SYMPOSIUM ON THE NATURAL RESOURCES OF THE MOBILE BAY ESTUARY

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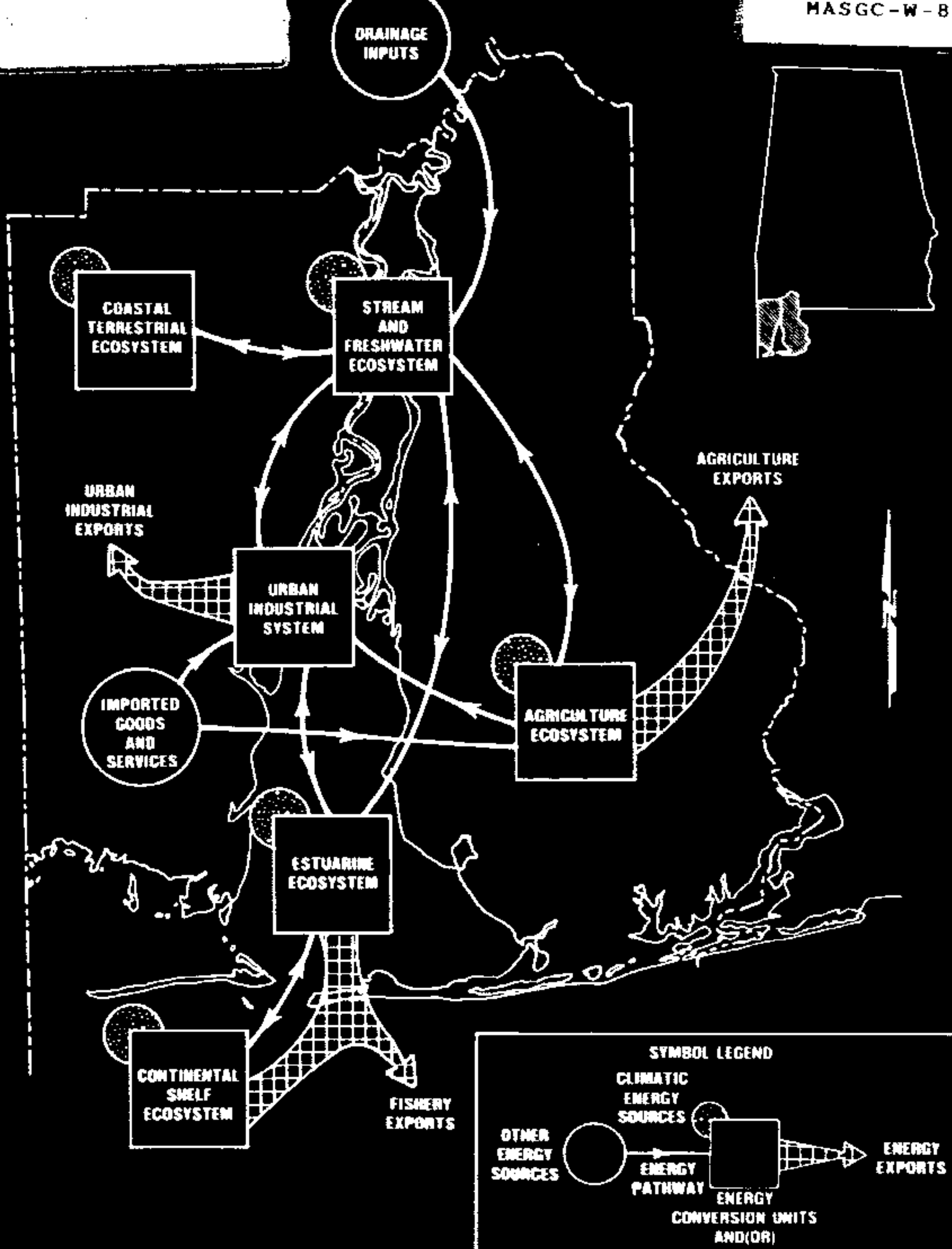

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SYMPOSIUM ON THE NATURAL RESOURCES OF THE MOBILE BAY ESTUARY

FEBRUARY, 1987

Editor
Tony A. Lowery
Alabama Sea Grant Extension Service

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PREFACE

On the 10th, 11th and 12th of February 1987 over one hundred and forty individuals participated in the Symposium on the Natural Resources of the Mobile Bay Estuary. This symposium was the second in a series to provide a forum to present the results of studies, management activities and related information pertinent to improving our communal stewardship of the Mobile Bay Estuary.

The Nation, State of Alabama and the coastal communities bordering the Bay have a vested interest in maintaining the Bay's productivity. In particular, the fiscal stability of coastal Alabama relies, to a large extent, on the diversity of economic activities which are Bay dependent. Our ability to avoid the economic losses experienced by other coastal communities, such as the Chesapeake Bay States, will depend on our ability to effectively manage the Mobile Bay Estuarine Ecosystem.

Thirty-eight papers were presented during the 1987 symposium. Many of these papers reported on the results of studies that were identified, during the 1979 symposium, as being critical to the development of the information base from which management decisions could be based. The papers presented dealt with: The Resources of Mobile Bay; Fisheries Research and Management; Benthic and Wetland Resources; Habitat Preservation, Restoration and Mitigation; Educational Efforts; Hydrography, Circulation, Water Quality and Pollutants. The primary objectives of this 1987 symposium were to bring this information together and to identify a new set of management/research recommendations.

The Symposium was held at the University of South Alabama in the University Center where the formal presentations were made. Posters were displayed by the Alabama Sea Grant Extension Service, Mississippi-Alabama Sea Grant Consortium, Dauphin Island Sea Lab, Weeks Bay National Estuarine Reserve, and the Environmental Studies Center.

ACKNOWLEDGEMENTS

The Symposium's Steering Committee would like to thank the presentors and moderators for a job well done. We appreciate the effort that went into preparing for the symposium and the papers received. We salute their dedication and professionalism.

We would like to express exceptional appreciation to the Agencies, Institutes and Organizations which provided support to the symposium. The symposium was truly a cooperative effort which relied on the talents and time of everyone involved. Without the commitment of funds and personnel, this symposium would not have been organized.

In particular, the support provided by the Alabama Department of Economic and Community Affairs, U.S. Environmental Protection Agency, Mississippi-Alabama Sea Grant Consortium, U.S. Army Corps of Engineers, U. S. Fish and Wildlife Service, Coastal Research and Development Institute, and Alabama Sea Grant Extension Service, were directly responsible for the symposium becoming a reality. We would like to express our appreciation for their support and interest in the symposium's mission.

Special thanks are due to the Alabama Conservancy, Alabama Sierra Club, Alabama Wildlife Federation, Coastal Area Chapter-Alabama Conservancy, Coastal Land Trust, Coastal Environmental Alliance, Fowl River Protective Association, Gulf Coast Conservation Association, Mobile Bay Area Sierra Club, Mobile County Wildlife and Conservation Association. Their early support and interest in the symposium provided much of the emphasis for the initiation of its organization.

Symposium Steering Committee

Tony Lowery - Chairman, Alabama Sea Grant Extension Service
David Barley, Alabama Dept. of Economic and Community Affairs
Eldon Blancher, TAI Environmental Sciences Inc.
John Borom, James H. Faulkner State Jr. College
Larry Goldman, U.S. Fish and Wildlife Service
Steve Heath, Alabama Dept. Conservation and Natural Resources
Robert Hodge, Fowl River Protective Association
Susan Rees, U.S. Army Corps of Engineers
Judy Stout, Marine Environmental Sciences Consortium

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KEYNOTE SPEAKER

WILL BAKER

Symposium on the Natural Resources of the Mobile Bay Estuary

I'm delighted to be down here, and if anything that's been learned on the Chesapeake can be of help to you all it will really be a very productive trip.

You know a wise man once told me that you need to start every speach with a joke and being sort of a wise guy myself, I decided to come with two jokes. The first one occurred to me this morning as I was eating breakfast -- ham and eggs. I was thinking about the relative success that we've had on the Chesapeake Bay and with the "save the Bay" effort. It occurred to me that a committed citizenry has really been the key, and we've always had people involved with environmental causes. It's only been of late (maybe in the last four or five) years that people have really been committed. Here's the funny part. As I looked down at my ham and eggs, it became very apparent to me what a great difference there is between being involved and being committed. You know, out there somewhere there is a chicken that was involved with those eggs, but I gotta tell you, the pig from whence that ham came was truly committed.

Now the next one -- this is a true story. There is a little island in Chesapeake Bay called Smith Island, and it's settled by some of the earliest colonists of this Country. They're remarkable people, only about 500 live there, and they speak with this marvelous sort of brogue. It's an accent which I've never been able to immitate -- nor have I seen anyone else in the country. And literally, all of those people make their living in one way or another off Chesapeake Bay. They are absolutely dependent on it. I was down last fall, over Labor Day Weekend for a funeral of an old waterman that I've known very well. As in many rural areas, the funeral can be quite elaborate, and it is on Smith Island. Eventually, we got out to the cemetery and I was sort of looking around after that part of the ceremony had gotten over. There are a lot of elaborate grave stones, and way over in the corner of a somewhat grown up area, weeds and grass, was a little tiny stone. The epitaph read in its entirety, "I told you I was sick". Well, there's a message in that story -- the Chesapeake Bay has been telling us that she's been sick for many years, but no one really would listen.

Up until the early 1980s, the prevailing policy of those in government was to put a rosy foot forward -- never say anything bad about the Bay for fear that it would reflect poorly on the state (may affect tourism). In fact, the highest ranking Maryland environmental official, in 1980, said in a major speach, "Those who say save the Bay are doing a grave disservice to our state". I suppose that he thought organizations like ours were being overly doomsdayish. And you know, its interesting -- only five or six/seven years ago, Maryland was always considered a very environmentally forward state, but no one would admit the Bay was gone and we almost lost her. Fortunately and remarkably, the situation has been largely reversed.

By late 1983, politicians were proclaiming to save the Bay. They began to appropriate money in huge amounts. The bureaucrats were forced to follow suit and the "save the Bay" movement gained momentum. We at the Chesapeake Bay Foundation turned our attention from trying to pursuade people that the Bay was in fact ill. To helping to orchestrate the most efficient and effective method of restoration, it's both interesting and intriguing to investigate just how and why the dramatic change took place. In my opinion, it had a lot to do with Ronald Reagan, Ann Burford and Jim Watt. Let me explain. You remember back in the early 60s -- perhaps the 60s/early 70s, the meaning of America really blossomed. A number of important laws were passed, regulations promulgated, and programs implemented. And, there was sort of a feeling that government was going to take care of all the problems relating to pollution in this country. The result of that was really a since of apathy among citizens that they had to become involved or committed.

Well, President Reagan changed that. For whatever reasons, he appointed Ann Burford and Jim Watt to run the Environmental Protection Agency and the Department of Interior respectively. The way those two individuals, systematically tried to reverse thirty years of bipartisan support of the environment was really appalling, and all across the country Americans reacted. I can remember an editorial in Chemical Week magazine that said we must have a credible strong EPA. They were worried about backlashing, perhaps that's what happened.

So, this new spirit in environmentalism began to grow as people realized that government was not going to solve all the problems. And up in Maryland, Virginia, and part of Pennsylvania, the Bay was the natural area of focus for that new environmental interest. At the same time, EPA was putting the finishing touches on a really massive 7-year/$30 million study. And although Mrs. Burford's region three administrator tried to play down the findings, enough specific information was leaked to our organization that the agency really had no choice but to go public. The first document they produced was this, and it's called A Chesapeake Bay Program Technical Studies: A Synthesis. (The full volume would fill up this table here). But, EPA still tried to minimize the significance of the report and refused to undertake the final and what I feel was the most important phase. One beyond just in describing the problem and making recommendations on how to clean up the estuary, and that was Congress' initial intent -- to go that second step.

The Senator, Charles Mathyus Republican from Maryland who had the initial idea of the Bay study held an oversight hearing to investigate EPA's conduct. There were two witnessess, the region three administrator I spoke of, Mr. Peter Bibcoe and me (this was back in '83). Well by the end of that hearing, it was clear the agency really had not met the congressional mandate. That was the least of their worries. A few months later, Mrs. Burford was fired, Mr. Bibcoe soon followed.

Fortunately, Bill Ruckleshouse rode into town on his white horse with his shining armor, and he saved the day -- and he did. He, along with Senator Mathyus secured funds to complete the study and insure its full documentation and dissemination. This report, equally large, is just the recommendation section of the overall study. Then they went one further step, to produce a very "user friendly" or laymen's guide to what they had done in only 24 pages or so. This need to communicate to the citizens and to the public has always been a cornerstone of the effort up on the Chesapeake.

One last thing that sort of coincided was the governor's race in Maryland. Harry Hughes, a democrat was running for re-election when Chuck Robs from Virginia (also a democrat) came over and campaigned for him. It was remarkable; they emerged from Governor Hughes' Office for a press conference and they came out and they said "together, we are going to save the Chesapeake Bay". It may seem a little bit hard to understand the significance of that, but that was the first time anybody in government (that I've heard) that ever said that term "save the Bay" without making it a disparaging remark, and it was the two governors of the two primary states -- it was remarkable.

To make a long story short, the ball went rolling toward the Bay Program, as it's come to be called, and nothing can stop it. Our biggest worry at that point -- something you all may consider here -- was how to keep up the momentum, at least 'til the end of that year when all the governors (Maryland, Virginia and Pennsylvania) were going to join together for a major governors' conference in which they were going to listen to all of the evidence and then present their recommendations as to what they were going to do. Well, the momentum was kept up, and I'm pleased to say -- still going strong.

Even better, progress is being made. Let me review just a few of the high points. Most basically, a superb cooperative working relationship has been developed between the three primary states (Virginia, Maryland, Pennsylvania) and the District of Columbia and the Federal Government. Whereas these jouristictions literally used to fight over the resources of the Bay, they are now fighting for them. Second, real attention is being given to non-point source -- pollution, and all that happens on land, including comprehensive land management, there is increased emphasis being placed on reducing nutrients at point sources, including phosphate detergent bands. We have a band in

Maryland, one in DC and one is just about to pass in Virginia. In addition, the technically difficult and expensive proposition of removing nitrogen is being squarely addressed and implemented through pilot programs.

Finally, we are slowly but surely ratcheting down on industrial and municipal discharges and improving against the violators. And before I go any further, let me take just a second to give you a brief physical description of the Bay.

By anyone's standards, its size really is impressive. From the mouth of the Bay down near the ocean, which is the Norfolk and Hampton Roads area, all the way up to its headwaters where the Susquehanna River enters the Bay, 200 miles. It's 30 miles at its widest where the Potomac River enters the Bay and 4 miles at its narrowest. There are over 8,000 miles of tidal shoreline. And although the average depth is only 21 feet, most of the Bay is far shallower, and I can attest to that having spent many an hour stranded in thin waters on sand bars. And you know the watermen say "A man that hasn't, run ashore from time to time -- just doesn't know the Bay", I feel like I must know it pretty well.

The interesting thing is as big as all this may sound, it really doesn't tell half of the story because we have learned, unfortunately I believe, to view of the Chesapeake in its entirety encompassing its full worth yet. It reaches well into New York State, drains one-half of the State of Pennsylvania, most of Maryland, most of Virginia and a small segment of Delaware -- even just a part of North Carolina. The massive network of rivers includes the James, the York, the Rappahannock, the Potomac and the mighty Susquehanna. The Susquehanna contributes over 50 percent of all the freshwater entering the Chesapeake Bay. Therefore, the need to get Pennsylvania and of course alternately New York involved.

Whatever pollutants the stormwater washes off that entire basin wind up in the Chesapeake, and there it stays hiding in the sediments resting on the bottom -- able to be resuspended by storm events. There is very little if any flushing in the Chesapeake, and I understand that's probably quite similar to Mobile Bay.

The Chesapeake is a drowned river valley, and I think Mobile Bay is as well. Over 15,000 years ago, the main stem of the Chesapeake was born from the Susquehanna. Fifteen thousand years ago with the Ice Age, the Susquehanna came all the way down to the ocean. As the Ice Age receeded and the ocean level rose, the river banks were flooded and the main stem of the Chesapeake was born of the lowlining areas along the banks of the river. And even today, a deep natural channel runs the entire length of the Bay, and that's the old Susquehanna riverbed. This main channel really requires no dredging what so ever, which is fortunate, but it's a full time job to keep the ports which are all located on the tributaries open, and the quantities of dredge spoil are tremendous.

To dredge Baltimore Harbor and its approach channels from a depth of 42 to 50 feet--which is now planned, will extract 64 million cubic yards of spoil. All of this spoil has to be contained because overboard dumping has been outlawed in Maryland and Virginia for some time.

As the Chesapeake's size is impressive, so too are the quantities of seafood that have been taken from its waters. H. L. Meagan called it an immense protein factory. In its past for instance, the Chesapeake provided one quarter of the nation's oyster harvest, and much of it is still taken by saildriven skipjacks, the last working sailing fleet in North America. Half of all the crabs in the Unites States, and crabs are America's fourth largest fishery, have come from Chesapeake Bay. More clams than all of New England combined, most of what comes out of the Bay are soft shell clams. Huge quantities of finfish have historically been taken. They have come into the Bay to feed and to spawn and have been taken in large numbers. Also, large flocks of overwintering waterfowl.

Captain John Smith in 1600 when he "discovered" the Chesapeake, said that it was a fruitful and delightsome land. Then he went on, "heaven and earth never combined to frame a better place for man's habitation". Well he was right, and it's sort of ironic that quality of the Chesapeake has been perhaps one of the main factors leading toward her downfall. In our numbers, we have really affected the Bay and its resources. She no longer produces generously as she once did. One of the things that probably contributes to that as much as pollution and other things is simply that our technologies have become too good and we're able to take too much at any given time. The catch of oysters, clams, and many species of finfish are at their all-time low. In addition, the commercial and recreational catch of shad and striped bass have been completely banned for recreational as well as commercial fishermen in Maryland and the restrictions are so great in Virginia it's going to be about as close to a moratorium as you could have. Unfortunately, although we think the populations will rebuild themselves, the bad news is that reproductive success still remains abismally low.

As wildlife has declined obviously, human populations have skyrocketed, growing from 8 to 12 million people in the watershed in only the last few decades. And although scientists are reluctant to point a finger at any specific cause for the Bay's decline, it seems clear to me that a multitude of insults are really what has caused the decline in productivity. In some areas, such as major metropolitan areas, you can say that toxic chemicals are probably the biggest cause for alarm. A section of the Baltimore Harbor for instance, contains every chemical compound known to man.

But moving away from the inner cities, out towards the mouth of the harbor, we see that man still has an impact. Richard Story, the architect calls this spread the suburban sprawl, "Sluburbia". It's taken its toll as forests are stripped away and increasing the non-point source runoff. Loss of habitat due to rapid growth and development on the shoreline has also taken its toll. But moving further away from the population center, the agricultural use of the land has contributed more and more soil and chemicals as farmers intensify their practices to get ever greater yields from the same acreage. Throughout the system, sewage treatment plants and private septic systems really do introduce huge quantities of nutrients, and the newer management is taking that into account. You don't have to have a real imagination to get the connection between these and the water quality. The newer management also is a major issue.

The result of all of this, toxicins bio-accumulating in the food chains, less habitat for those species that are able to survive, ever increasing stress from hypoxia -- and of course, the burden of overfishing. We have a heck of a dissolved oxygen problem on the Chesapeake as I understand you do here as well. Back in 1950, there were very low oxygen and low oxygen waters. We didn't have any anoxia at that point. But 30 years later, anoxic bottom waters are now prevailant. We have something on the order of a 15 fold increase both spatially and temporally of low dissolved oxygen throughout the year, what the watermen call "bad water". They have to move their crab pots closer and closer to shore to keep the crabs from dying if they are held in the pot, and that'll last from early June through late September. And of course, no dissolved oxygen below 15 feet translates into no oyster beds in deep water.

But much to the chagrin of Chesapeake's sportfishermen, no jubilees, maybe they have something to look forward to in that regard. Throughout the late 70s and early 80s, submerged aquatic vegetation (SAV) all but disappeared from the Chesapeake, and although a number of possible culprets were implicated, it now seems as if the plants were light-limited, dying off as the photosynthetic process is reduced primarily by massive algae blooms and of course by sediment loads. But recently, resurgence of SAV in many areas of the Bay have been documented, and this is good news. It seems that two severe drought years in a row have allowed the grass to make a comeback. We can't rely on such climatic events nor do we want to suffer from more drought obviously. But the good news is that it proves, I believe, that our strategy of trying to reduce non-point source pollution is viable. And in addition, I think the plants will gain just enough of a foothold that they may be able to hang on long enough until improved strategies are continued and take effect. Trying to maintain that restoration process and that the Programs have time to take effect is a major objective of the Chesapeake Bay Foundation.

As a non-profit organization, we are supported by over 40,000 members from every state in the union. I meant to get the figures on how many members we have in Alabama, but I was not able to before I left. The private funding -- this is something I've talked to alot with people since I've been down here -- private funding allows us a great deal of complete independence from government bodies. We have the freedom to critique and prod the public sector into doing what is best for the Bay. And that philosophy would need some help by Steve Muller who is the president of Johns Hopkins University. He said "only the checks and balances of the private sector can ultimately insure the integrity of the public sector" -- good thing to remember. I think we have made a difference on Chesapeake Bay, and I am proud of what we've done. I'm proud of the fact that we have over 70 dedicated professionals operating out of three offices in Richmond, VA; Annapolis, MD; and, Harrisburg, PA -- the three states' capitals. Our strategies for helping to save the Bay are to be teachers, watchdogs and advocates.

As teachers, we provide field instruction on estuarine ecology to over 25,000 students annually. We're not out there giving birds and the bees environmental brow beating to these kids; we're using the Bay as a scientific laboratory and as a classroom. They get the message once they start to understand and appreciate the resource, they become more interested. We don't have to give them an environmental diatribe on what's killing the Bay -- we do it a different sort of way. We operate solely in marshes and on the water using a variety of Coast Guard certified crafts.

As watchdogs we oversee the role of government and others who use the Bay. We have access to all public forums, administrative hearings and even the courts. I'll take just a second and talk a little bit about one of our projects. We have for the last 3 1/2 years been engaged in a major industrial discharge compliance monitoring project. Working with the monthly discharge report that industry and municipal discharges provide, we compiled a list of the most egregious violators. Fortunately, it was relatively small in comparison to all of the discharges of the Bay, under 10 percent. We took this list and we negotiated with the state and federal agencies and the companies themselves to try and reach negotiated fair settlements. We wanted to do that before going public and of course before going to court.

You know, there's a lot of controversy about whether to go to court or not. But sometimes to maintain your credibility, you have to do it. And, Al Capone had hit it right on the head, he said "you can get a lot more with a kind word and a gun than with a kind word alone". So, when we had a handfull of companies, really only four who absolutely refused to try and improve their situation at all, we did go to court. We won on all counts. I'm pleased to say, the corporate community had really supported us in the vast majority of the cases. You know they don't want a couple of rotten apples to make the whole barrel look bad. And I think on the Bay that's what was happening with the cases we brought to court.

One case against a meat packing company in Smithfield that had been violating their permit hundreds of times. Large amounts of chlorine, nitrogen, BOD dumped into the Pagen River had spent literally hundreds of thousands of dollars fighting the decision made at the lower courts then through the appellate courts and now the U.S. Supreme Court has agreed to take case because there are three separate interpretations of the Clean Water Act by three circuit courts in the country. Hopefully, we'll get a final interpretation by the Supreme Court by next fall. It's important to note that although we felt a responsibility to try and stop the polluters especially those who just absolutely refuse to abide by the law at all, and get them to improve. More importantly, we were trying to prod, if you will, the government agency into improving their enforcement activity. They have responded and we have seen some improvement in the enforcements over the last 24 months.

What we attempted to do was to be a catalyst for improved governmental functions. And that word catalyst is one that keeps reappearing in our vocabulary. It's especially pertinent for our third program, which is the land conservancy. Although we own and manage about 3,000 acres of prime habitat, we are not trying to become land barrons of the Chesapeake. Rather, we spend most of our time encouraging the wise use of land and the preservation of important areas by both the private and public sectors. This and the environmental education program are really superb long-term investments in the future of Chesapeake Bay. Our Environmental defense work is more short-term in nature, but still necessary of course.

Still, the situation on the Chesapeake has really improved immeasurably in recent years and yet there is an enormous sense of uncertainty for the future. The more that's learned about the Chesapeake and Mobile Bay, any estuary that's complicated as they all are, the more clearly it's understood that the ultimate restoration will not be measured in years, but really in decades. In anticipation of the question, is the Chesapeake Bay getting any cleaner, I'll say no. I'll tell you why. . . I think that the rate of decline has slowed, and the analogy is turned into a ship under full ahead. Once you drop it down into full astern, it takes a long time not only just to stop it but to keep it from going forward, and of course once you get to stopping it and actually get into stern way is a good deal of time. That kind of momentum, that kind of lag time is what we are seeing on the Chesapeake. Obviously, we can't give up now and we have to keep working to keep the pressure on.

One of the things that we're going to try and do a better job of in the years to come is to do an improved job of working with the corporate community in forming partnerships. This will be especially important for the scientific and environmental community to do. Business people, are so valuable to draw into a process like this. You know they have expertise in technical and fiscal matters, research and development, long-term planning, and just basic problem solving. In addition, just about all of the business community is well-tied to the community, they have a good deal of influence and talent. I am convinced that a broad-based coalition of scientists, environmentalists, and business leaders is just what it needs to carry the "save the Bay" movement into the next decade and really the next century.

It seems to me that due to the popularity of this Chesapeake Bay effort, such a coalition would offer the business community very real advantages and public relations benefits, and would offer environmentalists and scientists exposure to a group they do not often come in contact with, except maybe under adverserial conditions. I am committed to making it a priority for CBF in the years to come, and I would think it would be an absolutely fine strategy and I believe from what I've heard, one that's already been begun on Mobile Bay. You know that the time is right for working on environmental problems in that way because the myth that what is good for the enviroment is bad for the economy has finally been laid to rest, at least it has up in our neck of the woods. We continually stress, and others have too, that a clean and healthy Bay will actually improve the economy as a region. We must maintain and strengthen that belief, and you can't say that saving the Bay is something that we ought to do. You've got to say and you've got to have people believe, and I think they do, that it's mandatory. There's no other alternative. We've helped to develop a positive attitude about cleaning up the environment. It's really a "let's roll up our sleeves and get to work" sort of attitude. But, I don't want to leave you with the impression that everything is perfect, it's not. There are a number of areas where we can do a better job, and let me just touch on a few of them.

First, enforcement of existing environmental laws still can be a higher priority. We must do a better job of providing regional Bay-wide management. Now, if we have several states, hundreds of local jurisdictions, federal agencies all involved that's a hell of a job. Especially compared to Mobile Bay, where you're fortunate in only having one state and two counties involved. The final area of improvement is in land use management. We took the first steps in Maryland, fortunately, in which the law was passed to try and improve development within a thousand-foot buffer back from the shoreline. But beyond that, nothing is being done and in Virginia and in Pennsylvania nothing is being done.

And finally, avoiding finger pointing. You know we all find it easy to say, in theory, yes we've contributed to the decline of the Bay, whatever bay or the river, whatever environment you're talking about. And then, it's easy to say we must all contribute to cleaning it up. But that's in theory. Once you get it into practice, the old "not me" syndrome -- you know "don't look at me, but look at that guy - he's the one did a lot more" becomes prevailant.

What you all have done is so impressive and you've begun it in an early stage. I think of that commercial on television that says "you can pay me now or pay me later, it's $5 for a fram oil filter now or $305 for a rebuild six months down the road". But, you're in on the ground floor and if you can keep up the momentum, you're going to be in so much better shape than we were on the Chesapeake.

Well, let me change gears a little bit. I think Mark Twain said that a good audience is a one that's intelligent, well-educated, inquisitive and drunk. In drawing to a conclusion, you are a good audience and I sense I better wind down before I get thrown off the stage. Twain also said that you ought to give every audience the three Fs; a little fun, a little fact, and a little philosophy. We've had some fun and I think I've given you a few facts, permit me to philosophize just for a moment.

I'm reminded of a quote of a famous author who was writing about his land. I want to read that to you, but I want to see if anybody recognizes this and if anybody can tell me who it was or what he was talking about. It goes like this . . . "Our land, when compared with what it once was is like the skeleton of a body wasted by disease, the soft plump parts have vanished and all that remains is the bare carcass". He wasn't talking about Chesapeake Bay, he wasn't talking about Mobile Bay. . . he was talking about Greece in the fifth century BC and the author was of course Plato.

Well, I haven't been to Greece recently -- I haven't been to Greece at all, but I understand that those lush contours of the Golden Age have really never returned. History has a lot to teach us if we will listen. I hope that our generation can be remembered as the one that finally stops taking and taking and taking from the environment and started to give something back. We've got to do a better job of thinking globally and acting locally. Saving Mobile Bay, saving the Chesapeake Bay for future generations is so important. But you know we haven't inherited the earth from our parents, but really we're borrowing it from our children. Thank you very much.

INTRODUCTORY SPEAKER

BRUCE TRICKEY

Symposium on the Natural Resources of the Mobile Bay Estuary

Ladies and Gentleman, it is my privilege and pleasure this morning to say a few words about the background of the present symposium. It all began from the Alabama legislature of 1976--Act 534, creating the Alabama Coastal Area Board and charging the Board with preparing a Coastal Area Management Plan. This plan was, and I quote from the act, "to preserve, protect, develop and where possible to restore or enhance the resources of the state's coastal area for this and proceeding generations."

Now in writing the Coastal Area Management Plan, the Board considered three options: option (1), was to encourage economic development and allow for some losses of coastal resources; option (2), was to encourage economic development and try to hold coastal resources to present levels as far as practical; option (3), was to encourage economic development and at the same time to enhance or improve coastal resources.

After careful study and much discussion, option 1 was thought to be unacceptable to many people in the area. Option 3 was studied and a conclusion reached that it was unrealistic at the time. Option 2, trying the hold present levels was the option chosen. This option also has the advantage of leaving open the opportunity of improving conditions where necessary and possible at some future date.

At this point, the question arose . . . since we now have this present levels policy, what do we know about the present levels of our natural resources? In order to solicit input from those who should know the answer to this question, the Coastal Area Board sponsored a 1979 Symposium for coastal resources, inviting a number of noted local and regional scientists to present the information that they had available at that time about coastal resources.

As a result of the first symposium, many gaps in knowledge were identified. Subsequently, a number of studies were funded by the Board to fill in the gaps identified at the 1979 Symposium. The technical reports resulting from this effort will be presented during this 1987 Symposium, along with several other studies done by other institutions since 1979.

It is expected that the data now available is sufficient to provide a baseline for measuring changes in kinds and amount of natural resources and will help those charged with making decisions in the rational development of a coastal economy having regard to both development and the protection of the environment.

The present Symposium is especially timely because of the many important projects now unfolding in the Mobile and Baldwin Counties area. Just to mention a few: we have the Tenn Tom Waterway which was recently completed; we have very important gas and oil discoveries in the area; we have a problem of where to put dredge soil in disposal; the Theodore Outfall fight is still with us; there's a large effort for promotion of tourism and beach development; and the Navy Home Porting Project which so many people are working hard to get. Each of these are important projects that deserve our full support. However, proper consideration and necessary adjustments of such projects need to be made to give full emphasis to the prevention of the possibility of severe degradation of our coastal environment.

It is my belief that the present symposium is generally good news and will make a great contribution to the future of the development and growth of our community.

STATE FEDERAL MARINE FISHERIES MANAGEMENT

Hugh A. Swingle
Marine Resources Laboratory
P.O. Box 188
Dauphin Island, Alabama 36528

ABSTRACT: Management of Alabama marine fisheries consists of separate actions of the Department of Conservation and Natural Resources, separate actions of the U.S. Department of Commerce and by cooperative actions of both agencies.

Business and the Bay

A Baldwin County Perspective

by

Hattie Smith

Symposium on the Natural Resources of the Mobile Estuary

February 10, 1987

When you look at the history of a place, most often you read that the city sprang up along a waterway, a railroad, a highway junction. Growth began because you could "get there from here". And so, waterways were our beginnings. Especially in America where you could get here from countries by floating in.

But you stayed on that waterfront only if business was good. Look at our many "lost" or "dead" cities. You can read any Saturday in the Mobile Register's up home stories of many small towns that never grew, never will, perhaps.

What is business anyway? Some words that come quickly to mind: commerce; trade; industrial development; economics; "the bottom line".

Who is business? Picture the man, or woman, in the: 3-pc suit; gray flannel vest; camo; hard hat and work khakis; tennis visor & shorts; doctor greens and mask; woman exec in cocktail dress; Mardi Gras reveler.

Where is business? All around Mobile Bay. Most of you are from Mobile, but look with me at the mirror reflection of Mobile Bay ... Baldwin County. You even refer to us at Fairhope, and we do too, as the "Eastern Shore" ...that may be the eastern shore of the Mobile Bay, but when you're in Baldwin County, that's the Western shore of Baldwin County

I heard a prominent Mobilian say, in a recent industrial development workshop, that it is tough developing industry for Mobile because of its location on the Bay. He said that if you draw a circle around Mobile, 3/4 of it is in the water, and fish don't buy anything. In Baldwin County, we are developing the economy because we are on the bay. We believe that fish buy us an ambiance that is marketable and extremely desirable.

Baldwin County, if you'll envision your map of the county, is almost an island. It has only one land boundary, on the north. The other 3 sides of the county are surrounded by water.. The Gulf of Mexico on the South, Perdido Bay and Florida line on the east, and by Mobile Bay on the west. In addition we have many, many other waterways, bays, coves, rivers, lakes, inlets, marshes, the Intracoastal Canal, the Mobile Delta, etc... That BAY is business.

Look at it this way: what does an industrialist look for when he looks for a site? Of course he looks at the bottom line. He wants a location where the company can operate profitably...plus he wants a location where he and his family will be comfortable. He wants, in addition to the financial rewards, family security and that includes health, good schools, ample recreation, nice housing, and plenty of community activities. He wants the same things that the environmentalist wants. The environment is a business, too, you know. We're all here this morning on environmental business. Many of you earn your living in the environment business.

It is not a matter of us vs. y'all. We are all in this survival game together.

Just think, the year 2,000 which sounded so futuristic to us, is now only 13 years away. That 13 years is a very suitable time period for us to do, not long-range planning, but short range planning.

Now, down to specific issues:

EDUCATION -- Let's start with education because everything else does. A child in the 2nd grade this year, will vote in the Year 2000. He will begin to make a statement of his own philosophy about conservation and business that will impact the earth and perhaps the universe. I'm glad to see that a good portion of this symposium will address educational efforts. We are right now working on a coloring book that we can distribute to children who visit the Chamber office. It will emphasize care for the coastal environment.

COASTAL DEVELOPMENT ISSUES -- Ports and channels/Hazardous waste/solid waste disposal/Disposal of dredged material/Marina & shipyard siting/Condo setback lines/Water related energy facilities/Commercial & sportsfishing conflicts/Recreation/Coastal storm issues/Groundwater management, for a few Alabama's future depends, in large, on how well economic development issues are addressed today. The new state administration is talking loud and long on its emphasis on being more business-oriented. The changing federal role will increase the state's responsibility for programs and remedies.

Some of the subjects that interest the Baldwin County business community right now are:

The changing outlook of financial institutions. Banking has changed mightily. The financial community is taking a totally different view of the coastal situation.

Wastewater treatment systems. The dynamic growth of construction on the island was followed, for heaven's sake, by concern for wastewater treatment. Figuratively speaking, in some cases the plumbing was installed before the flushing was assured We are seeing a lot of privatization in that area, and not just seeing it, but smelling it in some instances

While Mobile County has a fine environmental center for the board of education, Baldwin County has yet to wake up and smell the coffee, as Ann Landers says. We see some interest beginning to be kindled for us and we are hopeful.

The Island is crying for a new access road and bridge for evacuation and tourism, and other parts of the county see four-laning HWY 98 as a priority. We are told that replacing bridges in Baldwin County is a big item for the Commissioner's attention.

But what we offer best in Baldwin County is a lifestyle that is enhanced by Mobile Bay and the Gulf of Mexico. What do we show a prospective industrialist after he's seen the Industrial Park? Oysters on the halfshell and boiled shrimp, softshell crabs, crabs claws, a view of the Gulf, and the bottom line gets wavy.

Weeks Bay Estuarine Reserve was a great "set-aside" of pristine Baldwin County. The Perdido tract that is now Bon Secour Wildlife Refuge was another. Annexing Gulf State Park to the City of Gulf Shores is an entirly different matter. How much land should be public, how much privately owned? What will happen with Federal flood insurance? Should industry be located on the Intracoastal Canal? Will they develop Little Point Clear? What issues do the businessmen in the seafood industry face? And the big issue in the past couple of years in Baldwin County has been zoning the unicorporated areas. Land use, by whatever term you use, is a big business issue, at the same time, a big environmental issue. But then, aren't all these issues both business and environmental?

"Fish don't buy anything?" Let me put it to you this way: In New Orleans, when Chef Paul Prudhomme went into his kitchen, scorched the redfish and started a conflict that is commercial, industrial developmental, economic and shows up on the bottom line..... Well, that's the kind of situation that makes us come together to talk about the wonderful matter of business on the bay

PETROLEUM RESOURCES

OF COASTAL AND OFFSHORE ALABAMA

Ernest A. Mancini
Robert M. Mink
Bennett L. Bearden
Alabama Geological Survey
P.O. Drawer O
Tuscaloosa, Alabama 35486

ABSTRACT: Coastal Alabama became an oil and gas producing region in 1950 when oil was discovered in the Lower Tuscaloosa sandstones (Cretaceous) at the South Carlton Field in Clarke and Baldwin Counties. The 1979 discovery of significant quantities of gas in Jurassic Norphlet sandstones at the Lower Mobile Bay-Mary Ann Field first demonstrated the natural gas potential of offshore Alabama. The Miocene shallow natural gas discoveries in coastal Alabama have shown that hydrocarbons are present in Tertiary strata in the state. Petroleum reservoirs in coastal and offshore Alabama occur at depths from approximately 1,800 feet (shallow Miocene) to depths in excess of 21,000 feet (deep Jurassic). Alabama's coastal plain and territorial waters should remain excellent areas to explore for oil and gas in the years ahead.

SPORT FISHERY RESOURCES

OF THE MOBILE DELTA

AN ECONOMIC PERSPECTIVE

William H. Tucker
Game and Fish Division
P.O. Box 245
Spanish Fort, Alabama 36527

ABSTRACT: Recreational fishing in the Mobile Delta is a valuable economic asset to Mobile and Baldwin counties. The sport fishery can potentially be adversely impacted by population growth, economic and industrial development which might lead to increased fishing pressure, and environmental degradation. Anglers provide funds for fishery management and development through license fees and excise taxes on fishing gear. The sale of fishing and boating supplies and equipment and all other related expenses associated with fishing inject millions of dollars into local economies. Consumer surplus associated with sport fishing adds more value to the resource. In planning for economic growth and development around the Mobile Delta, the sport fishing industry should be recognized as healthy and important, and the aquatic environment which supports the sport fishery should be protected.

THE PROSPERITY EQUATION
by
John H. Friend, Jr.

Symposium on the Natural Resources
of the
Mobile Bay Estuary

February 10, 1987

It is a great honor to follow the distinguished speakers that have preceded me today, particularly Will Baker of the Chesapeake Bay Foundation, who has brought us a profound message - a lesson in history and a warning applicable to our own future here in the Mobile Bay area. As the anchor man for this portion of the symposium, I would like to share with you a philosophy concerning the importance of both economic growth and environmental quality - a philosophy which I have developed over the past years as a market research consultant working for business and industry.

I first began to think deeply about the forces which fuel growth and development when making economic and population forecasts, and it wasn't long before I realized that many different forces affect economic activity and population levels. This, in turn, led me to ponder the true meaning of "progress," usually means an increase in the production of goods and services or the creation of jobs and incomes. Interestingly, the word "profits" is seldom mentioned.

When used in a purely social sense, the meaning of "progress" is generally much broader, embracing all aspects of a community's well-being under the catch-all phrase, quality of life. However, it soon became evident to me that, alone, each of these definitions is too narrow. To arrive at a true meaning of "progress," they had to be combined. Thus, the prosperity equation: Economic growth plus the quality of life equals prosperity. Take away either economic growth or the quality of life and you do not have "progress".

In a free enterprise, democratic society such as ours, jobs and incomes and ecomonic developments are absolutely essential; because in a no growth society, every time someone gains something, someone loses something. This, of course, would be intolerable for us, and would threaten the very fabric of our way of life. Thus, we must maintain a reasonably high quality of life, or ecomonic growth will be meaningless and counter productive.

Jobs and incomes are easily defined. Quality of life, on the other hand, is more difficult to articulate. It is the kind of thing you feel, but can't always explain. Educational opportunities, access to good health care, the absence of crime and violence, affordable homes, good roads and highways, ample recreational facilities, and a healthy natural environment all combined to determine the quality of our lives; for the things just mentioned do not come free - they all have big price tags, particularly environmental quality.

Let me put this in other words by quoting from Business Brief, an economic newsletter published by the Chase Manhatten Bank.

"Business growth is an increase in a nation's ability to produce goods, services and leisure. In America economic growth is not an end in itself. Economic growth derives its values only to the extent that it contributes to the broader objective of enhancing individual dignity and providing greater opportunities for individual development. As such, it is an intermediate objective."

> "But as history amply demonstrates, growing wealth is no guarantee of progress toward these broader objectives. It can provide the opportunity -- but how to use growing wealth constructively is one of the major challenges facing America."

Now let me get a little closer to home. The characteristic that distinguishes the Mobile Bay area from most other localities throughout the nation is its abundance of, and dependence on, water resources - both for recreational and economic purposes. Water activities comprise a great part of total leisure pursuits in the Mobile Bay area, including swimming, fishing, boating, and hunting. At the same time, water is a valuable economic asset for processing and transportation uses, as well as an indirect generator of jobs and incomes in many different sectors of the economy. If one were to add up the jobs and incomes associated with all the economic activities which depend on clean water, abundant marine life, and viable wetlands (commercial fishing, tourism, recreation, seafood dealers, restuarants, sporting goods shops, marinas, fish camps, yacht clubs, waterfront property management and sales), it would represent one of the largest, if not the largest, industry in the area.

Thus, those who would destroy wetlands or pollute the water as a trade off for jobs and incomes are playing a zero sum game, and are doing more to harm the economy than all the world's no growth proponents rolled into one. As such, the quality of the marine environment in the Mobile Bay area is a major component of both economic activity and the quality of life, and is worthy of great attention.

It is evident, therefore, that development and environmental quality are two sides of the same coin. Without growth, environmental quality cannot be afforded, and without the amenities provided by environmental quality, it is obvious that growth cannot be sustained. Development and environmental quality are therefore interdependent - not mutually exclusive as is so often proclaimed.

Now how does all of this translate into action? In my experience, I have found that attitiudes relative to environmental conflict conform to the classic bell curve. Out on the lips of the bell are those persons who place a very narrow interpretation on the meaning of prosperity: growth at any cost on the development side, and no growth on the environmental side. In the middle, however, is the majority who are more inclined to see both sides of the coin, and it is here that solutions to conflicts can be found.

Although a general concensus embracing the concept of balanced growth is not difficult to achieve among developers and environmentalists, agreements concerning specific issues even among those in the middle section of the bell curve are difficult to come by, primarily because of conflicting interpretations and assessments of impacts.

Thus, left to its own, the process often moves from agreement on the philosophical level to total disagreement when it comes to specifics. At this point, political and legal pressure enter the arena, further exacerbating the gridlock.

How can developmental-environmental gridlocks be avoided or ameliorated? By introducing into the process a mechanism for dialogue and communication before an impass is reached.

What kinds of mechanisms? A group of persons who comes from both sides of the lines in the middle section of the bell curve, who meet to resolve environmental disputes before gridlocks develop.

Who should initiate the formation of such group? The Mobile Area of Chamber of Commmerce would be my candidate.

What would be the guiding principles of the group? Commitment to the process, creativity in solving problems, and compromise - realizing that in a good compromise, everyone wins.

The existence of such a group would not interfere with the tasks of the Federal, State, and local agencies charged with Environmental matters. In fact, the work of the agencies, might be somewhat easier since less time would be consumed in responding to political pressure and more spent on purely professional matters. On the other hand, additional pressure could be felt as the result of greater demand for innovative soultions.

In closing, let me make two comments: We have reached a point where the matter of cumulative environmental impacts must be taken more seriously. Environmental evaluations of specific situations cannot be made in a vacuum apart from the impact of other situations, both present and future. Also, we must be prepared to increase the resources allocated to environmental evaluations, depending on the potential cost to some future generation of restoring and reclaiming the environment. Example, Chesepeake Bay. Example closer to home, Perdido Bay.

In addition to the preceding, it is important to understand that state of the art analysis involves innovative techniques as much as the latest equipment and scientific apparatus. In fact, the way something is done is often as important, if not more important, than the physical tools used. Again: the need for imaginative and creative thinking when dealing with conflict resolution.

Over three decades ago, Aldo Leopold, the great naturalist, had this to say about conflicts and compromise:

> "All ethics so far evolved rest upon a single premise: that the individual is a member of a community of interdependent parts. His instincts prompt him to compete for his place in the community, but his ethics prompt him to cooperate (perhaps in order that there may be a place to compete for)."

RESOURCES OF MOBILE BAY: AN ECONOMIC ASSET

Summary of Panel Discussion

The participants on the "Resources of Mobile Bay: An Economic Asset Panel" were:

Moderator: Susan I. Rees, Corps of Engineers
Hugh Swingle, Marine Resources Division,ADCNR
Hattie Smith, South Baldwin Chamber of Commerce
Ernest Mancini, Alabama Geological Survey
Fred Delchamps, Mobile Area Chamber of Commerce
Bill Tucker, Game and Fish Division, ADCNR
Jack Friend, Management Consultants

INTRODUCTION

In general, two topics were covered during the panel discussion. The topics pertained to: multiple use conflicts; and the interdependency of the Bay, quality of life and economic development.

MULTIPLE USE CONFLICTS

Our nation's remaining fragile coastal resources are subjected to various demands as a result of policies, plans, and decisions related to competing user groups. Mobile Bay provides much of the economic base of both Mobile and Baldwin County through transportation, tourism, seafood, sport and recreation, oil and gas revenues and yet also provides for a quality of life that makes this area and indeed the entire coast of the northern Gulf of Mexico one of the most popular locales in the continental United States. There are the competing user groups of Mobile Bay and yet within each 'group' you find individuals who are proponents of different user groups depending on the 'hat they are wearing'. The businessman who is vitally interested in waterborne transportation as his means of support may also be an avid fisherman on the weekends and enjoy vacationing on the beach. The conflicts which arise over use of the coastal resources often put individual against individual based on the benefits of an action to the perceived user group an individual is affliated with. These conflicts often do not allow a rational approach to management of uses of the coastal environment such that all users are able to gain from the resource. In the past the means that have been used to accommodate the needs of the various users have been regulatory in nature as was discussed in the presentations by Swingle, Tucker, and Mancini. Although these means are necessary and in most cases successful, they tend not to solve issues relating to compatible use and management of resources and indeed may result in individuals or groups taking sides of an issue.

MOBILE BAY, QUALITY OF LIFE, AND ECONOMIC DEVELOPMENT

The presentations by Smith and Delchamps discussed the more philosophical concepts of the relationship between development and the bay and how each rely upon each other. A common theme which seemed to weave throughout their presentations was that of education and the need for all the people of coastal Alabama to work together toward proper management of our limited resources. As Hattie indicated, it's not a matter of us and ya'll - we are all in the game together and Alabama's future depends on how well we address issues related to the economic assets of Mobile Bay and coastal Alabama. Thinking ahead, a second graders will vote in the year 2000 and begin to make their statements relative to the issues we discuss today. It is very important therefore that we provide them with a basis to make the required decisions and also that we have left to them a resource that is still an economic asset to the community. Fred Delchamps stressed that a community has to live with changes or the community will die. The concepts of 'stop', 'let things be', and 'return to what used to be' are not conducive to a vibrant community and therefore are not appropriate ways to approach management of the resources of Mobile Bay. Many people are frustrated by the confrontational way issues have been approached in the past and are looking for a means to provide for communication and compromise in managing resource issues.

Jack Friend's presentation which he entitles the "Prosperity Equation" brought together many of the issues and ideas that were presented by the other speakers. Although Jack's presentation was much more eloquent, I think that it can be pretty much summed up in a rather common and somewhat comical phrase - "There ain't no free lunch". Economic development associated with Mobile Bay allows us to live a quality of life which distinguishes Mobile from other areas in the United States. Therefore the bay is a major component of both economic development and quality of life. As Jack put it 'two sides of the same coin - interdependent not mutually exclusive.

In a more quantitative fashion, the attitude of individuals can be viewed similar to the distribution of grades on a bell curve. At one end we have the idea of 'growth at any cost' while at the other we have 'no growth at any cost'. The potential solutions to conflicts cannot be found on the ends - in reality the ends are more than likely the cause of the conflict. The solutions, if they are to be found, will be found within the bell of the curve. Even within the 'bell' there may be conflicts, however discussion and compromise are still viable mechanisms for resolving these conflicts. It may be easy to agree on philosophical points, however agreement on specific issues may be more difficult and when political and legal pressures are applied it may be impossible to agree. A mechanism therefore must be developed to allow for dialogue and communication before the impass is reached and compromise is no longer a viable option.

Recommendations which were made by the speaker which I felt stood apart from the rest included:

a. to conserve our resources it will be necessary to work together (Swingle);
b. education - a 2nd grade child will vote in the year 2000 (13 years from now) and begin to make a statement concerning quality of life, therefore we must provide them with the fundamentals to make rational decisions (Smith and others);
c. prudent development of our oil and gas reserves will take cooperation /discussion/compromise/and working together (Mancini);
d. development of hydrocarbon reserves in the Gulf of Mexico will impact future activities of the state - state needs to be involved in this development. What is the role of Alabama going to be? (Mancini);
e. establishment of a broad based group to discuss ideas of management and development before 'the swords are drawn' (Delchamps);
f. increase public interest in factors of environmental degradation-habitat alteration, etc. (Tucker);
g. cumulative impacts must be addressed (Friend);

From this list of recommendations, I believe that a mechanism can be developed to resolve multiple use conflicts and lead to prudent management of the resources in question.

Questions & Answers

Several questions were asked concerning establishment of a group, who would be involved, what authority the group would have. I believed that one commenter referred to this group as a revolt on the part of the people in middle against those on extremes. Mr. Will Baker, our keynote speaker indicated that this is how the efforts to clean up and manage the resources of Chesapeake Bay were started.

Have plans for future hydrocarbon development in the bay been developed? Utilization plans have been developed to minimize the number of wells in the bay both for economic and environmental reasons. These plans would provide for wise development of a resource which has significant economic and quality of life aspects.

Has anyone considered a provision for a buffer between state & federal waters relative to hydrocarbon development of the Outer Continental Shelf (OCS)? The previous administration has requested that the same restrictions which apply to the development in state waters be applied to federal waters. To date, the Minerals Management Service (MMS) has ignored these requests. In all instances, the State has been consistent in its' requests to MMS that the same restrictions apply to OCS waters.

STATUS OF THE SPORT AND COMMERCIAL FISHERIES

OF THE MOBILE DELTA, DECEMBER 1980 - NOVEMBER 1981

Stephen P. Malvestuto
Department of Fisheries and Allied Aquaculture
Swingle Hall
Auburn University, Alabama 36849

ABSTRACT: A catch assessment survey of the sport and commercial fisheries of the Mobile Delta revealed that fishermen exerted 400,000 fisherman-trips and harvested 640,000 kg of fish, giving harvest rates of 1.6 kg/trip and 46 kg/ha during the study year. Of these totals, the sport fishery contributed 96% of total fishing effort but only 55% to total harvest, atesting to the low visibility, but high yield capacity of the commercial fishery. The relatively high harvest per hectare is indicative of an effectively high harvest per hectare is indicative of an effectively exploited fish community where sport and commercial fishing pressure is largely directed at different species. The total economic value of the Mobile Delta fisheries over the study year, including fishermen expenditures, market value of the commercial harvest and willingness to pay by anglers, was estimated to be $13,000,000.

BIOLOGY OF SPOTTED SEATROUT (CYNOSCION NEBULOSUS) AND RED DRUM (SCIAENOPS OCELLATUS) IN ALABAMA ESTUARINE WATERS.

Mark S. Van Hoose
Marine Resources Division
Alabama Department of Conservation & Natural Resources
Dauphin Island, AL 36528

ABSTRACT: Until recently few specifics were known or published on the life histories of red drum (Sciaenops ocellatus) and spotted seatrout (Cynoscion) nebulosus) in Alabama inshore waters. Spawning seasons, early habitat preferences, and growth rates can be documented with six years of assessment and monitoring data and two years of creel survey data. Spotted seatrout have bi-modal spawning peaks, overwinter in tidal rivers and remain in the local area. Red drum spawn in late summer, stay along the shoreline their first year and are subject to the recreational fishery most probably for little more than one year. Future research is needed to answer specific questions raised by the present data.

INTRODUCTION

Spotted seatrout and red drum, two highly prized and highly controversial marine fish, have been the subject of vigorous discussion, regulations, legislative action, and legal battles across the gulf region. In Alabama, although many of the issues concerning commercial take and recreational size and creel limits have been debated much of the debate has suffered from the lack of concrete data on the biology of both species.

Only in this decade have programs been initiated that are capable of answering such questions as when are the species spawning peaks?, what habitats do juveniles prefer?, how many year-classes are in the fishery?, do the fish remain in Alabama waters and if not at what size do they emmigrate?. Current research, an assessment and monitoring program began October 1980, a marine recreational creel survey began October 1984, a weekly year-class assessment program during the respective spawning seasons begun June 1984 and spotted seatrout culture work have partly or completely answered the above and other questions.

In this paper, the life cycles of spotted seatrout and red drum in Alabama inshore waters will be divided into three parts. First, there is a postlarval and early juvenile stage monitored most effectively by plankton tows at selected sites. Data from this stage can answer questions concerning year-class strength, spawning season duration and peak spawning periods.

Second, a juvenile pre-creel stage monitored most effectively by seines and trawls is considered. Information from this stage addresses questions concerning early growth rates and juvenile habitat preference.

Finally a late juvenile, early adult stage, subject to the recreational fishery, monitored by the recreational creel survey, is discussed. Data from this final stage addresses such questions as the number of year-classes in the fishery and age and length at which fish are no longer captured by the inshore fishery.

Combining information from all stages gives fishery managers solid information on the life histories of these two fish in Alabama. Future fishery management decisions can now be based on data rather than dependent upon the experience or beliefs of user groups.

MATERIALS AND METHODS

The postlarval, early juvenile specimens were taken at target stations sampled weekly during the spawning season with a beam plankton trawl (BPL) (Renfroe, 1963). The BPL is 1.8m wide with a 0.935mm diameter mesh. The BPL was hand-towed approximately 65m out and then back for a total distance of nearly 130m. The target stations were established on the basis of the information compiled from the first three years of the assessment and monitoring program. The criteria for the target stations were consistently high abundance and yearly fidelity of the species at the site. Spawning season duration was determined to be the week in which the species began to consistently appear in numbers until its virtual disappearance from the target sites.

Specimens in the pre-creel juvenile size were taken by seine and otter trawl. The 15.2m bag seine with 5mm bar mesh was hand-towed approximately 6m from shore, pivoted 180 degrees and returned to the beach. Otter trawl samples were taken utilizing 4.9m trawls with 3.18mm bar mesh liners. Ten-minute tows were made during daylight hours.

Data on late juvenile and adult specimens were taken from the first two years, October 1984 - September 1986, of Alabama Marine Resources Division's, marine recreational creel survey of the hook and line fishery. All information from Alabama inside waters, consisting of the boat and bank modes of the survey plus the Fairhope Pier was considered.

For the boat and bank modes, the state was divided into five Mobile County and seven Baldwin County sampling areas. Area size was determined by the ability of a creel clerk to obtain a 20% interview rate at the maximum expected fishing level in that area over a four-hour period. Random non-uniform probability sampling (Malvestuto et al., 1978) was used to select each counties' area to be sampled for each fishing mode. Probabilities were originally assigned based on a previous knowledge of fishing effort distribution across all areas and revised in October 1985 based on the first year's data. In the case of the Fairhope Pier, non-uniform probability sampling was used but a fixed site was assigned a probability of selection rather than an area.

The survey for inside waters was stratified into weekdays and weekend days based on their relative percentages in any one month. For example a 30-day month with 10 weekend days and 15 sampling days available then (10/30)*15=5 weekend days sampled that month. The remaining 10 samples were then assigned to weekdays.

Once sampling dates and sites during a month were chosen a time was selected. Time choices were among three four-hour periods (6-10am, 10am-2pm and 2pm-6pm). Adjustments of up to one hour were made in certain months to allow for daylight savings time. No nocturnal boat or bank surveys were conducted. A 6-10pm time period was added the second year for the Fairhope Pier. Initial selection of time periods was equal and adjusted in October 1985 based on the first year's data.

The survey from April 1985 to September 1986 was conducted by the Auburn University Fisheries Department under contract to the Alabama Marine Resources Division. Data was compiled by Auburn University and analyzed by Marine Resources personnel. Marine Resources employees conducted the survey from October 1984 - March 1985.

Spotted seatrout growth rates were obtained form culture work currently underway at Alabama Marine Resources Division's Claude Peteet Mariculture Center (CPMC). Early growth rates are based on pond raised fish and later rates on returns from tagged and released pond fish.

RESULTS AND DISCUSSION

Red Drum

Red drum are known to spawn in the Gulf. How far offshore spawning occurs remains unknown. Larvae enter the estuary and begin to appear in BPL samples at 3 to 4mm SL. Age estimates of this size Alabama fish are unavailable. In Texas culture work red drum reached 5.1mm TL in 12 days. (Johnson et al., 1977).

Postlarval Early Juvenile Stage (3-30mm SL)

Table 1 gives the red drum time of postlarval abundance, year-class strength of the past three years as well as a description of the two target stations. Figure 1 shows target station locations. The reasons for the weak 1985 year-class are unknown. Since the assessment program began in October 1980, red drum postlarvae have been taken in salinities ranging from 8-31 ppt and temperatures from 19-31 C.

Figure 2 gives weekly red drum (3-30mm) capture peaks for 1984, 1985, and 1986. Figure 3 combines 1981-83 monthly sampling results with the weekly efforts of 1984-86 at the target stations. Red drum have only one extended spawning time and it falls within a six-week period. Actual Gulf spawning time is unknown since the figures are based on poslarvae and their age is unknown. The likely time of spawning is mid-August to early October.

Habitat preference for postlarval, early juvenile red drum are unclear. The two target stations have similar bottom types but dissimilar shorelines. Both stations; however, are adjacent to strong tidal current flows which could account for their productivity.

Early Juvenile Stage

Red drum disappear from BPL samples by 30mm SL. Between then and their appearance in the recreational fishery little data is available. Only 55 specimens 30-220mm SL have been captured in the assessment program from 1980-86. These captures indicate red drum at this stage have a shoreline habitat preference, yearling red drum are captured almost exclusively by seines. Of the 55 taken in six years 51 (93%) were seine captured.

Table 1. Postlarval Red Drum Time of Abundance and Year-Class Strength in Alabama (1984-86).

		C P U E	
Red Drum	1984	1985	1986
(9/1 - 11/15)	5.3	1.3	13.0

Time of Abundance (9/1-11/15)

Target Stations

Cedar Point - Sand-shell shoreline, mud bottom.

Pass Drury - Juncus marsh shoreline, mud-clay bottom.

Figure 1. Red Drum & Spotted Seatrout Postlarval Sampling Sites in Alabama

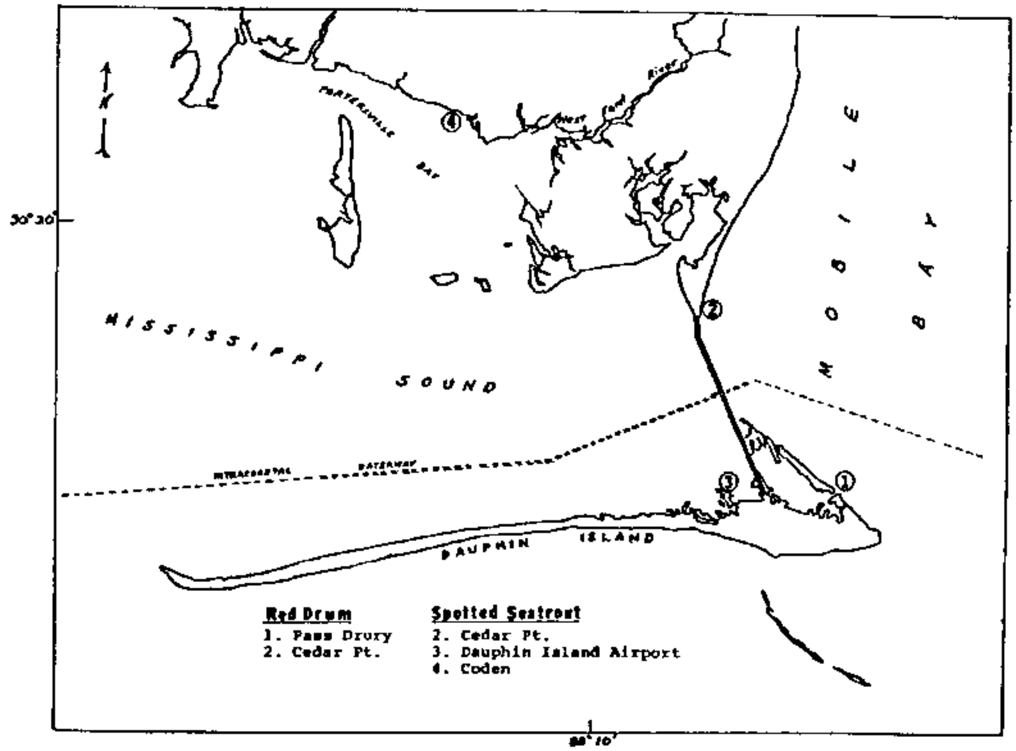
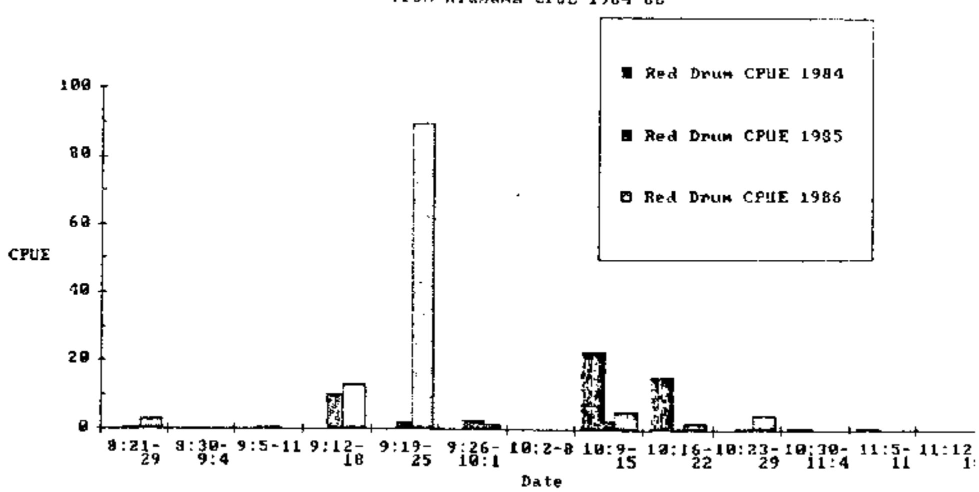


Figure 2

Weekly Postlarval Red Drum (4-32mm SL) From Alabama CPUE 1984-86



In a special project to collect yearling red drum for stock analysis 120 fish, (50-100mm S.L.) were taken in two seine hauls in a marsh tidepool in March 1985. The next January, 30 were seined from the same location. It is unlikely that red drum are avoiding trawls since fast-swimming species such as jack crevalle, and Spanish mackerel are captured more frequently in trawls than are red drum.

Table 2 gives the growth progression of the 55 red drum. From the table red drum reach 200-220mm by summer. It would seem that they begin to evade seine capture after 100mm as only 4 of the 55 fish were over 100mm SL.

Late Juvenile and Adult Red Drum

Table 2 showing monthly length frequencies from 30-220mm SL indicates the largest fish 160-220mm SL occured from June to August. In Table 3, monthly length frequencies from 200-500mm TL from October 1984-September 1986, shows the smallest fish first occur in June. These two tables are not directly comparable because the first is in standard length and the second in total length. But that measurement standard discrepancy does not alter the conclusion the small fish that appear in the June creel are part of the year-class spawned the previous fall.

Taking this 0 to 1+ year-class and obtaining monthly mean lengths starting in June a clear growth progression can be seen. This appears in Table 4. From this table red drum average 344mm TL at one year in September and 450mm TL by their second spring.

During their second spring most red drum disappear from the Alabama recreational creel. (Table 3) Between March and August only 11 red drum over 400mm have been recorded in creel interviews. This disappearance is abrupt as 15 red drum 400mm or greater have been recorded in February creels. Alabama red drum year-classes either emmigrate by their second summer or have been largely harvested by recreational fishermen during their first year and a half.

Available evidence is inconclusive as to which is the case. Other than noting a sharp decline in recreational harvest from March to May few other conclusions can be drawn. A tagging program is needed to determine if the fish are emmigrating or being overfished.

What the survey results show most dramatically is that Alabama's estuarine red drum fishery is based on age 0+ or 1+ fish. (Table 3). It relies on fish between 250-460mm. Of the 206 fish shown or listed on Table 3 199 (97%) are age 0+ or 1+. Also in the two years of creel data 96% of red drum landed in Alabama estuarine waters were landed from June through February.

Survey results also show that the proposed 18" Gulfwide red drum size limit would collapse Alabama's estuarine recreational red drum fishery. Only 14 fish (7%) taken in Alabama estuaries over the two year period were in excess of 18" (460mm). Seven of these fish were taken in lower Perdido Bay during the annual fall run of large red drum along Alabama's coast. The others were taken at scattered locations throughout the year.

Spotted Seatrout

The smallest spotted seatrout taken in BPL samples were 4mm SL. Most were at least 6-7mm when they were captured. As yet it is unknown if spotted seatrout spawn in the estuary or the Gulf although, postlarval and early juvenile stages (4-50mm) have occurred only three times in 46 weekly Gulf beach BPL samples and have never been taken in Gulf trawls or seines from 1981-86.

Postlarval - Early Juvenile Stage (4-50mm SL)

Three target stations were established in 1984 chosen by the criteria set forth in the materials and methods section. These stations were designed to monitor year-class strength and spawning season duration. Locations of these stations are given in Figure 1. Description of these stations time of postlarval abundance and year-class strength is given in Table 5. Data from 1984 and 1985 indicated a longer spawning duration thus in 1986 two additional weeks were sampled. A progressive increase has occurred since 1984 in year-class strength. The environmental or biological factors contributing to this trend are unknown but the last two years were extremely dry resulting in high estuarine salinities. Whether the offspring survive or not is likely related to environmental factors and food availability. Hydrographic data taken with every capture of young trout shows they can be found from 0-31 ppt salinity and 26-34 C temperatures. How long these young can tolerate the extremes, especially the low salinity ranges, is probably brief as evidenced from unpublished spotted seatrout culture work at CPMC.

Figures 4 and 5 show yearly spawning season duration and weekly peaks during 1984, 1985, 1986 and spawning season weekly peaks at the target stations cummulatively 1981-86, respectively.

Both figures show that the greatest abundance of 4-50mm spotted seatrout in Alabama waters occurs from late-August to mid-September. There is an earlier peak shown by both Figures 4 and 5 and Figure 4 indicates the timing can vary from mid-June to early July. Both these figures are based on number of postlarvae not actual spawning. Lab work at CPMC indicates young trout reach 6-7mm in approximately two weeks after hatching.

Early spotted seatrout growth rate data from lab work at CPMC is given in Figure 6. Pond raised trout reached 160mm TL in 100 days.

The target station habitats described on Table 5 indicate spotted seatrout are habitat specific. The grassflat at Coden is the most consistent producer of spotted seatrout postlarvae. Whether this is owing to the grass itself or hydrographic conditions normally found at the site is not known.

Early Juvenile Stage

At approximately 50mm SL spotted seatrout juveniles readily escape the BPL. From 50-200mm SL they are captured infrequently by seine and trawl. Trawl samples accounted for 55 of the total 63 captures (87%).

