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MARINE ADVISORY

SEA GRANT COLLEGE PROGRAM — TEXAS A&M UNIVERSITY

Airing Out the Problem

Methods of Reducing Water Quality Impacts and Fish Kills in Coastal Marinas

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Fish kills are occasional occurrences in marinas and other nearshore environments. The kills are usually quite sudden, so may seem fairly mysterious, but the actual causes are not difficult to understand. Fish kills occur because of degraded water quality, which may result from poorly designed marinas, from pollution in the immediate area or upstream from the marinas, or from some combination of these.

The Clear Lake/Galveston Bay area has the highest concentration of recreational boats in Texas with more than 30 coastal marinas and more than 8,200 wet slips (Hollin, 1997). Nearly 6,400 wet slips are located in 20 marina projects in Clear Lake alone, which represents 50 percent of the total marina wet slips in coastal Texas, and nearly 16 percent of the state total. This large concentration of boats in the Clear Lake area, the poor natural flushing action of some marina basins, plus other environmental problems associated with runoff and low water quality have resulted in several local fish kills in recent years.

During the spring and summer of 1997, the Texas Sea Grant College Program conducted a demonstration project at local Clear Lake marinas on ways to improve water circulation and provide better aeration techniques to help reduce the potential for fish kills in the area.

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What causes fish kills in marinas?

Diminished oxygen levels combined with increased amounts of fertilizer lead to eutrophication. Phytoplankton, or microscopic algae, use sunlight and fertilizer to produce oxygen during the day, but then consume oxygen along with animals, other plants and bacteria at night. When this occurs, excessive algal blooms can result in nighttime oxygen levels that are too low for animals to survive and this, in turn, results in "fish kills."

The fertilizers that result in eutrophication are the same as those used to grow food. Nitrogen and phosphorus are the two most important nutrients involved in eutrophication, and these are also two of the most important nutrients in man-made chemical fertilizers. The most common source for elevated concentrations of these nutrients in marinas is from contaminated runoff from adjacent fertilized grounds, or from similar sources upstream. Excess fertilizer from lawns and fields runs off and contaminates the receiving water body. Over-fertilization by these nutrients lead to a phytoplankton population that the available oxygen cannot support.

Sewage is another important contaminant that contributes to fish kills. Just as sewage makes an excellent compost for growing plants, it is an equally rich source of organic material for supporting the aquatic bacterial populations that consume oxygen in water. As with nutrients, there is usually a background level of carbon that supports a "normal" microbial population, but a large influx results in overpopulation that depletes oxygen. Sewage is also a rich source of "fertilizer" nutrients, particularly phosphorous. While fertilizers and organic contaminants are important contributors to oxygen depletion in marinas, other things such as water temperature, depth, salinity, turbidity, circulation and aeration interact to make it very difficult to predict precisely when a fish kill will occur.

Aeration and water circulation are important factors in avoiding marina fish kills. Aeration involves the mechanical addition of air (oxygen) to the water, while circulation redistributes oxygen and temperature already present in the water. Aeration and circulation have been shown to stimulate breakdown of organic material in sediments, reduce nutrients in the water column, increase dominance of beneficial algae over blue-green algae, increase fish habitat and population, reduce toxic gases in the sediments, increase benthic dissolved oxygen and

temperature, and disperse phytoplankton. The overall result is improved water quality.

Oxygen in any body of water has a tendency to stratify in layers unless it is mixed in some manner. The oxygen transfers to the water at the surface. The layer of water with the highest level of oxygen is at the surface and the layer with the lowest oxygen level is generally closest to the bottom. The bottom sediment and animals living in that sediment also use oxygen. Wind normally plays a key role in mixing oxygenated water from the surface with the lower layers of water through wave action, and acts to mix the layers and increase the oxygen level. Orientation of marina canals and basins along the mean axis of prevailing summer winds should help reduce the amount of stratification and aid in the mixing of the various layers of water.

