Summary of Findings and Conclusions
Summer 2000 Fish Kills – Inland Bays

August 15, 2000

Introduction

Delaware has been experiencing an unusually large number of fish kills in the Inland Bays and its tributaries this summer, more than in any summer previously recorded since the Department's official monitoring and investigation of fish kills began in 1980. The Inland Bays are an invaluable natural resource to Delawareans and the fish kills have engendered a plethora of regional and local media publicity, and public concern.

The water quality of the Inland Bays is a particularly instructive example of the environmental impacts of land use activities on the state's waterways. A number of water resource issues have arisen in the Inland Bays Basin over the past several years, from how to address habitat loss, to concerns about toxic outbreaks of *Pfiesteria.*

The Inland Bays are suffering from excessive nutrients (eutrophication) that contribute to unwanted algal blooms, including *Pfiesteria,* red and brown tides and other phytoplankton. Nutrients, especially nitrogen and phosphorous, act as fertilizer for algae and other aquatic plants and can lead to an excess of these plants through large blooms. The algal blooms block sunlight from reaching the bottom of the bays and cause the level of dissolved oxygen to decrease. Algae produce oxygen by photosynthesis during the day and utilize oxygen by respiration and decomposition in the absence of photosynthesis during the night. The level of dissolved oxygen can steadily decrease during the night and fall to a low, just before daybreak. Depending upon the aquatic requirements in a particular water body, the dissolved oxygen can decline to a level that results in a fish kill.

This year's fish kills, overall, have been associated with low or probable low dissolved oxygen, an abundance of menhaden, water bodies with elevated levels of excess nutrients, poor water circulation and seasonal inclement and cloudy weather. One fish kill on Pepper Creek affected menhaden with a five percent lesion manifestation that prompted the state's Pfiesteria Emergency Response Management Team to issue an advisory to the public. Menhaden with lesions sampled and examined from the area near the fish kill have been found to be infected with *Kudoa,* a parasite which is presently the focus of new research on fish with lesions in addition to ongoing *Pfiesteria* research. Tests at two laboratories have confirmed the presence of *Pfiesteria piscicida*, a potentially toxic microbe, in the water sampled at a fish kill site. *Pfiesteria piscicida* has also recently been confirmed in water sampled during a routine *Pfiesteria* monitoring at two sites not associated with a fish kill.

This report will briefly discuss the water quality of the Inland Bays, the prevailing water and weather conditions at several fish kill sites, the characteristics of the fish affected, results of laboratory tests, and the interrelationships among the factors attendant to this year's fish kills.

Fish Kills – Inland Bays

Summer 2000 through August 15

Date	*Location*	*Number*	*Species*	*% Lesions*
7/6/00	Bald Eagle Creek/ Torquay Canal	1,000,000	Atlantic menhaden	0
		12	Blue crab	Unknown
7/10/00	Pepper Creek	62,500	Atlantic menhaden	4.7*
7/19/00	Arnell Creek	200,000	Atlantic menhaden	0
7/22/00	Arnell Creek	250,000	Atlantic menhaden	0
7/23/00	Pepper Creek	Unknown**	Atlantic menhaden	Unknown**
7/26/00	Love Creek	1,500	Atlantic menhaden	0
		1	Weakfish	0
7/27/00	Pepper Creek/ Indian River Acres	2,500,000	Atlantic menhaden	0
8/13/00	Bald Eagle Creek	Unknown	Atlantic menhaden	0

*An additional 17.8 percent had some external physical abnormality such as a reddened area on skin
**No dead fish were in evidence when the kill was investigated

Dissolved Oxygen

DNREC monitors dissolved oxygen at many locations throughout the Inland Bays. Samples are taken at various times of day, including dawn when dissolved oxygen levels can be extremely low during summer months. In addition to crews taking samples, special monitors have been placed at different locations to collect data on a continuous basis.

