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Swingle,H.S.

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FISH KILLS CAUSED BY PHYTOPLANKTON BLOOMS AND THEIR PREVENTION

by

H.S. SWINGLE
Auburn University
Agricultural Experiment Station
Auburn, Alabama, U.S.A.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, ROME, ITALY
ORGANISATION DES NATIONS UNIES POUR L'ALIMENTATION ET L'AGRICULTURE, ROME, ITALIE
ORGANIZACION DE LAS NACIONES UNIDAS PARA LA AGRICULTURA Y LA ALIMENTACION, ROMA, ITALIA

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by

H. S. Swingle
Auburn University
Agricultural Experiment Station
Auburn, Alabama, U.S.A.

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Abstract

Growths of species of *Microcystis*, *Anabaena*, and occasionally *Trachelomonas* and *Gyrnodinium* that form dense concentrations or scums in surface waters have been a primary cause of fish kills in ponds. Dense concentrations of these algae absorbed heat from sunlight, causing a sharp rise in temperature of surface waters. This in turn caused shallow stratification and light winds stirred only the top waters. The heavy concentrations of algae absorbed and reflected sunlight and consequently insufficient light for photosynthesis penetrated to depths below 1m. Continuation of these conditions for approximately one week had the result that insufficient dissolved oxygen was present in waters below 1m to support fish life. Subsequent upwelling of deeper oxygen-deficient waters caused distress or death of fish from lack of oxygen. Upwellings were caused by cold air masses, heavy winds or cold rains.

Microcystis was the most common cause of such kills. Partial eradication of this alga with copper sulphate allowed deeper light penetration, deeper stratification and distribution of oxygen to greater depths, thus removing danger of a fish kill.

While fish were in distress following upwelling, circulation and aeration of top waters with pumps or by stirring with boat and outboard motor prevented fish kills.

The majority of ponds in Alabama impound stream waters or run-off waters by earthen dams constructed from hill to hill across a watershed. Maximum depths usually exceed 2 meters, with shallow water areas deepened to at least 0.6 meter. The average depth is between 1.5 and 1.8 meters.

1 DESCRIPTION OF FISH KILL

For many years, fish kills occurred occasionally in these ponds, the causes of which were unknown. Approximately 50 to 100 kills occurred each year in a total of 15,000 ponds. Some ponds had fish kills almost annually, whereas others 5 to 50 years old may have had one kill or none at all. Kills occurred in unfertilized as well as fertilized ponds, and in those receiving supplemental feeds. The kill occasionally affected only a particular species or only a particular size of fish. Sometimes all fish were killed, but more often only a part of the population died. Usually, by the time a biologist visited the pond a day or so after the kill, he found that no more fish were dying. Seining usually disclosed that remaining fish were in good condition and water analyses often indicated no reason why the fish died.

In many cases the water had a brown color with most of the phytoplankton dead and there was no soluble phosphate in the top layer. The kills were obviously caused by lack of oxygen. It was postulated that the cause of plankton death was lack of phosphate, and for a number of years super-phosphate was added to surface water when fish were found in distress. This seemed to stimulate photosynthesis by the living plankton, with gradual increase in oxygen content. In many ponds, phosphate was kept on floats so that some would always be present in the surface water. Later information indicated that this did not prevent fish kills.

2 CAUSES OF FISH KILLS

Research during a period of years has shed much light on the sequence of events leading to this type of fish kill. The immediate cause of kills was the complete absence or low level of dissolved oxygen (DO), often accompanied by high concentrations of free carbon dioxide.

2.1 Type of phytoplankton growth

The sequence of events leading to a kill is as follows: A type of phytoplankton becomes dominant which, under certain conditions, rises to the surface as scum or a dense concentration in the top 0.6 m* of water. Scum-forming algae usually have vacuoles filled with oil or a gas, which expands in warm water, lifting the algae to the surface waters. Blue-green algae, such as Microcystis and Anabaena belong in this scum-forming group; the former appears associated with the majority of fish kills. However, algae of the genera Trachelomonas and Gymnodinium have also been observed to be responsible for two kills.

2.2 Stratification and oxygen distribution

Once the algae have risen in dense numbers to or near the surface, they rapidly absorb heat from the sun, causing a sharp rise in temperature of the surface water (Beasley, 1963). A stratification then develops in which light winds stir only the hot surface water, thus preventing dis-

*1 meter (m) = 3.3 feet.

tribution of oxygen from upper to lower layers. At the same time, dense plankton in the upper layers absorb and reflect the sunlight so that inadequate light for photosynthesis penetrates to depths greater than 0.3 to 1.2 meters. Beasley (1963) found that oxygen was less than 1 ppm at depths where light had declined to 1 percent of incident radiation.