Figure 3

Weekly Postlarval Red Drum (4-30mm SL)
CPUE From Alabama 1981-86

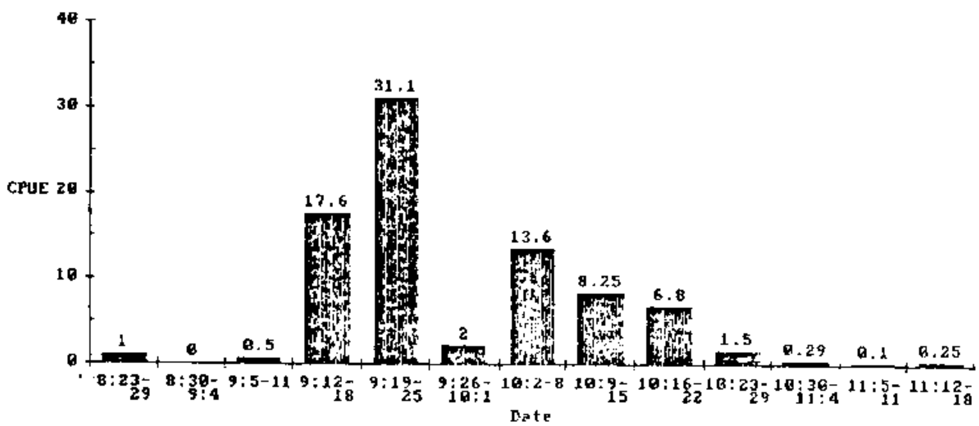


Table 2. Monthly Red drum (30-220mm S.L.) Captures from Alabama (10/80 - 09/86)

Length/mm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
30	1	1	11							1	3	1
40	1		7							1		1
50	1	1	4									2
60		2	1		1							
70		1	2	1								1
80				1								
90					1							
100												
110												
120												
130					1							
140												
150					1							
160						1						
170						1						
180						1						
190												
200								1				
210												
220							1	1				
Totals	3	5	25	2	4	3	1	2	0	2	3	5

Table 3. Red drum Monthly Length Frequencies (T.L.) from Alabama (10/84-09/86).

Length/mm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
200										1		
210						1		1				
220								1				
230						3						
240						1						
250						3		3		1		
260								2				
270							2	3		1		
280							2	5		1		1
290						2	3	7			1	
300							3	4	1	1		
310							2	7	1		1	
320						1	1	4	1	4		
330							1	3	1	4	3	
340								3		2		1
350							2	3		4	2	1
360								1		4	4	
370		1						1	1	1	2	1
380		1						1	1	5	1	1
390		2									4	1
400	1	6							1	1	6	
410		1				1				3	1	1
420		2								2	5	3
430		2								2		3
440		1	1							2		
450		1			2		1			1		
460		2	1			1						1
470			1							1		
480						1						
490												
500												
Totals	1	19	3	0	2	14	17	49	7	41	30	14

1 @ 120 in April
1 @ 150 in April
1 @ 630 in November
1 @ 550 in June
1 @ 550 in July
2 @ 720 in November
1 @ 640 in September
1 @ 640 in April
1 @ 970 in November

Table 4. Mean Alabama Redfish Lengths (mm/TL) Month by Month, 0-1+ Year-Class*.

Year	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May
10/84-09/85	241	285	294	310	418	420	-	-	-	460	-
10/85-09/86	283	305	311	350	348	376	395	400	413	455	450
10/84-09/86	254	303	301	344	361	377	395	400	413	457	450

Table 5. Postlarval Spotted Seatrout Time of Abundance and Year-Class Strength in Alabama (1984-86).

Spotted Seatrout	CPUE 1984	CPUE 1985	CPUE 1986
Time of Abundance (6/15-9/15) for 1984-85 & (6/15-9/30) for 1986	1.6	4.7	6.1

Target Stations

Dauphin Island Airport - Mud-sand bottom adjacent to Juncus Marsh.

Cedar Point - Sand-shell shoreline, mud bottom.

Coden - Halodule grassflat - mud bottom.

Figure 4

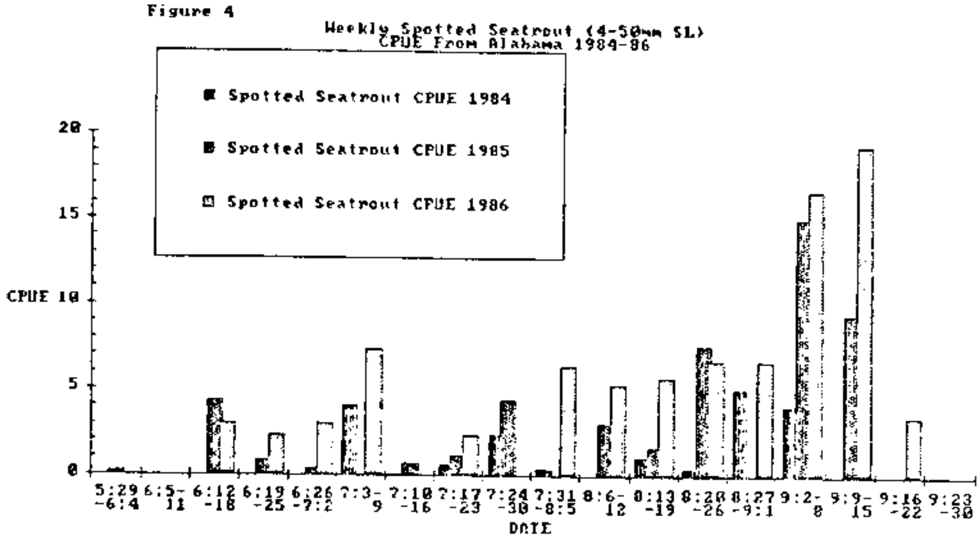
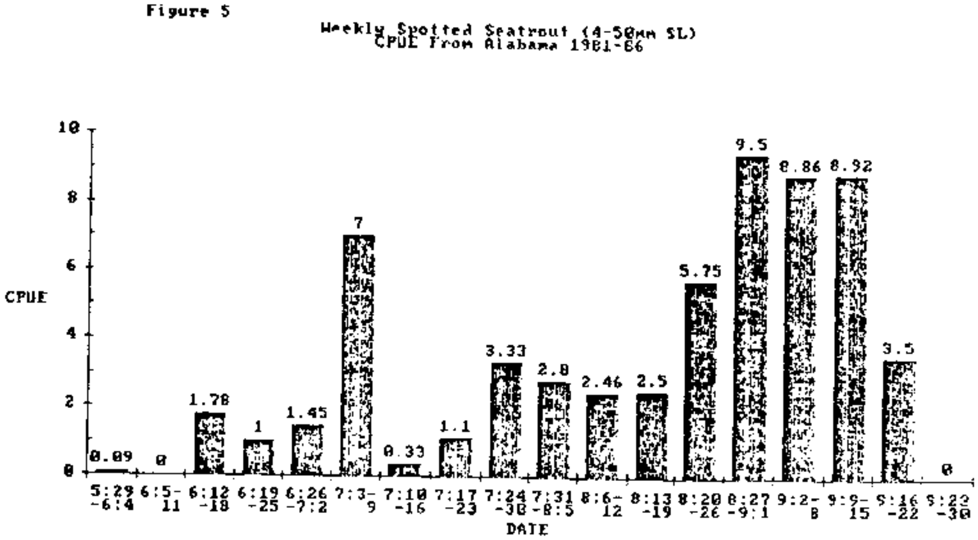


Figure 5



These first-year fish show a distinct habitat preference for tidal river mouths and channels. Over 1200 trawls were taken in the assessment and monitoring program from October 1980 - September 1986 and 300 (25%) of these were towed in tidal river mouths or channels. Of the 55 trawl-caught spotted seatrout, 50 (91%) were taken in those 300 trawls. Thus 25% of the trawls accounted for 79% of trout from 50-200mm captured. Of the five trawl caught spotted seatrout not taken in or at the mouths of tidal rivers four were taken in January after extreme cold weather suggesting that these fish moved into open bay waters in response to changes in water temperature.

Evidence on yearling spotted seatrout growth can be seen in Table 6 and Figure 7. That wide ranges exist, 50-100mm SL in October, 140-220mm SL in March, is reflective of the extended spawning season, June-September. A fish spawned in early June may reach 200mm by December whereas one spawned in early September may not reach that size until June. Figure 7 gives growth rate data from tagged, released, and recaptured pond raised fish. These fish were at 200 mm TL after 150 days. At that point they are subject to harvest by the recreational fishery.

Late Juvenile and Adult Spotted Seatrout (200-700mm TL)

Figure 8 shows length frequency data for the first two years of the creel survey. It cannot be determined whether each peak represents a single year-class because of the bi-modal spawning period of spotted seatrout and the resultant different growth rates of each group of larvae. The peaks at 290 and 350 could be year-classes I+ and II+ or year-class I+ August spawn and year-class I+ June spawn respectively. Evidence from hatchery-raised tagged and released May - June fish from Claude Peteet Mariculture Center (CPMC) indicates spotted seatrout are capable of reaching 360mm in a year (Figure 7).

Wade (1981) and Tatum (1980) both investigated Alabama spotted seatrout year-classes. Each used trout collected from the same November Baldwin County fishing rodeo. Their results are given in Table 7. The age determinations were made from scale annuli. The data is in relatively close agreement for classes II+ and III+. The larger sizes do not agree well possibly owing to small sample size and age class overlap resulting from the bi-modal spawn.

In sum, establishing the number of year-classes in Alabama's fishery and the length at age for each year-class presently involves evaluation of possibly inadequate data. In order to interpret the peaks on Figure 8 a research project involving trout collection and aging by otoliths is required.

Wade's study also found the III+ year-class to be prevalent in the fishery. The creel data would indicate the most harvested year-class is I+ or II+, or both, depending on the ages assigned to the peaks. It should be noted: however, Wade was studying tournament fish and fishermen at such events tend to select for larger fish.

Wade (1981) also investigated spotted seatrout wintering grounds from December through March using gill nets. He found Fowl River and Bayou La Batre to be preferred habitats. Creel results show that of the eight fish seen in Mobile County from December - March, six came from Fowl River and two from the Dog River Area. On the Baldwin County side, not covered by Wade, of the 17 winter creel captures 12 came from the Weeks Bay estuary, three from the upper reaches of Perdido Bay, and two, in late March from lower Perdido Bay. It would seem adult trout congregate in tidal rivers during the winter.

Hatchery studies at CPMC determined that spotted seatrout as small as 300mm can be sexually mature. However, the number of viable eggs an individual fish produces does not reach significant levels until they attain a size of roughly 360mm.

Until 1985 tagging efforts with spotted seatrout have been on a small scale. The longest distance traveled by an Alabama tagged trout is nearly 67 km from Boggy Point in Baldwin County to the Dauphin Island bridge in 1982. Other tag returns from that year indicate movements of 18 km, 10 km, and 8 km. More recent tag returns from fish released in 1985 and 1986 show no movement at all after 329 days to 34 km traveled after 216 days. All tag returns have been from Alabama waters and the 1985 and 1986 returns are listed on Figure 9.

Conclusions

Much has been learned over the past five years concerning the biology of red drum and spotted seatrout in Alabama. Research has answered many of the important questions making effective management of these fish less difficult.

Red drum are known to have fluctuating year-class strengths. They have a single, extended spawning period that occurs in the early fall. although the sample size is small, evidence is strong that first year fish prefer a shoreline habitat. The recreational inshore red drum fishery is almost solely dependent on age I+ fish and younger, and the fishery lasts from June to February. Red drum virtually disappear from the creel in Alabama in their second spring.

Spotted seatrout spawn over a four-month period with two postlarval peaks, one in mid-June to early July and the larger in early September. The early juveniles move into tidal rivers in late fall and overwinter there. Adult spotted seatrout in the recreational creel exhibit four or five distinct length-frequency peaks. Otolith aging is needed to confirm age at length for this species. Creel survey results reinforce conclusions of an earlier study that adult spotted seatrout overwinter primarily in tidal rivers. Limited tag returns indicate spotted seatrout remain within state waters.

Acknowledgements

The author wishes to express his thanks to Mr. Ralph Havard and Skip Lazauski for graphics work, Ms. Robyn Mellon for her assistance in data analysis and Ms. Audrey Collier for her invaluable help in compiling this paper.

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Figure 6 Growth Rate of Alabama Pond Cultured Spotted Seatrout - First 100 Days

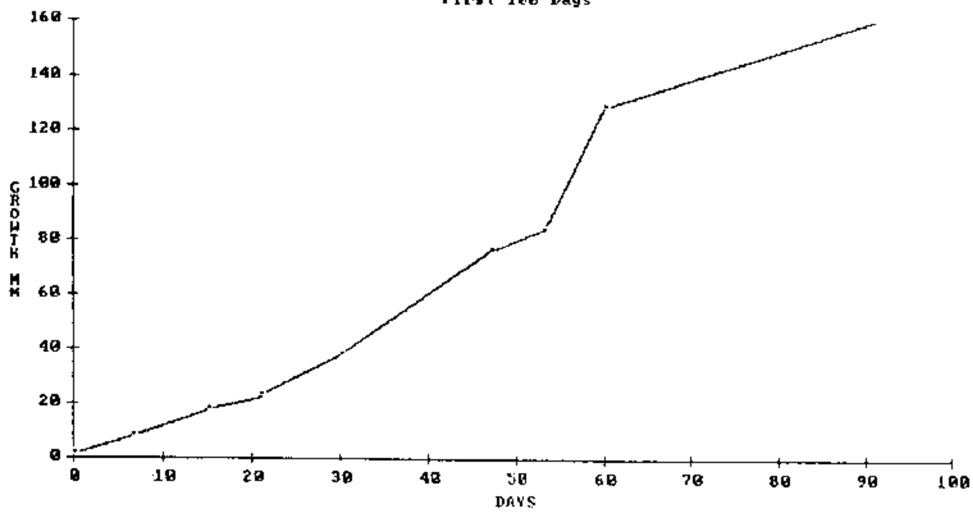


Figure 7 Growth Rate of Alabama Pond Cultured Spotted Seatrout Determined From Tag Returns - First 550 Days

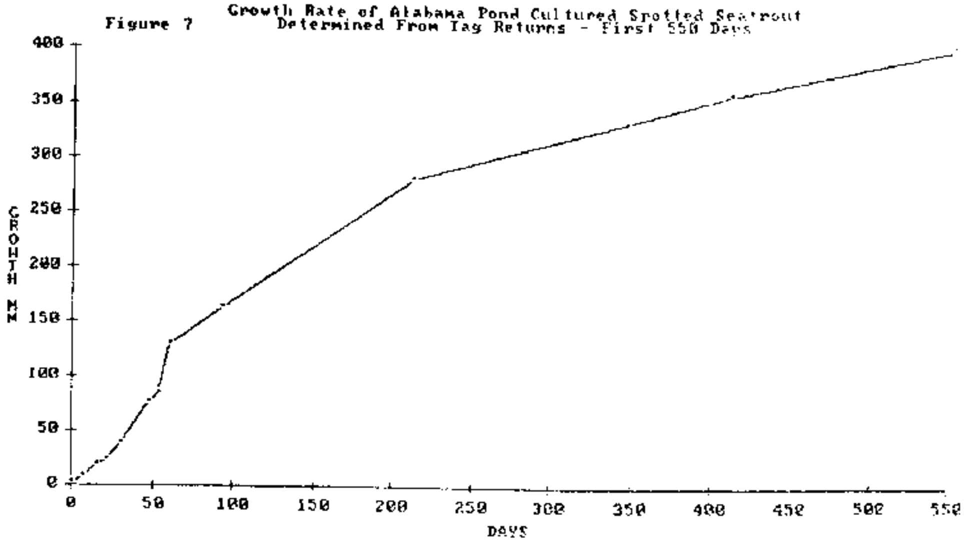


Table 6. Monthly Spotted Seatrout (30-220mm S.L.) Captures from Alabama (10/80 - 09/86).

Length/mm	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
30												
40												
50								1	1	2		
60								2	5	1		
70									3			
80								1	2	1		
90										1		
100	1									1		
110				2				1			2	
120	3			2					2		3	1
130	1	1		1							2	
140		1	4								1	1
150	1		1	1	1							
160		1								1		1
170	1											1
180						2				2		
190												
200			1									1
210			1							1		
220			1									
Totals	7	3	8	6	1	2		5	13	10	8	5

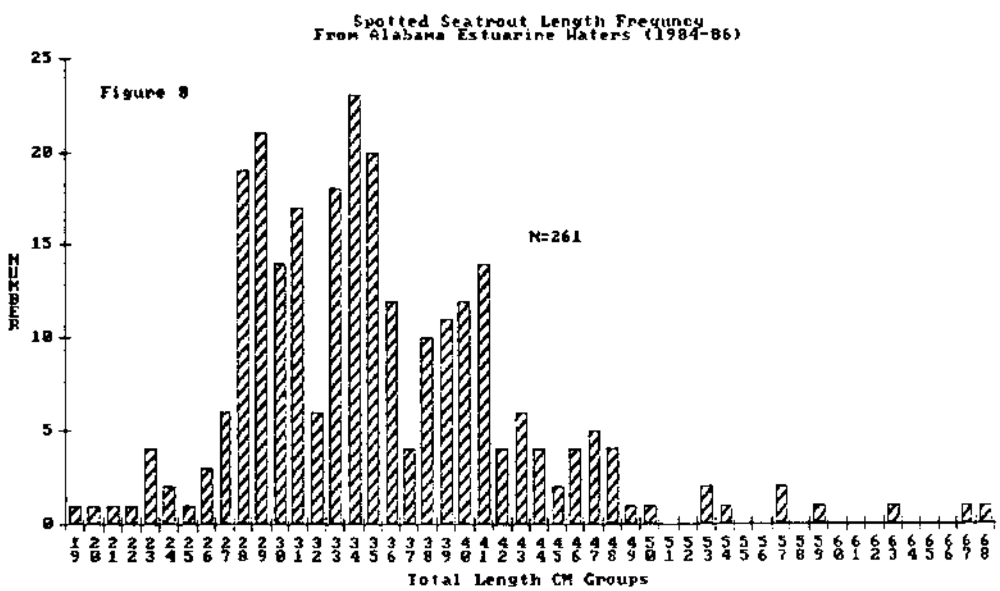


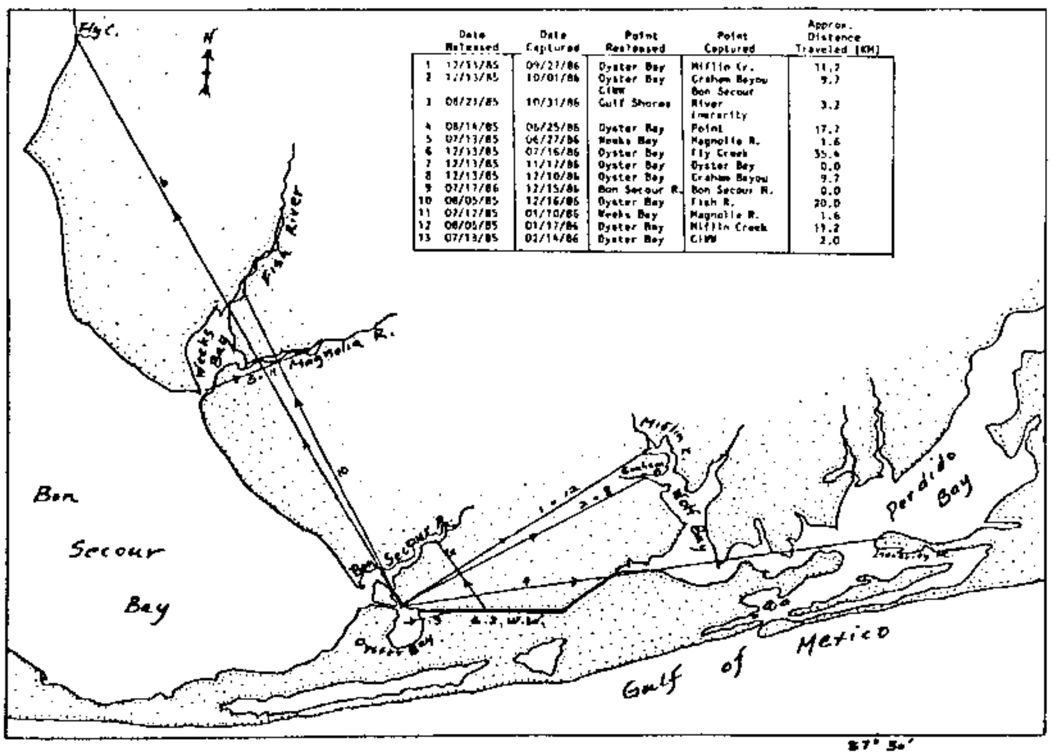
Table 7. Attained mean lengths (mm TL) for Spotted Seatrout landed in Alabama in November.

Study	I+	II+	III+	IV+	V+	VI+
Tatum (1980)[a]	225	330	415	450	480	525
Wade (1981)[b]		350	425	500	560	615

[a] Years 1964 - 1971 and 1973 - 1977

[b] Year 1978

Figure 9 - Movement of Tagged and Recaptured Spotted Seatrout from 1985 and 1986 Releases in Alabama.



	Date Released	Date Captured	Point Released	Point Captured	Approx. Distance Traveled (KM)
1	12/13/85	09/27/86	Oyster Bay	Miflin Cr.	11.2
2	12/13/85	10/01/86	Oyster Bay	Graham Bayou	9.7
3	08/21/85	10/31/86	GIWW Gulf Shores	Bon Secour River	3.2
4	08/14/85	06/25/86	Oyster Bay	Innerarity Point	17.2
5	07/13/85	06/27/86	Weeks Bay	Magnolia R.	1.6
6	12/13/85	07/16/86	Oyster Bay	Fly Creek	35.4
7	12/13/85	11/17/86	Oyster Bay	Oyster Bay	0.0
8	12/13/85	12/10/86	Oyster Bay	Graham Bayou	9.7
9	07/17/86	12/15/86	Bon Secour R.	Bon Secour R.	0.0
10	08/05/85	12/16/86	Oyster Bay	Fish R.	20.0
11	07/12/85	01/10/86	Weeks Bay	Magnolia R.	1.6
12	08/05/85	01/17/86	Oyster Bay	Miflin Creek	11.2
13	07/13/85	01/14/86	Oyster Bay	GIWW	2.0

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FOOD HABITS OF EARLY JUVENILE RED DRUM (*SCIAENOPS OCELLATUS*) IN COASTAL ALABAMA

Jonathan Brandon T. Morales
Department of Biology
Marine Science Program
University of Alabama
Tuscaloosa, Alabama 35487

Michael R. Dardeau
Dauphin Island Sea Lab
P.O. Box 369
Dauphin Island, Alabama 36528

ABSTRACT: Stomach contents of early juvenile red drum (10-119 mm sl) were examined for ontogenetic progressions in diet. Crustaceans were most important to smaller (< 60 mm sl) red drum. Juveniles 10-40 mm obtained the bulk of their prey weight from copepods and mysids; those between 40 and 60 mm ate mainly caridean shrimp. Larger individuals (> 60 mm), although still relying on crustaceans, fed increasingly on fish. Seasonal trends were obscured by ontogentic dietary progression of the rapidly growing young of the year fish.

INTRODUCTION

The red drum, *Sciaenops ocellatus*, commonly called redfish or channel bass, is an important sportfish and foodfish along the entire Gulf Coast region of the United States (Reagan, 1985). In 1977, U.S. fishermen landed 3, 452,000 lbs. valued at $1,288,000 (U.S. Dept. Comm., 1977). At present, however, there is fear among fishery experts that natural stocks of red drum are rapidly being depleted (Bill Hoskings, pers. comm.), primarily due to increased fishing pressure and the steady decrease of suitable habitat. Although steps have been initiated to curb this trend and assure sound management, a thorough knowledge of the life history and ecology of the species is required.

Red drum spawn from late summer (Pearson, 1928; Gunter, 1945; Perret et al., 1980) to early winter (Simmons and Breuer, 1962) in the Gulf of Mexico near the mouth of bays and in passes between barrier islands. Eggs and larvae are then carried into the bays by high salinity tidal currents (Marley, 1983; Norcross and Shaw, 1984). Once hatched, two larval stages, called yolk sac larvae and postlarvae, range from 4-7 mm long sl. Holt et al. (1983) specifically identified seagrass meadows as primary nursery habitat for postlarvae and juveniles (6-27 mm sl) in Texas. Juvenile red drum remain in the estuary their first year, occupying both the deeper waters of the bays as well as habitat along the shoreline. During their second spring, red drum disperse and move into the Gulf of Mexico or the deeper waters in or near the passes where they mature into adults (305-750 mm sl). Movement of juveniles seems to be controlled by salinity and temperature (Pearson, 1928; Simmons and Breuer, 1962).

Because of the dynamic spatial and temporal distribution of juvenile stages of red drum, a thorough study of the food habits of each stage is crucial to the formulation of management guidelines. This study examines stomach contents of early juvenile red drum (10 - 120 mm) from the estuarine waters of Alabama during their critical first six months. The results complement a spectrum of feeding studies ranging from Texas (Pearson, 1928; Miles, 1950; Matlock and Garcia, 1983), Louisiana (Bass and Avault, 1975) and Mississippi (Overstreet and Heard, 1978; Steen and Laroche, 1983) to Florida (Odum and Heald, 1972).

MATERIALS AND METHODS

Red drum were collected from estuarine waters of coastal Alabama from June 1985 to May 1986. Most sampling was done during the day using various seines in depths from 0.1 to 1.5 meters. Early juvenile red drum (10-120 mm) were measured and sorted to size class intervals of 10 mm for those falling below the 100 mm range. The largest size class considered in this study ranged from 100-120 mm. Stomach contents were pooled by size class and by month collected.

In the laboratory, stomach contents analysis was patterned after Carr and Adams (1972). This method employed a modified gravimetric procedure and made use of a preliminary fractionation of food items with a series of sieves. Large food items of similar types recognizable to the naked eye were removed onto pre-weighed filter pads (Whatman GF/C, 4.7 cm diameter). The remaining stomach contents were poured into a series of 3 inch diameter sieves (U.S. Standard Nos. 10, 20, 30, 60, 120, 200) arranged and clamped together

Table 1. Percentage occurrence by weight of food items found in each 10 mm size class interval of early juvenile red drum each month. TR indicates that only a trace of material was found.

MONTH:	NOVEMBER					
SIZE CLASS (MM SL):	10-19	20-29	30-39	40-49	50-59	60-69
NO. OF FISH:	39	21	19	7	8	3
NO. OF FISH WITH FOOD:	3	18	19	7	8	3
FOOD ITEM						
Insects		0.1				
Crustaceans						
Copepods	1.5	0.1	1.3			
Mysids		29.2	3.9	15.3	4.6	5.2
Tanaeids		4.6				
Amphipods		0.7	4.9			
Isopods						
Carideans			12.9	46.1	50.8	55.3
Penaeids		21.9	26.7	11.7	13.5	
Shrimp Remains	53.5	28.2	28.9	0.1	18.7	
Crab Remains		1.2	14.1	12.4	7.4	29.4
Polychaetes						
Nematodes						
Fish Remains	0.9	5.1	0.5	11.9	0.2	2.1
Plant Remains	2.3	0.4	0.7	0.1	0.1	0.4
Egg Mass						
Fecal Material		0.2	0.5	0.1		0.1
Sand Grains						
Particulates	41.8	8.3	5.5	2.2	4.5	7.5

MONTH:	DECEMBER						
SIZE CLASS (MM SL):	20-29	30-39	40-49	50-59	60-69	70-79	90-99
NO. OF FISH:	3	7	2	1	3	1	1
NO. OF FISH WITH FOOD:	2	7	2	1	3	1	1
FOOD ITEM							
Insects							
Crustaceans							
Copepods		0.9					
Mysids	52.3	34.8			0.8	81.1	
Tanaeids							
Amphipods		7.3	12.7				1.4
Isopods							
Carideans				97.9	41.3		43.1
Penaeids							
Shrimp Remains	8.5	22.2	13.8	0.4	10.6		36.4
Crab Remains							
Polychaetes		26.2	59.0				6.7
Nematodes							
Fish Remains	33.4	0.2			4.2		
Plant Remains		0.3			0.2		2.7
Egg Mass							
Fecal Material			7.3			5.9	0.8
Sand Grains							
Particulates	5.7	7.8	7.1	1.7	42.8	12.9	8.9

MONTH:	JANUARY						
SIZE CLASS (MM SL):	10-19	20-29	30-39	40-49	50-59	60-69	70-79
NO. OF FISH:	1	3	16	15	3	1	1
NO. OF FISH WITH FOOD:	1	3	16	15	3	1	1
FOOD ITEM							
Insects							
Crustaceans							
Copepods	7.0	71.7	TR				
Mysids			18.3				
Tanaeids			5.9				
Amphipods			1.9				
Isopods			1.2	0.2			
Carideans			10.3	62.6	100.0		
Penaeids							
Shrimp Remains			11.4				
Crab Remains	0.4	0.2	2.2	4.2			2.1
Polychaetes							
Nematodes	1.8	13.6					
Fish Remains	1.3	10.9	44.4	23.2		100.0	55.7
Plant Remains	0.3		0.5	0.4			3.4
Egg Mass		0.2					
Fecal Material			0.2	0.1			26.3
Sand Grains				TR			0.4
Particulates	89.1	3.4	3.6	9.3			12.0

MONTH:	FEBRUARY					MARCH			APRIL		MAY	MEAN
SIZE CLASS (MM SL):	40-49	50-59	60-69	70-79	80-89	50-59	70-79	80-89	80-89	90-99	100-120	OCCURRENCE
NO. OF FISH:	4	9	2	1	1	8	11	5	1	1	5	
NO. OF FISH WITH FOOD:	4	8	2	1	1	8	11	5	1	1	5	
FOOD ITEM												
Insects												TR
Crustaceans												52.8
Copepods						1.2						2.7
Mysids						22.6	1.4					8.7
Tanaeids												0.3
Amphipods												0.9
Isopods												TR
Carideans		59.9		14.8		8.6		24.3		16.0	46.5	22.3
Penaeids												2.4
Shrimp Remains		0.6	33.3		0.3	7.0		8.4		1.2	1.3	9.2
Crab Remains	3.5			62.4	19.2		2.2	5.3	20.2		7.4	6.3
Polychaetes					9.8							3.3
Nematodes												0.5
Fish Remains	90.2	36.8	58.6	0.6	41.1	42.5	95.1	58.9	48.1	81.5	43.3	28.7
Plant Remains		TR	0.2	0.2		9.6				0.8	0.1	0.7
Egg Mass												TR
Fecal Material	TR			15.3		3.8	0.1			TR		2.0
Sand Grains												TR
Particulates	6.2	2.6	7.9	6.7	29.5	4.6	1.1	2.9	31.7	0.4	1.2	11.9

in order of decreasing mesh size. The series of sieves were then shaken for 10-15 minutes while washing continuously under slowly flowing water. The contents of each sieve, comprising a sieve fraction, were then washed into a jar and retained for detailed analysis beneath a dissecting microscope.

Analysis involved subsampling each sieve fraction five times and recording the frequency of occurrence of each type of food item in each subsample. Identification was to the lowest taxon possible. Because all food items in a particular sieve fraction were of comparable size, relative biomass of each food type was directly proportional to frequency of occurrence.

After analysis of all sieve fractions, each fraction was vacuum-filtered onto a separate pre-weighed filter pad using a Millipore filter holder and a vacuum flask. Filter pads were dried overnight in a drying oven at 70° C and dry weights of food items were calculated after weighing the pads to the nearest 0.0001 g. on a microbalance.

RESULTS AND DISCUSSION

Early juveniles (10-120 mm sl) entered Alabama estuarine waters in November and grew larger than 120 mm by May. A total of 200 fish were examined, of which 162 (81%) contained food and were analyzed (Table 1). With the exception of the 10-19 mm size class from November, nearly all fish examined (97%) contained food. Composition of early juvenile red drum diet is shown in Table 1. Among the 19 distinguishable food categories, dominant prey items were crustaceans (primarily shrimp and crabs) with a mean occurrence of 52.8% by weight and fish remains (28.8%), suggesting a predatory, carnivorous feeding mode in the early stages of the red drum's life history. Although a certain amount of plant material was ingested, it was probably taken incidental to feeding activities (Boothby and Avault, 1971). Among the identifiable crustaceans were caridean shrimps, mainly the grass shrimp, Palaemonetes pugio, which accounted for 22.3% of all food and was the most frequently occurring crustacean. Other identifiable crustaceans included mysids, penaeid shrimp, and brachyurans. Shrimp remains, remnants of the dominant shrimp groups observed intact, also occurred frequently. Crab remains were mostly pieces of the carapace and walking legs; among those observed intact, the genus Uca predominated. Fish remains were mostly partially digested gobiids. Copepods and polychaetes were mainly observed in the smaller red drum size classes from 10-39.9 mm SL. Particulates, unidentifable, finely digested organic matter, were present in each month and in all size classes. Precipitates from the formalin preservative used to fix the gut contents sometimes inflated particulate percentages.

Figure 1 illustrates food categories eaten by red drum of each size class. Food categories were pooled across months in which that size class was present. As red drum increased in size, decapod crustaceans were a staple food item, present in all size classes at a minimum of a 25% weight frequency. For the first three size classes (10-39 mm sl), crustacean food items were mostly copepods, shrimp remains and mysids (Figure 2). Copepods appeared as the initial recognizable prey for the smallest size class of red drum. They increased in importance for the next two size classes (10-39 mm).

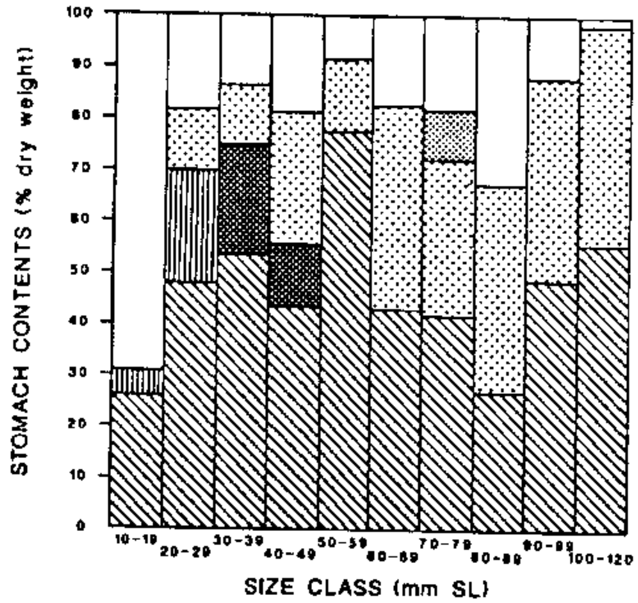

Figure 1. Diet of early juvenile red drum by size class interval.

Mysids, however, also constituted a significant portion of the crustaceans eaten by these size classes (38.2-55.4%). Bass and Avault (1975) also found zooplankters to be important prey items of similar-sized juvenile red drum from Louisiana. Their results, however, showed that copepods constituted 80-100% of the diet of the 0-19 mm sl size class and mysids constituted 64-67% of the diet of the 0-19 ml sl size class.

Caridean shrimp, specifically Palaemonetes pugio, appeared to dominate the diet of Alabama red drum as they increased in size. Grass shrimp were eaten by 30-119 mm sl red drum but were most important in red drum 40-69 mm long, where they contributed approximately 67% of the food weight. Crab remains, though insignificant in the size classes from 30-69 mm sl, begin to gain importance in red drum greater than 70 mm long. They, however, are still secondary to caridean shrimp. The presence of crabs in larger-sized juvenile red drum may indicate increasing mouth size and the ability to add these food items to the diet. After red drum exceed 20 mm sl, fish become increasingly important prey. Similar evidence of fish and shrimp as dominant prey in older juveniles was observed by Miles (1950) and Bass and Avault (1975). The importance of polychaetes as food in the 30-39 mm sl size class (Figure 1) appears to be unreported in the literature.

Similar trends were evident when dominant food items ingested by juvenile red drum were arranged by month (Figure 3). Crustaceans and fish accounted for 61-98% of the total diet throughout the whole sampling period. Crustaceans clearly dominated during the late fall and early winter season, then decreased gradually

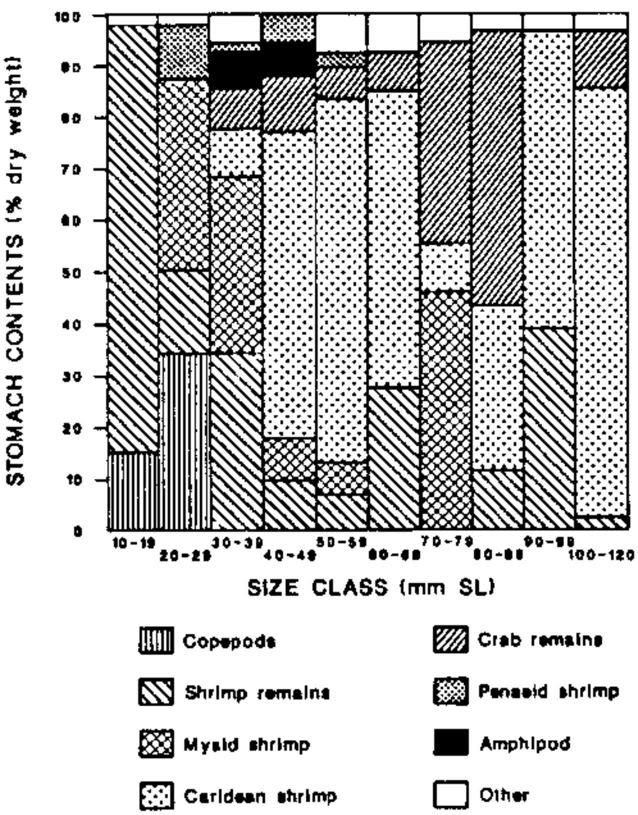

Figure 2. Crustacean diet of early juvenile red drum by size class interval.

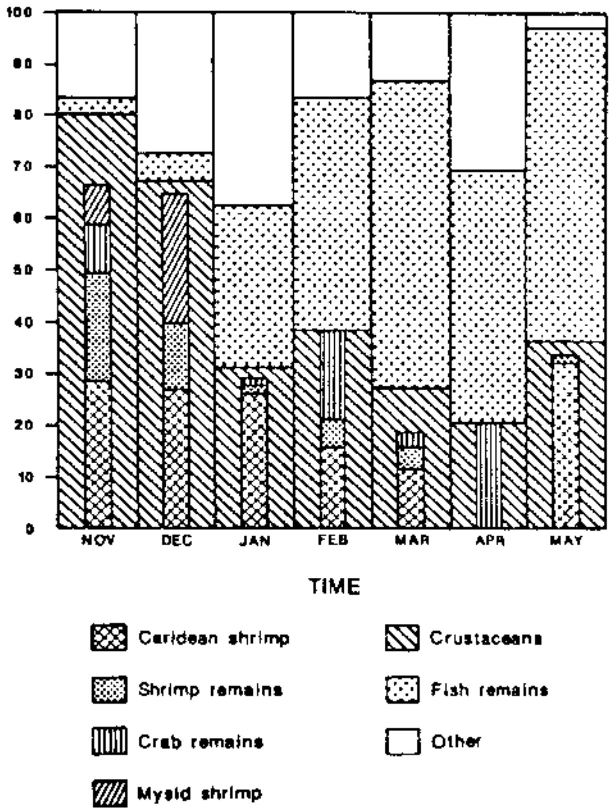

Figure 3. Diet of early juvenile red drum by month. Wide bars represent crustaceans and fish; superimposed narrow bars represent dominant groups of crustaceans.

until the middle of spring. Caridean shrimp appeared to closely follow the trend seen for the crustaceans as a whole, usually contributing to at least 50% of the crustacean prey. Crabs appeared to gain importance in the red drum diet only during the months of February and April. Mysids were frequent prey items only in December. As crustaceans decreased in importance during the progression from early winter to spring, fish were increasingly preyed upon during that time. Fishes (31-62% of the diet) were mainly taken from January to May by the juvenile red drum.

The seasonal patterns in food habits paralleled ontogentic transitions in diet. Following the early fall spawn of red drum, young of the year have increased in size. Larger juvenile red drum sampled during the months from January to May utilized larger prey so that fish increased in importance. Food availability, however, was not considered in this study. Relative abundances of crustacean and fish prey may change from winter to spring, encouraging a dietary shift to fish. Other studies of seasonal food preferences of red drum show fish to be more important during the fall and winter seasons while crustaceans dominate in the spring and summer months (Overstreet and Heard, 1978). These data, however, pertain to mature red drum ranging from 190-780 mm sl. The role of prey selection by red drum when both fish and crustaceans are available needs to be clarified (Matlock and Garcia, 1983). Future studies in Alabama should distinguish between seasonal availability of food and ontogenetic progressions in diet as well as examine the food habitats of older juvenile red drum (120-300 mm sl).

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ALABAMA'S MARINE RECREATIONAL CREEL SURVEY METHODS, RESULTS AND IMPLICATIONS FROM THE FIRST TWO YEARS

Henry G. Lazauski
Claude Peteet Mariculture Center
P.O. Box 458
Gulf Shores, Alabama 36542

ABSTRACT: Alabama's marine recreational creel survey utilizes a stratified non-uniform probability sampling design. Results from the first two years show differences in harvest, effort and harvest per unit effort between three month blocks and between Alabama's two coastal counties. The results suggest that the Spanish mackerel stocks are overfished, there are numerous under sized fish harvested and that anglers spend approximately $75 million annually on fishing trips and capital investments.

TEMPORAL DISTRIBUTION OF FINFISH EGGS AND

LARVAE AROUND MOBILE BAY

Robert L. Shipp
Department of Biology, University of South Alabama
Mobile, Alabama 36688

Introduction

Although estuaries have long been recognized as important in finfish productivity, especially those of the Gulf of Mexico (Gunter 1967), their precise role as a spawning area and in recruitment of newly hatched larvae is still an area of active research (see Ditty 1986). In Mobile Bay and adjacent areas, a number of studies recently have addressed this subject (Stuck and Perry 1982; Marley 1983; Williams 1983). The information presented herein stems from work initiated by the latter two studies but based on additional information obtained since their publications.

During 1981 and 1982 a study on fish stocks of Mobile Bay was initiated by the Alabama Coastal Area Board. This study followed earlier ones conducted in the late 1970's, supported by the University of South Alabama and the Dauphin Island Sea Lab. One of these, "spatial and temporal distribution of fish eggs in Mobile Bay" by R. Don Marley, and the other "the distribution of fish larvae in Mobile Bay" by Lawrence Williams, were based on field work completed during 1979 and 1980. The final reports (accepted theses) were accepted during 1982 and 1983 respectively, and are on deposit in the University of South Alabama Library. In addition, the study by Marley (1983) was subsequently published.

During 1981 the collections were taken from within Mobile Bay, and treated fish eggs, larvae and juvenile - adult populations. The eggs and larvae were collected from ten stations within the Bay by methods identical to those used in the present study.

During 1982, the study was restricted to fish eggs and larvae only; the station locations and methodology were identical to those of 1981. Therefore a year to year comparison was performed for these internal Bay stations. These findings were presented in the Final Report for 1982, submitted to the Alabama Department of Environmental Management, the successor agency to the Alabama Coastal Area Board.

In 1983, another study was initiated to expand the data base and application of the information acquired during these research efforts of the early 1980's. This latest study was directed toward the waters just outside the Bay, especially: around the passes, outside the barrier islands, the near shallow shelf; and the deep outer channel areas.

The rationale for this was as follows: strong evidence exists that some species may spawn in some or all of these locations, although the larvae may quickly move into the estuary Bay proper; controversy exists as to exact site of spawning for commercial species (e.g. speckled trout, Cynoscion nebulosus) resulting in confusion and inconsistencies in regulating and restricting areas to certain types of commercial fishing; the precise spawning locations of many near shore fish species is unknown.

During 1983, funding was by ADEM, and additional funding for the 1984 period was received from the Mobile Foundation for Public Higher Education, and in-house funding from the Dauphin Island Sea Lab.

This project is a component of a multi-year effort to assess the fish larvae and egg distribution in Mobile Bay and ajacent waters. To be fully appreciated, it must be used in conjunction with and comparison to final reports submitted to the Coastal Area Board and Alabama Department of Environmental Management for previous years (1981-82). Additional copies of these reports are also available through the Dauphin Island Sea lab.

Field Methodology

Sixteen stations were selected in and around the mouth of Mobile Bay and shown in Figure 1.

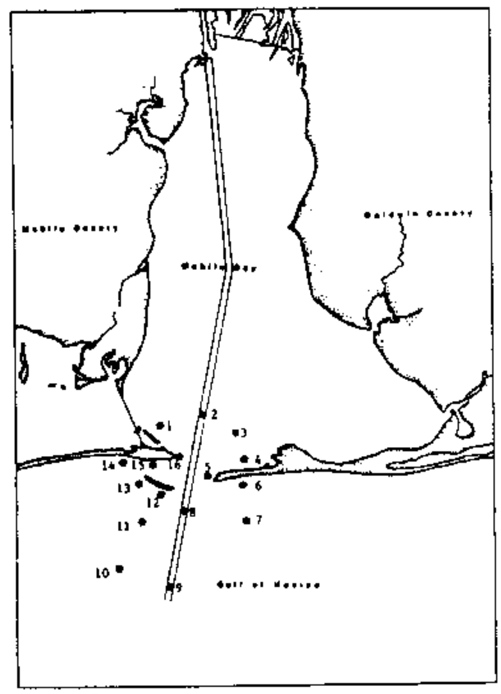

Figure 1. Site of station locations in and around Mobile Bay.

Plankton collections were taken at the surface (neuston) and bottom (demersal) of the water column at stations 1-16. The neuston was sampled using a 1.0 x 0.5 m rectangular PVC frame over which a 505 m nylon monofilament net was attached. Due to the design of the neuston net, approximately 75% of the net frame was submerged. This allowed only the surface of the water to be sampled. Deployed simultaneously with the neuston net was a 505 m demersal net. The demersal net was attached to a frame like the neuston net, but had skids with front and back stabilizers. Weights were attached to the skids to confer stability and enhance the sinking ability of the net and frame. A calibrated General

Oceanics digital flowmeter was used to determine the volume of the water filtered. The standard tow was made by fishing the neuston and demersal nets simultaneously at approximately 2 nots for 10 minutes. Plankton samples were preserved in a 3-5% buffered formalin solution. Buffering of the formalin was done with sodium borate (Borax) and marble chips.

At each station, water temperature, salinity, and dissolved oxygen were taken at the surface and bottom of the water column with a Hydrolab. Beginning and ending counts of the flowmeter were also recorded to determine the volume of water filtered by the plankton nets. Other information, such as meteorological conditions, reproductive state of species, parasitic or bacterial infections or any unusual conditions was recorded in the field notebook.

Lab Methodology

The preserved plankton was processed by several steps: removal of all contaminants such as twigs and leaves; sorting and enumerating all fish eggs and larvae; and curating the eggs and larvae. The initial removal of contaminants was done immediately prior to sorting the eggs and larvae from the remainder of the plankton. The ichthyoplankton was sorted from the plankton by removing just enough plankton to cover the bottom of a petri dish. This was then observed under low power of a dissecting scope with the eggs being removed from the plankton with an eye dropper and the larvae via fine tipped forceps. This process was repeated until the entire sample had been examined. In some instances where the volume of eggs and larvae made it impractical to count the contents of each stations sample, a Folsom plankton splitter was used to subsample the plankton. Rare or occasional species however, were separated from both the sample and subsample. Upon completion of sorting each station sample, the eggs and larvae were identified to the lowest taxon possible and counted (directly or by aliquot). These were labelled and placed into 2 dram glass vials into which about a 3-5% buffered formalin solution had been added. Marble chips were added to provide long term buffering capabilities.

In interpreting data, examining the Tables and Figures, and reading the results and conclusions, it should be emphasized that all eggs are not identifiable to species; thus for example, speckled trout (*Cynoscion nebulosus*) eggs are a component of the entire sciaenidae (drum family) eggs totals.

Data Analysis

Prior to analyses, the ichthoplankton data were standardized to quantitatively assess distribution patterns and abundances. This was accomplished by calculating the mean density for each neuston and demersal station using the equation:

$$n = a^{-1} b^{-1} c \ (100)$$

Where a = The area of the frame opening.
b = derived from the calibration factor of the flowmeter (b=fr where f=calibration factor in m/rev and r is the number of revolutions).
c = The number of eggs or larvae in a station sample.

In most instances the mean density was standardized to 100 m^3 of water filtered.

In order to provide some interpretation of the one year sampling effort, stations were grouped according to their physical characteristics and location. Stations within these groupings were assumed to function as replicates, thus station groupings were compared statistically - ANOVA (Analysis of Variance) to determine significant differences between areas. Significance at the 95% confidence level was determined, and this level is as indicated by "significant" in the text unless a different confidence level is indicated.

The station groupings (areas) are as follows:

I Interior Bay Stations: Stations 1, 3, 4
II Channel Stations: Stations 2, 8, 9
III Pass Stations: Stations 5, 16
IV West Barrier Island Stations: Stations 12, 13, 14, 15
V East shallow shelf stations: Stations 6, 7
VI West shallow shelf stations: Stations 10, 11

Results and Conclusions

Nearly 500,000 eggs and larvae were sorted and identified from 1983 collections. The occurrence of these by month, station, depth, and identification are contained in the Figures and Tables included in the Final Report (Dauphin Island Sea Lab Technical Report 84-002). These data are summarized herein.

The following questions may be answered wholly or in part from the results of this (and earlier) studies:

1) <u>Spawning sites of finfish</u>
   a) What is the role of the Bay?
   b) What is the role of the passes to the Bay?
   c) What is the role of the barrier islands and nearby shallow shelf areas?
2) <u>Spawning times</u>
   a) During what months or seasons do the estuarine dependent species reproduce?
   b) What year to year variations exist in spawning times?
3) <u>Species composition</u>
   a) Which species utilize the different areas of the estuarine system for spawning?
   b) What is the seasonal variation of the species composition, in terms of eggs and larvae?
4) <u>Larval transport</u>
   a) What role does the intrusion of the tidal salt wedge play in larval transport?
   b) What role does the Mobile Ship Channel play in larval transport?

The response to each of the above is subject to the limitations of a single year study. Thus statistical analysis and resultant confidence limits are only appropriate where comparisons are applicable between the results of the inside Bay study of 1981-82, or with the assumptions of station similarities as described in the Methods sections. Year to year comparisons possible at the completion of the 1984 sampling will greatly strengthen the validity and significance of the conclusions presented here.

Most estuarine dependent tropical and subtropical fish species have an extremely brief egg-development period. Thus, little time is available for passive transport of eggs before hatching. Therefore, presence of large numbers of eggs is assumed to indicate proximity of spawning site.

Spawning sites of finfish

The interior Bay is used as a spawning site for relatively few species. During early spring, spawning activity is dominated by anchovies (see Tables 1-4) and members of the drum family (Sciaenidae), by black drum (Pogonias cromis) and white or sand trout (Cynoscion arenarius). During this season the Bay stations (1, 3, and 4) were well represented with eggs. However these were about 90% Anchoa mitchilli, the bay anchovy. Sciaenid eggs showed highly significant (a = .01) difference in their occurrence by station groupings with more occurring at station group V, the shallow shelf stations east of Mobile Bay (off Ft. Morgan).

All egg collections at the interior Bay stations were significantly higher in demersal (bottom) collections than surface when there was strong stratification of water masses, unlike those from the outer stations. This infers that higher salinities are required for spawning than are found throughout most of the upper Bay.

Stations 5 and 16, located on either side of the pass to the Bay usually exhibited lower egg numbers although not statistically significant than most other station groupings, thus either spawning was less at these stations, or swift currents carried eggs away from station locations.

Station groupings outside the Bay became more important as spawning sites during late spring and early summer.

Barrier island stations (12, 13, 14, 15) demonstrated significantly more spawning activity during early June, than any other grouping. These eggs were more than 99% Anchoa mitchilli, the bay anchovy, indicating an offshore movement of this important forage species when compared to spring sampling.

The nearshore shelf and channel stations (2, 8, 9; 6, 7; 10, 11) are the stations of preference for spawning of the commercially important Sciaenidae. The collection periods of highest numbers for eggs of this family were July, August, and September (Table 4).

During this period there was a significantly greater number of eggs at the outside stations, with stations 6, 11, 13, and 15 having the highest number. Of the commercially important sciaenidae, there was a significantly higher number of eggs during August - September at the outside demersal stations and barrier island stations indicating very high salinity is required for species of this family spawning during this period. Importantly this is the peak spawning period for spotted sea trout (speckled trout) Cynoscion nebulosus, as indicated by larvae of this species (Table 2). (Eggs of sciaenidae cannot be identified to species).

Utilizing data from the previous year's study, the importance of the areas outside the Bay compared to those inside are in evidence. For example, during 1982, the total number of sciaenid eggs collected during the entire year, all stations, all months totaled approximately 3000. All these collections were from within the Bay or interior stations.

During several single cruises during 1983, when the outside stations were sampled, sciaenid eggs numbered three or more thousand. The peak periods were realized during July 1983, when almost 6,000 sciaenid eggs were taken during a single collection cruise and during August, when more than 10,000 were taken during a single cruise. Almost 1000 of these were taken during a single demersal trawl at station 14, just outside of Dauphin Island, at the extreme western section of "Pelican Bay", and nearly 1000 off Ft. Morgan in the shallow shelf area, during July. During August more than 3,000 eggs were taken during a single tow at demersal (bottom) stations 9 and 10, the outermost stations. This was significantly grater than at other stations.

In summary, the interior Bay stations function as an important spawning site during mid to late spring for the important forage species Anchoa mitchilli (the bay anchovy) and some few other species, including the popular sport species, the white or sand trout (Cynoscion arenarius); spawning activity progresses seaward during early to mid summer, and spawning of most species, including the speckled trout (spotted sea trout, Cynoscion nebulosus) occurs outside the barrier islands and near shallow shelf. The Bay mouth itself appears to have no particularly important role as a spawning site.

Spawning times

In cooler months spawning near the Bay is principally by the commercially important Gulf menhaden Brevoortia patronus. Spring spawning is dominated by the bay anchovy (Anchoa mitchilli) and some members of the drum family Selaenidae. Spawning by the greatest diversity of fishes occurs in late spring and summer. Indication of variation in this pattern must await an addition year's collections. However, data from previous year's (1981-1982) study of interior Bay stations indicate substantial variation in spawning periods for some species, probably related to occurrences of spring cold fronts.

Species composition.

The occurrence of the dominant estuarine species Anchoa mitchilli the bay anchovy is apparent by examination of Tables 3 and 4. However identification of eggs to the species level is extremely difficult or almost impossible for most species. Thus species occurrence is best determined by examination of Table 1 and 2 data based on presence of larvae. These data confirm the greater variation of species in late spring and summer indicated in the section above on "spawning times".

Mention of certain species is warranted.

Of the sciaenids, the black drum (Pogonias cromis), the spot (Leiostomus xanthurus) and the Atlantic croaker (Micropogonias undulatus) are predominantly components of early spring species groups, while white or sand trout (Cynoscion arenarius), speckled (or spotted sea) trout (Cynoscion nebulosus) and whiting or kingfish (Menticirrhus) species are late spring and summer spawners. Red drum or red fish (Sciaenops ocellata) are fall spawners.

As to location of greatest species diversity, outside shallow shelf stations consistently provided the high numbers of species. This infers that these areas, followed by the stations just outside the barrer islands, are utilized by the greatest number of species for their spawning activity.

Larval transport

Although egg concentrations are discrete, larvae appear more randomly distributed throughout the study area. This appears most evident during late spring and summer, when spawning activity is concentrated well outside the Bay, yet larvae occur in substantial numbers in the interior.

Larval motility is weak, and while larvae are easily capable of upward and downward movement in the water column, their ability to traverse long distances is doubtful. Therefore their identity with tidally influenced water masses, such as the high salinity salt wedge intrusion is the likely vehicle for their transport to nursery areas from spawning sites.

Data from this study are not totally conclusive as to larval transport in and out of Mobile Bay. However, during June-August, when greatest offshore spawning activity was indicated by egg distribution there was a greater concentration of larvae in the demersal (bottom) high salinity stations. This difference was highly significant in July samples.

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TABLE 1

Summary of larvae, by species, by month,
collected during Winter-Spring 1983

FISH LARVAE

SPECIES	FEB 4	MAR 9	MAR 31	MAY 5	MAY 13	MAY 24
Engraulidae	42	4675	5159	17938	51542	18190
Anchoa mitchilli		1		23	17	6863
Anchoa hepsetus				317	24	1801
Cynoscion arenarius		39	308	3086	3106	271
Harengula jaguana			876	111		
Opisthonema oglinum				890		
Clupeidae				142	1	4
Menidia beryllina				234	1	201
Membras martinica				85	5	112
Syngnathus louisianae	3	5	37	20	19	4
Sciaenidae		60	2	6		1
Gobiesox strumosus			7	27		17
Gobienellus sp.	4	9	36	8	1	3
Gobiosoma sp.		2	7	4		16
Dormitator maculatus	9	2		21	4	2
Brevoortia patronus	197	7804	2751	1		
Pogonias cromis	4	95	70	270	19	
Myrophis punctatus	8	3	4			
Peprilus triacanthus	1			2	9	1
Bothidae	2	6	22	27	141	21
Synodontidae	1	28			3	5
Lagodon rhomboides	191	91	54			
Leiostomus xanthurus	1	6				
Micropogonias undulatus	2		1			
Haemulidae		8				
Gobiidae		1		8		58
Syngnathus scovelli		2	1	1		
Anchoa lyolepis						
Soleidae					2	2

FISH LARVAE

SPECIES	FEB 4	MAR 9	MAR 31	MAY 5	MAY 13	MAY 24
Haemulon sp.		51	27			
Triglidae		5	1	4	10	3
Cynoscion nothus				1	1	
Blenniidae				4	7	7
Sphoeroides parvus				2	11	1
Scomberomorus maculatus					1	
Archosargus probatocephalus				2	5	
Anguilliformes				1		
Seriola zonata					1	
Tetradontiformes					1	
Trichiurus lepturus					7	
Microgobius						3
Balistidae				3		2
Bascanichthys sp.						2
Carangidae						1
Strongylura marina						1
Symphurus sp.					17	104
Menticirrhus sp.			79			
Mugil sp.			1			
Orthopristis sp.			4	2		3
Atherinidae				49		13
Cynoscion nebulosus			1		2	
Scombridae			1		2	
Elops saurus				1		
Gadidae						
Myctophidae				1		
Peprilus alepidotus				1	11	
Serranidae				4		
Ophidiidae				8	4	

TABLE 2

Summary of larvae, by species, by month, collected during Summer-Fall 1983

FISH LARVAE

SPECIES	JUN 8	JUL 18	AUG 18	SEP* 19	OCT 17	NOV 17	NOV 29
Engraulidae	7212	1950	3435	96	167		
Anchoa mitchilli	7863		3		9		1
Anchoa hepsetus	175	1	3				
Cynoscion arenarius	114	52	254	148			
Clupeidae	34	1	30				
Menidia beryllina	13	10					
Membras martinica	8	9					
Syngnathus louisianae	15	2	2		18	3	4
Sciaenidae	9	1		1	42		
Gobiesox strumosus	18	2	1		2		
Gobionellus sp.	50	7	1		11	6	19
Gobiosoma sp.	51	8			1		
Brevoortia patronus					72	221	12876
Pogonias cromis		5					6
Myrophis punctatus							3
Peprilus triacanthus					2	1	1
Bothidae	4	68	26	3	9		1
Synodontidae	4						
Lagodon rhomboides							75
Leiostomus xanthurus							50
Micropogonias undulatus			18		68	123	227
Haemulidae							
Gobiidae	53	64	4		6		

FISH LARVAE

SPECIES	JUN 8	JUL 18	AUG 18	SEP* 19	OCT 17	NOV 17	NOV 29
Syngnathus scovelli	3	5					
Anchoa lyolepis	4						
Soleidae	1					1	1
Haemulon sp.							
Triglidae		1	1		280		1
Symphurus sp.	15	66	151	17	18		
Menticirrhus sp.	5	82	17		6		
Mugil sp.							
Orthopristis sp.	5						
Atherinidae	7						
Cynoscion nebulosus	4	103	84	48	2		
Scombridae		2					
Elops saurus							
Gadidae			4	4			13
Myctophidae?	1						
Peprilus alepidotus		110	26	3	2	1	
Cynoscion nothus							
Ophidiidae		20	91	16	250		
Serranidae				1			
Blenniidae	21	13	2	2	2		
Sphoeroides parvus	1						
Scomberomorus maculatus		1					
Archosargus probatocephalus							
Anguilliformes		6	1	42			
Seriola zonata							
Tetraodontiformes			1	5	3		
Trichiurus lepturus							
Microgobius sp.							
Balistidae			3		21	4	1

FISH LARVAE

SPECIES	JUN 8	JUL 18	AUG 18	SEP* 19	OCT 17	NOV 17	NOV 29
Bascanichthys sp.		3	1		1		
Carangidae	3						
Strongylura marina		16	131	27			
Trinectes maculatus	1	759	1141	922	147	1	
Chloroscombrus chrysurus	2						
Dormitator maculatus	1						
Caranx sp.		9	4	6			
Oligoplites saurus		2					
Chaetodipterus faber					5		
Gerreidae			6				
Sciaenops ocellata					330		
Ophidiidae				16	250		
Aluterus schoefli					1		

*September represented by 13 samples constituting a subsample

TABLE 3

Summary of eggs, by species, by month,
collected during Winter-Spring 1983

SPECIES	FISH EGGS FEB 4	MAR 9	MAR 31	MAY 5	MAY 13	MAY 24
Anchoa mitchilli	3	2606	87985	12733	3991	483
Anchoa hepsetus	20	801	4	497	143	1
Symphurus sp.			7	239	1	14
Harengula jaguana				69		
Membras martinica				2		6
Gadidae				17		
Sciaenidae	15	1362	1046	2931	1156	396
Gobiesox strumosus						
Brevoortia patronus	1001					
Synodontidae	1	28		1	1	
Haemulidae	3					
Anchoa lyolepis	4					
Soleidae	1					

TABLE 4

Summary of eggs, by species, by month, collected during Winter-Spring 1983

SPECIES	FISH EGGS						
	JUN 8	JUL 18	AUG 18	SEP* 19	OCT 17	NOV 17	NOV 19
Anchoa mitchilli	57122	52416	57439	1297	37	14	
Sciaenidae	68	5983	10149	2406	1511		1
Symphurus sp.	3	2832	2734	320	22	2	
Membras martinica	1						
Harengula jaguana	1						
Anchoa lyolepis	3	8	4				
Atherinidae	1						
Trinectes		1013	305	331	1		
Chloroscombrus chrysurus		575	482	6	38		
Ophidiidae		12					
Brevoortia patronus					8873	362	30
Triglidae					1		
Anguilliformes			83	66	9		
Synodontidae			5				

FISHERIES RESEARCH AND MANAGEMENT

Summary of Panel Discussion

The participants on the "Fisheries Research and Management Panel" were:

Moderator: Henry G. Lazauski, Marine Resources Division, ADCNR
Stephen P. Malvestuto, Auburn University
Mark S. Van Hoose, Marine Resources Division.ADCNR
Robert L. Shipp, University of South Alabama

INTRODUCTION

In general, four topics were covered during the panel discussion. The topics pertained to the fisheries dependence on habitat, management of heavily fished stocks, the delta's fisheries status, and anchovies as indicators of Bay's health. These four topics and a synopsis of the panel discussion are listed below.

FISHERIES DEPENDENCE ON HABITAT

Problems with over fishing and natural flucuations in year-class abundance can be compensated for by reducing fishing pressure by fisheries regulation. However, populations of species which are habitat specific can be limited by the availability of that habitat. Red fish and speckeled trout are good examples of habitat specific species. The degradation and destruction of submerged grass beds and marshes are especially damaging to most of our commercial and recreational fisheries. Reduced availability of fisheries habitat results in reduced stocks of our currently valued fisheries, habitat loss and degration are very serious threats.

MANAGEMENT OF HEAVILY FISHED STOCKS

By monitoring fisheries stocks by sampling programs and creel surveys, overfishing can be prevented by the implementation of fishing regulations that decrease the fishing pressure on that particular species. Given enough time, years to decades, the problems caused by over fishing should be correctable by reducing fishing pressure. However, the ability to manage fisheries in this way is dependent upon the monitoring of the stocks in question. The information provided to fisheries managers and scientist by fishermen during studies and surveys is greatly appreciated and the type of information needed to monitor these stocks.

DELTA'S FISHERIES STATUS

In comparing the status of the fisheries in the Delta to what it was some twenty years ago, using Wayne Swingles 1963 and 1964 surveys, the changes don't suggest that the Delta Fisheries have been over exploited. The commercial fishery has really remained just about the same in terms of its' magnitude, while the recreational fishery has increased eight times since the 60's based on fishing efforts. There is considerable fishing pressure being placed on the Delta's Fisheries and it is having an effect. Catfish, the main commercial species, average about a pound and a half less than they did twenty years ago. Recreational catches of the larger sizes of blue gill don't occur as frequently as they did in the 60's. Based on the information available the Delta is supporting the increased level of fishing effort.

POTENTIAL USE OF ANCHOVIES AS INDICATOR SPECIES

Monitoring the relative health of the fisheries habitat of the Mobile Bay Estuarine System could possibly be accomplished by monitoring the Bay's Anchovy stocks. We hear of the chronic effects of pollutants, longterm exposures are necessary before any measurable effects can be seen. Anchovy spend their entire life in the Estuarine Environment and the populations present in the Estuaries may have been there for a long time, in the five to twenty year range reflecting generations of exposure to the conditions of the Bay. These anchovies can be collected by the thousands and if increased numbers of anomalous individuals start showing up, it could indicate some environmental degradation.

STATUS OF COLONIAL SEABIRD RESOURCES IN COASTAL ALABAMA

C. Dwight Cooley
U.S. Fish and Wildlife Service
Daphne, Alabama 36526

ABSTRACT: Coastal Alabama provides important habitat for a variety of nesting colonial seabirds. Of the 38 species of colonial seabirds occurring in Alabama, 11 are known to have nested. In coastal Alabama, colonial seabirds nest on barrier island and mainland beaches, on islands in Mississippi Sound, and on dredged material disposal areas. Formerly, the barrier islands were the major center of seabird nesting activity, but many colonies are now abandoned. Reasons for colony abandonment are unclear but human disturbance appears to be a major cause. Gaillard Island, a dredged material disposal island in Mobile Bay, is the site of the largest nesting seabird colony in coastal Alabama. Population levels of individual species fluctuate widely on the island but total number of individuals appears to be increasing. The historical status of colonial seabirds in coastal Alabama is compared to present status, and implications of increased development pressures on colonial seabird resources is discussed.

INTRODUCTION

Coastal Alabama provides habitat for an amazing variety of colonial seabirds. There are 38 species of colonial seabirds known to occur in coastal Alabama, of which 11 species are known to have nested (Table 1), the remainder nesting predominantly in polar or subpolar regions. Colonial seabird nesting habitat in the southeastern United States is of paramount importance to the maintenance of global population levels of no less than six of the 11 species nesting in Alabama (Clapp et al. 1982, 1983).

The purpose of this paper is to discuss the known distribution, habitat, abundance, and status of colonial nesting seabirds in coastal Alabama. I use the terms "colony" and "colonies" interchangeably to include any aggregation of birds of the same or different species nesting in proximity to each other. This includes birds nesting on the same island or section of island or mainland although populations may be separated by some distance and occupying different kinds of habitats.

There is no adequate information base of colonial seabird resources for coastal Alabama. Howell (1924, 1928) documented the location of several colonies and found that four species of colonial seabirds had nested in Alabama previously. Imhof (1962, 1976) documented the nesting of two additional species. Portnoy (1977) undertook the first systematic survey of colonial nesting seabirds in Alabama, although his survey included the barrier island and Mississippi Sound portion of Mobile County only. He documented the nesting of two additional species of terns, provided the location of many colonies, and gave estimates of the number of nests in each colony area. As a followup to his original study, Portnoy (1978 ms.) repeated his 1976 surveys, updated his atlas of colony locations, and compared his census results from 1976 and 1978.

