

North Carolina Division of Water Quality
Annual Report of Fish Kill Events
1998



Water Quality Section
Environmental Sciences Branch
Raleigh, NC

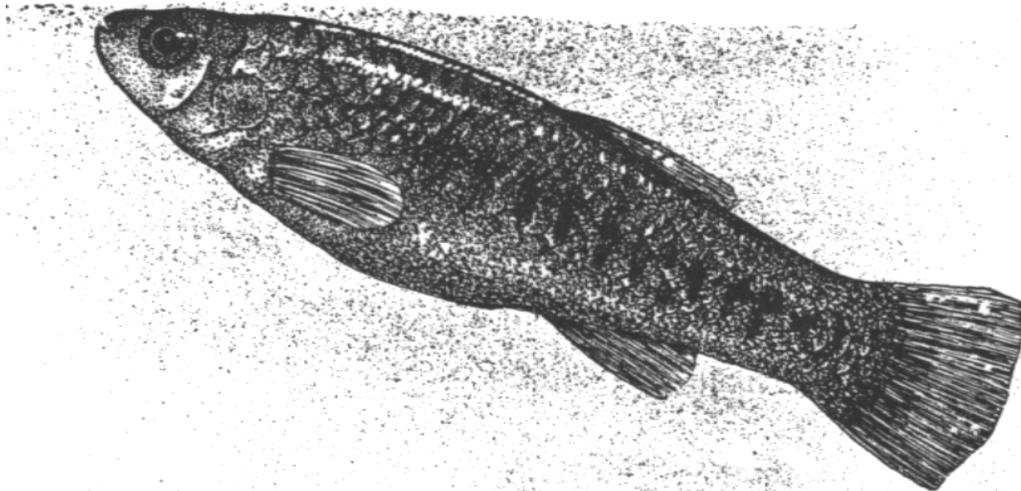
December 1998

Introduction

North Carolina Division of Water Quality (DWQ) efforts to monitor fish kill and fish health events continued to be a priority in the assessment of statewide water quality during 1998. The Division continued to improve and expand its fish health monitoring program during 1998 in response to growing concerns regarding fish mortality across the state.

Fish kill and disease event protocols established by the DWQ in 1996 have proven successful and have been fully adopted by most of the state's frontline investigators. Fish kill and fish health data are recorded on a standardized form and sent to the Division's Environmental Sciences Branch (ESB) where the data are reviewed. The procedure also requires the notification of appropriate state officials and scientists associated with the investigation of such events. Fish kill investigation forms and supplemental information sent to the ESB are compiled in a central database where the data can be managed and retrieved for use in reporting to concerned parties. Fish kills and disease events often involve a host of factors and underlying causes, therefore, it is the Division's intent to gather as much information as possible surrounding an event from all involved parties.

This report is the third yearly summary of fish kill activity in North Carolina mandated under Section 4 of Chapter 633 of the 1995 North Carolina General Assembly Session Laws.



Changes to DWQ Fish Kill Monitoring Efforts

During the Spring of 1998, ESB made several revisions and improvements to fish kill and fish disease monitoring efforts.

- ESB established guidelines for counting dead and diseased fish. Investigators have historically counted dead and dying fish using varying methods. After consulting with investigators from the North Carolina Wildlife Resources Commission, Regional Offices, and other agencies, ESB presented fish counting protocols based on the American Fisheries Society guidelines (American Fisheries Society, 1992). Through the use of standardized counting procedures, ESB has sought to improve the accuracy of data received from various agencies and field investigators.
- Additional revisions were made to the ESB fish kill investigation form. The form was modified to include sections for reporting information on obvious disease symptoms and harmful algal blooms associated with fish kill events. Changes were designed to allow reporting of sublethal elements often observed during fish kill investigations.
- The Division of Occupational and Environmental Epidemiology recommended work practices for investigators to reduce algal toxin exposure and human health risk while working in estuarine waters. It is unclear whether toxins generated by *Pfiesteria piscicida* and morphologically related organisms have produced human health effects in North Carolina, however, the recommendations are intended to reduce possible health risks associated with fish health investigations.
- Guidelines were also introduced for the handling and shipment of fish pathology samples related to fish kills. North Carolina State University Veterinary School pathologists have been working with the Division during the last two years in assessing histological and physiological symptoms associated with fish health events. NCSU guidelines provided to investigators will insure quality samples for use in their analyses.
- The proliferation of water quality problems in North Carolina's coastal rivers and estuaries has resulted in the need for intense monitoring and a quick response to water quality events. In an effort to address monitoring needs, the DWQ established a second coastal rapid response team for the Tar/Pamlico River and associated estuaries. The Tar/Pamlico Response Team is on call to respond to various water quality concerns and questions. The team has also assisted in the collection of samples for *Pfiesteria* research projects headed by Drs. Burkholder, Rublee and Steidinger. Members of the team have assisted Division of Marine Fisheries personnel, and worked in cooperation with federal agencies on SAV projects in the Neuse River.

