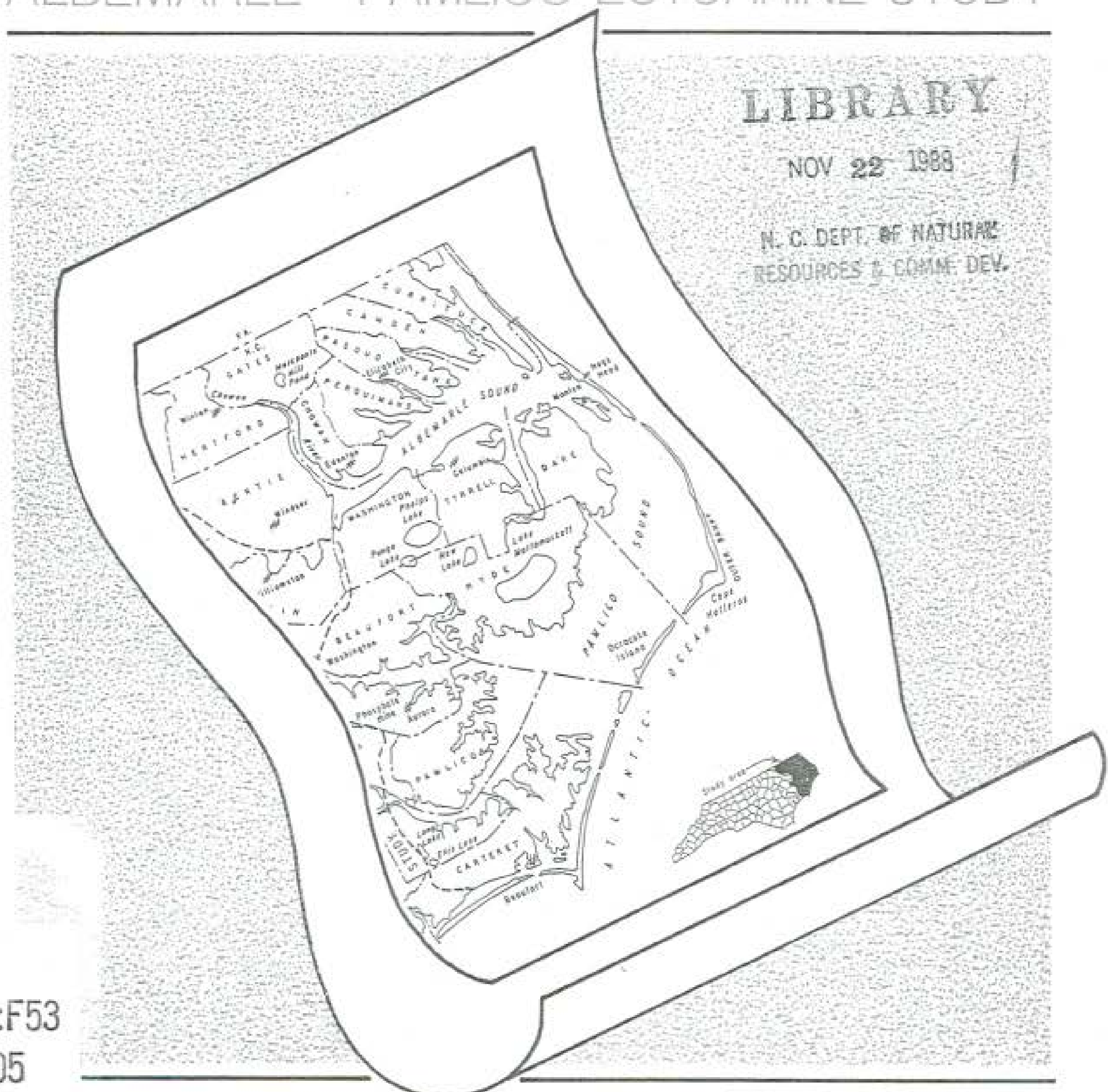
Report No. 87-05

PROCEEDINGS OF THE WORKSHOP ON FISHERY DISEASES FOR THE ALBEMARLE-PAMLICO ESTUARINE STUDY

ALBEMARLE - PAMLICO ESTUARINE STUDY



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The Proceedings of the Workshop on Fishery Diseases for the Albemarle-Pamlico Estuarine Study

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Edited by Jeri Gray, UNC Water Resources Research Institute

Preface

The Workshop on Fishery Diseases was the second of three workshops organized by the UNC Water Resources Research Institute for the Albemarle-Pamlico Estuarine Study. The first workshop on water quality modeling was held September 3 and 4, 1987, and the third, on remote sensing and land-use was held November 9 and 10, 1987. The purpose of the workshops was to determine what types of studies, resources, and new initiatives in these three areas would be most useful to the managers of this important estuary system.

The problem of fish diseases has become very visible over the last decade. We realize that there are major gaps in our knowledge base to understand the complex fish disease issues. In this workshop, we wanted to look at those studies and programs that can potentially be utilized by managers to solve problems related to fish disease issues in the Albemarle-Pamlico Estuarine Area.

Participating in this workshop were leaders in North Carolina state agencies and university research teams, as well as scientists involved in estuarine programs in Florida, Maryland, and Puget Sound in Washington state. These individuals were all invited to come together, share information, and make recommendations to the director of the Albemarle-Pamlico Estuarine Study regarding priorities for addressing the problem of fish diseases in North Carolina estuaries.

The specific objectives of the workshop were:

1. To review approaches for dealing with fish diseases and potentially associated water quality problems in a variety of estuarine settings

2. To assess the State's current capabilities to manage fish disease instances

3. To benefit from the experience of other agencies and universities that have attempted a similar approach

4. To review examples of expertise within the region for fishery diseases research

5. To recommend a practical strategy for addressing fish disease problems as part of the Albemarle-Pamlico Estuarine Study

James M. Stewart
(Associate Director
UNC Water Resources Research Institute)
Workshop Organizer

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SUMMARY AND RECOMMENDATIONS

There are three major reasons for concern about fish diseases in the Albemarle-Pamlico Estuarine system. The first reason is economic: (a) fewer fish or fewer marketable fish reduce the income from commercial fisheries, and (b) public perception of a declining environmental quality (which is likely to result from widespread fish disease) reduces the demand for coastal recreation, which in turn drives down the value of coastal property. The second reason is related to human health: (a) fish are known to accumulate certain toxins such as carcinogens and heavy metals if these substances are present in the aquatic environment, and accumulation of such toxins in edible fish can have adverse human health effects; and (b) fish can be infected by bacteria and other organisms which may be potential human pathogens.

The third reason we must be concerned about fish disease is that the health of fisheries is an indicator of the health of the ecosystem. For a disease to develop, we must have a host in a state of receptiveness, a pathogen or agent at a certain level of pathogenicity, and--most importantly--an environment in a particular state. The environment basically determines whether a disease will develop.

While occasional abnormalities can be found in fish anywhere and anytime, widespread dermatological fish diseases in the Albemarle-Pamlico system first came to light in the Pamlico and Pungo rivers in 1982. Southern flounder was the first species found to have lesions. Based on data from the North Carolina Division of Marine Fisheries (NCDMF) estuarine trawl survey and on observational data, lesions indicative of the disease ulcerative mycosis did not occur in menhaden before 1984, but in the fall of 1984, 80 percent of menhaden in random samples from Pamlico River pound nets had lesions. N.C. Division of Marine Fisheries data shows that most fish species in the Pamlico and Pungo rivers have been affected with lesions to some extent, but because of the prevalence of lesions in menhaden, attention has been focused on disease in that species. Efforts have been made to identify the cause or causes of the disease and to determine whether the disease is related to water quality.

Most of the experience environmental and fisheries managers have in investigating the relationship between water quality and fish health has come from investigations of fish kills, and those investigations have rarely been conclusive. Direct relationships between pollution sources, the quality of adjacent waters, and the killing of fish have almost never been established in the Albemarle-Pamlico Estuarine system. Indeed, fisheries officials find it impossible to determine whether a fish kill in the Albemarle-Pamlico Estuarine system is an acute phenomenon or the result of a chronic sublethal effect. Most of the kills in the Albemarle-Pamlico are related to algal blooms or to low dissolved oxygen (or both). However, hydrodynamic complexities which defy analysis severely limit the effectiveness of investigations so that gathering even basic information regarding the waters in which the fish died is difficult. The analyses needed to determine whether or not algal blooms or anoxia are at work in a kill zone are even more complex. The investigation of fish disease is even more difficult to bring to a satisfactory conclusion than are cases of acute mortality. It is likely that key elements of the Albemarle-

Pamlico system having a controlling influence over the frequency, magnitude, and duration of disease episodes are not being monitored by anyone.

Isolation of the pathogen causing ulcerative mycosis in menhaden has yielded only a few clues about how the fish actually become infected. Researchers at North Carolina State University found that the organisms responsible for the disease in menhaden are water molds of the genera Aphanomyces and Saprolegnia. These fungi had never been reported as the cause of disease problems in estuarine fish. They are considered to be classic opportunistic pathogens that affect freshwater fish, yet large numbers of fish infected by them were being seen in the Pamlico Estuary and other brackish areas. Water mold infections typically found in freshwater fish normally cause very superficial infections on the surface of the body. Yet in infected fish taken from the Pamlico River and other coastal areas the fungus was found to be very aggressive, producing inflammation extending deep into muscle tissue, even around very small lesions. Efforts to induce the same kind of lesions in laboratory fish by exposure to Aphanomyces were unsuccessful until the exposure was accompanied by injections of a corticosteroid. Elevated corticosteroid levels have been shown experimentally to increase the susceptibility of fish to opportunistic infection, such as bacteria or fungi. The conclusion was therefore drawn that there may be some relationship between immunocompetence of fish and the development of ulcerative mycosis. (Although visible ulcerative mycosis-like lesions have been found on a total of 11 other species of fish in the Pamlico River, it has not been possible to point to specific organisms causing the disease in species other than menhaden.)

Further evidence exists that environmental factors may be playing a role in the development of fish disease in the Albemarle-Pamlico Estuarine system. The National Oceanic and Atmospheric Administration began sampling sediments and fish tissue from representative estuaries around the U.S. coast in 1984 in an effort to discern relationships between contaminants and fish diseases. Sediment samples from North Carolina (taken at Hobucken) were analyzed for heavy metals and other trace elements, total organic hydrocarbons and individual hydrocarbons and DDT residues. Analyses revealed no unusually high level of any contaminant except for indicators of sewage: Clostridium perfringens spores, coprostonol, and total organic carbon. N.C. samples were found to have levels of chromium similar to levels of some industrialized areas. Analyses of Pamlico Sound spot and croaker revealed the presence of several abnormalities that may be indicative of environmental stress: proliferation of macrophage center in the kidneys (not prevalent in 1984); hyaline degeneration of kidney tubules (found in 40% of spot in 1984 and 30% in 1985); and cholangitis and hepatitis (both prevalent in 1985 croaker but not in 1984). Similar lesions were found in fish in other estuarine areas where contaminant level were found to be low. These results suggest two possibilities: (1) In less contaminated areas where fish have not been exposed to massive environmental insults over decades they may be more susceptible to small amounts of pollution; or (2) The contaminant causing these lesions is not being monitored for.

Some evidence of environmental influences emerged from a monitoring program conducted by NCSU researchers and the N.C. Division of Marine Fisheries on the Pamlico in 1985 and 1986. Monitoring data indicated that the disease was more prevalent in areas of lower salinity (which is supported by laboratory evidence), that the disease occurred most frequently in the cloacal region and adjacent flank of 65-120 mm FL menhaden (young-of-the-year), that the disease was most prevalent during May and June, and that the proportion of menhaden affected increased following periods of dry weather and declined during periods of heavy rainfall. Since young fish are primarily affected, it is believed menhaden are acquiring the infection in the estuary, particularly in the upper part of the estuary, and not in the sound.

Because young fish are primarily affected, concern has arisen about the effects of the disease on the total population of the Atlantic menhaden fishery, which has its roots in North Carolina estuaries and the Chesapeake Bay. Menhaden is an economically important species, with the Atlantic menhaden fishery worth about $40 million annually (at $.05 per pound dockside). The species is also valuable to the internal estuarine food-chain, providing 10 to 15 percent of the food for many other species. Perhaps as importantly, menhaden is valuable as an indicator of the health of the estuarine system because it typifies many other estuarine organisms. Menhaden spawn offshore at two to three years of age. Their eggs hatch offshore, and the larvae migrate or are transported into the estuary. They spend the first growing season in the estuary and move into the nearshore ocean waters in the fall. The adults and juveniles do not eat other fish: they eat plankton, so they could be ingesting the fungus spores thought to cause ulcerative mycosis. In the fall the adults and juveniles (about one year old) migrate south. In the spring they migrate north.

Sampling of commercial landings of menhaden in the Atlantic revealed no ulcerative fish in 1986. The only ulcerative fish found in a commercial purse seine catch were in 1984-85 North Carolina landings tracked to the Pamlico River. It may be that if ulcerative fish live long enough to migrate out to sea, the saltwater dip cures the disease. Because manifestation of ulcerative mycosis has not been found in commercial catches, it is very difficult to determine the effect of the disease on the species population. Statistical models predict that if chronic pollution caused an incremental decline of 0.5 percent a year in the survival of young fish over a 30-year period, there would be a 60 percent reduction in the normally expected biomass. Adding an acute mortality event in year 14 of the model reduces the projected biomass to 50 percent of normal. It is, however, impossible to gage the impact of local events of ulcerative mycosis on the Atlantic menhaden population.

In order to determine how fish diseases in the Albemarle-Pamlico Estuarine System can be managed, it would be helpful to definitively establish the cause or causes of the diseases. However, given the complexities of the host-environment relationship and the complexities of the estuarine system, establishing a direct causal link may not be possible. Certainly, identifying one element or a set of elements that cause fish in the Albemarle-Pamlico Estuarine system to be infected with ulcerative mycosis would require a long-term, expensive research and monitoring program. Neither the timeframe for establishing an estuarine management plan agreed to in the Albemarle-Pamlico Estuarine Study contract nor the budget available for examining estuarine problems allows for such a long-term, high-cost effort.

Since it has been established that infection rates are higher in certain geographic areas, it may be possible to identify the different elements that might be making fish in these locations more susceptible to the disease. It is certainly possible to show that fish from one area are not as immune competent as fish from another area or that fish with the disease show reduced immunocompetence. Localized reduced immunocompetence is evidence of an environmental effect, even if the specific agent is not identified. Since there is some knowledge of things that can reduce the ability of the immune system to respond to infectious organisms, some assumptions can be made about causes, and management decisions can be made to reduce those anthropogenic inputs that can affect fish immunity.

While this approach may not identify a specific cause, it does indicate causality and should convince the general public, who must ultimately support any management decisions, that there is significant environmental change in the Albemarle-Pamlico Estuarine System and that the system needs to be managed in order to preserve existing uses.

The following specific recommendations are, therefore, made:

1. A study should quantitatively determine the interspecific incidence of the ulcerative mycosis syndrome in seasonally high-risk locations of the Albemarle-Pamlico estuarine system during the next three years.

    a. The study should be focused on an estuary known to have a high disease incidence and compared with an estuary with a low disease incidence.

    b. The epizootiology of this syndrome should focus on the existence of a primary invader (virus, protozoan, bacteria, etc.) and the life history stages of the affected species.

    c. Detailed intensive and comprehensive water monitoring should be conducted concurrently with the biological sampling to define diurnal and seasonal changes.

    d. In-situ bioassays should be deployed in strategic locations to investigate the interaction between water quality and caged test fish. The physiological responses of the test fish should be utilized to aid in development of new detection techniques.

2. The disease problem should be used to focus a public education effort on the current state of knowledge of the Albemarle-Pamlico estuary and the research and management needs which must be addressed now and in the future.

3. The importance of fish diseases in the Albemarle-Pamlico Estuarine system and effects on the abundance of commercial fish stocks (e.g. menhaden) should be a long-term study goal.

Status of
Albemarle-Pamlico Estuarine Study

Douglas N. Rader, Coordinator
Albemarle-Pamlico Estuarine Study

The Albemarle-Pamlico Estuarine Study is a management study through which we are seeking ways to make management of the estuarine resources in 33 Northeast North Carolina counties effective. We do not want to erect a big new hierarchy but to fine tune what we have to make management effective.

To make this goal feasible, we have to have a great deal of technical information about the estuarine system, and we have established a process for selecting the technical studies to provide that information.

We have a draft workplan in place that will provide flexible guidance over the next five years for our technical studies. The workplan lays out specific high-priority items, several of which are pertinent to fish diseases. We sent out a broad call for proposals along with a prioritized listing of technical research topics. In response, we received 99 proposals, and we conducted more than 600 external reviews to evaluate their relative scientific merit. A joint peer review committee, established by the Albemarle-Pamlico Estuarine Study Policy Committee and chaired by Dr. Dirk Frankenburg of the Department of Marine Sciences at the University of North Carolina at Chapel Hill, considered the proposals and the reviews and made recommendations for funding for this year.

One of the topics that was not funded but was identified as a high priority for the Albemarle-Pamlico Estuarine Study because of its visibility as a symptom of significant environmental change in the estuarine system was fish diseases. During the summer of 1987 the issue continued to receive a great deal of exposure in the media, so the Policy Committee continued to feel it should be treated as a priority item. This workshop was organized to respond to the perceived need for information and guidance in this area, and the results of this session will be of direct utility to the study. The fifth workshop objective, " To recommend a practical strategy for addressing fish disease problems as part of the Albemarle-Pamlico Estuarine Study," is the key.