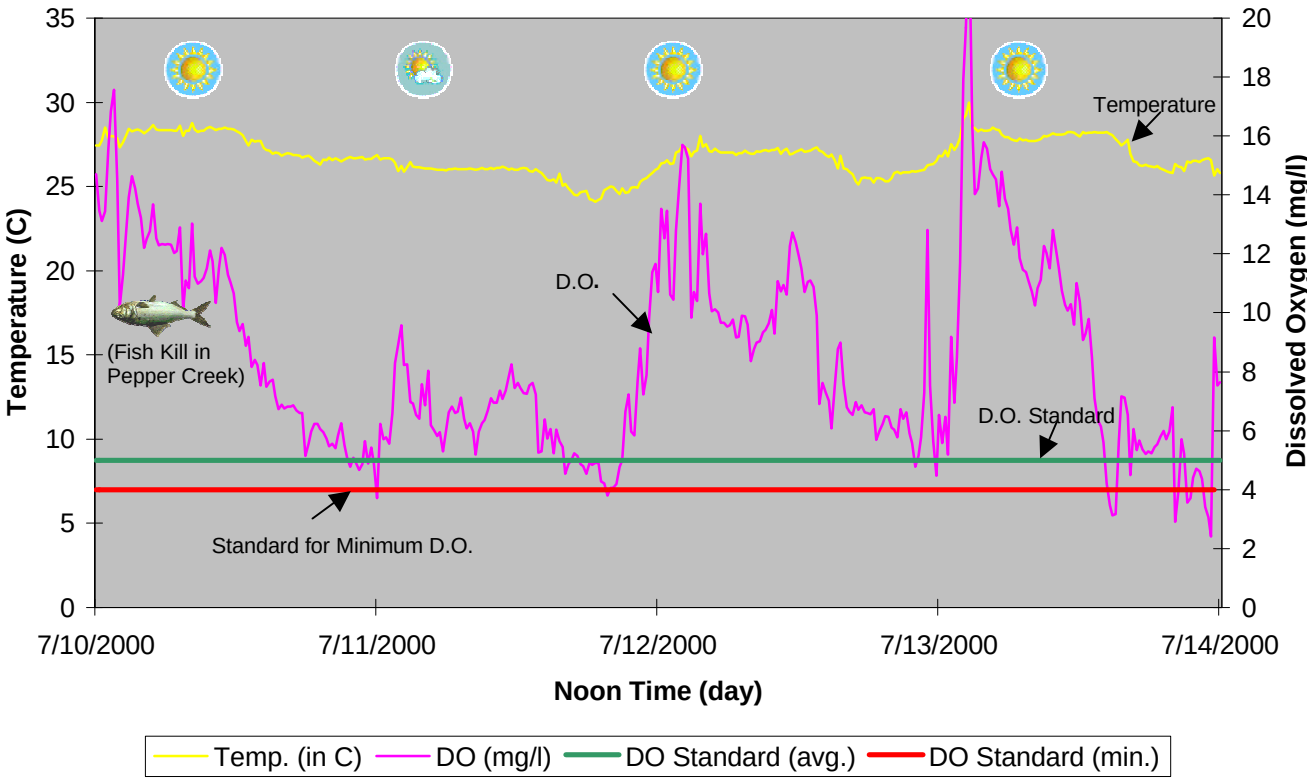
- Dissolved oxygen levels have been low enough in upper Pepper Creek to cause a fish kill, and a large kill has occurred in this water body.

- Dissolved oxygen levels have not reached levels low enough to kill fish in Indian River along the section from Possum Point to Buoy 32 and, to date, no kills have been reported from that water body.

- The general pattern of daily dissolved oxygen variations indicates that the classical photosynthesis/respiration phenomenon caused by algal blooms is responsible for the wide variations of dissolved oxygen levels.

- Weather conditions can have a significant impact on dissolved oxygen concentrations in a nutrient enriched system. Several cloudy or rainy days may push dissolved oxygen concentrations to critically low levels.

Figure 2. Temperature (degrees Celsius) and D.O. (mg/l) in Pepper Creek (Daymark 7) During the Week of July 10, 2000



Nutrients

High concentrations of nutrients (nitrogen and phosphorus) are characteristic of many water bodies in the Inland Bays watershed. Nutrient sources include: natural contributions, those transported by run-off from residential, agricultural and industrial areas; septic systems; wastewater treatment discharges; and air deposition of pollutants into the water.

- Pepper Creek and Indian River have total nitrogen concentrations that routinely exceed the Inland Bays Total Maximum Daily Load (TMDL) goal of 1.0 milligrams per liter (mg/L). In Pepper Creek, 79 percent of the 39 samples exceeded the goal; in Indian River 85 percent of the 39 samples exceeded the goal.

- Pepper Creek and Indian River have total phosphorus concentrations that routinely exceed the Inland Bays TMDL goal of 0.1 mg/L. In Pepper Creek, 78 percent of the 37 samples exceeded the goal while in Indian River, 75 percent of the 36 samples exceeded the goal.

- Sampling at upper Arnell Creek on the day of the July 19 fish kill, found the total nitrogen in water sampled to be 5.28 mg/L. This level is extremely high for a total nitrogen measurement in the tidal area of the Inland Bays.

Chlorophyll-a

Phytoplankton contain chlorophyll which is used by plants for photosynthesis. Blooms of algae and other phytoplankton , often generated by excess nutrients in the water, can create water quality problems. Monitoring of Chlorophyll-a levels is one measure used to assess total phytoplankton density.

