, and this activity reduces water clarity by increasing turbidity. The overabundant small panfish feed on zooplankton and deplete the zooplankton population. Because zooplankton graze on algae suspended in the water column, reduced populations of zooplankton usually results in lower water clarity. Lower water clarity result in a loss of aquatic plant biomass and further reinforces a shift to algal dominance. Lower aquatic plant biomass also eliminates zooplankton refuges.

There are many challenges involved with managing shallow lakes. One important challenge is that a single management technique may be inadequate to produce the desired effect of shifting from turbid to clear water. Another is the impact of legacy pollution in bottom sediments and the overriding effects of internal loading. Confounding factors such as annual and long term climate trends can counteract the intended influence of management activities. For the long term success of shallow lake management projects, the surest route of action is to develop a comprehensive strategy that sets

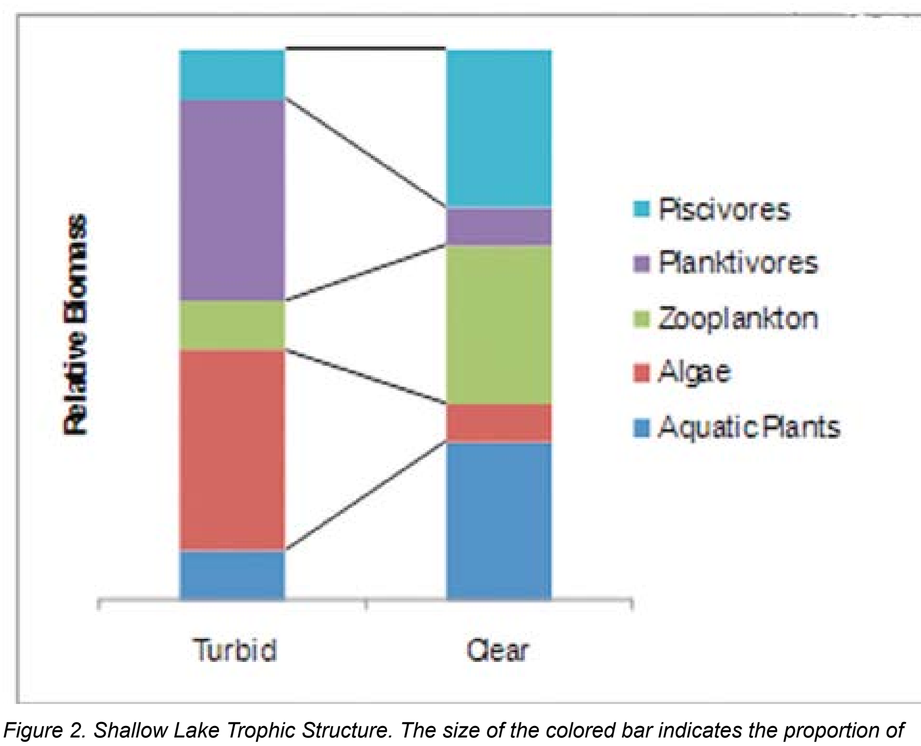


Figure 2. Shallow Lake Trophic Structure. The size of the colored bar indicates the proportion of each class of aquatic organisms present in a clear or turbid shallow lake.

realistic goals, uses numerous management techniques, and incorporates adequate monitoring programs to measure success or failure.

Management techniques for shallow lakes

Shallow lake management focuses on using the trophic cascade model to alter the balance of the aquatic organisms—aquatic plants, algae, zooplantkton, and fish—to achieve the clear water state. Intentionally altering the trophic cascade via management is called a biomanipulation.

The essential component of managing a shallow lake for the clear water state is to promote aquatic plant growth. All of the management techniques mentioned in this article have a potential positive influence on aquatic plants by improving water clarity and/or enhancing the amount of light reaching the lake bottom. Aquatic plants are the basis of the clear water trophic cascade by promoting predatory (piscivorous) fish populations, creating refuges for zooplankton, competing with algae, and limiting sediment resuspension.

Reducing external nutrient loading plays an important role in the long-term conservation of shallow lakes, but used alone is unpredictable as a restoration tool because of the effects of internal loading. Internal loading is the recycling of existing nutrients, like phosphorus, from lake sediments into the water column, which fuels additional plant and animal growth.

Most successful shallow lake management projects combine a number of techniques to produce results, and any management strategy should consider including multiple facets to optimize the chance for success.