Please remember, this is a management study. We need to identify the point in the web of estuarine causality at which fish diseases can be managed. That is the bottom line.

Therefore, our primary focus today is causality: What are people doing that could be causing fish diseases in estuaries. Secondly, we need to identify the significance of that effect for the entire system - that is from an economic standpoint, from a social standpoint, from an environmental standpoint.

We will begin our worksession by sharing what we do know about fish diseases and the potential for managing them, so that by the end of the session, we can all start from the same point to make recommendations for a practical management strategy.

Fish Disease Assessments and Current N.C. Division of Marine Fisheries Initiatives

Jess Hawkins
N.C. Division of Marine Fisheries

Historically, the North Carolina Division of Marine Fisheries (NCDMF) did not participate in any substantial fish disease investigations. To the best of my knowledge, past field investigations (before 1980) were limited to "red sore" studies in the Chowan River and investigations of lesions on fish in freshwater. Most investigations were isolated and short term.

The most extensive fish disease investigations in which NCDMF has been involved to date involves studies of ulcer diseases on fish and blue crabs. I will briefly describe how these investigations originated and how they have involved the NCDMF.

Significant Numbers of Fish with Lesions First Reported in 1982

In the winter of 1982, the NCDMF received reports of lesions on southern flounder (Paralichthys lethostigma) in the Pamlico and Pungo rivers, tributaries of Pamlico Sound (Figure 1). The fish were captured by the estuarine winter trawl fishery. The prevalence of flounder with lesions appeared to significantly decrease when water temperatures increased during spring.

During the period November 1983 to March 1984, the NCDMF again received numerous reports of southern flounder with lesions in the Pamlico and Pungo rivers. Whole individuals and histological samples were sent to Dr. Martin Newman of the National Marine Fisheries Service (NMFS) at Oxford, Maryland. The lesions were relatively sterile, with no bacteria cultured; however, some viruses were isolated. Dr. Newman felt that no definitive diagnosis could be made without additional samples or laboratory experimentation.

Disease Among Menhaden Reached Epidemic Proportions in 1984

During April and May 1984, large proportions of menhaden (Brevoortia tyrannus) and southern flounder with lesions were noted in Pamlico River pound net catches (Figure 2). The pound nets primarily capture menhaden for use as crab pot bait, with catches of several thousand pounds per net per day not uncommon. Most of the lesions on menhaden were located near the vent and caudal fin and had the appearance of a predator wound.

Dr. Ed Noga of the School of Veterinary Medicine at North Carolina State University was contacted and began work on the fish disease problems in the spring of 1984. The NCDMF obtained numerous samples of live individuals throughout 1984 for Dr. Noga.

During the fall of 1984, numerous menhaden kills that contained large proportions of individuals with lesions were observed in the Pamlico River by NCDMF and the Division of Environmental Management (DEM). Dr. John Merriner of the NMFS SE Fisheries Center, a major menhaden research facility, was contacted by NCDMF about the significant numbers of menhaden with lesions composing the fish kills. Inquiries were made about potential impacts on the menhaden population in the Pamlico River, as it serves as a major nursery area.

Monitoring for the Disease Was Broadened

The NMFS lab began noting lesions on menhaden during juvenile sampling in the Neuse and Pamlico rivers and tributaries of Chesapeake Bay. NMFS also began sampling menhaden purse seine catches for disease prevalence data. All state fish agencies from Maryland to Florida were contacted by the NCDMF concerning the fish diseases. South Carolina biologists observed a few menhaden with lesions from isolated estuaries, and Florida scientists reported large numbers of weakfish (Cynoscion regalis) and menhaden with lesions in the St. Johns River.

During the fall of 1984, as much as 80 percent of the menhaden in random samples from pound nets in the Pamlico River had lesions. Numerous other estuarine species with lesions were also observed in the pound catches during fall, including spot (Leiostomus xanthurus), Atlantic croaker (Micropogonias undulatus), silver perch, (Bairdiella chrysura), American eel (Anguilla rostrata), and weakfish.

Research into Causes of Disease Was Broadened

Because Dr. Noga had consistently observed fungal hyphae in the menhaden lesions, Dr. Michael Dykstra, a mycologist and director of electron microscopy at the NCSU School of Veterinary Medicine, began to assist the investigation. Dr. Jay Levine, an epidemiologist at the School of Veterinary Medicine, became involved with the investigation's field studies.

Fishermen reported high percentages of menhaden and flounder with lesions from the Neuse River and high percentages of flounder with lesions from the Albemarle Sound and Ocracoke during the fall of 1984. The lesions on flounder made the fish unmarketable, resulting in significant economic impacts. Samples of flounder were obtained from the areas by the NCDMF and sent to Dr. Noga.

Also at this time the U.S. Fish and Wildlife Service agreed to examine diseased and healthy menhaden for metal and toxic analyses of fish tissues. Fifteen controls and 15 lesioned menhaden were sent by NCDMF to the Fish and Wildlife Service in Missouri.

In the spring of 1985, Drs. Noga, Dykstra, and Levine received funding from the Water Resources Research Institute (WRRI), and the investigation continued until March 1987, with the NCDMF heavily involved in most aspects of the project. Throughout the investigation, meetings were held with state and federal representatives from North Carolina and other states to discuss hypotheses about the disease and to delineate feasible avenues of research. Sea Grant, the National Marine Fisheries Service, the U.S. Fish and Wildlife Service, the N.C. Division of Environmental Management, the Florida Department of Environmental Regulation, the Florida Department of Natural Resources, and the Virginia Institute of Marine Science have all been involved with the investigation.

NCDMF Data Base Indicates Disease Prevalence Highest in Pamlico/Pungo, Young-of-the-Year Primarily Affected

Besides being heavily involved in the WRRI-funded investigation, the NCDMF has modified its juvenile fish and shellfish monitoring survey and its Pamlico Sound survey to address fish disease problems.

The statewide estuarine trawl survey is composed of approximately 200 stations located in estuarine tributaries and pulled monthly from March through November. The Pamlico Sound survey includes approximately 50 random trawl stations sampled quarterly throughout Pamlico and western Albemarle sounds. These data are currently entered in the NCDMF data base in Morehead City. The juvenile survey has existed to some degree since 1974 but was expanded to its present state in 1978.

Based on data from this survey and fishermen/NCDMF observations, ulcerative mycosis on menhaden did not occur before 1984. The survey data also indicates that the Pamlico/Pungo system is the North Carolina estuary with the most frequent occurrence of ulcerative mycosis. The data from the ulcerative mycosis investigation and the survey show that most of the common estuarine fish species utilizing the Pamlico River have experienced lesion problems and most of the individuals are young-of-the-year fish which utilize the estuary as nursery habitat.

As a result of heightened awareness of fish disease problems, the NCDMF with the cooperation of the NCSU School of Veterinary Medicine and the Division of Environmental Management, has also initiated an investigation into an apparent blue crab disease in the Pamlico River. The NCDMF also has assisted Dr. Noga with an investigation into ulcer problems on American eel in the Pamlico River.

Fish diseases have become a very serious problem in the estuaries of North Carolina, especially in the Pamlico River. The NCDMF and investigators from the NCSU School of Veterinary Medicine have devoted significant effort in recent years to gaining information about fish diseases. This information is being collected to help understand why estuaries like the Pamlico River are suffering disease problems of epidemic proportions and to potentially aid management decisions.

Discussion

Question: Did you say the disease problem occurred mostly on young-of-the-year?

Hawkins: Most of the effects we've seen are on young-of-the-year except in Southern flounder, and anecdotal data indicate that the problem in Southern flounder is declining.

Question: Have you seen any fish diseases in lakes?

Hawkins: We get calls about sores on fish in various impoundments in this watershed - Lake Mattamuskeet and Lake Phelps, but we don't think it is the same thing as we see in the estuary.

Question: How many passages are there into the estuary through the barrier islands?

Hawkins: The major ones for the Pamlico Sound are Oregon Inlet, Ocracoke Inlet, Hatteras Inlet, Beaufort Inlet and then there is Drum Inlet. Water in the Pamlico Sound is characterized by long residence time.

Question: So the Pamlico Sound could be characterized as more like a lagoon?

Hawkins: Yes, I would agree with that.

Sindermann: Do you see more lesions on fish in fish kills than you do sampling live schools.

Hawkins: In other words, do lesions contribute to mortality? That's a good question, and I can't answer it. In years when we've had large disease outbreaks, we've seen large proportions of fish in mass mortalities with lesions. That was primarily in 1984 and this spring. In 1984, we found about 90 percent of the fish in mass mortalities affected with lesions. That was a reason we contacted John Merriner: We were concerned about the effect the disease might have on population.

Merriner: We should note that there are fish kills where ulcerative mycosis is not an important part of the picture. Menhaden die easily from normal anoxic conditions. Indeed, it has been acknowledged that sampling is biased in various ways.

Hawkins: One of the things I want to emphasize is that the Division of Marine Fisheries has no experts on fish disease. Drs. Noga, Levine, and Dykstra, the Division of Environmental Management, Sea Grant, the National Fisheries Service, and the U.S. Fish and Wildlife Service have all chipped in to address whatever aspect of the problem they can, and their participation has been helpful.

In my opinion we have a very serious problem in the sound, and I'd like to stress two pieces of information that we have learned from our investigations. First, we did not see the problem before 1984. Second, it seems to primarily affect young-of-the-year which are apparently getting infected in the estuarine waters.

FIGURE 1
PAMLICO SOUND TRIBUTARIES

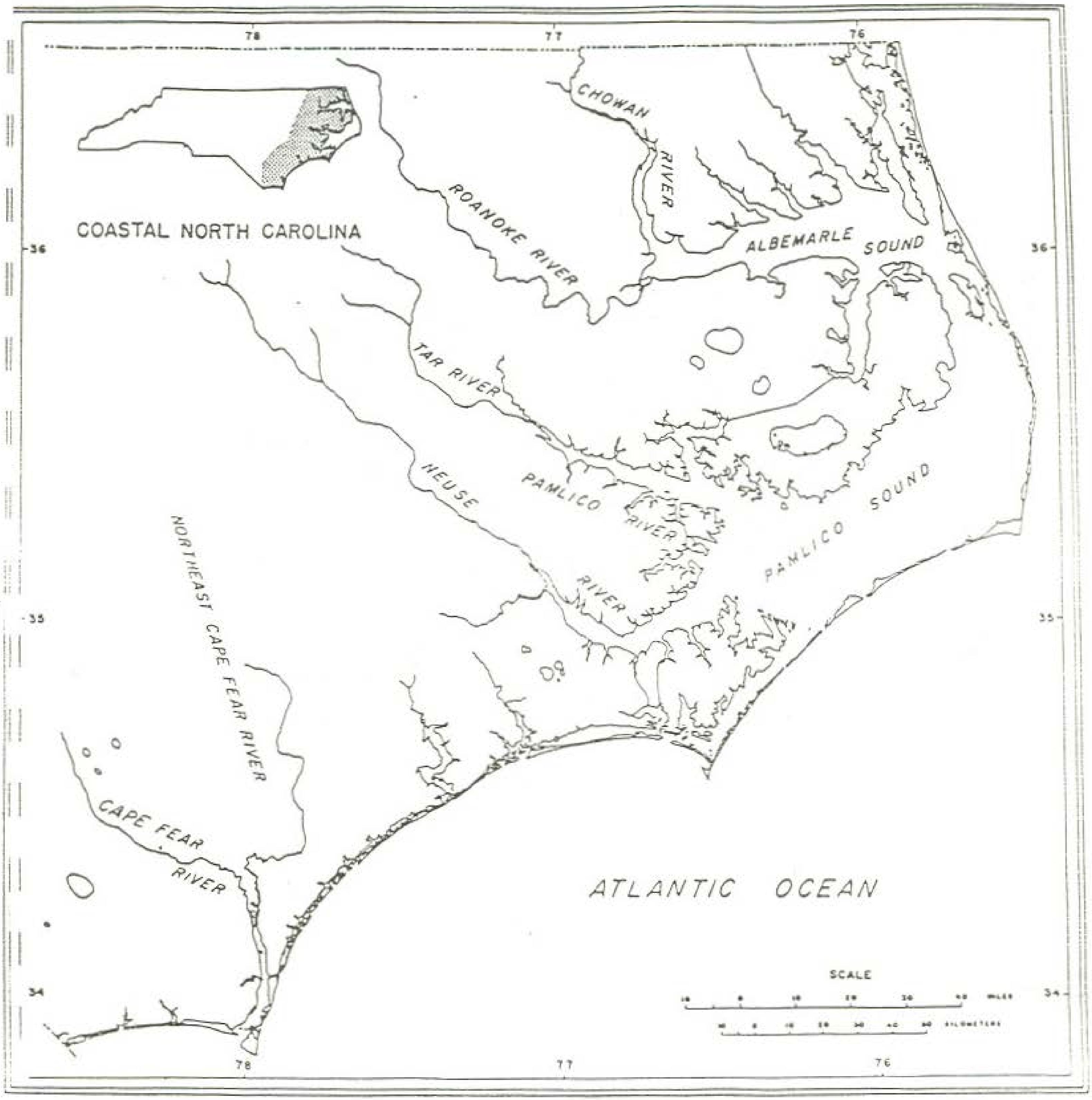
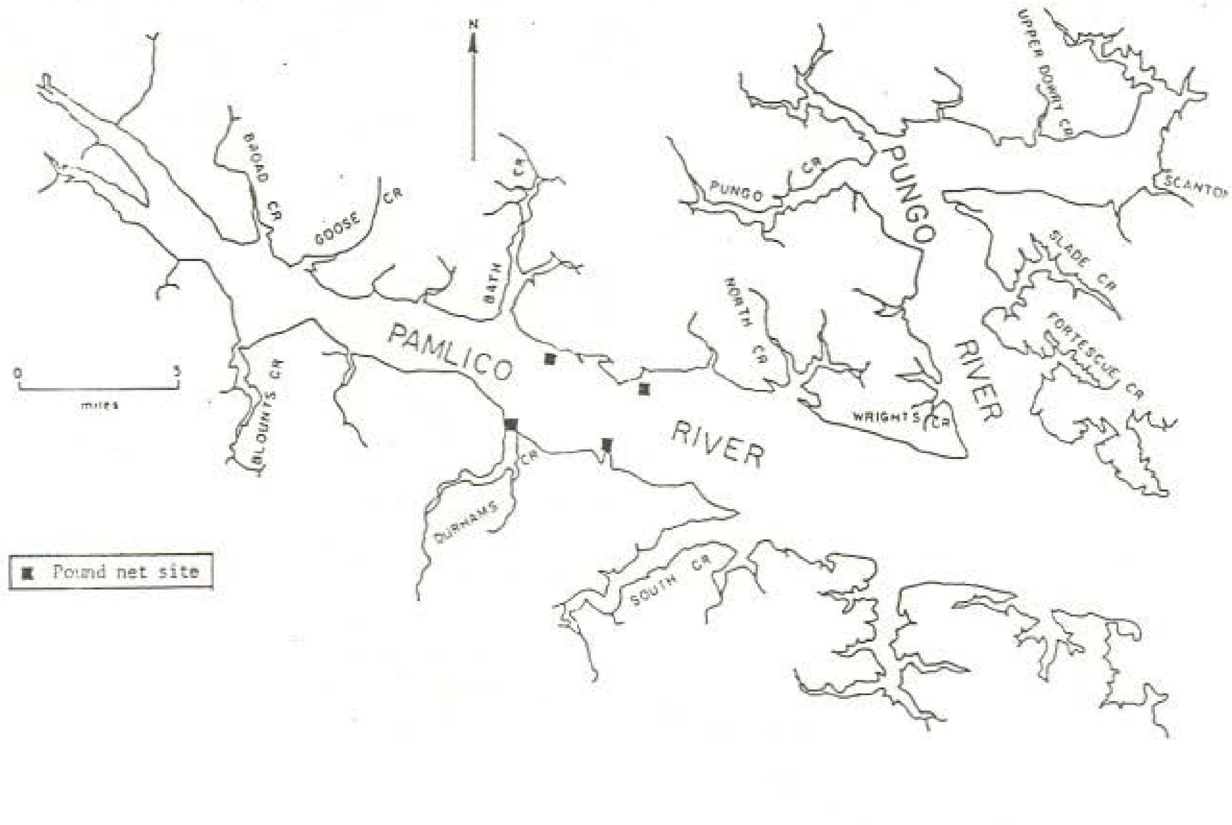


FIGURE 2
POUND NET SITES IN PAMLICO RIVER



State Response to Fish Diseases and Fish Kills

Jim Mulligan
N. C. Division of Environmental Management

In 1963, the N.C. General Assembly ratified the "Fish Kill Bill" [N.C. General Statutes 143.215.3 (a) (7)] which grants to the Environmental Management Commission (EMC) the power to direct the investigation of any killing of fish and/or wildlife which meets the following criteria:

(1) the magnitude of the event justifies investigation, and
(2) the event is the result (or is believed to have resulted from) the pollution of the waters, and
(3) the pollution is caused by negligent, careless, willful or unlawful acts.

When the polluter responsible for the killing is identified, the EMC may recover damages in an amount sufficient to replace the resource loss plus the cost of the investigation. Replacement costs can be based on reasonable estimates rather than actual number collected, counted, measured and weighed. Insofar as possible, funds recovered by this means are to be used as promptly as possible to replace the fish or wildlife killed. If this is not practicable, the proceeds shall be used to improve fish and wildlife habitat.