Oxygen levels in the water also vary from day to night due to algae growth and amounts present in the water body. Algae (microscopic plants) produce oxygen as a result of photosynthesis during the day, but become net consumers of oxygen during the night. Therefore, the lowest oxygen levels in the water column occur just before daylight. Temperature also plays an important role in oxygen transfer; generally oxygen transfers better into the water at cooler temperatures. Higher salinity levels also allow less oxygen to be transferred. Another factor that contributes to the process is the availability of nitrogen (a source of food for algae), which is affected by trace metals in the environment that influence the chemical reactions that take place.

How can the problem be eliminated?

Eutrophication can be caused by water quality problems in areas immediately adjacent to a marina or from areas further upstream that are outside the control of the marina operator. This publication provides guidance for those areas within the marina operator's control, but he or she should be aware of potential sources of contamination in the extended area to be able to discuss the issue intelligently and to explain the potential negative impacts to marinas.

Eutrophication can be controlled either by treating symptoms or treating causes. The most important symptomatic treatment is to provide oxygen into the water column, usually through increased water circulation and aeration. The Sea Grant demonstration project primarily used aerators as a fish kill preventive measure, rather than as a long-term solution to the oxygen depletion problem faced by marina operators. Proper circulation/aeration is a critical design feature and can actually overcome many of the other causative factors.

In the right conditions in poorly circulating water, an "algal" bloom can deplete all of the oxygen in a matter of hours, while a system with good circulation may be able to maintain oxygen levels above critical thresholds. Since the two principal sources of dissolved oxygen are diffusion from the air/water interface and photosynthesis, it is important to monitor dissolved oxygen (DO) levels at different times—late afternoon and early morning—to see if wide fluctuations occur. High levels in the afternoon and low levels in the morning may indicate high use of DO to support organisms in the water body.

During hot summer months with little or no wind action to mix the layers of water, it may be necessary to assist this process by providing a source of water circulation to promote a more natural oxygen transfer. Researchers at Auburn University found the air injection system and the paddlewheel aerators to be the most efficient and effective ways to circulate water. These two methods have also proven most efficient at water circulation and aeration in high-density fish culture ponds. This same technology can be applied successfully to marina water circulation/aeration to prevent fish kills and eliminate associated cleanup expenses.

Recent studies in the Galveston/Clear Lake area have determined that poor flushing of marinas and subsequent water circulation problems contribute significantly to critically low dissolved oxygen levels, leading to fish kills in area marinas and canal subdivisions. Closed-end and dead-end channels and the inner sections of marina basins are affected most often. Canal or marina basin depth is an important factor in the level of flushing activity. Proper design of a new marina or redesigning or reconfigur-ing an existing marina could help improve water circulation. While this can be an expensive solution, it may be possible to install a circulating canal and/or culverts to improve circulation for much less money.

A long-term solution to the eutrophication problem requires treating the causes. The marina operator should first take action to ensure water quality is not being negatively impacted from areas within his or her control. Steps must be taken to reduce the sources of contamination, including reducing sewage and/or nutrients in the water body. Measures to be taken may be as simple as providing more sewage pump-out stations. Operators should ensure that adjacent grounds are not overfertilized. Unfertilized buffer strips may be needed to absorb excess nitrogen in the runoff.

An important step toward eliminating the problem is to understand your system. If it is nutrient rich, it may be

very near critical thresholds where small additional inputs of nutrients in the summer put the system over the top with resulting population explosions. The most critical parameters to measure are biological oxygen demand (BOD), a measure of how much oxygen is needed by organisms to consume carbon compounds in the water, including sewage, and nutrients, mainly nitrogen and phosphorus. Dissolved oxygen (DO) is also an important parameter to measure, and may alert the marina operator to possible fish kills when DO begins to fall below 4 mg/l. Fish may also come to the surface when the DO is low. Under the right conditions, DO can be depleted below critical levels in a matter of hours, so monitoring DO alone may not give sufficient advance notice.

An important difference between freshwater and saltwater systems is the "limiting" nutrient that acts as a control on eutrophication. Nitrogen is usually the most limiting nutrient in saltwater systems, while phosphorous is the limiting nutrient in freshwater. The limiting nutrient is the one that has the greatest effect when it is supplied to the system.