Table 1. Colonial Seabirds Nesting in Coastal Alabama

Brown Pelican	*Pelecanus occidentalis*
Laughing Gull	*Larus atricilla*
Herring Gull	*Larus argentatus*
Gull-billed Tern	*Sterna nilotica*
Caspian Tern	*Sterna caspia*
Royal Tern	*Sterna maxima*
Sandwich Tern	*Sterna sandvicensis*
Common Tern	*Sterna hirundo*
Forster's Tern	*Sterna forsteri*
Least Tern	*Sterna antillarum*
Black Skimmer	*Rynchops niger*

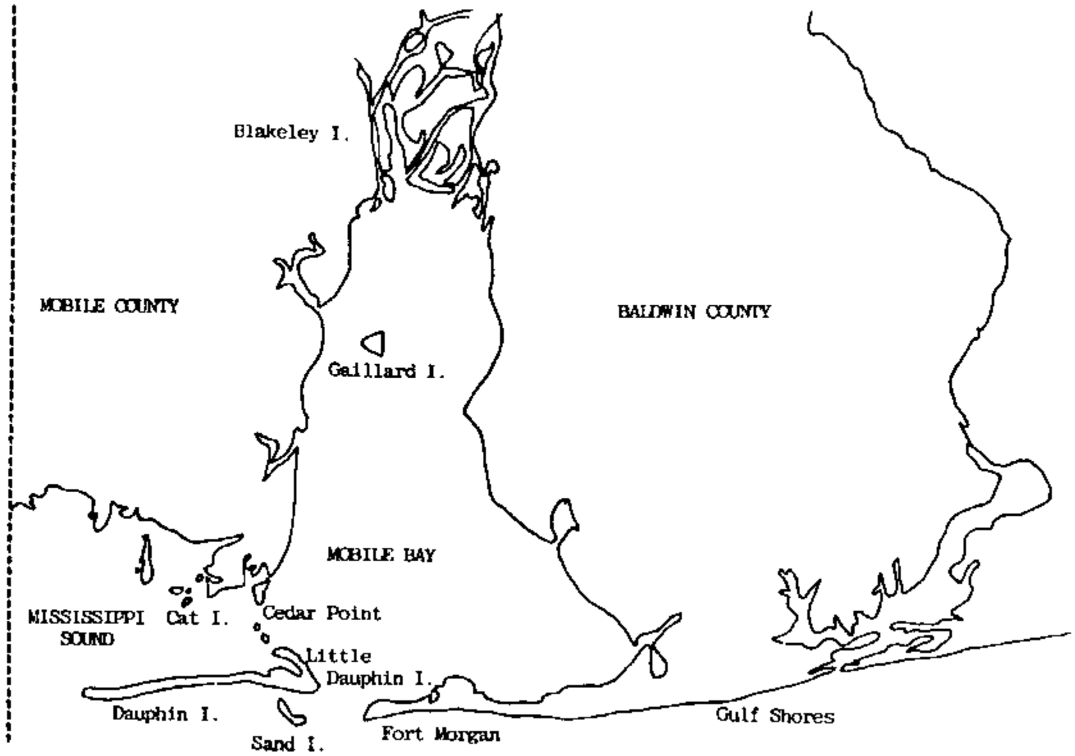

Figure 1. Coastal Alabama including place names frequently mentioned.

STUDY AREA AND METHODS

The geographic limits of this study (Fig. 1) include the mainland portions of Baldwin and Mobile Counties, Alabama; Mobile Bay; the Alabama portion of Mississippi Sound; and the barrier islands that form the southern boundary of the bay and sound. The coast of Baldwin County includes both natural and developed beaches of varying width from Perdido Key near the Florida border to Mobile Point at the western end of the Fort Morgan Peninsula. In Mobile County, natural areas providing potential nesting sites include Dauphin Island, Little Dauphin Island, Sand Island, and the islands in Mississippi Sound. Mainland portions of Mobile County, as in Baldwin County, provide few potential sites due to the prevalence of marsh and narrow beaches. Potential man-made nesting areas along the coast include Gaillard Island in Mobile Bay, parts of Blakeley Island and Cochrane Causeway at the head of Mobile Bay, and Little Dauphin Island south of Pass Drury. Man-made dredge material disposal sites in these areas are considered to be the most likely potential nesting areas.

From 1984-1986, aerial surveys by Cessna 172 and 206 fixed-wing aircraft were performed during late June. All potential nesting areas were surveyed and locations of colonies were noted. In addition, habitat conditions of all potential nest sites were noted. Following aerial reconnaissance, an attempt was made to visit each colony site. Numbers of nests were counted or estimated and species composition of colonies was noted on each flight or visit. In addition to data generated during this study, published records of nesting colonial seabirds are summarized and comparisons are made.

STATUS AND DISTRIBUTION OF BREEDING SEABIRDS

Even from the sparse data available, it is evident that breeding seabird status and distribution has changed drastically during this century. A comparison of past dispersion (Fig. 2) and colony areas in use during the study (Fig. 3) indicates a dramatic shift in breeding distribution and the abandonment of many colonies. In fact, during this study, seven of the 15 known colony locations were not used or were used at such low intensity that nesting was not recorded. This shift in breeding distribution was probably brought about by a host of circumstances specific to discreet areas of coastal Alabama.

Barrier Islands

Prior to this study, the barrier islands were the major center of distribution of breeding seabirds in coastal Alabama (Howell 1924, 1928; Imhof 1962, 1976; Clapp et al. 1983; and Portnoy 1977). Dauphin Island, Little Dauphin Island, and Sand Island provided the best habitat for nesting terns and skimmers. There were miles and miles of broad, flat beaches free from all but minimal human disturbance. Colonial seabirds could nest

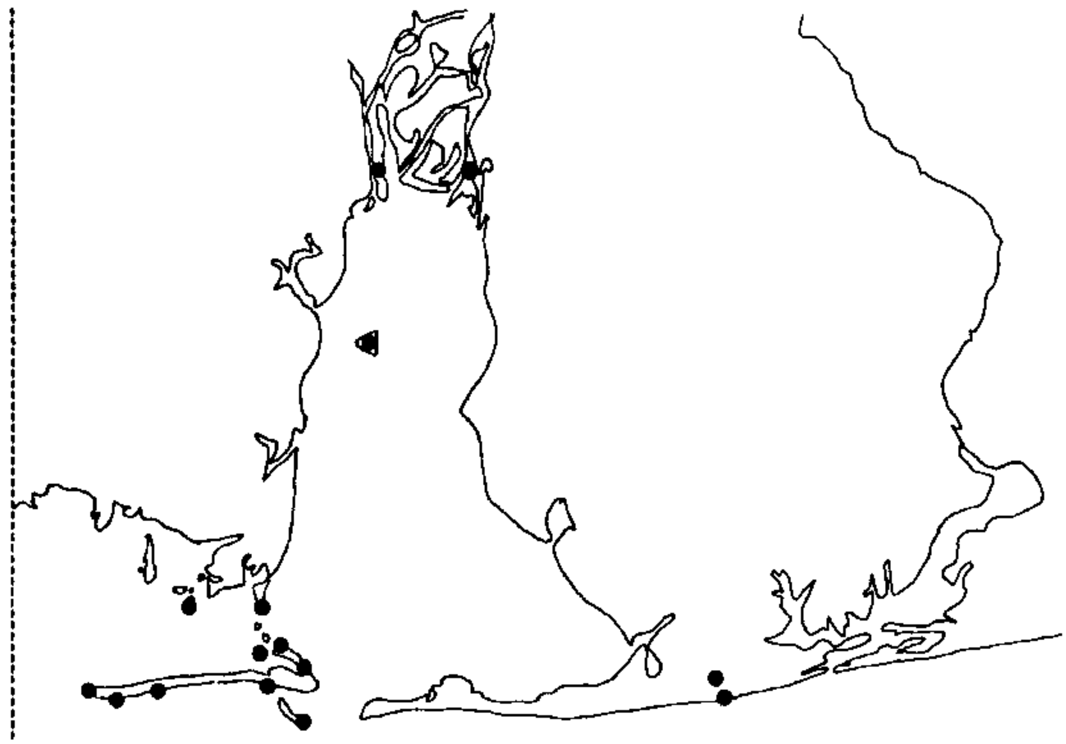

Figure 2. Dispersion of seabird nesting colonies in coastal Alabama prior to 1984.

in these areas essentially free from human intrusion and contend only with their natural enemies - weather and predators.

To be sure, these natural enemies were undoubtedly formidable, particularly the weather. The low-lying, broad, flat nature of the barrier islands, the same characteristics that make them suitable for seabird nesting, also renders them prone to storm overwash. The degree of impact weather can have on nesting seabirds on barrier islands is dependent upon timing and severity of the storm event. Timing is the most critical factor. Even a small storm surge at the peak of nesting activity can destroy many nests and disrupt the colony. Hurricanes at the peak of nesting activity can decimate large areas and result in nesting failure in many colonies.

There are a host of developments, not unique to Alabama coastal barrier systems, that probably act in synergism to influence seabird status and distribution. In 1956, a causeway and bridge were constructed between Cedar Point and Dauphin Island, linking the mainland and barrier islands. This bridge opened the once-isolated Dauphin and Little Dauphin Islands to increased human use and its associated impacts. Dauphin Island became a mecca for the development-hungry and recreation-starved. These islands were subjected to varying rates of residential development, along with its associated commercial development. Development induced an ever-increasing exodus of people to the islands with a concomitant need for recreational activities.

The recreational demands of an increasing coastal human population probably did more to influence seabirds on the barrier islands than any other factor. Boating activities increased dramatically. Even areas that were not accessible by road, such as Sand Island and the west end of Dauphin Island, became accessible by boat, subjecting seabird colonies to increased human disturbance. In recent years, off-road vehicle (ORV) use has become particularly acute on the west end of Dauphin Island even though there is a beach driving law that, in theory, should prevent much of the ORV use in this sensitive area.

The results of our aerial surveys in late June of 1984-1986 give some indication of the possible impact of ORV use on the west end of Dauphin Island. During this time, we recorded no colonial seabirds nesting in the area even though Portnoy (1977) found at least three substantial colonies in 1976. One does not have to look far to find the reason for this colony abandonment between 1976 and 1984. From tire marks it is evident that ORV use has been rampant in the past few years. Hardly a square foot of the west end did not show some evidence of ORV use. Seabird colonies could not stand this pressure.

Mississippi Sound

The status of seabird colonies on the many small islands in Mississippi Sound has probably not changed much recently. There are indications that there may be an increase in nesting activity (John Dindo, pers. comm.). Nesting habitat for many

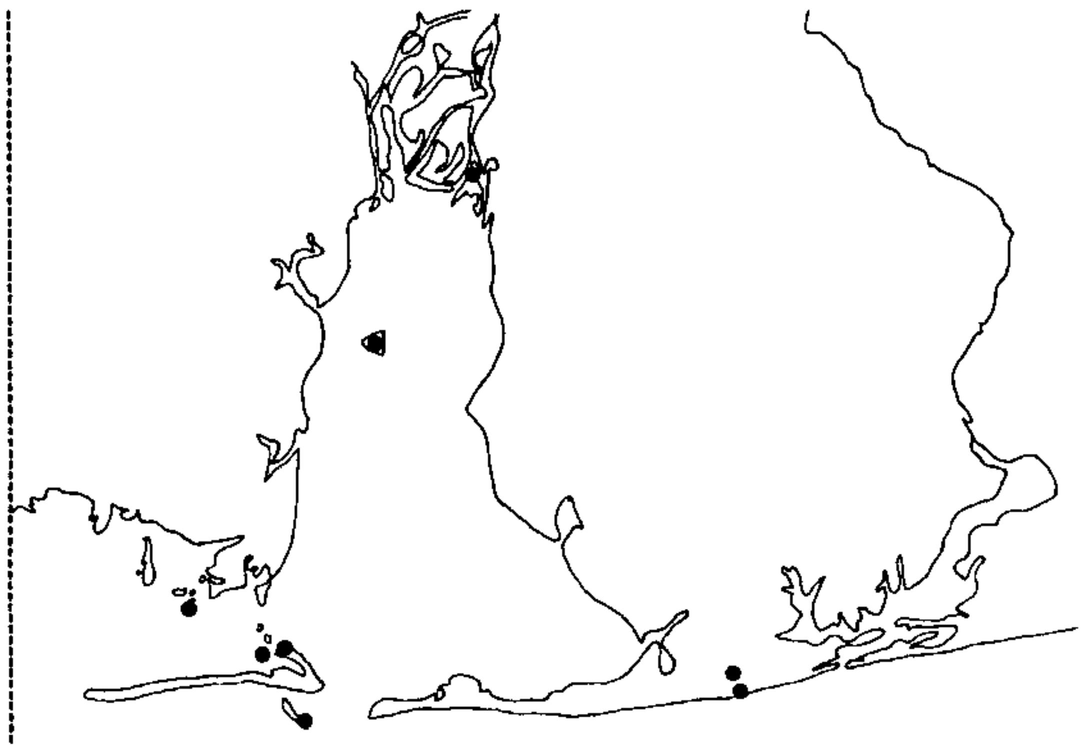

Figure 3. Dispersion of seabird nesting colonies in coastal Alabama, 1984-1986.

species, with the notable exception of Forsters Tern, is limited because most of these islands are dominated by marsh with only a small fringe of sand and/or shell beach around their periphery.

These islands may become more important to colonial seabirds in the future because of some of their attributes. All of the islands are relatively small and are not suited to residential development. The islands are not linked to the mainland by a transportation corridor and access is by boat only. These two attributes tend to limit human disturbance in the area. Also, the islands may provide a more stable nesting substrate because they are somewhat buffered from storm activity by Dauphin Island to the south.

There are recent developments that have the potential to negatively impact this area. There has been a dramatic increase in oil and gas exploration activity in coastal Alabama over the past ten years and this activity is not expected to decrease in the near future. Much of this activity has been centered in the lower Mobile Bay and Mississippi Sound vicinity. Fortunately, accidental spills associated with oil and gas production have not occurred in coastal Alabama but where they have occurred, they have resulted in catastrophic seabird impacts. One hopes we will never have to address this problem.

Mobile Bay

Formerly, very little habitat was available for nesting seabirds in Mobile Bay. Extensive beach habitat was lacking and marshes fringed much of the bay. Man's activities during this century has created fastland of varying quality within the bay that is suitable for seabird nesting. At the head of Mobile Bay, Blakeley Island and Cochrane Causeway were constructed from dredged material generated by harbor development and road construction, respectively. Within the shallow waters of the bay, east of Theodore Industrial Park, the Corps of Engineers (COE) has constructed Gaillard Island to contain dredged material generated during construction and maintenance of the Theodore Ship Channel.

Seabird nesting on Blakeley Island and along the Cochrane Causeway has been sporadic. In 1979, several species of colonial seabirds nested on Blakeley Island (John Winn, pers. comm.) but have not nested since. Along Cochrane Causeway, terns nest sporadically on sandy dredge material disposal areas north of the causeway. Nesting in both these areas is limited by the amount of habitat available, the easy human and predator access to that habitat, and continuing development of these areas.

The most important seabird nesting area in Mobile Bay and all of coastal Alabama is Gaillard Island. Construction of the island began in April 1979 and the present configuration was essentially complete by August 1981. Soon after the perimeter dikes were brought above water, colonial seabirds began nesting on the island. During this study (1984-1986), all 11 species of seabirds that have historically nested in coastal Alabama nested on Gaillard Island during at least one season. In each of the three seasons, nesting activity was substantial. In 1984, approximately 8000 pairs of seabirds nested on the island while 12,000 pairs nested in 1985 and 7000 in 1986.

The suitability of Gaillard Island as a seabird nesting area is the result of many factors. For the most part, this island has not yet been "discovered" by the general public and has, therefore, escaped many of the impacts associated with human intrusion. Access to the island is by boat only, further restricting human disturbance. As is common on newly formed islands, predators that might disrupt seabird nesting have not yet become established. Predator establishment may be slowed by the large expanses of open water between the island and mainland and a lack of cover on the island. In addition, invasion of the island by seabirds that formerly nested in the abandoned colonies of the barrier islands may contribute to use of the island.

Habitat diversity is the most important factor controlling the amount of seabird use of Gaillard Island. There are four distinct habitat types occurring on the island; areas where dredged material has been placed recently, older dredged material flats, dredged material banks, and vegetated areas. Areas where recent dredged material has been placed tend to be dominated by clays and silts with little shell material. These areas are used by depression nesters including Caspian and Royal Terns. The older flats contain sand mixed with varying amounts of shell material preferred by species such as Gull-billed, Common, Least, Caspian, and Royal Terns. Dredged material banks consist of areas of sandy material where the elevation is higher than the surrounding area, such as dikes and berms, preferred by Black Skimmers. Vegetated areas are those where grasses such as coastal bermuda (Cynodon dactylon) have been planted or where plants have naturally invaded. These areas are the preferred nest sites for Brown Pelicans and Laughing Gulls.

Mainland

The extent of colonial seabird nesting activity in mainland Mobile and Baldwin Counties is poorly known. Undoubtedly, nesting formerly occurred at several sites. However, the only information we have indicates that, at least recently, activity has been low. Nesting habitat along the mainland is limited in extent, open to human access, and subject to many development pressures and associated human disturbance. The only known seabird colonies on the mainland have been in the Gulf Shores area.

SPECIES ACCOUNTS

An annotated list of seabirds nesting in coastal Alabama can be found below. Figure 4 presents data on the historical and present distribution of colonial seabird populations.

Brown Pelican

Brown Pelicans occur regularly along the Alabama coast throughout the year, but nest in only one location. The first documented nesting in Alabama occurred in 1983, when they were found nesting on Gaillard Island in Mobile Bay. They have continued to nest on the island in subsequent years. In 1983 and 1984, nests were constructed in debris along the eastern side of the island. In 1985, nests were again constructed near the previous years' site but were abandoned in early May as dike revetment work progressed to within 600 ft. of the nests. Fortunately, the birds relocated to a vegetated area on the southeastern corner of the island and had a productive year. In 1986, again nesting on the southeast corner of the island, approximately 300 pairs produced in excess of 500 young.

Laughing Gull

Laughing Gulls are the most abundant breeding marine bird in the southeastern United States (Clapp et al. 1983), and are common along the Alabama coast throughout the year (Imhof 1976). Although they are abundant during the nesting season, they have nested in only two locations. In 1979, they nested on an island in an alkaline pond known as Alcoa Mud Lake #1 on Blakeley Island (John and Bev Winn, pers. comm.). They were nesting in a mixed colony consisting of Caspian, Gull-billed, and Forsters Terns, Black Skimmers, and Black-necked Stilts (Himantopus mexicanus). The colony was not present at that location in 1978 nor has it been active since 1979.

The largest Laughing Gull colony along the northern Gulf of Mexico and the only one presently extant in Alabama is on Gaillard Island. They first nested there in 1983 (Dan Holliman, pers. comm.) and have nested there in intervening years (1984-1986). On Gaillard, they nest solely in vegetated areas and seem to select thick mats of coastal bermuda grass as their favored nesting substrate. During this study, the number of nesting pairs peaked at approximately 10,000 in 1985 and fell to an estimated 4500 in 1986.

Herring Gull

The Herring Gull is a common winter resident in coastal Alabama with a few remaining through the summer. The one and only nesting in Alabama occurred on Gaillard Island in 1986 (Cooley et al. 1987 ms.) when a nest with two eggs was found in a Laughing Gull colony adjacent to the Brown Pelican nesting area. Both adults were seen to incubate and the nest and adults were found on subsequent trips. Herring Gulls are not known to nest any closer to Alabama than coastal North Carolina some 600+ miles away (Clapp et al. 1983).

Gull-billed Tern

Gull-billed Terns were first discovered nesting in Alabama in 1956 when three nests were found at Cedar Point (Imhof 1962). Since that time, they have nested at four additional locations. Within the barrier islands, 23 nesting adults were found on the west end of Dauphin Island in 1976 (Portnoy 1977) and 100 pairs nested on Sand Island in 1979 (Jackson and Cooley 1979). At the head of Mobile Bay in 1979, 64 nesting adults were found on an island in Alcoa Mud Lake #1 on Blakeley Island (John and Bev Winn, pers. comm.) but not thereafter. In recent years, Gaillard Island has contained the highest number of nesting Gull-billeds in Alabama where the number of nesting pairs peaked at 200 in 1985.

Caspian Tern

Caspian Terns are a recent addition to the breeding seabird list of Alabama. Portnoy (1977) found the first evidence of nesting in Alabama in 1976 when he noted 132 nesting adults on Little Dauphin Island. In 1979, 340 nesting adults were among a mixed species colony on an island in Alcoa Mud Lake #1 on Blakeley Island (John and Bev Winn, pers. comm.), but they have not nested there since. Since 1983, this species has nested on Gaillard Island only. It was a major component of the nesting assemblage in 1985 when approximately 1000 pairs nested on the island. Numbers of nests on this island plummeted in 1986 when approximately 100 were counted.

Royal Tern

The Royal Tern is one of the most common year-round residents in coastal Alabama, yet nesting is sporadic and at low levels. The species was first recorded nesting "prior to 1893" on an island at the mouth of Mobile Bay. However, nesting was interrupted in 1893 when the island was washed away by a storm (Howell 1924). In 1958, 50+ nests were found on Sand Island (Imhof 1962). Nesting on Gaillard Island since 1983, the species has not increased as one might expect. The most productive year on the island was 1985 when approximately 150 nests were recorded. The number of nests in 1986 decreased to 50, approximately the same as 1984.

Sandwich Tern

The Sandwich Tern is a low density nester in Alabama that associates with Royal Terns in nesting colonies. As far as we know, Sandwich Terns have nested at only two locations in Alabama. They nested with Royal Terns prior to 1893 on an island at the mouth of Mobile Bay and suffered the same fate when the island washed away in 1893. Since that time, they have nested only on Gaillard Island in association with Royal Terns. There were 50 nesting adults in 1983 and 1984, no nesting recorded in 1985, and only two nests in 1986 on the island.

Common Tern

Nesting locations for the Common Tern are few in Alabama, and for that matter, along the Gulf of Mexico as a whole. Outside of Alabama, there are fewer than 10 documented nesting locations in Gulf of Mexico coastal areas (Clapp et al. 1983). In Alabama, they have nested at two locations. Portnoy (1977) recorded the first nesting record for Alabama when he noted 12 nesting adults toward the west end of Dauphin Island in 1976. These 12 birds were the only ones he recorded in Louisiana, Mississippi, and Alabama during his extensive 1976 aerial and ground surveys. On Gaillard Island, Common Terns have nested in 1983 and 1985-1986. In 1983, 50 nesting adults were noted while ten and seven nests were recorded in 1985 and 1986, respectively.

Forsters Tern

The status of Forsters Tern in Alabama is similar to that of Common Tern. Only two nesting areas are known. In 1962, a "few pairs" nested in southern Mobile County (Imhof 1976). In 1984 and again in 1986, they nested on Gaillard Island. There were 50 nesting adults on the island in 1984 and nine nests recorded in 1986.

Least Tern

Least Terns breed abundantly on coastal islands, mainland beaches, sandy areas near highways, and rooftops, frequently nesting near Black Skimmer colonies (Portnoy 1977). In Alabama, they are widespread nesters, though population levels are not high. The first recorded nesting in Alabama was in 1911 when 20 nests were found on Dauphin Island (Howell 1924). In 1924, nesting was recorded on the east tip of Petit Bois Island. At that time the eastern end of Petit Bois was in Alabama (Jackson and Jackson 1985). Imhof (1962) listed them as probable nesters on Dauphin Island, near Cochrane Causeway, and at Cedar Point in 1958. In 1976, Portnoy recorded 2350 nesting adults in four colonies on Dauphin Island and 367 nesting adults on Cat Island in Mississippi Sound. When he re-surveyed the same areas in 1976 he found only two small colonies, each of less than 100 birds, on Dauphin and Little Dauphin Islands (Portnoy 1978 ms.). Recent nesting was noted in coastal Baldwin County at Gulf State Park and along the Gulf Intracoastal Waterway, 1984-1986. The nesting population on Gaillard Island appears to be slowly increasing. Approximately 100 nesting adults were recorded there in 1983 and 220 in 1984. In 1985, 20 nests were counted while 194 nests were recorded in 1986.

Black Skimmer

The distribution of Black Skimmer in Alabama closely approximates that of the Least Tern. Black Skimmers were first recorded as probably nesting in Alabama in 1911 on the west end of Dauphin Island. In 1913, they probably nested on the east tip of Petit Bois Island, then a part of Alabama, and on the west end of Dauphin Island (Howell 1928). In 1956, they were again probable nesters on the west end of Dauphin (Imhof 1962). Portnoy (1977, 1978) recorded 500 nesting adults on the west end of Dauphin in 1976 but did not find them there in 1978; however, he did find a small colony of less than 100 nesting adults on Sand Island in 1978 (Portnoy 1978 ms.). In 1979, 56 birds nested on Blakeley Island (John and Bev Winn, pers. comm.) while 1000 pairs nested on Sand Island (Jackson and Cooley 1979). Black Skimmers have been common nesters on Gaillard Island since at least 1983 when 500 nesting birds were recorded. Over the past three years, numbers on the island have been erratic, with 3150 birds present in 1984, 450 nests in 1985, and 1700 nests in 1986.

CONCLUSIONS

Colonial seabirds are known to have nested in coastal Alabama since before the turn of the century. Some 11 species have nested at 15 known locations in Mobile and Baldwin Counties. Systematic surveys of colonial seabirds in Alabama are lacking and the historic record of colony locations is incomplete. Taking these facts into account, the true status and distribution of colonial seabirds is poorly known. It appears that at least through the first half of this century, the barrier islands of southern Mobile County were the major centers of breeding seabird distribution in Alabama. The 1950's and 1960's were a time of ornithological inactivity in coastal Alabama and we know little of seabird status and distribution. In 1976, Portnoy systematically surveyed the barrier islands and Mississippi Sound portion of Mobile County and found several seabird colonies still there (Portnoy 1977). However, when he resurveyed the same area in 1978, he found that some of the traditional colony sites had been abandoned (Portnoy 1978 ms.). Subsequent to this time, the major center of breeding seabird distribution appears to have shifted from the barrier islands to become more uniform, with large concentrations of nesting birds occurring on Gaillard Island in Mobile Bay. Gaillard Island continues to be the most important seabird nesting area in coastal Alabama.

The reason for the shift in nesting seabird distribution from the barrier islands to other areas is unclear. About the time that this shift was occurring, (1950-1980), several human-related developments were occurring. The barrier islands were becoming accessible and there was a general trend of recreational, residential, commercial, and industrial development in all coastal areas. More and more people were moving to the coast. During this period, the population in the 19 states bordering (within 100 miles) the Atlantic and Gulf of Mexico coast increased by 47 percent (USDI 1983). Present projections indicate that about 50 percent of the U.S. population now lives within 50 miles of the coasts or the Great Lakes, and that population growth in coastal areas is three times that of the national average (Friend et al. 1981).

With the increase in human population along the coast, more people were walking the beaches, boating the shoreline, and building homes. These undoubtedly placed great human-disturbance pressure upon nesting seabirds. Pressures that, in all probability, they could not endure. The only thing left for them to do was move somewhere else, if that somewhere else were available. During the early part of this period, colonial seabirds nested where they could. Then in the early part of this decade, a new habitat was opened up to them.

Gaillard Island was constructed by the COE to contain dredged material from the Theodore Ship Channel. Seabirds initiated nesting there as early as 1982, and nesting populations have increased dramatically in intervening years. However, we should not forget that no matter how important the area is to colonial seabirds, construction of the island caused many sacrifices. Approximately two square miles of productive, shallow water bay bottoms were covered up, thereby forever withdrawing that acreage from fish and shellfish production, a resource that colonial seabirds depend upon. Ultimately, we should realize that Gaillard Island is a colonial seabird gem. We should also realize that if we protect our existing colonial seabird nesting areas, we do not need other dredged material disposal islands in Mobile Bay or Mississippi Sound, for any reason, seabird nesting or otherwise. The sacrifices may be too great.

MANAGEMENT RECOMMENDATIONS

1. Develop and institute a comprehensive colonial seabird survey and monitoring program.

Baseline data on colonial seabird status and distribution in coastal Alabama is lacking. Reliable baseline data is needed if we are to assess any future changes in seabird status and distribution. A comprehensive survey and monitoring program to develop that baseline is absolutely necessary.

2. Develop a protection plan for existing colonial seabird resources.

Over the past two decades, almost 50 percent of the colonial seabird colonies in coastal Alabama have been abandoned. The reason for this is not clear but all indications are that human disturbance was, in part, the reason. Aggressive enforcement of existing statutes and posting of colony areas should reduce impacts considerably.

3. Develop a public education program documenting the values of colonial seabird resources.

We are going to conserve only those resources that we understand. Public education to the values of our natural resources is the first and most important step in developing a public conservation ethic. This program should involve the input of local, state, and federal agencies, conservation organizations, local media, and the local citizenry and could be integrated into the Nongame Wildlife Program of the Alabama Department of Conservation and Natural Resources, benefitting both causes.

4. Promote colonial seabird use of traditional colony sites that have been abandoned.

Enforcement of existing statutes should largely eliminate human-related disturbance in areas, such as the west end of Dauphin Island, that no longer support nesting colonies. Once human disturbance has been eliminated, these areas should be assessed as to their potential to support nesting populations. If this assessment reveals that the habitat is no longer suitable for nesting, measures should be initiated to improve the habitat.

5. Institute an aggressive acquisition program aimed at protecting not only existing colonies but also traditional colony sites that have been abandoned.

Many of the traditional and existing seabird colony sites are located in sensitive areas that are subject to many development pressures. An acquisition program aimed at acquiring colony sites would insure that these sensitive areas were not developed and that the resources utilizing these areas remained in the public domain.

6. Develop a dredged material disposal program for coastal Alabama.

Colonial seabird use of dredged material disposal areas is increasing. Unfortunately, seabird nesting and use of these disposal areas for their intended purposes can conflict. A multi-agency/organization - developed management program aimed at promoting seabird use during the nesting season while at the same time allowing for intended uses could eliminate seabird-dredged material disposal conflicts.

7. Designate Gaillard Island a Colonial Seabird Sanctuary.

The importance of Gaillard Island as a seabird nesting area is unquestioned. The administration of the island at present is unclear and the potential for many impacts is great. Designation of the island as a Seabird Sanctuary would add some measure of protection and provide for continued colonial seabird use.

ACKNOWLEDGEMENTS

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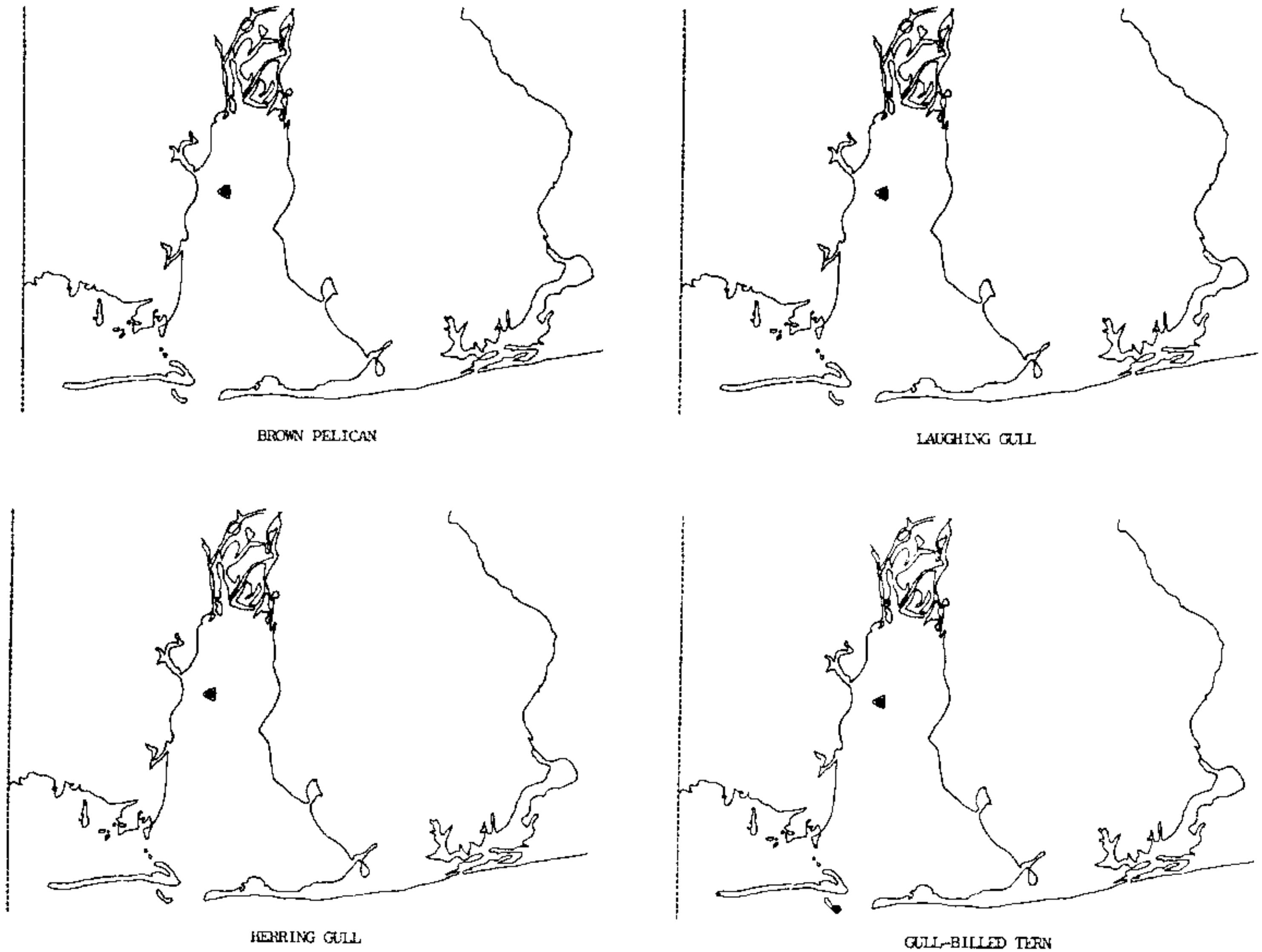


Figure 4. Dispersion of seabird colonies in coastal Alabama (●- active; •- inactive).

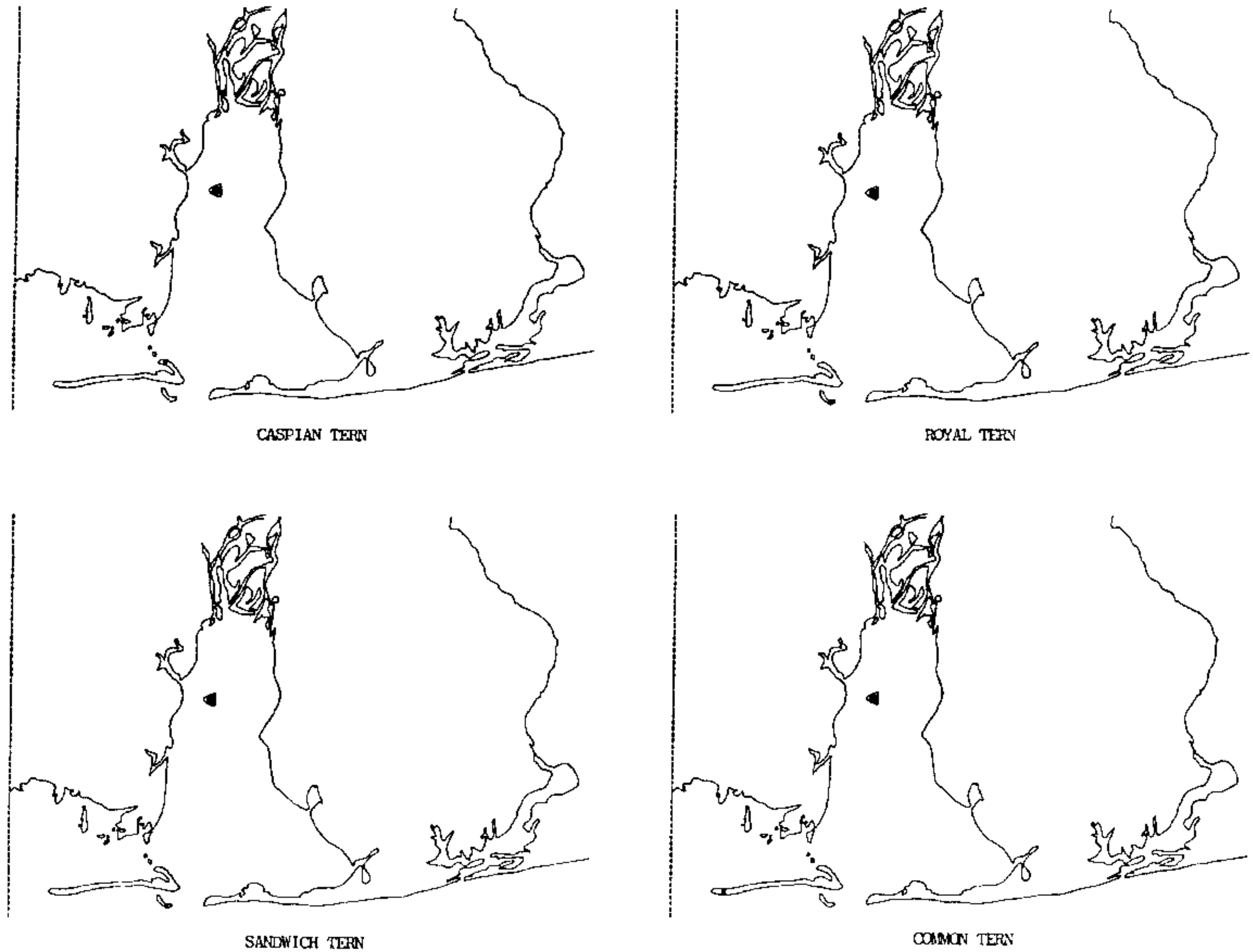
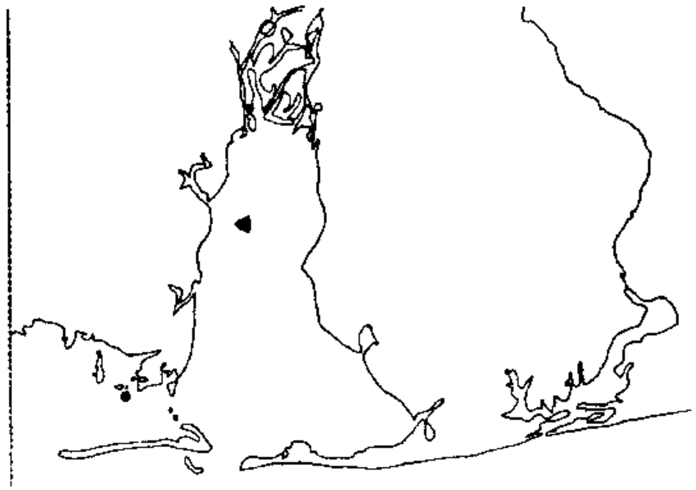
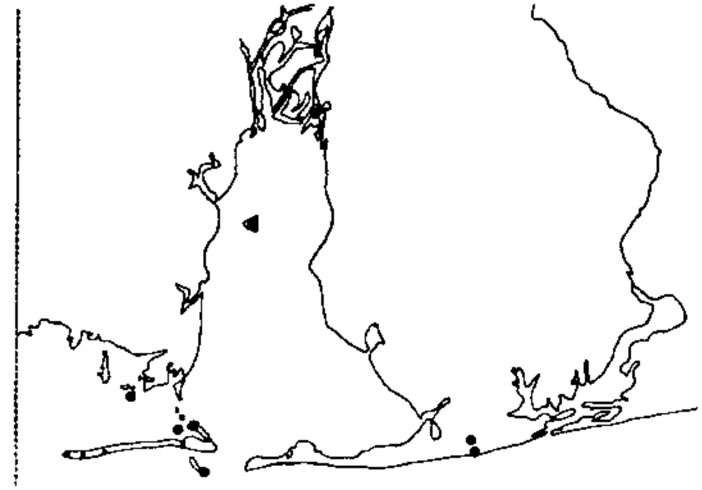


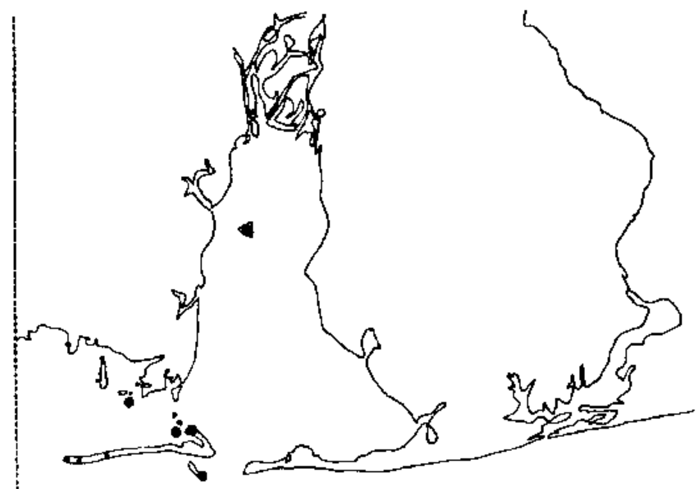
Figure 4 (cont.). Dispersion of seabird colonies in coastal Alabama (● - active; • - inactive).



FORSTERS TERN



LEAST TERN



BLACK SKIMMER

Figure 4 (cont.). Dispersion of seabird colonies in coastal Alabama (●- active; • - inactive).

EVALUATION OF COLONIAL NESTING HABITATS; CAT ISLAND, LITTLE DAUPHIN ISLAND, AND SURROUNDING AREAS

John J. Dindo
Dauphin Island Sea Lab
Dauphin Island, Alabama 36528

Ken R. Marion
University of Alabama at Birmingham, Dept. of Biology
Birmingham, Alabama 35294

Dan C. Holliman
Birmingham Southern University, Dept. of Biology
Birmingham, Alabama 35204

ABSTRACT: Industrial and urban development in our area has left suitable breeding habitats for migratory wading birds at a premium. Within the complex estuarine ecosystem of Mobile Bay and Mississippi Sound, only a few nesting sites are utilized by colonial birds. Cat Island supports the largest assemblage of Tricolor Herons (Hydranassa tricolor) in the State of Alabama. Two to three thousand birds of several species nest on this small 5.2 ha. island. A decline in the number of young fledged in 1976 and observations of large numbers of dead post-fledglings in 1986 reflect the influence of natural perturbations. Early Spring rains in 1976 resulted in only a 18.1% nesting success for Tricolor Herons. The total nesting population declined in 1986 in response to the loss of suitable nesting habitat as a result of the three hurricanes of 1985.

INTRODUCTION

Suitable breeding habitats for migratory wading birds are becoming increasingly scarce due to encroachment by industrial and urban development. Although wading birds in the past have shown resilient characteristics, they may not be able to overcome the combined effects of habitat loss and reduction in environmental quality. Kushland and White (1977) demonstrated that South Florida wading bird populations continued to decline (89% since the 1930's) due to altered feeding habitats. Others believe that pollutants play a major role in population declines. Accordingly, the U.S. Fish and Wildlife Service is attempting to establish a nationwide data base for all coastal colonial nesters (Portnoy, 1977). Custer and Osborn (1979) and Portnoy (1977) both feel strongly that changes in nesting populations of colonial wading birds may be used as biotic indicators of the stability of coastal ecosystems. Members of the family Ardeidae particulary have been found to be good indicators of wetland disturbances (Giard and Taylor, 1979; Custer et al., 1983). Commonly, these birds occupy limited areas in high densities, resulting in resource partitioning and interspecific competition (Mckrimmon, 1978). Finally, colonial nesters are of recent interest because toxicologic research on such birds may be applicable to human health both as models for mechanics and descriptive studies and indirectly as monitors of environmental quality (Hill, 1984).

Our knowledge of the population responses of these nesters to influences of a density-dependent (e.g. biological or demographic) or density-independent nature (e.g., major weather events) is limited. While predation and inclement weather usually have the effect of destroying whole broods (Ricklefs, 1969) there is very little data on reproductive responses of these species to drastic fluctuations in weather as it relates to egg hatching, nestling, survival, and fledgling mortality (Johnson, 1979; Jenni, 1972; Custer et al 1983). The synergistic effects of both density-dependent and density-independent pressures on responsible "strategies" of colonial nesters needs to be evaluated.

Alabama has a very limited coastline, within which Mobile Bay, Mississippi Sound and adjacent areas constitute a complex ecosystem that supports the valuable shelf fisheries of the Gulf of Mexico. Cat Island, Marsh Island, Isle Aux Herbs and Raccoon Island are all within a half mile of each other within Mississippi Sound. Of these, only Cat Island has high enough relief to support a colonial nesting colony. Little Dauphin Island, 8 km north of Dauphin Island, is a new site of colonial nesting (Dindo and Marion,1986).

CAT ISLAND

Cat Island is a 5.2 hectare tidal marsh island located 11 kilometers north of Dauphin Island (Fig. 1).

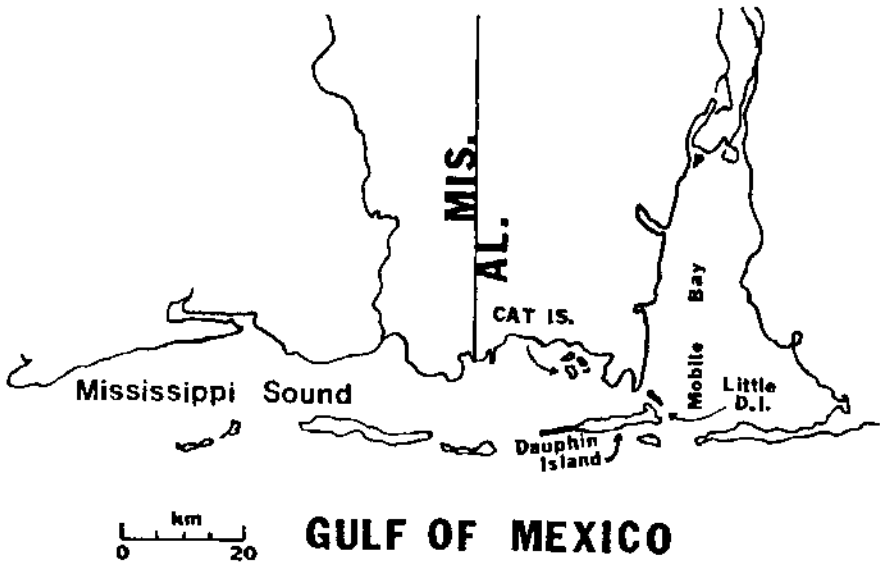


Figure 1. Location map showing study site in relation to Alabama coastline.

Accummulation of oyster shells around the island causes an increase in elevation within which the shell ridges support a dense growth of groundsel tree (Baccharis halimifolia) and marsh elder (Iva frutescens) (Stout, 1985; Gaston and Johnson, 1977). Although these plants occupy 18%-20% (.93 ha - 1.04 ha) of the island, they provide the primary nesting sites and materials for the two to three thousand herons and egrets that nest there. Cat Island has been reported to support the largest assemblage of nesting Tricolor Herons (Hydranassa tricolor) in the state of Alabama (Dusi and Dusi, 1968; Dusi et al. 1971; Gaston and Johnson, 1977). This mixed nesting colony is also comprised of Snowy Egrets (Egretta thula), Little Blue Herons (Florida caerula), Great Egrets (Casmerodius albus), and Cattle Egrets (Bubulcus ibis). In addition, Gaston and Johnson (1977) reported nestings of the Green-backed Heron (Butorides virescens) and the Glossy Ibis (Plegadis fatcinellus) on this island. Cat Island was the site of the only previous population study of a coastal Alabama heronry (Gaston and Johnson, 1977).

Many other species of birds also utilize Cat Island, either as nesting sites or staging areas. Throughout the spring both Brown Pelicans (Pelecaus occidentalis) and White Pelicans Pelecanus erythrorhynchos can be seen on the shell hash beach areas or feeding in adjacent waters. Their numbers fluctuate day to day with 30-70 Brown Pelicans and 20-100 White Pelicans are frequently seen early in the spring. Only Brown Pelicans are present throughout the summer and winter. Cat Island may become a potential site for nesting of the Brown Pelican as the population within the Mobile Bay estuary continues to grow. Least Terns (Sterna albifrons) and the American Oystercatcher (Haematopus palliatus) also establish nest sites on the shell hash areas of the island. Other shore birds can be seen feeding in and around Cat Island and in the fall, numerous species of waterfowl utilize the inland pond areas. Cat Island is not utilized by man so disturbance is minimal.

Population Dynamics

Since 1984 we have conducted population studies of the heronry on Cat Island. In December of 1984 two semi-permanent blinds were built on Cat Island for observation. The blinds stood nine feet off the ground and were camouflaged to allow the observer freedom of movement within the blind without detection by the nesting birds. This proved highly successful with Tricolor Herons and Snowy Egrets establishing nests as close as two feet from the blind. In October of 1985, both blinds were lost due to Hurricanes Elena, Juan and Kate. The primary blind was reestablished in December 1985. Five 50-meter transects were cut through the vegetation to allow for marking of nests and banding of young. The colony was visited up to three days a week. The frequency of trips and time periods within the colony were selected to minimize the impact of human disturbances. Clutch size, incubation times, percent hatching, and nestling survivorship to fledgling size were analyzed for each marked nest. A modification of the Mayfield (1961) and Teal (1965) nesting success techniques was employed. A circular plot and strip transect method was employed to estimate population densities in peripheral versus central areas of the colony (Reynolds, 1980; Connor, 1980). Changes in vegetation (% coverage, and canopy height) were also evaluated.

In 1985, the population of nesting wading birds on Cat Island was estimated to be approximately three thousand birds. Of special importance was the successful nesting of the Reddish Egret (Dichromanassa rufesens). According to Imoff (1976), the only other occurrence of this was a probable nesting observed in 1965. In 1986, two pairs of Reddish Egrets again established successful nests. The Glossy Ibis (Plegadis falcinellus), which had nested on Cat Island in previous years (Gaston and Johnson, 1977),did not nest in the 1984 and 1985 seasons, but two pairs established successful nests in 1986.

One hundred seventy-one and 240 nests were marked in 1985 and 1986, respectively. Eggs and hatchlings were followed through fledgling stages each year.

Nest density was figured for ten 25 square meter transects randomly selected throughout the colony during 1986. Nest densities ranged from a high of 1.68 nests/m^2 to a low of 1.47 nests/m^2 of nesting habitat. Many nests were established in habitat that had not been utilized in past years.

Tables 1 and 2 show the clutch size and the number of birds fledged per species respectively. No significant difference can be seen between the 1985 and 1986 breeding season. Table 3 compares nesting success between the Gaston and Johnson (1977) study and the current study. Here again no significant differences can be seen between species nor between years although the colony size itself was reduced to approximately 1500 nesters.

TABLE 1. NUMBER EGGS LAID PER SPECIES (Clutch Size).

	1985			1986		
SPECIES	N	MEAN	STD. DEV.	N	MEAN	STD. DEV.
Tricolor Heron	78	3.08	0.55	109	3.02	0.62
Reddish Egret	3	2.00	----	2	2.00	----
Snowy Egret	34	3.35	0.69	61	3.19	1.07
Little Blue Heron	19	3.05	0.71	9	3.62	1.06
Cattle Egret	37	2.91	0.72	46	2.52	0.62
Glossy Ibis	--	----	----	2	3.00	----

TABLE 2. NUMBER BIRDS FLEDGED PER SPECIES/PER NEST.

	1985			1986		
SPECIES	N	MEAN	STD. DEV.	N	MEAN	STD. DEV.
Tricolor Heron	78	2.85	0.84	109	1.99	0.93
Reddish Egret	3	2.00	----	2	1.50	0.70
Snowy Egret	34	2.41	1.01	61	1.77	1.04
Little Blue Heron	19	2.00	1.15	9	2.33	0.70
Cattle Egret	37	1.67	1.27	46	1.78	1.13
Glossy Ibis	--	----	----	2	2.00	----

TABLE 3. NESTING SUCCESS (% FLEDGED TO NO. EGGS).

SPECIES	1976 (GASTON & JOHNSON)	1977 (GASTON & JOHNSON)	1985	1986
Tricolor Heron	18.1	71.7	92.5	87.8
Snowy Egret	----	----	71.9	60.7
Little Blue	----	----	65.5	72.7
Cattle Egret	78.0	58.4	57.3	86.6
Reddish Egret	----	----	33.3	33.3
Glossy Ibis	----	----	----	66.6

LITTLE DAUPHIN ISLAND

Little Dauphin Island is located off the coast of Alabama within the Mobile Bay estuarine system (Fig. 2). It is a marine tidal marsh island (344.5 ha). The eastern end of Little Dauphin Island supports a small stand of loblolly and slash pine (Pinus taeda and Pinus caribaea) The western end of the island is a Juncus dominated marsh, with elevated oyster shell mounds containing growths of dwarf live oak (Quercus virginiana). Adjacent to Little Dauphin Island is the much smaller Peavy Island (1.4 ha), a site previously used by motor campers, and other for picnics, fishing and camping.

Little Dauphin Island was followed closely during 1985 and 1986 for evidence of nesting activities. In the spring and summer of 1986 the first recorded successful nesting of the Great Blue Heron (Ardea herodias), the Great Egret (Casmerodius albas), and the Green-Backed Heron (Butroides striatus) on Little Dauphin Island occured during the spring and summer of 1986. Approximately one hundred Least Terns (Sterna albifrons) and fifty-sixty black skimmers (Rynchops nigers) also nested on sand ridges on the northwestern edge of the island. In addition the American oyster catcher (Haematopus palliatus) and many species of the Charadridae and Scolopacidae families utilized the shallow waters around Little Dauphin Island for feeding.

Little Dauphin Island Island is now being utilized as a nesting site primarily as a result of Hurricane Frederick in 1979. Prior to the hurricane, the highway and bridge system (Hwy. 163) that connected the mainland to Dauphin Island was approximately 12 feet off the water (Fig. 2). This old highway offered easy access to Peavy Island and Little Dauphin Island. Hurricane Frederick destroyed the bridge, requiring the building of a new elevated (7.62 m) causeway. This allows no access to Little Dauphin Island and the surrounding areas. Our observations suggest that the recent lack of disturbances by man has provided new nesting sites for colonial water birds on Little Dauphin Island.

DISCUSSION

The vegetation on Cat Island was reduced in height from an average of 1.96 meters to an average of .52 meters at nesting time as a result of the three Hurricanes of 1985 (Juan, Elena, Kate) (Fig. 3). These occured late enough in the year to cause no observable loss of fledglings or adults. The lower colony size observed during 1986, however, is believed to be a result of reduced available nesting sites due to decreased vegetation height. In both the 1985 and 1986 breeding seasons the Tricolor Herons had better success than that observed by Gaston and Johnson in 1977. Our data indicates that for Snowy Egrets the percent fledged was lower in 1986 than 1987 but not significantly. Cattle Egrets percent fledged increased by thirty percent in 1986 and is believed to be a result of their lack of preference for specific nesting sites. No significant weather related event occured in the spring of either 1985 or 1986 resulting in reasonably high nesting success.

Since a higher percentage of nests were built with very little protective cover, there was considerable predation. Fish crows were seen throughout the nesting cycle and were observed breaking eggs and carrying off nestlings.

Gaston and Johnson in 1977 showed a nesting success for Tricolor Herons of 71.7% in 1977, as compared to only 18.1% in 1976 (Table 3). They attributed the low nesting success to adverse weather conditions, resulting in high mortality of hatchlings.

The role that the inland tidal waters play as a potential food source for adults and fledglings may be critical. Prior to the hurricanes of 1985, open water areas on Cat Island had considerable tidal flow and exchange with the waters of Mississippi Sound, which in turn resulted in an abundance of juvenile fish, shrimp and crabs inhabiting the inland waters of the island. Following the hurricanes, the tidal creek flow was extensively altered, with a much lower volume exchange occuring only during very high tides. It is believed that fewer fish were able to enter this area because of

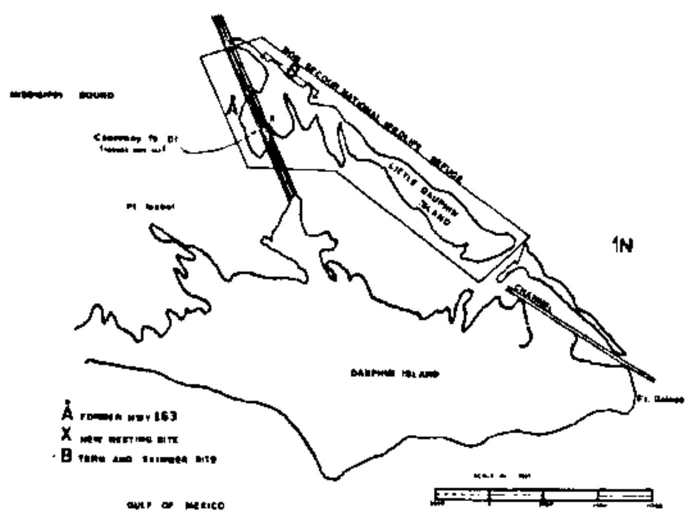


Figure 2. Location map showing new colonial nesting sites on Little Dauphin Island.

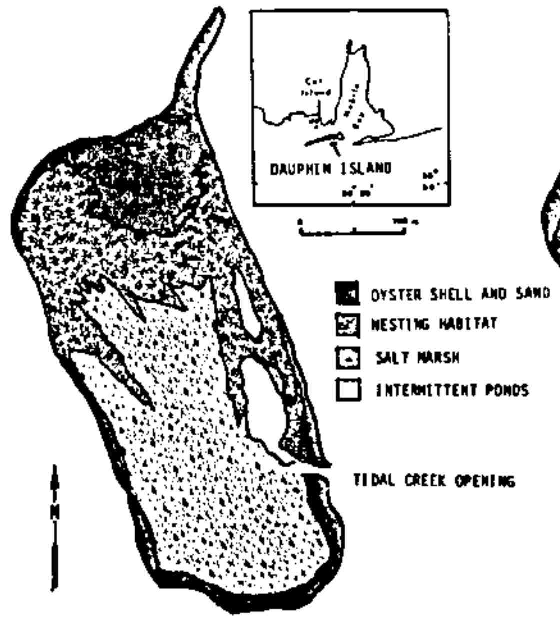


Figure 3. Cat Island, Alabama. Map of island showing habitat types in 1976 and following Hurricane Elena in 1985.

this physical change. Our data (Tables 2 and 3), however show only birds followed until they left the nest. The relatively high nesting success shown does not reflect our observations that large numbers of young post-fledged birds were found dead during 1986. A possible cause for these deaths may have been starvation as a result of the altered tidal flows to the inland pond following the 1985 hurricanes. This possibility will be investigated during 1987.

The importance of Cat Island can be measured in the utilization of this site as both nesting habitat and food source for the numerous other species of birds found here. The adjacent islands (Racoon, Marsh, Isle of Herbs) are used primarily as feeding sites. These islands are tidally inundated and sustain vast growths of Juncus roemerianus. No significant elevated areas exist on them. Thus, there is very little growth of vegetation that would support nesting sites for colonial water birds.

The establishment of a nesting site by colonial water birds and other species of colonial nesting sea birds on Little Dauphin Island indicates a potential for increased usage of this habitat for nesting. The relative inaccessibility to the island by man and the incorporation of Little Dauphin Island into the Bon Secour National Wildlife Sanctuary will help safeguard this new nesting area. Cat Island, however, is not protected and lies within a very valuable gas lease block. The mainland marshes adjacent to Cat Island have been extensively seismic surveyed . The continued monitoring and assessment of Cat Island is vital to safeguard this site from future exploration or development. We are beginning to understand how these colonial water birds recover from major density-independent pressures, but how they react to possible contaminants and habitat loss due to industrial encroachment is not known.

There are few sites in Alabama coastal waters that support wading bird colonies. Protection of these habitats is crucial to their continued productivity. In addition, with dredging of Mobile Bay becoming more of a reality, a possible utilization of the dredge spoil could be the establishment of additional small spoil islands in Mobile Bay or Mississippi Sound. Such islands could in time support additional nesting habitats for colonial nesters. Soots and Parnell (1975) have shown that the establishment of habitats of nesting sites for herons and egrets on spoil islands takes approximately ten years.

The 1978 symposium on Mobile Bay management plan called for a more refined and comprehensive survey program to assess environmental impacts of habitat alteration and contamination on wading bird populations in the coastal zone. In addition, management of dredge material into suitable nesting sites was suggested. Many of these goals were accomplished. Dr. Dan Holliman completed a project in 1980 funded by the Coastal Area Board titled A STUDY DESIGN TO DETERMINE THE PRESENT LEVELS OF BIRDS AND MAMMALS IN THE COASTAL ZONE. Again this study called for a sound management and research plan due to the increased alteration and destruction of natural habitat along the Gulf Coast. This CAB funded study developed a design for sampling methodology, location, frequency, work schedule, and a line item budget for these studies. This study has shown that without a management plan for the west end of Dauphin Island there can be no productive shore bird breeding habitat where there is uncontrolled human use of the beach-dune complex.

In 1984 the U.S. Fish and Wildlife Service funded Dr. Holliman to do a population survey of specific coastal birds under the Accelerated Research Program. This study evaluated Gaillard Island, Sand Island, Isle Aux Herbs, Marsh Island, and Cat Island.

The 1979 summary included the very real problem of pollutants. Pesticides and heavy metals in eggs and young need to be evaluated if indeed colonial wading birds are considered to be indicators of the quality of the habitat. Before further permitting is allowed the Mobile Bay ecosystem needs to have an accumulative impact study which would identify the types and quantities of effluent being discharged into the system from the upper river system to the offshore state waters. If we continue to permit discharges on a case by case basis without the knowledge of the total accumulative impact we may end up with a situation similar to the Chesapeake Bay, an ecosystem that collapsed.

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REPTILES AND AMPHIBIANS OF COASTAL ALABAMA

Steven D. Carey
Division of Natural Science
Mobile College
Mobile, Alabama 36613

ABSTRACT: Coastal Alabama supports a rich and diverse herpetofauna and boasts several endemic and poorly known forms. This paper lists species and subspecies of reptiles and amphibians believed to utilize the Mobile estuary. Habitat preferences and status category assessments are provided for each herptile. Reasons for the decline in numbers of many forms and recommendations for their recovery are discussed.

INTRODUCTION

Coastal Alabama and the Mobile estuary support a rich and diverse reptile and amphibian fauna that reflects the geographical location, subtropical climate, and habitat complexity of the coastal environment. This paper summarizes the occurence, status, and habitat preferences of coastal Alabama's herpetofauna and provides management recommendations for this important resource.

Mount (1975) published locality data and distribution maps that indicated the presence or probable occurence of 119 species and subspecies of reptiles and amphibians within coastal Alabama. Of these, the Alabama red-bellied turtle, and the southern black-knobbed sawback are endemic to Alabama. Carey (1982, 1983, 1985) published several locality records for herptiles previously unknown from coastal Alabama including the one-toed amphiuma, the greenhouse frog, and the Texas horned lizard. Nelson and Carey (1986) added the Mediterrean gecko to coastal Alabama's reptile fauna, noting its occurence in the cities of Mobile and Fairhope. In total, the concentration and diversity of coastal Alabama's reptile and amphibian fauna is unequalled by any other region of the state.

COASTAL HERPTILES

The occurence, status, and habitats of coastal Alabama's herpetofauna are summarized in Table 1. The inventory consists of (1) a literature search, (2) a review of existing collections, (3) personal communications with herpetologists familiar with Alabama herpetofauna, (4) personal observations, and (5) unpublished data.

Alabama's coastal area, as defined by Alabama law, is that region of the state extending seaward of the 10-foot contour line to the outer limits of the territorial sea. Few herptiles inhabit this region exclusively; many occur in suitable habitats throughout the Lower Coastal Plain and the remainder of the state. Others utilize the coastal area on a temporary or seasonal basis. Some forms are poorly represented in the coastal area due to a scarcity of preferred habitats or other limiting factors. This report includes reptiles and amphibians known to occur within the Alabama coastal area and, in cases where locality data are lacking, those whose known or assumed range would place them within the coastal area.

Status categories presented in Table 1 are those currently used by the United States Department of the Interior (USDI) and the Alabama Department of Conservation and Natural Resources (AL). The USDI categories (defined by the Endangered Species Act of 1973) and abbreviations are Endangered (E) and Threatened (T). Alabama designations, termed priority categories, were established during Alabama's First Nongame Wildlife Conference held July 15-16, 1983 (Mount 1986). The priority categories and their abbreviations are:

1. Endangered (E). Forms in danger of extinction or extirpation in all or a majority of their range in Alabama within the foreseeable future.

2. Threatened (T). Forms likely to become endangered in all or in a majority of their range in Alabama within the foreseeable future.

3. Special Concern (SP). Forms that must be continually monitored because of imminent threats to the habitat, limited range in Alabama, or because of other physical or biological factors that may cause them to become threatened or endangered within the forseeable future.

4. Poorly Known (SP). Forms for which data on status, distribution, and/or life history are insufficient to permit categorization otherwise.

STATUS OF COASTAL HERPTILES

Of the 123 species and subspecies of reptiles and amphibians known or assumed to occur within coastal Alabama, six are listed by the United States Department of the Interior as endangered or threatened and 28 are given priority category status by the State of Alabama (Mount 1986). Many other coastal herptiles are experiencing a decline in numbers.

Mount (1984) noted that Coastal Plain species and populations are faring poorly when compared to their upland counterparts, and offered the following explanations for this situation: (1) longer term exposure to imported fire ant predation on eggs and/or young, (2) adverse impact of "rattlesnake roundups," (3)more widespread and frequent use of pesticides, (4) armadillo predation on eggs and/or young, (5) destruction or adverse modification of some particularly significant Coastal Plain habitat types, such as salt marsh, and (6) possible adverse long-term effects of annual burning of forestland during winter and spring.

Incidental catch and drowning in shrimp nets and fishing trawls is an important cause of sea turtle mortality (Hillestad, Richardson, and Williamson 1977, Ulrich 1978, Bjorndal 1981). An estimated 13,811 sea turtles are captured annually in the Gulf of Mexico of which 4,005 die (Henwood and Stuntz 1986).

Needless killing of coastal herptiles, especially turtles and snakes, takes its toll as does the commercial exploitation of these animals for food, the pet trade, and scientific research. Presently, the American alligator, gopher tortoise, eastern indigo snake, Atlantic loggerhead, Atlantic green turtle, Atlantic ridley, and Atlantic leatherback are the only coastal herptiles protected from collecting in Alabama.

RECOMMENDATIONS

1) A comprehensive status survey to document the existence, distribution, habitat use,

and population densities of coastal herptiles should be conducted. The resultant baseline information would be used to monitor population changes and assist the decision-making process of lawmakers, and environmental planners and managers.

2) The ecological requirements and limiting factors of many coastal herptiles are poorly known. Additional studies are urgently needed to insure the survival of Alabama's coastal herpetofauna. Funding and other forms of assistance should be made available in support of such studies.

3) Existing legislation protecting Alabama's coastal herpetofauna must be rigidly enforced. State protection should be extended to include all priority category herptiles.

4) State legislation banning the "gassing" of gopher tortoise burrows should be enacted. This harmful practice, used to flush out rattlesnakes, is deleterious to the tortoises and their burrow associates (Speake and Mount 1973).

5) The use of turtle-exclusion devices by commercial shrimping and fishing trawlers should be changed from a voluntary to a mandatory basis.

6) Intensive education efforts are needed to inform the general public about the status and importance of Alabama's coastal reptiles and amphibians.

7) Predator control may be necessary to insure the survival of some coastal herptiles.

8) The acquisition and maintenance of habitat critical to the survival of many coastal herptiles should be continued.

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TABLE 1. Reptiles and Amphibians of Coastal Alabama

Species and Subspecies	Status[1] USDI	Status[1] AL	Comments
Class Amphibia			
Order Salientia - Frogs and Toads			
Oak Toad *Bufo quercicus*			Fossorial. Prefers sandy soils of pine flatwoods and sandhill communities. Breeds in temporary pools.
Southern Toad *Bufo terrestris*			Prefers friable soils for burrowing. Breeds in temporary pools, flooded roadside ditches, and permanent ponds.
Fowler's Toad *Bufo woodhousei fowleri*			Prefers sandy areas near freshwater. Breeds in lakes, streams, ponds, and drainage ditches.
Northern Cricket Frog *Acris crepitans crepitans*			Inhabits sparsely vegetated margins of streams, lakes, floodplain pools, ponds, and other freshwater situations.
Southern Cricket Frog *Acris gryllus gryllus*			Prefers weedy margins of both permanent and temporary bodies of freshwater. Intergrades with Florida cricket frog, *A. g. dorsalis* in extreme Southern Baldwin County.
Bird-voiced Treefrog *Hyla avivoca*			Arboreal. Favors cypress and hardwood swamps.
Green Treefrog *Hyla cinerea*			Arboreal. Inhabits swamps, lakes, ponds, streams, and other freshwater situations having abundant emergent vegetation.
Northern Spring Peeper *Hyla crucifer crucifer*			Inhabits damp woodlands near semipermanent ponds and swamps.
Pine Woods Treefrog *Hyla femoralis*			Arboreal. Favors pine flatwoods, and cypress swamps.
Barking Treefrog *Hyla gratiosa*			Arboreal during warm months. Spends winter and dry periods burrowed beneath roots or clumps of vegetation. Breeds in streams, cypress swamps, and other semi-permanent aquatic habitats.