Using a rather parochial interpretation of this law as the mandate, the staff has investigated fish kills statewide for the past 24 years. Valuable experience in conducting investigations was gained through the implementation of other laws and regulations targeting pollution sources for permitting and monitoring. Kill investigations vary widely in nature and scope due to the individual peculiarities of the pollution sources themselves.

More Fish Die in Albemarle-Pamlico Estuary than in the Rest of North Carolina

There was no statewide format for collecting kill information until 1984. This format is a modification of one for oil spill reporting. A long overdue major change in the format and process is now underway through coordinating recommendations by the Division of Environmental Management (DEM) and the Division of Marine Fisheries (DMF). Kills reported through the statewide network total:

39 for 1984
57 for 1985
45 for 1986
35 for the first seven months of 1987

Because of the variability in how kill events are counted, the numbers are not totally reliable. Although these are admittedly "soft" data and the numbers may be deceiving, in the recent years when they are likely to be the most accurate, my region - the northeastern 21 counties - has had a disproportionate share of kills. Of the 45 reported in 1986, 13 were in my region; of the 35 reported so far this year, 19 are in my region. Even more noteworthy is the fact that 10 of the 13 in the region reported during 1986 were in the estuarine portion of the Pamlico, while the other three were in the estuarine portion of the Neuse. In 1987, of the 19 kill in my region, 14 were in the Pamlico and one each was in the Neuse and Albemarle.

Although I have no accurate numbers to back me up, I feel very confident in saying that on average, each year more fish die in the Albemarle-Pamlico estuary than in the rest of the state. And, of all the kills in the Albemarle-Pamlico that have ever been investigated, I can recall only three that were caused by a direct pollution source.

In other words, the area of the state having the largest number of kill events is also an area where the statute-based mandate has the least direct application.

This problem was recognized a number of years ago, and an attempt was made to coordinate the investigative powers of the N.C. Wildlife Resources staff, Marine Fisheries, and DEM on a continuous basis so that all incidents of fish and wildlife mortality which constituted a loss of public resource could be addressed, regardless of the presence or absence of a link to a pollution source. This cooperative program has succeeded in putting previously unheard of manpower resource levels to work on the kill problems.

Direct Relationships Between Pollution Sources and Fish Kills Have Rarely Been Established

What has been the outcome of this extraordinary effort? Frankly, the clear successes have been very few and limited in scope. For the most part, we have learned the investigative means and methods which are useful and descriptive in almost all other regions of the state are poor when applied to the Albemarle-Pamlico. Direct relationships between pollution sources, the quality of adjacent waters and the killing of fish have almost never been established. Either the pollution sources are small in relation to the size of the affected waters, or the concentrations of materials discharged have no known causative relationship to the mortality. Hydrodynamic complexities which defy analysis severely limit the effectiveness of investigations so that gathering even basic information regarding the waters in which the fish died is difficult.

So many of the kills in the Albemarle-Pamlico are related to either algal blooms or to low dissolved oxygen (or both) that a primary task of kill investigators is to determine whether or not these mechanisms are at work in the kill zone. The basic data set needed includes temperature, dissolved oxygen, salinity, Secchi depth, pH, alkalinity, nutrients (N and P), and chlorophyll and phytoplankton counts. Vertical and horizontal profiling in each segment of the affected water are also needed. The analyses of the samples generated by investigating large kill areas regularly overloads our capability. Analytical requests are therefore prioritized and many are never performed once a descriptive pattern of data is established.

Up until very recently, data collection during these investigations was specific to the area of the reported kill and immediately adjacent water thought to be directly related to the kill event. Because of the unpredictable water movement and the more than four hours between the onset of mortality and the initiation of sampling, the location of the "affected water" is often subtle. This time lag will be discussed in further detail later.

Unfortunately, patterning data collection in this way has not made trend analysis an easy task.

We are now attempting to include new monitoring stations established due to a particular kill event along with repeat monitoring at locations previously fixed by recurrence of past events or by ongoing monitoring programs. Insofar as possible, the important locations identified by Marine Fisheries due to fish activity are also targeted for inclusion in the monitoring schemes related to emergencies. This location coordination between the agencies sounds routine, but it has only become possible in the last three months, following long overdue equipment upgrades by the DEM staff.

Time Lag Between Kill and Report Presents Problem

The time lag between the active kill and the sampling of the waters has presented a real challenge. The reports of dead or dying fish usually come from fishermen or shoreline residents. Both have "built-in" time lags. Shoreline residents usually report dead fish soon after they see them, but they rarely see fish dying. The mortality occurs either at night and is seen in the morning or during the day and is seen when residents return home in the evening. Or, the kill occurs in another location, and the dead fish are driven to the reported location by wind or current.

Fishermen do see fish in distress but are involved in fishing and often do not report the event until the end of the day or report it through a chain of several people before contact is made with DEM or DMF.

The equipment and personnel needed to perform the investigation are often not readily available since the existence of both is justified by ongoing programs in which they are involved on a daily basis - often at locations in the field. We try to maintain a response capability continuously throughout the day, but the actual response capability does fluctuate.

Data collected indicate that the estuarine portions of the Roanoke/Chowan, Pamlico and Neuse all have at almost all times enough nutrients and organic material to cause algal blooms and/or anoxia when water movement and temperature conditions are conducive. The nutrient loading threshold for response has already been greatly exceeded, the type and degree of utilization of the nutrients seems to be dictated by flow (and thereby salinity) and temperature.

The investigation of fish disease is much more difficult to bring to a satisfactory conclusion than are the cases of acute mortality. Neither DEM nor

DMF has had staff experts in fish disease. Since the early 1970s in the Chowan and the early 1980s when the first large disease incident occurred in the Pamlico, we have depended on outside experts from other agencies and universities.

DEM does not expect to acquire the expertise necessary to complete the first steps in disease investigation: the definition of the mechanism of mortality and the epidemiological factors surrounding its occurrence. Once the mechanism of mortality is fixed and related to environmental factors, the monitoring of parameters that describe that environment can begin, with the expectation that management will follow.

It is likely that key elements of the Albemarle-Pamlico system having a controlling influence over the frequency, magnitude and duration of disease episodes are not being monitored by anyone. The key location may not be known or the parameter of interest at the important concentration may not be measured. It is probable that we have no appreciation whatsoever for the magnitude of change, rate of change, or recurrence frequency which controls the outbreak and severity of the episodes.

We are getting much, much better at describing the Albemarle-Pamlico system in the terms with which we are familiar. Recognizing the limitations of our resources to meet even these needs, we are anxious to receive information from the Albemarle-Pamlico Estuarine Study effort to guide us in setting program directions.

Discussion

Question: What do you use as a definition of a "fish kill"?

Mulligan: For years we relied on the statutes, which said that a mortality event had to be of significant magnitude. That was as specific as it got. The criteria were that it had to be significant enough to warrant investigation and that it be attributable to a pollution form. Frankly, none of the events in the Pamlico meet both those criteria. So we scrapped that definition, but we did not adopt a new one. I have personally told my staff that if it is a public resource loss that is attributable to a water quality change, then we need to quantify that water quality change if possible.

We are getting a new type of request for response, however, that has nothing to do with a public resource. We have a lot of information from fishermen with dead crabs in their pots or fish dead in pound nets or fish dead in unusual rates in gill nets and so forth. These events do not involve a public resource so I don't feel I have the same kind of mandate to investigate and try to describe these events.

Question: Is your reporting tied into EPA in any way?

Comment: EPA has abandoned its program of nationwide reporting of fish kills.

Mulligan: An EPA fish kill reporting form has been resurrected as of April 1986.

Question: Should be really be focusing on kills? How important are they in terms of overall population?

Merriner: It is likely that acute local impacts are not greatly significant in a population like menhaden with a wide range. The local effect is likely to be diluted by the normal survival in other areas.

Rader: The other side of that coin is that you have some pound net fishermen whose gear is static in an area where fish mortality is high so their resource is down to nothing. They have to leave the business. We have a significant loss of fishermen in the Pamlico region this year. That is a problem that we as a policy group need to address.

Hawkins: You can also look at fish kills as symptomatic of problems in the estuary. Anoxia may be natural and one kill by itself may not tell us much, but can we learn anything significant by looking at frequency of kills and location of kills? Is one area more susceptible to a kill than other areas? And if so, why? Is it because of the hydrodynamics of the area or some input caused by man? We are not even close to being able to answer that question.

Sindermann: But we need fish kills to get public attention and get public support for dealing with the underlying causes of mortality.

Mulligan: I wish we had a means of quantifying the primary producers. At one time North Carolina Phosphate, as part of its permit condition, was looking at phytoplankton count in the Pamlico River. I would think that if there were a change in the water chemistry or in the level of macro or micronutrients, that someone could detect it in phytoplankton data. We know, for instance, that there are toxic dinoflagellates there on occasion. We don't know what they are because they are so fragile we can't transport them to the lab to count or identify them.

We need some kind of capability in the area to do that kind of work.

Rader: I want to point out that we will be addressing that kind of issue between now and March. We are beginning to plan for a new or adapted monitoring program. This is a specific requirement of the new Water Quality Act under which we hope to be designated as part of the National Estuary Program.

I also want to emphasize that because this is a nonpoint-dominated system, the consensus building effort that has been alluded to is very fragile and takes a great deal of work.

A third thing I'd like to observe is that the time-lag factor Jim just addressed is critical in the design of a monitoring system. Some preliminary information from Duke Marine Lab shows a very strong diurnal periodicity in nutrient concentration, algal concentration, and DO concentration. No known response mechanism in place currently will allow quantification of those changes. So the design process we're embarking upon is very subtle, and I ask for your expertise in helping with the design.

Comment: Three or four weeks ago, just before we had a fish kill I stood on the shore in the Pamlico area and observed with one of the fishermen that the water had a flat, gray look, that the wind was calm, and that the temperature had been high for some time. The fisherman said, "We're going to have a fish kill."

Is there anything to this? Is it folklore or is there something we can learn from these fishermen.

Merriner: They know the water. They know where the fish are and where they are not going to be. Or where, if they are there, they're going to die.

Rader: They describe very interesting situations that we haven't quantified. What they call "dead water" and what it does to beasts in crab pots, for example, is something we have no good understanding of.

Merriner: We have been in places, monitoring the water while the fish were dying, collecting a good set of parameter data, and have been left unable to explain why fish are dying.

However, there are events that can be explained. One is building of anoxic water on the bottom over several calm, hot days, followed by wind which stirs up water and pushes it up onto shore. That water wipes out everything that can't run upstream and get away. The fishermen usually know which way the wind is going to blow, so they can predict where the kill will occur.

Hawkins: Because the hydrodynamics of Pamlico system are wind-dominated and because the sound is dominated by prevailing winds that typically last for several days, you get a calm side on the river, and that calm side is where most of the problems crop up.

Rader: DEM did a fairly extensive two-day survey on the 21st and 22nd of July in the Pamlico River and found levels of chlorophyll a exceeding 380 micrograms per liter whereas the seasonal standard for chlorophyll a is 40 micrograms per liter. So there are very large numbers of brackish water phytoplankters in that water.

Introduction: Approaches to Understanding the Importance of Disease Problems in Aquatic Systems

Ed Noga
North Carolina State University
School of Veterinary Medicine

The most obvious significance of the health of fisheries is that disease and mortality can result in a reduction in commercial yields.

Another aspect of the significance of the health status of fisheries is aesthetic. Obviously, people are not going to accept sick fish. Because of this, even though a fishery may be very productive, the actual sustainable yield in terms of market value is going to be reduced if the fish have obvious skin ulcers.

A related consideration which has not really been investigated but may have some importance to economic value is the public perception of the quality of life in an area where fish disease is prevalent. This perception could be particularly important to recreational fishing, which is an increasingly valuable industry in our Coastal area.

The third aspect of the health of fisheries that should be considered is the potential importance to human health. A number of studies done in other estuarine systems in the United States and throughout the world have found evidence that fish have a tendency to accumulate certain toxic substances such as carcinogens or heavy metals when they are present in the aquatic environment. If such toxins accumulate in edible fish, it can be very important from the standpoint of human health.

A consideration closer to our own situation is that many of the dermalogical diseases which we see in fish in the Albemarle-Pamlico Estuary can be primarily caused by or be secondarily infected by organisms which may be potential human pathogens. Particularly important are bacterial organisms such as Aaeromonas hydrophila and a number of other bacteria which are definitely known to be human pathogens.

Finally, the health of fisheries is also important as an indicator of the health of the ecosystem. It is important to know the relationship between fish diseases and other changes we're seeing within the estuarine system that have not been associated with pollution.

Steps to Developing a Strategy for Managing Fish Diseases

I would like to suggest several steps we must go through to understand how to manage fish diseases.

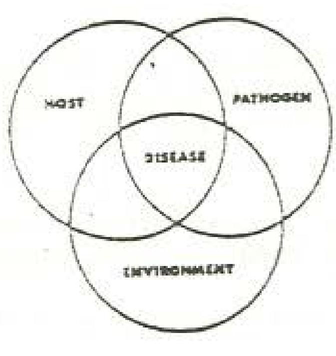
Of course, we have to first ask if we want to manage fish diseases. If there is no significant human input or human effect on these diseases, the question becomes, is it worthwhile or is it even possible to control them from a management standpoint. Unfortunately, we presently have very little information about what effects human activity or pollution have on these problems in the Albemarle-Pamlico Estuary.

We are currently still trying to identify the diseases, trying to discern what problems are present. This is important because many diseases can look similar, but each disease can have different risk factors associated with it. The disease problems can be defined in terms of the infectious organisms that are causing the diseases, but for the purposes of the Albemarle-Pamlico Estuarine Study, the primary concern is identifying the risk factors in terms of water quality that are allowing these diseases to develop in epidemic proportions.

Finally, if we are successful in determining the most important factors influencing the development of these diseases, it becomes the managers' duty to determine the appropriate controls to manage the problem.

Triad of Interrelationships Necessary to the Development of Disease

There is a very widely recognized relationship associated with the development of any particular disease. For any disease to occur in any particular environment, three major interacting factors have to be present in a particular state. First we have the host, which has to be in a particular state of receptiveness, that is, its immunity to the particular disease has to be at a particular level. Secondly, the pathogen or any noninfectious agent has to be present at a certain level of pathogenicity to cause the disease. And, most importantly, in order for these two factors to be in the proper state to produce disease, the environment has to be in a particular state. The environment influences and basically determines whether or not the disease will develop. So, it is the environment about which we are most concerned.



TRIAD OF INTERRELATIONSHIPS

North Carolina Research on Ulcerative Mycosis

Ed Noga
North Carolina State University
School of Veterinary Medicine

This project has been a particularly collaborative effort. Jay Levine, an epidemiologist, has coordinated the field aspects of the work. Michael Dykstra, another researcher in the School of Veterinary Medicine, has been primarily responsible for the mycological studies. Jess Hawkins of the Division of Marine Fisheries and Pete Kornegay from the Wildlife Resources Commission, as well as other people from the Division of Marine Fisheries, Wildlife Resources Commission, Division of Environmental Management, and the National Marine Fisheries Service Beaufort laboratory made essential contributions.

In our studies of ulcerative mycosis and some other diseases in the Albemarle-Pamlico Estuary, we have tried first to identify the hierarchy of infection. It is very critical to identify the primary, initiating pathogen because many skin lesions can be secondarily infected by opportunistic agents. Next, we have tried to reproduce the disease so that we have a model to help us understand why the disease develops in the natural situation. We have tried to develop a controlled method of infection so that we can expose fish to the organism under various water quality conditions and observe how the disease develops. Finally, as part of our overall approach, we have tried to determine all the diseases present, especially in relationship to those we want to focus on. Our group became involved with ulcerative mycosis in 1984 when Jess Hawkins approached us about working on the menhaden problem in the Pamlico River. Michael Dykstra, who is a mycologist, identified the organisms in these particular lesions. At the time ulcerative mycosis was presented to us, I had never seen any disease like it, and it is unusual.

Water Mold Identified as Cause, Not Known To Infect Saltwater Fish

We found that the organisms responsible for the disease are water molds of the genera Aphanomyces and Saprolegnia. These fungi had never been reported as the cause of disease problems in estuarine fish. They are considered to be classic opportunistic pathogens that affect freshwater fish, yet we were seeing large numbers of fish infected by them in the Pamlico Estuary and other brackish areas.

Developmental Stages of the Disease Reveal Aggressive Infection

Based upon examination of a number of menhaden, we defined a series of developmental stages for ulcerative mycosis and confirmed that this is a very aggressive fungal infection. It produces a dramatic response in the host, with inflammation extending deep into the muscle tissue, even around very small lesions. Water mold infections typically found in freshwater fish normally do not cause deep ulcerative lesions in fish. They normally cause very superficial infections on the surface of the body.

In the early stage of ulcerative mycosis, when the lesion starts to develop we see the formation of one of the characteristic features of this disease - what is known as granulomatous inflammation. In this inflammation, the host's cells actually surround the individual fungal filaments. It is a very unusual host response to water molds. We also see muscle necrosis and spread of inflammation.

It should be stressed that what we know about these lesions and how they progress has been learned from examinations of spontaneous lesions in wild fish. We have been able to do little study of the disease in fish in captive situations.

As the lesion increases in size, it reaches the advanced stage at which the central area of the lesion begins to slough and what we have is a large swollen mass of white dead tissue. At this stage we also see a swelling at the periphery of the lesion.