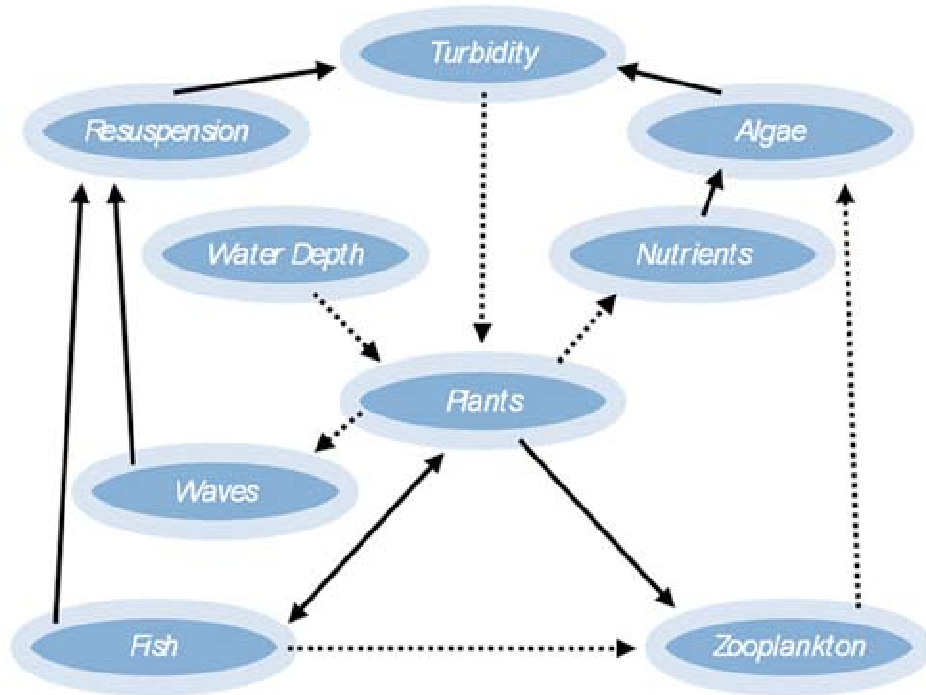


Figure 3 Shallow Lakes Management Model (Single-arrow solid lines = positive influence; Single-arrow dotted lines = negative influence; Double-arrow lines = either) Source: Modified from Scheffer et al. 1993

A general management model for shallow lakes (Figure 3) indicates how ecosystem components interact, and the relative influence of each component. In a general sense, biomanipulation focuses on removing factors that can contribute to the turbid water state and enhancing others that contribute to the clear water state. Ultimately the most important goal is to promote a healthy aquatic plant community.

Research has indicated that it is often difficult to determine the exact cause or mechanism contributing to a shift from clear to turbid water or vice versa, but rather it is a combination of in-lake processes, external watershed inputs, and climate variables resulting in small incremental changes. This issue is compounded because many lakes lack sufficient data to fully analyze scientifically, so the key questions become:

1. What has changed and/or what has stayed the same?
2. Can we find enough information to make any preliminary conclusions?
3. What information do we need to assess which management techniques are feasible for our lake?

Monitoring

The foundation of any management program is monitoring. Monitoring allows for the determination of a project starting point and a measure of success or failure. Monitoring programs will vary from project to project and be specific to the management actions or questions being addressed.

Water Level Management

Water level management is the intentional manipulation of water depth to enhance aquatic plant growth. Many lakes are maintained at artificially high levels to facilitate navigation or other forms of recreation. Lowering the water level will

Figure 4 Seasonal Water Level Management Plan
Source: WDNR 1996

allow light to reach the lake bottom in sufficient amounts to promote aquatic plant growth over a larger area.

There are two types of lake level management. The first is a long-term change in water level where historic high levels are abandoned for a lower water level. This will likely have encourage aquatic plant growth, but the preferred method of water level management is to mimic the natural seasonal fluctuations with relatively high levels in the spring and fall and relatively low levels in the summer and winter (Figure 4).

Sediment Resuspension

Sediment resuspension can be a major problem in shallow lakes. Sediment resuspension is a source of both nutrients and turbidity. The resuspended particles intercept light and limit how deep light can penetrate the water column. This could potentially affect aquatic plant growth. Resuspension also introduces nutrients into the water column. Experiments have shown that sediment resuspension increases phosphorus release rates up to 20-30 times greater than undisturbed sediment.

The causes of sediment resuspension are either physical or biological. Biological resuspension is usually due to carp. Physical resuspension is due to waves which can be generated naturally by wind or via boating activities in shallow areas. Key management options to reduce the impacts of waves are “slow no wake” zones in areas with a silty or marl bottom less than 6-8 feet deep, establishing breakwater areas to reduce the overall fetch length, and naturalizing shorelines to encourage absorption of wave energy.

Nutrient Abatement

Controlling the external nutrient load is not a stand-alone tool, but managing nutrient sources in the watershed is the key to long-term improvements in water clarity and water quality in shallow lakes. The first step in developing a nutrient abatement strategy is to develop water and nutrient budgets. Nutrient budgets quantify the amounts of nutrients entering a lake from different sources.
They identify problem areas in the surrounding watershed and enable managers to target efforts. In some cases nutrient budgets may identify internal loading as the dominant nutrient source (up to 80% in some shallow lakes) and eliminate nutrient abatement as a feasible management option.

Fishery Management

Fishery management is the addition or removal of desirable or undesirable individuals or altering habitat in such a way as to benefit particular species.

One of the most common fishery management tools is stocking. Stocking is a vital component of many shallow lake management projects. Predatory fish are often stocked to increase predation of panfish fish and carp. In both cases water clarity improvement is often the result.

Removing carp is another common fishery management tool. The two most effective means of removing carp are chemical treatments and commercial harvesting. Carp removal results in less bottom disturbance, less internal loading, and may provide better spawning opportunities for other fish species.

Wisconsin Lakes Partnership

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