TABLE 1. Continued

Species and Subspecies	Status[1] USDI	AL	Comments
Squirrel Treefrog *Hyla squirella*			Arboreal. Found almost anywhere there is moisture and insects. Breeds among emergent vegetation of shallow, semipermanent pools, ponds, flooded ditches, and similiar aquatic habitats.
Cope's Gray Treefrog *Hyla chrysoscelis*			Arboreal in vegetation near or in permanent aquatic habitats.
Southern Chorus Frog *Pseudacris nigrita nigrita*			Inhabits pine flatlands, wet meadows, damp woodlands, and flooded roadside ditches. Prefers sandy soils.
Ornate Chorus Frog *Pseudacris ornata*			Found in most shallow water situations where sandy, friable soils are present.
Greenhouse Frog *Eleutherodactylus planirostris planirostris*			Introduced species. Known to occur in Fairhope, Baldwin County. Probably widespread throughout coastal Alabama. Prefers areas of human habitation.
Eastern Narrowmouthed Toad *Gastrophryne carolinensis*			Fossorial. Prefers areas near water where it can burrow or find shelter.
Eastern Spadefoot Toad *Scaphiopus holbrooki holbrooki*			Fossorial in areas of friable soils. Breeds in temporary pools following heavy rains.
Dusky Gopher Frog[2] *Rana areolate sevosa*		T	Relies on gopher tortoise and possibly crawfish burrows for shelter. Breeds in semipermanent or permanent pools or ponds following heavy rains. Declining due to rapid loss of breeding and non-breeding habitat.
Bullfrog *Rana catesbeiana*			An aquatic frog of ponds, lakes, and large slow-moving streams.
Bronze Frog *Rana clamitans clamitans*			Inhabits small streams, floodplain pools, flooded ditches, ponds swamps, and their environs.
Pig Frog *Rana grylio*			Prefers ponds, lakes, and freshwater marshes with plenty of emergent or floating vegetation.

TABLE 1. Continued

Species and Subspecies	Status[1] USDI	AL	Comment
River Frog *Rana heckscheri*			Prefers swampy margins of slow-moving streams, cypress bays, beaver ponds, and bayous.
Southern Leopard Frog *Rana pipiens sphenocephala*			Found in all types of freshwater habitats; sometimes venturing into brackish marshes. Declining for unknown reasons.
Order Caudata - Salamanders			
Flatwoods Salamander[2] *Ambystoma cingulatum*		SC	A salamander of pine flatwoods. Breeds in temporary pools, swamps, and flooded roadside ditches. Known only from Baldwin, Covington, and Mobile counties in Alabama. No recent records for this species from coastal Alabama.
Spotted Salamander *Ambystoma maculatum*			Inhabits bottomland hardwoods near woodland ponds and flooded depressions. Declining or absent throughout much of coastal Alabama, perhaps due to loss of breeding and non-breeding habitat.
Marbled Salamander *Ambystoma opacum*			Resident of low swampy areas and damp woodlands. Declining due to loss of breeding and non-breeding habitat and perhaps other factors.
Mole Salamander *Ambystoma talpoideum*			Fossorial. Occurs in bottomland hardwoods, floodplains, and low swampy areas.
Small-mouthed Salamander *Ambystoma texanum*		SP	Inhabits floodplains and low swampy areas. Few Alabama records for this species.
Eastern Tiger Salamander *Ambystoma tigrinum*		SP	Fossorial. Knowledge of ecological requirements incomplete.
One-toed Amphiuma *Amphiuma pholeter*		SP	Prefers mucky situations along floodplain streams. Known only from Baldwin and Mobile counties in Alabama.
Two-toed Amphiuma *Amphiuma means*			Inhabits most freshwater situations, but avoids fast-moving streams.

TABLE 1. Continued

Species and Subspecies	Status[1] USDI	AL	Comments
Three-toed Amphiuma *Amphiuma tridactylum*			Aquatic. Oxbows, bayous, swamps, lakes, ponds, and flooded ditches all favored habitats, especially if muddy or mucky. No records from coastal Alabama but assumed to be present.
Southern Dusky Salamander *Desmognathus auriculatus*		SP	Prefers margins of cypress ponds, floodplain streams, swamps, and other mucky environments. Knowledge of this species' life history is incomplete.
Two-lined Salamander *Eurycea bislineata*			Frequents riverine swamps, floodplains, and seepages.
Three-lined Salamander *Eurycea longicauda guttolineata*			Inhabits forested floodplains, low swampy areas, seepages, and stream sides.
Dwarf Salamander *Eurycea quadridigitata*			A salamander of pine flatwoods, floodplains, and swampy areas. Seems to be declining in numbers. Reasons for decline unknown,but loss of habitat probably a factor.
Four-toed Salamander *Hemidactylium scutatum*			Associated with floodplains, low swampy areas, and sphagnum bogs.
Slimy Salamander *Plethodon glutinosus glutinosus*			Inhabits floodplains, bottomland hardwoods, and moist woodlands.
Gulf Coast Mud Salamander *Pseudotriton montanus flavissimus*		SP	Restricted to floodplains and low, wet areas. Few records from coastal Alabama.
Southern Red Salamander *Pseudotriton ruber vioscai*		SP	Associated with small streams, springs, seepages, and their environs. Few records from coastal Alabama.
Gulf Coast Waterdog *Necturus beyeri*			An inhabitant of rivers and creeks. Nomenclatural status of this and other Alabama waterdogs unclear.
Greater Siren *Siren lacertina*		SP	Inhabits lakes, ponds, and streams. Few Alabama records.

TABLE 1. Continued

Species and Subspecies	Status[1] USDI	Status[1] AL	Comments
Eastern Lesser Siren Siren intermedia intermedia			Inhabits flooded ditches, ponds, lakes, and other shallow bodies of water, especially if weedy. Apparently intergrades with the western lesser siren, Siren i. nettingi, throughout much of coastal Alabama.
Central Newt Notopthalmus viridescens louisianensis			Adults aquatic. Juveniles (efts) terrestrial. Inhabits shallow pools or ponds, flooded ditches, and quiet sections of streams. Declining, perhaps due to loss, modification, or pollution of habitat.
Class Reptilia			
Order Crocodylia - Crocodilians			
American Alligator[3] Alligator mississipiensis	E	SC	Inhabits rivers, lake, swamps, bayous, freshwater marshes, and similiar environments. Increasing in numbers in coastal Alabama.
Order Squamata - Lizards and Snakes			
Suborder Lacertilia - Lizards			
Eastern Slender Glass Lizard Ophisaurus attenuatus longicaudus			Largely fossorial. Occupies pine flatwoods, sandhill communities, and similiar habitats where the soil is sandy and friable. Declining.
Eastern Glass Lizard Ophisaurus ventralis			Inhabits pine flatwoods and moist, grassy areas. Declining.
Mediterranean Gecko Hemidactylus turcicus turcicus			Introduced. Restricted to urban areas within coastal Alabama.
Green Anole Anolis carolinensis carolinensis			Arboreal. Common to most terrestrial habitats in coastal Alabama where vegetation and shade is present.
Texas Horned Lizard Phrynosoma cornutum			Introduced. Prefers dry, sandy areas. One record from Daphne, Alabama.

TABLE 1. Continued

Species and Subspecies	Status[1] USDI	AL	Comments
Southern Fence Lizard *Sceloporus undulatus undulatus*			A lizard of pine flatwoods, sandhill communities and other dry woodlands. Often abundant around fallen timber and old woodpiles.
Southern Coal Skink *Eumeces anthracinus pluvialis*		SP	Inhabits mesic woodlands, pine flatwoods, and possibly swampy environs and pitcher plant bogs. Appears to be declining in many areas.
Northern Mole Skink *Eumeces egregius similis*			Fossorial. Inhabits coastal dunes, sandhill communities, pine flatlands, and areas of sandy, well-drained soil. Declining.
Five-lined Skink *Eumeces fasciatus*			A lizard of mesic woodlands. Also found around abandoned houses and trash piles.
Southeastern Five-lined Skink *Eumeces inexpectatus*			Prefers dry, sandy habitats such as sandhill communities, but occasionally may be found in pine flatwoods and moist grassy areas.
Broad-headed Skink *Eumeces laticeps*			Frequents mesic woodlands where they utilize rotting stumps and hollow trees.
Ground Skink *Scincella lateralis*			Prefers dry and mesic woodlands. Commonly seen in lawns. Declining throughout of much of its range in Alabama.
Eastern Six-lined Racerunner *Cnemidophorus sexlineatus sexlineatus*			Common in dry areas such as coastal dunes and sandhill communities. Declining.
Order Squamata - Lizards and Snakes			
Suborder Serpentes - Snakes			
Northern Scarlet Snake *Cemophora coccinea copei*			Fossorial. Inhabits pine flatwoods, sandhill communities, and other areas where the soil is sandy and friable. Declining.
Southern Black Racer *Coluber constrictor priapus*			Inhabits nearly all terrestrial environments, but prefers brushy areas near water, open woods, and forest edges.

TABLE 1. Continued

Species and Subspecies	Status[1] USDI	Status[1] AL	Comment
Ringneck Snake Diadophis punctatus			Coastal populations are intergrade between the southern ringneck snake, Diadophis punctatus punctatus, and the Mississippi ringneck snake, D. p. strictogenys. Found in mesic woodlands, pine flatwoods, near swamps and springs, and almost any terrestrial habitat where some moisture is present. Declining.
Eastern Indigo Snake Drymarchon corais couperi	T	E	An inhabitant of dry pine woods and sandhill communities. Utilizes gopher tortoise burrows for shelter. Apparently extirpated in Alabama, but has been introduced into the coastal area.
Corn Snake Elaphe guttata guttata			Found in most terrestrial habitats including old fields and farmlands. Declining, especially in southern Alabama.
Gray Rat Snake Elaphe obsoleta spiloides			Moist woodlands, swamps, old fields, and farmlands are favored habitats.
Eastern Mud Snake Farancia abacura abacura			Found in shallow aquatic habitats including swamps, ponds, lakes, freshwater marshes, and slow moving streams, especially those with abundant aquatic vegetation.
Western Mud Snake Farancia abacura reinwardti			Habitats similiar to those of eastern mud snake. Intergrades with eastern mud snake in Baldwin County.
Rainbow Snake Farancia erytrogramma erytrogramma		SP	Favors streams, rivers, lakes, springs, and ponds having mats or vegetation along the shoreline. Eels are mainstay of diet. Relative abundance of this subspecies in Alabama is uncertain.
Eastern Hognose Snake Heterodon platyrhinos			Occurs mainly in dry, sandy habitats such as pine flatwoods, sandhill communities, and xeric woodlands. Seems to be declining in numbers.
Southern Hognose Snake Heterodon simus		T	Prefers areas having dry, sandy soils. No recent records for this species in coastal Alabama. Population densities at an all-time low.

TABLE 1. Continued

Species and Subspecies	Status[1] USDI	AL	Comments
Mole Snake *Lampropeltis calligaster rhombomaculata*			Largely fossorial. Its numbers have declined throughout its range in southern Alabama.
Eastern Kingsnake *Lampropeltis getulus getulus*			Found in almost all terrestrial habitats including the margins of streams and swamps. Declining.
Speckled Kingsnake *Lampropeltus getulus holbrooki*			Habitats similiar to eastern kingsnake. Declining in numbers. Intergrades with eastern kingsnake in northern Baldwin County.
Scarlet Kingsnake *Lampropeltus triangulum elapsoides*			Secretive. Most often collected from rotting pine stumps associated with pine flatwoods and sandhill communities. Declining.
Eastern Coachwhip *Masticophis flagellum flagellum*		SC	Prefers dry habitats including pine flatwoods and sandhill communities. Has suffered a marked decline.
Green Water Snake *Nerodia cyclopion cyclopion*			Inhabits swamps, oxbows, bayous, slow-moving streams, and freshwater marshes. Sometimes found in brackish water. Declining.
Florida Green Water snake *Nerodia cyclopion floridana*			Prefers weed-choked ponds and marshes. Alabama populations all from southern Baldwin County. Declining. Recent hurricanes may have had a negative impact upon coastal poplations.
Yellow-bellied Water Snake *Nerodia erythrogaster flavigaster*			Frequents swamps, floodplain pools, sluggish streams, and most permanent aquatic habitats.
Banded Water Snake *Nerodia fasciata fasciata*			Inhabits most permanent aquatic habitats, especially shallow pools and densely vegetated swamps. Intergrades with the broad-banded water snake, *N. f. confluens* in Mobile County and western Baldwin County.
Gulf Salt Marsh Water Snake *Nerodia fasciata clarki*			Restricted to salt and brackish marshes. Declining in coastal Alabama due to loss of habitat.

TABLE 1. Continued

Species and Subspecies	Status[1] USDI	Status[1] AL	Comments
Diamondback Water Snake Nerodia rhombifera rhombifera			Inhabits most permanent aquatic habitats.
Brown Water Snake Nerodia taxispilota			Inhabits rivers, lakes, streams, and large ponds. Declining.
Rough Green Snake Opheodrys aestivus			Arboreal. Frequents vegetation overhanging lakes and streams. Declining.
Black Pine Snake[5] Pituophis melanoleucus lodingi		T	An exceedingly rare snake of pine flatwoods and sandhill communities. Known only from Clarke, Mobile, and Washington counties in Alabama. Intergrades with the Florida Pine Snake, P. m. mugitus, in Baldwin County.
Gulf Glossy Water Snake Regina rigida sinicola			Inhabits margins of lakes, ponds, swamps, and other wet areas.
Queen Snake Regina septemvittata			Prefers fast-moving streams where it often basks in vegetation overhanging the water.
Pine Woods Snake Rhadinaea flavilata		SP	Inhabits damp pine flatwoods and edges of floodplains. Little is known about this secretive snake.
Marsh Brown Snake Storeria dekayi limnetes			Assumed to occur in Alabama's coastal marshes. Intergrades with the midland brown snake, S. d. wrightorum, throughout much of Baldwin and Mobile counties.
Midland Brown Snake Storeria dekayi wrightorum			Prefers mesic woodlands, and the environs of freshwater marshes, swamps, and bogs. In the Alabama coastal zone, this subspecies is found in the upper Mobile delta. Intergrades with the marsh brown snake, S. d. limnetes in Baldwin and Mobile counties.
Northern Red-bellied Snake Storeria occipitomaculata occipitomaculata			Inhabitant of damp woodlands and sphagnum bogs. Apparently declining.
Southeastern Crowned Snake Tantilla coronata coronata			Prefers dry, sandy habitats including xeric woodlands and sandhill communities. Declining.

TABLE 1. Continued

Species and Subspecies	Status[1] USDI	Status[1] AL	Comments
Eastern Ribbon Snake *Thamnophis sauritus sauritus*			Semiaquatic. Prefers edges of marshes, bogs, beaver ponds, swamps, lakes, and streams. Not as common as in years past.
Eastern Garter Snake *Thamnophis sirtalis sirtalis*			Usually found near water and wet meadows. Occasionally encountered in urban areas.
Rough Earth Snake *Virginia striatula*			Lives in dry woodlands and pine flatwoods. Scarcer now than in years past.
Eastern Smooth Earth Snake *Virginia valeriae valeriae*			Prefers mesic woodlands, edges of marshes, and other damp places. Frequently encountered in wooded residential areas. Intergrades with the western smooth earth snake, *V. v. elegans*, in Mobile County.
Eastern Coral Snake *Micrurus fulvius fulvius*			Largely fossorial. Inhabits pine flatwoods and mesic woodlands where soils are friable.
Southern Copperhead *Agkistrodon contortrix contortrix*			Inhabits floodplains, edges of swamps, and cypress-bordered streams. Rare in extreme southern Baldwin Mobile counties.
Western Cottonmouth *Agkistrodon piscivorus leucostoma*			A snake of swamps, bayous, ponds, rivers, streams, and other permanent aquatic habitats. Intergrades with the eastern cottonmouth, *A. p. piscivorus*, in Baldwin County.
Eastern Diamondback Rattlesnake *Crotalus adamanteus*		SC	An inhabitant of pine flatwoods, sandhill communities and abandoned farmland. Frequently utilizes gopher tortoise burrows for shelter. Declining dramatically throughout much of its range due to human persecution and loss of habitat.
Timber Rattlesnake *Crotalus horridus*			Prefers wet lowland forests and pine flatwoods. Declining due to human persecution and loss of habitat.
Dusky Pigmy Rattlesnake *Sistrurus miliarius barbouri*			Common in pine flatwoods, sandhill communities, and near the margins of freshwater marshes.

TABLE 1. Continued

Species and Subspecies	Status[1] USDI	AL	Comments
Order Testudines - Turtles			
Atlantic Loggerhead *Caretta caretta caretta*	T	E	Marine. Occasionally nests on Alabama beaches. Declining due to increasing coastal development, death by drowning in shrimp nets, and possibly marine pollution.
Atlantic Green Turtle *Chelonia mydas mydas*	T	E	Marine. Rare in Alabama coastal waters. Declining due to coastal development, predation by humans and animals, death by drowning in shrimp nets, and marine pollution.
Atlantic Ridley *Lepidochelys kempi*	E	E	Marine. An occasional visitor to Alabama coastal waters. A victim of human depredation and death by drowning in shrimp nets.
Atlantic Leatherback *Dermochelys coriacea coriacea*	E	E	Marine. Rare in Alabama coastal waters. Declining due to increasing coastal development, marine pollution, and death by drowning in shrimp nets.
Common Snapping Turtle *Chelydra serpentina serpentina*			Inhabits most permanent aquatic habitats. Scarce or absent from sandy-bottomed, clear streams in coastal Alabama.
Alligator Snapping Turtle[2] *Macroclemys temmincki*		SC	Prefers rivers, lakes, streams, bayous, swamps, and embayments. Occasionally found in brackish water. Rapidly declining throughout most of its range because of human depredation, water pollution, and loss of habitat.
Southern Painted Turtle *Chrysemys picta dorsalis*			Prefers permanent aquatic habitats having mud or silt bottoms and abundant vegetation.
Eastern Chichken Turtle *Deirochelys reticularia reticularia*			Semiaquatic. Inhabits weedy ponds, lakes, and swamps.
Southern Black-knobbed Sawback *Graptemys nigrinoda delticola*			Endemic to freshwater streams and lakes of the upper Mobile delta.

TABLE 1. Continued

Species and Subspecies	Status[1] USDI	Status[1] AL	Comments
Alabama Map Turtle *Graptemys pulchra*		SC	Inhabits streams and rivers having an abundance of mussels, snails, and other molluscs. Declining from many areas of its range due to loss of habitat, water pollution, and commercial collecting for pet trade.
Mississippi Diamondback Terrapin *Malaclemys terrapin pileata*		SC	Prefers salt marshes. Declining in coastal Alabama due to loss of habitat, water pollution predation by humans, and death by drowning in crab traps.
Alabama Red-bellied Turtle[4] *Pseudemys alabamensis*		T	Endemic to Alabama where it is most abundant in the upper regions of Mobile Bay and the brackish and freshwater streams of the lower Mobile delta. Known to nest at only a few sites within the Mobile Bay drainage. Declining due to predation by humans and animals, disruption of nesting sites, and modification of habitat.
River Cooter *Pseudemys concinna concinna*			Inhabits streams, rivers, and lakes having abundant vegetation. Hybridizes with the Florida cooter, *Pseudemys floridana floridana*.
Florida Cooter *Pseudemys floridana floridana*			Habitats similar to those of the river cooter with which it often hybridizes.
Red-eared Pond Slider *Pseudemys scripta elegans*			Inhabits most permanently aquatic habitats, especially lakes, rivers, and large streams. Intergrades with the yellow-bellied pond slider, *P. s. scripta*, throughout most of coastal Alabama.
Box Turtle *Terrapene carolina*		SC	A turtle of mesic woodlands. Box turtles from coastal Alabama are intergrades of up to three subspecies. Declining for unknown reasons.
Eastern Mud Turtle *Kinosternon subrubrum subrubrum*			Found in almost all aquatic habitats except creeks and rivers. Intergrades with the Mississippi mud turtle, *K. s. hippocrepis*, throughout most of coastal Alabama.
Musk Turtle *Sternotherus minor*			Coastal populations are intergrade between the loggerhead musk turtle, *S. m. minor*, and the stripe-necked musk turtle *S. m. peltifer*. A resident of rivers and streams throughout coastal Alabama.

TABLE 1. Continued

Species and Subspecies	Status[1] USDI	AL	Comments
Common Musk Turtle *Sternotherus odoratus*			Shallow ponds, lakes, and the still waters of rivers and streams are the preferred habitats of this species.
Gopher Tortoise[5] *Gopherus polyphemus*		T	An inhabitant of sandhill associations, pine flatwoods, and other xeric, sandy habitats. Rapidly declining, due to the loss of habitat, human predation, and the gassing of burrows to drive out rattlesnakes.
Florida Softshell *Trionyx ferox*			Inhabits lakes, ponds, freshwater marshes, and sluggish streams.
Gulf Coast Smooth Softshell *Trionyx muticus calvatus*			An inhabitant of rivers and streams.
Gulf Coast Spiny Softshell *Trionyx spiniferus aspera*			A resident of lakes, ponds, rivers, and streams.

[1]The U.S.D.I. status categories are from U.S. Department of the Interior, Fish and Wildlife Service. 1985. Endangered and Threatened Wildlife and Plants, Review of Vertebrate Wildlife. Fed. Regist. 50(181):37958-67. Alabama status categories are from Mount, R. H. (ed.). 1986. Vertebrate Animals in Need of Special Attention. Ala. Agr. Expt. Sta., Auburn Univ. 124 pp. Status category abbreviations: E (Endangered), T (Threatened), SC (Special Concern), SP (Poorly Known).

[2]Candidate for Federal listing.

[3]Proposed for Federal reclassification as Threatened due to Similarity of Appearance.

[4]Proposed for Federal listing as Endangered.

[5]Mobile County population proposed for Federal listing as Threatened. Baldwin County population is a candidate for Federal listing.

AMPHIBIAN, AVIAN, AND REPTILIAN POPULATIONS

Summary of Panel Discussion

The participants on the "Amphibian, Avian, and Reptilian Populations Panel" were:

Moderator: Steven D. Carey, Mobile College
Dwight C. Cooley, U.S. Fish and Wildlife Service
John J. Dindo, Dauphin Island Sea Lab

INTRODUCTION

The panel discussion following the Amphibian, Avian, Reptilian Populations Session identified three areas of concern: (1) adverse impacts to coastal habitats and vertebrates due to increasing human encroachment, (2) the need for public awareness of the value of coastal habitats, and (3) the paucity of baseline data concerning the ecological requirements of coastal vertebrates.

ADVERSE IMPACTS

Rapid population growth was recognized as the greatest problem facing the Mobile Estuary. With increasing human population comes increasing habitat intrusion and utilization. The result is habitat degradation and/or habitat loss. Those charged with managing Alabama's coastal resources are encouraged to develop a management plan that incorporates both habitat preservation and generation. Gaillard Island was cited as an example of what can be accomplished in the area of habitat generation.

PUBLIC AWARENESS

No management plan for the Mobile Estuary can be successful without support and cooperation of the public. Current educational programs, that stress the value of coastal wildlife and habitat should be continued. Efforts to involve the public in the development and implementation of the management plan should be intensified.

ECOLOGICAL REQUIREMENTS

The ecological requirements of many coastal vertebrates are poorly known as are the long term impacts of natural and human alteration of habitat upon coastal amphibian, avian, and reptiltian populations. Urgently needed are baseline studies that can aid in the development of management proposals for these populations.

Laboratory analysis of coastal wading bird tissue has been proven to be of use in detecting heavy metal and pesticide contamination of the environment. The use of coastal wading birds as indicators of environmental quality may be of value in monitoring the health of the Mobile Estuary.

BIOLOGICAL MONITORING STRATEGIES

FOR MOBILE BAY: AN INTERGRATED APPROACH

Eldon C. Blancher
Randy Austin
Charles Tucker
TAI Environmental Sciences, Inc.
1717 Old Shell Road
Mobile, Alabama 36604

ABSTRACT: Assessment of biological conditions within estuarine areas such as Mobile Bay require an integrative approach incorporating several ecological methodologies. Baseline information on all biological communities must be collected along with corresponding hydrographic and chemical data. These are correlated with the major driving variables for the system such as tidal flux and river flow. Biological methods to be assessed include collection of classic biological field data along with methods utilizing toxicity testing and bioaccumulation studies. The integration of these data require the development of a conceptual model as a framework for examining the relationships between state variables. Data will be presented from several projects from Mobile Bay and vicinity illustrating several assessment methodologies. A conceptual model integrating this information will be introduced along with an inventory of data currently available for Mobile Bay. Possible assessment strategies for future studies will also be presented.

A CONSIDERATION OF INDICATOR SPECIES SAMPLING FREQUENCY AND SAMPLE SIZE FOR THE MANAGEMENT OF BENTHIC INVERTEBRATE ASSEMBLAGES OF THE MOBILE BAY AND EAST MISSISSIPPI SOUND SOFT BOTTOM SUBSTRATES

Thomas S. Hopkins
Kenneth L. Heck
Marine Environmental Sciences Consortium
P.O. Box 369
Dauphin Island, Alabama 36528

ABSTRACT: From early April 1980 through late April 1981 fourteen (14) cruises collected thirty (30) replicate 0.1 m2 Peterson Grab samples [along with (a) aliquots for TOC and grain size and (b) hydrographic data] at each of eight (8) stations which were distributed over the length of the Mobile Bay estuary (including East Mississippi Sound and Bon Secour Bay). Organisms were (a) sieved onto a 0.5 mm mesh screen, (b) sorted into major groups (Polychaetes, Molluscs, and Crustacea) and (c) identified to LPIL and enumerated.

Twenty three (23) polychaetes, five (5) molluscs, and two (2) crustaceans were chosen as candidates as "indicator species". Using stepwise multivariate discriminant analysis, species assemblages have been identified for [a] each station over 14 months, [b] for high and low river flow conditions, and [c] warm, hot, cool and cold seasonal temperature ranges.

Random sampling interrogation of all replicates from the 8 stations from four different cruises suggests that 10 replicates will cover the indicator species adequately.

WETLAND CHANGES IN COASTAL ALABAMA

E. R. Roach
U.S. Fish and Wildlife Service
Daphne, Alabama 36526

Mary C. Watzin, James D. Scurry and James B. Johnston
U.S. Fish and Wildlife Service, National Wetland Research Center
Slidell, Louisiana 70458

ABSTRACT: A comparison of wetland habitat changes occurring between 1955 and 1979 was undertaken on a 1609 square mile area in coastal Alabama. Fresh marshes and estuarine marshes declined by approximately 69% and 29%, respectively. Losses of nonfresh marsh considering just Mobile Bay itself were 35%. These losses are considerably higher than previously reported nationally or in the southeastern region of the United States. Major causes of nonfresh marsh losses were industrial development - navigation (24%), residential-commercial development (20%), natural succession (30%), and erosion-subsidence (17%). Loss of fresh marsh was attributable primarily to commercial-residential development (61%) and silvicultural development (27%) in the upper Mobile Bay portion of the study area.

INTRODUCTION

The pressure to convert wetlands to other land uses is acute nationally as well as in the coastal zone of Alabama. In the continental United States, wetland losses in the 20-year period after 1955 totaled 9 million acres -- an area roughly 3 times the size of Connecticut. The average rate of loss during this period was 458,000 acres per year: 440,000 acres of palustrine wetland losses and 18,000 acres of estuarine wetland losses (Tiner, 1984).

Wetland change in coastal Alabama has not been studied in any comprehensive way. Estuarine marsh losses resulting directly from human activities were examined by Stout (1979) in portions of Mobile Bay, but other wetland types were not studied. Shoreline changes have been documented (Hardin et al., 1976) for coastal Alabama, however, marsh losses were not correlated to these changes. Wetland changes attributable to other causes such as natural succession, erosion, and/or subsidence have not been characterized. This report discusses the changes that occurred in all wetland types in coastal Alabama during an approximately 25-year period from 1955 to 1979.

METHODS

Wetland Mapping

Through the cooperative efforts of the Geological Survey of Alabama (GSA), Fish and Wildlife Service (Service), the Minerals Management Service (MMS), and U.S. Army Corps of Engineers, coastal wetlands in Alabama were mapped. GSA delineated habitat types by stereoscopic interpretation of 1:20,000 black and white aerial photographs taken between January and July 1955. The Service performed the same task using 1:60,000 color infrared photographs, taken in November 1979. After photointerpretation, data from each time period were transferred to 27 7½ minute (1:24,000) U.S. Geological Survey (USGS) topographic stable base maps (Figure 1).

The habitat maps were then digitized into the geographic information system at the National Wetlands Research Center (formerly the National Coastal Ecosystems Team). A color map for each time period was then generated from the computerized data for four regions within the study area: upper Mobile Bay, southwestern Mobile Bay, southeastern Mobile Bay, and southeastern coastal Alabama (Perdido Bay, Wolf Bay, Gulf Shores). These color maps were composites of 7½ minute USGS topographic maps that were produced at a scale of 1:75,000.

The wetland habitat types included on the original 27 quadrangle maps were taken from a hierarchial wetland classification system outlined by Cowardin et al. (1979). Using this classification system, wetlands are initially classified into one of five systems--marine, estuarine, riverine, lacustrine, or palustrine. Within a system, each habitat is further classified into a subsystem and a class. Several dominant upland land-use types described by Anderson et al. (1976) were also delineated on all the maps. These represent Anderson's Level I categories, with the addition of an oil and gas modifier to the upland developed category.

Most of the wetland habitat types included on the color composite maps are more general than those on the original quadrangle maps. They are general categories of wetlands that include several distinct classifications in Cowardin et al. (1979). Fresh marsh, for example, includes emergent vegetation in the riverine, lacustrine,

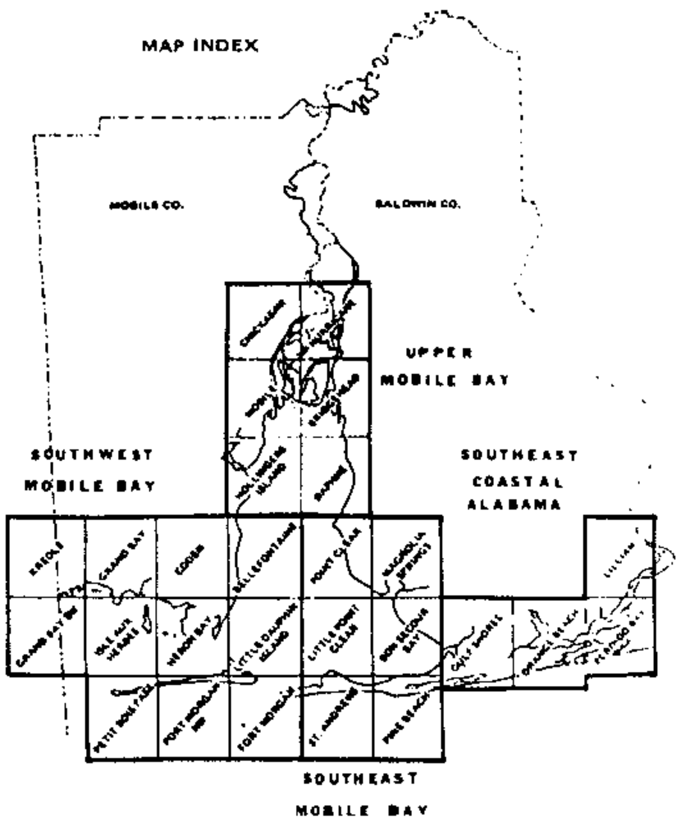


Figure 1. The 27 quadrangle maps comprising the study area. Subsections of the study area are highlighted.

and palustrine systems; nonfresh marsh is emergent vegetation in the estuarine system. The fresh water habitat includes natural and human-made open water areas, including lakes, ponds, sewage lagoons, industrial disposal ponds, and spoil disposal areas in the lacustrine, and palustrine systems. The nonfresh water habitat includes natural and human-made open water areas in the estuarine system. Diked and impounded spoil disposal areas were classified as fresh marshes, mud-sand flats, and scrub-shrub wetlands. The estuarine-riverine boundary was delineated by the Service on the 1979 maps, on the basis of three criteria: tidal influence, salinity, and percent shrub cover. The same boundaries were used on the 1955 maps to provide consistency in the tabulation of habitat data.

Submerged aquatic vegetation (SAV) was not easily distinguished on either the 1955 or 1979 photographs, therefore, the distribution of these areas is incomplete on the habitat maps. Although SAV was present in the study area in 1955, its areal extent could not be precisely mapped and, therefore, no comparisons of distribution between 1955 and 1979 were made.

Calculations of Wetland Change

Two different calculation methods were used for upper Mobile Bay and the rest of the study area. For upper Mobile Bay, a more detailed analysis was undertaken. For each of the six individual quadrangles, the 1955 and 1979 stable base mylar maps were compared by overlaying the two maps and color coding all the wetland changes by hand. After the areas of change were determined, color-infrared photography, soil survey data, and ground-truthing were used to accurately determine the cause of the change. The acreage involved in the change was determined using a standardized English Area Grid (where 1 dot equals 1.435 acres). Because of scale limitations, small changes (< 1 acre) could not be detected.

For the remainder of the study area, only estuarine marsh losses and the causes for their decline were determined. This was done by overlaying the 1955 and 1979 color composite maps. Acreage determinations were calculated using a standardized dot grid (1 dot equals 2.48 acres). Changes were classified into 10 categories (described below): erosion-subsidence, natural succession, commercial-residential development, industrial-navigation development, recreational development, oil and gas development, agricultural development, highway construction, drainage for silvicultural development, and photointerpretation errors.

Categories of Wetland Change

Erosion-subsidence. Erosion and/or subsidence is a cause of losses in estuarine marsh. We did not attempt to determine whether estuarine marshes are failing to be nourished and consequently subsiding, or whether substantial erosion is occurring. However, it is apparent that the shoreline is retreating, particularly in the interior bays of the Mobile-Tensaw Delta.

Natural succession. This term is used to describe the invasion of woody plants into an emergent herbaceous wetland (either estuarine or fresh) and the change in successional stages in wooded wetlands (palustrine forested and scrub-shrub).

Commercial-residential development. We found it was inefficient (time consuming and costly) to distinguish between these types of development. Many businesses (commercial developments) operate out of residences and are difficult to distinguish from residential property unless a site inspection is made for each area in question. Commercial development could generally be distinguished from heavy industry, however, and it included shopping malls, marinas, small warehouses, and small businesses.

Industrial-navigation development. These two causes were placed together because it was often difficult to determine if the filled area was created merely to dispose of dredged material or if it was purposely created for industrial development. Included in this category were dredged material disposal areas, aluminum ore processing waste disposal areas, the State Docks, and paper processing waste disposal areas.

Recreational development. This category includes areas primarily devoted to camping, picnicking, and boat launching. Meaher State Park and Gulf Shores State Park were included in this category.

Oil and gas development. This type of development was fairly limited in the study area; it included oil and gas pipelines, key hole slips for drilling site access, and oil storage areas (tank farms).

Agricultural development. This category dealt primarily with the clearing of forested wetland for crop production and plant nurseries.

Highway construction. Wetland losses related to this cause were the result of several activities such as disposal of dredged material from work channels, dredging work channels, filling to construct the road, and channelization to provide road drainage.

Silvicultural development. This development resulted primarily from providing improved drainage in fresh marshes in order to improve growth of pine trees.

Photointerpretation errors. By analyzing soil survey data, comparing aerial photography from both years, and making site inspections, we evaluated the correctness of the photo-interpretation. In some cases apparent wetland changes were simply the result of interpretation errors in the 1955 maps.

RESULTS

General Wetland Changes

At a very general level, habitat changes over the entire 1,660 square mile study area were examined. If the wetland acreages totaled from the 1955 maps are compared to those totaled from the 1979 maps, some general patterns of gains and losses are apparent (Table 1). However, care must be taken in interpreting these numbers; they can be misleading if not placed in proper context and if the causes for the changes are not recognized.

Of the wetland types found in the study area, nonfresh marsh showed the greatest loss (in acreage) followed by nonfresh open water (Table 1). Fresh marsh also showed a substantial loss in acreage. In the case of fresh marshes actual losses were considerably underestimated primarily due to mapping errors originating from misinterpreting the 1955 black and white photos. On the other hand nonfresh water losses were overestimated, due again to the inability to map accurately mud and sand flats and submerged aquatic vegetation using the 1955 black and white photography. If the sum of nonfresh water, mud and sand flats, and submerged aquatic vegetation for 1955 and 1979 are combined, a net gain of 1,509 acres is apparent (Figure 2). This is a more accurate reflection of what is happening in estuarine open water areas.

Some very substantial gains were shown in the entire study area for forested wetlands and scrub-shrub wetlands. These gains again were due largely to mapping errors (misinterpretation of 1955 photographs). We base this observation on the soil survey for Mobile (Hickman and Owens, 1980) and Baldwin (McBride and Burgess, 1964) counties and ground-truthing. Wetland soil types were apparently not given enough weight in delineation of wetland habitats on the 1955 photographs. Consequently, many pitcher plant bogs that should have been classified as emergent freshwater wetlands were mapped as upland range (pasture and grassland).

Upland habitat changes were not analyzed in detail for underlying causes. However, developed and agricultural areas in the uplands increased subsdtantially between 1955 and 1979 (Figure 3). Approximately 50% of the upland development occurred in upper Mobile Bay which encompasses only 23% of the study area.

Upland agriculture increased by approximately 22% within the overall study area. This increase probably resulted from the conversion of pasture to cropland. Range decreased dramatically, partially due to the photointerpretation errors mentioned previously, but also due to the conversion of these areas to cropland and commercial, residential and industrial developments.

The remaining portion of the results is organized in sections corresponding to the four sections of the study area (Figure 1): upper Mobile Bay, southeastern Mobile Bay, southwestern Mobile Bay, and southeastern coastal Alabama.

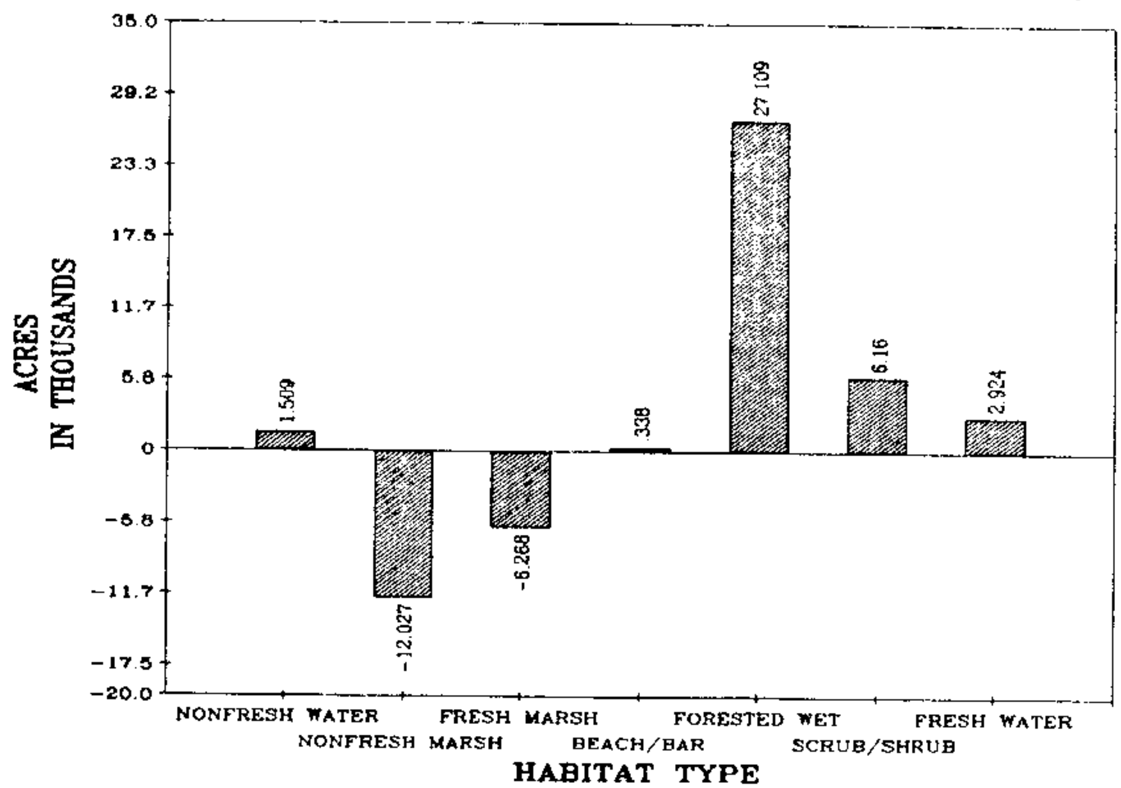
Upper Mobile Bay

The habitat changes occurring in upper Mobile Bay from 1955 to 1979 are presented in Table 2. After

Table 1. Habitat and Land Use Changes Occurring in Coastal Alabama (all 27 Quadrangles) from 1955 to 1979

Habitat Type	1955 Acreage	1979 Acreage	Acreage Change	% Change
Nonfresh Water	605,010	595,438	- 9,572	- 2%
Beaches and Bars	919	1,257	+ 338	+ 37%
Nonfresh Marsh	41,309	29,282	-12,027	- 29%
Mud and/or Sand Flats	903	6,819	+ 5,916	+655%
Fresh Marsh	9,135	2,867	- 6,268	- 69%
Forested Wetlands	77,417	104,526	+27,109	+ 35%
Scrub-Shrub Wetlands	13,679	19,839	+ 6,160	+ 45%
Fresh Water	3,185	6,109	+ 2,924	+ 92%
Floating and Submerged Aquatic Vegetation	226	5,391	NA	NA
Upland Agriculture	78,692	95,658	+16,966	+ 22%
Upland Barren	5,576	3,735	- 1,841	- 33%
Upland Forest	82,867	81,008	- 1,859	- 2%
Upland Range	80,961	4,513	-76,448	- 94%
Upland Developed	29,779	72,572	+42,793	+144%
TOTAL	1,029,658	1,029,014		

FIGURE 2. NET CHANGES IN WETLAND HABITATS 1955–1979



analysing these changes, it became apparent that some of them were real and others were the result of incorrect interpretation of the 1955 black and white photography and differences in tidal elevations when the 1955 and 1979 photographs were taken. In the first case the conversion of fresh marshes (i.e. pitcher plant bogs) to scrub-shrub and forested wetlands was vastly underestimated due to a general lack of interpretation of pitcher plant bogs on the 1955 photos. Most of the pitcher plant bogs existing in 1955 were classified as upland range. This error was first recognized when large areas on the habitat maps appeared to have become wetter since 1955. After a review of the 1955 photography and the soils data for the areas in question, we determined that a large percentage of the land classified as upland range should have been classified as fresh marsh. The losses associated with fresh marsh were, therefore, underestimated.

Another mapping error compounds our interpretation of the changes in forested wetland. Many areas on the 1955 maps were also incorrectly classified as

FIGURE 3. NET CHANGES IN UPLAND HABITAT 1955-1979

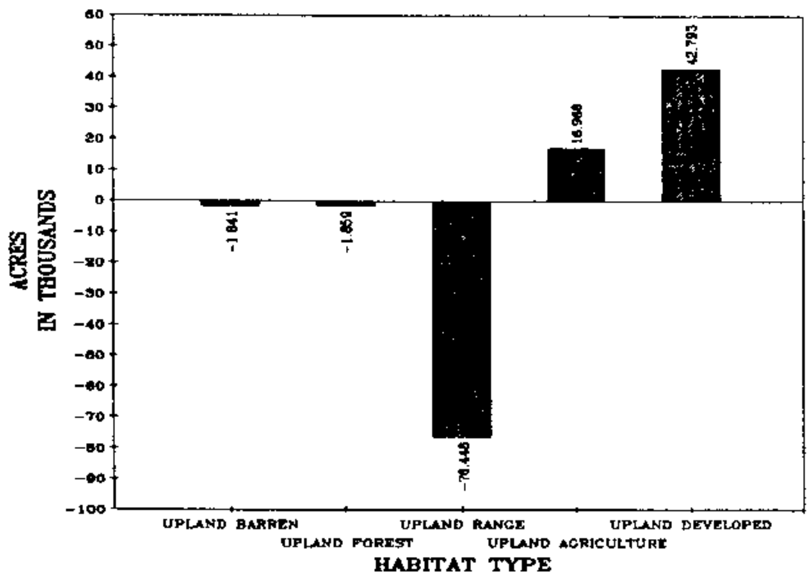


Table 2. Habitat and Land Use Changes in Upper Mobile Bay showing acreage and percent change by habitat type.

Habitat Type	1955 Acreage	1979 Acreage	Acreage Change	% Change
Nonfresh Water	89,939	85,085	-4,854	- 5%
Beaches and Bars	61	7	- 54	- 89%
Nonfresh Marsh	19,016	12,336	-6,680	- 35%
Mud and/or Sand Flats	626	2,308	+1,682	+269%
Fresh Marsh	1,195	608	- 587	- 49%
Forested Wetlands	45,069	44,522	- 547	- 1%
Scrub-Shrub Wetlands	2,336	4,482	+2,146	+ 92%
Fresh Water	2,347	4,340	+1,993	+ 85%
Floating and Submerged Aquatic Vegetation	39	4,358	NA	NA
Upland Agriculture	10,603	4,396	-6,207	- 59%
Upland Barren	513	913	+ 400	+ 78%
Upland Forest	33,358	35,125	+1,767	+ 5%
Upland Range	14,259	543	-13,716	- 96%
Upland Developed	26,570	47,884	+21,314	+ 80%
TOTAL	245,931	245,907		

upland range when they were in fact forested wetland. This created a gain in forested wetlands. However, real and significant losses in forested wetland also occurred from 1955 to 1979 due to commercial and industrial development and spoil disposal. These real losses led to the overall net loss of forested wetland in Table 2, but this relatively small net loss would have been much larger if the gains introduced by interpretation error had not offset some of the loss.

The conversion of forested wetlands to commercial-residential development and industrial-navigation development accounted for 68% of the reported losses (Figure 4). Most of these losses (81%) occurred in the Mobile and Chickasaw quadrangles which cover 33% of the area in the upper Mobile Bay section. Several cities including Mobile, Prichard, Saraland, and Chickasaw occur in these quadrangles. The mapping error reported in Figure 4 is the result of a variety of misinterpretations, such as including fresh marsh in 1955 forested wetland delineations and delineating some uplands as forested wetlands.

Scrub-shrub wetlands showed a substantial gain, i.e., this habitat almost doubled in extent (2,146 acres). A relatively large percentage of this gain (19%), however, was due to misclassifying scrub-shrub wetland as upland range in 1955. True gains in scrub-shrub wetlands were primarily a result of natural succession (46%) and industrial-navigation development (27%) (Figure 5). Most of the natural succession gains occurred in the Mobile-Tensaw Delta in areas that were classified as brackish marsh. Most of the gains in scrub-shrub wetlands associated with the industrial navigation cause were the result of diked disposal areas becoming vegetated shrub wetland largely at the expense of nonfresh marshes.

Although our results show a net gain of scrub-shrub wetlands, losses also occurred.

Eighty-six percent of these losses were due to residential-commercial developments; natural succession to forested wetland (8%) and industrial-navigation development (6%) accounted for the remaining losses.

FIGURE 4. CAUSES OF FORESTED WETLAND LOSSES IN UPPER MOBILE BAY

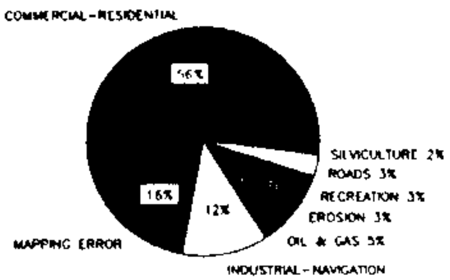
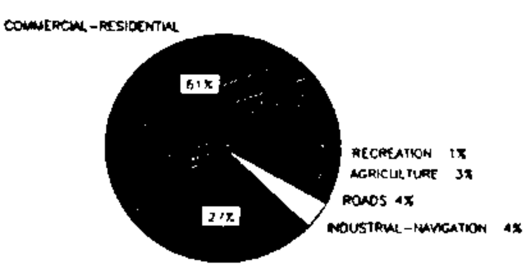


FIGURE 5. CAUSES OF SCRUB-SHRUB GAINS IN UPPER MOBILE BAY

The study analysis showed mud and/or sand flats in upper Mobile Bay increasing by 269%. Approximately one-fourth (423 acres) of this increase was mud flats that formed in diked disposal areas created after 1955. However, the rest of the increase resulted from differences in tidal elevation at the times the aerial photographs were taken and the difficulty in interpreting this habitat on the 1955 black and white photographs. It probably does not represent real gains.

The causes for the loss of fresh marsh were primarily residential-commercial development and conversion to forest following drainage, here termed silvicultural development (Figure 6). Had more fresh marsh been typed correctly on the 1955 maps (i.e., upland range classified as pitcher plant bog or fresh marsh), silvicultural development probably would have been more important as a cause of loss. We noted substantial drainage in forested sections of the study area.

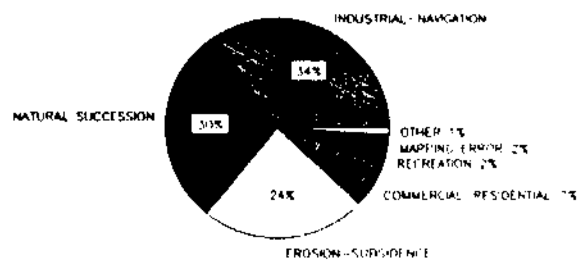
FIGURE 6. CAUSES OF FRESH MARSH LOSSES IN UPPER MOBILE BAY



Nonfresh marshes sustained the greatest loss of any wetland type in the upper Mobile Bay portion of the study area: 6,680 acres. Approximately 88% of the losses (Figure 7) can be attributed to one of three causes--industrial-navigation development, erosion-subsidence, or natural succession. Surprisingly, commercial-residential development accounted for only 7% of the losses.

Upper Mobile Bay was the first section of the study area to be analyzed for causes of change. Because we discovered so many large interpretation errors in all wetland types except nonfresh marsh, only nonfresh marsh was analyzed in the other subsections.

FIGURE 7. CAUSES OF NONFRESH MARSH LOSSES IN UPPER MOBILE BAY



Southeastern Mobile Bay

Southeastern Mobile Bay nonfresh marsh losses were analyzed in six quadrangles (Table 3). The Magnolia Springs, Bon Secour Bay, and St. Andrews Bay quadrangles accounted for the majority of the marsh losses. This section of the study area accounted for 86% of the losses for nonfresh marsh while occupying only 23% of the southeastern bay area.

The major cause of marsh loss in this section of the study area was natural succession (Figure 8). Commercial-residential development, erosion-subsidence, and mapping errors accounted for most of the rest of the changes.

Southwestern Mobile Bay

Ten quadrangles in southwestern Mobile Bay were analyzed for nonfresh marsh losses (Table 4). Five of the ten quadrangles in this portion of the study area accounted for 92% of the losses; here these were Little Dauphin Island, Heron Bay, Grand Bay, Coden, and Belle Fountaine.

The major cause for marsh loss in this section of the study area was residential-commercial development (Figure 9), followed by natural succession and erosion-subsidence. These three causes for marsh losses together accounted for 92% of the marsh losses in the southwestern bay.

Southeastern Coastal Alabama

Nonfresh marsh losses were analyzed in five quadrangles (Table 5) in southeastern coastal Alabama. The Gulf Shores quadrangle accounted for most (41%) of the losses in this portion of the study area.

The major causes for the marsh losses in this section were residential-commercial development and natural succession. These two causes accounted for 71% of the losses (Figure 10).

Table 3. Nonfresh Marsh Losses (in acres) by Quadrangle for Southeastern Mobile Bay.

	Point Clear	Magnolia Springs	Bon Secour Bay	Pine Beach	Little Point Clear	Saint Andrews Bay	Total
Res./Comm. Dev.	10	111	14	9	0	18	162
Erosion/Sub	0	6	42	8	0	64	120
Natural Suc.	0	215	92	37	63	113	520
Mapping Error	0	0	91	9	0	44	144
Spoil	0	0	11	0	0	0	11
Total	10	332	250	63	63	239	957

FIGURE 8. CAUSES OF NONFRESH MARSH LOSSES IN SOUTHEASTERN MOBILE BAY

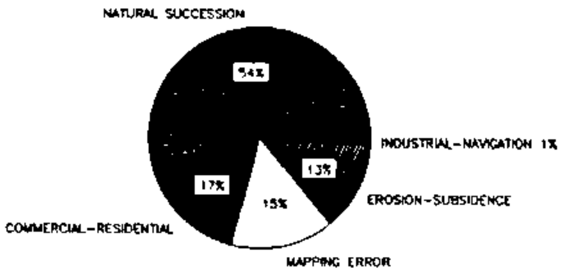


FIGURE 9. CAUSES OF NONFRESH MARSH LOSSES IN SOUTHWESTERN MOBILE BAY

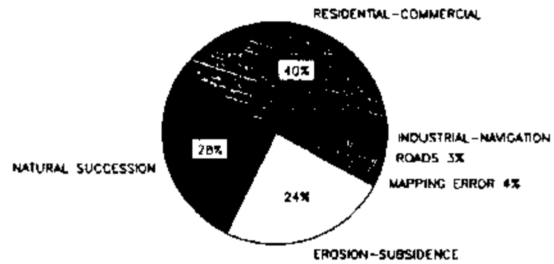


Table 4. Nonfresh Marsh Losses (in acres) by Quadrangle for Southwestern Mobile Bay.

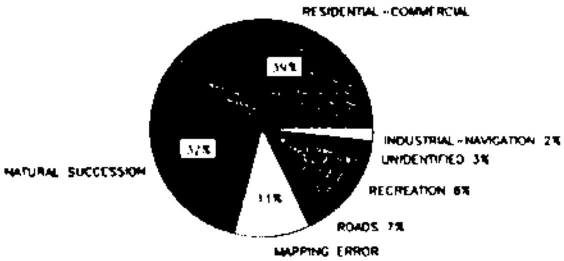
	Little Dauphin Island	Petit Bois Island	Fort* Morgan	Heron Bay	Isle aux Herbes	Grand Bay	Coden	Belle Fountain	Kreole	Fort Morgan NW	Total
Res./Comm. Dev.	206	0	0	198	0	85	154	205	0	0	848
Erosion/Sub.	125	0	0	136	87	70	0	3	6	85	512
Road	18	0	0	37	0	0	0	0	0	0	55
Natural Suc.	18	0	0	223	0	201	130	7	0	0	579
Other	0	0	0	0	0	0	0	0	0	0	0
Mapping Error	0	0	0	25	0	0	66	0	0	0	91
Spoil	0	0	0	0	0	31	0	0	0	0	31
Total	367	0	0	619	87	387	350	215	6	85	2,116

*Fort Morgan had only gains

Table 5. Nonfresh Marsh Losses (in acres) by Quadrangle for Southeastern Coastal Alabama

	Lillian	Perdido Bay	Orange Beach	Gulf Shores	Gulf Shores (South)	Total
Res./Comm. Dev.	27	14	303	388	186	918
Erosion/Sub.	5	0	7	29	0	41
Natural Suc.	422	53	103	175	0	753
Mapping Error	0	1	172	78	0	251
Spoil	0	0	21	29	0	50
Recreational Dev.	0	0	21	97	15	133
Roads	0	0	0	175	0	175
Unidentified	0	0	62	0	0	62
Total	454	68	689	971	201	2,383

FIGURE 10. CAUSES OF NONFRESH MARSH LOSSES IN SOUTHEASTERN COASTAL ALABAMA



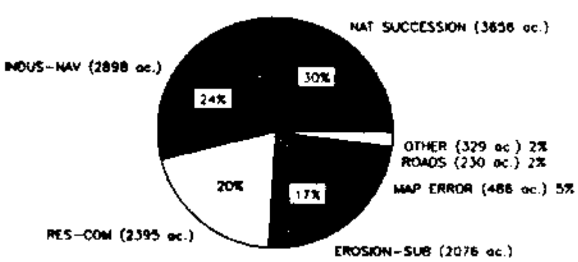
DISCUSSION

Analysis of the underlying causes of wetland changes in coastal Alabama has clearly defined the need to develop land-use plans sensitive to wetland resources. The findings of this study indicate substantial wetland losses have been sustained in coastal Alabama. Efforts to maintain or increase current acreage may require some innovative approaches on the part of developers as well as regulators.

The cumulative loss of about 29% of coastal Alabama's nonfresh marshes and a loss of at least 69% (Table 1) of the fresh marshes is indeed significant. In Mobile Bay alone losses of nonfresh marsh were 35%. National trends over the same mid-50's to mid-70's time period indicate a loss of 8% of nonfresh and 5% of fresh marshes (Frayer et al. 1983). A regional study of southeastern Atlantic and Gulf coastal states had results similar to Frayer et al.; net losses of nonfresh marshes were 8% and losses of fresh marshes were 18% (Hefner et al. 1983).

Most studies have related the causes of nonfresh marsh losses to some form of human activity. In our study, 48% of marsh losses could be attributed to human activity and 47% to "natural" processes such as erosion-subsidence and natural succession (Figure 11), although erosion-subsidence is probably exacerbated by human activities. The implications of this are important when one realizes that not all nonfresh marsh losses are directly under the control of federal or state agencies via permitting authorities. Extending these trends into the future, unregulated causes of marsh loss could result in the loss of all nonfresh marshes in coastal Alabama within the next 125 years.

FIGURE 11. CAUSES OF NONFRESH MARSH LOSSES IN COASTAL ALABAMA



The term erosion-subsidence as used in this study is actually a complex of causes stemming from reduced sediment input from upstream sources, a rise in sea level, hurricane and storm damages, saltwater intrusion, damage by nutria (Myocastor coypus) and muskrat (Ondatra zibethicus), oil and gas exploration, and marsh fires. Some of these causes are so closely interrelated that it is difficult to determine the amount of damage caused by each. Yet this one lumped category accounted for 17% and approximately 2,076 acres of estuarine marsh loss. Seventy-seven percent of these losses (approximately 1,600 acres) occurred in the Mobile-Tensaw Delta.

Ryan (1969) and Hardin et al. (1976) agree on a sedimentation rate of 1.2 m (3.9 ft) per 110 years in the delta. Hardin et al. reported the rate of filling appears to be decreasing in the upper bay and increasing in the lower bay. They cite a rate of filling in the upper bay of 0.58 m (1.9 ft)/100 yrs. between 1852 and 1920, and determined this rate decreased to 0.30 (1 ft)/100 yrs. between 1920 and 1973. Tanner et al. (1969) identified four human activities that have altered the natural sedimentation rate in Mobile Bay. These include (1) change in sediment input into the bay because of water conservation and agricultural practices; (2) modification of circulation in the bay because of the construction of causeways, residential landfills, and spoil banks adjacent to navigation channels; (3) resuspension of sediment by dredging navigation channels and oyster shells; and (4) introduction of solid wastes from municipal and industrial plants. Of these four, changes in sediment input into Mobile Bay is probably having and will continue to have the most profound effect on sedimentation.

Several historical events have played an important role in reducing sedimentation rates. In the 1800's large tracts of forest were cleared for agricultural purposes. In this century there has been a trend toward less extensive farming, and more land acreage is reverting to forests and pasture. Although there are insufficient data to prove a reduction in sedimentation rates, it is probable such a reduction has taken place. Dam construction on all the major rivers throughout the Mobile basin has caused a reduction in the amount of river-borne sediment. At present there are 20 dams on these rivers. The Corps of Engineers is also in the process of changing dredging disposal from within bank areas to floodplain areas, thus further reducing sediment entering Mobile Bay.

Sea-level rise has been implicated recently as a cause of wetland losses (Kana et al., 1984 and Pendleton and Stevens, 1983). Titus et al. (1984) have predicted that 50% of the nation's coastal wetlands could drown during the coming century. They divide the effects of sea-level rise on coastal wetlands into three categories: induced tidal flooding, wave-induced erosion, and saltwater intrusion. If sediment input to the marsh does not keep pace with sea level rise, the lowest marsh drowns and marsh soil erodes, portions of high marsh become low marsh, and upland areas become low marsh. Whether sediment input to marshes above the causeway is keeping pace with sea level rise, which at present is estimated to be 1.8 mm per year (i.e. 1.8 in. between 1955 and 1979, Aubrey and Emery 1983), is an area of concern and should be studied further.

Large storms can force large quantities of water onto marshes causing wind and wave damage. Such events have the greatest effect on marshes during the nongrowing season or following marsh fires. The reduced amount of above-ground plant material allows peat to become suspended and washed from the marsh when waters recede. Hurricanes did affect Alabama during the period of this study.

Very little trend information could be found regarding changes in salinity over the course of the study. It is apparent that salinity has increased in the vicinity of the ship channel, but the effects on delta wetlands are unknown.

Herbicides enter Mobile Bay marshes either directly through application to "undesirable" vegetation or indirectly through run-off from agricultural applications via the tributary river system. The Mobile River system alone drains 43,629 sq. mi.; this water ends up in Mobile Bay and part of it spreads out over the Mobile Delta wetlands. The quantity and the effect of the herbicides entering Mobile Bay wetlands are virtually unknown.

The nutria, introduced into the Mobile Delta in 1949 and 1950 (Leuth 1963), now competes with the native muskrat. Populations of nutria can expand tremendously in a relatively short time (2 years). Nutria numbers, if unchecked by trapping or hunting can result in small devegetated or "eat-out" areas (0.1 acres to 1 acre) and narrow channels dissecting the marsh. Such eat-outs can bring about considerable erosion and subsidence of marsh soils during the winter months and storm events. Marsh fires were used between 1955 and 1979 in "nutria rodeos" (once an annual event) to concentrate the animals and make them easier to find. Fire was and still is considered a valuable tool in managing the marsh for muskrat. Burning the marsh in the winter leaves large areas vulnerable to erosion during high water events, either high river discharges or storm tides.

The vehicles used in seeking oil and gas reserves often cause compaction of marsh soil and leave scars (tracks) visible for many years. Since the Mobile Bay wetlands have only recently been explored for oil and gas, an almost insignificant amount of wetland loss resulted from this activity during the period of study.

Direct causes of wetland losses have only recently been regulated or controlled. Laws protecting marshes, such as the Clean Water Act (1972), the National Environmental Policy Act (1969), and the Coastal Zone Management Act (1972), were not passed or fully implemented until the later part of the study period. After 1979 loss rates may have diminished. The data base established in this study is available for future reference and comparison.

Studies like this one give wetland managers general information useful in developing long range management plans for the resource. Information on the effect of wetland changes on fish, shellfish, and wildlife and on other wetland functions is the other critical information that is essential to management planning.

SUMMARY

Data presented in this paper indicate nonfresh and fresh marshes declined very significantly from 1955 to 1979. Some causes for these declines are regulated by governmental agencies. However, nearly half of the causes of nonfresh marsh losses are at present uncontrolled and regulations protecting against fresh marsh losses have only recently been implemented. These wetland trends pose a challenge to all managers and planners working in the coastal zone.

Acknowledgements

This investigation was supported in part by the U.S. Army Corps of Engineers. The authors would also like to thank the Alabama Geological Survey (AGS) for their help in mapping the 1955 habitats, particularly Karen Richter and William Martin. Also, Everett Smith (AGS) was helpful in investigating the general wasting away of marshes in upper Mobile Bay.

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ALABAMA'S MARSHLAND RESOURCES

Judy P. Stout
Marine Environmental Sciences Consortium
P.O. Box 369
Dauphin Island, Alabama 36528

ABSTRACT: Approximately 25,000 acres of fresh, brackish and salt marshes were mapped along Mobile and Baldwin Counties shorelines. Alterations and losses due to dredging, filling, logging, utility corridors and erosion are continuing to diminish these valuable resources. Salt marsh primary productivity, faunal dynamics and waste assimilative capacity have been assessed. However, little is known of the functional role of the brackish and freshwater marshes currently under the greatest alteration pressures.

SEAGRASS BEDS

OF COASTAL ALABAMA

Judy P. Stout
Marine Environmental Sciences Consortium
P.O. Box 369
Dauphin Island, Alabama 36528

ABSTRACT: Inventories of the distribution and species composition of meadows of submerged vascular plants were completed in 1981 and 1982. Three seagrass species, widgeon grass (Ruppia martima) shoal grass (Halodule wrightii) and turtle grass (Thalassia testudinum) were located in coastal waters of south Mobile and Baldwin Counties. Changes in species dominance and aerial coverage have occurred since these surveys. Assessment of habitat use by fish and invertebrate and growth patterns of the plants have been initiated.

CHANGES IN SUBMERGED GRASS BEDS

OF THE MOBILE DELTA 1979 - 1986

Joe Zolczynski
Game and Fish Division
P.O. Box 245
Spanish Fort, Alabama 36527

ABSTRACT: In 1979 the Alabama Department of Conservation and Natural Resources, Game & Fish Division, conducted a survey of the aquatic plants in the bays and streams of the Mobile Delta. information from this study indicated that eurasian watermilfoil, Myriophyllum spicatum, was the dominant submerged plant. Since that date, changes in the submerged weed beds have been noted. One contributor to these changes was the initiation of an aquatic plant management program in the delta using 2,4-D DMa as a tool to reduce the biomass of eurasian watermilfoil. This was done in an effort to open bays to small boat traffic and to encourage the regrowth of native aquatic plants. From 1979 through 1986 the area of milfoil infestation has remained fairly constant, but the density of the stands has been lowered. Also the abundance of native aquatic plants has been on the rise.

BENTHIC AND WETLAND RESOURCES

Summary of Panel Discussion

The participants on the "Benthic and Wetland Resources Panel" were:

Moderator: Judy P. Stout, Marine Environmental Sciences Consortium
Eldon C. Blancher, Taxonomic Associates, Inc.
Thomas Hopkins, Marine Environmental Sciences Consortium
Randy Roach, U.S. Fish and Wildlife Service
Joe Zolcynski, Game and Fish Division - ADCNR

INTRODUCTION

In general, the panel's discussions centered around three topics which were the evaluation of discharge impacts via in-lab toxicity testing, the benefits and cost of estuarine modelling, and historic changes/losses of wetlands and grassbeds associated with the Mobile Bay Estuarine System. These discussions have been summarized and their synopsis follow.

TOXICITY TESTING

Concern was expressed over the applicability of lab-conducted toxicity test results to field situations. Since 1984, EPA has implemented "water quality based guidelines" for NPDES discharge permits. This approach emphasizes in-stream, or in-estuary, toxicity testing as well as lab tests. Permit requirements for testing toxicity will hopefully produce a more comprehensive data base to evaluate discharge impacts on the biota. Testing is an expensive requirement and costs are being primarily covered by the permittee industries who gain the greatest benefit from the discharge permit.

To better evaluate impacts on estuarine organisms, Mysidopsis bahia has been selected by EPA as the most sensitive estuarine species which can be practically maintained for testing purposes. It was recommended that additional species representative of the local environmental setting also be tested and results compared using Mysidopsis as a baseline.

MODELLING

A great deal of interest was expressed in the usefulness of models as tools in management and planning. For Alabama coastal areas, two hydrodynamic models are available - Mobile Bay (Rainey, UAT) and Mississippi Sound (USA/COE, Mobile District). Although significant progress has been made since the 1979 Symposium in developing a working data base, numerous remaining data gaps have been pointed out in the various presentations of 1987. No model is available to assist in assessing biological impacts.

Several related efforts were discussed which may provide some local insight when completed. The Corps of Engineers Waterways Experiment Station at Vicksburg, Mississippi, is initiating a five-year, $5 million, development of a water quality model for Chesapeake Bay. No biological components will be included and cost estimates do not include any data collection. The State of Florida has funded "Water Quality Based Effluent Limitation" (WQBEL) studies throughout the estuaries of Florida.

It was emphasized that models are expensive; are designed only to answer specific questions; are only as good as the data upon which they are based; and may require long-term data sets in order to have some reliable predictive capabilities for assessing cumulative impacts.

WETLANDS CHANGES AND LOSSES

Significant changes in species composition and loss of acreages of grassbeds were reiterated and reinforced by the audience. Most observations noted the greatest changes occurring since the 1950s, changes which could not be documented by the Fish and Wildlife study of the 1950 and 1979 photographs. It was suggested that a historical review of shoreline development, dredging, channelization and silvaculture/agriculture practices be undertaken to include the time period 1940s on, to determine if there is any relationship suggested by coincident increases in anthrogenic activities and grassbed loss.

Scientists have been unable to acquire the funds necessary to extend the completed wetland/grassbed resource assessments to an ongoing program monitoring resource health and cause-effect studies. Natural perturbations such as the cold winters of 1983 and 1984, a season when grasses may be exposed to air by low water levels, may have significantly effected their distribution. The synergistic effects of man and natural impacts cannot be evaluated at this time. Restoration of previously vegetated areas was suggested.

COASTAL LAND TRUST, INC.

MOBILE-TENSAW DELTA PROJECT

Arthur C. Dyas
Coastal Land Trust
P.O. Box 1029
Mobile, Alabama 36633

ABSTRACT: The Mobile-Tensaw Delta is one of the nation's last virtually untouched delta systems. Its 200,000 acres of marshes, islands, hummocks and prime bottomland hardwoods are vital to the health and maintenance of a wide array of endangered plants and animals. Three major industries in South Alabama are strongly dependent on this resource. The recreation, commercial seafood and timber industries employ tens of thousands of workers and generate hundreds of millions of dollars annually as a result of the Delta. More importantly, the Delta and Bay are responsible for a truly unique quality of life in south Alabama. To attempt to insure the viability of the Delta, the Coastal Land Trust is attempting to raise $10 million through private sources in order to acquire 50,000 acres of the lower Delta. A wildlife management area will be developed under the multiple use concept and will provide for the timber and wildlife resources in this important system. Many local, state and federal agencies and organizations are supporting this effort.