As the lesions become mature, the granulomas start to coalesce and surround the adjacent muscle fibers. Then, the central area of the lesion is sloughed, leaving a smooth periphery and a scooped-out appearance.

Secondary Bacterial Infections May Halt Growth of Lesions

One of our questions has been why do these lesions appear to slow down in development, or at least do not increase in size, when they reach a certain size. One factor could be that once the lesions become a certain size, the fish will inevitably die. However, this may not be the entire reason. Because we had observed this phenomenon, we wanted to find the relationship between the development of the lesions and the growth of the fungi. We wondered if perhaps the menhaden muscle tissue is really a poor medium for the growth of the fungi and if that limited the size of the lesion.

We inoculated sterile menhaden muscle with Aphanomyces and found no inhibition of growth. In fact, there was much more vigorous growth in the sterile menhaden muscle than on the medium normally used to grow the fungus in the laboratory. But we did find that if the muscle was contaminated with bacteria, there was very little fungal growth. So, we concluded that one reason that the lesions do not continue their rapid growth may be the heavy secondary bacterial infections present in the advanced stages of the lesions.

Occasionally, we will see in the field lesions which appear to be healing - that is, situations in which the fish seem to have overcome the infection. Usually, these healing lesions are very small, and one of their characteristic features is a pigmented area caused by pigmented cells from inside the peritoneal cavity. The pigmented area is actually a portion of the body cavity that can be seen through the surface of the skin.

Our studies of the distribution on the body of fish of these lesions shows a very site-specific relationship. In fact, over 65 percent of all lesions occur in or near the anal area.

Other Fish Diseases Present in Pamlico, Chowan

I would also like to point out that menhaden is not the only species affected by this disease. We have also seen ulcerative mycosis-like lesions on other fish as well. I call them ulcerative mycosis-**like** lesions because, while they all have the pathologic characteristics that we see in menhaden, we have not isolated fungi from these other fish, primarily because lesions are relatively uncommon. These organisms - even though you readily see them in the lesions - are very difficult to grow in culture, so they have not been identified.

So, while we cannot point to the specific organism causing the disease in species other than menhaden, we have confirmed a similar disease in a total of 11 species of fish. These species run the gamut, including seven different families. The only thing they seem to have in common is their ecological presence in a particular area - the Pamlico River.

In addition to ulcerative mycosis, there are a number of other diseases we have identified in fish in the Albemarle-Pamlico Estuarine System. (See Table 1) One is a red-sore kind of disease common in the American eel. We have tentatively identified the bacterium responsible for this infection.

The message is that there are a lot of different diseases at work in the Pamlico River and that the most prevalent one is ulcerative mycosis.

We have also conducted some studies of fish diseases in the Chowan River. We found a number of skin diseases in this river, and found that even though they look similar to the naked eye, they are caused by different infectious agents. Some are caused by parasites, such as protozoans; some are caused by bacterial and fungal infections; and some are the result of other disease problems. However, all the problems produce grossly visible lesions.

Experiment Indicates Reduced Immunity

In one of our experiments we exposed menhaden by injection to an Aphanomyces isolated from menhaden. In about eight days, there was a swelling response, but it did not produce any obvious ulceration. Then we injected the fish with a corticosteroid and simultaneously exposed them to Aphanomyces. In this case, we found that there was often a pronounced swelling that appeared as soon as one day, and histologically, we could detect the appearance of some ulceration. We also found granulomatous inflammation that we have associated with infection by the fungi. The conclusion that we draw from this preliminary data is that there may be some relationship between immunocompetence of fish and the development of the disease.

I have discussed the host and the pathogens. Jay Levine will present some information about the environment, specifically in terms of the development of field monitoring surveys which he has designed to try to identify areas of high risk for developing the disease.

Discussion

Question: Can you elaborate on what you think may be the initial cause that allows the fungus to invade?

Noga: One study that suggest a possible mechanism is one in which catfish were exposed to low dissolved oxygen. These studies have suggested that such adverse conditions may facilitate colonization by opportunistic pathogens. The fact that these organisms grow very quickly in necrotic muscle also suggests that prior muscle damage may facilitate infection. But we do not have enough evidence at this point to make any determination. Obviously, something is reducing the resistance of the host. That is the real question: What particular factors are reducing the ability of the host to resist the pathogens.

Comment: It would not seem that entire schools would be affected by mechanical abrasions.

Noga: I do not think trauma, itself, is an important factor. I think our studies exposing healthy menhaden to the fungi show that they resist very well. I think it is evident we are dealing with a situation of reduced resistance to infection. Whether that is due to local damage to muscle or to immune damage on an organismic level we do not know.

Question: Have you looked at individual survivors of the infection to see whether they have any biochemical changes?

Noga: We have not analyzed any enzyme changes or that kind of information yet. That data is often difficult to interpret because information we have about responses such as enzyme changes is based on domesticated animals, not fish, and thus we are making extrapolations to wild fish.

Question: In the course of your investigations have you categorized what would be a normal bacterial flora on the skin of fish and whether the loss of that would allow fungal invasion.

Noga: That is possible. We have not really identified every single organism present. But we do know from a quantitative standpoint the relative concentration of the bacteria that are present on the skin of normal fish. The bacterial concentrations on normal "healthy" skin (i.e., with no obvious skin lesions) are very low.

Question: What was the rationale for using the corticosteroid? What were you looking for?

Noga: Because the disease is being caused by opportunistic pathogens which are normally present in the environment and presumptively do not infect healthy hosts, I felt that something was reducing the resistance of the host. Elevated corticosteroid levels have been shown experimentally to actually increase the susceptibility of fish to opportunistic infection, such as by bacteria or fungi.

Question: What do you think is the significance of the lesions appearing on a particular site on the body, and are the lesions site-specific in all species or just in menhaden?

Noga: That was only for menhaden. This is our thinking on the site-specificity, and it is strictly speculation: Some work has been done with freshwater molds which indicates that pathogenic water molds may be attracted to low-level concentrations of nutrients. So, you can simplistically hypothesize that they may be attracted to chemeattractants released from the intestine. In addition, the anal area is one of the thinnest areas of the body, so it may be easier to get established there.

Question: Have you considered viruses as a trigger?

Noga: Viruses are a possibility. One thing that argues against it is that there are so many species of fish affected. Marty Newman can address the issue of viruses better than I can.

Newman: We have isolated infectious pancreatic necrosis virus from southern flounder in the Pamlico Estuary. We found it when we were looking at potential causes of a fish kill that occurred several winters ago. There was a low-grade inflammation that would be expected with infectious pancreatic necrosis. But we were not able to reproduce disease in the laboratory. So the virus is there, but it is not producing overt disease. But no one has explored the possibility of synergistic effects of viral infections in ulcerative mycosis.

Question: Are elevated corticosteroid levels something you would expect to result from an external threat?

Noga: Yes. Many kinds of environmental perturbations, including many pollutants, can cause elevated corticosteroid levels. And the acuteness versus the chronicity of the response is dependent upon the type and duration of pollution. It is an adaptation response to environmental threat.

TABLE 1
SKIN LESIONS OBSERVED ON FISHES IN THE PAMLICO RIVER

	Parasitic Dermatitis	Bacterial Dermatitis	Bacterial Myositis	Fungal Dermatitis	Lympho-cystis	Idiopathic Dermatitis	Idiopathic Myositis
Southern flounder				+	+		
Atlantic menhaden	+	+					
Gizzard shad							+
Atlantic croaker	+				+	+	
Grey sea trout	+						+
Spot		+	+		+		+
Silver perch		+					
White Shad							+
American eel		+	+				

Estuarine Monitoring for Ulcerative Mycosis

Jay Levine
North Carolina State University
School of Veterinary Medicine

Since May 1985, in cooperation with the North Carolina Division of Marine Fisheries with funds provided by the Water Resources Research Institute, we have been monitoring the occurrence of ulcerative mycosis in fish populations in the Pamlico River. The monitoring program was initiated to estimate the occurrence of ulcerative mycosis in fin fishes in the Pamlico River and to attempt to identify locations at which fish were possibly acquiring the infection. Initially, two methods of sampling were chosen: pound nets and trawling. A brief cast net survey has also been conducted, and in this coming year we will use sentinel fish held in pens to spatially focus on the problem.

Our initial studies have focused on the species distribution of the problem, the age classes that are affected, and temporal and spatial trends that might be associated with the problem.

Trawl Surveys Reveal Temporal and Relative Spatial Distribution of Ulcerative Mycosis

To choose sampling sites for our trawl survey, we defined 300 1/2-square-mile grids, then randomly chose 24 as sampling sites. Adjacent grids were discarded because the gear used did not permit exact measurement of the grid area while trawling. The sampling sites selected included a variety of bottom strata and represented a cross section of the river from the middle of Blount's Bay to Pamlico Point.

Samples are obtained by scouting the shoreline for landmarks then trawling at 74 meters/minute for 10 minutes with a 23-foot work boat. Salinity, dissolved oxygen, and temperature are monitored at each trawl site. During the first three months of the study, we evaluated different types of trawling gear to determine which would provide the most appropriate representative sample of our target species, menhaden. A 20-foot, three-seam wing net with 3/4 bar mesh and tail bag mesh proved most fruitful. Unlike the crab and surface trawls we attempted to use, this net fishes nine feet of the water column.

In March 1986, we evaluated the difference a switch from diurnal to nighttime sampling would make in our catch per unit effort. Day and night replicate trawls were collected in February 1986. Nighttime sampling dramatically increased our catch per unit effort. In March 1986, we switched from daytime trawling to evening trawling and more than tripled the number of fish caught per trawl.

In April 1986, we once again altered our trawling routine. Preliminary work from the trawling conducted in 1985 and complementary laboratory work suggested that the disease might be more prevalent in areas of lower salinity. Indeed, in the laboratory, the fungus that is associated with the lesion seemed to grow best at salinities between two and six parts per thousand. Accordingly, in an effort to focus our trawling in areas where the fish were most likely to be infected, we shifted our trawling activities up river.

Twelve sites east of Bayview were replaced by six sites in the upper Pamlico, and our trawls are now conducted from an area adjacent to Washington Park to Ragged Point.

To date, more than 50,000 fish representing 32 species have been collected by trawling and examined for lesions.

Any gear that potentially could be used is inherently biased toward collecting a certain size fish. The majority of spot, cro ker, and menhaden - the three most frequently collected species - have ranged from 31-201 mm in fork length (FL).

Each fish in the trawl is examined for lesions. Lesions are later scraped and wet mounts stained with lacto-phenol cotton blue to determine if fungal hyphae are present. We consider characteristic lesions from which the fungus is recognized compatible with a diagnosis of ulcerative mycosis.

Menhaden was the most frequently affected species. Indeed, ulcerative mycosis appears to be primarily a disease of menhaden. Although lesions were found in other species, the number of fish of other species found infected was small.

Lesions occur most frequently in the cloacal region and adjacent flank of 65-120 mm FL menhaden. Although spot and croaker occasionally have cutaneous ulcers, fungal hyphae are only occasionally observed in the lesions.

The collections may be biased toward collecting sick fish that are not able to move out of the way of the trawl, but we have collected considerably more healthy than diseased fish. Although we may not be able to say precisely what proportion of the fish in the population are affected we feel that the trawl survey provides a reasonable estimate of the temporal and spatial distribution of the problem in the system.

The disease was most prevalent during May and June in 1985, with a slight increase observed in the winter. In 1986, we observed a similar seasonal pattern. More than 60 percent of the menhaden collected during May of 1986 were affected. Indeed, at times 100 percent of the fish in individual trawls would be affected. Individual schools seem to have quite variable infection rates. A single large specimen greater than 150 mm is often collected with a cohort of smaller fish, and this large specimen is often affected. Small numbers of affected fish are collected throughout the year.

Infection Potentially Correlates with Rainfall

The salinity, dissolved oxygen, and temperature of the water are assessed at each site of a trawl sample. There was no apparent association between mean salinity, dissolved oxygen, and temperature and the occurrence of disease in menhaden.

The potential association of rainfall and the occurrence of the disease was evaluated as well. Rainfall data was provided by the U.S. Geological Survey. In 1985 and 1986, the proportion of menhaden affected increased following periods of dry weather and declined during periods of heavy rainfall. This relationship seems somewhat paradoxical in light of the fact that the disease was apparently initially recognized during 1984 when there was extensive rainfall and salinities in the system were suppressed. Although it would have been interesting to compare the temporal occurrence of ulcerative mycosis in May 1985 and 1986 with the occurrence of the disease in May 1987, during a particularly wet spring, the project terminated in April 1987.

Pound Net Sampling Also Shows Peaks

Since May 1985, we have obtained samples from a pound net located in the Bayview area of the Pamlico. A second net was sampled during August 1985 through May 1986. Two additional nets initially available are no long available for sampling: one was dismantled for cleaning and the second was lost in a storm.

The pound nets are static devices, which are nonselective for species greater than 70 mm FL. Because the nets are at fixed locations, they have not provided a representative sample of the general prevalence of the disease in fin fishes in the Pamlico. They have, however, provided us with the ability to monitor the species distribution of the disease and the temporal occurrence of the disease in the river.

To date more than 9,000 fish representing 29 species have been collected in the pound nets and examined. Menhaden was the most frequently collected species and the most frequent species found affected with UM. The disease was most prevalent in May and June of 1985 and 1986 when about 14 percent of the fish collected in the pound nets was affected. A winter peak was observed in December 1985 in our Bayview net and January 1986 in our Durham Creek net. A small number of affected fish (less than one percent) were found at other times throughout the year.

There was no apparent association of salinity, dissolved oxygen, and temperature with the occurrence of disease in menhaden collected in the pound nets. However, as we observed with the trawl survey, the rate of infection appears to peak after periods of drought and decline during extended periods of rainfall.

Although up to 100 percent of an individual trawl sample has been found affected, no more than 14 percent of menhaden in any single pound net sample has been found to have lesions. This may be due to the static nature of pound nets. A single 24-hour harvest from the pound net schools may include different schools of fish affected to varying degrees. The location of the net may also determine the direction the fish are moving when collected. If fish are acquiring the infection upstream and a given net tends to collect fish moving upstream, the infection rate in that net may be lower than expected. In contrast, the trawling effort may collect a single school with a high rate of infection. Therefore, pound net samples may be diluted by the movement of nonaffected schools into the net. The trawl may also be biased toward collecting less mobile diseased fish that cannot swim out of the way of the net as it is pulled through the water.

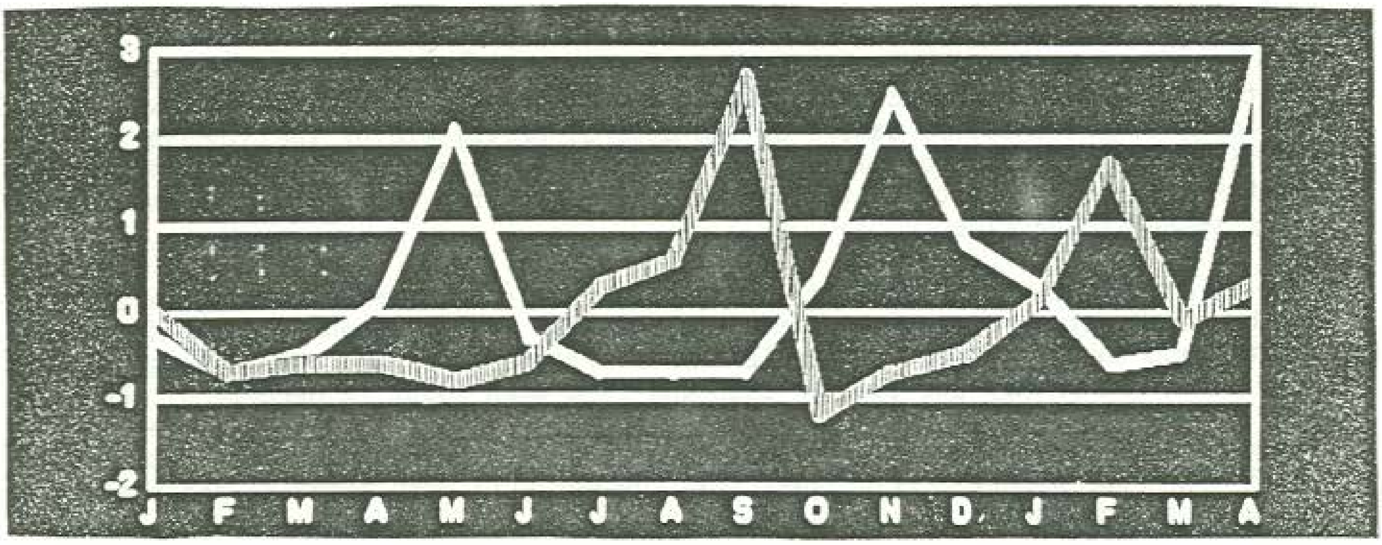
FIGURE 4

OCCURRENCE OF ULCERATIVE MYCOSIS

IN BREVOORTIA TYRANNUS IN THE PAMLICO

AND RAINFALL

JANUARY 1986 - APRIL 1987



Z SCORE PERCENT WITH LESIONS

Z SCORE MEAN RAINFALL

Cast Net Survey Facilitated Sampling Further Upstream

Unusually high salinities during the summer and fall of 1986 facilitated the movement of menhaden into the Tar River and small tributaries of the Pamlico, areas that were too shallow to use our trawling gear. In October and November 1986, we conducted a cast-net survey in these tributaries to facilitate sampling in these locations where trawling could not be conducted. We worked at eight sites between Washington Park and Bear Canal in the Tar River in October and November 1986. In October, the proportion of fish affected seemed first to increase as we moved up river and then decrease again as we moved toward fresh water. Our success in catching menhaden in November declined drastically as the fish moved out of the river. However, in November, we observed an increase in the proportion of fish affected both in our trawl and pound-net survey, as the fish began to move out of the estuary. Since fish between 65 and 120 mm are primarily affected, we believe menhaden are acquiring the infection in the estuary, particularly in the upper part of the estuary. Indeed, researchers with the National Marine Fisheries have similarly suggested that ulcerative mycosis is being acquired in the estuary and not in the sound.