Fish Kill Overview

Statewide, 58 fish kill events were reported to the DWQ from January to November – no kills were reported during December. The 1998 total is comparable to kill numbers observed during 1996 and 1997 – 60 and 57 respectively. Kill events are tracked by the

1998 Fish Kill Summary

Total Kill Events	58
Total Mortality	600,000
Mortality Range	25 to 300,000
Median Mortality	300
Freshwater Kills	49
Estuarine Kills	9
Basins with Activity	11 (of 17)

Division when at least 25 fish are affected and the event can be confirmed by field investigators. Kill events were reported from the coast to as far west as Haywood County in 11 of the states 17 major river basins.

A majority of kill events occurred in the eastern half of the state and in the Cape Fear basin. Large events occurred mainly along the coast in the lower Cape Fear/Northeast Cape Fear, New, and Neuse basins (see Figure 1). Many of the eastern events were the result of low dissolved oxygen (DO) effects from Hurricane Bonnie which struck North Carolina on August 26 (see Suspected Causes).

Reported fish mortalities ranged from 25 to 300,000. Total fish mortality for 1998 (the sum of all 58 events) was about 600,000. This figure was significantly higher than the total of 97,000 fish reported for 1997. The 1998 yearly total was elevated due to several large coastal kills and a significant kill at Lake Junaluska (Haywood Co.). Only about 10% of the year's 58 events involved 5000 fish or more, and the median mortality figure for 1998 was 300 fish.

**Figure 1. Fish kill Events Reported to DWQ
January to November 1998**



The majority of kill events occurred in freshwaters during 1998. Reports noted 49 events affecting freshwater species and 9 involving estuarine fauna. Freshwater species most commonly identified during investigations included largemouth bass, sunfishes, and catfishes. Estuarine species most commonly encountered included menhaden, spot, and croaker. Menhaden, which have historically been the subject of large fish kills along the coast, were cited in six kill events during 1998 and were the main victims in the year's two largest kills. Menhaden were also observed as stressed and/or diseased in numerous coastal investigations and citizen complaints. Other affected animals were observed in 11 of the 58 kill events during 1998. These included blue crabs, crayfish, shrimp, insects and snails. Blue crabs were noted more frequently than other non-fish species and were observed walking ashore during events.

Basin Summaries

Investigators reported fish kill events in 11 of the state's 17 major river basins during 1998. Most events occurred in the Cape Fear, Neuse and Pasquotank watersheds, and for the third year since 1996 when ESB began tracking kill events, the Cape Fear basin has exhibited the most fish kill activity (Table 1). Except for isolated events, waters west of the Yadkin Basin experienced relatively few kills during the year. Upper sections of the Tar /Pamlico, as well as the Chowan, and Roanoke basins also remained uneventful. The most intense kill activity in 1998 was generally seen along the coastal plain and in an area from Wake to Guilford counties. Many fish kills in coastal basins were caused by after effects (organic loading, DO depletion) from Hurricane Bonnie. Detailed summaries of 1998 fish kills are presented in the appendix.

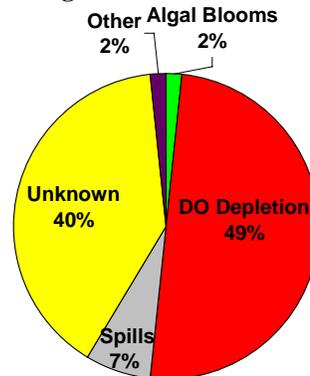
Table 1. Fish Kill Reports and Causes by Basin