- Both Indian River and Pepper Creek have chlorophyll-a concentrations that range from two to 10 times the TMDL goal of 20 micrograms per liter (ug/L), and are regarded as highly eutrophic (overenriched with nutrients) with the degree of eutrophy increasing with distance upstream. In Pepper Creek, 84 percent of the 25 samples exceeded the TMDL goal while in Indian River, 67 percent of the 30 samples exceeded the TMDL goal.

Atlantic Menhaden

The Atlantic menhaden is found in coastal and estuarine waters along the East Coast from Nova Scotia to Florida. A small fish used primarily for industrial rendering purposes to extract fish oil and make fish meal and to a lesser extent for bait, it is also important prey for other fish and sea birds. In Delaware the chief use of menhaden is crab bait. The juvenile population of Atlantic menhaden hatched in 1999 is the second largest on record using preliminary data since 1955. The size range observed in six of the seven Inland Bay

fish kills were juvenile Atlantic menhaden from the 1999 year class. In addition, menhaden:

- swim in large schools close to the water's surface during the spring and summer and enter estuarine waters like the Inland Bays to feed on plankton;

- return to the ocean to spawn from March to May and again in September and October; and

- can be lured into areas with dense phytoplankton and/or can be chased by larger fish and become entrapped in waters with high dissolved oxygen requirements and suffocate due to their numbers and needs.

Pfiesteria Monitoring

DNREC has been conducting Pfiesteria monitoring during the summer months since 1998. In addition to collecting information on water quality from various locations in the Inland Bays, the effort has also focused on areas where large algal blooms and/or fish kills have occurred. Using several independent labs, the program has determined:

- *Pfiesteria* was found in only one location where a fish kill occurred this summer – July 19 in Arnell Creek, north Rehoboth Bay.

- *Pfiesteria* was found in a routine surveillance sample from Miller Creek, Little Assawoman Bay, July 5, and in Love Creek, June 28. No dead fish or fish with lesions were found.

- *Pfiesteria* (shumwayae), which can also emit toxins, was found in Indian River.

- Menhaden collected from the Inland Bays with lesions have been analyzed and determined to be carrying the parasite, *Kudoa*. However, scientists are still trying to determine the cause of the lesions and the potential relationship between *Kudoa*, *Pfiesteria,* fungus and bacteria that may also contribute to the formation of lesions.

Conclusions

Although the media, members of the public and government officials are seeking a primary, definitive answer to the unusually large number of fish kills in the Inland Bays this summer to date, the answer is not likely to be singular, but a combination of conditions that coalesce at the right moment to cause a fish kill.

Under typical conditions, photosynthesis, wind and wave action provide enough dissolved oxygen to support the respiration of all aquatic life. However, these typical conditions can be easily upset by one or a combination of events:

Nutrient enrichment can produce extremely dense phytoplankton as well as the production of unwelcome algae. The dense plant life can produce so much oxygen on a sunny day that the water becomes supersaturated to the point where it will actually diffuse out of the water. At night, the respiration of the phytoplankton, along with the fish, can cause dissolved oxygen levels to drop to very low levels, occasionally low enough to trigger a fish kill. During wet years, more nutrients run into the water. Often the water will have an intense green or mahogany color during dense blooms. These conditions have been seen in Pepper and Love Creeks with associated low morning dissolved oxygen.

Extended periods of warm, overcast days, with or without thunderstorms, can lessen the photosynthesis occurring in the water and consequently, lessen the amount of available dissolved oxygen. Although little oxygen is being produced, consumption by all aquatic life remains unchanged and the dissolved oxygen level can drop and remain low for days, long enough to cause serious problems. Thunderstorms seem to exacerbate the situation as the air pressure drops associated with the storms allow more dissolved oxygen to diffuse out of the water. These conditions can also lead to die-offs of the phytoplankton blooms, which also worsen the problem as no photosynthesis is occurring while the oxygen demand remains high. The organisms feeding on the dead phytoplankton increase in number and increase oxygen demand. These overcast conditions appear to be integral to the majority of menhaden fish kills in the Inland Bays this summer.

When Atlantic menhaden have a good reproductive year, they travel in large schools. Fall 1999 was a good year for Atlantic menhaden spawning. They feed on phytoplankton, so they will often travel up into small creeks with phytoplankton blooms. Once in the smaller creeks, the big influx of heavily respiring menhaden may help deplete the dissolved oxygen to a level such that they suffocate.

Although we can determine whether *Pfiesteria* was present at a fish kill site, we cannot always be certain whether low dissolved oxygen or *Pfiesteria* killed the fish. Unless the biotoxin released by *Pfiesteria* can be identified in water samples collected during a fish kill event, it will be difficult to prove beyond a shadow of a doubt whether *Pfiesteria* or some other agent is responsible for a given fish kill.