Conclusions

In conclusion, we believe that ulcerative mycosis is primarily a disease of menhaden, particularly those between 65 and 120 mm and that the disease may be acquired in the upper part of the estuary.

Discussion

Question: Have you looked at your data in terms of life history stage in comparison to station and salinity?

Hawkins: The data we have indicates that typically, the fall infection peak strikes mainly young-of-the-year individuals migrating out of the estuary or downstream. The spring peak tends to affect a conglomerate of the fish that grew to some extent over winter - over a 100 mm in fork length. We have sampled three peaks: the '85 fall peak, the '86 spring peak, and the '86 fall peak. So, we are trying to correlate with just three peaks. That is why it would have been good to have data from spring 1987. There was anecdotal evidence from fishermen that there was a large outbreak of the disease in the spring of '87. If we had been able to sample then, it would have cleared up some of the questions we have about these peaks.

Levine: There are a number of things we would like to do with data, but because our data has been taken only once a month, every two months, or quarterly, essentially the only useful information we have is these peaks. We would like to look at various water quality parameters to see whether or not perturbations of the parameters could be associated with the peaks, but the data is not frequent enough or consistent enough to use for these purposes. It looks as if we are dealing with a disease that may develop over a period of a couple of weeks, but we are not monitoring frequently enough to know what is going on in the system during periods of rapid change.

Question: Are the size distributions the same in pound net and trawl samples?

Levine: No. The pound nets catch fish larger than 70 mm. In the trawl collections we have gotten fish in the 30-40 mm range.

Question: What distribution of infection in relation to length did you see in the trawl surveys during the spring and fall peaks?

Levine: There is a change in the length of the fish throughout the season.

Question: Have infected crabs been examined yet?

Noga: The histological data are not in yet. There appear to be a lot of bacteriological agents present, but we have not been able to identify any organism as the initiating agent of the lesions in crabs.

Concerns for Fish Diseases in EPA Region IV

Jerry Stober
U.S. Environmental Protection Agency
Environmental Services Division

There is an increasing focus on marine and estuarine problems in Region IV. In just the last year and a half, a regional marine and wetlands group has been established. Since joining EPA, I have spent some time traveling around the coastal areas talking to research groups about important coastal issues and current research efforts.

So far I have visited researchers in Georgia, South Carolina, Mississippi, Alabama, and northwest Florida. The concern over fish diseases does not seem to be as great as it is in the Albemarle-Pamlico area. As far as I have been able to discern, fish diseases have not posed serious problems in these areas possibly because of better estuarine and marine circulation. There are some major hydrodynamic differences between North Carolina estuaries and other estuaries along the coastal area in Region IV. The coastal barrier beaches in North Carolina entrap and retain estuarine waters exacerbating any existing water quality problems.

Puget Sound Project Illustrates Need for Long-Term Research, Interim Management Action

To give you some idea of what you may be facing, I want to discuss briefly the Puget Sound Estuary Project in Washington state. In the 1950s and 1960s, there were problems associated with excessive discharges of oxygen demanding wastes from municipal plants and pulp and paper mills in the Puget Sound. Those problems were solved by requiring primary and eventually secondary treatment. In the 1970s and 1980s, it was discovered that many of the toxic wastes discharged over the years were concentrated in the sediments in parts of the sound, primarily river mouth estuaries which are currently termed "toxic hot spots." The "toxic hot spots" affect only about 5 percent of Puget Sound; however, the river mouths are critical for many fish and shellfish and are the focal points of human activities on the Sound.

When toxic sediment is the problem in an estuarine system, there are no obvious fish kills, so the problem is not immediately evident. In the river mouth estuaries of the Puget Sound, fishermen and researchers began to find flatfish (English sole and starry flounder) which exhibited higher than normal rates of epidermal papillomas, liver tumors, and other associated lesions. Research over the last 10 years has tried to make a connection between the veritable chemical soup found in sediments and the high incidence of cancer in flatfish. While there is a good correlation, and while it is fairly certain that there is a connection, no one as yet has been able to induce these tumors in fish under controlled conditions. It takes a very long time to get results from this kind of research. It requires persistence and program continuity.

The diseases of concern in the Albemarle-Pamlico Estuarine System are much different from the cancerous bottom fishes in the Puget Sound, but the lesson is the same. If you really want to determine a connection between impaired water quality and fish diseases in the Albemarle-Pamlico System, you must make a long-term commitment. There are few short term answers. However, because this kind of research does take a long time, while the research continues, management actions must also proceed.

Fish Diseases Present Opportunity to Educate Public, Build Consensus

In the Puget Sound case, one thing the cancerous fishes did was galvanize public opinion. The problem may have been somewhat blown out of proportion by the media because the area affected made up only a small percentage of the Sound. The publicity did keep the issue alive, and people were aroused to take action. It became an issue in the gubernatorial campaign, and the politicians decided they were going to do something about it. Unfortunately, politicians rarely realize how long it takes to solve these kinds of problems. Nevertheless, the state did establish a new agency, the Puget Sound Water Quality Authority, to bring together federal, state, county, and city agencies and to focus the resources and limited authorities of all these agencies on the water quality issues troubling the sound.

You may have the same situation of fragmented responsibilities and authorities in North Carolina, but I am not recommending an authority to you - at least until the Puget Sound Authority has been in operation a couple of years and can give you some idea if this approach will be successful. What they have done thus far is develop a management plan and initiate a public education process to make people in the Puget Sound region aware of the problems, what the problems have to do with their life styles, and the possible options for improvement. Fish disease does get people in a variety of situations thinking about the same thing. If the disease can be tied to environmental degradation, it can be very helpful in promoting a consensus on effective management actions.

The management agencies need to take advantage of the attention the National Estuary Program study is focusing on the Albemarle-Pamlico System to start consensus building. It is important to formulate a management structure for the future to deal with the multitude of agencies with responsibility for water quality and associated resources. A consensus will allow the focus of more local, state, and federal resources on this problem. Federal funds alone cannot be expected to fund these efforts to the level required.

Concept of Adaptive Management May Be Key to Dealing with Situation Now

In closing, I will mention that the Puget Sound Water Authority was modeled on the Northwest Power Planning Council (NPPC), which has a little longer track record. It was established by Congress in the late 1970s by the Northwest Power Act and began operation in 1980. The fish and wildlife program under the NPPC is now beginning to show some timely results due to the application of the philosophy of adaptive management. This approach has the benefit of allowing managers to proceed on the best available information and to implement corrective actions as research produces new information. The annual management of renewable resources must continue; however, the system must allow continual incorporation of new concepts into the plan. The successful use of this strategy is beginning to show in the Columbia River Basin.

Ulcerative Disease Syndrome Research In Florida

Tom Savage
Florida Department of Environmental Regulation

Our fish disease problems have appeared in Tampa Bay and in St. Johns River near the Jacksonville area. Our research has been centered in Jacksonville.

We received our first reports of diseased fish in 1984 from shrimpers in landings in the St. Johns River Estuary, on the Atlantic coast of Florida. There was a public outcry, and in 1985 the governor designated the Department of Environmental Regulation as the lead agency in investigating the disease.

Surprisingly, there was little turf-defending by other agencies, even though there are many state agencies that can claim some responsibility in the issue. That may be because some people foresaw another "red tide" problem. In Florida, "red tide" is a code for lots of money up front, lots of equipment, lots of personnel, many years spent to determine that this is a natural event that we have to adapt to and that management strategy does not include eradication.

In April 1985 a technical advisory committee was established including personnel from pollution control in Jacksonville, the Fish and Wildlife Service, the Department of Environmental Regulation, the Game and Fish Commission, the Department of Natural Resources, and others. This group was established to devise strategies and approaches to solving the problem, but they had very little information. When they started looking for contacts, they discovered the research on ulcerative mycosis being done by the group in North Carolina and began looking to them for information that would allow them to anticipate the progression of the syndrome.

Water Mold Discovered in Diseased Fish in Jacksonville Estuary

In June 1985, a team was assembled to survey the problem through field collections. They found that although menhaden is the species most affected, in our area the yellow mouth trout is also heavily affected with these lesions. The
lesion characteristics were found to be basically the same as those found in Albemarle-Pamlico fish. Microscopic characteristics were found to be the same also, with Aphanomyces being the primary degenerative agent. We also found that on menhaden, the lesions were fairly site-specific in the anal area.

Although we did find evidence of a degenerative disease in mullet in the Manatee River area below Tampa Bay, we were not able to characterize the disease. What we saw in the Manatee River samples were basically different from the ulcerative disease syndrome (UDS) we saw in the trout and menhaden in the Jacksonville area. We have not found any evidence of UDS on the south Atlantic coast of Florida - not because it is not there, probably, but because we do not have a good response capability.

Once we documented the extent of the problem in the Jacksonville area, it became evident we would have a full-blown program to deal with it. It then became necessary to design the program. Our technical committee outlined a strategy for a comprehensive approach. This included the following (not in priority order):

1. Analysis of existing data
2. Coordination with North Carolina group
3. Collection of specimens
4. Assessment of human health risk
5. Pathological study
6. Fish microbiological study
7. Fish body burden study
8. Epidemiological study
9. Ambient water quality study

Along with information from the North Carolina research group, something that has been very valuable to us is the knowledge of local fishermen. They have helped to bring in samples, provide historical information and, in some cases, predictive data.

In regard to human health risk, we have had a person from the state human resources staff on all our committees to review requests for proposals (RFPs).

Prior to the time that the Florida legislature appropriated funds for UDS research, we got some EPA 205-J money, which is discretionary money that can be expended for problems related to pollution. That money helped fund research by Dr. Diane TeStrake at the University of South Florida, who did some of the early work on the ability of Aphanomyces to tolerate salinities, and research by fish pathologist Dr. Harry Grier at the Florida Department of Natural Resources.

In June 1986, the legislature appropriated $250,000 to the Florida Department of Environmental Regulation for UDS research focused on the Jacksonville area. This appropriation came about in large part because freshman legislators from the Jacksonville area were looking for issues. There was, then, a parochial aspect to this research. Sometimes that can be harmful - if localities compete for and dilute funding, but, in this case, it worked out well because the Jacksonville area was the only place we had problems.

Shortly after research funds were appropriated, we established an external peer review panel to give us advice on RFPs. We formalized our connection with the North Carolina research group by asking Ed Noga to serve on the peer review panel.

We have a statutory requirement that contract research money has to be spent by the end of the contract year, so money isn't just encumbered. The legislature has recently appropriated an additional $150,000 to allow us to do a year's survey.

We have four kinds of projects underway: sampling to determine UDS distribution and frequency, water quality, pathology, and data base development. Jay Levine at NCSU has the contract for data base development, integration, and interpretation. We expect that this data interpretation will help us decide at the end of the year whether we know enough to set management goals or whether we need to go back to the legislature and request funding for additional research.

Ecosystem and Fishery Implications of Ulcerative Mycosis

John Merriner and Douglas Vaughan
National Marine Fisheries Service
Southeast Fisheries Center
Beaufort, North Carolina

Many different anomalies are seen in estuaries and their fauna. We see pug-headed striped bass, humped-back fish, fish with sores, dropped-jaw fish.

However, when you see a dead menhaden with ulcerative mycosis, you probably will see several thousand, and we do not really know whether disease, pollution, DO, or some other factor causes these fish kills.

Our concern is not strictly what kills the fish but what effect fish kills and fish disease have on fish populations. You are familiar with the triad of interrelationships - the host/pathogen/environment match that must exist for disease to develop. Our focus will be on the host and the environment.

The host/environment relationship is extremely complex. We find it impossible to determine whether what is occurring in the Albemarle-Pamlico Estuarine system is an acute fish kill phenomenon or a chronic sublethal effect.

Menhaden Life Cycle Depends on Estuaries

The host we will focus on is menhaden. Menhaden typifies many other estuarine organisms. It utilizes the inshore water as a nursery ground: it lives and eats and breathes in the estuary, near man. It does spawn offshore, and it does migrate both north and south, so it can be a vector for disease or it can be exposed to a number of other contaminants during its migrations.

The typical life history of an estuarine animal - using menhaden as an example - is as follows: Menhaden spawn offshore at about two to three years of age. Their eggs hatch offshore, and the larvae migrate or are transported into the estuary. They spend the first growing season in the estuary and move into the nearshore ocean waters in the fall. Obviously, menhaden are euryhaline: they live in salinities ranging from full strength seawater to near zero salinity.

The adults and juveniles do not eat other fish: they eat plankton, sieving food organisms as small as seven or nine microns in size, so they could be ingesting the oomycete zoospores thought to cause ulcerative mycosis. Larvae pick individual food particles, but, once they reach the juvenile stage, they are not selective, eating any plankton retained by their gill raker apparatus.

In the Southeast, their sieving efficiency is assisted by detritus, which can contain bacteria, algae, and maybe the fungus that seems to cause this disease.

Range and Mixing of Menhaden May Dilute Local Impact of Disease

In the fall, the adults and juveniles (about one year old) migrate south. In the spring they migrate north. We see menhaden from Florida to Maine. Other species that have been observed with disease problems and with ulcerative mycosis have a similar range. In assessing the effect of disease on populations, it is important to recognize the range of habitat and mixing of individuals from different areas. A broad range and extensive mixing mean that a severe local impact must be weighed against what is happening elsewhere in the system before it can be said to be of great consequence on a population scale.

Individual fish may indeed be vectors for the disease. If they catch it in North Carolina estuaries and migrate north or south, they could be transporting it. On the other hand, they could die of the disease while they are here, or they could migrate out and be cured by the saltwater dip.

Ulcerative Mycosis Is Not Seen in Commercial Menhaden Fishery

Atlantic menhaden are subject to extensive purse seine fishing from Maine to Florida. We talk about the size of this fishery in terms of thousands of metric tons. The Atlantic menhaden fishery together with the Gulf menhaden fishery account for about 41 percent of U.S. commercial finfish landings by weight.

Menhaden landings have not been stable historically. Since the 1940s we have seen increases and declines. Since the mid-1950s the National Marine Fisheries Service has had a monitoring and fishery research program on Atlantic menhaden. Our data base on age and size in landings is as comprehensive as any that NMFS has. So, when we try to determine population level effect of a disease or some catastrophic event, we have a good handle on the numbers of this population.

North Carolina and the Chesapeake Bay are the roots of the menhaden fishery. A standard menhaden steamer lands up to a million and a half standard fish (two-thirds-pound). That translates to one million pounds of fish. We sample catches at port, taking a dipper full out of the top, to determine the size and age composition. Sometimes we sample more intensely, as when trying to check on incidence of ulcerative mycosis.

In 1986, we did not see any ulcerative fish in commercial landings. We did find ulcerative fish in North Carolina landings in the winter of 1984-1985. We tracked the ulcerative fish from catches that were made in the Pamlico River system. They migrated out of the estuary, and the fleet followed, fishing on the migrating fish schools. Some "peanuts" with ulcerative conditions also were found in the catches made in the ocean waters off Bogue Banks and southward. That was the only time we have seen ulcerative fish in a commercial purse seine catch.

Chronic Effects of Ulcerative Mycosis on Menhaden Population May Be Worse Than Acute Effects

If we do not find manifestation of ulcerative mycosis in commercial catches, how do we determine the effect on the population? Menhaden support the nation's largest fishery, and this disease has been cited as a potential cause of future declines in the fishery, so the effects are of obvious concern.

However, since we find the disease only in the estuary and since a seawater dip is a good curative agent of fish culturists, if ulcerative fish live long enough to migrate out to sea they may get rid of the fungus disease. If that is the case, the disease may have little effect on population numbers.

We have a very good data base on Atlantic menhaden population, so we went through an exercise to construct indices of abundance to see if we could detect a reduction in numbers. This exercise, of course, is based on the hope that the disease outbreak in 1984 was a one-time event and not a chronic problem.

Our first index of abundance was catch-at-age-two during the period 1973-84, when the fishing effort was relatively constant. The other index of abundance was recruits-to-age-one - the age group where you would see the effects of disease first. (See Table 2)

To summarize the results of these analyses:

* For an alpha level of 0.05, there is a 50:50 chance of detecting a 40 percent reduction in catch-at-age-two or a 71 percent reduction in recruits-to-age-one.

* If the type I error is increased to 0.1, then for a 50:50 chance of detection, a 33 percent reduction in catch at age-two and 64 percent reduction in recruits-to-age-one are detectable.

* Finally, for an alpha level equal to 0.05, if we require statistical power of 95 percent, a 66 percent decline in catch-at-age-two or a 90 percent decline in recruits-to-age-one is needed for detection.

These results are from Vaughan, Merriner and Schaaf (1986) "Detectability of a reduction in a single year class of a fish population." The Journal of the Elisha Mitchell Scientific Society 102:122-128.