River Basin	Number of Kills Reported to NCDWQ			Major Causes and Problems Reported in 1998
	1996	1997	1998	
Cape Fear	21	16	23	Sewage spills in upper sections of basin, DO problems in lower sections after Hurricane Bonnie, sores and disease reported near Wilmington.
Pasquotank	10	2	8	Low DO associated with Hurricane Bonnie
Neuse	14	12	8	DO problems throughout the basin. Stratification, hypoxia, and Pfiesteria identified in lower reaches. Lesions and stress noted in lower reach fish.
Tar/Pamlico	3	6	5	Possible pesticide runoff, DO problems after Hurricane Bonnie.
Lumber	4	3	5	Low DO, effects after Hurricane Bonnie
French Broad	none	2	3	Lake drainage, unknown causes
Yadkin	1	10	2	Winter shad kill, animal waste runoff
Chowan	2	2	1	Unknown causes
Catawba	none	3	1	Unknown causes
Roanoke	2	none	1	Effects from Hurricane Bonnie
White Oak	3	3	1	Physical damage and sores observed on fish, low levels of Pfiesteria observed.
Totals	60	57	58	

Suspected Causes of 1998 Fish Kill Events

Specific causes of fish kill events may or may not be obvious to investigators depending on a host of factors. Many causes may quickly be defined, but others remain unconfirmed or unclear due to investigations occurring after the fact. Kill events often result from many environmental conditions, and sorting out the major reason(s) why fish die is frequently a difficult and often subjective task. The NCDWQ reviews and tracks suspected causes of fish kills conveyed by field investigators. Cause observations aid in evaluating potential water quality trends and problems, and assist scientists and decision-makers with formulating future courses of action. Cause observations should not be viewed as a definitive label for a particular event. Figure 2 shows the proportion of kill events during 1998 attributed to four major cause categories.

Figure 2. Major Suspected Causes for Fish Kills During 1998



Algal Blooms: Nutrient enrichment of waterbodies throughout North Carolina has resulted in eutrophication, frequent algal blooms, and an increase in subsequent fish kill events. Algal blooms cause DO and pH fluctuations as well as DO depletion through diurnal cycles and decomposition. These elements often precede fish kills events. Certain types of algae also release toxins during the course of a bloom that are detrimental to aquatic life (see *Pfiesteria* below). Aside from *Pfiesteria*, algal blooms were cited as a possible cause in 3 of the 58 kill events for 1998, a decrease from 1997 where 11 of 57 events were attributed to algae.

Pfiesteria and similar organisms: Since its identification in the early 1990's, the dinoflagellate *Pfiesteria piscicida* and has been reported as the cause for a number of massive fish kill events in North Carolina's estuaries, especially in the New, Neuse and Tar/Pamlico systems. Scientist believe that the presence of fish, especially schooling species such as menhaden, may induce changes in *Pfiesteria* cells resulting in the emission of a toxin which act on the schools. Currently, scientists consider the presence of *Pfiesteria* at levels greater than 250-300 cells/ml to be toxic or capable of inducing fish kills (Burkholder, 1995).



Pfiesteria has a complex life cycle with 24 reported forms and at least three similar species that are indistinguishable under light microscopy. The ESB laboratory does not have the capability to accurately identify the organism and its look-alikes, nor determine if it is a direct causative factor in disease and kill events. ESB does, however, use light microscopy to monitor levels of *Pfiesteria*-like organisms in water samples associated with disease, kills, and bloom events. ESB has also worked closely with the NCSU Aquatic Botany Laboratory and other scientists who

have the capability to identify *Pfiesteria* forms through scanning electron microscopy (SEM), and perform fish bioassays to confirm the presence of toxic *Pfiesteria* in water samples. Findings from the ESB staff, NCSU, and other experts are compiled in the ESB database as part of the assessment of *Pfiesteria* in fish disease and kill events.

Pfiesteria-like organisms were identified in samples from 4 of 58 fish kill events in 1998 (Table 2). During 1998, positive SEM identification and positive bioassay toxicity results were reported for one large event on the Neuse River the by the NCSU Aquatic Botany laboratory.

Table 2. Summary of 1998 fish kills associated with *Pfiesteria*-like organisms

Date	Waterbody	Location	ESB <i>Pfiesteria</i> Cell Count cell/ml	NCSU Cell <i>Pfiesteria</i> Count cells/ml*	SEM Results*	Bioassay Results*
14-Jul-98	Neuse River	Flanner's Beach	122	250	none	none
28-Jul-98	Neuse River	Fisher Landing Point to Hancock Creek	0-367	100-1560	positive	positive
25-Sep-98	Pamlico River	Long Point	no count	230-470	none	none
29-Sep-98	New River	Frenchs Creek and Grey Point	23-64	no count	none	none

*Reported by the NCSU Aquatic Botany Laboratory

Dissolved Oxygen Depletion: Fish kills associated with low DO levels were reported statewide during 1998. DO depletion prior to kill events often occurred as a result of heavy rain or following periods of drought and low flow. Anoxic conditions also occurred in estuaries as nutrient and organic loading coupled with water column stratification depleted DO levels during the summer months. DO depletion was cited as a factor in 31 kill events in 1998. Kills linked to low DO levels were reported more frequently in 1998 than the previous year. In 1997 only 21 of 57 kills were linked to DO.