BON SECOUR NATIONAL WILDLIFE REFUGE

IT'S HISTORY AND CURRENT STATUS

Jerome T. Carroll
U.S. FISH AND WILDLIFE SERVICE
P.O. Drawer 1197
Daphne, Alabama 36526

ABSTRACT: Located 50 miles southeast of Mobile, Alabama near the town of Gulf Shores, Bon Secour National Wildlife Refuge was authorized by Congress in 1980 to preserve fragile barrier island habitat along Alabama's gulf coast from development. Commercial development of Alabama's 32 miles of gulf beaches jumped drastically following Hurricane Fredric's passage in September 1979. The objectives of the bill establishing the refuge were to preserve the land for the flora and fauna that depend on it; provide a living laboratory to scientists and students of the area and provide for wildlife oriented recreation for the public. Since 1980, acquisition has totalled nearly 4,000 acres reaching from Little Dauphin Island on the west to Oyster Bay on the east. acquisition continues, but is complicated by a multitude of landowners and land prices that have escalated every year. Only time will tell if the proposed 10,000 acres can be acquired before development takes over the rest of the Fort Morgan peninsula.

POLLUTION, WATER QUALITY

AND THE CORPS OF ENGINEERS REGULATORY PROGRAM

Davis L. Findley
U.S. Army Corps of Engineers
P.O. Box 2288
Mobile, Alabama 36628

ABSTRACT: The Corps Regulatory Program operates under four different authorizations: Section 9 and 10 of the Rivers and Harbors Act, Section 404 of the Clean Water Act, and section 103 of the Marine Protection, Research, and Sanctuaries Act. All applications (except those which qualify for regional or nationwide permits) are subjected to coordination and public notice and public interest review. Many of the review factors are directly and/or indirectly concerned with pollution and water quality and involve coordination with Federal and State agencies who have regulatory control over various aspects of pollution and water quality. Permit decisions involve the preparations of detailed documents which must conclude that permit issuance is in the public interest and is found to comply with all quality standards and pollution criteria.

WETLAND HABITAT CREATION - WETLAND MITIGATION
NEW ANSWERS TO OLD PROBLEMS

Hugh M. Dowling
Wetland Biologist
Dowling Environmental Services
Mobile, Alabama 36660

ABSTRACT: The value of coastal wetlands has become recognized in recent years. Due largely through man's unmitigated activities such as dredge and fill the acreage of this valuable habitat has been dwindling. Wetland mitigation/creation projects can compensate for the loss of wetland acreage and provide "new" highly productive habitat for fish and wildlife. Both fresh-water and saline wetlands have been successfully created and are functioning as man-made habitats similar to the naturally occurring wetland habitats. By matching physical and biological factors wetland acreage can be established by modifying upland transitional zones thus providing new alternatives for coastal development.

INTRODUCTION

Over the past decade or so the coastal states have been faced with a dilemma, trying to balance growth and development with environmental controls. The value of coastal wetlands has become widely recognized and efforts are being made to minimize the impacts to these critical areas. Due largely through man's non-mitigated activities such as dredging, spoil disposal, bulkheading, and filling the acreage of this valuable habitat has been dwindling. The concept of wetland mitigation (habitat creation) as compensation has sprung from this conflict of differing interests and priorities.

Wetland mitigation by way of habitat creation is the last step or final alternative available to industry and development when fill or dredge in regulated areas is an issue. By definition mitigation means the reduction in the harshness of an activity. Any modification of the initial project's scope or size intended to accommodate the environmental concerns is mitigation. There is a whole array of mitigating measures that can be incorporated into a project during the permitting procedure with habitat creation being only one.

The balance of this paper will deal with the creation of a 9.2 acre fresh-water marsh to serve as compensation for impacts associated with the expansion of Scott Paper Company's Mobile facility. Disturbed wetlands (8.4 acres) along Threemile Creek were permitted to be filled for a water dependent loading facility adjacent to the creek.

NEED FOR MITIGATION

To compensate for the loss of 8.4 acres of historically disturbed wetlands Scott Paper Company created 9.2 acres of marsh and forested wetlands along Eightmile Creek in Mobile County, Alabama. By lowering the elevation of an upland slope to that of the adjacent swamp and transplanting the dominant herbaceous and woody vegetation associated with this habitat type additional acres of marsh and forested wetlands were created. The ecological advantages of this mitigation program are (1) direct net increase in the total amount of wetland acreage by mitigating 1.1 to 1.0 creation to impacted habitat (2) create a more productive and desirable wetland than that existing along Threemile Creek (3) create and set aside a forested wetland in a non-industrial area as opposed to the conservation of a weedy impacted marsh and shrub habitat within a heavily developed area (4) create a habitat type capable of supporting two plant species of threatened and special concern status, i.e. *Gordonia lasianthus* (Loblolly Bay) and *Chamaecyparis thyoides* (White Cedar) (5) data obtained from this mitigation planting and subsequent two year monitoring program will help establish guidelines for decision making policies with regard to future mitigation planning.

HABITAT TO BE ESTABLISHED: BAY FOREST

Bay Forests occur along most rivers and streams in our area. It has been estimated that there are 3,291 acres of this type habitat associated with the Mobile-Tensaw River Delta (Stout, 1982). The vegetation of these swamps varies depending on the amount and duration of flooding. If flooding is extensive *Taxodium distichum* var. nutans (Pond Cypress) and *Nyssa sylvatica* var. biflora (Swamp Tupelo) may dominate the canopy. Usually, under moderate flooding the dominant trees are *Magnolia virginiana* (Sweet Bay), *Acer rubrum* (Red Maple), Swamp Tupelo, and *Persea palustris* (Swamp Bay).

An understory of *Cyrilla racemiflora* (Swamp Cyrilla), *Cliftonia monophylla* (Black Titi), *Itea virginica* (Virginia Willow), and *Cornus stricta* (Swamp Dogwood) may be common when the canopy is open.

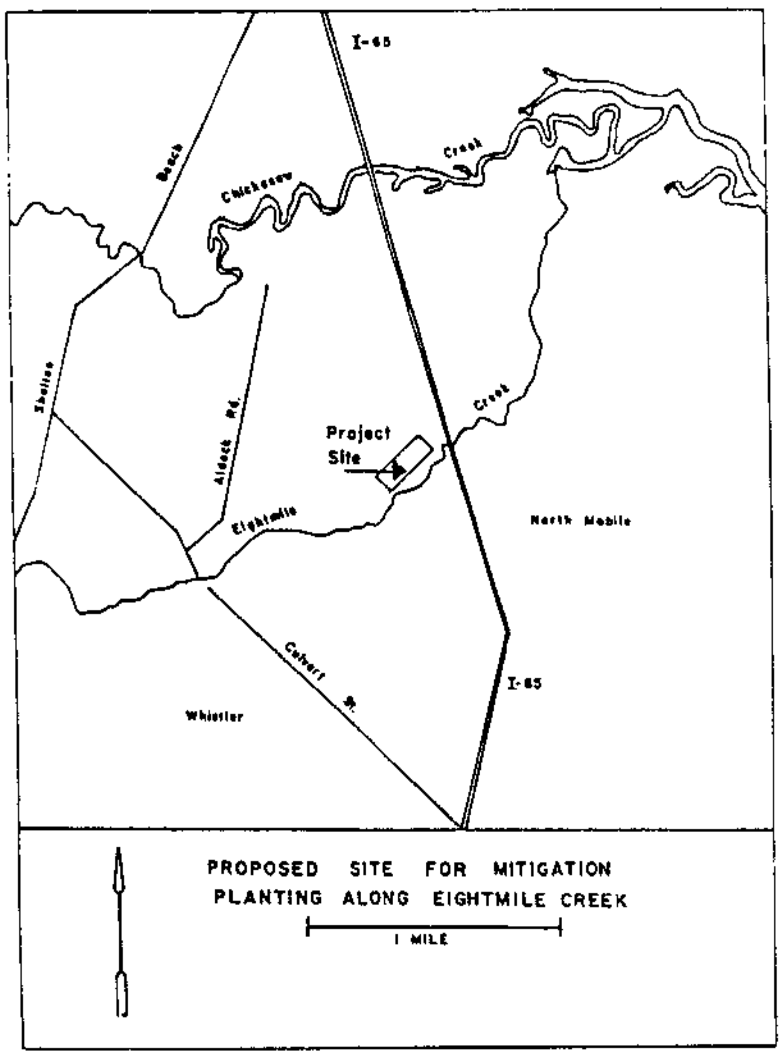
As this type of forested wetland grades into upland pine/oak forest plants more adapted to better drained sites will begin to appear. The proposed mitigation planting site is this type of transition zone between swamp and upland habitats.

MITIGATION PLANTING SITE

The site selected for mitigation planting is owned by Scott Paper and was a portion of a Long Leaf Pine plantation which bordered a forested wetland. The project site is adjacent to the existing Bay Forest for a distance of 1,320 feet and extends up the slope for approximately 300 feet. This area of transition between swamp and upland is not optimal for pine plantation nor will it support wetland vegetation and its endemic biota.

All vegetation over the mitigation site was removed prior to the replanting of the pines. Wetland plant species began to invade denuded areas where the forestry equipment caused depressions along the lower edge of this transitional zone. This fact alone would suggest the preference of wetland species where suitable elevations exist.

The elevations over the project vary from 2.5 to 8.0 feet above Mean High Water (MHW). These elevations were reduced to that of or slightly above the water table providing an adequate site and elevation for the mitigation planting. This elevation would also insure adequate flooding would occur over the mitigation site corresponding with the adjacent wetlands in depth and duration. The flood water retention capacity of the created wetland would be similar to that of the Bay Forest. Utilizing a transitional zone between swamp and uplands minimizes the amount of excavation necessary to obtain the critical elevation for planting.



PROPOSED SITE FOR MITIGATION PLANTING ALONG EIGHTMILE CREEK

FORESTED WETLAND ADJACENT TO PROJECT SITE

In the upper reaches of Eightmile Creek the water shallows sufficiently to allow aquatic plant species such as Decodon verticillatus (Water Willow) and Ludwigia peploides (Ludwigia) to form mats over the surface of the creek with dense emergent vegetation intermixed. A thin canopy of Swamp Tupelo, Sweet Bay and Pond Cypress occurs over these shallow regions of Eightmile Creek permitting a mixture of marsh and swamp.

Bay Forest exists in the area between the edge of the creek and the upland slope (below the five foot contour). At this elevation Pinus elliottii (Slash Pine) begins to appear, marking the upper limit of this type of forested wetland. A dense understory exists over the entire swamp probably as a result of recent timber operations removing the canopy. This shrub layer consists of Virginia Willow, Swamp Cyrilla, Swamp Dogwood, and others. Small isolated depressions and higher sandy ridges are common in the adjacent swamp resulting in an abundance of aquatic and semi-aquatic vegetation.

THREEMILE CREEK SITE

The Threemile Creek site consists of shoreline property owned by Scott Paper and is located in Mobile County, Alabama along the north bank of the creek upriver from the Mobile River confluence. The majority of undeveloped land along the creek is zoned for industrial development.

The characteristics of the creek have changed drastically over the last several years. At one time Threemile Creek was similar to Chickasaw Creek to the north but as a result of dredging and channelization for flood control coupled with industrial use the adjacent swamps and marshes have been altered. Increased upland run-off from urbanized areas comprising most of the creek's drainage basin has necessitated these type flood control measures.

The plant species and their composition observed in the marsh along the fringe of Threemile Creek are indicative of a disturbed wetland. Because of the industrial use of the higher elevations of this area and the increased drainage load created by urban development the marsh to a large extent has been confined to man made boat slips and drainage ditches. There are small stands of Zizaniopsis milicea (Water millet) in these old boat slips and a low herbaceous marsh dominated by Cat-Tail, Sagittaria latifolia (Arrowhead), and Peltandra virginica (Arrow Arum) along a red clay road which restricts water flow. What little amount of Panicum virgatum (Switch Grass) present on the site is scattered and not characteristic of the large monotypic stands usually found along streams and rivers of the Mobile Delta. The area dominated by desirable marsh species comprises a small percent of the total site. By far the dominant woody species are Salix nigra (Black Willow) and Tallow spp. (Pop-corn Tree), while the dominant herbaceous species are Alligator weed and Rumex spp. (Swamp Dock). Upon review of the species lists presented in the Habitat Assessment (ERT) followed by a field investigation of the site, there are unquestionable signs to indicate long standing disturbance associated with the Threemile Creek site. Both the composition of the species present and the absence of typical dominance characterizing the marshes and forested wetlands in less impacted areas would point to a stressed environment with low productivity and wildlife potentials.

MATERIALS AND METHODS

Spacing: Herbaceous and grass-like plants were planted on 3-foot centers over the 9.2 acre project site. This involved transplanting 45,000 sprigs of perennial wetland plants. Transplanting the trees and shrubs on 18-foot intervals involved 3,000 bare root seedlings. These figures are approximations but do give some idea as to the volume of transplants that were handled. In addition to the transplants, seeds of the dominant shrubs were gathered and spread by broadcasting over the project site.

Planting Stock: All transplants of herbaceous and grass-like plants were obtained from the Bay Forest adjacent to the planting site. Transplants were hand dug and transported by wheel-barrow to the mitigation site. Wetland vegetation can be damaged if allowed to dry, so all transplants were replanted the same day as procured to prevent dessication. Transplants were obtained as close as possible to the planting site to guard against ecotypic variations. When dealing with large numbers of transplants extreme care should be taken during stock procurement to prevent excessive damage to the existing wetland donor site. A recommended procurement rate is one planting unit per square meter. However, this rate may vary according to species and abundance.

Elevational Changes: The portion of the pine plantation used for the mitigation planting had a height which varied from 2.5 to 8.0 feet above MHW (water table). The entire planting area was first cut down to approximately four inches below MHW. Then 4 - 6 inches of highly organic material from Scott Paper's mill facility were mixed with sandy soils to provide a favorable substrate for planting and at the appropriate elevation. All efforts were made to extend the elevation of MHW over the site, thus eliminating competition from weedy species invading from the surrounding uplands. On the average 4 to 6 feet of overburden were removed from the project area to obtain the critical elevation necessary for the mitigation planting. Preliminary core samples indicated a sandy - clay soil material to a depth of eight feet below the project site. The pH of this type soil when saturated with water runs slightly to strongly acid.

Spoil Disposal: Approximately 80,000 cu. yds. of material were removed to establish the desired elevation for mitigation planting. This material was placed and contoured on an upland site within the limits of the pine plantation. The slopes were well grassed and planted with oaks and poplars. Areas of potential erosion were also matted and rip-rapped. The containment of the excavated material is most important in maintaining the integrity of the mitigation site in addition to protecting the adjacent wetlands from erosion of the slopes and stockpile areas.

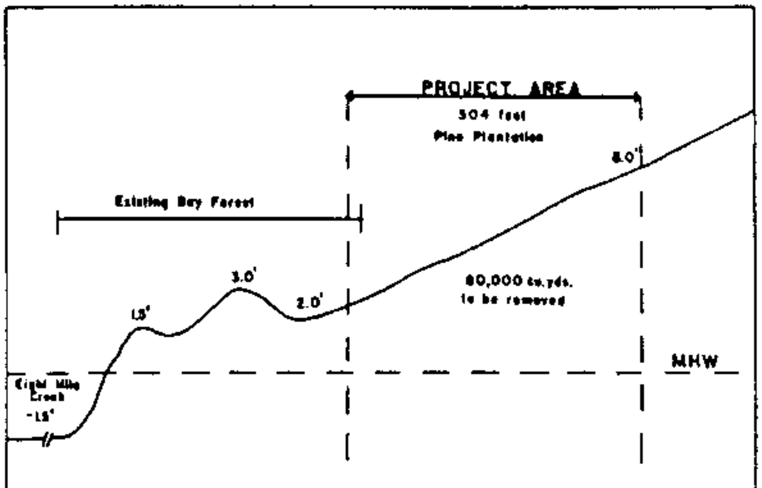


FIGURE 1. PROJECT PROFILE BEFORE EXCAVATION

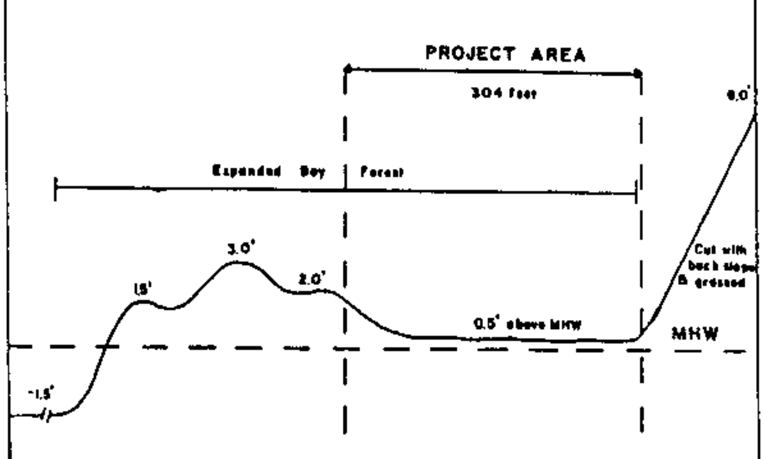


FIGURE 2 PROJECT PROFILE AFTER EXCAVATION

SPECIES TO BE PLANTED

<u>Herbaceous Plants</u>

Peltandra virginica (Arrow Arum)
Description: Perennial herb in dense clumps; without true stems, leaves basal arrow shaped; flowers May - June.
Habitat: Fresh-water wetlands, marshes and margins of streams.
Establishment: Transplants; rapid propagation

Sagittaria latifolia (Broadleaf Arrowhead)
Description: Perennial aquatic herb about 1.2 meters high, from fibrous tubers; leaves spear-like; flowers June-September.
Habitat: Stream margins and swamps.
Establishment: Transplants.

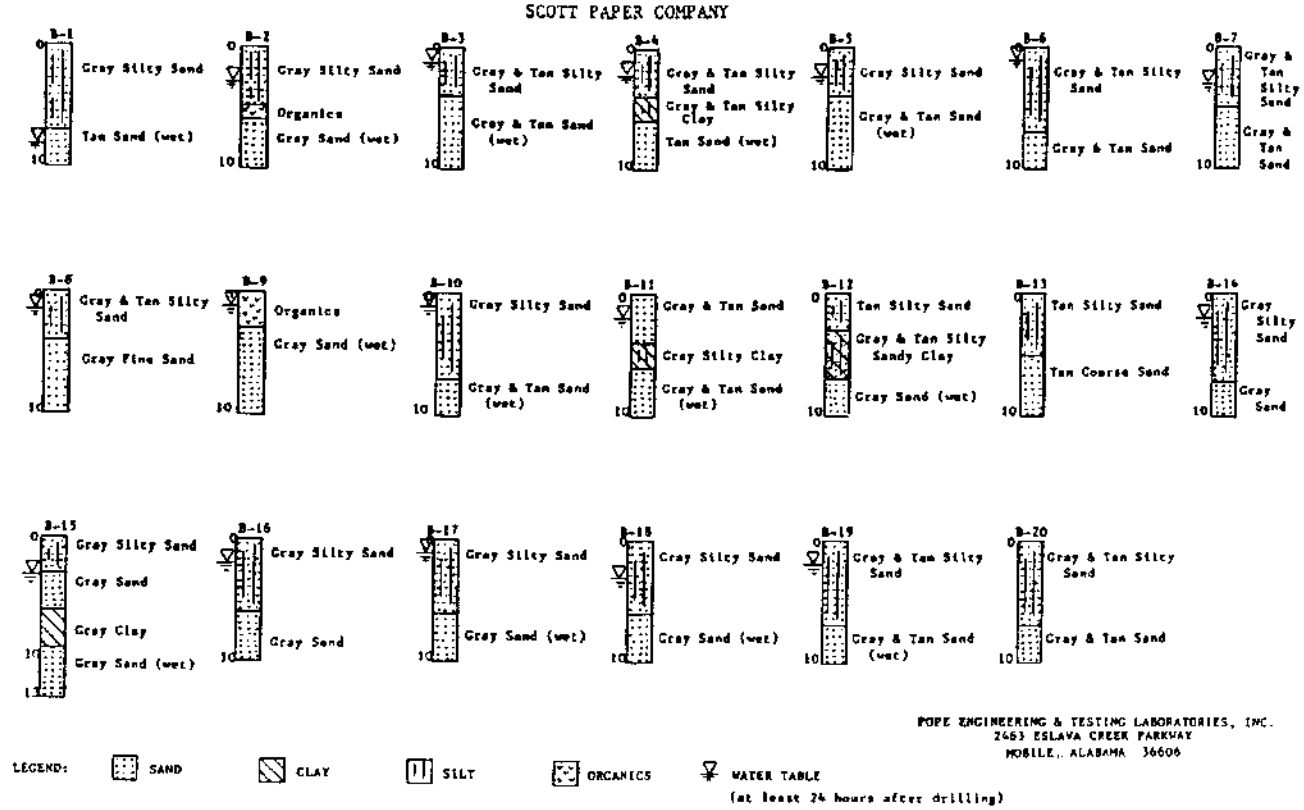
Saururus cernuus (Lizard's Tail)
Description: Perennial aquatic herb from fleshy rhizomes, 0.5-1.0 meter high; flowers May - July.
Habitat: Stream margins and fresh-water marsh
Establishment: Transplants.

<u>Shrubs</u>

Itea virginica (Virginia Willow)
Description: Shrub to 2 meters high, flowers April - July.
Habitat: Low wood; Bay Forest
Establishment: Transplants

Cyrilla racemiflora (Swamp Cyrilla)
Description: To 8 meters tall; semi-evergreen
Habitat: Bay Forest
Establishment: Transplants

SOIL ANALYSIS - MITIGATION SITE
SCOTT PAPER COMPANY



Trees

Species to be planted at the mitigation site would include:

Magnolia virginiana (Sweet Bay Magnolia)
Persea palustris (Swamp Bay)
Taxodium distichum (Bald Cypress)
Nyssa sylvatica var. biflora (Swamp Tupelo)
Acer rubrum (Red Maple)
Fraxinus pennsylvanica (Green Ash)

Acreage Determinations

Area of Dredge and Fill Operations Along Threemile Creek

Removal of approximately 364,162 sq. ft. of impacted marsh and shrub zone dominated by Alligator Weed and Black Willow.

Total Loss --------------- 8.36 acres

Area of Mitigation Planting (Creation)

Project site 1,320 ft. X 304 ft. Replacement ratio 1.1 - 1.0 creation to disturbance. Establishment of 401,280 sq. ft. of coastal marsh.

Habitat Creation -------- 9.20 acres

Less Total Loss -------- 8.36 acres

Net Gain Wetlands -------- 0.84 acres *

* This figure does not include comparative productivity and wildlife benefits derived from the creation of freshwater marsh maturing into coastal Bay Forest. Wildlife values will be enhanced more than the figure of 0.84 acres would imply. Through the establishment of successional zones or edge effect (Leopold, 1933) exceeding what now exists at both the Threemile and Eightmile Creek sites diverse habitat types in juxtaposition can be achieved. Completion of this project would put in close proximity a pine plantation, grassed erosion control area, the mitigation planting site, and the existing Bay Forest which grades down to a permanently flooded swamp.

Methods of Maintenance

(1) Minimum of 2 year monitoring program :
- A. Washouts and dead plants will be replaced by fresh transplants.
- B. Fertilization as needed; mixture of primary and secondary sludge will serve as slow release organic fertilizer.
- C. Selective Weeding.
- D. Limited access to project site.
- E. Applicant and contractor(s) make long term commitment to wetland establishment.

(2) Erosion Control:
- A. Back slope placed at top of all cut banks.
- B. Excessive erosion controlled by grassing, reinforced mat, rip-rap, regrade.
- C. All slopes were grassed with Rye and Bahia.

(3) Schedule of Reporting
- A. Reports submitted to Federal and State Agencies every 6 months for a minimum of 2 years.
- B. Reports to include:
  - Photography of project area
  - Quadrate sample data
  - Stem Counts
  - Number of Plant Replacements
  - Estimates of Species Viability as Planting Stock.
- C. Open communications between agencies and applicant.
- D. Availability of Data for Use in Future Projects

Guarantee

The contractor for this mitigation planting was required to provide a written guarantee of 70 percent survival and spread of all transplants, with replacement as required in order to achieve this rate . The period of guarantee remained in effect for a two year period.

Results
Eighteen Month Post Planting Monitor

The purpose of the eighteen month post planting monitor and report is to evaluate the success and progress of the wetland mitigation project and to make recommendations if necessary.

One meter square quadrate samples were taken in various locations over the planting site. These samples generated stem count numbers per meter square (m^2). The stem count data pertains only to the species planted and does not reflect natural colonizers from the adjacent wetlands present in the samples.

The project and the sample data were divided into two distinct areas. The northern portion was covered with primary and secondary paper mill sludge while the southern portion received no sludge. The differences in the stem count numbers and plant densities are obvious from the data presented. The area with paper mill sludge incorporated into the soils produced nearly twice the number of plants per meter square. Plant propagation on the "sludged areas" also exceeded stem count numbers in the donor sites or adjacent wetlands. The lack of competition and canopy over the mitigation area would also contribute to the high plant density at the site.

Erosion Control

The severely eroded slopes of the excavated material stockpiled adjacent to the planting site were reshaped and stabilized with filter cloth, rip-rap, reinforcement matting, and regrassed during November, 1984. These techniques and devices have proven more than adequate in resolving the erosion problem.

The area of deposition of the eroded materials has been reduced from 0.42 acres at the six month interval to 0.13 acres at eighteen months post planting. Wetland plant species are colonizing from the margins and reducing the size of the denuded area. Serious erosion was halted at the eighteen month interval.

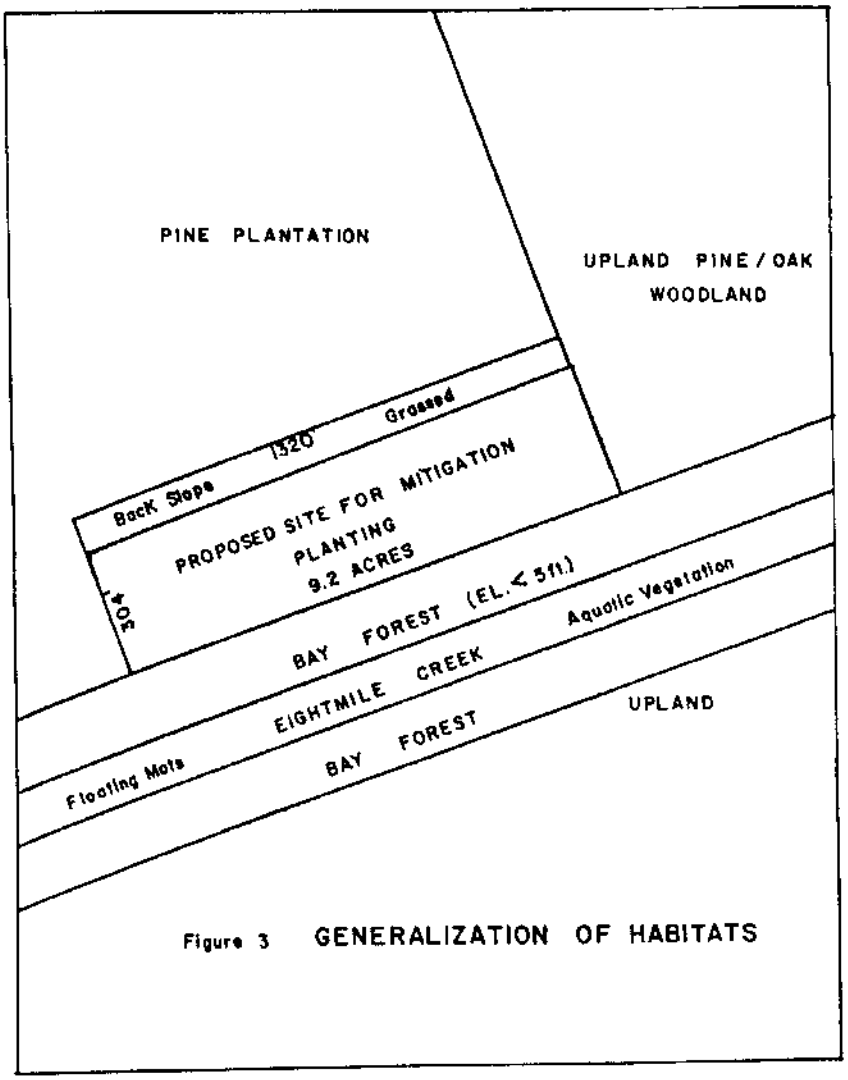


Figure 3 GENERALIZATION OF HABITATS

Quadrate Sample Data
(Stem Count/m^2)

I. Area Covered With Primary and Secondary Paper Mill Sludge:

Station	Stem Count and Species
1	57 Sagittaria latifolia; 5 Decodon verticillatus
2	58 Sagittaria latifolia
3	47 Sagittaria latifolia
4	94 Sagittaria latifolia
5	38 Sagittaria latifolia
* Total	299 Plants

Average Number of Plants/m^2 = 59.80 Plnats/m^2

II. Area Not Covered With Paper Mill Sludge:

Station	Stem Count and Species
1	7 Scirpus cyperinus
2	36 Decodon verticillatus; 1 Sparganium americanum
3	28 Decodon verticillatus; 3 Sparganium americanum
4	9 Scirpus cyperinus; 2 Sparganium americanum
5	16 Decodon verticillatus; 9 Sparganium americanum
6	11 Scirpus cyperinus
* Total	122 Plants

Average Number of Plants/m^2 = 20.33 Plants/m^2

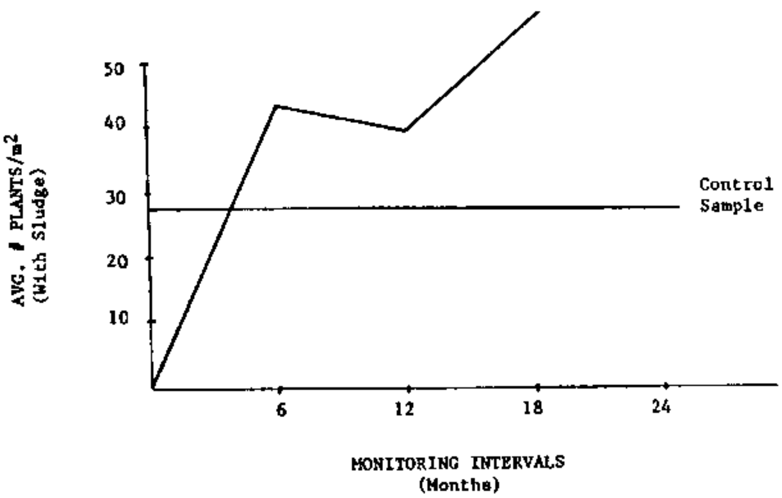
III. Control Area (Adjacent to Donor Sites)

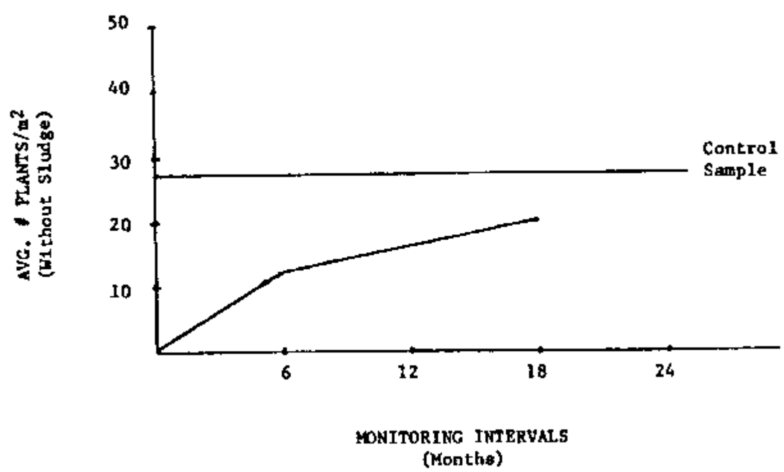
Station	Stem Count and Species
1	14 Sagittaria latifolia; 12 Sparganium americanum
2	9 Sagittaria latifolia; 17 Sparganium americanum
* Total	52 Plants

Average Number of Plants/m^2 = 26 Plants/m^2

* Totals indicate numbers of plants per m^2 for only the species used as planting stock. Natural colonizers were not counted, but were common in all areas sampled. Numerous woody and herbaceous species were present in the control samples which reflects lower stem counts due to the canopy cover and competition.

QUADRATE SAMPLE DATA





Success of Seedling Trees

Quantitative data is not available for the number of trees (Taxodium distichum and Fraxinus pennsylvanica) that have survived the first eighteen months, but after extensive examination of the entire project an estimated seventy percent of all bare root seedlings planted on the project floor have survived and are showing significant growth.

The Bald Cypress seedlings have a higher rate of survivability than the Green Ash. Similar planting techniques (dibble bar) were used with both species.

Native Colonizers

A floristic survey was conducted over the entire mitigation site and the dominant herbaceous and grass-like plants were noted. Plants noted were species other than those transplanted onto the site. The following list are the planted species which volunteered in the greatest numbers.

Juncus marginatus; J. effusus
Scirpus cyperinus; S. americanus
Eleocharis flavescens
Cypress spp.
Panicum spp.
Salix nigra
Ludwigia alterniflora; L. leptocarpa;
L. linearis
Polygonum punctatum
Typha spp.

Summary

The Scott Paper Company wetland mitigation planting has responded most favorably to the physical and biological conditions established by the habitat alterations. New acres of freshwater marsh have been created by lowering the elevation of an upland slope to that of the adjacent swamp and transplanting the dominant vegetation associated with this habitat type. This expanded wetland area will serve a two fold purpose. (1) New acreage of a limited habitat was established with all the associated functions such as flood water retention, filtration, detrital productivity, and habitat for aquatic organisms. (2) The expanded mitigation area would further isolate the existing swamp from encroachment.

The development and creation of wetlands is not a new concept. Water fowl managers, agricultural operations, hydro-electric facilities, and sportsmen have developed wetlands for years. It is the concept of using a creation program as compensation for habitat losses and impacts that is new and provocative. Wetland mitigation can take the shape of enhancement, expansion or restoration and does not have to be coupled with development. These projects can stand alone as being contributors to the environmental quality and not as secondary work associated with the prime development.

Wetland mitigation is a viable alternative in coastal development and the concept should be expanded to include a variety of compensatory measures. Through mitigation or land banking funds could become available to undertake numerous environmental projects that could show immediate results and enhancements.

By using wetland mitigation (creation) as a tool to compensate for cumulative effects associated with growth and development our estuarine systems need never lose another acre of wetland habitat.

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CREATION OF A BRACKISH TIDAL MARSH AT WEST FOWL RIVER, ALABAMA

Barry A. Vittor and Julian R. Stewart, Jr.
Barry A. Vittor & Associates, Inc.
8100 Cottage Hill Road
Mobile, Alabama 36609

Arthur L. Middleton
Mobile District
Corps of Engineers
P. O. Box 2288
Mobile, Alabama 36628

ABSTRACT: A 40-acre brackish marsh is being created near West Fowl River, for North American Gulf Terminals, Inc., as a condition of the Corps of Engineers permit for construction of a coal/grain facility at Theodore. The mitigation site was selected for its low elevation (+1.3 m MSL) and access to tidal recharge via an existing canal network. It contains a Juncus roemerianus-Phragmites communis zone near the River and the Pinus elliotti zone which is being excavated. An average of 1 m of topsoil and sandy clay has been removed by dragline, in order to attain a finished elevation of +0.3 m MSL. Four tidal canals allow an adequate flow of brackish water into the site during flood tide. Excavated material forms mounds which will eventually provide upland habitat in the midst of the new wetland. A lower zone (+0.15 m) is being created along the waterways to improve the quality of new Spartina alterniflora marsh to be planted. The site becomes fully flooded during high tide and flushes very quickly during ebb tide.

INTRODUCTION

Restoration of former wetlands or creation of new wetlands has become a means of compensating for unavoidable losses of wetlands due to dredging or filling. In Alabama, such mitigation is typically associated with issuance of permits by the Mobile District Corps of Engineers and Alabama Department of Environmental Management, in conjunction with activities regulated under Section 404 of the Clean Water Act of 1972, as amended. These permits are issued where wetland losses cannot be avoided in constructing water-dependent facilities, and where such construction is determined to be in the public interest. The President's Council on Environmental Quality (40 CFR 1508.20) included wetland creation in addition to avoiding wetland impacts through alternative project design, in its definition of mitigation for wetland impacts. While this guideline was not intended to encourage development in wetlands, it did acknowledge that some kinds of waterfront development could be accommodated provided that provisions were made for replacing significant wetland functions.

North American Gulf Terminals, Inc.'s (NAGTI) U.S. Army Corps of Engineers permit for construction of a coal and grain transloading facility on the Theodore Ship Channel required that excavation of 23.5 acres of tidal marsh plus other wetland impacts be mitigated by creation of 40 acres of tidally-influenced brackish marsh and 2 acres of fresh marsh. Thirty-six (36) acres of the tidal marsh habitat were to be excavated prior to or concurrently with construction of NAGTI's shipberthing basin on the ship channel, while the remaining mitigation was to be performed in conjunction with bottomland hardwood (swamp) losses due to drainage ditch construction, dike building, and dredged material disposal. The mitigation approach stipulated as a special condition of NAGTI's permit was developed by NAGTI with considerable advice and input from Mobile District Corps biologists, the U.S. Environmental Protection Agency, U.S. Fish & Wildlife Service, U.S. National Marine Fisheries Service, the Alabama Department of Environmental Management, and the Alabama Department of Conservation and Natural Resources. The principal objective of the final mitigation program was to replace the ecological functions of wetlands destroyed at the NAGTI site. This included primary production of marsh grasses; nutrient exchange between upland intertidal, and estuarine waters; and habitat for marsh and estuarine invertebrates and vertebrates. The ecological values of the wetlands lost at the NAGTI site were estimated by use of the Fish & Wildlife Service's Habitat Evaluation Procedures (HEP), and the size of NAGTI's mitigation area was based on replacement of the number of habitat units that were destroyed.

The purpose of this paper is to describe the important features of this mitigation plan, and the progress and status of marsh creation at the time of this symposium (February, 1987).

GENERAL CONSIDERATIONS IN MARSH CREATION

The marshes characteristic of Mississippi Sound and southern Mobile Bay are primarily irregularly flooded marshes built on deltaic plain sediments. The Gulf Coast marshes, in general, lack any relief features and are situated only slightly above mean sea level. The occurrence, areal coverage, and community composition of wetlands depends upon several environmental parameters, including tidal range, shoreline elevation, sediment sources and composition, topography, and salinity of flooding waters. Banks of tidal bayous and creeks are typically vegetated with the holophytic species Spartina alterniflora (smooth cordgrass) rather than the less inundation tolerant Juncus roemerianus (black needlerush), while on slightly higher elevations behind the S. alterniflora zone, S. patens (saltmeadow cordgrass) generally becomes the dominant species (Stout, 1981).

Juncus is a major component of marshes at both the Theodore Ship Channel and at NAGTI's mitigation site (Figure 1). According to Sapp et al. (1976), Juncus is very euryhaline and is most abundant at elevations above mean high water. This species is replaced in estuarine areas exposed to regular, diurnal tidal inundation by Spartina alterniflora. The mean high tide line is thought to be marked by the seaward edge of Juncus marsh where S. alterniflora is not present. Juncus is replaced by S. patens at elevations above 0.5 m MSL to 0.6 m MSL, where tidal influences exist. Juncus occurs on fine sand and silt sediments which are rich in organic matter and are somewhat reduced (Gosselink et al., 1977). According to Hopkinson et al. (1978) Juncus is second only to S. patens with respect to rate of biological production (Table 1). It produces an average of $3416g/m^2$ live biomass per year. However, its decomposition rate is much lower than S. patens ($3105g/m^2/yr.$) and its biomass turnover rate is very low compared to other coastal marsh species. Consequently, it contributes less organic detritus to estuarine waters than do most other species in this area.

Smooth cordgrass (S. alterniflora) is an important component of coastal marshes, but occurs only in patches in West Fowl River. According to Allen et al. (1978), at Galveston, Texas, this species grows best at elevations near mean low water, where it is inundated from 69-87% of the time (Figure 2). Seneca et al. (1976) found that S. alterniflora occurs at elevations up to 0.8 m but is most productive near open water. As an intertidal species, S. alterniflora serves to buffer the shoreline against wave action and erosion, and also collects sediment (Broome et al., 1973). Hopkinson et al., 1978 reported that S. alterniflora is moderately productive, with an annual average production rate of $2658g/m^2$ in coastal Louisiana (Table 1); this is roughly 80% of the annual production rate of J. roemerianus, and less than half that of S. alterniflora is somewhat higher than Juncus but is considerably lower than S. patens.

Saltmeadow cordgrass (S. patens) is expected to become established in fringe areas of the created habitat due to the species' ability to establish in a relatively broad range of soils and hydrologic regimes. Field investigations related to habitat development on dredged material indicate that S. patens is able to survive and flourish on sediments ranging from sand to clay at elevations from slightly above mean high water to over one meter above mean high water (Allen et al., 1978; Kruczynski et al., 1978). Saltmeadow cordgrass is also one of the most productive marsh species in terms of annual biomass generation. Hopkinson et al. (1978) found that S. patens produces an annual average of

TABLE 1

Annual biomass and production parameters of 7 species of marsh grass.

Taxa	Annual mean biomass (g/m^2) Live	Annual mean biomass (g/m^2) Dead	Peak live biomass (g/m^2)	Production† $\bar{x}$ & range $(g\ \bar{x}\ m^{-2}\ x\ yr^{-1})$	Annual disappearance§ $(g\ \bar{x}\ m^{-2}\ x\ yr^{-1})$	Biomass turnover rate Live $(\bar{x})$¶	Biomass turnover rate Live (max)¶	Biomass turnover rate Dead $(\bar{x})$**
Distichlis spicata	560	1143 (0.49)	991	3237 (3108–3366)	3171	5.7	3.1	2.8
Juncus roemerianus	827	905 (0.91)	1240	3416 (3029–3794)	3105	4.1	2.8	3.4
Phragmites communis	478	2222 (0.21)	990	2318 (1825–2811)	3244	4.9	2.3	1.5
Sagittaria falcata	199	228 (0.87)	648	1501 (1389–1613)	1572	7.5	2.3	6.9
Spartina alterniflora	469	958 (0.49)	754	2658 (2523–2794)	2412	4.6	3.5	2.5
Spartina cynosuroides	394	951 (0.41)	808	1355 (1052–1659)	1631	3.4	1.6	1.7
Spartina patens	900	1530 (0.58)	1376	6043 (4924–6163)	5138	6.7	4.4	3.4

*Number in parentheses shows the ratio of the live to the dead biomass.

†Calculated from bimonthly data using pooled mean r values. Range shown indicates variation found using 2 different 12-month periods for calculation.

§Disappearance = $\bar{D} \times \bar{r} \times 365$ days = annual mean dead biomass, and $\bar{r}$ = annual mean disappearance rate calculated from pooled means.

¶Ratio of production to live biomass.

**Ratio of annual disappearance to mean dead biomass.

Source: Hopkinson et al., 1978

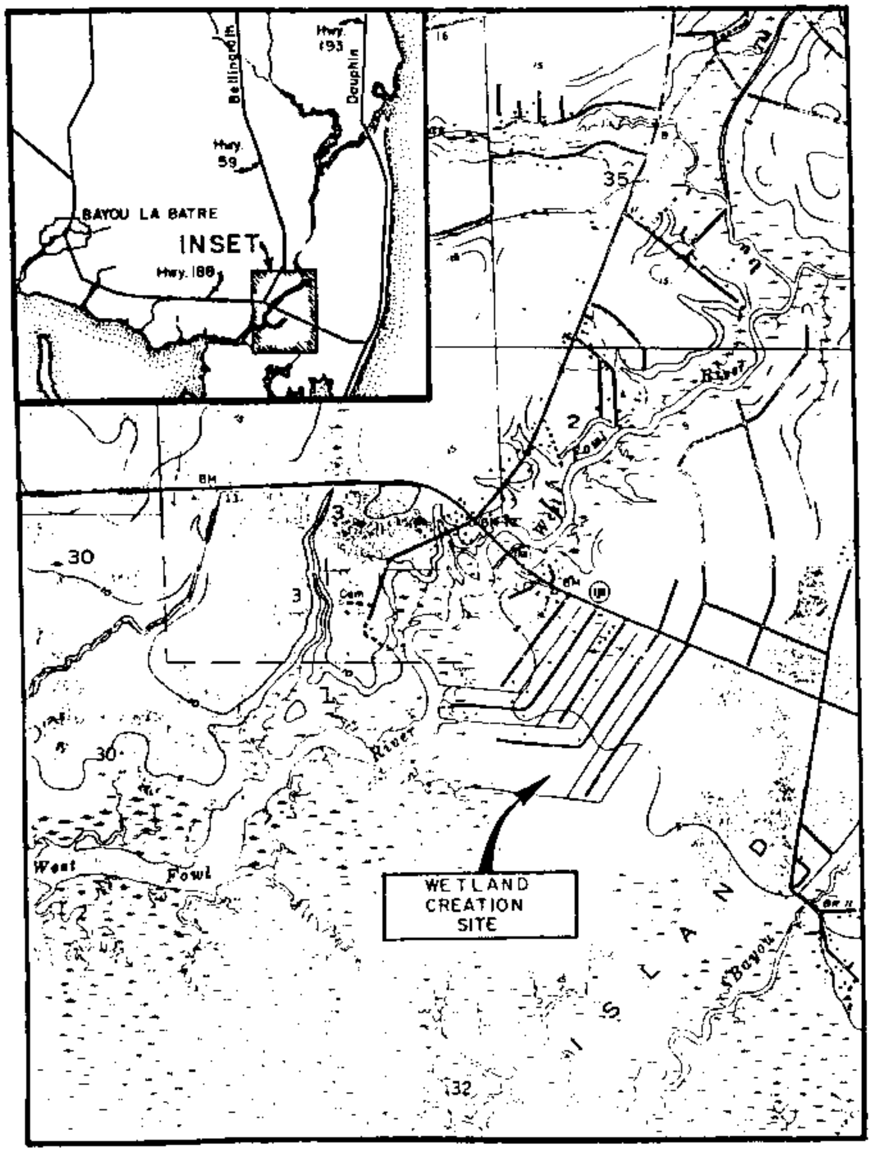
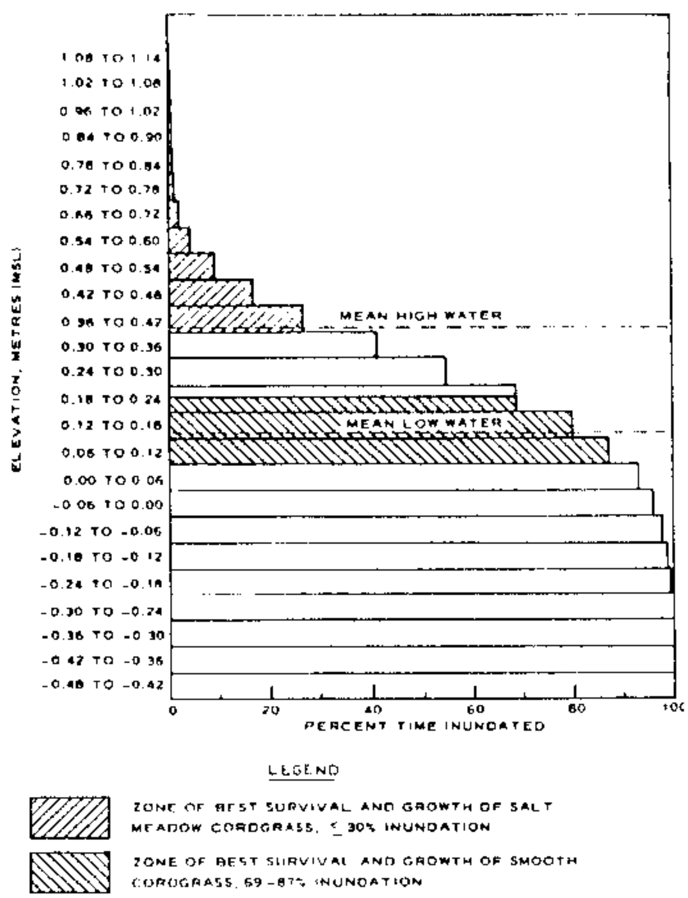


FIGURE 1. Vicinity map of the West Fowl River marsh creation site.



NOTE. TIDE DATA ARE FROM 1 FEBRUARY TO 31 AUGUST 1977, A PERIOD COVERING THE MAJORITY OF THE GROWING SEASON.

FIGURE 2. Elevational zones of best survival and growth of saltmeadow and smooth cordgrass with percent inundations. (Source: Allen et al., 1978)

6043g/m^2 of biomass (Table 1). That level of biomass generation is the highest of the seven species they studied.

CHARACTERISTICS OF THE WEST FOWL RIVER SITE

The proposed primary mitigation site near West Fowl River consists of 54 acres of low relief pine savannah. The dominant overstory is slash pine (Pinus elliottii) with small isolated stands of live oak (Quercus virginiana) in slightly higher, better-drained areas. The understory is characterized by a wide variety of herbaceous plant species, including panic grass (Panicum spp.). Saltmeadow cordgrass (Spartina patens) occurs in small moist depressions, while cane (Phragmites communis) is found between the West Fowl River tidal marsh and the pine savannah.

Most of the site had been previously drained by a system of canals. The primary drainage canal was approximately 2 m deep and 9 m wide and drained to the west into a small bayou which empties into West Fowl River. This main canal was joined by three smaller and shallower ditches on the northern bank. This drainage system altered the natural groundwater regime by lowering the water table an undetermined amount and intercepting the groundwater flow towards the Sound. J. roemerianus occurred in the drainage ditch system, along the canal, and along West Fowl River.

The West Fowl River site is characterized by Bayou soil, except at its southern edge, where tidal marsh muck sediments are found. The Bayou soil series consists of poorly drained, moderately slowly permeable soils that formed on loamy marine sediments. Bayou soils occur on uplands of Gulf Coast flatwoods and are seasonally saturated to, or within 1 foot of the surface from December through May. The terrain typically presents little relief with slopes ranging from 0 to 2 percent. Table 2 presents the soil profile characteristic of soils on the West Fowl River project site.

Table 3 presents a summary of the physical and chemical profile of Bayou soils. This analysis reveals that Bayou soils are low in calcium, magnesium, and potassium; however, low levels of these elements may not be significant. Gosselink et al. (1977) related soil parameters to biomass and found that no soil parameter accounted for more than 11 percent of the biomass variability. Barko et al. (1977) related the establishment and growth of S. patens to a variety of dredged material sediment characteristics, includidng nutrient concentrations and texture. They reported that, although finer-textured sediments have a greater adsorptive area and typically contain higher concentrations than coarse sediments, texture probably has little direct effect on plant growth. The nutrients cited are N and P. Coarse-textured (sand) sediments are characteristically poor in nutrients, and growth of all wetland species on sand was

TABLE 2

Typical soil profile of Bayou Soil Series

A11	0 to 5 inches; very dark gray (10YR 3/1) sandy loam; weak medium granular structure; friable; common fine roots; very strongly acid; clear wavy boundary.
A12	5 to 9 inches; dark gray (10YR 4/1) sandy loam; few medium distinct gray (10YR 6/1) mottles; weak medium granular structure; friable; common fine roots; very strongly acid; clear wavy boundary.
A2g	9 to 18 inches; light brownish gray (10YR 6/2) sandy loam; common medium distinct light yellowish brown (2.5Y 6/4) and few medium distinct very dark gray (10YR 3/1) mottles; weak medium subangular blocky structure; friable; few fine roots; very strongly acid; gradual wavy boundary.
B1g	18 to 26 inches; light gray (10YR 7/1) sandy loam; common medium distinct brownish yellow (10YR 6/6) and few medium distinct pale yellow (2.5Y 7/4) mottles; weak medium subangular blocky structure; friable; few fine roots; very strongly acid; gradual wavy boundary.
B21tg	26 to 43 inches; light gray (10YR 7/1) sandy loam; common medium distinct brownish yellow (10YR 6/6), strong brown (7.5YR 5/8), light brownish gray (10YR 6/2), and red (2.5YR 5/8) mottles; weak medium subangular blocky structure; friable; sand grains coated and bridged with clay; very strongly acid; gradual wavy boundary.
B22tg	43 to 60 inches; light gray (10YR 7/1) sandy clay loam; many medium distinct yellowish brown (10YR 5/6) and common medium distinct yellow (2.5Y 7/6) and red (2.5YR 4/8) mottles; weak medium subangular blocky structure; friable, slightly compact; thin patchy clay films on faces of peds; very strongly acid; gradual wavy boundary.
B23tg	60 to 66 inches; gray (10YR 6/1) sandy clay loam; few to common medium distinct yellowish brown (10YR 5/6), pale yellow (2.5Y 7/4), and light reddish brown (2.5YR 6/4) mottles; weak medium subangular blocky structure; friable, slightly compact; thin patchy clay films on faces of peds; few pockets of sandy loam; very strongly acid.

Source: Soil map for Mobile County, Alabama (U.S.S.C.S., 1961)

TABLE 3

Physical and chemical properties of Bayou soils

Soil and sample number	Depth	Horizon	Particle-size distribution: Sand (mm 2.0-0.05)	Silt (mm .05-.002)	Clay (mm <0.002)	Extractable bases: Ca	Mg	K	Extractable acidity	Base saturation	Reaction (1:1 soil-water)	Cation-exchange capacity
	In					Meq/100 g soil				Pct	pH	Meq/100g soil
Bayou:												
S76AL-049-006-1—	0-5	A11	70.0	24.2	5.8	0.16	0.08	0.04	4.14	6.41	4.3	4.43
S76AL-049-006-2—	5-9	A12	69.3	25.1	5.6	0.14	0.06	0.03	4.16	5.67	4.2	4.41
S76AL-049-006-3—	9-18	A2g	68.7	25.0	6.3	0.10	0.03	0.01	1.92	7.14	4.4	2.06
S76AL-049-006-4—	18-26	B1g	67.8	24.7	7.5	0.08	0.05	0.01	2.40	6.22	4.5	2.55
S76AL-049-006-5—	26-43	B21tg	64.2	23.2	12.6	0.06	0.04	0.02	3.92	3.33	4.5	4.05
S76AL-049-006-6—	43-60	B22tg	65.6	13.6	20.8	0.08	0.07	0.03	6.00	3.23	4.3	6.20
S76AL-049-006-7—	60-66	B23tg	67.6	11.8	20.6	0.10	0.08	0.03	6.00	3.58	4.3	6.22

nutrient limited. However, plant growth on fine-textured sediments, where not inhibited by high salinity, was comparable to estimates of plant production in natural marshes. High productivity of marsh vegetation is maintained in part by the continual replenishment of nutrients in the form of nutrient-rich sediments deposited on the marsh. Thus, regardless of the initial sediment characteristics, if the hydrologic regime of the created wetland favors introduction of nutrients from both upland areas and through tidal action, the nutrient and textural properties of the sediments should not influence the viability of wetland establishment.

The West Fowl River site exhibits very slow surface runoff; most drainage occurs through lateral seepage into the artificial drainage system, from the perched water table above the clay loam soil stratum. Tidal influence is seen in the drainage canal and connecting ditches. The canal is deeper (-1.0 m MSL) than the natural bayou into which it drains (-0.6 m MSL). Tidal range in West Fowl River (and in the canal) is approximately 0.5 m, as in Mississippi Sound (Figure 3). Mean high water is +0.3 m MSL in the Sound and West Fowl River, while mean low water is -0.2 m MSL. Similar tidal ranges are experienced in the mitigation site canal system.

The Juncus marsh along West Fowl River has an elevation of approximately +0.2 m to 0.6 m MSL and is influenced primarily by storm tides. The Phragmites zone that borders the Juncus marsh is approximately 0.3 m higher and is inundated only by very high storm tides and rainfall runoff.

WETLAND CREATION APPROACH

The brackish marsh excavated at NAGTI's shipberth area ranged in elevation from approximately +0.15 m MSL to +0.6 m MSL. Roughly 12 acres of this area were below mean high tide and were regularly inundated by tidal action, while the remainder was affected by area rainfall runoff and periodic high tides. Consequently, the NAGTI wetland creation project was designed to create a variety of habitat types ranging from tidally inundated smooth cordgrass marsh to infrequently flooded black needlerush (Juncus) marsh. The lowered area would be designed to communicate with adjacent open water (West Fowl River) through the existing canal and across the existing Juncus marsh at the edge of the River. The lowest elevations would extend eastward along the existing canal and northward along newly-created tidal canals and would be at approximately mean high tide (+0.3 m) and conducive to formation of Juncus marsh.

Approximately 54 acres of low pinewoods near West Fowl River (Figure 4) are being altered by excavation and soil stockpiling, in order to develop 40 acres of brackish marsh habitat (primarily Juncus and S. alterniflora). Excavation is being accomplished with conventional earthmoving techniques and includes arranging the removed soil to form upland islands. Over 14 acres of such uplands will eventually be created and will represent valuable habitat for a variety of wildlife species.

The wetland creation project is proceeding in two phases: (1) site clearing, excavation, upland island formation, grading, and planting; and (2) post-habitat creation monitoring and re-planting (if needed). The duration of this program will be three years (three growing seasons) after completion of phase one.

Phase I: Site Excavation, Grading, and Upland Island Formation

The mitigation site was first cleared of large trees (generally Pinus elliottii), although scattered oaks and two large cypress (Taxodium distichum) were preserved. Stumps were not removed prior to excavation, but rather, are being placed in the soil islands.

The next step in lowering the project site to mean high water was to excavate three new or expanded tidal canals northward from the original canal (Figure 4). These canals were designed to perform two functions: (1) to drain the ground and thereby facilitate excavation and soil placement; and (2) to increase the volume of water for flushing and exchange in the lowered area. These canals are 6 m wide, with a depth of 0.6 m below mean sea level.

In order to achieve elevations that will sustain viable, productive stands of S. alterniflora and Juncus, an average of approximately 1.3 m of soil must

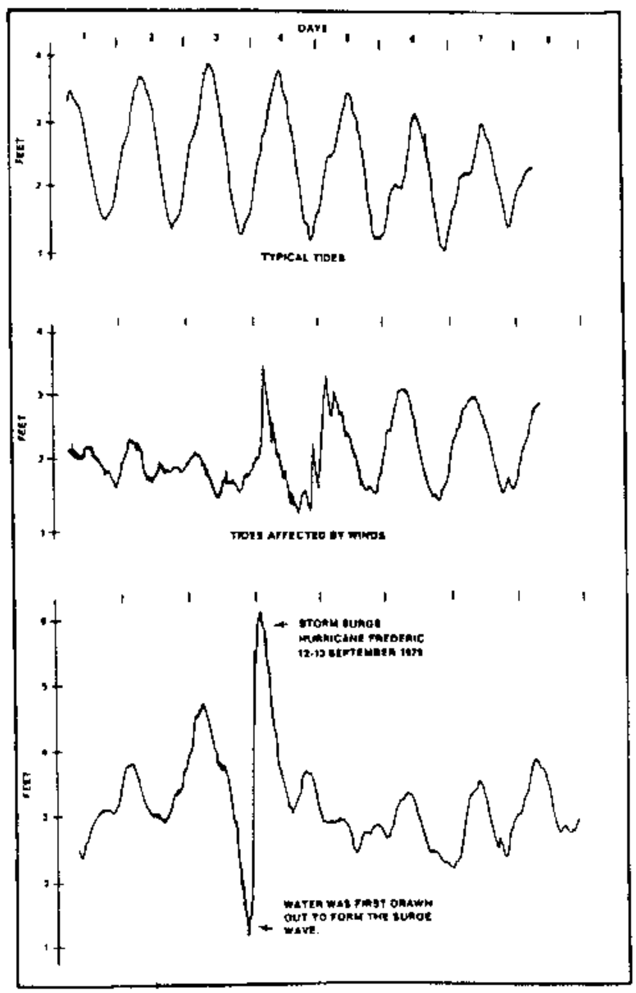


FIGURE 3. Examples of tides in Mississippi Sound. (Source: Eleuterius and Beaugez, 1981.)

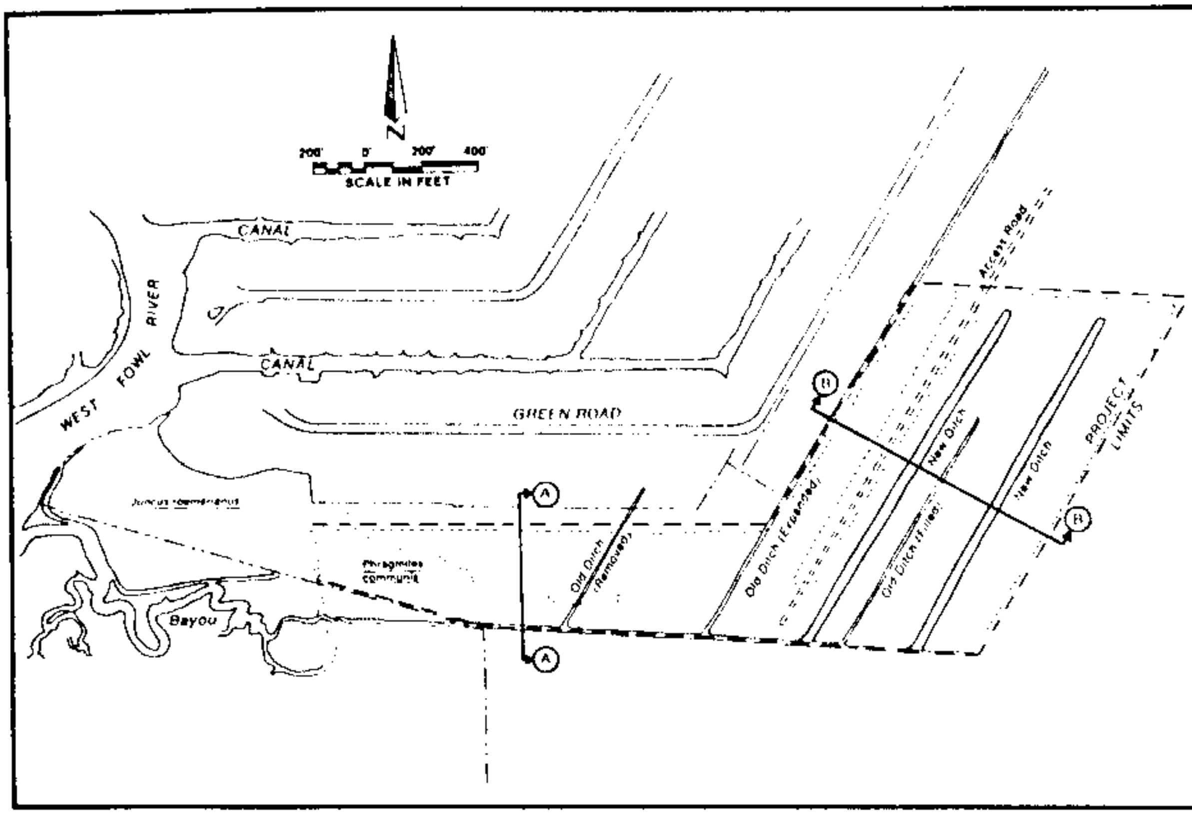


FIGURE 4. Approximate boundaries of the NAGTI marsh creation project adjacent to the Delta Port subdivision. The area identified is approximately 52 acres. The dotted line shows the approximate limit of tidal influence and encompasses roughly 42 acres.

be removed. The mitigation site was first topographically surveyed and staked to ensure that the appropriate elevations (+0.3 m) are created. The primary goal of the shaving-down program is to create elevations that are subject to at least occasional tidal inundation over the entire site, in order to replace the amount of ecological value that was lost at the NAGTI project site. Roughly 10 acres of the 40-acre site will be planted in J. roemerianus and 30 acres will be planted in S. alterniflora. It is probable that natural plant succession will cause this shaved-down area to become vegetated by a variety of other wetland species as well, including P. communis and S. patens. For example, S. patens habitat will be formed at the base of each upland island.

Successful creation of tidally-influenced habitat is facilitated by NAGTI's plan to extend the existing Juncus marsh to the east. This extension borders the canal, which contributes further to tidal influence in the excavated area. Excavation of the ground along the canal system to near mean sea level effectively widens the area over which daily tidal influence is experienced.

Approximately 160,000 cu. yds. of overburden are being redistributed on the 54-acre site. This material is stockpiled within a series of upland islands that range from 2.5 to 5 m high (Figure 5). The upland islands will be seeded with an appropriate vegetative cover (primarily, bermuda, bahia, and winter rye grasses). In addition, pine seedlings will be planted on all of the islands and oaks and popcorn trees may also be planted. Some oaks and other mast-producing trees will be planted on the islands to enhance their value as wildlife habitat (e.g., for deer). These islands will encompass nearly 14 acres of the 54-acre site.

Although the final excavated elevation was originally specified as +0.3 m MSL (i.e., MHW), NAGTI decided to excavate to +0.15 m along the canal, along new and expanded tidal canals, and in the center of created open areas. The reason for expending this additional effort and cost was to ensure that areas actually suitable for S. alterniflora survival and growth be provided, since the permit required that the property be shaved down to +0.3 m but also required that S. alterniflora be planted on 30 acres of the site. In fact, we estimate that two-thirds of the new marsh will be at an elevation conducive to daily tidal inundation and S. alterniflora growth. The remaining third of the site will be at +0.3 m and will be suitable for Juncus.

Juncus areas will be sprigged with plants obtained from NAGTI's adjacent marshland. Sprigs will be dug by hand and will consist of plugs approximately 5 cm square, containing several live stalks and root mass. Sprigs will be planted at one-meter intervals (4050/acre) in one-acre plots scattered around the site.

S. alterniflora areas will also be planted with sprigs, which will be obtained from either a commercial source or from existing stands on NAGTI's property. In addition, a test plot will be seeded with seed collected from S. alterniflora stands on Mississippi

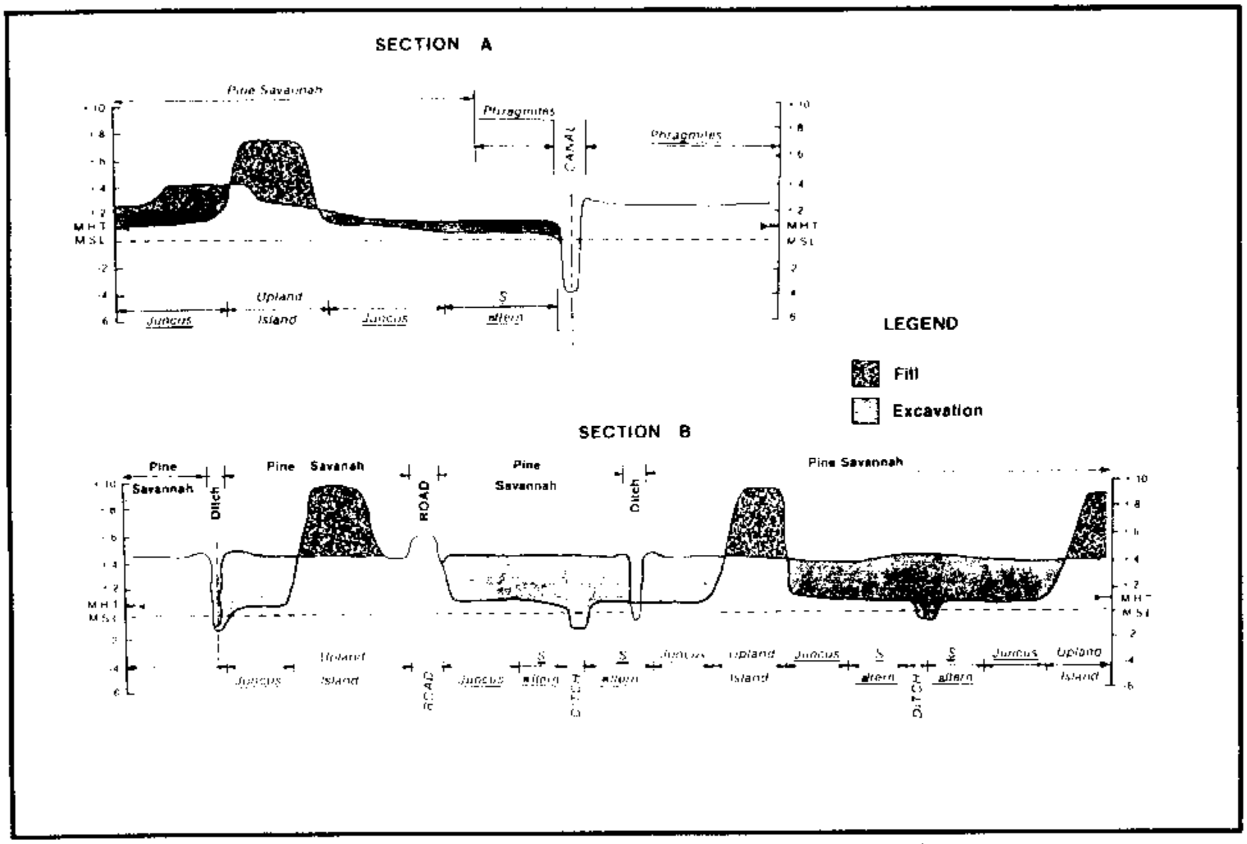


FIGURE 5. Schematic of natural (top identifiers) and modified (bottom identifiers) topography at the NACTI marsh creation site.