When this shallow stratification continued for several days or weeks as a result of hot sun and light winds, a condition developed where the surface 0.3 to 1.2 meters contained adequate oxygen for fish and the surface water was occasionally supersaturated with oxygen; however, inadequate or no oxygen was present at greater depths. This was a gradual development and in itself seldom caused distress since the fish moved into the upper waters where oxygen was adequate.

2.3 Upwelling and its causes

The trouble came with overturns, or upwelling of the oxygenless waters to the surface. This sometimes occurred over the entire pond causing complete kill, or only in local areas killing whatever sizes and species that were trapped by the upwelling. At times, no fish were killed, but most were in distress at the surface because of inadequate oxygen following mixing of top and bottom waters.

There were various causes of upwelling. A sharp drop in air temperature caused colder surface water to drop toward the bottom and the oxygenless waters to rise to the surface. This is most likely to occur in late summer or early fall when the first cold air masses move southward.

Upwelling has often been caused by heavy winds that blow the surface waters towards the opposite bank, pulling deeper oxygen-deficient waters to the surface on the side from which the winds came. This cause of upwelling could be detected by chemical analyses for 6 to 12 hours following the event. Analyses on the leeward side of the pond showed no, or abnormally low oxygen in surface water. Analyses on the windward side showed abnormally high oxygen in deeper waters because of the oxygen-laden surface water being blown to that side and a reverse underwater current carrying it into deep waters.

Another cause of overturns was heavy cold rains falling on the pond surface and forcing deeper waters to the surface. When heavy cold rains fell on the watershed, cold stream water entered ponds, flowed along the pond bottom, and caused upwelling of oxygen-deficient bottom waters.

3 PREVENTION OF FISH KILL

3.1 When fish were in distress

When fish were found in distress because of upwelling waters, fish kills could usually be prevented by pumping water from 0.5 to 0.7 meter depths and throwing it with force at an acute angle against the pond surface. This caused a current of oxygenated water to move toward the far bank and an underwater circulation back to the pump, thus allowing oxygen-containing water to break up stratification and gradually bring oxygen to larger and larger areas. A pump delivering 19,000 liters of water per hour was sufficient for a 1-hectare* pond. A pump delivering 114,000 liters per hour was effective in preventing kills over approximately 4 hectares.

A boat equipped with a 10 hp outboard motor, twisting and turning at high speed, required 4 hours to bring D.O. from 0.3 to 2 ppm to a depth of 1.5 meters in a 0.4-hectare pond.

3.2 Addition of phosphate to surface water

Often a pond had a series of overturns a few days apart before fish were found in distress. It was apparently prior overturns forcing the living plankton into oxygenless, lightless areas that had caused the

*1 hectare = 2.5 acres.

"death" of plankton observed in some ponds. In such cases, often no soluble phosphate was found in surface waters following the overturn; phosphate was absorbed and/or precipitated on iron salts as these were oxidized to ferric salts by the oxygenated, downward moving surface water. At such times, addition of 10 to 20 Kg super-phosphate per hectare broadcast over the surface water often appeared to stimulate photosynthesis and release of oxygen. When this was done during mid-morning hours with strong sunshine, many times sufficient oxygen was released to prevent a fish kill.

3.3 Control of phytoplankton scums

Since a primary cause of fish kills was surface scums, or excessive concentrations of *Microcystis* in surface water, it appeared better to kill part of the algal bloom so that light could penetrate to greater depths. When *Microcystis* became abundant, oxygen analyses were made daily. As long as oxygen was found below 1.3 meter there appeared no danger to the fish. However, when no oxygen could be found below 1 meter, the pond was in danger of a kill if conditions causing overturns developed. Killing part of the *Microcystis* with copper sulphate in 1 or 2 applications a week apart usually did result in deeper light penetration and distribution of DO down to 2 m or more. It was found very important to kill only part of the *Microcystis* at any one time. When enough copper sulphate was used to kill all of it, rapid decomposition removed the remaining DO and caused total fish kill.

The amount of copper sulphate recommended by Crance (1963) and Lawrence (1966) for use in waters with 25 ppm hardness, expressed as $CaCO_3$, was 800 g per hectare* surface area. Copper sulphate is placed in cloth bags and tied about 10 cm** under the water surface to a stake

*Equivalent to 0.75 pound copper sulfate per surface acre.

**Approximately 4 inches.

driven in the pond bottom. Copper sulphate gradually dissolves and water currents distribute it to various areas of the pond. One bag per 1 to 2 hectares is sufficient. Several treatments at 1-week intervals may be necessary.

This method for controlling phytoplankton adds to the total BOD in the waters, and the nutrients may later be recycled to cause heavy scums. Biological control, using plankton-feeding fishes would appear promising and should be investigated.

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