What Causes Fish Kills?
Part I

by
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As aquatic consultants, we often receive phone calls as a result of fish kills. In most cases, the reporter believes the fish have been poisoned intentionally as an act of vandalism or inadvertently as a result of a pesticide or chemical application. Our experience has shown that such inconsiderate or accidental events are extremely rare and a much simpler explanation can be found for most fish kills.

Periodically environmental conditions occur which result in sudden mortality in the fish population. A rapid loss of oxygen or sudden increase in ammonia concentration in the lake is usually the culprit. This article describes how loss of oxygen resulting in fish kills can occur. The role of ammonia will be discussed in the next issue of the publication.

Oxygen is absorbed by lake water at the water-atmosphere interface. It is also produced during daylight hours by algae during the process of photosynthesis, a light dependent process. Oxygen dissolves in the water; the colder the water, the more dissolved oxygen it can hold. Fish and other aquatic animals use the dissolved oxygen to respire (breathe). Oxygen is consumed by aquatic animals and bacteria by their normal respiration process and by the microbial community as it decomposes organic matter. The organic matter is composed of dying algae and aquatic weeds, waste products, and other animal and plant products that wash into the lake via irrigation or stormwater runoff. Animals and bacteria consume oxygen during the day and night. When atmospheric absorption and photosynthesis cannot provide sufficient dissolved oxygen to match bacterial respiration demand (called the compensation point), a sudden decrease in oxygen can occur. This commonly occurs at night when there is no photosynthesis (remember the process requires light) and bacterial demand for oxygen remains about the same. When oxygen levels decrease to 3 mg/L or less, fish will become stressed. The mores sensitive sill die from suffocation. As this occurs, it is common to see fish swim to the surface and actually appear to "gulp" air prior to succumbing to anoxia.

Factors That Promote Fish Kills

The following factors can trigger the onset of a fish kill:

Temperature: During the summer when water holds less oxygen and warm temperatures make bacteria grow faster, oxygen depletion can occur in a matter of hours.

Cloud Cover: Although a much slower process, a few cloudy days can reduce oxygen production by algae to a point where dissolved oxygen concentrations cannot satisfy the demand of bacterial respiration.

Algae Blooms: An over abundance of algae can provide the organic matter (food)

for bacteria. Algae "blooms" usually occur at or near the water surface. The surface algae eventually shade deeper water algae causing them to die and sink to the bottom of the lake. This provides a food source for bacteria. The more food, the more bacterial growth, and the more oxygen consumed by microbial respiration. In some lakes (but usually not in reclaimed water lakes as Ocotillo) an algae bloom can deplete all available nutrients in the water that are required for algae growth. The entire algae population dies, sinks, and becomes food for the bacteria. Not only is oxygen rapidly consumed by the bacteria, but oxygen is not replenished as a result of the lack of algae and minimal photosynthetic activity.

Thermal Stratification: Surface waters are rapidly warmed by solar radiation. Because warm water is less dense than cold water, it usually sits at the surface of the lake. The density difference actually produces a physical barrier to the transport of dissolved materials including dissolved gases as oxygen. Oxygen absorbed from the atmosphere and produced by algae at the lake surface cannot be transferred to deeper waters. The deeper waters eventually lose all oxygen. Although fish can swim up to the oxygenated water, many species are intolerant of the high surface water temperatures characteristic of central Arizona lakes during the summer. There is no escape-the fish can swim to the surface an be subjected to thermal stress or they can stay at the bottom and suffocate from lack of oxygen.

Runoff: During storm events, large amounts of organic matter can be carried into a lake via runoff and serve as a food resource for bacteria. The additional food increases bacterial respiration and oxygen uptake. When coupled with cloud cover during frontal storms characteristic of Arizona winters, rapid loss of oxygen from external organic inputs can occur even in relatively cold waters.

Mitigation

There are a number of ways a lake can be managed and operated to minimize occurrence of fish kills resulting from oxygen depletion.

Algae Control: Limiting nutrient concentrations in the lake will reduce algae density. Although this is a common management practice for many urban lakes, is nearly impossible to do in a reclaimed water lake because the water source provides a constant supply of nutrients that can stimulate algae growth. Chemical and application costs can be considerable.

Stormwater Retention: Re-directing stormwater and irrigation runoff away from the lake minimizes organic inputs that can feed bacteria. It also limits input of additional nutrients originating from fertilized turf and landscaped areas. Because some lakes are designed as stormwater retention basins, street cleaning and careful irrigation and fertilization practices can help reduce nutrient inputs. Even grass clippings should be directed away from the lake because they provide an organic resource for bacteria.

Mechanical Aeration: Creation of water falls, riffles, fountains, and other water features which mechanically mix lake water with the atmosphere can increase dissolved oxygen levels. Where feasible, low-oxygen content, deep water should be pumped over the feature to improve its oxygen concentration. When deep water aeration is practiced during the summer, the system can be operated at night when oxygen stress is most likely.

Thermal De-stratification: Mechanical aeration systems typically consist of small on-shore compressors, diffusers at the bottom of the lake, and associated piping. Mechanical aerators prevent thermal stratification. They add very little oxygen directly to the water; most oxygen uptake takes place at the water-atmosphere interface. A vertical mixing pattern is created by the upwelling bubbles and lifts low-oxygen deep water to the surface where it can absorb oxygen form the atmosphere. The vertical mixing pattern breaks the physical barrier to the exchange of oxygen caused by density differences. Oxygen can then be absorbed at the surface and diffuse throughout the water column. Many systems are operated constantly as a preventative measure. Capital equipment costs and system maintenance and electricity costs associated with these systems are major considerations.