The bottom line is that it is very difficult to determine whether some apparently catastrophic event on a single-year class can have a future impact on the population, particularly a population like Atlantic menhaden, which is highly variable in recruitment and abundance and is spread over a very wide geographic area. Some other statistical techniques can reduce the variability and thus increase the statistical power of the analysis, but there is no guarantee that these techniques will reduce the variability by very much.

TABLE 2

PERCENT REDUCTION DETECTABLE IN SUBSEQUENT CATCH IN NUMBERS AS AGE-2 OR SUBSEQUENT RECRUITS TO AGE-1 FOR ATLANTIC MENHADEN

Percent reduction detectable in subsequent catch in numbers as age-2 or subsequent recruits to age-1 for Atlantic menhaden. Alpha is the probability of incorrectly rejecting the null hypothesis that there is no reduction (Type I error) and power is the probability of correctly accepting the null hypothesis of no reduction (1 - type II error).

Alpha	Catch at Age-2	Recruits to Age-1
	Power = 0.50	
0.05	40%	71%
0.10	33%	64%
	Power = 0.95	
0.05	68%	90%

To put it in the vernacular, you have to kill a lot of fish before you are going to see a difference. As Jay Levine indicated, infected fish in their pound net samples ran as high as 90 percent. In the catches of "peanuts" mentioned earlier, the rate of infection ran from one to two percent. What are we to conclude from this?

Model Assuming Chronic Effects Predicts Reduction to 60 Percent of Biomass

Our staff has constructed a model to tell us what would happen if chronic pollution caused an incremental decline of 0.5 percent a year in the survival of young fish over a 30-year period. The model projects a reduction to 60 percent of the normal expected biomass. The ramification of this on the fishery is far greater than the effect we have seen from the acute events that have been analyzed. We added an acute mortality event to the chronic scenario - one event in year 14 - and got an additional 10 percent drop, knocking the projected biomass to 50 percent of what would normally be expected.

We do not want to diminish the concern about the acute impact of ulcerative mycosis on the Atlantic menhaden fishery, but we do believe that the long-term effects are potentially greater, if it is a chronic mortality event, something that will be with us long term. Thirty years down the line we may be wondering where all the menhaden, trout, or flounder went. Fishermen are already saying that for some species; sometimes we need to pick up on anecdotal evidence.

Fish Diseases Can Have Economic Effects On More Than Commercial or Recreational Fishery

But before we even get to the long-term economic impact on the fisheries, there will be aesthetic effects that will impact economically. You will not be able to sell ulcerative flounder. You will not be able to sell eels with ulcers. The general public will see ulcerative fish as a sign of poor water quality, and you will not see as many tourists because they do not want to swim in the water.

If you cannot swim in the water or eat the fish and seafood, why go to the coast? Then, we will begin to see impacts on land values as well.

In summary: The Atlantic menhaden fishery is an important national resource, but it is impossible to gage the impact of local events of ulcerative mycosis on the menhaden population. To do that we need to know the scope of the disease on the Atlantic coast, and we do not have a consistent search for evidence of the disease throughout the Atlantic seaboard. However, ulcerative mycosis may be a symptom of something wrong in the estuarine system. Mother Nature may be trying to tell us something, and the question for the Albemarle-Pamlico Study is whether or not we are listening.

Discussion

Question: Do you have any idea what proportion of all the menhaden would go through the North Carolina estuarine system?

Merriner: I would not want to estimate a percentage, but I will say a fairly large proportion. North Carolina and Virginia represent the heart of the menhaden population on the Atlantic seaboard. We do not have figures on what proportion various nursery areas contribute to the overall menhaden population. We would like to have those figures, and some studies underway may allow some estimates eventually.

Question: What is the annual value of the Atlantic menhaden fishery.

Merriner: The Atlantic and Gulf menhaden fisheries together are valued at about $120 million, if we ascribe dockside value at $.05 per pound. The Atlantic fishery is about one-third of that, so its value is about $40 million annually.

Comment: So over a period of 14 years, a fifty percent reduction comes out to a lot of dollars.

Question: What is the potential food-chain impact? Of what importance to the internal estuarine food-chain are the "peanut" menhaden?

Merriner: Menhaden is a dominant plankton feeder in the estuary, and nearly everything else eats menhaden to some extent - trout, striped bass, flounder. I know of no particular species that depends on menhaden exclusively, but if the menhaden are not available, a lot of other species will have greatly reduced food sources. Menhaden probably represent 10 to 15 percent of the food for a lot other animals.

Question: Did you see any evidence that UM is affecting total abundances in juvenile menhaden at any particular time of the year?

Merriner: We do not have a method of estimating the standing stock of juveniles. In the future, there may be a methodology for making quantitative estimates, but right now there is not.

Question: Was 1984 a good harvest year for menhaden?

Merriner: Yes. But a problem you have with using landings as an indication of abundance is that fishing efforts are not consistent. There are plant closings. The industry itself on the Atlantic seaboard has been in a squeeze for several decades.

Question: You have said 1984-85 was the peak year for UM in the Albemarle-Pamlico system. Was that also a peak year for fish disease in the Chesapeake and in Florida?

Merriner: That was the year we became acutely aware of it. I do not know if we can say that it was a peak year everywhere, but there were observations both north and south of us.

Question: Then, how can we link it to any particular activity if it occurs from the Chesapeake Bay to Florida?

Comment: The only thing we all really share is the weather system.

Comment: And potentially where the ulcerative fish come from - that being the estuaries. We can assume that since the ulcerative fish are juveniles and the juveniles' habitat is restricted to the estuaries.

Merriner: One thing to think about is how do non-native species get into areas? Simple bait-bucket transfers and bilge-water transfers of infectious agents are not impossible.

Comment: In 1984 we did have unusually low salinities because of rainfall throughout the spring and early summer months. That was in contrast to what we have had the last few years.

Comment: That is one of the few phenomena that cut across the entire Southeastern Region, and it seems to me that is the kind of thing we have to look for.

Question: You mentioned the saltwater bath. Do you mean to say that once an infected juvenile migrates and gets into the ocean environment, it is cured of the disease, or can an infected fish be a carrier as it migrates?

Merriner: I do not know. I just know that a saltbath cures a lot of diseases in freshwater aquaria and hatchery fish.

Question: It seems to me the question of possible spreading of the infection is a key. Do infected juveniles survive, migrate, and intermingle with adults and spread the disease? Or do fish become infected only within inshore waters under some adverse environmental condition?

Question: What size are the infected fish found in Florida?

Savage: They are good sized - adults.

Question: Then the question is are they being infected as adults in Florida or are they developing the disease as juveniles there?

Savage: We do not have monitoring of our tidal streams.

Merriner: We have detected it in Lanceford Creek, Florida, during our tagging efforts on juvenile menhaden.

Noga: I would like to make the point that we do not find viable fungi in advanced lesions. It seems that in the early stages, the disease advances very rapidly, then secondary bacterial infections inhibit the further growth of the fungi. We have never seen reproductive fungi on the host. That is very important because these organisms normally transmit themselves by zoospores. Also, these fungi are not adapted for high salinity.

Merriner: I have two related publications available: "Implications of Waste Disposal in Coastal Waters on Fish Population" and "Observations of Ulcerative Mycosis Infections on Atlantic Menhaden (Brevoortia tyrannus)." The latter publication summarizes our observations of UM in juvenile menhaden.

Status and Trends for Fish Diseases

Martin W. Newman
National Marine Fisheries Service

NOAA began sampling for the National Status and Trends (NS&T) program in 1984. The program was designed as an extensive monitoring program to assess contaminants in representative U.S. estuaries around the coast by sampling sediments and fish tissues and monitoring biological effects on estuarine fishes and filter-feeding bivalve molluscs.

The program consists of two major field sampling projects and an effort to acquire data from other sources. Under the Benthic Surveillance Project, bottom-feeding fish and sediments are collected from 50 sites around the United States during the spring and summer of each year. The Mussel Watch Project involves the collection of bivalve molluscs and sediments at 150 sites nationwide. As a trial effort to acquire data from other sources, a nationwide search for historical data on levels of polychlorinated biphenyls (PCBs) and organochlorine pesticides in fish and shellfish tissue has been completed and these data have been added to the NS&T data base.

Four objectives have been established for the early years of the NS&T program. The prime objective is to establish a national data base using state-of-the-art sampling, preservation, and analysis methodologies which are applied consistently and subject to rigorous quality control and assurance. The second objective is to use the information in the data base to estimate environmental quality, establish a statistical basis for detecting spatial and temporal changes, and identify areas of the nation that might benefit from more intensive study. The third objective is to seek and validate additional measurement techniques, especially those that describe a biological response to the presence of contaminants. This objective will be stressed during 1987 and 1988. The fourth objective is to create a cryogenic, archival specimen bank containing environmental samples collected and preserved through techniques that will permit reliable analysis over a period of decades. This archive has been established at the National Bureau of Standards.

The program was not designed to examine pollution "hot spots." Sites were chosen because they were felt to be representative of different types of estuaries along the coast. Each coastal state has at least one site; some, like Florida, have several.

Our monitoring as it relates to fish diseases is more extensive than intensive at present. We sample each site for sediment and tissue chemistry and biological effects once a year, and we only analyze 30 fish - one species - per site (originally we had targeted two species at each site but were having difficulty obtaining them). Basically, we are trying to establish a data base and a time series so that we can see trends in contaminant levels and fish diseases - whether there is a discernible increase or decrease over time. The sampling is not intensive enough to detect year-to-year variation at any one site. I do think the data will be adequate to show extensive differences between sites within a given year. In the future we may increase our annual sample size per site but look at fewer sites each year.

Some of the problems related to sampling for fish diseases are that there is not one representative species that can be used throughout the coastal United States. Moreoever, obtaining enough fish for an adequate sample to analyze tissue contaminant levels has been difficult in some areas.

Comparison of Contaminants Reveals High Sewage Indicators in Pamlico Sound

Comparison of North Carolina samples (N.C. site in Pamlico Sound near Hobucken) and samples from other sites in both the Northeast and Southeast reveals no unusually high levels in North Carolina of any contaminant for which we analyzed except those that are indicators of sewage. Sediment samples were analyzed for chromium, copper, lead, silver, cadmium, mercury, and other trace elements; total organic (aromatic) hydrocarbons and individual hydrocarbons; and DDT residues. The only notable aspect in this data is that N.C. samples were found to have levels of chromium that were not greatly different from some industrialized areas of the Northeast like Buzzards Bay, Massachusetts. [1]

However, when we look at sewage indicators in sediments (Figures 5,6), we see something more interesting. The first indicator is Clostridium perfringens spores, the second is coprostonol, and third is total organic carbon levels.

The total organic carbon level in North Carolina is higher than any of the East or Gulf coast samples. There is probably an explanation for this aside from contamination. [2]

The coprostonol level is also similar to that in many highly developed and populated areas of the Northeast. Coprostonol is a chemical produced by bacterial degradation of cholesterol and is prima facie evidence of human fecal contamination.

Fish Tissues Show a High Incidence of Hyaline Degeneration of Kidney Tubules in Pamlico Sound Spot

The following information on fish disorders was selected to focus on disorders that occurred at a significant prevalence in at least one sampling site and that revealed significant differences between areas. In different regions, the information is from different species. From New Jersey north, the data come from examination of winter flounder; in Delaware Bay, windowpane flounder; south of Delaware Bay the data come from spot or croaker. Our 1984 Pamlico Sound samples consisted of both spot and croaker. The lesions we found in the spot and croaker in 1984 which met the above criteria are the following:

* Necrotizing granulomas in kidneys: These may be due to parasites and are fairly common.

* Proliferation of macrophage centers in the kidneys: A number of studies have indicated a relationship between increased contamination or

FIGURE 5
COMPARISON OF SEWAGE INDICATORS
NORTHEAST COAST

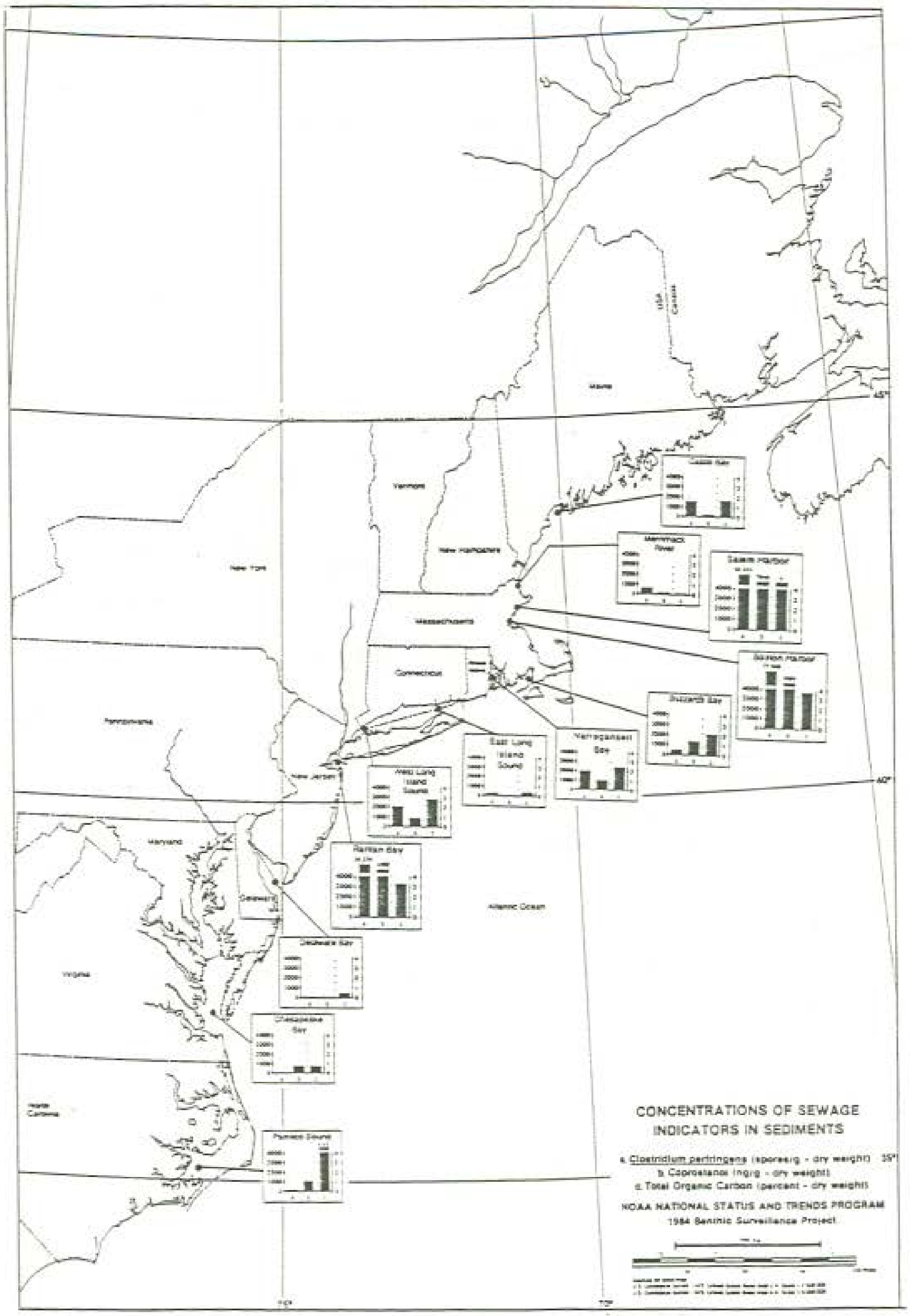
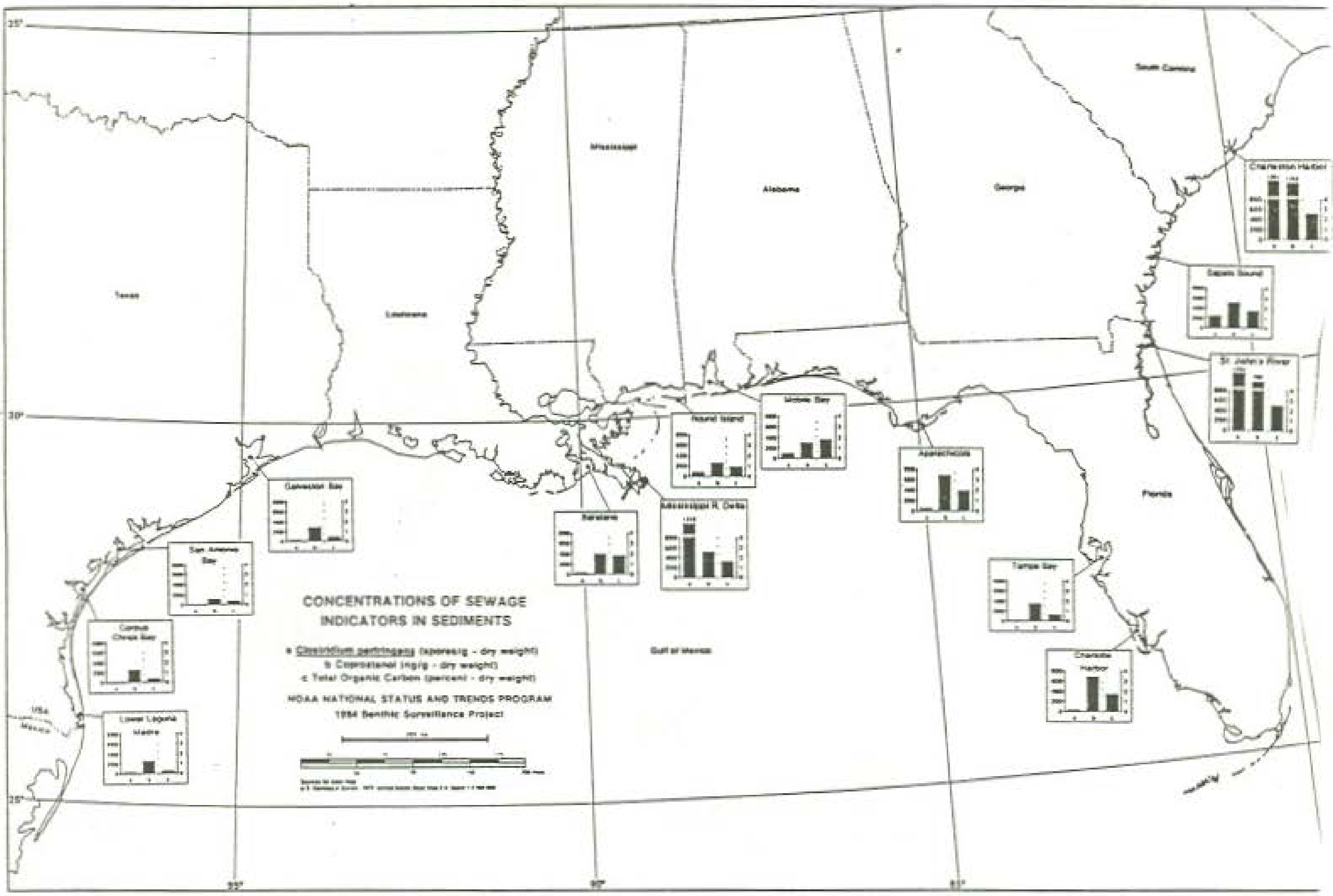


FIGURE 6
COMPARISON OF SEWAGE INDICATORS
SOUTHEAST ATLANTIC AND GULF COAST



stress and an increase in the number and size of these centers. This lesion seems to be a fairly sensitive indicator of stress in the environment, especially in flounder, but may be useful in spot and croaker also. This lesion was <u>not</u> prevalent in Pamlico fish in 1984.