Hurricane Bonnie, which struck the North Carolina coast and followed a track over the coastal plain on August 26 and 27, was a major cause of DO depletion and subsequent fish kills in many waterways. Heavy rains from the storm flushed swamps, caused flooding, and washed large quantities of organic matter into rivers and estuaries. Investigators reported very low DO levels shortly after the storm in numerous counties along the coast, especially in the Cape Fear, New, and Neuse drainages. Hurricane Bonnie was cited as a major factor in 22 fish kill events.

Spills: Waste spills either deplete DO levels in receiving streams or induce kills outright through physical or chemical toxicity. Five spill-induced fish kills were reported for 1998 in Guilford, Iredell, New Hanover, and Wake counties. Spilled substances included pesticides, herbicides, animal waste, and sewage. Spill-induced kills decreased from 1997 when 17 of 57 kills were traced to the cause.

Unknown Causes: Causes for kill events are listed as unknown when investigators fail to report specific reasons for an event. Investigations may not provide definitive causes when they are conducted too long after an event and no clear factors are determined, or when causes are suspected but not confirmed. Investigators reported 21 kills without clear causes during 1998 (16 of 57 in 1997). The four fish kills where *Pfiesteria* cells were identified were also listed as having unknown causes due to the presence of other possible causes, or the lack of evidence suggesting the organism was the sole agent.

Large Fish Kill Events (mortality counts \geq 5,000 fish)

Investigators reported six events during 1998 where 5,000 or more fish were affected. All large events, except one at Lake Junaluska (Haywood Co.), were located in coastal plain counties.

Pete Dye Lake, New Hanover County, Cape Fear River Basin, June 25

Improper application of copper sulfate to control algal growth was suspected as the cause of a kill involving 10,000 carp, sunfish, bass, and eels in Pete Dye Lake, a private golf course impoundment located in the Landfall subdivision. The event was contained due to the isolation of the lake from other waters except during extreme flooding.

Neuse River from Fisher Landing Point to Hancock Creek, Craven County, Neuse River Basin, July 28

A kill of 188,000 menhaden along the lower Neuse River was one of the higher profile events during 1998. Reports from investigators suggested the kill may have resulted from a number of environmental factors. River monitors showed chronic hypoxia in the lower third of water column during month prior from the Trent River to Hancock Creek. Weather conditions may have resulted in large-scale mixing in the river on July 26-27 near Marker 11. Mixing of bottom waters with upper layers resulted in a sudden change in dissolved oxygen, pH, salinity, and temperature, contributing to the stress of fish populations in the area. *Pfiesteria*-like cell counts from water samples taken in area by ESB and NCSU were greater than 300 cells /ml, a level considered toxic or capable of inducing a kill. As much as 40 to 50% of live fish in the area showed lesions, and approximately 90% of dead fish showed lesions. NCSU reported active *Pfiesteria* toxicity confirmed from bioassays of water samples with test fish.

Waccamaw River near Old Dock, Columbus County, Lumber River Basin, August 31

Investigators observed a kill in the Waccamaw River of 5,000 bass, sunfish, pickerel, and catfish during the days following Hurricane Bonnie. Reports indicated severe flooding, high organic loading from surrounding swamp areas, and DO depletion as reasons for the event. Investigators also observed fish gasping at the surface and exhibiting lethargic behavior.

Northeast Cape Fear River near Castle Hayne, Pender County, Cape Fear River Basin, August 31

A second large fish kill in the wake of Hurricane Bonnie was observed along the Northeast Cape Fear River near Castle Hayne. The event affected 10,000 fish composed of primarily hogchokers as well as crabs and crayfish. Investigators noted many fish gasping at the surface in shallow areas. UNCW investigators reported a hog waste spill and sewage bypass upstream prior to the event. Dead fish were noted by various sources throughout a ten-mile stretch of the river around Castle Hayne.