It is difficult to determine the level at which any one factor will result in sufficient oxygen depletion for a fish kill because all of the factors interact. The marina operator needs to reduce all the factors as much as possible to lower the overall threshold at which oxygen depletion occurs.

What has been done to address the problem?

While water quality impacts from marinas along the Texas coastline have been studied recently it has been well documented in other areas of the country that marinas and associated boats are a major source of pollutants, including heavy metals, fecal coliforms and nutrients. Poorly designed marina basins can also reduce flushing action and water circulation, which can allow contaminants and pollutants to become concentrated during times of minimal water circulation.

While the Clear Lake/Galveston Bay area has a large concentration of recreational vessels (more than 8,200 wet slips in 1997), until recently there were only a few sewage pumpout facilities, resulting in much of the sewage waste being discharged directly into Galveston Bay or Clear Lake. While surveys conducted in the area failed to document extensive fecal contamination at Clear Lake marinas, the increased availability of pumpout facilities should help reduce the potential for illegal dumping of boat sewage. It is advisable that the marina industry continue to increase the availability and use of pumpout stations. Future efforts by state and county regulatory agencies to designate various marine water body segments as no discharge zones, such as has been done with Clear Lake, should further protect the water quality near marinas

New marina sites should be located near areas with sufficient currents to provide adequate mixing and aeration of the water column. Marina entrances should be as wide as possible, and multiple entrances, preferably at opposite ends of the marina, should enhance water circulation. In existing marinas, the use of water circulation devices and aerators during summer months may be desirable if oxygen deficiency is a problem. Water depths should be restricted to reduce the potential of stratification and to increase flushing. Raised bulkheads and/or open breakwaters should be used where possible to reduce stagnant water conditions and promote flushing of marinas. New and existing marinas should employ best stormwater management practices to minimize runoff from boat yards and maintenance facilities.

Clear Lake demonstration project — aeration of marina basins

Four Clear Lake marinas that had experienced recent fish kills agreed to participate in a demonstration project to test various types of aeration equipment and aeration methods. The Texas Sea Grant College Program sponsored the marina aeration project during Summer 1997 in cooperation with Lafayette Landing Marina, Marina Del Sol, Seabrook Shipyard and Watergate Yachting Center. Sea Grant provided funds for aeration equipment, oxygen meters and installation costs, while the marinas provided space for the equipment and personnel to monitor the equipment during the project.

To implement the demonstration project, marina personnel were briefed on why and how fish kills occur. In past years, marina personnel detected a potential fish kill only when they saw fish gulping for air at the water's surface and noticed an increased "fishy/oily" smell around the marina basin. Sometimes marina personnel would ask boat owners to turn on their

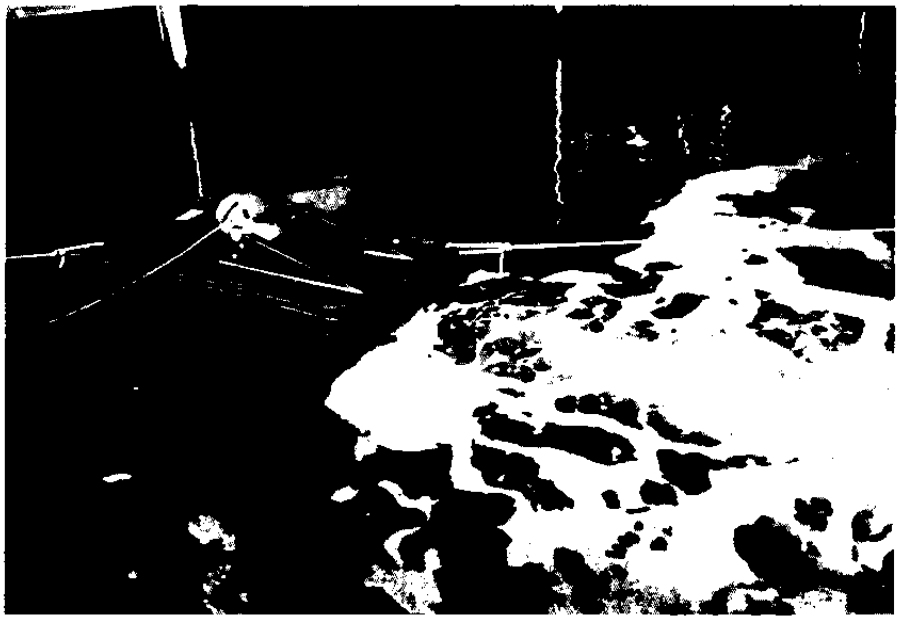
engines while boats were in their slip in an effort to help oxygenate the water and prevent a fish kill.