Sound. These seeds have been treated as recommended by Woodhouse et al. (1974) and will be ready for planting during spring 1987. The test plot will be seeded at a rate of approximately 100 viable seeds per square meter (after-ripened seeds may have a viability of over 60% if properly treated). This plot will be used as a continuing source of sprigs if good germination is achieved.

S. alterniflora sprigs are to be planted at five-meter intervals (167/acre); however, a closer spacing will be used and will decrease the time needed to obtain good coverage of the site. The exposed soil consists of silty clay with some fine sand. Most of the area's new surface soil also contains organic material, as well as receiving nutrients such as nitrate and phosphate from the estuarine waters that enter the project area during flood tide. Consequently, no fertilization of the new marsh is anticipated. Woodhouse et al. (1974) found that use of fertilizers is generally effective in S. alterniflora sprigging areas where the substratum consists of sand with little or no silt or clay, or where surrounding waters are low in nutrients.

Phase II: Post-Habitat Creation Monitoring

After site preparation and required planting have been completed, the stage will be set for the further development of the wetland community. It is expected from reviewing previous habitat development investigations (e.g., Allen et al., 1978) that plant invasion should rapidly repopulate the site with the species suited to this environment. As suggested by Kruczynski et al. (1978), the rate of sprigged species population growth and native plant invasion is difficult to predict. Therefore, NACTI will monitor the newly created wetland site to ensure that a reasonable level (at least 4800 plants/acre) of S. alterniflora and Juncus (and other species such as S. patens) establishment does occur. Semi-annual reports to the Mobile District Corps of Engineers and the U.S. Fish and Wildlife Service will document natural wetland community establishment of upland islands, vegetation and stability, on-site sediment movement, and other relevant aspects of habitat development. Such reports will be provided for three growing seasons, by which time an average wetland plant density of at least 4,800/acre should have been attained. If after three growing seasons there were less dense colonization than the projected level, additional transplanting of S. alterniflora and Juncus sprigs will be performed to establish this density.

Other aspects of wetland creation at West Fowl River that may be assessed during Phase II include wildlife utilization of upland islands, marshes, and open water. Numerous vertebrates have already been observed on the site, including an alligator (Alligator mississippiensis), black-crowned night heron (Nycticorax nycticorax), common egret (Casmerodius albus), and green heron (Butorides striatus). Also of interest is the colonization of marsh and canal sediments and waters by invertebrates and fishes. There will be an investigation of the succession of benthic macroinfauna communities as well as important fish and shellfish populations as the marsh becomes established.

STATUS OF THE MARSH CREATION PROJECT

As of the end of January, 1987, the entire 54-acre mitigation site had been surveyed and cleared. The original canal was extended to the eastern edge of the new marsh, and two new tidal canals were excavated northward from the canal to the northern boundary of the planned marsh creation site. Approximately 26 acres of land have been excavated to marsh elevation. Soil has been placed in several linear piles rather than in 0.2-acre piles as originally planned, because of the added volume of material generated by lowering the area to elevations of from 0.15 to 0.3 m instead of 0.5 m.

The highest parts of the excavated site are inundated by periodic high tides (generally those caused by sustained southerly winds). All but the tidal canals are exposed during very low tides that occur during sustained northerly winds. The majority of the marsh site is flooded daily by lunar tides. During ebb tide, water flows out of the new area very rapidly: a velocity of roughly 1.5 knots was estimated on one occasion in the original canal, near the existing Juncus marsh.

The next step in this project will be to shape the soil islands, seed them with grasses, and begin sprigging the excavated area. Very little erosion or siltation from the stockpiled soil has occurred, despite recent heavy rains. At the same time, tidal movement as well as rainfall have tended to smooth the surface of the excavated site.

RECOMMENDATIONS

1. Procedural guides or manuals should be developed to describe when, where, and how wetland creation should be performed. This publication would explain important requirements for wetland development and growth, as well as functions sought through wetland creation.

2. Oversight agencies should develop a joint plan for monitoring construction and success of wetland creation projects. Such a plan would consider soil characteristics, elevation control, hydrology, vegetation survival and growth, and faunal communities.

3. Wetland creation banks should be considered as a means of providing mitigation for unavoidable wetland losses, in a carefully managed, demonstrably successful wetland creation program.

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HISTORY, STATUS AND MATURITY OF STATE LANDS IN THE MOBILE DELTA

David C. Hayden
Department of Conservation and Natural Resources
Game and Fish Division
Montgomery, Alabama 36130

ABSTRACT: The State of Alabama owns approximately 13,000 acres of shallow submerged and emergent marsh and forested lands in the Mobile Delta and when funds are available, plans are to continue the acquisition of additional properties from willing sellers. The Alabama Department of Conservation and Natural Resources, Game and Fish Division presently regulates the major portion of this property plus the bay and stream bottoms. The Game and Fish Division is currently acquiring additional acreage with the ultimate goal of conservation of the natural system and perpetuation of this unique and invaluable wetlands. The importance of natural wetlands in the State of Alabama cannot be overemphasized, especially that of the Mobile Delta. Continuation of existing surveys and enhancement projects are planned. No curtailment of existing traditional hunting, fishing, trapping, bird watching and other outdoor activity is anticipated.

INTRODUCTION

The State of Alabama owns approximately 13,000 acres of land in the Mobile Delta. In addition, all water bottoms are State property. Therefore, in excess of 70 percent of the Lower Mobile Delta is controlled by the State of Alabama. This area includes the lands and water bottoms of Grand Bay southward to below the Causeway, eastward to near Spanish Fort, northward through Bay Minette and Bay Minette Basin, and then generally westward to Grand Bay. Unfortunately in the Upper Mobile Delta, State holdings are not nearly as extensive; however, suffice to say, we would be more at ease if the same were true in the Upper as in the Lower Delta. Approximately 3,000 acres plus water bottoms are under State control. The majority of this property is located northeast of Chuckfee Bay.

HISTORY

The Department of Conservation and Natural Resources, Division of Game and Fish, regulates the vast majority of these lands. During the 1950's, the Division purchased approximately 3,850 acres in the Lower Mobile Delta with revenues provided through Federal Aid to Wildlife Restoration (also known as Pittman-Robertson) Funds. In 1982, about 3,700 acres of property were purchased with oil and gas revenues. Nearly 3,000 acres of this is situated in the Upper Delta and the remainder in the Lower Delta. Swamp and overflow lands account for nearly 2,900 acres with ownership being held partially by the Division of Game and Fish and partially by the Alabama Mental Health Board and the Alabama Department of Mental Health and Mental Retardation. Land formed by accretion accounts for approximately 3,250 acres.

As part of the mitigation for wetlands loss at the Frank Jackson State Park at Opp, the Alabama Mental Health lands were dedicated to sound wildlife management principles with the Division of Game and Fish being responsible for management of surface rights. With this dedication the Division presently regulates the major portion of the surface lands as well as the water bottoms.

STATUS

So what does all this mean? This does not mean that the Division of Game and Fish or the Department of Conservation and Natural Resources is satisfied to sit on what we have. We know what has occurred to wetlands in other areas. We desire to own and regulate even more of the Mobile Delta. At the present time, the Division of Game and Fish has one transaction underway. Through the Ducks Unlimited MARSH (Matching Aid to Restore States Habitat) Program, the Division may receive money to acquire, enhance or restore waterfowl habitat. We are currently in the process of purchasing approximately 284 acres of wetlands between Chocaloochee and Big Bateau Bays. This property is now held by Coastal Land Trust. We plan to utilize additional DU MARSH Funds for more acreage in the same area if the Coastal Land Trust is still willing to transfer the lands to us. In addition, the feeling is so strong that this wetland area is of the utmost importance, the Division plans to commit an equal amount of other funds to obtain even more property. The additional revenue may come from Alabama Duck Stamp Funds, Pittman-Robertson Funds, or other sources that may become available.

In the Upper Delta, one transaction is also active. Approximately 500 acres immediately adjacent to and north of the present holdings should soon be purchased by the Department. This land is part of the Frank Jackson State Park mitigation program and is currently held by Scott Paper Company. The wetland area will be managed in accordance with sound wildlife management practices as will all other lands.

Plans are to continue acquiring wetlands when funds are available and where landowners are willing sellers. Thus far, this approach has been very successful and the Department certainly desires that the mutually satisfactory relationship continues.

OBJECTIVES

The primary objective of the Game and Fish Division is to obtain as much of the Mobile Delta as practicable and to practice sound conservation principles. The perpetuation of this unique and invaluable resource is our aim. The value of wetlands cannot be over-emphasized. This value has been discussed by many individuals. Just to briefly mention a few, we know that the diverse ecosystem is highly productive resulting in large exchanges of species, energy and nutrients between the terrestrial and aquatic environments (Wharton 1980). Wetlands improve water quality by filtering or removing pollutants from the water (Odum 1978). Water flow is slowed, thereby reducing the potential adverse effects of flooding during high water periods. Water is stored and released during low water periods. Wetlands contribute significantly to groundwater recharge (Winger 1986). In many areas wetlands provide greenbelts in what would other wise be a totally developed area (Odum 1979). Both recreational and commercial opportunities are afforded by wetlands, particularly by those as extensive and productive as the ones that lie in the Mobile Delta.

The Division plans to manage the wetlands for long-term natural benefits. The benefits everyone currently receives are too great to sacrifice for any ill-advised short-term gain.

KEY SPECIES AND GROUPS

When discussing key species or species groups, difficult decisions and differences of opinions are frequent. From the Department's point of view, the Delta is of particular importance to waterfowl, sport fish, shrimp and crabs, wading and shore birds, and alligators.

The shallow marshes of the Delta have been extremely beneficial to waterfowl for years and are probably of even more importance now, due to the loss of marshes in other southern states. Fairly large numbers of waterfowl utilize the area in fall and spring migration and many birds winter in both the marsh and flooded timber (Seahears 1979). The importance of migrational and wintering habitat has recently been emphasized in the North American Waterfowl Management Plan, a strategy for cooperation between the United States and Canada. One of the priority wintering areas identified is the lower Mississippi River-Gulf Coast region. Over three-fourths of this region's habitat has been lost and most of the remainder is unprotected (U.S.D.I. 1986).

The Mobile Delta is extensively utilized by sport fishermen. The habitat provides for a variety of freshwater species and, during periods of low river flow, several marine species of sport fish interest (Tucker 1979).

The importance of the seafood industry, especially shrimp and crabs, to the local area as well as the State of Alabama is well documented. Wetlands around Mobile Bay contribute significantly to these species. The Lower Mobile Delta is important as nursery and feeding grounds for shrimp and crabs, and also for many of the fish species. We must avoid, if at all possible, allowing any pollution, periods of low dissolved oxygen, habitat destruction, and other factors detrimental to the area.

Wading and shore birds are another important species group. Large numbers may be observed in the shallow marshes during the fall and spring migration. However, many of the wading bird species can be observed throughout the year in both the marshes and forested lands. Johnson (1979) reported three nesting colonies of wading birds and one nesting colony of shore birds in the Delta. All were active colonies at the time of the survey.

The American alligator is also considered a key species in the Mobile Delta. The alligator is a common predator capable of consuming any other animal species occurring in the wetland area. Even though the American alligator is currently listed as an endangered species, that status is under review by the U. S. Fish and Wildlife Service and may be down-listed to Threatened by Similarity of Appearance. The Game and Fish Division supports the down-listing and was not in support of the endangered status in Alabama initially. The influence of the alligator in the delta has been and should continue to be of major importance due to their size and numbers, their diet and their associated mystique.

PROGRAMS AND PROPOSALS

Current Projects and Surveys

The Game and Fish Division is currently undertaking a number of programs in the area. Several have been on-going for a number of years and plans are to continue these programs. Beshears (1979) reported on wintering populations of ducks and coots in the Lower Mobile Delta. The pre-hunting season (November) and mid-winter (January) duck and coot populations (Table 1) have declined over the past eight years. This decline can be attributed to a number of factors including: 1) overall lower continental populations; 2) weather conditions at the times of the surveys; 3) use of adequate habitat to the north (frequently termed "short-stopping"); and possibly, 4) reduction of desirable submerged aquatic duck foods. These are the same factors mentioned by Beshears in 1979.

Another survey conducted annually is the waterfowl hunter bag check. Beshears (1979) reported 1.64 ducks and 2.30 coots per day for the Delta, considered good for a public shooting area. For the past eight seasons (1979-80 through 1986-87) the success has remained high with 1.97 ducks and 1.95 coots taken per day of hunter bag check (Table 2).

The species composition of waterfowl taken in the Lower Mobile Delta has varied somewhat year to year; however, since 1953 the most important birds have been green-winged teal, scaup and gadwall. This was true from 1953 to 1978 (Beshears 1979) and also in the past eight seasons (Table 3). Mallards, a preferred species, have remained very low on the list of birds in the bag.

	November		January	
Year	Ducks	Coots	Ducks	Coots
1979-80	5,800	7,400	14,000	12,000
1980-81	8,600	25,000	13,500	16,700
1981-82	7,700	11,300	7,900	22,100
1982-83	7,800	10,200	8,600	10,300
1983-84	4,500	19,000	9,300	12,300
1984-85	7,400	5,400	5,100	7,900
1985-86	2,600	6,500	8,400	12,400
1986-87	1,200	10,600	3,800	4,800

Table 1. — Wintering Populations of Ducks and Coots in the Lower Mobile Delta.

Year	Hunters Checked	Hours Hunted	Hours/ Hunter	Ducks Checked	Ducks/ Hunter	Coots Checked	Coots/ Hunter
1979-80	297	1015	3.42	389	1.31	517	1.74
1980-81	288	1070	3.72	468	1.62	345	1.20
1981-82	210	830	3.95	628	2.99	328	1.56
1982-83	221	934	4.23	629	2.85	603	2.73
1983-84	269	951	3.54	363	1.35	533	1.98
1984-85	92	442	4.80	319	3.47	267	2.90
1985-86	25	97	3.88	61	2.44	56	2.24
1986-87	117	510	4.36	129	1.10	309	2.64

Table 2. — Waterfowl Harvest and Hunting Pressure in the Lower Mobile Delta.

Year	Mal.	Gad.	Nor. Pin.	G.W. Teal	B.W. Teal	Amer. Wid.	Nor. Shov.	Red-Head	Ring-Neck	Scaup	Rud.
1979-80	3.1	9.8	8.5	36.0	5.7	2.6	16.5	-	2.3	2.6	8.7
1980-81	3.0	14.5	3.8	24.6	7.7	12.8	7.9	.6	4.5	3.0	13.9
1981-82	5.1	3.5	2.9	41.7	6.7	2.7	3.0	.8	1.4	25.3	4.3
1982-83	8.4	8.1	2.5	38.2	13.5	4.1	5.7	.5	1.0	14.3	2.7
1983-84	3.9	6.3	2.2	33.6	17.6	2.8	11.0	1.4	5.0	4.4	8.5
1984-85	1.0	1.9	1.3	20.1	30.1	-	5.3	1.6	3.8	27.9	4.4
1985-86	-	1.6	-	1.6	1.6	-	-	3.3	-	88.5	1.6
1986-87	-	15.5	-	7.0	9.3	3.1	7.0	11.6	9.3	14.7	10.1

Table 3. — Species Composition (Percent) of Commonly Harvested Ducks in Lower Mobile Delta.

An alligator survey has been conducted in the Mobile Delta for a number of years in a cooperative program throughout the southeastern United States. The number of alligators has remained comparatively high during this period but has fluctuated because of weather conditions and events (such as hurricanes). The size of alligators observed has also varied to some extent but has been basically what was expected: many small, moderate numbers of medium-sized, and a few large animals.

A new program begun this year in the Delta was the erection of wood duck nesting structures. The wood duck is the only waterfowl species commonly nesting in the state. At one time the species was in serious jeopardy throughout its range but has recovered to a great extent. We believe that many current land management practices have been detrimental to the wood duck. Such practices include: hardwood timber replaced by coniferous timber, cutting of over-mature hardwood forests, elimination of snags and trees with hollows, conversion of forest lands to agricultural lands, elimination of beaver ponds and many drainage programs. Placement of nesting structures in adequate habitat should enhance the opportunity for wood duck nesting. If adequate nesting cavities are lacking, a nesting structure program could significantly increase the overall wood duck production throughout the state.

Some of the other Division programs that are on-going will be discussed at other times during this symposium. These programs include aquatic plant surveys, Eurasian watermilfoil management, fish population surveys and hybrid striped bass surveys.

New Activities Considered

A number of other potential projects have been proposed and discussed; however, a final decision has not been made at this time. Among these are the: 1) prospects for a resident Canada goose flock; 2) erection of osprey nesting platforms; 3) study of effects of marsh-burning; and 4) erection of an observation platform similar to the one near the U.S.S. Alabama. Many details must be considered and discussed prior to a final decision concerning each project. For example, some of the items discussed thus far relative to Canada geese have been: could the geese be adequately protected initially, would sportsmen respect a closed season on Canada geese, would an adequate winter food supply be available, would nest predation be too severe to allow hatching, could hatchlings survive or would we just be providing an easy meal for an alligator, and the list goes on. Free-flying Canada geese could be aesthetically pleasing to those that enjoy the Delta and, perhaps someday could add a small but new dimension to the waterfowling experience. However, we desire to provide beneficial programs to those that entrust us with the responsibilities of resource management. Many times the decisions are not easy and are not quickly determined.

MATURITY

So what is the maturity of the Mobile Delta from the Division's standpoint? As I mentioned we plan to continue the acquisition of property when both funds and willing sellers are available. No immediate plans exist to place a manager on the area; however, it is not unreasonable to anticipate that one may be on the Delta in the future. At the present time, acquiring as much natural wetland as possible is the primary objective. Enhancing the area is secondary. If the land is not protected first, how can it be enhanced? No curtailment of the existing traditional uses is anticipated. Hunting, fishing, bird-watching, boating, trapping and the many other on-going outdoor activities are encouraged.

One important change will occur in the near future and the change will be significant, especially from the hunters standpoint. Beginning with the 1990-91 hunting season, waterfowlers in Baldwin and Mobile Counties will be required to use non-toxic shot. This is necessitated by the regulations developed by the U. S. Fish and Wildlife Service and litigation brought by various groups. This is a requirement that many people are not pleased with; however, it is a law that everyone can live with and must accept. Therefore, let all of us work together with the idea that wildlife will benefit from the regulation.

SUMMARY

The value of the Mobile Delta wetlands cannot be over-emphasized. Acquisition of these lands and protection from all detrimental impacts should continue. The Division of Game and Fish is a resource management oriented agency. The ultimate goal for the Delta should continue to be conservation of the natural system and perpetuation of this unique and invaluable wetlands. Existing programs and surveys that provide a means of monitoring some of the key species or species groups should be continued and expanded when justified. Enhancement programs should also be initiated and expanded as warranted.

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HABITAT PRESERVATION, RESTORATION AND MITIGATION

Summary of Panel Discussion

The participants on the "Habitat Preservation, Restoration and Mitigation Panel were:

Moderator: Larry Goldman, U. S. Fish and Wildlife Service
Art C. Dyas, Coastal Land Trust, Inc.
Jerome T. Carroll, U.S. Fish and Wildlife Service
Davis L. Findley, U.S. Army Corps of Engineers
Hugh M. Dowling, Dowling Environmental Inc.
Barry A. Vittor, Vittor and Associates Inc.
David C. Hayden, Game and Fish Division, ADCNR

INTRODUCTION

Six general topics were covered during the panel discussion. The topics pertained to the relative value of wetlands created by man from areas that were formerly uplands versus values of natural wetlands, and to the policies and procedures being followed by the state and federal agencies that administer and participate in regulatory programs which control man's use of Mobile Bay's natural habitat. The six topics and a synopsis of the panel discussion are listed below.

HUMAN CREATED WETLANDS VERSUS NATURAL WETLANDS

When mitigation projects call for the establishment of emergent wetlands (marsh or bottomland hardwood forest) by converting upland areas (through excavation) to elevations where adjoining water bodies will temporarily flood the site, do we actually get a full replacement of all wetland values found on natural sites? Consultants on the panel believe that all values associated with projects of this type are reflected in newly created wetlands, with one exception. The one exception is that such areas cannot provide a fully mature wetland habitat. This is particularly true for forested wetlands where it is not possible to immediately replace mature trees. Consultants believed that such created wetlands are producing plants, detrital export, wildlife habitat, and providing the floodwater accommodation and water filtering functions associated with all natural wetland areas. The U.S. Army Corps of Engineers and the Environmental Protection Agency are currently initiating research programs to determine more precisely the relative values of human-created wetlands versus natural wetlands, including areas in the southeastern United States.

FEDERAL AND STATE MITIGATION POLICIES

Are the methods and policies used by federal and state agencies to determine the type and amount of mitigation necessary to compensate for habitat destruction satisfactory? Consultants on the panel did not express concern with methods used to determine the amount of mitigation necessary for given projects. However, they did express a concern that existing mitigation policies appeared to be narrowly focussed on creating "in-kind" replacement for destroyed wetlands. That is, creation of a wetland type similar to that destroyed by permitted activities is usually required by the agencies. The consultants on the panel felt that alternative forms of compensation, such as placing threatened private wetlands in the public domain, should be given greater credit and consideration as a habitat preservation mechanism in terms of mitigation measures. They also strongly believed that there was a need for definite specific guidelines to be developed for application to mitigation measures in terms of what should be accomplished, why and how it should be carried out.

MITIGATION AS JUSTIFICATION FOR WETLAND DESTRUCTION

Is habitat mitigation being used to justify the inappropriate destruction of wetlands? Concern was voiced from a conservationists viewpoint that federal and state agencies have embraced mitigation to the extent that it is being used inappropriately as a tool to justify destruction of wetlands. Specific concern was also voiced about accepting mitigation sites in entirely different ecosystems from where the impact takes place. Also, concern was expressed about the lack of followup on mitigation projects to assure that they were constructed according to approved plans and achieve the desired results. Federal and state agencies indicated that they will soon be joining together to establish a formal mitigation followup program that will be focussed on assuring compliance with permit conditions and determining how improvements can be made in future mitigation projects.

MITIGATION AND PERMIT ISSUANCE

Does mitigation actually amount to buying a permit? Agency-representatives indicated that a great deal more complex evaluation is carried out for a proposal that will destroy habitat than just determining if mitigation is appropriate and/or adequate. The Corps of Engineers examines closely the water dependency of proposed permit activities, including those that involve some habitat destruction. Many factors, such as water dependency are closely examined before a decision to require mitigation is made by the Corps of Engineers. Those factors are analyzed to assure the activity is in the public interest. In some cases, these factors are not resolved and the permit is denied or withdrawn. While a lot of mitigation projects are carried out by large companies, some smaller groups have also carried out mitigation actions. Also, it was recognized that while large projects proposed by large companies have involved mitigation measures smaller companies and groups tend to propose smaller projects. Often these smaller projects can be modified to eliminate or minimize environmental damages and the corollary needs for mitigation. These smaller projects often have other alternatives, whereas the large corporations by virtue of existing plant sites of a need to be near deep draft navigation channels are often very restricted in their alternatives and must rely on mitigation measures.

MITIGATION AND DEVELOPMENT

Where does mitigation fit in with an overall development plan? Mitigation has been viewed as a means to allow destruction of wetland areas in certain places. It was pointed out that mitigation is often debated in context of larger issues, particularly the question of whether new major facilities should be located in designated industrial areas with access to deep draft navigation channels and in the process destroy some wetlands (that are in turn mitigated) or whether additional large-scale development should be forced into areas that have never been impacted by development. There was widespread recognition that additional development should best be directed through an overall comprehensive plan toward areas already generally developed, particularly those having deep draft channel access, with mitigation provided as appropriate.

PHILOSOPHICAL QUESTIONS

Conservationists expressed concern that as mitigation has been practiced, an overall loss of wetlands was continuing to occur and some parts of the ecosystem were being sacrificed while uncertain mitigation actions were being carried out in different areas. They believed that primary emphasis should be on protection, and further research should be carried out to determine the value of human-developed wetlands.

THE MISSISSIPPI-ALABAMA SEA GRANT CONSORTIUM EDUCATIONAL PROGRAM

Sharon H. Walker
Education Specialist
Mississippi-Alabama Sea Grant Consortium
Ocean Springs, Mississippi 39564-7000

ABSTRACT: The mission of the National Sea Grant College Program is to strengthen the understanding, use and conservation of our Nation's ocean and Great Lakes resources through research, education, and public outreach. Coincident with this mission, a primary goal of the Mississippi-Alabama Sea Grant Consortium (MASGC) is to enhance the marine literacy of people within Mississippi and Alabama through increasing awareness, understanding, and wise use and development of our coastal and marine resources. Historically, the educational component of the Consortium has represented a significant portion of the total program effort. The educational element interacts with the research component to promote formal education and in conjunction with the Sea Grant Advisory Service (SGAS) to serve as a vehicle for public education. The MASGC educational component has achieved both regional and national recognition. A primary educational achievement has been the six-year development and publication of a senior high school curriculum series, Man and the Gulf of Mexico (MGM). Another major achievement has been the minority education efforts conducted at Jackson State University (JSU). Sea Grant embodies a full range of educational activities within the Sea Grant trilogy of research, advisory service, and educational components.

INTRODUCTION

For those of you unfamilar with Sea Grant, I would like to share with you this background information. The National Sea Grant Program was created on October 15, 1966, with the signing of Public Law 89-688, The National Sea Grant College and Program Act, by President Lyndon B. Johnson. The term "Sea Grant" emphasizes the parallel between the Nation's present need to study its marine environment and the past need to develop the land, which was established with the signing of the Morrill Act of 1862. Just as the Land Grant Program is credited with a major role in developing the Nation's preeminence in agriculture, so is the Sea Grant Program striving to achieve similar success in the marine area.

Sea Grant is a partnership of government, institutions of higher learning, and industry which is comprised of 29 programs throughout the country. Sea Grant awards are made predominantly to Land Grant colleges and universities. Every coastal and Great Lakes state (except Pennsylvania) has a Sea Grant program, as well as Puerto Rico and the U.S. Trust Territories. The basic goal of the National Sea Grant program is to enhance the development, conservation, proper management, and economic use of our country's marine and aquatic resources. This goal is accomplished through research applied to current problems, education and training, and through the Sea Grant Advisory Service which is responsible for the transfer of technology and research from the laboratory to the public.

The Mississippi-Alabama Sea Grant Consortium (MASGC) is one of only three, two-state programs in the Nation. There are nine member institutions within MASGC: Auburn University, the Gulf Coast Research Laboratory, Jackson State University, Mississippi State University, the University of Alabama, the University of Alabama at Birmingham, the University of Mississippi, the University of South Alabama, and the University of Southern Mississippi. The Consortium has Sea Grant Advisory Service offices in Biloxi and Mobile. The administrative office is housed at the Gulf Coast Research Laboratory in Ocean Springs, Mississippi.

Before I begin with the educational objectives of the Consortium, I would like to share some national educational report findings with you. Within the last decade, there have been many (e.g. "A Nation at Risk," National Commission on Excellence, 1983; and "Educating Americans for the 21st Century," National Science Board, 1983) which have indicated that America's public schools are not meeting the national need in producing informed students capable of meeting the scientific and technological challenges which will alter our immediate environment, as well as our world.

The National Forum for School Science (1986) report revealed that 65 percent of our country's high schools require one year or less of science. In 1981 the National Center of Educational Statistics reported that less than 25 percent of our high school students take three years of science. Through personal communication with the State Departments of Education in both Mississippi and Alabama, I have learned that all 1986 high school graduates in Mississippi are presently required to take two years of science; as a district mandate a number of Mississippi schools require a third year of science for graduation. Alabama graduates are required to take two years of science for a standard diploma and three years of science for an advanced diploma.

The one bright hope which glimmers on this "cloudy" technological horizon is the classroom teacher. In 1978 the National Science Foundation reported that "What science education will be for any one child for any one year is most dependent on what that child's teacher believes, knows, and does - and doesn't believe, doesn't know, and doesn't do. For essentially all of the science learned in the school, the teacher is the enabler, the inspiration and the constraint." In fact, the teacher is the key to reversing the dangerous lack of interest in science by the coming generation.

In 1980 Klein reported that since the teacher is the most important instructional variable, a great deal of attention should be given to the teacher's own background and experience. Staff development at both the preservice and inservice level is essential if teachers are to remain the key in producing a scientifically literate populace. In 1986 Stone revealed that the area of marine education was particularly lacking in that most science methods courses are focused on the more general disciplines of biology and physical sciences. MGM teacher inservice workshops have been instrumental in providing marine concepts and activities for the participants to utilize in their classrooms, thereby striving to develop a cadre of teachers motivated toward instilling marine education in both inland and coastal classrooms.

OBJECTIVES

I would like to discuss the educational objectives of the Consortium from the viewpoint of these research findings and the needs of the citizens of Mississippi and Alabama. Our primary objective is to enhance the marine literacy of people within Mississippi and Alabama through increasing awareness, understanding, and wise use and development of our coastal and marine resources. In our view, meeting this objective should begin through the education of our young people. Before continuing, let me share two recent educational success stories with you. The first is that of the development and publication of the Man and the Gulf of Mexico (MGM) curriculum series for grades 10-12.

This series has met an educational need within high schools on both a regional and national basis, because it provided the availability and use of marine curricular materials for both students and teachers in the classroom.

Although the primary objective in the development and publication of these marine curricular materials has been to educate students, it became apparent during the MGM field-testing period that teachers needed to either learn or augment marine concepts which were outlined within the series. Therefore, teacher inservice workshops, to include preservice teachers, were an indirect result of the development and publication of the MGM series.

There are presently over 1300 teachers predominantly from Mississippi, Alabama, Louisiana, Florida, Texas, and Arkansas, who have participated in these intensive short courses during the past six years. In 1983 Irby revealed that these MGM participants have returned to the classroom and have either infused marine educational activities within existing curricula, or created new curricula for secondary school level students. It was further reported that both inland and coastal students master MGM subject matter equally well and that these students gain content knowledge and develop positive attitudes toward the marine environment. It should be noted that the MGM series is presently on the Addendum to the Louisiana State Adopted Science Textbook listing. Further, it is anticipated by the MGM Principal Investigator that this series will be placed on the Mississippi and Alabama State Adopted Science Textbook listing in 1987 and 1988, respectively.

Another highly successful program initiated by Sea Grant was developed by Dr. Sylvia Morgan of JSU, a historically black institution. The program design allowed a faculty team, using strict criteria, to select five post-sophomore students from one of four disciplines: geology, biology, chemistry, or physics. These students spent one year in an on-campus marine research training program with an appropriate mentor. Four of the students spent the summer of this one-year program at the Virginia Institute of Marine Science (VIMS) and one student went to the Duke Marine Laboratory in Beaufort, North Carolina. During this ten-week immersion in marine science, the students developed, presented, and defended their research. As a direct result, recruiters for interns from Michigan, California, North Carolina, and Virginia have contacted JSU for trainee placement. All of these students have remained in science, three in marine science and two in medicine. Two alternates, in the summer of 1986, attended VIMS, one in computer science and one in biology. Through personal communication with Dr. Morgan (1986), I learned that the president of JSU has received a letter from VIMS requesting students for the summer of 1987.

To complement our primary objective of enchancing the marine literacy of the populace within Mississippi and Alabama through increasing the awareness, understanding, and wise use and development of our marine and coastal resources, the educational element has four additional objectives: 1) to continue to monitor, assess, and coordinate the marine and coastal educational and informational needs of people of Mississippi and Alabama; 2) to develop and implement programs which respond to those needs such as facilitating the fellowship program, continuing to promote student research within MASGC member institutions, and maintaining science fair participation; 3) to disseminate Sea Grant research through workshops and presentations to educational professionals and civic organizations as well as through media; and 4) to foster an educational exchange between Sea Grant educators, nationwide, and educators in other state and federal agencies.

APPROACH

In order to meet these objectives and define areas of opportunity, our professional staff and SGAS program leaders frequently visit our nine member institution campuses. The process involved in program development activities following the campus visits includes: proposal development, review, evaluation, and implementation. Additionally, the education specialist attends state science teachers' meetings, evaluates and reviews manuscripts, cooperatively coordinates and conducts workshops and seminars as needed, interviews MASGC principal investigators and prepares quarterly progress reports, and assists in the dissemination of six Sea Grant supported newsletters and other publications. Thus, through the combination of these activities, results of Sea Grant research are broadly available to not only the scientific community but also the general public.

ACCOMPLISHMENTS

Recent MASGC educational achievements are as follows:

- A two-week Bahamian field trip for Mississippi and Alabama secondary school teachers and marine educators was conducted in the summer of 1985. The Mississippi-Alabama participants were introduced to three atypical marine habitats as compared to those habitats found in the Mississippi Sound, Mobile Bay, and portions of the Gulf of Mexico. These habitats included coral reefs, carbonate sediments and mangrove swamps.

- Teacher inservice, marine education workshops, which have included preservice participants, have been conducted for the past seven years. These workshops have been supported both by tuition and grant funds.

- Close contacts have been maintained with marine, scientific, and educational communities through the dissemination of a number of recurring newsletters and other publications to inform these invididuals of educational resources available through Sea Grant or other marine programs.

- A highly successful, national Sea Grant internship was completed in 1985. The internship was served with the National Advisory Committee on Oceans and Atmosphere in Washington, D.C. by a law student from the University of Mississippi. Additionally, three internships were sponsored by MASGC. One at the administrative MASGC office, one cooperatively with the Alabama Sea Grant Advisory Service and the National Marine Fisheries Service, with the third internship being served in the Mississippi Sea Grant Advisory Service. Through these national and local programs, highly skilled and motivated individuals have been provided the opportunity to work closely with government agencies or other organizations as participants at varying professional levels within that agency or organization.

- The MASGC, the University of Southern Mississippi (USM), and the Naval Ocean Research and Development Activity (NORDA) hosted the Mississippi Region VI Science Fair. The Consortium provided first, second, and third place trophies for grades one through twelve. NORDA provided the facility, and USM provided the registration and computer data. This involved six counties and over 1,500 students. On a state level, one student from Mississippi and one from Alabama are selected as recipients of the esteemed Sea Grant Scholarship Award, which involves support to the Discovery Hall Program offered at the Dauphin Island Sea Lab.

- A continuation of the MASGC competitive Graduate Fellowship Program for students attending member institutions was initiated in 1983 (Table 1). In 1986, MASGC awarded its first undergraduate fellowships, with four fellowships awarded to students attending member institutions. The students were provided the opportunity of attending one of two marine research laboratories in Alabama and Mississippi. This summer study gives the students an opportunity to engage in "hands-on" marine activities and research within the major science disciplines.

- In 1985, support was provided to enhance minority involvement at the pre-baccalaureate level in marine education at JSU. A cooperative program involving the Virginia Institute of Marine Science, the College of William and Mary, Exxon Corporation, JSU, and MASGC was initiated to enchance pre-baccalaureate minority student marine education opportunities. This program involved four students from JSU for summer research activities at VIMS.

- The Consortium provided travel, hotel accommodations, and a meal allowance for two master's degree recipients and one doctoral level recipient for the esteemed Sea Grant Association Awards, as well as for two high school Youth World of Water Awards recipients, thereby allowing the students to personally receive their respective awards.

- A total of 865 pre-baccalaureate and graduate students involving approximately 2400 man-months in time, have been supported through MASGC projects since 1971 (Table 2).

- Within the last decade, four secondary school programs have successfully increased the marine literacy of a large number of 15-17 year-old students. These schools which have been involved are: Biloxi, Ocean Springs and Pascagoula High Schools, as well as the Piney Woods Country Life School. Biloxi, Ocean Springs, and Pascagoula are all coastal schools with a mixed student population. The Piney Woods Country Life School is an inland school of minority students.

- Two permanent exhibits were established. One is located in the Mobile County Environmental Studies Center (MCESC) in Alabama. The MCESC is supported by the County Public School System. The other permanent exhibit is located in the Scranton Museum. The Scranton is a 70 foot refurbished shrimp boat, supported by the City of Pascagoula, Mississippi. In the MCESC a 160-gallon, salt-water tank was established for fishes indigenous to the Mississippi Sound and Mobile Bay. Annually, over 20,000 students from local schools visit this marine educational facility. Aboard the Scranton, a 19"-video-monitor and video-cassette recorder have been installed, as well as a touch-tank located on the stern of the ship. Several educational videos are available for viewing by students and the general public in both facilities.

- A final 10th-12th grade level text of the MGM series entitled Coastal Marine Environments was developed and reviewed for scientific validity during 1985-86. It will be field-tested in the fall of 1987 in various schools in Mississippi, Alabama, and Louisiana.

- A birding guidebook, Birds and Birding on the Mississippi Coast, has been written, reviewed, and revised. It is presently in press with a September 1987 availability date. The design of the guide is suitable for both amateur birdwatchers and professional orinthologists. Information provided in this publication will include breeding status, abundance, geographical distribution, and habitat type for more than 300 species of birds.

- The MASGC educational specialist has been invited to act in the following roles of significant educational importance:

  Regional Director for the Southeastern Mississippi Valley Annual Youth World of Water Awards Program, involving eight states and 16 student applicants in 1985 and eight student applicants in 1986.

  Chairperson for the National Sea Grant Educational Network in 1985-87 which involves coordinating the educational activities which will occur during the annual Sea Grant Week Conference.

  Co-Director of the Mississippi Regional VI Science and Engineering Fair which involves coordinating and organizing this six coastal county event.

  Additionally, the educational specialist has been invited to present papers on Sea Grant's role in promoting education to a number of organizations.

CONCLUSION

Marine education activities in the states of Mississippi and Alabama have expanded tremendously over the past few years. These activities have made important contributions in educating our students, teachers, and the general public concerning the environment, and is an effort that is not complete. The concept is just now beginning to build into a significant force for change. We must never allow ourselves to express our educational standards and expectations in terms of minimum requirements or to become lethargic. It is essential that we continue to aggressively increase our efforts in order to have a well-informed population.

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Table 1

1983-1986 SEA GRANT FELLOW SUMMARY

Total Number of Students: 18

Number of Males: 13

Number of Females: 5

Race: a) white - 17
b) black - 1

Degrees by Category: a) Bachelor's - 4
b) Master's - 8
c) Doctoral - 6

Member Institutions Represented:

a) University of Alabama at Birmingham - 2
b) University of Alabama - 4
c) Auburn University - 3
d) University of South Alabama - 1
e) University of Mississippi - 2
f) Mississippi State University - 1
g) University of Southern Mississippi - 4
h) Jackson State University - 0
i) Gulf Coast Research Laboratory - 1

Table 2

Year	GRADUATES		UNDER-GRADUATES		TOTALS	
	Students	Man-Months	Students	Man-Months	Students	Man-months
1971	34	117	0	0	34	117
1972	81	242	0	0	81	242
1973	74	142	0	0	74	142
1974	68	264	7	8	75	272
1975	55	195	11	24	66	219
1976	70	284	30	17	100	301
1977	58	170	25	28	83	198
1978	40	142	2	3	42	145
1979	39	107	0	0	39	107
1980	37	87	4	3	41	90
1981	33	103	6	11	39	114
1982	46	132	8	12	54	144
1983	32	71	19	26	51	97
1984	35	63	3	8	38	71
1985	24	64	1	1	25	65
1986*	19	23	4	7	23	30
	745	2206	120	148	865	2354

*Man-month figures for 1986 are budget figures. All other figures on this line were taken from Financial Reports received as of January 16, 1987.

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PROJECT SEA OATS

AN EXAMPLE OF INTERAGENCY

COOPERATION TO PROMOTE MARINE EDUCATION

D. Lloyd Scott
Environmental Studies Center
P.O. Box 1327
Mobile, Alabama 36633

ABSTRACT: A vital component of the movement to better understand and appreciate our estuarine resources is the inclusion of structured marine education programs in our elementary and secondary schools. Further, the success of these programs depends greatly on careful planning and close cooperation between area agencies offering funds and resources for implementation. This presentation focuses on one such program conducted recently through joint effort by the Mobile County Schools' Environmental Center, the Dauphin Island Sea Lab, the Alabama Sea Grant Advisory Service and the Mississippi-Alabama Sea Grant Consortium. A summary of the results of this project will be presented in hopes of encouraging similar cooperative efforts in the future.

COASTAL AWARENESS ACTIVITIES

IN MOBILE AND BALDWIN COUNTY MIDDLE SCHOOLS

Jennifer V. Cook
Dauphin Island Sea Lab
P.O. Box 369
Dauphin Island, Alabama 36528

ABSTRACT: A series of units have been written and designed to incorporate coastal awareness activities into the already existing middle school science curricula of Mobile and Baldwin County schools. Funded and initiated by ADECA, the staff of the Discovery Hall Program at the Dauphin Island Sea Lab have developed these units with objectives aimed to awaken the student to the concepts and issues surrounding the natural processes and man's uses of Alabama's coastal environment. Classroom and field activities emphasize the value of Alabama's coastal resources while presenting content matter in an attempt to produce future decision-makers and voters who will make educated and well informed decisions concerning our coast. A brief overview of these units will be presented.

EDUCATION EFFORTS

AT THE WEEKS BAY NATIONAL ESTUARINE RESERVE

John L. Borom
Faulkner State Junior College
Fairhope, Alabama 36532

ABSTRACT: Effective April 7, 1986, Weeks Bay National Estuarine Reserve was established as a protected education and research site. The initial boundaries encompassed 2,668 acres of land and water in and around Weeks Bay. Acquisition of additional tracts is planned for expansion of the reserve. The Alabama Department of Conservation and Natural Resources is responsible for overall management of the reserve. Weeks Bay estuary is a field laboratory for scientists and students and a place for the public to learn about estuarine ecology in a natural setting. Future plans include development of nature trails and construction of an estuarine science education research center to be managed by Faulkner State Junior College. Other organizations playing key roles at the reserve are the Baldwin County Board of Education, The Nature Conservancy, the University of South Alabama and the Mississippi-Alabama Sea Grant Consortium.

EDUCATIONAL EFFORTS

Summary of Panel Discussion

The participants on the "Educational Efforts Panel" were:

Moderator: George F. Crozier, Dauphin Island Sea Lab
Sharon H. Walker, Mississippi-Alabama Sea Grant Consortium
D. Lloyd Scott, Environmental Studies Center
Jenny V. Cook, Dauphin Island Sea Lab
John L. Borom, Faulkner State Jr. College

INTRODUCTION

In general, three topics were covered during the panel discussion. The topics pertained primarily to the future of marine environmental educational programs in Alabama, funding of these programs, and cooperative programs.

MARINE ENVIRONMENTAL EDUCATIONAL PROGRAMS

Alabama's educational systems have been under considerable fiscal constraint for some time now. Faced with seven to ten years of budget cuts, prorationing and the like, these programs have reluctantly had to reduce the scope of their activities. Examples of this can be seen at the Sea Lab's Discovery Hall Program which has gone from two full time professionals to 1 1/2. The Sea Grant Consortium has gone from supporting a full time specialist to a half time specialist. The Environmental Studies Center has lost staff and faces further budgetary problems.

FUNDING CONSIDERATIONS

The funding situation is not anticipated to improve anytime in the near future. Maintaining the current level of funding may prove to be a considerable challenge. The priority which is given marine environmental educational programs by the State and Federal legislators reflect their attitudes about the relative worth of the benefits that these programs provide.

COOPERATIVE EFFORTS

Given the present fiscal constraints placed on our marine environmental educational programs, the cooperative efforts will become more important in maintaining program delivery and the integrity of whats been developed so far. Pooling of available resources in the form of man-power, facilities and funding could forestall, to some degree, the inevitable effects of inadequate funding. Hopefully, the beneficaries of these cooperative efforts will prevail, at some future date, on the legislators to expand and enhance these efforts.

NUMERICAL MODELLING OF SALINITY PROPAGATION IN MOBILE BAY

Donald C. Raney
Professor of Engineering Mechanics
The University of Alabama
Tuscaloosa, AL 35487-2908

John N. Youngblood
Professor of Mechanical Engineering
The University of Alabama
Tuscaloosa, Alabama 35487-2995

ABSTRACT: The purpose of this study was to investigate the general nature of salinity propagation in Mobile Bay, Alabama as it is affected by river inflow levels and tidal effects. A two-dimensional-depth-averaged finite difference numerical model (BAY) is utilized. This model has been demonstrated to produce salinity results that are in very good agreement with prototype values when applied to other well mixed bays. No rigorous effort is made to verify quantitatively the solutions that were generated for Mobile Bay because of a lack of synoptic prototype data with which to calibrate and verify the numerical model. The model was simply driven with typical tidal and river inflow levels to qualitatively investigate the salinity variation over a tidal cycle. With the increased importance of Mobile Bay and plans to deepen the main channel additional numerical modelling efforts are required to evaluate the environmental effect of proposed changes. However, the need for additional numerical modelling activity points out the more fundamental requirement for a synoptic data collection program in Mobile Bay to provide fundamental prototype data for a variety of scientific disciplines.

THE HYDRODYNAMIC MODEL

A two-dimensional depth averaged model (BAY) is used in this investigation. The vertical components of velocity and acceleration are neglected and the general three-dimensional governing hydrodynamic equations are integrated over the water depth. A pseudo three-dimensional effect is present since the equations are forced to satisfy the boundary conditions at the bottom and surface of the water column. A depth-averaged two-dimensional flow field is obtained but three-dimensional geometry can be considered. The most important approximations used in the model are those of constant density and relatively small variations of velocity over the depth, conditions which are reasonably valid much of the time in Mobile Bay. The rectangular coordinate system used is located in the plane of the undisturbed water surface as shown in Figure 1.

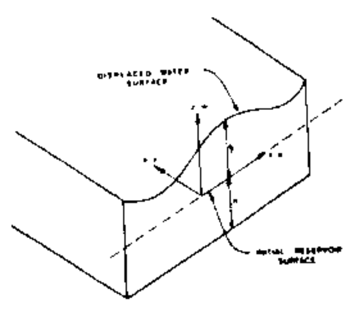


Figure 1. Model Coordinate System

A major advantage of BAY is the capability of applying a smoothly varying grid to the given study region.[1] This allows efficient simulation of complex geometries by locally increasing grid resolution in critical areas. For each coordinate direction, a piecewise reversible transformation is independently used to map prototype or real space (x,y space) into a computation space (α_1,α_2 space). The transformation takes the form

$$x = a + b\alpha^c$$

where a, b and c are arbitrary constants. By applying a smoothly varying grid transformation which is continuous and which has continuous first derivatives, many stability problems commonly associated with variable grid schemes are eliminated provided that all derivatives are centered in α space. The transformed basic governing equations of momentum and continuity in α space can be written as

$$\frac{\partial u}{\partial t} + \frac{1}{\mu_1} u \frac{\partial u}{\partial \alpha_1} + \frac{1}{\mu_2} v \frac{\partial u}{\partial \alpha_2} + \frac{g}{\mu_1}\frac{\partial \eta}{\partial \alpha_1} - fv = R_x + L_x$$

$$\frac{\partial v}{\partial t} + \frac{1}{\mu_1} u \frac{\partial v}{\partial \alpha_1} + \frac{1}{\mu_2} v \frac{\partial v}{\partial \alpha_2} + \frac{g}{\mu_2}\frac{\partial \eta}{\partial \alpha_2} + fu = R_y + L_y$$

$$\frac{\partial \eta}{\partial t} + \frac{1}{\mu_1}\frac{\partial}{\partial \alpha_1}\{(h+\eta)u\} + \frac{1}{\mu_2}\frac{\partial}{\partial \alpha_2}\{(h+\eta)v\} = 0$$

where

u = depth-averaged velocity component in the x direction

t = time

x,y = rectangular coordinate variables

v = depth-averaged velocity component in the y direction

g = acceleration due to gravity

η = water level displacement with respect to datum elevation

f = Coriolis parameter

R_x, R_y = the effect of bottom roughness in x and y directions

L_x, L_y = the acceleration effect of the wind stress acting on the water surface in the x and y direction

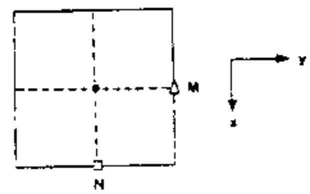
h = water depth

$\mu_1, \mu_2 = \frac{\partial x_1}{\partial \alpha_1}, \frac{\partial x_2}{\partial \alpha_2}$ = grid expansion factors

To solve the governing equations, a finite difference approximation of the equations and an alternating direction technique are employed. A space-staggered scheme is used in which velocities, water-level displacement, bottom displacement, and water depth are described at different locations within a grid cell as shown in Figure 2. This solution scheme is similar to that originally proposed by Leendertse.[2]

Three types of boundaries are involved in the calculations: Solid boundaries at fixed coastlines, artificial tidal input boundaries arising from the need to truncate the region of computation and river inflows into the bay.

The finite difference grid used for the model of Mobile Bay-East Mississippi Sound was developed using a 1:80000 scale nautical chart.[3] A variable grid was developed with the primary objective of good resolution of the main ship channel as well as reasonable representation of other geometric and bathymetric features. The dimension of the resulting grid was 55 by 56 cells or 3080 total cells. After mapping the



□ - VELOCITY IN THE X-DIRECTION (U)

Δ - VELOCITY IN THE Y-DIRECTION (V)

• - SURFACE ELEVATION (η)
WATER DEPTH (d)
FRICTIONAL COEFFICIENT (C or n)
SALINITY (s)

Figure 2. Variable Definition in Finite Difference Cell

grid, it was used as an overlay on the nautical chart to assign boundaries, depths and Manning friction coefficients for each finite difference cell. The finite difference grid is apparent in Figure 3 where each velocity vector is plotted at the center of a finite difference cell.

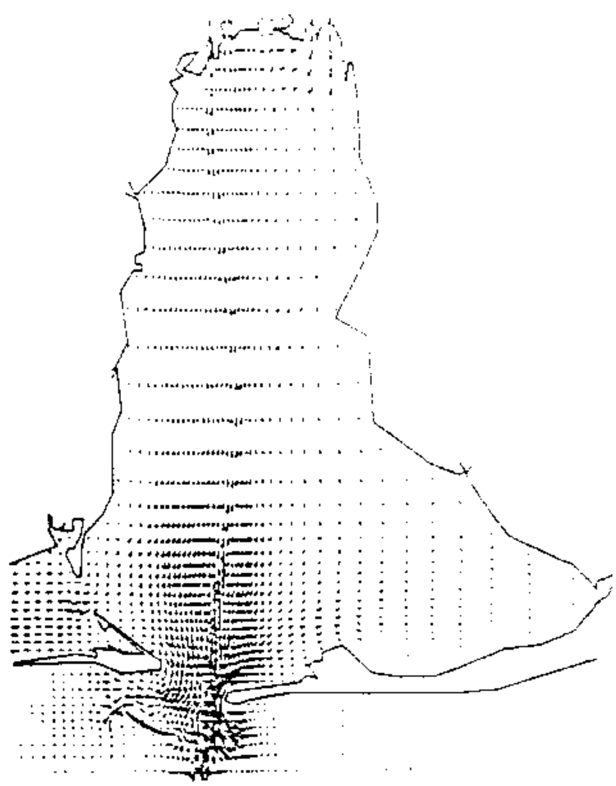


Figure 3. Mobile Bay Finite Difference Grid and Circulation Pattern

Small cells were used in the inlets since these are critical areas for the tidal hydraulics. Larger cells were used in Bon Secour Bay, the Gulf of Mexico and in upper Mobile Bay where the bathymetry was reasonably constant and/or boundary geometry was relatively simple.

Tide-elevation boundary conditions were specified at the Gulf of Mexico boundary and the East Mississippi Sound boundary. River-flow boundary conditions were specified for the Mobile and Tensaw Rivers.

THE TRANSPORT MODEL

A two-dimensional depth-averaged transport model (TRANS) was developed to complement BAY in the simulation of water quality effects. The vertical components of advection and diffusion are neglected and depth averaging is performed in a manner similar to the hydrodynamic model. The coordinate system and the nonlinear grid transformation that were previously used in the hydrodynamic model were repeated in TRANS.

The transformed equation of transport can be written as

$$\frac{\partial}{\partial t}\{(h+\eta)P_i\} + \frac{1}{\mu_1}\frac{\partial}{\partial \alpha_1}\{(h+\eta)uP_i\} + \frac{1}{\mu_2}\frac{\partial}{\partial \alpha_2}\{(h+\eta)vP_i\}$$

$$-\frac{D_i}{\mu_1^2}\frac{\partial}{\partial \alpha_1}\{(h+\eta)\frac{\partial P_i}{\partial \alpha_1}\} - \frac{D_i}{\mu_2^2}\frac{\partial}{\partial \alpha_2}\{(h+\eta)\frac{\partial P_i}{\partial \alpha_2}\} =$$

$$(h+\eta)S_i + \sum_{j=1}^{N} K_{ij}\ (h+\eta)P_j$$

for $i = 1,N$

where

P_i = concentration of the ith constituent

D_i = molecular diffusion coefficient, assumed homogeneous and uniform

K_{ij} = reaction coefficient for constituents j on i

S_i = source input rate

N = the number of constituents

and others as described in the previous section.

To solve the transport equations a similar space-staggered, alternating direction scheme is defined on the same grid as the hydrodynamic model. The transport model may be used as a subprogram by the hydrodynamic model to generate solutions at selected steps, or it may be a self-contained simulation relying only on hydrodynamic data from earlier simulations. In each case, it is convenient to embody a compatible grid definition. Since the primary purpose of this study was to perform salinity calculations, repeated solutions were obtained with hydrodynamic data that had been previously verified.

THE STUDY AREA

Mobile Bay is located on the northeastern shoreline of the Gulf of Mexico east of the Mississippi River delta. The estuary is about 31 miles long and varies in width from 8 to 10 miles in the northern half to about 24 miles wide in the southern portion. The bay is connected by narrow passes to the Gulf of Mexico and also to Mississippi Sound. A representation of the bay is shown in Figure 4.

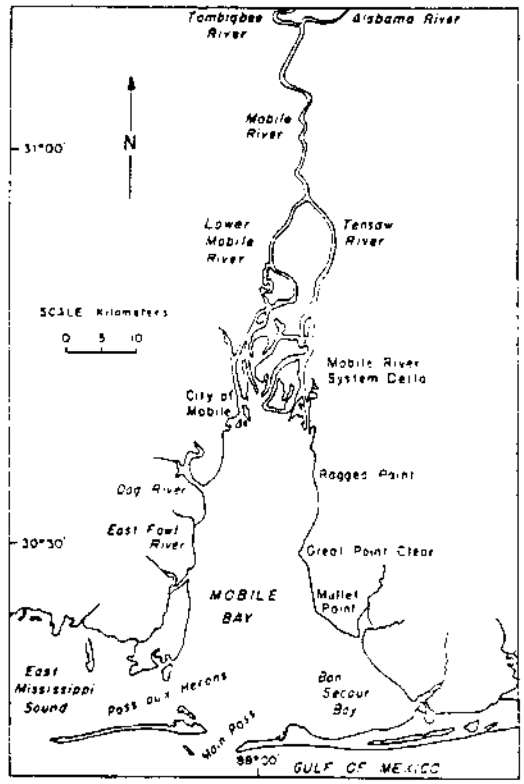


Figure 4. Mobile Bay - The Study Area

The bay is the terminus of a river system which consists of more than 43,000 square miles of drainage basin. The average depth of the bay is 9.8 feet at mean low tide and the hydrodynamic characteristics are vertically uniform over most of the bay. In areas of deeper water within the protected bay, salinity stratification does occur. In the lower bay there is cyclic lateral movement of large volumes of water of variable salinity. Within the dynamic region stratification is minimized by vertical mixing.

Water outside the lower bay has the salinity of sea water. Dynamic excursions of high-salinity water through the passes and into the bay are governed primarily by tidal action. Salinity decreases rapidly through the middle regions and into the upper portion of the bay. Also short-term tidal lateral motion decays rapidly in the middle bay.

Salinity levels in the upper bay are primarily affected by fresh water inflow rates. During periods of heavy rainfall, all but the lower sections of the bay become virtually fresh water. On the other hand, during dry periods, sea water incursion can extend into the lower reaches of Mobile River.[4]

The narrow band across which the salinity changes from low to high values affects the preferred location of a wide variety of marine organisms. Fluctuations in the position of the band can become a serious determent. For example, periods of low salinity due to spring floods have killed major portions of the oyster crop numerous times in this century.[5] On the other hand extreme excursions of sea water in dry periods bring invasions of high salinity predictors such as the oyster drill causing great damage to marine life in the upper bay.[4]

The application of the transport model to the study of salinity propagation in the bay was initiated to establish its general validity in estimating the long and short term motion of waters of various salinity. The trends that were established using the model can be compared to actual salinity data[6] to judge the effectiveness to the model.

While a complete calibration and verification test was not possible using the data at hand, the present test allows a number of significant comparisons. Of particular interest is the general shape of the isohalines for a particular river inflow and time in the tidal cycle. A very significant estimate is the location of the fresh-to-saline transition region in the bay as a function of river inflow. Another interesting calculation is the lateral range of isohaline movement over a tidal cycle.

MODEL APPLICATIONS

Salinity exchange and diffusion in an irregular geometry and large flow rate process is very complex. Simulation problems can be largely overcome with effective hydrodynamic and water quality models. Effects of stratification are minimized naturally in large volume, highly dynamic processes, where mixing is stimulated. Since three-dimensional models are prohibitive for high resolution studies, other means of dealing with vertical non-uniformity involve judicious choices of model parameters and estimation from time averages.

This model can effectively simulate tidal action, river discharge, and steady wind conditions as well as predict their effects on bay hydrodynamics. The transport model can effectively use the hydrodynamic data to generate information about water quality, in particular, depth-averaged salinity.

A representative 2 foot diurnal tidal cycle was taken for Mobile Bay and Mississippi Sound, and nominal river inputs were assumed in the upper bay.[7] The tide in East Mississippi Sound was given a 3 hour phase lag relative to the bay. The hydrodynamic model was run with a time step of 90 seconds. Elevation and velocity data at all points in the bay were taken at 30 minute intervals for 24 hours, after an initial 12 hour start up. The hydrodynamic data was then cycled at the tidal frequency to drive the water quality model. The salinity model could be run for a number of tidal cycles repeating the hydrodynamic data for the single tidal cycle.

The water quality model was started with a uniformly increasing salinity from zero at the upper bay to 34 ppt. at the gulf interface. A distinctive, time varying, reasonably stable pattern was achieved after 5-10 tidal cycles.

A river system inflow rate equal to a nominal measured value was used. This moderate value was 33270 cfs for the Mobile River and 30230 cfs for the Tensaw River. A heavy inflow rate of 100% greater value was used for comparison. The lateral shift to the entire salinity distribution pattern appears to be a sensitive function of the river discharge level. No fresh water input other than that of the Mobile and Tensaw river system was modeled.

The salinity pattern for moderate river discharge is shown in Figures 5 through 8. The isohalines have a distinct northwest to southeast orientation. This effect has been noticed in sampling studies.[6]

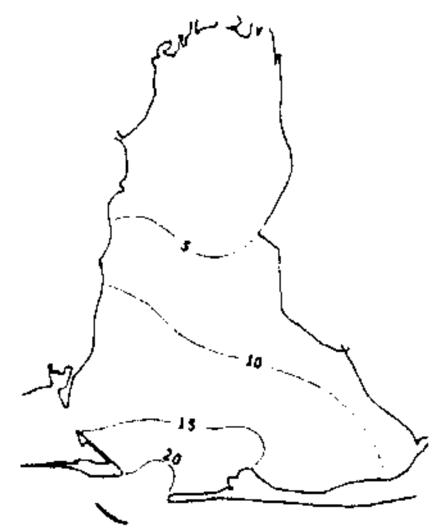


Figure 5. Moderate Rivers Discharge:Incoming Tide

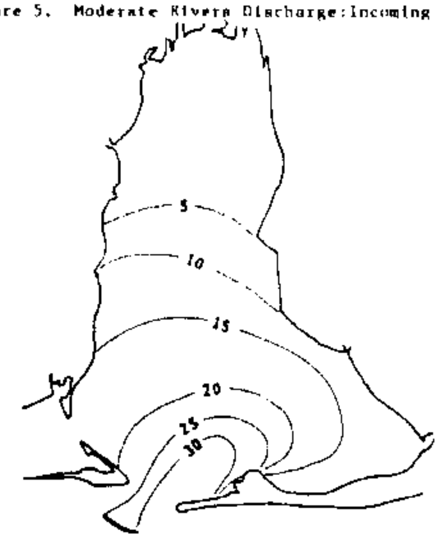


Figure 6. Moderate Rivers Discharge:High Tide

The general shape and location of the isohalines compare favorably with those determined by measurement. The salinity patterns measured and reported by Schroeder[6] are more tongue shaped, indicating a higher degree of fresh water extending down the shoreline toward the lower bay. The most apparent explanation of this effect is the fact that fresh water input was neglected at all points other than the main river delta.

Motion of the isohalines over a tidal period is considerably more pronounced in the lower bay. A range of approximately 6 to 10 miles is seen for the 15 ppt line, but the range for the 5 ppt line is only 3 to 5 miles. This is to be expected as tidal dynamics are

HALINE STRATIFICATION IN MOBILE BAY

A SHORT REVIEW

William W. Schroeder
Marine Environmental Science Consortium
P.O. Box 369
Dauphin Island, Alabama 36528

ABSTRACT: Since the work of Austin (1954) it has been known that strong haline stratification occurs within the waters of Mobile Bay. Subsequent studies (Loesch 1960; McPhearson 1970; Bault 1972; May 1973; Schroeder 1976, 1977, 1978, 1979; Schroeder and Lysinger 1979; Schroeder and Wiseman 1986, in press) have documented the spatial and temporal variability as well as identified processes responsible for stratification- destratification cycles. Vertical salinity gradients of 5 to 10 ppt are common in oligohaline regimes (0 to 10 ppt) through euryhaline regimes (20 to 30 ppt). During flooding events surface to bottom differences of over 25 ppt have been measured in the lowered Bay. The greatest changes in salinity have been observed in haloclines with gradients of 16 ppt in less than 2 m.

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LOW DISSOLVED OXYGEN PHENOMENA

IN ALABAMA'S ESTUARIES

Stevens R. Heath
Marine Resources Laboratory
P.O. Box 188
Dauphin Island, Alabama 36528

ABSTRACT: For many years much circumstantial evidence has been compiled indicating a significant problem with areas of low dissolved oxygen in Alabama's estuarine and marine waters. A variety of events ranging from fish kills to popular "jubilees" have occurred in these areas for many years. However, very little sound scientific data have been collected to determine the causes. A historical overview of events is presented along with a general scenerio of impacts and results of low dissolved oxygen conditions. Recommendations of possible research projects to meet data needs are presented.

ORGANIC POLLUTANT LEVELS IN BIVALVES OF MOBILE BAY

Ken R. Marion
Department of Biology
University of Alabama at Birmingham
Birmingham, Alabama 35294

Steven A. Barker
School of Veterinary Medicine
Louisiana State University
Baton Rouge, Louisiana 70803

Robert L. Settine (deceased)
Department of Chemistry
University of Alabama at Birmingham
Birmingham, Alabama 35294

ABSTRACT: Organic pollutant levels in Mobile Bay were monitored seasonally over a four-year period by identifying and quantifying contaminants (via GC/MS analysis) found in the tissues of the American oyster (*Crassostrea virginica*) and the brackish water clam (*Rangia cuneata*). A wide variety of organic contaminants were found. Compounds identified with insecticides, solvents, plasticizers, intermediary compounds, coal tars, and fossil fuels occur. Concentrations, however, generally were in the low ppb range, with the exception of phthalates, which exceeded one ppm at a few sites. Some seasonal trends exist and inter-site variability occurs, with a tendency for slightly higher levels and increased variety of pollutants in bivalves from the upper reaches of the Bay. Overall, the results indicate that organic pollution in Mobile Bay is currently not severe, but needs to be closely monitored for further changes. This data will serve as a baseline for future environmental quality trends in Mobile Bay.

INTRODUCTION

Mobile Bay is one of the major estuaries within the boundaries of the United States. The waters flowing into Mobile Bay drain a watershed that includes sizeable portions of three states. With an average flow of 62,500 cubic feet per second, the discharge rate into the Bay is the fourth largest of all river systems in the United States (Loyacano and Busch, 1979). Mobile Bay is also one of the major estuarine nursery grounds of coastal North America. Large quantities of shrimp, oysters, crabs and fish are harvested in or adjacent to the Bay and have historically been a major economic resource to the region. During 1985 alone, 29.5 million pounds of seafood were harvested in coastal Alabama. This harvest had a dockside value of 40.0 million dollars and a retail value in excess of 300 million dollars (pers. comm.; Ala. Sea Grant Advisory Svc.). More than 5,000 people in Baldwin and Mobile Counties participate annually in the harvest of seafood for all or part of their livelihood. Processing operations employ up to 2,000 people on a seasonal basis (CAB report, 1980).

Mobile Bay, however, is an estuarine ecosystem experiencing a growing series of events that have the distinct potential for lowering its environmental quality. Over the last two decades, industrial and commercial development have expanded rapidly in the Bay area. Much of this development has occurred in the chemical industry. A number of large chemical-oriented industries stretch from the Mobile River north of the city to a point halfway down the Bay. As a result, a whole volume of chemical by-products and intermediates, the effects of many of which are unknown, likely eventually find their way into the waters of Mobile Bay. In 1980, more than 130 million gallons of industrial wastewater (primarily from 39 major industrial sources) and 32 million gallons of treated wastewater from 19 municipal plants already poured into Mobile Bay on a daily basis. These discharges were in addition to those from various non-point sources (CAB report, 1980). An outfall with a capacity of 25 million gallons/day of industrial effluent and treated wastewater is planned to open directly into the Bay from one industrial park. The South Alabama Regional Planning Commission also has indicated that approximately 4,000 additional acres of industrial land will be required to satisfy the anticipated industrial requirements for the year 2000. Due to the water dependency of this industrial base for both shipping and as an intake source, 3,000 of these acres will need direct access to the Bay or its tributaries (CAB report, 1980). Thus, when added to the runoff reaching the Bay from industrial, urban and agricultural areas upstream in the large watershed, it is clear that future industrialization will likely bring increased pressure on current water quality and existing ecosystems in Mobile Bay.

The recent opening of the Tennessee-Tombigbee Waterway, the possible expansion of the Alabama State Docks, and the anticipated deepening of the Mobile Bay ship channel will also all likely contribute to the increasing environmental pressures on the Bay. The resulting additional barge and tanker traffic will increase the possibilities for spills and accidents. Oil and natural gas exploration is also moving toward the production phase. Finally, population levels are gradually increasing in Baldwin and Mobile Counties. A population of near one-half million is projected for the year 2000 (CAB report, 1980).

Directly or indirectly, all of these respective activities reflect the likelihood that Mobile Bay is being subjected to increasing levels of a wide variety of potential pollutants, ranging from heavy metals to organic compounds. Many of these are known to be detrimental to living organisms, the public health and the integrated functioning of ecosystems. It is evident that some baseline information on the current water quality of Mobile Bay is badly needed for future decision-making involving resources and development. Recognizing this, we initiated a multi-year study using bivalves as biological monitors of the water quality of Mobile Bay by identifying and quantifying the major organic pollutants found in their tissues.

BIVALVES AS INDICATORS OF POLLUTION

Bivalves have been employed in a number of studies as biological indicators or monitors of estuarine pollution. They possess several characteristics which make them good bio-indicators of pollution:

1. Since most bivalves are filter-feeders, their tissues accumulate and concentrate a wide variety of environmental contaminants.
2. Because they concentrate pollutants at much greater levels than those found in the immediate water column, accurate analyses are therefore easier and reproducible.
3. Their sessile nature allows an evaluation of local pollution problems.
4. Bivalves generally reflect the relative composition of contaminants in the ambient water, as relatively little metabolism of most compounds has been reported.
5. There is a persistence of many pollutants in their tissues, even after long depuration periods.
6. They represent a time-integrated sample, rather than a measurement of a single point in time (eg., a water sample).
7. The ease of collecting and high densities in coastal waters make bivalves readily available monitors and the ubiquitous distributions of many species permits comparisons to be made with other studies (NAS, 1980).

Though the interpretation of pollutant levels in bivalves must be with full cognizance of their limitations (as regards the seasonal reproductive and lipid cycles effects on the uptake and storage of hydrocarbons, uptake and depuration rates, etc.), the concept of using bivalves as bioindicator organisms of estuarine pollution is a generally accepted, direct and practical method for pollution analyses. Using this method, it is possible to show exactly which contaminant compounds are reaching and influencing biotic systems.