New River near French's Creek, Onslow County, White Oak River Basin, September 29

Investigators reported damaged gill plate areas on many fish involved in a kill on the New River near French's Creek. The event turned out to be the year's largest reported kill with an estimated 300,000 fish affected (primarily menhaden). Numerous shrimp trawlers were noted in the area at the time of the event (the area was opened for shrimping the day before) which raised the possibility of dead fish being bycatch. ESB staff members reported *Pfiesteria*-like cell counts of 23-64 cells /ml, a level below what scientist currently consider toxic. The cause of the event was reported as unknown.

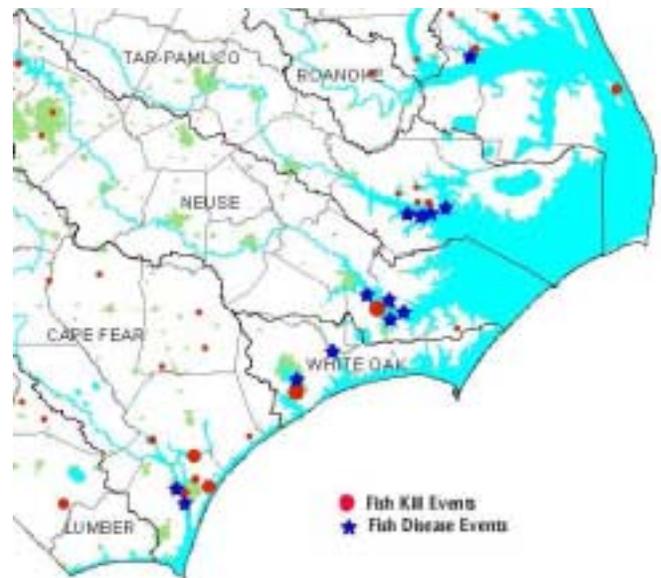
Lake Junaluska, Haywood County, French Broad River Basin, November 19

Rapid draining of Lake Junaluska for maintenance work caused a kill of 50,000 bass, sunfish, carp, catfish, and goldfish. The rapid drop in the lake level caused silt suspension and DO problems, and caused a kill below the dam in Richland Creek. The DWQ initiated enforcement action against the Junaluska Assembly, owners of the impoundment.

Fish Disease Reports

The DWQ initiated the process of tracking stressed and diseased fish sightings during 1997. The DWQ expanded monitoring efforts to include fish health-related events that do not meet criteria necessary for tracking under the Division's current fish kill investigation protocol. Poor water quality in trouble spots throughout North Carolina has produced sub-lethal effects on fish populations that warrant investigation and tracking, but remain unaccounted for in DWQ fish kill assessments. Stressed or diseased sightings are therefore compiled and reviewed by the DWQ to further augment fish kill data from the state's waters.

Figure 2. Confirmed Fish Disease Sightings - 1998



Investigators confirmed 13 stressed or diseased fish events in North Carolina during 1998. Disease sightings in 1998 were down from 1997 during which investigators reported 21 events. Confirmed sightings were limited to coastal waters in the Cape Fear, White Oak, Neuse, and Pamlico basins (one sighting was reported in the Pasquotank Basin). Most events involved menhaden, a species often observed in poor condition during the summer months in coastal rivers and estuaries. Investigators often observed stressed or diseased menhaden when other species in the immediate area appeared healthy. A majority of fish were reported as suffering from ulcerative lesions (see NCSU Pathology) in conjunction with lethargy or gasping behavior.

NCSU College of Veterinary Medicine Pathology Results

During 1998, Dr. Mac Law along with NCSU College of Veterinary Medicine staff and veterinary students, assisted DWQ investigators by performing gross and microscopic evaluations of stressed/diseased fish. Dr. Law is an ACVP board certified veterinary pathologist at the North Carolina State University College of Veterinary Medicine. The pathology team examined more than 100 fish samples from ten different sites in the Pamlico and Neuse estuaries (Table 3). Fish species examined included menhaden, croaker, mullet, striped bass, red drum, and speckled trout