* Hyaline degeneration of kidney tubules: In 1984 this lesion was present in over 40 percent of spot from Pamlico Sound. In 1985 Pamlico Sound croaker had a 30 percent prevalence of hyaline degeneration of the kidney tubules. As was the case with the spot sampled in 1984, several other sites equaled or exceeded this level. I was surprised by this and by the high prevalence of this lesion in other areas such as Sapelo Sound and Apalachicola Bay where contaminant levels are low. Perhaps in these areas, the lesions are due to something other than environmental degradation, or perhaps there are differences in our handling of specimens at different sites that may be causing these early degenerative lesions of the kidney. Some experimental studies will be developed to address the last possibility.

* Cholangitis (inflammation of the bile ducts) and hepatitis (inflammation of the liver) were both prevalent in 1985 croaker samples from Pamlico Sound but were not in 1984.

All of the above should be considered as preliminary results. Because of the relatively small sample sizes employed and the young age of the fish examined in the Southeast and Gulf Coast areas, the significance of the various lesions observed will take some time to determine. I would be uncomfortable in drawing conclusions from our histopathological observations at the Southeast and Gulf sites until I have had a chance to examine the data from the first two years of the study. It may prove necessary to average data from two or three years to obtain significant results.

It is difficult to extrapolate from the lesions we now see to effects on populations or indications of overall fish health. I have come to think that the subtle lesions we see now are the result of biochemical changes resulting from fish adapting to changes in the environment. It is conceivable that in some of these less contaminated areas, where the fish have not been exposed to massive environmental insults over decades, they may be more susceptible to small amounts of pollution. In grossly contaminated areas, if fish still survive, they may show relatively fewer effects.

Another possibility is that we are not monitoring for a particular contaminant that is responsible for some of these lesions.

An experimental study we have recently initiated indicates that fish from clean environments may be more susceptible to stress. In an effort to relate liver cancer to mortality in fish, we collected flounder from Boston Harbor - where flounder are known to have a very high prevalence of liver cancer - and put them in tanks in our aquarium in Woods Hole. As a control, we also collected flounder from Cape Cod Bay - a relatively clean area - and put them in tanks in the aquarium. We have three tanks of fish from Boston Harbor and three tanks from Cape Cod Bay. After four months, about 90 percent of the Boston Harbor fish were alive and about 30 percent of the Cape Cod fish were alive. The Cape Cod fish had succumbed to bacterial infections. The immune systems of the Boston Harbor fish appear to have been primed by their environment, enabling them to better fend off infection.

Literature Reveals High Fecal Coliform Bacteria Level in Pamlico Sound

When I first became involved with diseases in North Carolina fishes several years ago, I tried to find some environmental data that might help indicate what might be causing these problems. I found that in 1980 there was an East Coast Data Atlas published by the Council on Environmental Quality and NOAA. [3] It covered numbers and distribution of fauna, power plants, wastewater discharges, oil rigs, shipping, and a multitude of other things.

I reviewed the data and could find only one parameter that stood out in Pamlico Sound. It appeared that, for all the activities and contaminants listed, the Pamlico Sound was on the low end of the scale - with the exception of one thing in which it was at least average and in some areas a little above. That is fecal coliform bacteria.

This was the only item that was higher than I expected, and it supports the NS&T Program finding that sewage indicators were higher than one might suppose.

[1]. A participant in the workshop remarked that cadmium was sometimes added to superphosphate fertilizer as a nematicide.

[2]. There was general agreement among participants that the explanation is probably organic soils.

[3]. Ray, G.C, M.G. McCormick-Ray, J.A. Dobbin, C.N. Ehler and D.J. Basta. 1980. Eastern United States Coastal and Ocean Zones Data Atlas. Office of Coastal Zone Mgmt., NOAA, U.S. Dept. Commerce, Wash., DC.

Discussion

Question: Would gross adaptation to salinities during migration of estuarine fishes affect kidney tubules?

Newman: There would be changes in the kidney, but they would most likely involve the corpuscles of Stannius. I don't believe that salinity alone would cause appreciable changes in the tubular epithelium over the range of salinities experienced by these fishes. Other aspects of water chemistry (e.g. pH, hardness) might result in changes in the appearance of tubules. I need to look into this.

Overview and Conclusions

Carl Sindermann
National Marine Fisheries Service

My review of the published literature on ulcerative fish diseases shows that there is a global component. What we see along the coast of North Carolina is not unique: there are major outbreaks of ulcerative disease in other parts of the world. Recent literature reveals current outbreaks in Southeast Asia and Australasia. These outbreaks began in the 1970s and persist to the present. They have affected principally freshwater fish but to some extent those in the inshore brackish water habitat too.

Papers published recently on ulcer problems in other parts of the world may shed light on our problems. Some that might be helpful are FAO reports "Field and Laboratory Investigations into Ulcerative Fish Diseases in the Asia Pacific Region," "A Preliminary Account of Ulcerative Fish Diseases in the Indo-Pacific Region," and "Report of the Expert Consultation on Ulcerative Fish Diseases in the Asia-Pacific Region." The last named report contains a ten-page list of recommendations based on an extensive study in Southeast Asia, Australia, and New Guinea. These recommendations, I believe, have some relevance to the Atlantic Coast of the United States. There are many counterparts to findings here, including mycotic infections--fungi of the same groups that we find here--with the difference that, in the case of the Asian experience, they seem to be secondary invaders. There are also reports from Australia on ulcerative diseases that bear striking resemblances to what we see on the Atlantic Coast.

Ulcerative Conditions Relate to Various Diseases

While there is clearly a global aspect to ulcerative diseases in fish, I must emphasize that ulcerations do not constitute a specific disease entity in marine fish pathology. These lesions are simply a generalized disease sign in the same category as fin erosion, distention of the abdomen, or some of the internal granulomas. All of these are generalized signs that relate to a number of diseases; therefore, I hesitate to call them "diseases." They might better be called "syndromes" because they go through an evolution. The FAO expert consultation I referred to stepped back even further and recommended that we call any widespread ulcerative condition in fish "epizootic ulcerative syndrome," which I think is reasonable. In many cases of ulcerative conditions, as you can see in the list provided (see Table 3), very few have a recognized specific etiologic agent: the causes of most of them still have to be considered unknown.

Ulcerative Conditions Have Increased in Variety, Become Epizootic

It is important to note that ulcerations of fish are not new. For decades, we have been coming across the occasional fish of almost any species in almost any location that has a gross ulceration. What we are seeing now that is different are epizootic levels of ulceration, which I interpret as

TABLE 3
ULCERATIVE DISEASES IN COASTAL/ESTUARINE FISH

Disease	Geographic area	Outbreak period(s)	Cause
Ulcerative mycosis of Atlantic menhaden	Atlantic coast of U.S., from Chesapeake Bay to Florida	1982 to present	Oomycete fungi (presumptive)
Red spot disease of mullet and barramundi	Australia, New Guinea	1972-74; 1975; 1986 to present	Unknown (rhabdovirus suspected)
Ulcerative disease of mullet and other species	Southeast Asia	1980 to present	Unknown (rhabdovirus suspected)
Ulcus syndrome in cod	Denmark	1972 to present	Unknown (bacteria and viruses implicated)
Red disease of eels	Europe, Japan	1718 to present (Europe); 1975 to present (Japan)	*Vibrio anguillarum*
Spring ulcer disease of eels	Denmark	1973 to present	Unknown (several bacterial genera implicated)
Red sore disease of sheepshead and black drum	Gulf of Mexico	1965 to present	Ciliate *Epistylis* and *Aeromonas hydrophila*
Ulcer disease of red hake	New York Bight	1978 to present	Unknown
Ulcers of mullet	France	1978	Associated with "Amoco Cadiz" oil spill

involvement of at least five percent of any fish population. " Epizootic" generally means levels far above what would be expected in normal populations.

In the last two decades or so, we have begun to see a variety of distinct epizootic ulcerative syndromes. One example is the ulcer disease of red hake that was first seen in the New York Bight in 1978. In this disease we see highly hemorrhagic ulcers with irregular outlines.

Another example is the "ulcus syndrome" in cod first found in Denmark in 1972. This ulceration has a distinct evolution. It begins with minute hemorrhagic areas underneath the scales. It then becomes enlarged and confluent, and then develops into a major impacted area, usually on the lateral body surface. These ulcers are also characterized in later stages by healing, so the syndrome is less destructive than the ulcerative syndrome you are dealing with here. The Danish Royal Veterinary Institute has been studying this condition since 1972. The cause was first thought to be bacterial, then two viruses were found lurking in the infected tissue too, and it is now believed one of these viruses is the primary etiological agent. This is after some 15 years of study and appreciable evolution in thinking, and even now I am not sure that the cause is not some kind of synergistic activity between the two groups of microbes--viral and bacterial.

These examples clearly illustrate, I think, that there are distinct syndromes and, I believe we can assume, they are caused by quite different pathogens. The fungal groups that you are dealing with in ulcerative syndrome on the Atlantic Coast of the United States are found in other impacted areas. However, I know of no other case where they have been identified as the primary pathogen.

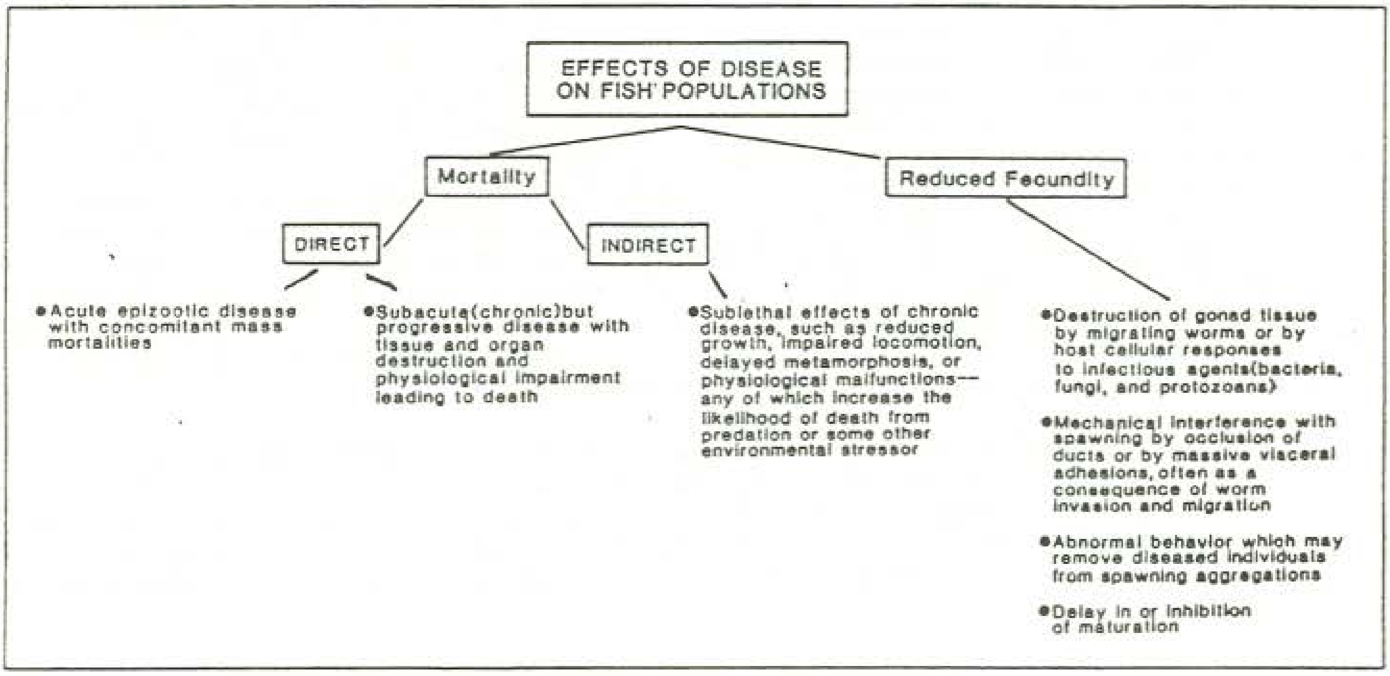
Strategies for Dealing with Fish Diseases Should Put Major Emphasis on Demonstrating Effect on Survival

My recommendations for strategies to confront disease problems in fish are as follows:

* To assure continued funding support for research and long term disease monitoring, an effect of the disease on survival and fecundity must be demonstrated.

  This is difficult to accomplish, but such efforts must be a consistent part of every investigation. Otherwise, interest in and funding for research dwindles rapidly. Disease studies must go beyond mass mortalities, and that is often a difficult concept to get across to administrators. The dead fish on the beach are just a tiny fraction of the total disease-caused mortality in a population. The observed deaths are important because they point out that disease really does kill fish, and there are still some administrators who do not admit that that is true. But, I think it is important to continue to assess disease effects on populations in three categories:

FIGURE 7
EFFECTS OF DISEASE ON FISH POPULATIONS



1) mass mortalities associated with acute disease outbreaks,

(2) continuing but less dramatic mortalities resulting from chronic but progressive diseases, and

(3) indirect mortalities resulting from debilitation and consequent reduced survival potential, increasing the likelihood of death from predation or some other environmental stressor. (See Figure 7)

Additionally, population effects may result from reduced fecundity - by mechanical or physiological interference with maturation and spawning.

It is this **totality** of disease effects on survival that must be conveyed to administrators and politicians, and not just the "Oh, My!" aspects of mass mortalities.

* Once administrators have been convinced that disease studies must be done, they must also be convinced that it is not a one-man effort, that investigations cannot be narrowly conceived.

It is impossible to hire a virologist or bacteriologist or parasitologist or mycologist and expect to get a rounded investigation. A team approach must be developed drawing on any number of competencies, including environmental competencies. The accompanying drawing illustrates my concept of a research team to confront fish disease problems in the estuarine environment. (See Figure 8) Absence of such a mix of specialists will lead, as it has in the past, to all the frustrations of incomplete information and results that are important scientifically, perhaps, but inconclusive for management purposes.