PREVIOUS STUDIES OF ORGANIC POLLUTANTS IN BIVALVES OF MOBILE BAY

Studies on oyster populations in Mobile Bay provided early suspicions of pollution problems. May and his co-workers reported decreased survivorship and recruitment during the 1960's and early 1970's, and suggested increased pollution as one of the important elements in the decline of oyster resources occurring in the Bay at that time (May, 1971). Eckmayer (1979) provided continued documentation of this decline, citing industrial pollution and possibly pesticides as two important contributors.

Few actual studies on chemical pollutant accumulations have been performed on oysters from Mobile Bay, with none on other bivalves, and all of these have been rather limited in scope or in pollutant types surveyed. Chlorinated hydrocarbon pesticides were examined in oysters from several Bay reefs by Casper et al. in 1965 (published in 1969), Butler in 1968-69 (published in 1973), and again by Butler et al. in 1977 (published in 1978). The first two studies detected several pesticide compounds in oyster tissues, and revealed that DDT and its metabolites were found at essentially all sites examined and were by far the most common of the chlorinated pesticides. The site averages for total DDT in the 1965 study ranged upwards to 4.6 ppm, close to the level of 7.0 ppm then allowable by the Food and Drug Administration as a residue in meat and food items destined for human consumption. Pesticide levels in oyster tissues, however, decreased during the period of the three studies, with the latter study reporting no detectable residues in a one-shot sample from two of the original collecting sites.

In the more extensive study by Casper et al. (1969), definite seasonal fluctuations in DDT levels were noted, with peak values coinciding with maximum freshwater inflows during spring. Significant differences were also noted in oysters taken from different reefs.

The only other examination of organic contaminants in oysters from Mobile Bay was performed by Goldberg and others in January, 1977, as part of an extensive and broad survey of fossil fuel contamination of selected U.S. coastal sites in conjunction with the EPA Mussel Watch Program. The tissue concentrations of a very limited number of polycyclic aromatic hydrocarbons were analyzed from a site near Dauphin Island. The results indicated moderate accumulations of fluoranthene and pyrene for this one sampling collection (NAS, 1980).

Thus, previous studies of organic contaminants in bivalves from Mobile Bay have been limited in scope and have dealt primarily with early pesticides. Almost nothing is known concerning levels of most organic contaminants of a primarily industrial origin. In addition, there is currently no routine monitoring of most chemical pollutants in the water and sediments of the Bay. Recent increased industrialization and other changes in the Mobile area have provided a potential ready source of many contaminant hydrocarbons, which to date have gone virtually unmonitored in Mobile Bay.

DESIGN OF STUDY AND METHODOLOGY

Oysters (Crassostrea virginica), limited to areas of moderate salinities, were collected at seven sites in the lower half of Mobile Bay during 1982 and 1983 (Fig. 1). Brackish water clams (Rangia cuneata), more tolerant of freshwater than oysters, were collected at ten sites, generally in the upper half of the Bay, during 1983 and 1984 (Fig. 1). Several of these sites were located near industrialized areas of the City of Mobile. Samples of both oysters and clams were collected during each of three seasonal periods (spring, summer, and fall), with the exception of clams in 1983, which were collected only during summer. During summer 1984, bivalves were placed in baskets and transplanted for three months to eight additional sites (Fig. 1), primarily selected to investigate areas previously uninvestigated or suspected to be potential pollutant "hotspots."

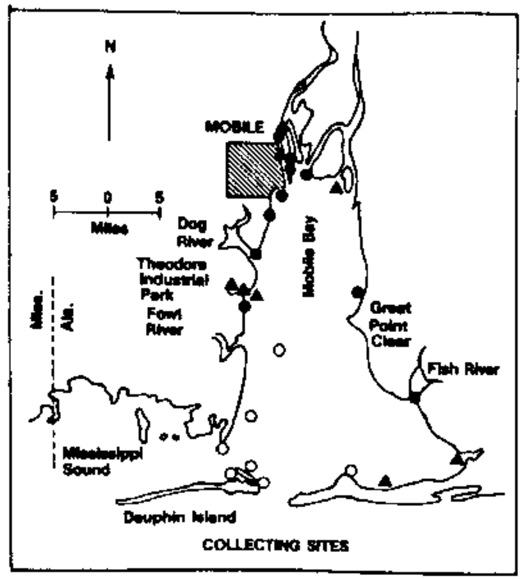

Fig. 1. BIVALVE COLLECTING SITES IN MOBILE BAY. Open circles = oysters (Crassostrea virginica; closed circles = clams (Rangia cuneata); triangles = transplanted bivalves.

Extraction methodology, and identification and quantification of compounds in bivalve tissues followed procedures previously reported (Settine et al., 1983). Identification and quantification of compounds was performed by gas chromatography/mass spectrometry. Fifty-nine compounds from the U.S. Environmental Protection Agency's list of priority pollutants (NAS, 1980) were selected for analysis (Table 1). Such compounds qualify for listing on the basis of their known occurrence in the environment, their known or suspected health effects, their persistence in the aquatic food chain, and their known or suspected toxicity to aquatic organisms. We specifically selected compounds for investigation in order to reflect major groups of probable contaminants from agricultural, industrial, and transportation-related sources.

ORGANIC POLLUTANTS IN BIVALVES

The results of our study have shown that a wide variety of organic contaminants that appear on the U.S. Environmental Protection Agency's list of priority pollutants occur in the tissues of bivalves from Mobile Bay. Contaminants found, their frequency of occurrence at sampling sites, the percentage of positive samples collected, the maximum concentration found, and the mean concentration of all positive samples are presented for oysters in Table 2, for clams in Table 3, and for bivalves transplanted to other areas of

TABLE 1. LIST OF EPA PRIORITY POLLUTANTS EXAMINED

Base-Neutral Extractable Compounds

Acenaphthene	3,3'-Dichlorobenzidine
Acenaphthylene	Diethyl phthalate
Anthracene	Dimethyl phthalate
Benzidine	2,4-Dinitrotoluene
Benzo[a]anthracene	2,6-Dinitrotoluene
Benzo[k]fluoranthene	Di-n-octyl phthalate
Benzo[ghi]perylene	1,2-Diphenylhydrazine
Benzo[a]pyrene	Fluoranthene
Bis(2-chloroethoxy)methane	Fluorene
Bis(2-chloroethyl)ether	Hexachlorobenzene
Bis(2-chloroisopropyl)ether	Hexachlorobutadiene
Bis(2-ethylhexyl)phthalate	Hexachlorocyclopentadiene
4-Bromophenyl phenyl ether	Hexachloroethane
Butyl benzyl phthalate	Indeno[1,2,3-cd]pyrene
2-Chloronaphthalene	Isophorone
4-Chlorophenyl phenyl ether	Naphthalene
Chrysene	Nitrobenzene
Dibenzo[a,h]anthracene	N-Nitrosodiphenylamine
Di-n-butyl phthalate	N-Nitrosodi-n-propylamine
1,2-Dichlorobenzene	Phenanthrene
1,3-Dichlorobenzene	Pyrene
1,4-Dichlorobenzene	1,2,4-Trichlorobenzene

Pesticide Compounds

Aldrin	Dieldrin
α-BHC	α-Endosulfan
β-BHC	β-Endosulfan
γ-BHC	Endosulfan sulfate
δ-BHC	Endrin
4,4'-DDD	Heptachlor
4,4'-DDE	Heptachlor epoxide
4,4'-DDT	

interest in Table 4. Compounds identified with pesticides, industrial solvents, intermediary compounds, plasticizers, dyes, coal tars, and petroleum and fossil fuel combustion products were found. At least some evidence of impact from industrial, agricultural and transportation sources is noted. A number of the compounds are polycyclic aromatic hydrocarbons (PAH's) and are by-products of pyrogenic, industrial, and transportation activities. Others are pesticides/herbicides associated with agriculture. Still others are general evidence of industrial activity in the surrounding area. Many of the compounds shown are known to be detrimental to human health in sufficient quantities, and others have been implicated (NAS, 1980). It is to be noted, however, that, with few exceptions, the concentrations of nearly all individual contaminants found were only in the low parts per billion (ppb) range, and that samples varied considerably in both the presence or absence of many contaminants and in concentration levels.

Thirty-one of the 59 compounds searched for were found in the tissues of oysters in at least some samples (Table 2), and 27 of these were found in at least some clam samples (Table 3; more total oyster samples were taken than clam samples). Thirty-five contaminants were detected in bivalves transplanted to "suspicious" or industrial regions of the Bay (Table 4). As expected, there was considerable similarity in compounds found in bivalves throughout the Bay, as 21 compounds are common between the three tables.

A number of compounds were routinely found in bivalve tissues throughout the study, whether considering sites or samples. These included the dichlorobenzenes, phthalates, many of the PAH's and related compounds, and the DDT degradation products (DDE and DDD). Seven compounds were detected at all oyster, clam, and transplant sites. These were naphthalene, phenanthrene, fluoranthene, pyrene, diethyl phthalate, di-n-butyl pthalate, and bis (2-ethylhexyl) phthalate. Two compounds were found in all samples of bivalves taken over the course of the study (naphthalene and bis(2-ethylhexyl) phthalate), and five others were found in essentially all samples (fluorene, phenanthrene, fluoranthene, diethyl phthalate, and di-n-butyl phthalate). When

TABLE 2. POLLUTANTS DETECTED IN OYSTERS OF MOBILE BAY (1982-83) Samples were collected at seven sites three times a year. Concentrations are reported as ppb (parts per billion).

Compound	% Sites Positive	% Samples Positive	Max. Level Found (ppb)	Mean Level of Positive Samples (ppb)
Base-Neutral Extractable Compounds				
Acenaphthene	100	55	17	5
Acenaphthylene	100	33	14	4
Anthracene	71	21	4	2
Benzidine	17	6	1	1
Benzo[a]anthracene	71	15	8	4
Benzo[k]fluoranthene	43	9	32	26
Benzo[ghi]perylene	29	9	63	29
Benz,[a]pyrene	83	31	11	6
Bis(2-chloroethoxy)methane	17	6	13	13
Bis(2-ethylhexyl)phthalate	100	100	551	240
Butyl benzyl phthalate	100	50	438	71
Chrysene	43	15	13	7
Di-n-butyl phthalate	100	94	152	75
1,2-Dichlorobenzene	100	56	22	18
1,3-Dichlorobenzene	100	63	33	26
1,4-Dichlorobenzene	67	31	21	20
Diethyl phthalate	100	69	401	117
Dimethyl phthalate	50	25	16	15
Di-n-octyl phthalate	100	50	34	20
1,2-Diphenylhydrazine	67	25	21	8
Fluoranthene	100	64	91	22
Fluorene	100	67	27	21
Indenol[1,2,3-cd]pyrene	83	31	206	123
Naphthalene	100	100	163	36
Phenanthrene	100	94	227	48
Pyrene	100	33	68	21
1,2,4-Trichlorobenzene	100	50	19	18
Pesticide Compounds				
4,4'-DDD	71	39	61	18
4,4'-DDE	71	55	62	19
4,4'-DDT	43	9	23	14
Heptachlor	29	9	53	32

these compounds are categorized into groups, several trends become evident.

Compounds likely derived from coal tars, and petroleum and fossil fuel combustion were widespread in occurrence, with moderate levels present at a few sites. Prominent among this group were a number of polycyclic aromatic hydrocarbons (and related compounds): naphthalene, phenanthrene, acenapthylene, acenapthene, fluorene, fluoranthene, and pyrene. Naphthalene, phenanthrene, fluoranthene, and pyrene were found at all bivalve sampling and transplant sites. In addition, naphthalene (used in the manufacture of dyes and resins and found in solvents, lubricants and motor fuels) was found in the tissues of bivalves from all samples taken, with fluorene, phenanthrene, and fluoranthene occurring in 95% or more of total samples.

The widespread occurrence of PAH's and the variety found likely indicates a mixed origin from pyrogenic sources (fossil fuel combustion) and petroleum inputs (eg., diesel fuel). Our findings are similar to other findings near urban areas along the U.S. coastline (NAS, 1980). Pyrogenic sources would include runoff and particles in the air settling in the water and eventually the sediments. Widespread small boat use and water transportation in Mobile Bay probably account for a reasonable portion of the levels found.

Generally, bivalves from sites in the upper portions of the Bay near industrial areas contained slightly elevated levels of PAH's. Naphthalene and phenanthrene were somewhat higher at these sites, and are indicative of fuel contamination or boat traffic. Other PAH's strongly associated with coal residues and fossil fuels (anthracene, fluorene, pyrene, fluoranthene, chrysene, and benzo(a)anthracene) were found in more abundance and at a greater frequency at sites in the upper reaches of the Bay and close to the harbor, though this trend was not dramatic. Clams collected near the McDuffie Island coal loading facility were noticeably high in a number of PAH's. Higher than normal levels of naphthalene and

TABLE 3. POLLUTANTS DETECTED IN CLAMS OF MOBILE BAY (1983-84). Samples collected at ten sites three times a year during 1984, but only in summer during 1983. Concentrations are reported as as ppb (parts per billion).

Compound	% Sites Positive	% Samples Positive	Max. Level Found (ppb)	Mean Level of Positive Samples (ppb)
Base-Neutral Extractable Compounds				
Acenaphthene	90	81	25	9
Acenaphthylene	80	74	15	6
Anthracene	80	67	19	7
Benzo[a]anthracene	70	48	40	17
Benzo[ghi]perylene	40	15	58	31
Bis(2-ethylhexyl)phthalate	100	100	1430	493
Butyl benzyl phthalate	90	33	200	84
Chrysene	40	22	27	20
Di-n-butyl phthalate	100	100	427	108
1,2-Dichlorobenzene	100	70	19	10
1,3-Dichlorobenzene	100	48	37	29
1,4-Dichlorobenzene	100	74	23	10
Diethyl phthalate	100	100	3506	410
Dimethyl phthalate	60	48	8	4
Di-n-octyl phthalate	100	63	69	25
Fluoranthene	100	100	205	51
Fluorene	90	89	20	10
Hexachlorobenzene	10	4	6	6
Hexachloroethane	10	4	4	4
Isophorone	10	4	3	3
Naphthalene	100	100	72	28
N-Nitrosodiphenylamine	50	26	39	19
Phenanthrene	100	100	97	31
Pyrene	100	100	149	39
1,2,4-Trichlorobenzene	80	33	19	15
Pesticide Compounds				
4,4'-DDD	80	52	114	30
4,4'-DDE	100	85	92	39

phenanthrene also occurred in the tissues of oysters from the enclosed Dauphin Island Bay and Cedar Point Reef. This likely reflects a high level of boating activity in these areas. This was especially noticeable during Spring 1982. Significant boating activity had occurred in the area during the previous months, associated with the ferrying of islanders and construction workers and the completion of the new Dauphin Island Bridge.

A second major trend observed was that compounds classified as pesticides/herbicides were generally absent in our samples, with the exception of the widespread occurrence of the metabolites of DDT. This was somewhat surprising in view of the size of the drainage basin of Mobile Bay. The major portion of the agricultural areas, however, are considerably upstream. Other than DDT and its derivatives, none of the other compounds classified as pesticides that we examined were found in natural populations of bivalves in Mobile Bay, with the exception of two oyster sites surveyed in 1982, whose samples contained low to moderate levels of heptachlor. There was no evidence of other pesticides, such as endrin, dieldrin, the lindanes, etc. Endosulfan sulfate and lindane (in the form of alpha and gamma BHC) were recorded from clams transplanted into a Mobile harbor site in 1984.

DDT was detected at three of seven oyster sites sampled during 1982 and 1983 (Table 2), but only 9% of the total samples showed evidence of active DDT, and these were in samples with larger, older oysters. Further, concentrations were quite low. No DDT was found in clam samples or at any bivalve transplant sites. The degradation products of DDT (DDD and DDE), however, were observed at most sites and in most samples in both natural and transplanted populations of bivalves. The levels and frequency observed are most likely the results of the past use of DDT on agricultural fields. It was officially banned by the U.S. Environmental Protection Agency in 1973, and observed results are in line with natural half-life times. Samples taken at a

TABLE 4. POLLUTANTS DETECTED IN TRANSPLANTED BIVALVES IN MOBILE BAY (1984). Samples were collected at eight transplant sites. Concentrations reported as ppb (parts per billion).

Compound	% Sites Positive	Max. Level Found (ppb)	Mean Level of Positive Samples (ppb)
Base-Neutral Extractable Compounds			
Acenaphthene	88	13	6
Acenaphthylene	100	5	3
Anthracene	88	43	10
Benzo[a]anthracene	75	36	20
Benzo[k]fluoranthene	13	22	22
Benzo[ghi]perylene	25	62	34
Benzo[a]pyrene	25	50	28
Bis(2-ethylhexyl)phthalate	100	2748	742
4-Bromophenyl phenyl ether	13	4	4
Butyl benzyl phthalate	88	164	99
2-Chloronaphthalene	50	7	4
4-Chlorophenyl phenyl ether	13	6	6
Chrysene	63	49	23
Di-n-butyl phthalate	100	312	127
1,2-Dichlorobenzene	88	10	3
1,4-Dichlorobenzene	63	3	2
Diethyl phthalate	100	390	147
Dimethyl phthalate	100	38	7
2,4-Dinitrotoluene	25	159	102
2,6-Dinitrotoluene	13	110	110
Di-n-octyl phthalate	88	98	64
Fluoranthene	100	87	40
Fluorene	100	16	9
Hexachlorobenzene	13	4	4
Hexachloroethane	50	42	17
Indeno[1,2,3-cd]pyrene	13	64	64
Naphthalene	100	76	33
N-Nitrosodiphenylamine	63	45	27
Phenanthrene	100	52	24
Pyrene	100	77	32
Pesticide Compounds			
α-BHC	13	11	11
β-BHC	13	16	16
4,4'-DDD	75	91	30
4,4'-DDE	88	65	33
Endosulfan sulfate	13	34	34

"control" site in Cedar Key, Florida, during 1982 and 1983 showed almost no DDD, DDE, or DDT residues. This can likely be attributed to the lack of a large freshwater effluent draining agricultural areas near Cedar Key. The presence of these type compounds does, however, indicate the potential vulnerability of estuaries in areas draining large agricultural regions.

The levels and frequency of DDT, DDD, and DDE, as well as other pesticides/herbicides, found in Mobile Bay oysters during our study (Table 2) were considerably less than those found during earlier studies on oysters in the Bay. A long list of pesticides were examined at several area reefs by Casper et al. in 1965 (published in 1969), Butler in 1968-69 (published in 1973), and again by Butler et al. in 1977 (published in 1978). The first two studies found that DDT and its metabolites were found in essentially all oyster samples and were the most common of the chlorinated pesticides. Tissue levels of total DDT in the 1965 study ranged up to 4.61 ppm, close to the level of 7.0 ppm then allowable as a residue in meats and food items destined for human consumption. Aldrin, lindane, chlordane, dieldrin, and endrin were also all detected in some samples at the low ppb range by Casper et al. (1969). Butler (1973) detected some dieldrin in the low ppb range in 1968-69. Pesticide levels in oyster tissues, however, decreased during the period of the three studies, with the latter study (Butler et al., 1978) reporting no detectable residues of any pesticides in a one-shot sample from two of the original collecting sites in Mobile Bay. The decline in pesticide levels over this time period followed the national trend of significant reductions in chlorinated hydrocarbon contamination due to bans on DDT and reduced use of earlier, more persistent pesticides. Our data also show little evidence of most pesticides examined and DDD and DDE concentrations generally only in the low ppb range. Active 4,4'-DDT was negligible.

A third trend noted was that, as a group, the phthalates were consistently the most abundant contaminants. Diethyl, di-n-butyl and bis(2-ethylhexyl) phthalate were recorded at all natural and transplant sites, with bis (2-ethyhexyl) phthalate found in all samples. There was considerable inter-site variability, but tissue levels of phthalates at many sites examined were in the moderate to high ppb range. A few samples reached concentrations in the parts per million (ppm) range; the greatest level recorded was for diethyl phthalate at 3.5 ppm (Table 3). Levels in Mobile Bay were considerably elevated over tissue levels found in a sample from a non-industrially impacted "control" site at Cedar Key, Florida.

Phthalate esters are listed by the U.S. Environmental Protection Agency as priority pollutants because of a wide variety of potential and suspected carcinogenic and other health effects at elevated concentrations (EPA pub., 1980). Further, they serve as indicators of generalized industrial activity and the effect of population centers on ecosystems. These compounds are ubiquitous plasticizers associated with any plastic product (particularly polyvinyl chloride), but also have many other industrial uses, ranging from insect repellents to solvents (EPA pub., 1980). They are often used as solvents in the manufacture of celluloid, dopes, and varnishes. Recent research has revealed that phthalates, primarily as leachates from plastic products, are now common-place and widespread in many areas of the environment, including water sources, sediments, and aquatic life. Studies have also shown that phthalates can be concentrated in organisms found in water (EPA pub., 1980). For example, after less than two weeks phthalate concentrations in trout, crayfish, and mussels were 350-3900 times that in water under experimental conditions (Mayer and Sanders, 1973; Brown and Thompson, 1982). Even though acute toxicity levels of phthalates for most aquatic organisms, particularly bivalves (Brown and Thompson, 1982), are high (generally in the low to mid ppb range; EPA pub., 1980), sublethal effects at much lower levels are virtually unknown. Further, there is no knowledge of the effects on more sensitive aquatic species (Sanders et al., 1973).

Although information is limited on the concentrations of phthalates occurring in aquatic organisms, phthalic esters have been reported at the ppm level in water and fish (EPA pub., 1980). These elevated readings have generally been detected near "industrial" areas, with levels recorded for organisms found in the open ocean or areas removed from industrial regions being much less. Fish from several studies near developed areas have been found to have tissue phthalate levels comparable to or exceeding the levels we found in bivalves (Stallings et al., 1973).

Unfortunately, information on phthalate levels in bivalves from coastal waters is virtually nonexistent. The levels we found in Mobile Bay bivalves were, however, slightly higher than those found in clams from the harbor at Portland, Maine (Ray et al., 1983). Thus, based on limited residue information in the environment, it is difficult to accurately ascertain whether the levels we observed are typical of bivalves in estuaries at the mouths of major river systems or whether they represent a localized situation.

Though there was wide variation between sites and samples, concentrations of phthalates found in the tissues of clams were higher than those found in oysters (Tables 2,3). This may well reflect the fact that clams were sampled generally in the upper portions of the Bay and near developed, industrial areas (Fig. 1). Similarly, within clam populations, those sampled near or in the City of Mobile and below the sewage treatment plant at Fairhope had higher phthalate levels when compared to other locations. Results from the transplanted bivalves also generally supported this trend. Clams collected below McDuffie Island contained the maximum level found and the highest mean for all phthalates as a group.

Several trends in timing of collections and site location were also noted in our study. Seasonality in abundance of contaminants in bivalve tissues was observed in oysters collected during 1982 and in clams (seasonally collected in 1984). Although individual pollutants varied, most compounds were found at highest levels in spring and were lowest in the fall samples. This is likely attributed to a greater freshwater influx in spring, with resulting increased runoff from the land of agricultural and industrial chemicals, and to the loss of lipids (associated with the reproductive cycle) in bivalves during the latter portion of the year. Seasonal trends were not evident in oysters collected during 1983, however. Spring 1983 was exceptionally wet, and oysters were exposed to extended periods of almost total freshwater in Mobile Bay. Extended "shutdown" of feeding and filtration could have accounted for lower levels of accumulated contaminants during this period. The precise timing of collections as to localized reproduction or recent rain events could have also reduced significant seasonal variations.

For both oysters and clams, between-year variability in the types and levels of pollutants detected was not great. Most compounds were found at roughly similar frequencies of occurrence and concentrations.

Though intersite variability occurred, similar types and levels of contaminants were observed at most oyster collecting sites. Dauphin Island Bay oysters had slightly more total contaminants, though not significantly different from other sites. For clams, there was a tendency for tissue pollutant levels to be higher at sites adjacent to more industrialized areas in the upper Bay (eg., near McDuffie Island and the harbor) and lower in areas more removed from industrial sources (eg., Fish River and Polecat Bay). This same trend was observed in the transplanted bivalves. The peak levels of most compounds detected (particularly those related to industrial solvents and coal residues) occurred in the three baskets planted in the harbor and extreme upper Bay region. The levels of total contaminants averaged slightly higher at these sites when compared to other transplant sites. One of these sites (harbor) was particularly notable. It was the only transplant site at which benzofluoranthene, indenopyrene, 2,6-dinitrotoluene, lindane(BHC), and endosulfan sulfate were detected. It was the only time during our entire study that the latter three compounds were detected. Overall, however, despite those trends, it was evident that no severe "hotspot" of chemical contamination was detected, as the observed trends were not dramatic. Generally, roughly similar levels and concentrations of pollutants occurred at most sites. Currents, tides, and other hydrologic forces in Mobile Bay must, therefore, distribute contaminants to widespread areas of the Bay.

Finally, clams were observed to be slightly "dirtier" than oysters in that 1) levels of most of the compounds searched for were generally higher in clams, 2) the mean and mean maximum of total contaminants found were two to three times higher in clams, and 3) a similar number of compounds were detected in clams with fewer total samples than oysters. This most likely reflects the fact that many of the clam collecting sites were located in the upper reaches of the Bay (Fig. 1), closer to industrial areas and potential pollutant sources.

ASSESSMENT OF ORGANIC POLLUTION

The results of our study have shown that a wide variety of organic contaminants are found in the tissues of bivalves from Mobile Bay. Compounds associated with pesticides, industrial solvents, dyes, plastics, coal tars, and petroleum and fossil fuel combustion products were found, indicating at least some impact from industrial, agricultural and transportation sources. It is to be noted, however, that, with few exceptions (primarily phthalates), the concentrations of most contaminants found in individual samples were in the low ppb range, and that samples varied considerably as to the presence or concentrations of many contaminants.

Considering that the levels of contaminants found in bivalve tissues were generally in the low ppb range and that no severe pollution "hotspots" were found, it is apparent that overall organic pollution in Mobile Bay, as reflected in these indicator species, is currently below what we would consider to be high or critical values. This is supported by comparison of contaminant levels previously found in bivalves from other estuaries in North America and Europe (NAS, 1980; Kidder, 1977).

Numerous studies have shown widely varying levels of pollutants in shellfish throughout the world (NAS, 1980; Kidder, 1977). Comparisons between studies, however, are often difficult and can usually only be done in a qualitative sense. Differences in species used, collection techniques, analyses and extraction procedures, instrumentation quality, and the time frame all contribute to potentially cloud comparisons. Further, most studies have measured different chemical parameters, some quantifying total classes of compounds (eg., total hydrocarbons), others measuring only one or two specific compounds, while still others attempted to measure a whole range of potentially deleterious compounds (eg., this study). In addition, not all compounds are taken up and released by shellfish in the same manner.

Given these limitations, a comparison of data available from the large amount of literature on concentrations of contaminants in shellfish worldwide reveals that bivalves from many areas previously studied show considerably higher levels of most contaminants or groups of contaminants when compared to our results. Numerous examples can be documented that appear to be (or have been) more affected than Mobile Bay by total hydrocarbons, PAH's, or pesticides (NAS, 1980; Kidder, 1977). In particular, much greater levels of pesticides have been historically documented in many locations. When specific compounds quantified in our study are compared to data available for some of these same compounds in shellfish from other locations, the conclusions are similar. For example, fluoranthene, pyrene, phenanthrene and naphthalene levels were shown to be much higher (some approaching 6 ppm) at a good number of bay and estuary areas at which collections were made along the U.S. coastline by the Mussel Watch Program in the mid-to-late 1970's (NAS, 1980).

Based primarily on the results of the Mussel Watch Program and qualitative comparisons to other studies, it would appear that Mobile Bay is in the wide mid-range of chemically-impacted estuaries and/or coastal sites. An overall view of the Mussel Watch data indicates that a fair number of specific sites sampled along the North American coast appear "cleaner", but a significant number of other sites appear considerably more impacted. It should also be noted that our study showed minimal pesticide problems in Mobile Bay, indicating an improvement over conditions found during the 1960's and early 1970's. On the other hand, the phthalate concentrations found appear elevated, but comparative data for coastal bivalves is lacking for adequate comparisons. Though the levels of phthalates found are of concern, these compounds do have relatively low toxic qualities (EPA pub., 1980).

While the overall organic pollutant levels in Mobile Bay, as indicated by tissue levels in bivalves, is below what we consider to be high or critical levels, our study indicates a wide variety of industrial and fossil fuel-related contaminants are present in Mobile Bay waters. The effects of many of these compounds on shellfish and humans are virtually unknown. Further, their combined synergistic effects and interactions are potentially significant. Our study also investigated only a small number of potential contaminants. Others, uninvestigated by our study, may be reaching and significantly affecting biological organisms in Mobile Bay.

Based on the levels of organic contamination found in our study, a potential human health threat, considering normal consumption patterns and current food standards, is not likely indicated. Current tolerance and action levels established by the FDA for human foods in general and shellfish in particular are well above levels found in bivalves from Mobile Bay for those compounds for which standards have been established (ex, aldrin, dieldrin, endrin, BHC, DDT, heptachlor, heptachlor epoxide) (FDA pub., 1982). However, acceptable standards for most of the compounds we examined have yet to be established.

The data gathered in this study, showing a wide variety of contaminant classes, even though currently at relatively low levels for most, serves as a potential warning that changes have occurred or are occurring in the Mobile Bay estuarine enviroment. Unfortunately, we have little historical comparative data for most pollutants. The present data, however, can serve as a baseline to evaluate any potential future changes in bivalve contaminant content and, ultimately, water quality in Mobile Bay. The current National Status and Trends Program of NOAA has urged that sampling of bivalves for organic contaminants take place at strategic stations and sensitive locations along the U.S. coast at least every five years. Such efforts could establish rates and severity of change in coastal and estuarine habitats. In view of our results and changes in the commerce and industrial aspects of Mobile, we strongly urge that Mobile Bay be included in any future sampling and monitoring program.

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MOBILE BAY: THE RIGHT ESTUARY IN THE WRONG PLACE?

Wayne C. Isphording, Department of Geology-Geography, University of South Alabama, Mobile, AL 36688

George C. Flowers, Department of Geology, Tulane University, New Orleans, LA 70118

ABSTRACT: No estuary in the northern Gulf of Mexico has been the subject of greater controversy during the past five years than Mobile Bay. The discovery of a major gas field beneath the bay, its selection as a homeport site for the new Gulf flotilla, a request for docking privileges for a toxic waste incinerator ship near the head of the bay, and a request for construction of new outfall lines and sediment disposal sites within the bay have all generated lively discussion.

When compared with other bays in the northern Gulf, however, Mobile Bay is found to be less able to cope with potential environmental incidents than the other estuaries. This, because of its already environmentally stressed nature and the fact that its basic characteristics have conspired to assure that it receives maximum impact from any environmental accident. A high smectite clay and organic carbon content, combined with the extremely fine textured nature of its sediments, increase the probability that both organic and inorganic pollutants will enjoy long term residency should an accident occur. Some indication is now also present to indicate that spill-over of heavy metals to the resident biota has already taken place.

INTRODUCTION

Mobile Bay is the terminus of the Nation's fourth largest river system and is exceeded, in terms of discharge, only by the Mississippi, Columbia, and Yukon rivers. The river systems that empty into the bay include the Warrior, Tombigbee, Coosa, Alabama, and Mobile and each drains areas of moderate to heavy industrial and municipal development. As a consequence of this, large quantities of effluent are routinely discharged into these rivers and, ultimately, finds its way into Mobile Bay. Prior to the passage of Federal and State regulations controlling the quantities of such effluent, large amounts of contaminants entered Mobile Bay on a daily basis. Even now, with major restrictions placed on levels of materials that can be discharged, an estimated 162 million gallons of municipal and industrial effluent enters the bay each day just from sources in the Mobile area (Loyacano and Busch, 1979) . When it is realized that the watershed that terminates with Mobile Bay drains more than two-thirds of the State of Alabama, and portions of neighboring Georgia, Tennessee, and Mississippi, as well, it is not difficult to understand why the bay has been characterized as "environmentally stressed."

In addition to contaminants that are brought into the bay by the Mobile River system and by discharge of effluent from sites near, and marginal to the bay itself, the bay has, or will be, subjected to additional stresses that must be carefully examined or monitored in order to minimize the effect on the bay. The selection of Mobile as a "homeport" for a portion of the planned Gulf-Caribbean fleet may require some additional dredging of the existing ship channel and, possibly, the identification of new spoil disposal areas in the bay. While the dredging, in itself, should create few problems, any decision as to where spoil is to be placed must be carefully considered. Similarly, whereas the drilling of gas wells by major oil corporations has, to date, had little impact upon the bay (to the obvious distress of those who had forecast a variety of dire consequences), wise decisions were made to prohibit the dumping of drilling wastes within the bay. This, not because the drilling wastes themselves pose any great environmental threat to the bay, but simply because the average depth of this estuary is only 3 meters, hence the disposal of any material in the bay could create problems. Further, because of the shallow nature of the bay, its complex circulation patterns, and the restricted passage to the Gulf of Mexico, any pollutants that find their way into Mobile Bay are generally assured of an extended residence time. Therefore, even though regulations now control the quantities of organic and inorganic contaminants that may be discharged directly into the bay, or into rivers terminating in the bay, the situation is akin to "closing the barn door after the horse has escaped." For example, while regulations now control the quantities of actual metal compounds that can be discharged in the bay, prior to the imposition of these limits excessively large quantities (of several orders of magnitude, or greater) were routinely discharged on a daily basis. This discharge took place, not over a period of several years but, in the case of some metals, over a period of several decades. Further, because of characteristics of the bay more fully elaborated in the following paragraphs, the bay has acted as a "sump" for many of these compounds and, not unexpectedly, the bottom sediments now contain elevated quantities of a number of different metal species.

As a consequence of the above, Mobile Bay is in a delicate state of health and could be suffer long term environmental impact by the inadvertent discharge of toxic material within the bay. Thus, while the authors are wholly in favor of the incineration of toxic wastes, and applaud the use of incinerator ships for the destruction of such compounds, Mobile Bay is simply not the place to base such vessels for reasons to be discussed below. A similar statement would also apply to the granting of permission for new outfall lines, unless of course the discharged material was first processed to eliminate, or preclude, the further accumulation of toxic wastes in the bay.

CHARACTERISTICS OF MOBILE BAY

Water Budget

The Mobile River watershed area encompasses a total area of nearly 112,000 km2. As such, this watershed is the sixth largest in the United States, in terms of total area and, as mentioned previously, the fourth largest in terms of discharge. Unlike the other river systems, however, the discharge exiting the Mobile River enters a largely enclosed estuary, rather than the open sea. Consequently, outflow of water from Mobile Bay is restricted and is confined to two relatively narrow passes. One, emptying into Mississippi Sound, carries off approximately 15% of the total discharge of the river system whereas that between Dauphin Island and the Fort Morgan Peninsula carries off the remaining 85%. Besides the narrow openings available for discharge and the complex circulation patterns that exist in the bay, extensive spoil banks associated with the ship channel further act to restrict water movement in the bay and impede the natural "flushing" action that would normally take place. These factors, combined with an annual sediment influx of some 4.7 million metric tons (Ryan, 1969), create a situation wherein contaminants carried into the bay accumulate on the particulate matter and largely remain in the bay.

Sediment Description

Approximately 65 km north of the City of Mobile, the Alabama and Tombigbee rivers join to form the Mobile River. This river flows in a single channel for an additional 8 km and then branches into a number of distributary streams, forming the Mobile River delta. The delta has profoundly affected the bottom sediments of the Mobile Estuary by acting as a trap for the removal of coarse grained sediments both sand and gravel). Hence sediments that are discharged into the bay are dominated by silts and clays and any sands present are largely derived from erosion of the Plio-Pleistocene Citronelle Formation and Miocene Ecor Rouge Sand that are exposed in highland areas adjacent to the bay (Isphording and Lamb, 1979). Thus, when plotted on a ternary diagram (Fig. 1), the sediments of Mobile Bay are seen to be conspicuously different from those of other estuaries in the northern Gulf of Mexico in containing markedly higher concentrations of fine grained sediments. This creates an immediate complicating factor from the standpoint of heavy metal or organic contamination of the sediments because as the particle size decreases, the surface area increases. Thus, the surface area available for adsorption of contaminants whose average size is 0.001 mm (clay size) is 1,000 times greater than that for particles of 1 mm (sand size). Stated another way, clay-rich sediments are therefore 1,000 times more likely to be affected by spills resulting from the inadvertent influx of municipal and industrial contaminants.

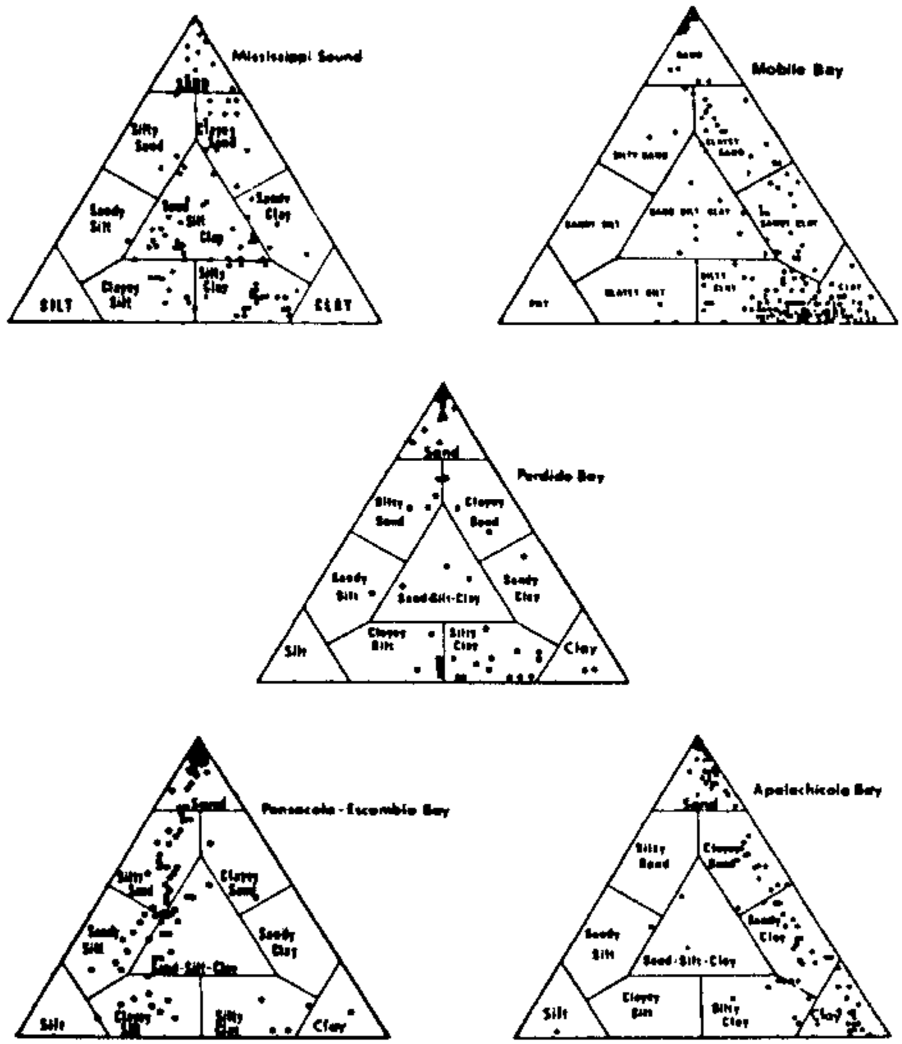

Fig. 1.-- Ternary diagrams showing bottom sediment sand-silt-clay percentages for major bays and estuaries in the northern Gulf of Mexico.

Carbon Content

Table 1 shows a comparison of carbon levels, both in the form of organic carbon and carbonate carbon for all major estuaries in the northern Gulf of Mexico. Mobile Bay sediments are seen to contain the highest levels of organic carbon for the estuaries listed and to possess carbonate carbon levels that are exceeded only by sediments in Apalachicola Bay, Florida.

Carbonate carbon was found in Mobile Bay in amounts ranging from zero percent, in sand-rich sediments, to nearly 8 percent in the vicinity of modern and ancient oyster reefs. Microscopic examination of samples revealed that the source for this material was largely from shell debris rather than from a directly precipitated, inorganic source.

Organic carbon averaged over 3 percent and abundances were strongly related to the grain size of the sediments. Areas of clay-rich sediments contained carbon percentages in excess of 2 to 3 percent (often as high as 6 percent) whereas coarse grained material was generally deficient in organic carbon. The latter stems from the fact that the higher permeability of such sediment allows active water circulation which causes more extensive bacterial action and oxidation of

Location	Pct. Smectite	Pct. Illite	Pct. Kaolinite	Pct. Organic Carbon	Pct. Carbonate Carbon
Miss. Sound	74	13	12	0.82	0.60
Perdido Bay	65	10	25	1.33	0.23
Pensacola Bay	67	12	21	2.90	0.55
Apalachicola Bay	46	9	33	0.75	1.94
Mobile Bay	70	10	20	3.24	0.98

Table 1.-- Principal clay minerals, organic carbon and carbonate carbon percentages for bays and estuaries in the northern Gulf of Mexico (modified from Isphording, Stringfellow and Flowers, 1985).

the organic matter present. The overall high levels noted in the Mobile Bay sediments, however, can be traced to a combination of the periodically strongly negative redox potential and the high clay content of the sediments which provides an environment favorable to the the persistence of organic material. Unfortunately, these same two factors also strongly favor the adsorption ,and retention, of a variety of organic and inorganic pollutants.

Clay Mineralogy

Table 1 reveals that the mineralogy of Mobile Bay bottom sediments is dominated by smectite group clays and also contains lesser amounts of kaolinite and illite (clay mica). Phillipsite, a zeolite mineral, was also observed on a number of X-ray diffractograms. Highest levels of smectite clays were observed near the head of the bay (up to 80 percent) whereas kaolinite was most abundant near the mouth of the bay. The former is simply a reflection of the fact that older rocks in the Coastal Plain (and Piedmont) have served as the principal sources for the smectite clays. While some kaolinite is undoubtedly derived from the weathering of these rocks and, to a lesser extent, from erosion of Citronelle and Ecor Rouge formation units that are immediately adjacent to the bay, the higher concentration of kaolinite near the mouth of the bay probably reflects material that is washed into the bay from the Gulf of Mexico (see Isphording and Lamb, 1974).

From an environmental standpoint, the clay mineralogy of Mobile Bay has also worked a dis-service. Smectite clays possess the highest cation exchange capacities of all common clay minerals (those for Mobile Bay range from 60 to nearly 300 meq/1) providing for the adsorption of elevated levels of metals and various organic contaminants. Thus the sediments of the bay possess three characteristics that offer the potential for retention of intentionally, or inadvertent, discharged pollutants in the bay: (1) an abundance of clay-sized particulate matter, (2) high levels or organic carbon, and (3) a clay mineralogy dominated by the Smectite Group clay, montmorillonite.

Heavy Metal Chemistry

Though a number of natural sources can act to release significant quantities of heavy metals into the environment (see Taylor, 1970; Cousma et al., 1979), anthropogenic point sources of metals rank as the most important factor controlling heavy metal contamination of sediments. Brady (1979) reported that a total of 189 million gallons of industrial and municipal effluent is discharged into Mobile Bay, each day, simply from sources located in the Mobile metropolitan area. Sources for this discharge can be traced to 19 municipal wastewater point sources, 38 industrial sources, and an additional 49 semi-public and private discharge sources. When similar contributions from locations elsewhere in the 112,000 km2 watershed are considered, it becomes obvious that there are many hundreds (even thousands) of distinct point sources discharging effluent that eventually finds its way into Mobile Bay. Even though the allowable discharge quantities are now controlled by the National Pollution Discharge Elimination System (NPDES), which strictly limits discharge levels of specific pollutants, this act did not become law until 1972 (Public Law 92-500). Prior to that time, essentially unrestricted discharge of wastes was routinely carried out throughout the entire watershed. As an example, prior to the enactment of Public Law 92-500 one company in the Mobile area was releasing an average of 1,470 kg of zinc each day. Quantities on some days reached as high as 4,250 kg. NPDES regulations now restrict allowable levels for this metal to no more than 45 kg per day but, as will be shown in the following paragraphs, the damage to the bottom sediments has already been done. The effect of unrestricted discharge into rivers emptying into the bay over the period of many years has been to "load" the bottom sediments of the bay with excessive levels of a number of heavy metals (see Isphording, 1983) . This can be seen in Table 2 which shows a comparison of heavy metal levels in Mobile Bay with those of other bays in the northern Gulf of Mexico. Metal levels in Mobile Bay are generally seen to exceed those in each of the other bays, often by amounts of up to one order of magnitude.

Element	St. Louis Bay	Miss. Sound	Perdido Bay	Pensacola Bay	Escambia Bay	Mobile Bay
Cadmium	1	1	1	1	1	1
Lead	15	15	nr	40	19	51
Iron	53,300	23,107	32,740	24,074	29,298	35,648
Nickel	9	24	36	16	9	57
Cobalt	8	13	37	10	12	29
Chromium	10	57	15	56	40	63
Copper	10	20	31	19	9	32
Vanadium	6	80	72	47	74	163
Barium	nr	261	95	nr	nr	89
Zinc	69	74	72	140	43	360

Table 2.-- Bottom sediment heavy metal contents (in ppm) for northern Gulf of Mexico bays, lagoons, and estuaries (modified from Isphording, Stringfellow and Flowers, 1985).

In order to obtain a measure of the degree to which the bottom sediments of the bay have been "impacted" by metal contamination, the 10 lowest values obtained from clay-rich sediments were averaged for each metal. This value was then divided into the average value obtained from analysis of all samples analyzed from the bay to produce an "average enrichment" value. The results are shown in Table 3 and must represent a truly minimum figure. This because: (1) the 10 lowest values for Mobile Bay may be substantially higher than those for other, "minimally impacted" bays, and (2) the average value obtained for the 100 samples from Mobile Bay includes analyses from samples collected from the margin of the bay which consisted almost wholly of sand and, therefore, would possess little in the way of heavy metal contamination.

Note that each of the metals in Table 3 occurs in amounts 2 to 4 times above the estimated background levels. Zinc, in particular, was present in amounts at least 7 times that which might be expected in a bay showing minimum environmental impact and chromium was present at levels nearly 5 times above estimated background quantities.

With respect to the spatial distribution of metals in the bay, some metal species indicated distinct point sources for the contamination whereas others were observed to be more randomly distributed. Zinc, for example, was present in amounts of 1800 ppm in the vicinity of the State Docks where the Mobile River enters the bay. The source for this anomalously high zinc is not the State Docks, however, and the elevated value simply reflects sediment adsorption of the metal at the head of the bay as a consequence of large quantities of zinc brought in by the Mobile River System.

Iron, similarly, showed high concentration toward the head of the bay and along the eastern side of the bay at the mouths of several small streams. Its higher concentration at the head of the bay probably results from a combination of bottom clay adsorption of the metal and its precipitation in the form of an insoluble hydroxide brought about by a change in pH as the more acid river waters enter the bay. The higher amounts of iron near the mouth of Fish River and the Magnolia River along the eastern shore undoubtedly reflect high iron levels in these streams associated with the historic brick manufacturing industry located upstream and adjacent to the rivers.

Strontium also was site specific in the bay but the locally elevated concentrations probably are related to higher carbonate levels for sediments at these sample stations. The common substitution of both strontium and barium for calcium in the

Metal	Mean	Range	Background	Enrichment
Zinc	360	13-2,689	50	7.2
Copper	32	8-49	20	1.6
Iron	35,648	2,230-57,830	13,652	2.6
Chromium	63	2-214	13	4.8
Vanadium	163	31-250	74	2.2
Nickel	57	17-100	31	1.8
Strontium	44	1-156	19	2.3
Barium	49	20-640	20	2.5
Cobalt	29	6-38	17	1.7

Table 3.-- Means, ranges, estimated background levels and estimated "enrichment" levels (in ppm) for Mobile Bay bottom sediments (Data modified from Isphording, 1983).

lattice of both calcite and aragonite would explain, at least in part, the similar distribution patterns for these metals (see Isphording, 1982).

Heavy Metal Partitioning

The utility of determining the site partitioning behavoir of metals in bottom sediments for the purpose of assessing biological availability has been discussed in a previous paper (see Isphording, 1983). Briefly, however, the procedure involves determining the percentage of a specific metal that is contained in the sediments in the form of: (1) a pore water fraction, (2) exchangeable ions, (3) an easily reducible phase associated with disseminated manganese oxides and hydroxides, (4) a moderately reducible phase associated with disseminated iron oxides and hydroxides, (5) ions associated with sulfides, organic compounds and organo-metallically chelated compounds, and (6) structurally coordinated ions occupying defect positions in the crystal lattice or occurring in octahedral or tetrahedral voids in the clay mineral lattice. The importance of identifying the partioning behavoir of a metal lies in the fact that, depending upon how a metal is partitioned, it may or may not be in a form that allows its later release back into the water column or allows the metal to be absorbed by bottom-dwelling, filter-feeding organisms (clams, oysters, crabs, etc.). Metals partitioned in the pore water fraction, the exchangeable ion phase, and associated with organic and organo-metallically chelated compounds are especially mobile whereas those held as structurally-coordinated ions are essentially "locked" in the lattice and not subject to re-mobilization. Metals held as either easily reducible or moderately reducible phases are intermediate in their re-mobilization behavoir but may permit significant release if processes act to markedly change the pH at the sediment-water interface. Partitioning data for 7 metals from Mobile Bay bottom sediments is shown in Table 4.

Several observations can be drawn from the data presented in Table 4: (1) the percentage of structurally-coordinated ions is generally less than 50 percent; thus, with the exception of nickel, a significant portion of the metals held in Mobile Bay bottom sediments are susceptible to resuspension in the water column or transfer to the biota by ingestion, (2) low values are generally obtained for metals held in both the pore water and exchangeable phases; this is in agreement with the results of Brannon, et al. (1977) who found elevated values in this phase for manganese only (3) site partitioning of metals cannot be predicted solely from the metal's position in the Periodic Table; though copper and zinc show some semblance of similar behavior, nickel, iron, chromium and manganese differ significantly; the reasons for these differences undoubtedly involve differences in pH, redox potential and other physico-chemical factors existing at the depositional site when when the metal is incorporated into the mineral lattice (see Gambrell, et al., 1980), (5) iron and manganese oxides and hydroxides are important scavengers of metal ions; possible future use of this fact might involve the utilization of such compounds to control metal pollution in restricted bodies of water in the event that an accidental industrial spill takes place, (5) a significant portion of the metals present in bottom sediments are partitioned in organic compounds; this form, in fact, may represent the greatest threat to environmental contamination because of the general instability of these compounds stemming from their sensitivity to changes in pH and redox potential.

Biota Contamination

A discussion of the effects of heavy metal contamination of the resident oyster population of Mobile Bay was previously published (see Isphording, Stringfellow, and Flowers, 1985). The results of that study will be briefly summarized in the following paragraphs.

Metal	Percent in Pore Water & Exchangeable Phase	Percent in Reducible Phases	Percent in Organic Phases	Percent in Structurally Bound Phases
Copper	0.5	4.1	48.5	46.9
Zinc	0.9	15.1	49.8	34.2
Iron	1.5	73.8	16.1	8.6
Chromium	0.2	51.2	3.5	45.1
Nickel	0.4	30.3	2.6	66.7
Barium	2.1	53.9*	30.9	13.1
Manganese	9.9	29.0	43.4	17.1

*includes 12.7% associated with carbonate minerals

Table 4.--Partitioning behavoir of metals from bottom sediments of Mobile Bay, Alabama (modified from Isphording, 1983).

In order to assess the impact of apparently elevated heavy metal levels in Mobile Bay bottom sediments upon the indigenous fauna, samples of oyster tissue were obtained from all major commercial reefs in the bay. Heavy metal levels were then determined for each of the samples and were then compared with analyses published for tissue samples from other sites in southeastern United States.

Background.-- Oysters serve as excellent indicators of metal pollution in the environment and have been extensively studied (see Zaroogian, 1980; Ayling, 1974, Siewicki, et al., 1983). The common oyster, *Crassostrea virginica*, is especially useful because numerous studies have documented the toxicity levels of a number of different metals for this species and have established the mechanism of metal uptake and tissue accumulation (Zamuda and Sunda, 1982; Zaroogian, et al., 1979; Cunningham and Tripp, 1973). Oysters, as well as other filter feeders, basically obtain trace metals by ingesting sea water and suspended organic and fine particulate matter. Certain trace elements and nutrients necessary for life are retained whereas those unnecessary are excreted from the animal. As with higher trophic forms, certain metals are necessary for normal growth and development but excessive amounts can be toxic or result in altered productivity or a decrteased capacity to withstand environmental stress (Zamuda and Sunda, 1982). Specific uptake of individual metal species occurs, in part, by binding of the metal to ligand sites at cell surfaces, followed by subsequent passage into the tissue where the metal becomes fixed to metal-binding proteins (Roesijadi, 1982). Once fixed in this form, elimination of the metal is, at best, a slow process. Moody (1981), for example, described the removal of oysters from Mobile Bay which had natural levels of zinc in tissue in excess of 2,000 ppm. Depuration of the metal amounted to only 25 percent when the oysters wre placed in tanks for a period of six months. Greig and Wenzlof (1978), similarly, showed that no significant elimination of cadmium had occurred in oysters after 40 weeks in a low cadmium environment. Zaroogian (1980) further noted that (p. 276) "...a highly significant linear relationship existed between cadmium concentration in the total soft parts and cadmium concentration in sea water....it thus appears that *Crassostrea virginica* does not regulate cadmium in its tissues." The significance of this observation are that oysters apparently have the ability of concentrating certain metals to levels in excess of those normally fouynd in the form of low molecular weight metalloenzymes (metallothioneins). As such, "spillover" of metals into the high molecular weight fraction may occur and these may succeed in reaching sites of toxic action (enzymes and genetic material). Though some have argued that such "spillover" does not occur under natural conditions (see Bascom, 1983), those conclusions were reached by analyzing samples of tissue collected from animals from open marine environments. It is therefore more likely that fauna collected from restricted estuaries that are receiving (or have received in the past) high levels of contaminants would behave in a manner more similar to "dosed" laboratory speciments and can suffer the effects of "spillover." Estuaries having high levels of metal (and organic) contaminants should therefore be viewed with concern by regulatory agencies not only because of the health of the resident fauna but also because of the etiological effects that may result from consumption of these fauna by others higher in the trophic pyramid (see Isphording, et al., 1983).

Mobile Bay Results.-- A comparison of the average zinc content in tissue from the common oyster *Crassostrea virginica* from various sites in southeastern United States is shown in Table 5.

While Bascom's (1983) opinion that high concentrations of metals pose no problems to animals in the open sea, it would certainly be incorrect for an estuary such as Mobile Bay. Table 5 shows that Mobile Bay contains the highest levels of zinc for any major estuary in southeastern United States and that sizeable accumulations (i.e., "spillover") can take place in the tissues. It should also be noted that the figure in Table 5 is an average value and that some samples exceeded 4,000 ppm! Zinc concentrations of this magnitude exceed those threshold values at which damage to the organism takes place. Thus, levels of this metal have now been documented in the bay that should command the attention of regulatory and monitoring agencies.

Logically, if zinc is present in the bay oysters in such anomalous amounts, it is only reasonable to conclude that other metals might also be present in elevated quantities. To examine this premise, Table 6 shows a comparison of heavy metal levels in the tissues of Mobile Bay oysters versus those from St. Louis Bay, Mississippi (which was also characterized by high levels of zinc).

It is obvious from Table 6 that, with the exception of Titanium, Mobile Bay oysters possess significantly higher levels of all other heavy metal species. As noted in an earlier paper (see Isphording, et al., 1983), there is little liklihood that metals now present as either free ions or complex ions in the water column are a significant cause for the high metal levels in the bay's oysters. This conclusion stems from the simple fact that water column samples from both St. Louis Bay and Mobile Bay contain essentially the same quantities of dissolved metals. Rather, it was concluded that the source of the higher levels in the Mobile Bay fauna were the result of extraction of metals from the heavily contaminated bottom sediments (and possibly the hydrosol layer immediately above the sediment-water interface) by the oysters during feeding activity. Only these sites differed significantly in metal contents when samples

Location	Zinc (in ppm)
Mobile Bay, Alabama	1,887
San Antonio Bay, Texas	322
Flower Garden, Texas	268
Graveline Bayou, Mississippi	618
St. Louis Bay, Mississippi	821
U.S. Southeast Coast (average)	103
Apalachicola Bay, Florida	158

Table 5.-- Zinc levels (in ppm) in Crassostrea virginica for sites in southeastern United States (modified after Lytle and Lytle, 1982; Isphording, Stringfellow, and Helton, 1983).

Metal	St. Louis Bay Mississippi	Mobile Bay Alabama	Concentration Factor
Cobalt	0.04	11.0	275
Chromium	0.1	0.1	1
Copper	32	106	3.3
Iron	57	694	12.2
Nickel	0.2	18	90
Titanium	2	1	0.5
Vanadium	2	63	31.5
Zinc	821	1,887	2.3

Table 6.-- Average heavy metal content (in ppm) in specimens of Crassostrea virginica from St. Louis Bay, Mississippi and Mobile Bay, Alabama. Relative difference between samples from the two sites is shown as "concentration factor."

from the two areas were compared. This would indicate, almost certainly, that it is not the present level of metals in the water column that have created the problem situation in Mobile Bay. Rather, the problem can be traced to the large quantities of metals that were discharged into the bay and were incorporated into the sediments prior to the imposition of present discharge standards.

CONCLUSIONS

The history of Mobile Bay is similar to many other estuaries in that it has acted as a reservoir for heavy metals and its sediments have adsorbed significant quantities, over the years. These metals have been derived chiefly from the discharge of municipal and industrial effluent but, in part, also stem from natural causes. Because the sediment is a reservoir, and not a sink, a flux may exist in either direction at the sediment-water interface, depending upon ambient conditions. Hence, the sediments have the ability of releasing metals either back into the water column or, by ingestion, into the resident fauna. Samples of oyster tissue analyzed from Mobile Bay show that the fauna have, and are, accumulating elevated amounts of some heavy metal species. Some metals, in fact, have reached levels in the tissue that should be cause for concern. Because of this, man's activities in the bay will have to be carefully monitored to insure that the delicate balance that now exists is not disturbed. The very nature of the sediment properties in the bay makes this necessary. Three factors have conspired to place the bay in jeopardy: (1) the bay is dominated by fine grained sediments (silts and clays) that have an enhanced ability to absorb pollutants and contaminants, (2) the sediments are also characterized by high levels of organic carbon; this material, similarly, has a strong affinity for the absorption of contaminants, and (3) the clay mineral fraction of the bottom sediments contains high quantities of smectite clays; these clays, more so than any others, have the ability of sequestering organic and inorganic contaminants, both on the surface of the clay platelets and within the lattice of the mineral. These factors, combined with the fact that Mobile Bay is both highly industrialized and serves as the terminus for the discharge of one of the Nation's major river systems, have acted to create a potentially complex situation. Because the bottom sediments do have the ability to absorb larger quantities of pollutants than those in other bays and estuaries in northern Gulf of Mexico, and because the bay does serve as a major source of commercial seafood, care must be taken to prevent any serious incidents involving either inadvertent discharge or spillage of contaminants in the bay. For this reason, the authors would advise against the basing of toxic waste disposal vessels in the bay. This stems not from the "emotional issue" raised by some that the vessels are unnecessary or that there is a danger of spillage caused by a collision in the bay. Rather, (1) such vessels are not only necessary, but are desirable; far better to insure the destruction of toxic compounds at high temperatures under conditions permitting the total monitoring of the activity (rather than burying the wastes in a landfill that, possibly, could "leak" in the future) and (2) the "collision" of large vessels in Mobile Bay has such a statistically small probability that it merits little serious consideration; more likely, however, would be the spillage of toxic contaminants during the loading of the vessel or, similarly, the release of such contaminants at the storage site adjacent to the bay during transfer from transport vehicles or by possible leakage of the containment vessel. From a purely scientific standpoint, Pensacola Bay would be a far better site for such an operation. The sand-dominated bottom makes absorption of contaminants far less likely as does also the more active water circulation pattern and lower organic carbon content of the sediments. Thus, in spite of "massive quantities of point source wastes" (see Isphording, et al., 1985) that were discharged into Pensacola Bay during the interval 1955 to 1964, it was able to recover quickly and remains as one of the "cleaner" bays in the northern Gulf of Mexico. Mobile Bay, in contrast, remains notably impacted and will require the deposition of many years of "clean" sediments to bury and conceal the effects of many years of pre-regulatory, unrestricted discharge.

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EFFLUENT FLOW STUDY USING RHODAMINE DYE IN THEODORE BARGE CANAL, A TIDALLY FLUSHED BAYOU IN MOBILE BAY, ALABAMA.

David M. Dean
Department of Biological Sciences
University of South Alabama Mobile, Alabama 36688

Abstract: Theodore Barge Canal and Ship Channel are modifications of Deer River; the system is a tidally flushed bayou and is similar to the relatively unmodified adjacent bayous, Fowl River and Dog River. Flushing studies of an industrial effluent, tagged with Rhodamine WT dye, were run in Theodore Barge Canal in November, 1986 to assess the potential effect of waste water from proposed industrial expansion in the area. Twenty seven stations were sampled for 30 days. The major flow of effluent, 53 percent in one day, is attributed to the movement of the low density effluent on the surface. The low density effluent, that was tagged, had a residence time (99% flowed out of the canal) of only 15 days. A "Cell Model", derived from the sampled data, is used to predict the dye concentrations values at equilibrium. The model predicts that effluent will not become concentrated in the canal. Data from the study suggests that Mobile Bay and Theodore Ship Channel act as a salt-wedge estuary. Sea water moves in along the bottom of the system and surface water flows out.

INTRODUCTION

Degussa Corporation's Alabama plant is located in Theodore, Alabama. The plant manufactures a number of products including hydrogen cyanide, cyanuric chloride, silicon tetrachloride, and methionine. Cyanuric chloride is used in the manufacturing of biodegradable herbicides. Methionine is used as an additive to soy bean feeds which are deficient in this essential amino acid. Two new plants are currently under construction: a hydrogen peroxide plant and an Ultraform plastics plant. Hydrogen peroxide will be used as an oxidizer and bleaching agent, as a substitute for chlorine, by a number of industries including the paper industry. Hydrogen peroxide forms water when it degrades and it does not form chlorinated hydrocarbon degradation products like chlorine. Ultraform is a thermoplastic somewhat similar in to nylon. It has a very low thermal expansion coefficient and is useful for the manufacturing of machine parts with critical tolerances.

Effluent from Degussa Corporation's proposed Ultraform plant and waste from the existing Methionine plant will produce up to 0.4 million gallons of effluent per day with a residual biological oxygen demand (BOD). When organic compounds are metabolized by microorganisms in the aquatic environment, the organisms use dissolved oxygen. Biological oxygen demand is a measure of the rate that microorganisms take oxygen out of the water as they metabolize organics. To assess the potential effect of the organic compounds in this effluent on the dissolved oxygen (DO) in the receiving waters, the Alabama Department of Environmental Management requested a dye study to delineate the flow and flushing characteristics of Degussa's effluent in the Theodore Barge Canal.

During this study, 3.4 million gallons of Degussa's effluent was labeled with 10 gallons of dye over 24 hours (approximately one tidal period). Water samples were taken periodically from stations in Theodore Barge Canal and analyzed for dye; over 1400 water samples were analyzed over a period of one month.

Study Area

Theodore Barge Canal and Ship Channel are modifications of Deer River; the system is a tidally flushed bayou (Figure 1). Degussa has run an environmental water quality monitoring program in the Theodore Ship Channel and Theodore Barge Canal for over five years; water samples have been taken once or twice a week. Data from this sampling program is being used to describe the physical and biological characteristics of the area.

The biggest physical difference between this system and the relatively unmodified adjacent bayous, Fowl River and Dog River, is depth. The ship channel (Figure 2) is 40 feet deep; the average and maximum depths of Fowl and Dog Rivers is considerably less. Surface water from the Gulf of Mexico fills the deeper part of the ship channel. Salinity measurements at 30 to 40 feet in the ship channel usually run from 25 to 30 parts per thousand (ppt); these values are at or close to the salinity of sea water. The surface water, formed by fresh water runoff, has a salinity of 0 to 5 ppt, depending on the recent precipitation history. A midwater, with salinity of 10 to 20 ppt, can usually be defined by haloclines between the surface and deep water masses. The system is always stratified. There is a strong tendency for descending vertical stability, i.e. lack of vertical mixing, between the surface and deeper water; ascending vertical mixing, from the bottom to the surface, occurs at an undefined rate.

Circulation of water in the deep part of the ship channel is poorly understood The dissolved oxygen levels are usually significantly lower than the surface waters suggesting that circulation is poor, but occasionally the dissolved oxygen level changes fairly rapidly and may reach near saturation levels. This indicates the movement of deep water into the ship channel. The water in the dead end of the ship channel, the ship turning basin, moves upward. This vertical mixing of the deep layer of water into the surface water is typical of a salt-wedge estuary and this is the process by which intermediate salinity estuarine water is produced. Circulation of the surface is primarily a function of flow down the geostrophic slope, the average of the gravity and density slopes, from land toward the sea. Tide, wind, and bottom irregularities influence the periodicity of this flow and the creation of eddies which increase mixing. Oceanic plankton occasionally appears in the surface water of the ship canal and barge canal. This also indicates the movement of sea water into the surface waters of the area.

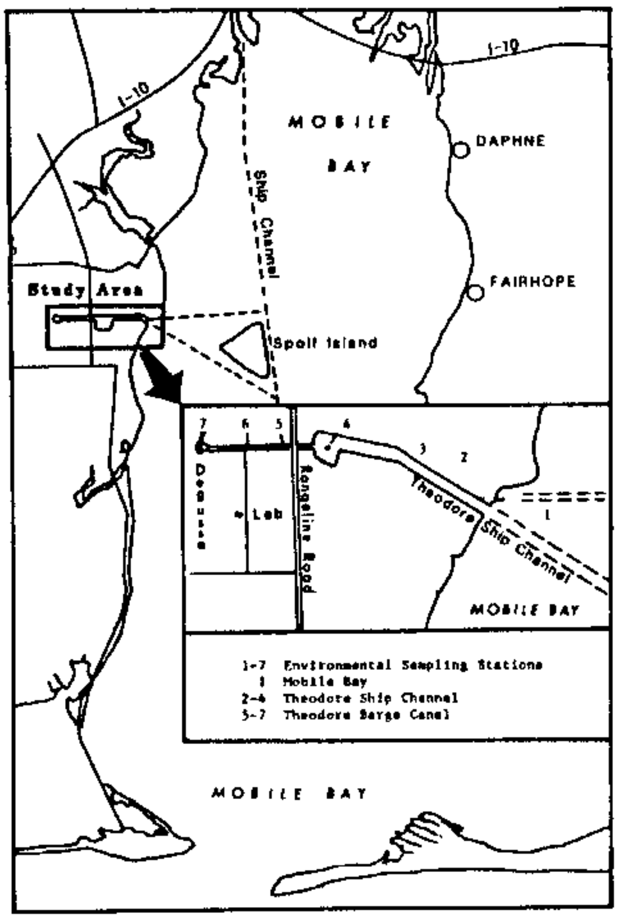

Figure 1. Mobile Bay and Theodore Ship Channel

Theodore Barge Canal (Figure 3) is a shallow narrow extension of the ship channel; it is about 6500 feet long, 165 feet wide and 12 feet deep; the volume is about 112.9 million gallons. There is a shoal in the center of the canal just west of Station 6 and directly in front of Degussa's outfall. The barge canal is also vertically stratified; the salinity in the barge canal is slightly lower than the ship channel because the canal is much smaller and has a proportionately larger inflow of fresh waters from small streams. The largest stream that flows into the canal drains the land south of Degussa's property and Degussa's effluent; the outfall from this stream enters the middle of the barge canal. Degussa's effluent is the primary source of water during periods of low rainfall. The salinity of this water is 1 to 2 ppt; the density is lower than the receiving water and forms the surface water in the east end of the barge canal.