Table 3. Fish Samples Examined by NCSU College of Veterinary Medicine Staff

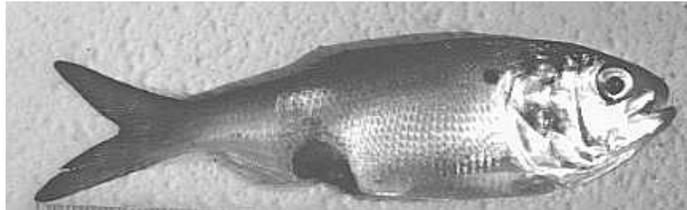
Sampling Date	Sampling Location	Number Fish in Sample	Number Fish with Lesions*
7-14-98	Neuse: Flanner's Beach, CM 11	5	2
7-15-98	Slocum Creek, CM 7	4	4
7-19-98	Pungo: Wade's Point Pamlico: North Creek	7	6
7-22-98	Slocum Creek	3	3
7-28-98	Pamlico: Wade's Point	13	13
7-28-98	Pungo: Mouth of Fortescue's Creek	10	6
8-18-98	Pamlico: PCS 40%	5	5
9-10-98	Broad Creek	1	1
10-7-98	Albemarle Canal: Holiday Island	24	18
12-9-98	Neuse River: Kennel Beach	4	4

**These fish were not randomly sampled.*

Dr. Law's Findings: Many fish had one to several ulcerative lesions of the skin and underlying muscle tissue which were often circular and crater-like. These lesions ranged from 4 mm to >3 cm in diameter, were of variable depth, and occasionally penetrated through the body wall of the fish. Lesions were most severe in the menhaden, although a few of the croaker and mullet had small ulcerative lesions. Several striped bass from the Neuse River were submitted which had small skin hemorrhages, many of which were

associated with “anchor worm” parasites. Other fish (mostly menhaden) had extensive areas of dead muscle tissue and only a small overlying ulcer. Within some injured areas, special stains revealed abundant bacteria and fungal infections. All of the ulcerative lesions associated with fish kill and/or stressed/diseased fish samples contained chronic forms of inflammation. This type of inflammatory process takes at least a week to develop to the point observed by the NCSU veterinary staff.

In general, most of the ulcerative lesions in these fish were compatible with the “ulcerative mycosis” lesions of menhaden reported by Noga *et al* in 1986 (Journal of Fish



Diseases 9:47-53) and later attributed to a dermonecrotic toxin produced by the *Pfiesteria* organism (Burkholder *et al*, Nature 358:407-410, 1992; Noga *et al*, Marine Pollution Bulletin 32:219-224, 1996; Baden, unpublished data, 1997). The small hemorrhagic lesions in the striped bass, however, were probably caused by heavy skin parasitism (anchor worms).

The significance of the fungi in the initiation and development of these lesions is uncertain at this time. It is likely that some primary stressor such as a toxin, low dissolved oxygen, trauma, parasitism, etc. causes an initial breach in the fish’s skin, allowing secondary invasion of fungi and other organisms. The apparent time lag between initiation of these lesions and development of an ulcer with the presence of chronic inflammation makes determination of the primary cause difficult under field conditions.

Summary

The total number of fish kills reported to the DWQ in 1998 was comparable to numbers reported during 1996 and 1997. Furthermore, events observed in 1998 were the result of similar causes of fish mortality seen in previous years. Problems with DO depletion continued to be a major cause of events statewide. Spills of pesticides, sewage, and animal wastes were reported in a number of instances. Coastal rivers and estuaries continued to experience eutrophication, stratification, and associated hypoxia, especially along the shallow, poorly flushed reaches of the Neuse and Pamlico rivers. The presence of *Pfiesteria*-like organisms was observed in conjunction with a number of events, and concentrations were sometimes much greater than levels considered as harmful. Disease in estuarine menhaden populations was noted from the Cape Fear to the Chowan basins. Disease symptoms included skin and musculature injuries consistent with “ulcerative mycosis” lesions seen in the past. Perhaps the year’s most conspicuous influence of fish kill events was the arrival of a third hurricane to North Carolina’s shores since 1996. Hurricane Bonnie inundated coastal watersheds causing organic loading that depleted DO concentrations to lethal levels across the coastal plain. The storm was a factor in over one third of the kills reported.

Although numerous threats to fish health persisted in 1998, some factors appeared to moderate during the year. Spills of wastes and sewage were less prevalent in 1998 than in 1997. Except for a few large events, favorable weather conditions seemed to preclude the widespread and severe estuarine stratification that helped to initiate massive fish kills in years past. *Pfiesteria* was identified in conjunction with only 4 events in 1998 and kills from other algal blooms were rarely reported. The reprieve during 1998 from the intense fish kill activity seen earlier this decade probably does not signal improving water quality or fish health. More likely, a “quieter” year came as a result of more favorable meteorological and hydrological conditions that prevented widespread disease and mortality.

DWQ fish kill reports are also available on the world wide web at the ESB homepage under the Special Topics section (<http://esb.ehnr.state.nc.us>).



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