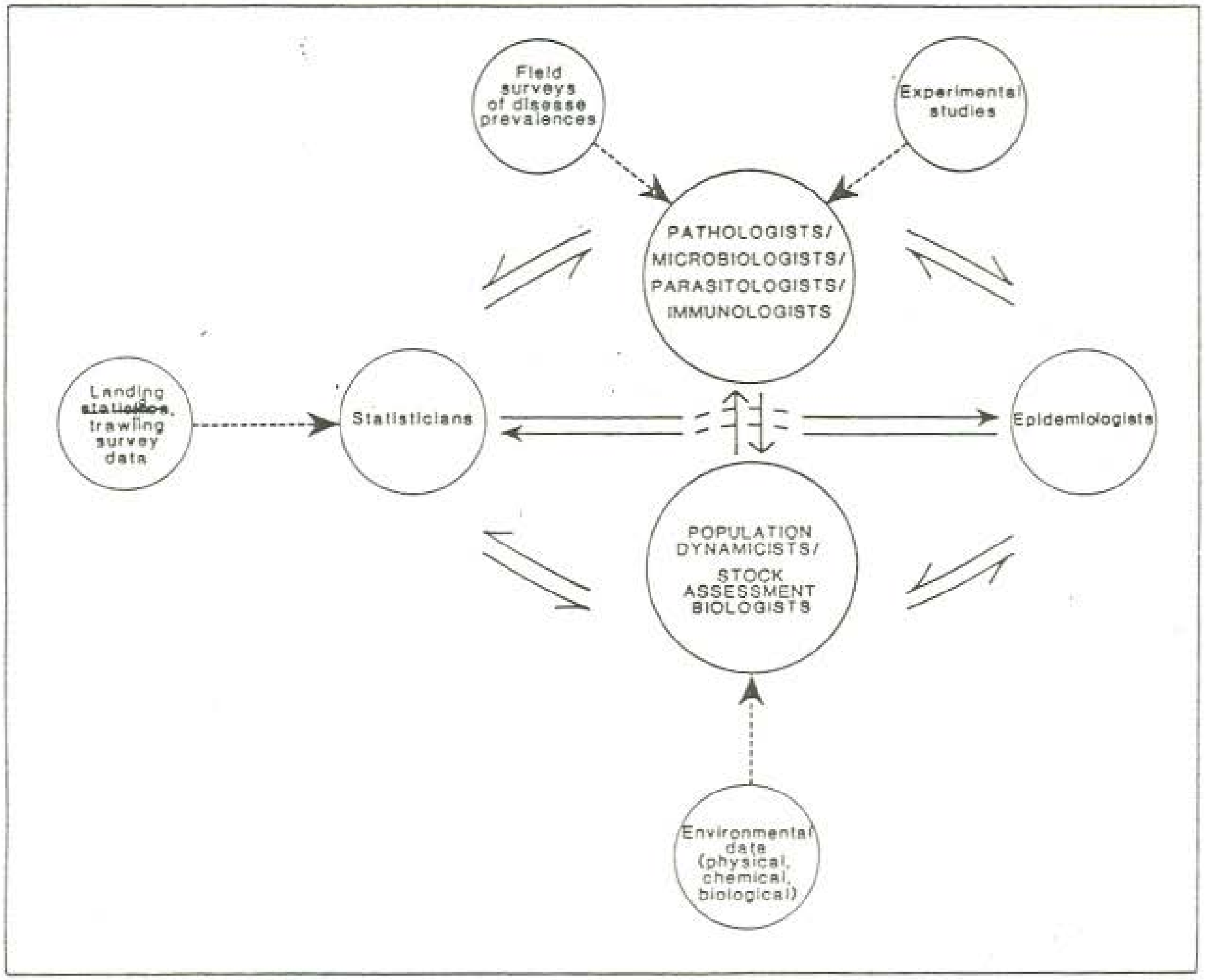
* Unless concurrent studies of total fish biomass are conducted, it does little good to estimate how many fish are dying. Neither does it do any good to assess prevalence alone. Prevalences indicate how many fish are diseased at any given moment, but what is really needed is information about incidence--the numbers of the fish being infected per unit time and dying per unit of time.

This is important because in the presence of a virulent infection, fish can die very fast and a low prevalence results. This makes it appear that there is no disease problem. So, there needs to be a dynamic component to fish surveys. This component is hard to acquire because it requires experimental as well as field observations.

It sounds as if you in North Carolina and adjacent states should be aiming for a fairly formal regional disease management group. I witnessed the evolution of a formal relationship among disease experts and management experts, all acting in official capacities, in New England in connection with shellfish diseases. I think this relationship has worked for them, and I believe it can work for you. You have the nucleus for such a group in this workshop today.

But I suggest that you not allow the objectives to become too diverse, that is to address other problems. For instance, I think it would be counterproductive to try to address crab mortalities in this group at the present. You should stay on one track, and for this group that is the matter of ulcerations in fish--an important but difficult problem.

FIGURE 8
FISH DISEASE RESEARCH TEAM COMPOSITION



Discussion and Development of Recommendations

Rader: We in North Carolina are poised to do something about the problems of estuarine fish diseases. What we should do is not immediately clear, but the workshop today has provided views and opinions from a broad range of expertise to help us move toward some practical recommendations. We are eager not only to devise a study that will produce an effective management plan for our own estuarine system but also to fit our study into a larger regional and national effort on fish diseases.

I have three major observations about the information presented in today's workshop with which I believe everyone will agree.

First, it is clear that we need to continue and perhaps formalize communications and collaboration on this issue at the agency level - intrastate, interstate and federal.

Second, we as public officials need to continue educating both the general public and our elected officials about the need to support the use of nonpoint source controls in this region and other management implementation strategies.

Third, ulcerative mycosis is a very highly visible indicator or symptom of significant environmental changes that need to be addressed.

At this point, I believe, the consensus ends, and the question, "What do we do?" enters.

Remember that the Albemarle-Pamlico Estuarine Study is dedicated to management. At the end of five years we have to have a comprehensive conservation and management plan in place.

I have three simple questions with which I'd like to elicit comments and suggestions about development of a management plan.

The first question is: What, if anything, should we be doing to establish causal relationships between human activities and significant symptoms, such as ulcerative mycosis, in the estuaries?

The second question is: What, if anything, do we need to do to evaluate the system significance of ulcerative mycosis?

The third question is: What do we need to know or to do in order to manage the system effectively?

I want to focus on how this condition can be managed, if it can be managed.

Response

Hawkins: The underlying objective of the investigations in which the N.C. Division of Marine Fisheries has taken part was to identify the geographic locations in the river where the rate of infection is highest, then identify the different elements that might be making fish in these locations more susceptible to the disease.

Rader: Was the goal to establish causation or to establish a management plan.

Hawkins: Take it one step at a time. First, establish causation, then different agencies responsible for different management plans would take whatever steps seemed indicated.

Rader: Is that a recommendation to produce an effective monitoring scheme to detect regional differences?

Hawkins: It is a recommendation that management objectives of the Albemarle-Pamlico Estuarine Study, the Division of Marine Fisheries, and the Division of Environmental Management be correlated.

Mulligan: I think some effort should be focused on making a clear case that touches the legislative mandate that the Division of Environmental Management has to investigate the killing of fish and wildlife. I think it is likely that fish diseases and kills are related to nonpoint sources or a combination of nonpoint source/point source or a cumulative impact and that our present legislative mandate is insufficient to address these causes.

I think it is most possible to approach the legislative mandate through making a case that the resource loss is of sufficient magnitude to justify the laws. I think if you can make this case, you can drive the monitoring effort without necessarily knowing the link to a known source of pollution.

We in the Division of Environmental Management do not yet have a definition of the problem that clearly meets the test of our mandate. When we have to go back to the legislature for resources necessary to do the monitoring, they are going to want to know why the monitoring should be done.

Merriner: One of the problems we have is that the impact from legislation relates to acute effects and the worst effects will be the chronic ones. I think through modeling it is possible to show that it doesn't take much to drive a resource down over a long period of time. The premise that you could potentially have a steady decline in water quality - measure that by whatever parameters you wish - that could bring about significant resource loss is not hard to accept. I think we could convince the general public that there are these problems in our system. Perhaps we could demonstrate it as an impact on reproduction. There may be a lot of spot out there that are infertile - sperm motility down, for instance.

The smoking gun is going to be extremely difficult to find. You're dealing with chronic effects, with generational levels of impacts.

Rader: Is it important from a management study perspective to find the smoking gun? Or is it sufficient to go to the public and convince them that we have significant enough evidence of environmental change that we need to manage it.

Noga: You can say whatever you want about the relationship of pollution and fish disease, but I don't think it is a very good argument unless you have some very strong data to back it up. We are at the very early stages of understanding the problem. In most cases we are still questioning what the initiating pathogens are. I think we need to have a lot more information about what particular environmental conditions are responsible before people will really be convinced.

Neither do I think we should base a rationale totally on fish resource loss. An even more critical force is people's perception of the quality of our ecosystem. Acid rain is not going to kill people, but when people see trees dying and other serious changes in the quality of the environment, they think more and more about the quality of life and not just the quantity of a resource. This perception is very important politically.

Mulligan: I agree with all your facts, Ed, but I don't agree with your conclusion. Ulcerative mycosis is not the only problem we have to deal with, but if we deal with it in a way that allows us to quantify its significance economically on commercial fisheries and recreational fishing, we can use that same approach to deal with the other problems that we know about in these same waters. I don't think we have enough money to buy enough science to reach the point where everybody in North Carolina recognizes that this is THE answer to this question. We have got a number of symptoms of declining estuarine water quality that need to be addressed in a management framework. I don't think the solution has to be completely descriptive.

Hawkins: Most of us in high levels of management agencies have been trained as scientists, and we are accustomed to requiring numbers. If you don't have the numbers to support what you're saying, even though the policy might go the way you want it to now, if the administration changes or the public perception changes, you're vulnerable to a change in the management strategy. Management decisions are made everyday without the numbers. You can get management strategy passed without the numbers, but you're opening yourself up to future changes.

Rader: Let me phrase the question differently: Assume that you have a change operating in the estuary and you want to know what the effect is and the cause is. Is it possible, given reasonable amounts of money and current technology and the symptoms of this present condition, to establish that causal link? And, if it is possible, how can we go about doing it?

Noga: Establishing a causal link is a crap shoot.

Levine: We could look for causes and come up with nothing. On the other hand, we could declare a nutrient-sensitive area and get nothing. Maybe the best use of the money is to spend it on improving our ability to look at the problem.

Sauber: It seems that what this boils down to is putting a value on aesthetics. If we wait for absolute proof to decide on management action, we will let other development add to the problem. On the other hand, there are legal issues. We have to have good reason for regulations forbidding people to do certain things or we're in trouble in court.

It seems to me what we've got to do is solve our public perception problem. We don't really know where the public's values are. The N.C. 2000 survey showed that the public's number one priority is economic development - jobs and so forth - but that a very close second is quality of the environment. What needs to be done is to educate the public to the fact that sometimes they have to choose between the two, so that those priorities are reversed, then communicate that public perception to elected officials.

Planning board member from coast: It has been astonishing to me, but I've found that residents where I'm from are much concerned about the quality of the environment - whether the water's clean. I think people are becoming aware that the environment is extremely important - that if environmental quality isn't there, what good does it do to make investments in the coastal area.

Bisterfeld: I would like to ask Dr. Noga where he would next look to find factors that you can do something about.

Noga: I'd look at horses not zebras. Look at the parameters - pH, DO, salinity, temperature, and so forth - that are traditionally associated with water quality, not at toxics, which haven't been problems here.

Bisterfeld: Do the fisheries people in the state have any handle on the movement of menhaden within the estuary. Do we know anything about their general movements on which to base some investigation of spatial zones of incidence.

Noga: That's one of the problems.

Bisterfeld: EPA initially backed away from funding for the fish problem. This group must identify some area where EPA has something to gain.

Levine: Perhaps this work can be used as a model for methodology and to integrate efforts on fish disease.

Bisterfeld: This study was set up with key people on its technical committee from the Water Resources Research Institute, Sea Grant, and other research funding avenues so that all research efforts can be coordinated and aimed at trying to find the most important and useful things about the Albemarle-Pamlico Estuary.

Sauber: Seems to me we may have to make management decisions based on faith and evaluate measures as we go.

Newman: I'd like to make two points: The first one addresses what can be done about this particular disease. In the broad sense, we know there are two possible causes. Either there is something compromising fish immunity or there is something making the infectious organisms more virulent. It is probably the former, but there are research approaches that can pin that down - approaches that will let us say that fish from this area are not as immune competent as fish from another area or that fish with the disease show reduced immunocompetence. So in a broad sense you can show environmental effects on fish even if you can't say that there is any one contaminant that is causing fish to lose immunocompetence. If you can do this, then you know you're not having some big genetic shift in menhaden populations producing menhaden that are not immune competent - that there is some external factor causing it. You can then assume that some anthropogenic input may be causing it and you can make management decisions to reduce those inputs that you know are present and that you know can cause these kinds of problems. We know things that can reduce the ability of the immune system to respond to infectious organisms.

The other thing I'd like to talk about is how best to spend your money, assuming you can show something in the environment is reducing immune competency. It is a lot easier to monitor the prevalence of this disease than to measure three or four dozen different contaminants or environmental parameters at three or four hundred different sites in the state of North Carolina. If you can get a handle on a problem like this and use it as an indicator, it is a lot easier and cheaper to monitor it than to monitor all the possible individual inputs into the system. Meanwhile, you can spend the rest of the money on controlling the inputs into the system that you think might have harmful effects.

Levine: With this approach, you can only talk in generalities. I'm not sure the public is going to be satisfied with generalities.

Perry: There are two veins of thought here. One is the concern that we have an obligation to manage the ecosystem of the estuary. Then there is the problem of fish - specifically menhaden. My question is: Are menhaden the best bioassay tools of that estuary or are there several better indicators of management needs in the estuarine system.

Merriner: I would look to a planktivore as an indicator.

Levine: Part of the problem is in knowing where to look. Sentinels can help define locations.

Sauber: Sindermann's recommendation for formalizing a work group should be followed.

Bisterfeld: A degree of formalization is provided for by the technical workgroups such as this one.

Stober: I'd like to suggest that you take a look at the monitoring effort we heard about today - the one that produced a year and a half of baseline data and was then chopped off - and assuming that we don't have enough money to pick it up where it was and continue it - take the heart of the program and refocus it on the nearshore etiology of this particular disease in menhaden or better yet look at resident species in this system. Rethink that whole program and rescope it so that it gets to the heart of understanding the disease problem. Throw in some pathological aspects, and mesh it with the Sea Grant monitoring program.

Rader: Please write down any concrete recommendations you have for the monitoring program or any aspect of the fish disease study and send them to us.

WORKSHOP SPEAKERS AND PARTICIPANTS

Jerad Bales
US Geological Survey
PO Box 2857
Raleigh, NC 27602
(919) 856-4791

Ted Bisterfeld
US EPA
345 Courtland Street
Atlanta, GA 30365
(404) 347-2126

Derb Carter
2108 Dunnhill Drive
Raleigh, NC 27608
(919) 833-4859

Micky Clemmons
NC Wildlife Res. Comm.
1603 Lark St.
Elizabeth City, NC 27909
(919) 338-1050

Dirk Frankenberg
UNC-Marine Science
UNC-Chapel Hill
Chapel Hill, NC 27514
(919) 962-1252

Jeri Gray
Water Resources Research Inst.
Campus Box 7912
NC State University
Raleigh, NC 27695-7912
(919) 737-2815

Jess Hawkins
Div. of Marine Fisheries
NC NRCD
PO Box 1507
Washington, NC 27889
(919) 946-6481

J. W. Kornegay
NC Wildlife Res. Comm.
120 Japonica
Camden, NC 27921
(919) 338-3607

Wilson Laney
US Fish & Wildlife Service
PO Box 25039
Raleigh, NC 27611-5039
(919) 856-4521

Jay Levine
Sch. of Veterinary Medicine
Campus Box 8401
NC State University
Raleigh, NC 27695-8501
(919) 829-4397

Tom Mather
The News & Observer
215 S. McDowell Street
Raleigh, NC 27602
(919) 829-4528

John Merriner
National Fisheries Service
Southeast Fisheries Center
Beaufort, NC 28516
(919) 728-8708

Jim Mulligan
NC Div. Env. Mgt.
Washington Regional Office
Box 1507
Washington, NC 27889
(919) 946-6481

Tony Mullis
NC Wildlife Res. Comm.
307 Harvey Drive
Greenville, NC 27834
(919) 756-7749

Martin Newman
NOAA/NMFS
Oxford Lab
Oxford, MD 21654
(301) 226-5193

Ed Noga
School of Veterinary Medicine
Campus Box 8401
NC State University
Raleigh, NC 27695-8401
(919) 829-4236

Ray Noggle
Natural Systems Associates
5048 Avent Ferry Road
Raleigh, NC 27606
(919) 828-1893

Thomas O. Perry
Natural Systems Association
5048 Avent Ferry Road
Raleigh, NC 27606
(919) 859-0031

Doug Rader
APES, NRCD
512 N. Salisbury Street
PO Box 27687
Raleigh, NC 27611
(919) 733-0314

Jay Sauber
DEM Water Quality Section
512 N. Salisbury Street
PO Box 27687
Raleigh, NC 27611
(919) 733-6510

Tom Savage
WQA & QAS
Dept. of Env. Regulation
2600 Blair Stone Road
Tallahassee, FL 32301
(904) 487-0505

Bill Schimming
Texasgulf Chemicals Company
PO Box 48
Aurora, NC 27806
(919) 322-4111

Vince Schneider
NC DEM, NRCD
512 N. Salisbury Street
PO Box 27687
Raleigh, NC 27611
(919) 733-6510

Terry Sholar
NC Marine Fisheries
DEM, NRCD
PO Box 1507
Washington, NC 27889
(919) 946-6481

Carl Sindermann
National Marine Fisheries Service
Oxford Lab.
South Morris St., Extended
Oxford, Maryland 21654
(301) 226-5193

James M. Stewart
Water Resources Research Inst.
219 Oberlin Road
Campus Box 7912
NC State University
Raleigh, NC 27695-7912
(919) 737-2815

Q. Jerry Stober
US EPA, Region IV
Environmental Services Division
Athens, Georgia 30613
(404) 546-2294

Frank Tursi
Winston-Salem Journal
418 N. Marshall Street
Winston-Salem, NC 27102
(919) 727-7267

Douglas Vaughan
NMFS
Beaufort Lab.
Beaufort, NC 28516
(919) 728-8761

Erick Umstead
Agricultural Resources Center
615 Willard Place
Raleigh, NC 27603
(919) 833-8249