In lieu of checking for fish at the water's surface and the smell, marina personnel were trained to use DO meters to monitor when oxygen levels were low or depleted in marina basins. A salinity standard of 10 parts per thousand was established on the DO meters since marinas did not have access to refractometers to measure salinity.

The use of the DO meter was a obstacle for some marina personnel at first because they felt uncomfortable using something they perceived as very complicated and "hi-tech." Several training sessions were needed to familiarize everyone with the DO meters. Marina personnel ultimately became very adept at measuring DO levels using the meters. Seabrook Shipyard purchased its own DO meter for future use. Readings were taken several times per week at various times and locations by marina personnel.

Two different types of floating surface aerators were selected for testing and installed at the marinas during the project. A 1/2-horsepower floating surface aerator with a V pattern display funnel (available through Kasco Marine, Inc.) was selected for two sites. This unit was low priced and produced a small fountain-like display that marina owners found attractive and that was popular with marina patrons (see photo). The fountain-like display proved so popular, in fact, that marina operators sometimes ran the aerator during the day when the aeration was unnecessary.

These particular units, available from aquaculture equipment dealers for between $400 and $500, have a circular floatation and center-mounted motor with a 50-foot power cord. They are easily installed into one unit, lightweight and can be moved easily from site to site by the lines attached to the floatation unit.



The second surface aerator was an Aeration Industries International, Inc., AIRE-02 air injection unit featuring a 2-horsepower propeller aspirator pump that injects air through a hollow shaft and forces atmospheric air as bubbles below the water's surface (see photo). This unit injected more air into the water column and created more diffusion of air in the water with more efficient transfer of oxygen. The unit is larger than the Kasco units and more expensive (about $1,200). This unit was set up at the Watergate Yachting Center and produced excellent aeration for the marina's basin.

Results

Marina personnel used the aerators during the entire summer whenever DO levels were dropping or they saw fish on the water's surface. No fish kills were reported during this time. Many marina operators reported conditions conducive to fish kills, but the aerators seemed to alleviate the condition when they were turned on and no fish kills resulted. Fishing also improved in the marina basin during the aeration, probably as more and larger fish were attracted to the area by smaller fish.

Benefits

The aerators provided marina operators with a simple solution to an often smelly and expensive problem. One marina harbormaster said he believed the aeration device prevented a fish kill in his marina and he was hopeful a permanent system would be installed after the project ended. Participating marina operators also stressed the public relations benefit, citing favorable comments both from the general public and from boaters using the marina facilities.

The use of aerators in marinas gives marinas an "insurance policy" and an effective tool to deal with low DO levels in these circulation-restricted areas in their basins. It is not the final solution to the water quality problem, but it is an excellent preventive measure for fish kills and maintenance of better water quality.

The initial cost of aerators is minimal, particularly when compared to the cost of cleaning up a basin. Fish kills vary greatly in size, so there is no typical cost for clean up.

Fish kills in marinas frequently stem from poor flushing action. Often the clean up is assisted by providing artificial flushing action by using high-pressure water hoses to "flush" dead fish from the marina basin into stronger currents in a nearby channel. This type of clean up is both inexpensive and efficient with the dead fish being "flushed" by water pressure into the main channel.

Larger fish kills, however, are not so easily, or inexpensively, remedied, particularly if vacuum trucks are needed. Costs of two 1996 Clear Lake fish kill cleanups using vacuum trucks vary from about $3,000 at Lafayette Landing to about $28,000 at Seabrook Shipyard. If a $500 to $1,200 aerator can prevent these kills, there is a major cost savings to the marina operator and better water quality in the marina basin.

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