The dissolved oxygen (D.O.) in the surface water of the barge canal is low during the summer months. The D.O. seldom goes below 5 parts per million (ppm) at station 6 near Degussa's outfall; 5 ppm D.O. is the State of Alabama minimum for Fish and Wildlife water classification except where natural conditions cause the value to be depressed. In 1985, the D.O. fell below 5 ppm one time during the biweekly field sampling program. The great variation in dissolved oxygen during the summer months is due to high water temperatures, which lowers oxygen saturation values,

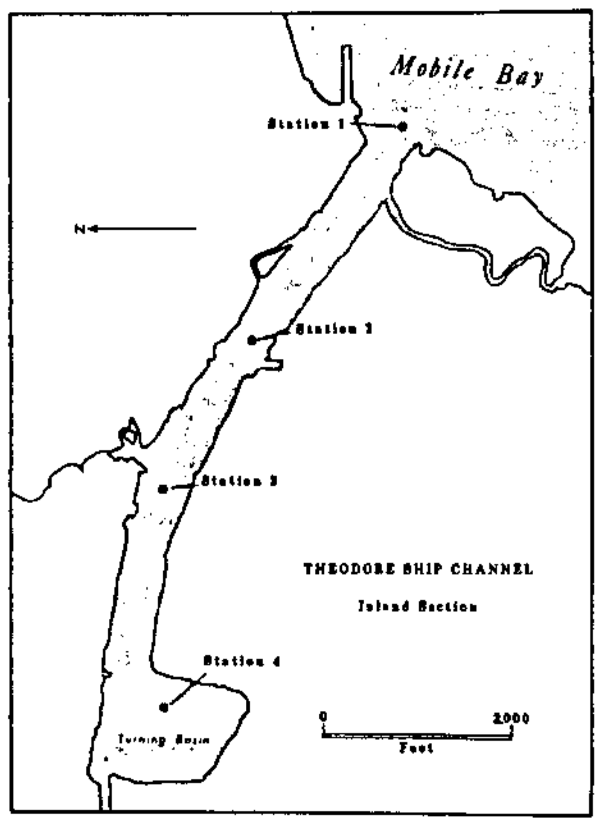

Figure 2. The inland extention of Theodore Ship Channel

temperatures, which lowers oxygen saturation values, and to dynamic phytoplankton populations which produce oxygen when the populations are prolific and depress oxygen values when the populations are dying off.

METHODS

Dye Injection

Dye was released at Degussa's flume; injection commenced on November 6, at 1400 hours. Flume flow was monitored and maintained at 3.4 million gallons per day. Rhodamine WT dye was injected at a rate of 10 gallons (37.9 liters) of dye over a 24 hour period; the resulting effluent concentration was 2.94 ppm dye. Rhodamine WT is visible at about 100 ppb; the initial tagged effluent flow was highly visible both in the effluent and in the surface of the eastern end of the barge canal.

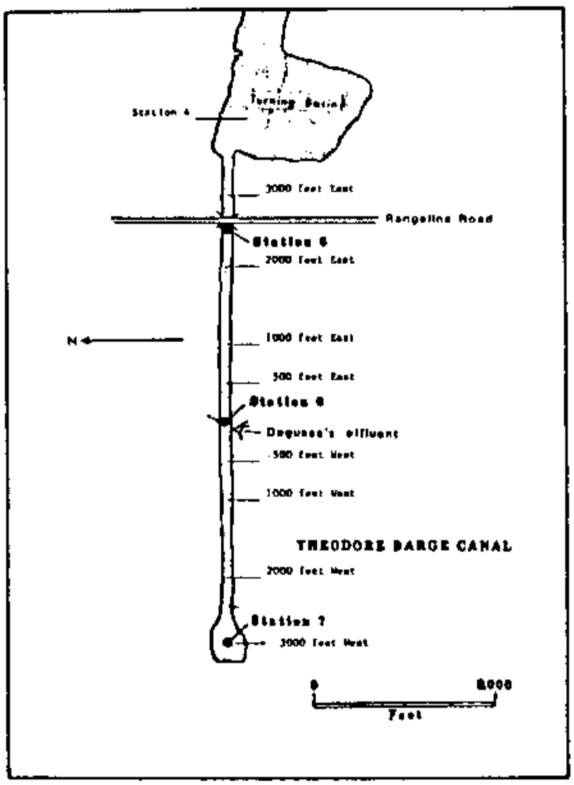

Figure 3. Theodore Barge Canal and stations.

Sampling

Injection was monitored by sampling at the flume and at the outfall adjacent to the barge canal. The outfall was monitored with an automatic sequential sampler which was set to sample hourly. Since the flume, where injection occurred, and the outfall are separated by a stream and pond, there is about a nine hour delay between injection and the flow of dye into the barge canal. Dye began to enter the canal at 2300 hours on November 6; this time was designated the starting time or hour (day) zero.

Prior to the dye injection, the canal water was monitored once a week for one month. Background interference, during this time, averaged below one part per billion expressed as Rhodamine WT dye. The barge canal and ship channel were sampled, from a small boat. There are nine sampling stations in the barge canal; sampling stations are marked every 1000 feet east and west of station 6 which is near Degussa's outfall (Figures 3 and 4). In addition, there is one station 500 feet east and one station 500 feet west of station 6. One station, Station 4, in the ship channel turning basin, was sampled regularly with the barge canal stations. Samples were taken at 3 depths at each station; 1 foot, 5 feet, and 10 feet. Samples were taken every three hours for the first two days, every six hours for the next two days and every 12 hours for the next 12 days.

Degussa has run an environmental water sampling program in this study area concurrently with the dye study and the stations in Theodore Ship Channel (Station 1-4) were taken at least two times per week during the dye study. Salinity, dissolved oxygen, and temperature are measured in situ and pH, total organic carbon, total dissolved solids, total suspended solids, total chloride, biological oxygen demand, and total Kjeldahl nitrogen are measured in Degussa's environmental laboratory. Analysis of water samples taken weekly for one month prior to the start of the dye study indicated that background interference was at or below 1 ppb expressed as Rhodamine WT dye.

During this study, water samples were taken for 36 days; at the end of the study the average fluorometer readings for each station converted to dye concentrations below 2 parts per billion (ppb).

Dye Analysis

A Turner 111 filter fluorometer with a five milliliter flow-through cell was used to analyze the water samples for Rhodamine WT dye.

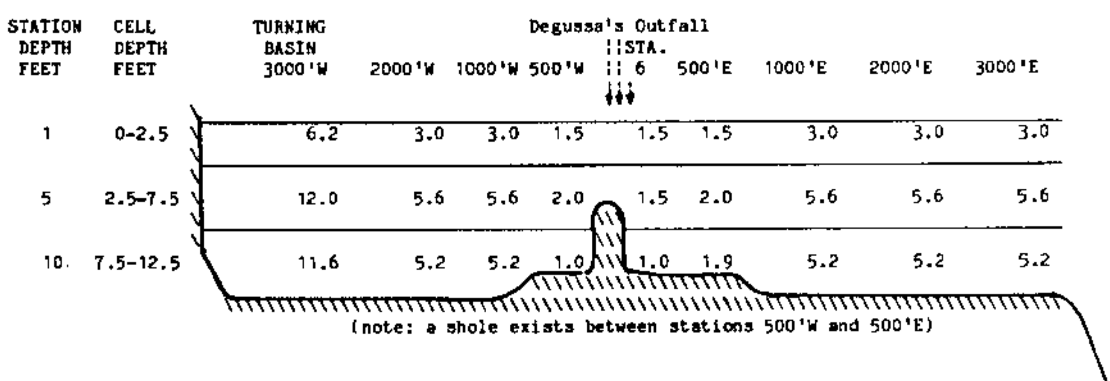

Figure 4. Cross section diagram of Theodore Barge canal. The volume of the cells is given in million gallons. Each sample station is represented by a cell.

Calculation of the Flushing Rate of Theodore Barge Canal

The methods typically used for analysis of wastewater transport consists of either continually feeding dye into the system until equilibrium states are reached in the receiving water, or rapidly injecting a large batch of dye into the water and following the dye over a period of time (Carpenter, 1960; Bailey, 1966). The continual injection method can not be applied to a single ended tidally flushed canal. The generation of an equilibrium condition for the calculation of isopleths (lines of equal concentration) is not practical; it is estimated that it would take 30 to 60 days of dye injection to reach an equilibrium in the canal. The batch method is not appropriate for tracing an effluent into a receiving water system effected by tidal periods. Dye injection should run for some fraction of a tidal period or preferably for a whole tidal period (Yotsukura et al., 1972). The movement of water in a tidally flushed, dead ended, stratified estuarine bayou is compicated. Fischer (Fischer et al., 1979) points out that both field data and models together can help to provide answers to the complexity of water movements in stratified estuaries. The transport of effluent in Theodore Barge Canal can be obtained from the data gathered during a dye study to calculate the rate of decrease of the total dye mass in individual areas of the barge canal. The rate of change of the dye mass in the canal can then be used to define a model that can reconstruct the behavior of the system over longer time periods.

In this study, a known mass of dye is injected into the effluent entering the canal over 1.5 tidal periods and then the movement and decrease of this dye mass is defined by the sampling in the canal. This dye mass is expressed as a dye volume or as a percentage of the volume of injected dye. The dye volume in the canal, at any specific sampling time, is estimated by assuming that the dye concentration value recorded for an individual station at a specific depth represents an average for a water mass or cell:

cell dye volume =
(cell dye conc./ stock dye conc.) X the cell volume

In rhodamine dye studies, the stock dye is defined as having a concentration of 1 and the fluorometer readings are calibrated by diluted stock dye; thus:

cell dye volume = cell dye conc. X the cell volume
and dye percentage =
(cell volume / injected volume) X 100

The injected volume was 10 gallons.

To define the water volume in each cell, the dimensions and volume of Theodore Barge Canal were calculated using physical measurements, aerial photographs and depths from a bathymetric survey of the canal. At the time this survey was being made, the U. S. Corps of Engineers was also conducting a survey of the canal. A copy of this survey, when it is published, will be used to compare the calculations.

The barge canal is divided into 27 cells with volumes varying from 1 to 12 million gallons each (Figure 4) The sample depths are not arbitrary but are based on temperature and salinity data from Degussa's regular sampling program. There are normally three water masses in the barge canal separated by water density. The total volume of the Theodore Barge Canal is estimated to be 112.9 million gallons. The horizontal to vertical bottom profile is estimated to be 2:1; the dimensions and volume of the cells at a typical station is shown in Table 2.

Sample Depth	Cell Depth	Cell Length	Cell Width	Cell Volume
1'	2.5' (0-2.5)	1000'	160'	3.0 MG
5'	5' (2.5-7.5)	1000'	150'	5.6 MG
10'	5'(7.5-12.5)	1000'	140'	5.2 MG

Table 2. Station 2000 East (dimensions in feet; volumes in million gallons).

Errors in estimating the barge canal volume have little effect on this method of monitoring water movement because, for each time frame, the same volume values are used. The total canal dye percentage is the sum of the dye percentages in all 27 cells. Any set of cells i.e. surface, five foot, ten foot, eastern end or western end can be quantified in the same way.

Estimations of mixing and flushing were made by calculation of the rate of change of dye percentages, in defined water cells, with time. The time was based on the actual flow of dye into the canal. Dye flow began November 6 at 2300 hours and this was defined as time zero.

This method of calculating flushing rate has three advantages:

1. The method is not dependent on the quantity of dye initially injected or the period of injection if the injection process creates a reasonably high concentration of dye in the receiving waters during a short period of time. Once the dye has entered the receiving waters, the amount of dye in the canal can only decrease by flushing out of the canal. The only dye loss in measurements is the dye that is below the fluorometer detection limits and any dye lost by oxidation. As noted above, degradation of dye was not considered to be significant in the test.
2. The method is not affected by background interference if the initial dye concentrations are relatively high. Minor background interferences, if constant, have no effect on the calculated flushing rate slope.
3. This method allows for the calculation of dye movement by depth or area of the study site, thus a dynamic multidimensional image can easily be constructed. This is important in this study because of the vertical water stratification and the variations in flushing rate from different areas of the barge canal.

Two factors are important in creating a relatively high dye concentration in the receiving water. The amount of dye should be as great as practical, and the injection period should be minimized. Since Theodore Barge Canal is tidally influenced, the injection period should take the tidal period into account. During this dye tracer study, 10 gallons of Rhodamine WT dye injected into Degussa's effluent flume over a 24 hour period. Ninety percent of this dye was accounted for by the Isco samples taken in the outfall in a period of 30 hours.

Special Problems Encountered During the Study

There were two notable problems during the study. The wind velocity, during the first three days, was exceptionally high and from the South East; the average wind vector for November 6 through 8 was 6.1 miles per hour from the south southeast with southeast gusts to 23 miles per hour. Wind from this direction funnels into the high banks of the barge canal from the East; thus there was an exceptionally high western surface wind sheer during the first three days of the study and a tendency to push the surface water, which contained most of the dye, back into the barge canal. Rain was below average during the study; there was some light rain on November 11. Flushing was not enhanced by storm water runoff.

A second problem occurred on November 13; due to mechanical problems within Degussa's facilities, the effluent discharge was shut down for one week. Since the low density effluent is a major factor in the easterly flow of surface water in the barge canal, this factor was eliminated for the period of November 13 to November 20. By November 13, essentially all of the injected dye had entered the canal; injection was not influenced by this shutdown of Degussa's discharge.

RESULTS

Injection and Outfall Flow Pattern

Ninty percent of the injected dye was accounted for by the sequential sampler at the outfall in 1.5 days (Figure 5) and there was no significant dye flow after two days.

Dye Flux in the Barge Canal

The sum of all the cell values in the barge canal produces a picture of the total dye flux for the study (Figure 6). The highest values recorded occur at about day 1.5; 71 percent of the total dye injected can be accounted for in the cells. Day 1.5 coincides with the end of the significant inflow of dye from the outfall. From day 1.5 to day 3, there is a sharp decrease in dye levels from 71 to 26 percent; this decrease in the total barge canal dye is primarily due to the decrease in the East surface values. The total dye values proceed to decrease, at a slower rate; at day 15, less than one percent of the dye remains.
(day 1 and 2). The East surface cells contain most of the measured dye during the first two days and then the values fall off sharply; simultaneously the outfall values are high for 1.5 days and fall off sharply (Figure 7).

Dye Flux in the East Surface Cells

The large quantity of Rhodamine WT dye used in this study made the flow visible detectable; the morning after the beginning of dye injection, the flow pattern could be discerned in the barge canal. Despite easterly winds, the dye turned eastward after entering the canal and flowed toward the Theodore Ship Channel. Most of the dye stayed at the surface and the eastern end of the barge canal and about one quarter mile of the ship channel was visibly red on November 7 and 8, (day 1 and 2). The East surface cells contain most of the measured dye during the first two days and then the values fall off sharply; simultaneously the outfall values are high for 1.5 days and fall off sharply (Figure 7).

Dye Flux in the West Cells

The percentages of dye in the West surface and five foot cells are significant (Figure 8); there are sharp increases in dye percentages between day 0.5 and 1. Between day 1 and 3, there were sharp fluctuations in dye values recorded in the five foot West stations; the sharp increases correlate with flood tides . This was also the period of strong easterly winds in the barge canal.

DISCUSSION OF THE RESULTS

Dilution

Dilution is the ratio of dye in the barge canal to dye in the outfall expressed as a percentage. The highest dye concentrations were measured in the east surface cells; consequently, the minimum dilution is based on the east surface cells during the period of time that the dye is flowing into the canal (the 2 day period following November 6 at 2300 hours. The average

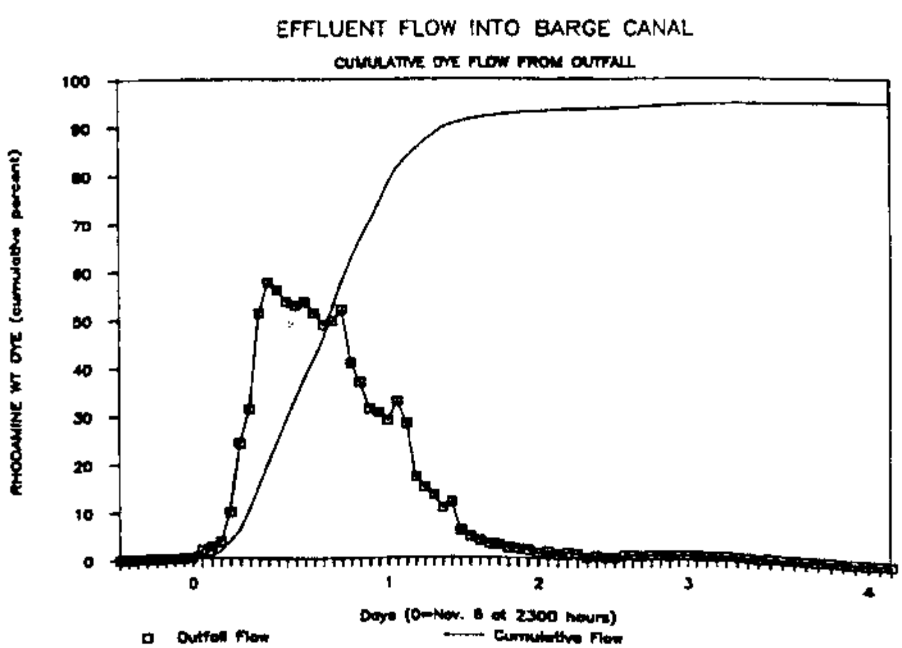

Figure 5. Cumulative flow of dye in the outfall (percent of 10 gallons) and relative concentration.

ratio of the concentrations in the east surface cells (area of highest concentration in the barge canal) to the outfall is 8.7 percent (standard deviation 1.3; maximum 10.9; minimum 5.2).

Residence Time of Dye in Theodore Barge Canal

Residence time is the period (days) that a specified percentage of dye continues to reside in the barge canal. Residence time can be measured from the point immediately after the dye stops entering the

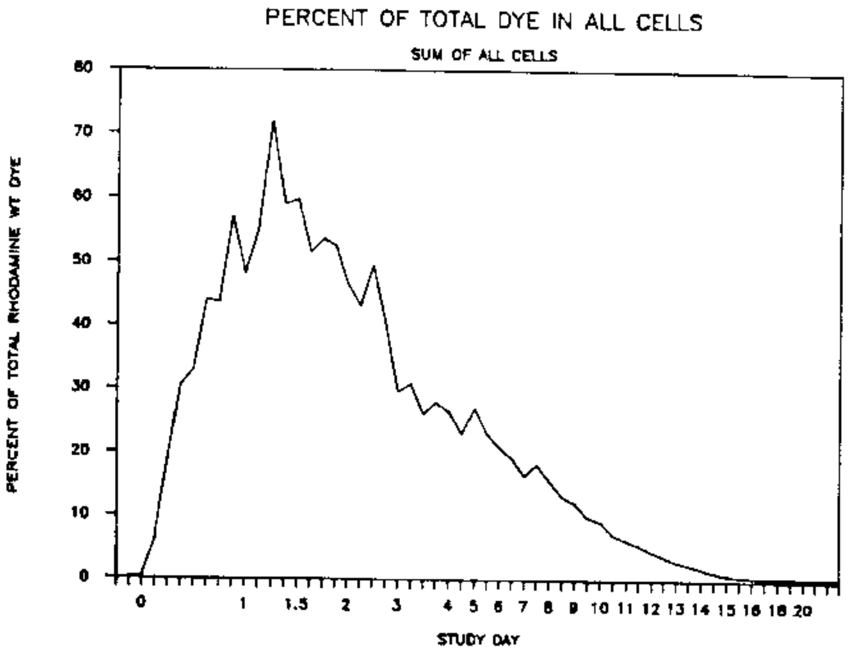

Figure 6. Total percentage for all cells in the barge canal from day 0 through day 20.

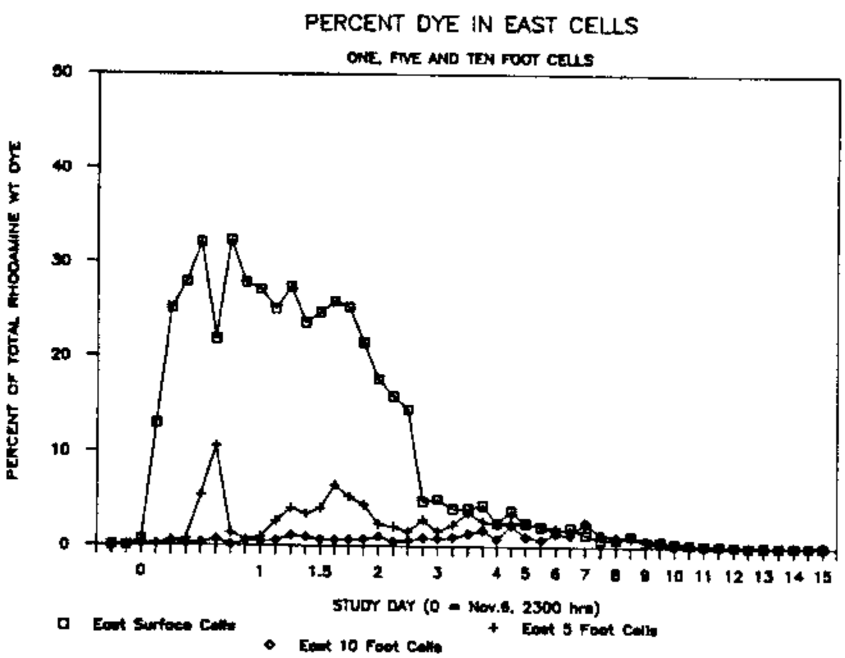

Figure 7. Percent dye in east one foot, five foot, and ten foot cells.

canal; this is November 9 at 0500 hours (termed day 0 for residence time). For example, Residence time 50 is the period, starting at the specified day, during which the dye volume in the canal decreases from 100% to 50%. Note that residence time (Figure 9) is inversely proportional to flushing rate for the canal.

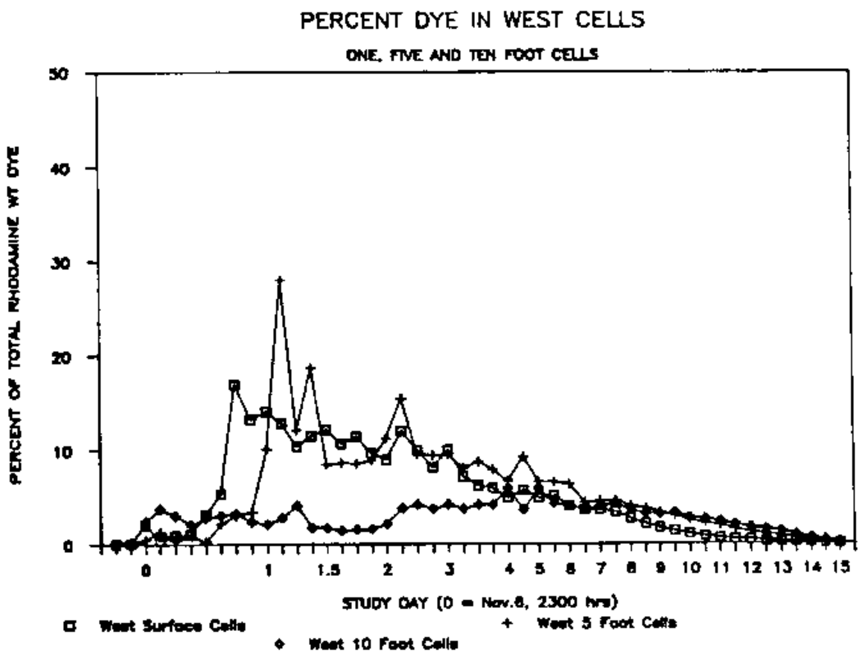

Figure 8. Percent dye in the west one foot, five foot, and ten foot cells.

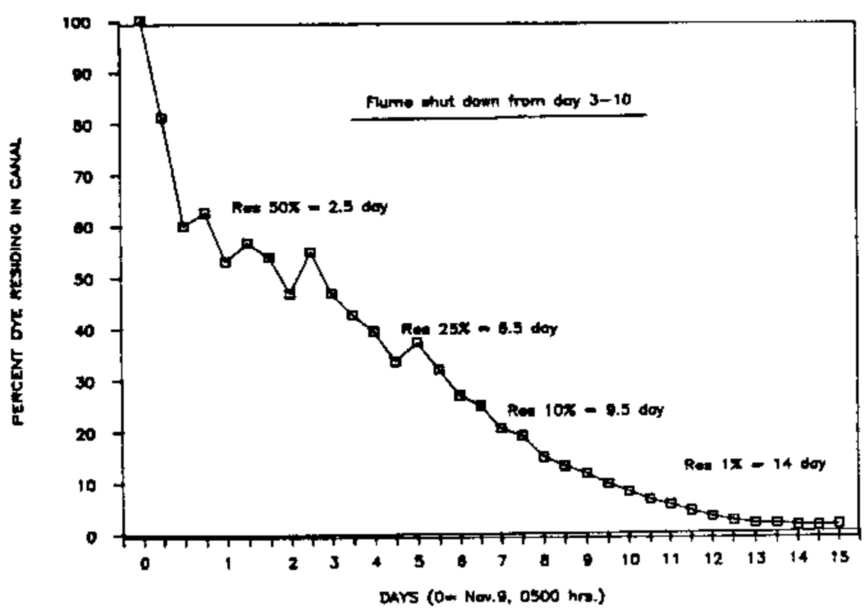

Figure 9. Residence time of the tagged effluent in the barge canal.

Regression Analysis of Cell Data and Derivation of Flushing Rates

Dye percentages from each depth were used to calculate the rate of decrease in dye at each depth by linear regression. The rapid runoff of surface water is apparent (Figure 7) between day 1 through 4 of the study (November 7 through 10) and was visibly apparent during the test. The estimated flushing rate for the one foot East station is significantly different from the other stations (Table 3) and is termed flow. The East surface flow slope at day 1.5 to day 3, immediately following the flow of dye into the canal, 0.63 percent per hour or 15 per cent per day. There is a good correlation between the outfall samples taken by the Isco sampler and the dye levels in the East surface cells.

Linear regression run on blocks of data gives a good quantitative comparison of the differences in mixing and flushing in different areas of the canal. Note (in Table 3, below) that:

1. the East surface cells have a significantly high negative slope from day 1.5 through 10. Dye is flushing out of these cells.

2. the 10 foot west cells have a positive slope from day 1.5 through 10. Dye is mixing into these cells.

DAY	W Sur.	W 5'	W 10'	E Sur	E 5'	E 10'
1.5-3	-0.008	0.038	0.091	-0.632	-0.105	0.003
1.5-5	-0.035	-0.035	0.051	-0.339	-0.030	0.003
1.5-10	-0.051	-0.041	0.003	-0.099	-0.017	-0.001
5-20	-0.024	-0.024	-0.019	-0.007	-0.008	-0.005

Table 3. Linear regression slopes for the East and West cells at the three depths. Slope values represent change in percent of total dye per hour. A negative slope represents decreasing dye or flushing; a positive slope increasing dye and thus dye mixing into a cell

The slower flushing rate of dye that has mixed into the five and ten foot depths is apparent. The flushing rate of dye mixed into the subsurface levels is not linear; it is based on existing dye concentration and time. Where C1 is concentration at time 1 and C2 is the concentration one hour later:

$$dC/dt = 1\ hr / (110 \times C1)$$
$$C2 = C1 - 1\ hr / (110 \times C1)$$

This curvilinear regression gives a hyperbolic like curve.

The rapid decrease in the East surface cells represents the flow of the relatively low density effluent out of the barge canal. The rate of percent decrease is represented by:

$$dC/dt = -.63 / hour$$

Model Analysis

The point samples used in this study and the derived cell values can be used to model water movement in the barge canal. This model, termed Cell Model, is very similar to the computer run Link-Node model developed by Water Resources Engineers, Inc. which was used to predict water conditions in the barge canal for the Mobile 208 study (South Alabama Regional Planning Commission, 1977) before the canal was constructed. The Cell model is derived from dye concentration values and includes a vertical component as well as a horizontal component. Further more, the sampling points or nodes in this model are much closer together than the model used in the 208 study; the Link-Node model used 2 and this study uses 27. The Cell model derives flushing rates from regression analysis of the sampled data; these exchange rates between cells are analogous to the links of a link node model.

The sum of the curvilinear and linear regression gives an empirical fit to existing data; structural meaning can not be read into the terms. However, the fit of these two equations, which were derived from field data, can be tested further for fit by

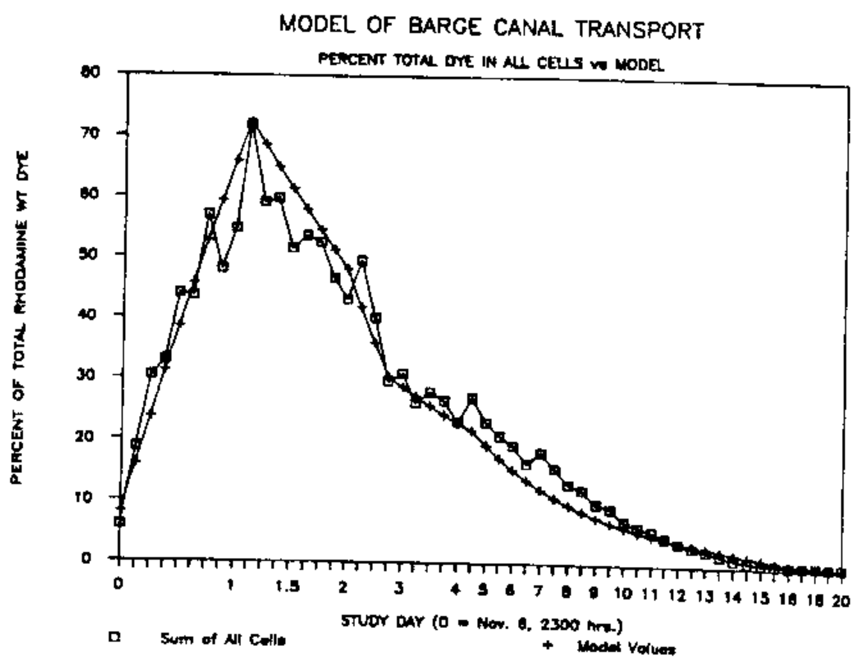

Figure 10. Cell Model: +0.33 gal. dye/hr. for 30 hours; minus east surface flow and subsurface flushing.

introducing a third, known, data set; this is the injection of 10 gallons of dye over a period of approximately 30 hours. The model adds 100/30 percent dye per hour for 30 hours and subtracts the two derived equations,shown above, to flush dye from the model. The model is run by a computer and the output plotted. The resulting curve gives a good fit between the model and sampled data (Figure 10 and Table 4). No attempt was made to separate of define the tide or wind effects in to the Cell Model; however, it should be noted that the Cell Model is derived from field conditions which were affected by wind and tide. When the Cell Model is run continuously with a constant injection rate of 0.3333 gallons per hour (the same rate used in the test) an equilibrium is reached in 60 days (Figure 11). The average dye concentration in the model cells, excluding the east surface cells, is below one percent of the outfall concentration.

	DAY	DAY
Slope	0-1.5	1.5-20
Intercept	0.86	0.73
R Squared	5.09	5.86
Std error of estimate	0.92	1.06
Std error of coefficient	5.48	2.98
Number of observations	10.00	44.00

Table 4. Linear regression of two phases of the Cell Model versus field data. Day 0 through 1.5 is the injection phase; day 1.5 through 20 is the flushing phase. Injection volume and period is 10 gallons of dye in 30 hours.

CONCLUSIONS

Estuarine Circulation

The Mobile Bay estuary is a salt-wedge estuary. The circulation processes (Figure 12) involve a landward movement of sea water and a seaward movement of fresh water. A sloped density discontinuity, pycnocline, is formed primarily by salinity differences (thus a halocline) tends to keep these two water masses separated, but friction and internal waves cause eddies and mixing to form an estuarine water mass of intermediate salinity. Water mixing across the pycnocline is primarily an upward vertical process of seawater mixing into the fresh surface water layer. The mixing of surface water into the deeper layer is contrary to the density slopes and requires energy. Energy for mixing may be supplied by surface waves produced by strong winds, water flow over bottom irregularities, and internal waves. Theodore Ship Channel and Theodore Barge Canal are a branch of this salt-wedge estuarine system. The barge canal receives water from Mobile Bay and in addition receives fresh water from the surrounding land drainage courses.

The data from this effluent transport study supports the postulation that the barge canal also functions as a salt-wedge estuary with an inflow of high density water on the bottom and a flow of lower density surface water towards Mobile Bay.

The waste from the Ultraform and methionine plants will be treated with large oxidation ditch, clarifier, holding ponds, and a rock-reed filter. The rock-reed filter is an artificial marsh. A scale prototype system is currently being tested at Degussa. These biokinetic design studies are being continuously run on

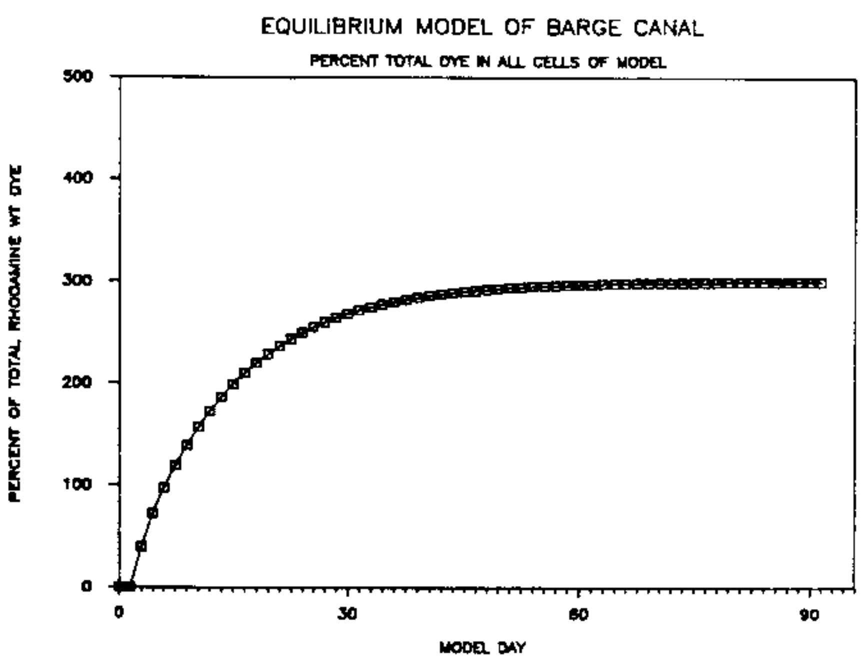

Figure 11. The Cell Model run with constant injection of 0.33 gallons of dye per hour minus the east surface flow and the subsurface flushing. Note that equilibrium is reached in about 60 days. The average concentration in the canal at equilibrium is 268 parts per billion dye.

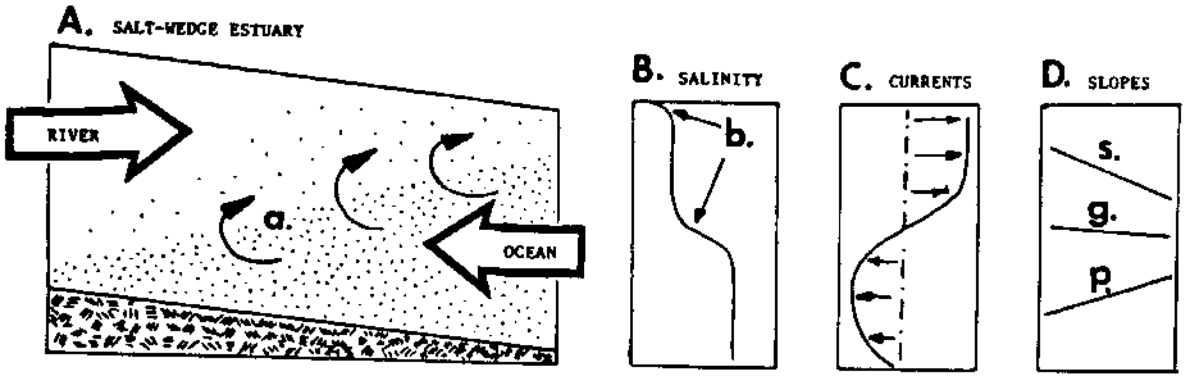

Figure 12. Schematic representation of a simple salt-wedge estuary (A.) showing the layered structure, the landward flow of oceanic water, the seaward flow of river water, and the upward vertical mixing process which forms estuarine water. The salinity profile (B.) shows sea water, estuarine water and fresh water each separated by sharp discontinuities or haloclines (b.). The average currents (C.) show the vertical distribution of water movement; river and estuarine water moving out on the top and sea water moving in below the surface layers. The driving force for the horizontal movements of water (D.) are the density slopes, which are shown with vertical exageration: s. = the surface slope; g. = the geostrophic slope; p = the pycnocline or halocline slope. The driving force is the geostrophic slope (g.).

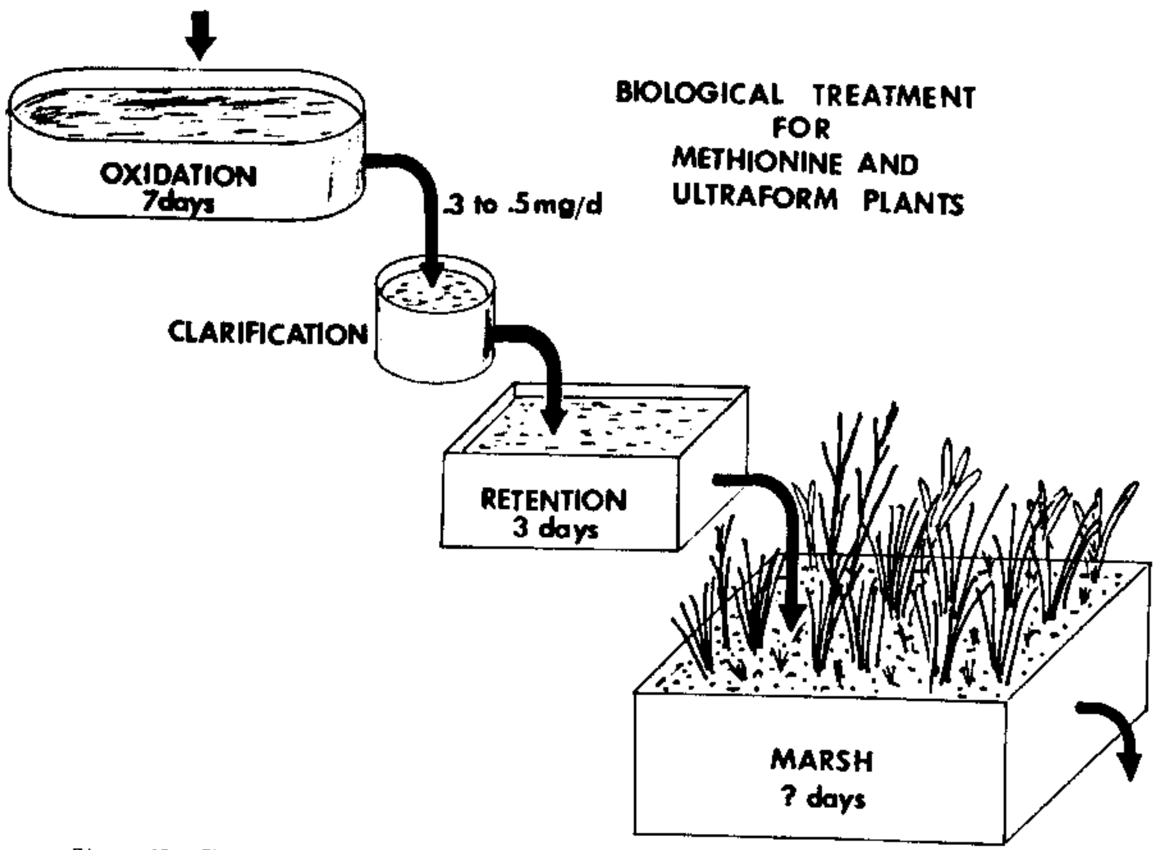

Figure 13. The prototype biological treatment system uses an oxidation ditch for bacterial degredation of organics. variety of microorganisms and vascular plants to further treat the effluent.

waste obtained from an Ultraform plant in Europe in a scale model treatment system (Figure 13.) As the microorganisms, used in the system become acclimated and proficient at metabolizing the waste, the concentration of organic compounds in the waste will decrease.

This tagged effluent study was designed to estimate the potential effect that the proposed waste and treatment system will have on Theodore Barge Canal, the receiving waters. Recent data (January 1987) from the prototype treatment system indicates that the five day BOD average is 3.7 and ten day BOD average is 6.0. These values are based on undiluted raw waste that has been run through a prototype oxidation ditch and before complete treatment and mixing with other effluents. The ratio of existing inorganic effluents and cooling water to the Ultraform waste stream will be about 10 to 1. The combination of these streams is referred to as total treated waste water (TTWW). The potential effect of refractory or long term BOD is important. The estimated difference between the Ultraform waste stream's contribution to the five and ten day BOD of TTWW is about 0.7 ppm. In the barge canal, the highest concentrations of effluent will be in the eastern surface waters. In this area there is a further dilution of 10:1 or greater, the estimated difference in contribution of five and ten day BOD will be below 0.1 ppm. The dissolved oxygen in this area averages above six ppm DO during the summer months when the DO levels are at their lowest values. The estimated difference in the effect of the five and ten day BOD on the barge canal is not significant.

Flushing of the Tagged Effluent in the Barge Canal

The major flow of effluent is attributed to the flow of the low density effluent on the surface. The East surface cells alone account for 53 percent of the dye in the barge canal just after day 1 when the total canal dye peaked. The movement of this water was visibly apparent during the study and is also apparent in the East surface cell graph (Figure 7).

In considering the whole barge canal, more than 75 percent of the dye was flushed out in the first five days; 83 percent in 5 days after the end of dye addition from the outfall. Ten days after the dye began to enter the canal, 93 percent of the dye flushed out. By 15 days, less than 1 percent was measured, and the canal was near background values.

Testing Conditions

The strong East and Southeast winds which occurred during the first few days of the study, the lack of rain preceding and during the study, and the shutdown of Degussa's discharge during the second week of the study, all decreased the flushing rate of the barge canal to some unknown extent. In particular, tide induced mixing between the surface and five feet in the western end of the barge canal is indicated by the data Flushing conditions were less than optimum during the study, therefor, the data gives a conservative or worse case estimate of the transport characteristics of Degussa's effluent in the Theodore Barge Canal.

The effects of tidal periods has not been completely analyzed at this time; however there are correlations between tide stage and the mixing of dye from the surface into the five foot level west of the outfall. The shoal in this area induces mixing during flood tide (Figure 14).

Correlation of the Field Data and the Model.

The Cell model was constructed from three different subsets of data; all three of the flow equations were started at day 0. The model falls within the 95 percent confidence limits and accounts for 101 percent of the dye. The model implies that the field data, which appears to account for only 72 percent of the total injected dye, is correctly accounting for all of the dye because dye is flowing, on the surface, out of the sample area into the Theodore Ship Channel during the injection period. Although the ship channel was sampled during the study, it was assumed before the study started that it was impractical to provide the high sampling density needed to extend the Cell Model concept into this relatively large area.

Both the field data and the Cell model indicate that maximum dye concentrations in the barge canal are about 10 percent of the concentration in the outfall in the east surface cells. The Cell model predicts that

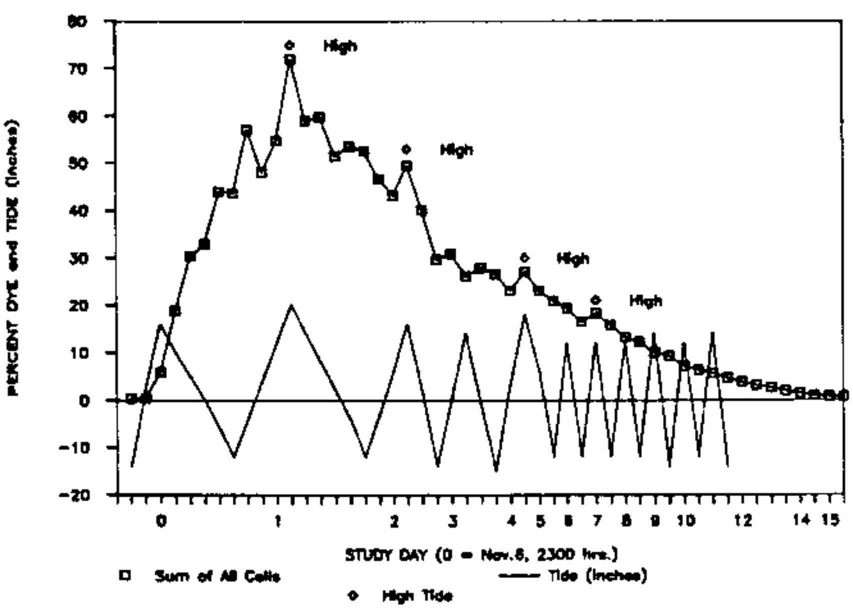

Figure 14. Total dye in all cells compared with tide. Note the dye increases that correlate with flood tide. These increases are in the west cells.

the average concentration in all the other cells, besides the east surface, will be below one percent of the outfall concentration when the system reaches equilibrium.

The dye study and the model support the concept that the barge canal functions as a salt-wedge estuary system with an inflow of salt water on the bottom and a outflow of low salinity water on the surface; however, the separation of the barge canal by a central shoal causes turbulence during tidal movements and increases downward mixing in the western end of the canal. This is especially apparent when the differences between the flushing slopes of the five foot levels are compared in the eastern and western ends of the canal. During the period just following the end of injection (day 1.5 through 3) the eastern five foot level was losing dye (slope -0.105) and the western five foot level was still gaining dye (slope +0.038). This indicates that the shoal, that divides these areas, interrupts the normal inward movement of deep water and outward movement of surface water. Downward vertical mixing is enhanced by this shoal.

RECOMMENDATIONS

Although the normal approach to improving the interaction between an industrial outfall and the receiving waters is to encourage dilution through mixing, the opposite approach is more appropriate in a salt-wedge estuary. If the effluent has a relatively low density, it will form the surface layer, tend not to mix down into the salt wedge, and move seaward more rapidly. The surface layer in the Theodore Barge Canal is best capable of assimilating the effluent because it has the highest concentration of microscopic phototrophs and heterotrophs. Due to the photosynthetic activity of phytoplankton, the dissolved oxygen levels are usually at or above saturation values. Data from Degussa's field environmental program indicates that dissolved oxygen in the surface of the barge canal almost never goes below five parts per million; samples have been taken weekly or biweekly for over five years. During to late summer, the most critical time of the year for rapid environmental changes in the canal, the dissolved oxygen is often above saturation because of the intense activity of phytoflagellates. These organisms are facultative heterotrophs and are probably capable of assimilating organics from the water. During the same period, there are large populations of nonpigmented flagellates which are obligate heterotrophs. In the late summer and fall, the dissolved oxygen at the ten foot level frequently falls below five parts per million; the biological oxidative assimilation of organics is inhibited at this depth because oxygen levels are low.

Both the effluent flushing rate and assimilation of organics can be enhanced by encouraging the normal salt-wedge flow in the barge canal. This can best be accomplished by removing the shoal in the center of the barge canal.

ACKNOWLEDGEMENTS

This study was supported by Degussa Corporation, Theodore, Alabama by contract to the University of South Alabama. I would like to thank the personnel in the Environmental Department at Degussa Corproation for their help; in particular Gene Sheppard, Corporate Environmental Manager and Lynne Newman, Corporate Environmental Coordinator for Water Compliance. I also thank Robert J. Beyers, Chairman, Department of Biological Sciences, University of South Alabama, for his assistance with computer processing.

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HYDROGRAPHY, CIRCULATION, WATER QUALITY AND POLLUTANTS PANEL

Summary of Panel Discussion

The participants on the "Hydrography, Circulation, Water Quality and Pollutants Panel" were:

Moderator: James I. Jones, Mississippi/Alabama Sea Grant Consortium
William W. Schroeder, Marine Environmental Sciences Consortium
Steve R. Heath, Marine Resources Division, ADCNR
Kenneth R. Marion, University of Alabama at Birmingham
Wayne C. Isphording, University of South Alabama
David M. Dean, University of South Alabama

INTRODUCTION

A comparison of the objectives of the First Mobile Bay Symposium with that concluded today demonstrates that the goals of these symposia were near identical, with resource evaluation, user-group competition, management strategies and environmental preservation emphasized in each. The rationale for the symposia was derived from knowledge of the ongoing conflict over the best use of the Bay, with multiple user groups advocating different uses. The Bay is utilized variously as a depository for industrial and domestic waste, as a human food source through the development of its fishery and other living resources, as a commercial port and as a major recreational resource for local and tourist populations. The "best" use of the Bay is that which provides optimum utility to each group of competing users, while maintaining a conservative ethic which guarantees the long-term utilization of this resource with little or no environmental degradation. Such "use" may appear utopian, but with sufficient information and judicious management this resource can maintain its many and varied roles indefinitely. Defining the scope and required level of precision of this essential information, and its use for management purposes are goals of this panel discussion and indeed, of this Symposium itself.

Although the topics addressed by this panel are of singular importance they may be conveniently consolidated within the combined categories of "Water Quality and Pollution" and "Hydrography and Circulation". The discussion by the panel and audience emphasized identificiation of water quality and pollution problems, with further emphasis on the role of the Bay's hydrography and circulation characteristics as they specifically relate to the identified problems. The following summarization of the discussion follows this format. It need be noted that the information from each panelist's presentations will not be included in this summary, its purpose being rather to provide a review and synopsis of the resulting deliberations.

WATER QUALITY AND POLLUTION

Heavy Metals

The type, quantity and consequence of heavy metal pollution in Mobile Bay was a primary concern of both the panel and the audience. The metal identification, source, rate of accumulation and severity of impact on the biota were major topics of discussion. These subjects were discussed in detail by the panelists, whose presentations appropriately formed the basis for most of the discussion. Copies of the individual panelists' presentations precede this section.

Multiple sources for Mobile Bay heavy metal contamination may be generally classified as industrial, municipal and domestic. Contamination through man's activities date principally from that period of the industrialization of Alabama which began approximately fifty years ago. The advent of environmental regulations in the late sixties curtailed much of this pollution, although the results of it will be with us far into the future in the form of the contaminated sediments which have been deposited in Mobile Bay and the Mobile River Delta. It was noted that over 200 million gallons of effluent empties into the Bay daily, from a watershed including approximately two-thirds of the the state of Alabama and portions of the neighboring states of Mississippi, Tennessee and Georgia. Many industries and municipalities are located along these rivers (Alabama, Warrior, Coosa, Tombigbee) and they have all had a role in the pollution of the Bay. As a result, it is impossible to define any single industry, company or municipality as the primary heavy metal pollutant source. It was noted that both cadium and mercury, which are extremely toxic pollutants occurred at low levels, well within an "acceptable" range or concentration.

Toxicity levels of specific heavy metals are poorly known, generally. Thus, it is extremely difficult to define "acceptable" levels of concentrations of heavy metals for purposes of human consumption or impact on living resources. Current procedures for defining "safe" concentrations were faulted as having little value under natural (as opposed to laboratory) conditions. The difficulty of evaluating the availablility of heavy metals to organisms or the environment is due to their particular chemical make-up, or specific bonding characteristics, making such an assessment difficult in the extreme. The panelists noted that current levels of heavy metal contamination have been achieved over a period of several decades and that these levels of concentration in the sediments should be expected to continue indefinitely unless extraordinary clean-up measures are successfully undertaken. Further, depuration rates for heavy metals in bivalve molluscs is very slow and a period of many years may be required to achieve significantly lower metal concentrations in these living organisms. In general, little is known about the capacity of most organisms to concentrate heavy metals, or of their ability to rid themselves of these contaminants under less polluted conditions. Little is known about toxic (sublethal) levels or the effect of heavy metal concentration in humans. A study to measure heavy metal concentrations in long-term residents of Mobile County is in progress at the University of South Alabama Medical School and will hopefully provide some much-needed information on this critical topic.

Dissolved Oxygen

Historically, low dissolved oxygen (DO) values have been reported and documented in Mobile Bay on many occasions. The values range from slightly depressed to hypoxic and anoxic. These conditions affect the Bay's biota in a variety of ways, the most obvious being extensive finfish and shellfish kills. As would be expected, these events are viewed negatively and seen as problems by many local persons even though such oxygen depletion is a natural phenomenon and characteristic of water bodies such as Mobile Bay. The view of the fishermen is, of course, that any event which kills trout and crabs is "bad", and should be rectified if possible. The fact is that the DO regime for the Bay is a natural cycle, and has probably been functional for hundreds of years, even to the point of anoxia. Anthropogenic activities over the last several decades have probably exacerbated low DO phenomena to some extent. Dredging activities for shell material and for the channel construction and maintenance have impacted on the natural condition severely, as has the introduction of industrial and domestic effluent. The present state of knowledge is insufficient to define and evaluate the extent of even the natural processes, much less those caused or influenced by man. The modifications to the natural system which man has already imposed prohibit an evaluation of what was "naturally" occurring prior to significant anthropogenic alteration. Thus, the problem of evaluating man's impact on the DO component of the ecosystem becomes even more perplexing. Some things are clear, however. The restriction of circulation caused by spoil disposal along the dredged channels is a major hindrance to lateral circulation across the Bay. The deep holes which have been left as a result of shell dredging create "pockets" where low DO water first accumulates at the onset of the cycle. The decrease in circulation and increase in stratification resulting from these factors prevents mixing of the deeper low DO containing water with well-oxygenated surface waters, leading to the observed hypoxic and anoxic conditions. Any solution to this "problem" requires that first the natural system be well understood, then the anthropogenic effects evaluated, and finally a management recommendation developed and implemented. Clearly, without a fundamental knowledge and understanding of the essential environmental characteristics of the Bay none of this may be achieved. While a common complaint of the scientist is that he "needs more data", this is indeed the case. Unless and until considerably better understanding of the natural characteristics of the Mobile Bay ecosystem has been achieved most actions to solve its "pollution problem" will continue to be random and largely ineffective, if not actually detrimental.

Sewage

The combination of domestic sewage and seafood processing waste creates a major disposal dilemma. The problem of domestic sewage disposal in the Bay is closely related to the dissolved oxygen deficiency just discussed, and constitutes a severe impact on the productivitiy of the local shellfish industry. A variety of experiments have been conducted to evaluate unique methods of disposal of these waters. None has been utilized on a large scale and traditional methods of treatment and disposal are being expanded to manage the ever-increasing loads of these pollutants. The panel discussed the variety of mechanisms which had been evaluated, including marsh and offshore disposal techniques. It was concluded that the offshore disposal option would probably have the least impact on the Bay. There was considerable discussion on the proposed development of sewage treatment plants in the area. The efficiency of functional plants was emphasized, noting that with sufficient effort the effluent could achieve potable quality. The problem of breakdown of the sewage system is considerable, since raw sewage will need to be discharged if the plant fails, after temporary storage reservoirs become filled. Plant design and system redundancy must address this prospect. Pollution by domestic waste is a pervasive problem in the country. The efforts which are being made to contain and curtail pollution (the Clean Water Act, in particular) address this problem. Such activities are desperately needed if much of the coastal area of the country is not to eventually drown in its own filth. Indeed, it is clear that water pollution is one of the most significant and critical current problems with which this nation must deal.

The most obvious impact of domestic sewage disposal is the closing of oyster reefs to harvesting in Mobile Bay. A representative of the South Alabama Seafood Association reviewed the recent history of closures. He expressed industry concerns regarding sewage disposal requirements and outfall location as they could reasonably be expected to impact upon oystermen. Additionally, he questioned the extent and reliability of the environmental data utilized in evaluating and recommending for waste disposal procedures in the Bay. The relationships between treated sewage outfall and health of the Bay oysters are complex and poorly understood. Aspects of concentration, level of treatment, circulation, outfall location and measurement of contamination are obvious areas where definitive information is badly needed. There is a critical need to evaluate the accuracy and sufficiency of existing data and to define future data requirements for management and scientific purposes. It was generally concluded that existing data are insufficient for this purpose, and that a coordinated effort for scientific and management purposes need be implemented.

HYDROGRAPHY AND CIRCULATION

Dredging and Channelization

Much of the discussion by the panel and audience emphasized the effects of channelization and dredge disposal in the Bay. Two general topics were addressed - (1) the consequences of channel maintenance and deepening for commercial purposes and, (2) the impacts of spoil disposal from these activities.

The effects of channel deepening on heavy metal accumulation and resuspension is poorly understood. It is known that the channels themselves are well flushed and that the sediments removed from them for channel deepening are relatively little contaminated by heavy metals. Thus, the effect of the removal of the material and resuspension of significant portions of it should not have a major negative impact on the Bay from the standpoint of heavy metal pollution. The major areas of heavy metal contamination are toward the head of the Bay and away from the channels.

Circulation, Flushing and Transport

It is suspected that the net movement in the main ship channel is toward the head of the Bay during certain periods. Therefore, material that is temporarily trapped in the channel can be transported up the Bay. Some of this material may be washed out of the channel, settling around the shoal areas near the head of the Bay. The sedimentary material that is transported up-channel is eventually resuspended, the sediment is transported by these currents to shallow areas in the upper portion of the system. Simple gravitational flow, induced by the salinity gradients and offshore sea surface slopes are the driving mechanism for the observed phenomena. This brief explanation may account for the observed distribution pattern of some heavy metals in the system as well as the observed high salinity water (30 parts per thousand) in the Theodore Ship Channel and other channel areas near the head of the Bay. The circulation and flushing regimes are but poorly understood, with only their gross characteristics partially known. The role of flocculation and its role in the retention of heavy metals is another fertile area for study.

A further complicating factor is the natural history of coastal plain estuaries, in which each eventually fills with sediment to become a delta, with these changes occurring rather quickly, geologically. This is the natural fate of all coastal plain estuaries unless other factors impinge on the characteristic process. The estuary will gradually become more riverine and the influence of the river will be felt further and further offshore. This will ultimately happen in spite of the best efforts of man (principally the U.S. Army Corps of Engineers) to inhibit the natural process. It is obvious that one of the most pressing needs is a comprehensive study of the flushing, circulation and transport characteristics of the Bay, to provide sufficient information for management and long-range planning purposes.

RECOMMENDATIONS

A number of research recommendations have been developed based on the discussion of the panel and the audience. It need be understood that this list is neither comprehensive nor exhaustive, and that the recommendations specifically derive from the panel discussion. The specific recommendations follow.

1. A comprehensive monitoring program must be established to describe and evaluate the natural history and pollution characteristics of Mobile Bay. The purpose of this program is to provide the information necessary to develop and conduct management efforts appropriate to optimum non-destructive multiple-use of the system. This program, over a significant period of time (decades), will need to monitor the kind and amount of heavy metal pollution in the waters, sediments and biota of the system; the chemical and physical aspects of the water; the ecosystems floral and faunal characteristics; and the demographic qualities of the Mobile Bay area human population.

2. A number of detailed investigations need to be initiated or further developed (if already begun). The purpose of these studies is to provide the quantitive and other information necessary for a clear understanding of the characteristics of the natural systems and to complement the development of predictive models for management purposes. The topics of these studies are, minimally - circulation, flushing, pollutant and sediment transport, low dissolved oxygen phenomena, pollutant uptake effects on the biota (including man), sewage treatment and disposal for minimal environmental degradation and maximum economic benefit, and the development of a mechanism for comprehensive evaluation, including the synergistic aspects of all these research elements.

It is recognized that a primary impediment to achieving the goals defined in the recommendations is a lack of sufficient funds to conduct the investigations. The lack of federal and state funds adequate to implement these studies creates a significant (if not insurmountable) obstacle to acquiring the knowledge and expertise to judiciously manage the Mobile Bay system. Local governmental resources are grossly insufficient to adequately address the scope and range of the necessary investigations. While a combination of federal, state and local resources may provide a portion of the required funds, the bulk of these must be obtained from industry and other private sources. This will require the development of an effective adminstrative framework to provide the base for developing the fiscal resources from any appropriate source and to formulate, identify, and initiate the necessary scientific and other work required to provide information to effectively manage Mobile Bay. A model for this activity is the Chesapeake Bay Foundation, Inc. A similar organization for Mobile Bay could provide the necessary administrative, legal and other elements required for an endeavor of the magnitude necessary for the task.

SUMMARY AND CONCLUSIONS

It is clear from the foregoing that while significant new information has been developed since the time of the First Mobile Bay Symposium (1979), knowledge of most aspects of the Bay's environmental and other characteristics are still poorly understood. In general, the level of existing knowledge is insufficient to allow an orderly and reasoned multi-use, environmentally sound development scheme to be developed and implemented. Critical gaps in knowledge preclude a comprehensive evaluation of most of the biologic, chemical, physical, geologic and hydrologic characteristics of the system. Those areas for which significant information does exist need be strengthened, particularly from the standpoint of temporal data over time periods ranging from a few hours to decades. There is no doubt that the demands upon the Bay will not lessen in the future and that increased growth in population and industrial development will make ever-increasing claims on its ecosystems. It is critical at this time to institutionalize and initiate a method and mechanism to provide the most comprehensive resource management structure possible - one which will simultaneously provide the fiscal resources necessary for scientific and other studies, while guiding and directing the studies themselves. These studies must include, at a minimum, those recommended above.

This Symposium has provided an opportunity for the scientific community and lay public to define, discuss and evaluate many of the myriad environmental, economic and other problems facing Mobile Bay. Clearly, extraordinary actions are required if the health of Mobile Bay is to be maintained at its present level or improved. The amelioration of the social, industrial and economic impacts presently imposed on the Bay system, and the additional ones which will positively occur in future years require immediate action, if their effect is not to further degrade this magnificent and complex natural system.

CLOSING REMARKS

TONY LOWERY

Symposium on the Natural Resources of the Mobile Bay Estuary

The purpose of this series of symposia has been to make the latest information on Mobile Bay available to the public at large, coastal decisionmakers, as well as the corps of regulatory personnel and researchers working on Bay-related activities. Since the economic development and fiscal stability of coastal Alabama are so intricately tied to the Mobile Bay Estuary, it's extremely important that information on the Bay's health and status become common knowledge within the communities which would be affected by changes in the health of the Mobile Bay Estuarine Ecosystem.

This 1987 symposium was the second in the series. The first was held in 1979. Much of the information presented in this 1987 symposium as identified during the 1979 symposium as being critical to the development of an information base from which management decisions concerning the Mobile Bay Estuarine Ecosystem could be based.

In general, most estuaries are managed using the same federal regulatory statutes which are augmented by state regulatory statutes. Traditionally, the state regulatory statutes parallel the federal regulatory statutes. The states assume primary responsibility for the enforcement of their regulatory statutes. However, the U. S. Army Corps of Engineers and U.S. Environmental Protection Agency can override the states' managerial authority, if the states' actions are inconsistant with the federal regulatory statutes. This is obviously a gross oversimplification of a very elaborate and involved regulatory process which may vary significantly from state to state.

Luckily, we are not the only community faced with the responsibility of managing the resources of a large estuary. Having the advantage of learning from the experiences of other Bay-dependent communities, we can at least be aware of potential problems without having to experience them for ourselves. One of the most graphic examples of what can, unfortunately, happen when these regulatory processes fall short of their intended goals can be seen in the collapse of the Chesapeake Bay Estuarine Ecosystem.

Concern there prompted a seven-year, $30 million study performed by the U.S. Environmental Protection Agency. Completed in 1983, the study confirmed what fishermen and scientists had long suspected; Chesapeake Bay, the nation's largest and formerly most valuable estuary, could no longer support many native marine species.

Those who finally realized the Chesapeake Bay problem included residents and industrialists alike in the Bay's coastal states of Virginia, Pennsylvania and Maryland.

Seafood harvesters had noted that catches of finfish, clams and oysters began declining markedly in the late 70s. The EPA study implied that if drastic measures weren't taken, Chesapeake Bay, the cradle of up to 90 percent of the East Coast striped bass population, could be barren of the magnificient fish.

The study revealed that the estuary had been overenriched with human sewage and fertilizers. The overenrichment caused excessive growth of algae and phytoplankton in the water which robs the estuary of its life-giving oxygen. Also, vast tracts of nusery habitat, submerged grassbeds, had been lost due to large quantities of soil and sediment washing into the Chesapeake.

As the result of public concern, the governors of the three states pledged December 1983 to work to save the Bay. The states have since appropriated in excess of $250 to $300 million toward the Bay effort. President Reagan, in his 1984 State of the Union Address, announced the allocation of $10 million in continuing monies to the three Chesapeake Bay states to help save the Bay.

Most importantly, the coastal population has become heavily involved with the Bay restoration efforts. Privately funded organizations like the Chesapeake Bay Foundation have been augmenting the state and federal efforts. With a budget of $3 million and a 40-thousand plus membership, the Chesapeake Bay Foundation has been very effective in spearheading the restoration efforts.

EPA estimates that cleaning up the Chesapeake will cost between $1- $3 billion over the next 20 years, with no foreseeable reversal of the situation for a decade or so. In the meantime, the economic benefits that accrue to the Bay's coastal states of Virginia, Pennsylvania and Maryland, from their fishing industries and recreational activities, will continue to be severely diminished.

One interesting thing to note is that prior to the discovery that the Chesapeake Bay Estuarine Ecosystem had collapsed, the regulatory statutes used to safeguard the Chesapeake's health were perceived to be doing an adequate job. The pre-crisis regulatory processes tended to regulate specific activities without consideration of the Chesapeake's ability to absorb the cummulative impacts of those activities in concert with all the other activities impacting on the ecosystem.

Interestingly, a recently released U.S. Office of Technology Assessment report indicates that many of the nations estuaries will degrade considerably during the next decade under the current regulatory processes. These same regulatory processes are the ones which most bay-dependent communities depend on to protect the resources afforded them by their estuary. To date, the majority of bay-dependent communities, including Mobile Bay's, still rely on these processes.

However, upon the realization that the Chesapeake had crashed, more creative and aggressive management initiatives were pursued. Managing the Chesapeake as a whole, instead of regulating specific activities taking place on her, has been seen as the only hope for saving the Chesapeake. And a program has been implemented to focus the various Federal, State and private resources on managing the Chesapeake Bay Estuary as an ecosystem which has its limitations as far as absorbing impacts.

The establishment of site specific estuarine management programs in combination with the regulatory processes may prove to be the most effective means of maintaining estuaries. The economic consequences of crashing an estuarine ecosystem are severe. The loss of productivity and the cost of restoration are astronomic compared to maintaining an estuary's health.

Armed with the knowledge of other bay-dependent communities successes and failures, we should be able to adjust, and avoid the pitfalls previously encountered. Hopefully, we'll be able to maintain the health of the Mobile Bay Estuarine Ecosystem well into the future. Thank you for your attention and interest.

RECOMMENDATIONS RECEIVED FROM MODERATORS AND PRESENTORS

Raise Public Awareness and Understanding of Coastal Issues

1. Public at Large

   A. All agencies and institutions should do a better job of informing the general public about their research and information generation activities through publications (both popular and scientific), speaking and other avenues. -- Larry Goldman

   B. Efforts need to be extended to educate the adult population. -- Jennifer Cook

   C. Programs for adult education need to be designed and implemented -- George Crozier

   D. Agencies and institutions should organize a speaker's bureau that will publicize the area's values and ongoing research to inform the public - Extension Service coordinate and solicit opportunities aggressively. -- Larry Goldman

   E. Institutions and agencies should work together to sponsor Bay Day or other annual public awareness event that publicizes the Bay and its values and educates the public. -- Larry Goldman

   F. Increase public interest in factors of environmental degradation-habitat alteration, etc. -- William Tucker

2. Future Decision Makers

   A. Teacher training efforts need to continue expanding. -- Jennifer Cook

   B. More teacher training programs should be implemented. -- George Crozier

   C. Expansion of pre and in-service teacher marine education intensive short courses offered through institutions of higher education at appropriate area marine laboratories. -- Sharon Walker

   D. Work with local school districts to infuse marine concepts into the regular classroom program. -- Lloyd Scott

   E. Commitment by state legislators that education be given an appropriate funding priority, thereby ensuring that future generations will be well informed and capable of making decisions involving the conservation, proper management, development, and wise utilization of our marine and aquatic resources. -- Sharon Walker

   F. Education - a 2nd grade child will vote in year 2000 (13 years from now) and begin to make a statement concerning quality of life therefore we must provide him with the fundamentals to make rational decisions. -- Smith and others

3. Cooperative Efforts

   A. If possible, cooperative studies should be undertaken to avoid duplication of efforts in both the development and publication of curricular marine materials. -- Sharon Walker

   B. Cooperatively develop educational programs. -- Larry Goldman

   C. Duplication of programs and facilities must be minimized due to the funding constraints and even available audience. -- George Crozier

   D. The commitment to avoid duplication of educational efforts needs to continue. -- Jennifer Cook

   E. Continue efforts to encourage cooperative participation between area educational institutions and marine-related agencies in support of marine education. -- Lloyd Scott

4. Educational Efforts Session

   A. The forum provided by the Symposium was appreciated and valuable in itself. It should be formalized and made a regular event. -- George Crozier

   B. Continuation of on educational session within furture symposia. -- Sharon Walker

Enhancement of Management Capabilities

1. Cooperation and participation

   A. To conserve our resources, it will be necessary to work together. -- Swingle

   B. Establishment of a broad based group to discuss ideas of management and development before 'the swords are drawn'. -- Fred Delchamps

   C. Prudent development of our oil and gas reserves will take cooperation/discussion/compromise/working together. -- Ernest Mancini

   D. Development of hydrocarbon reserves in the Gulf of Mexico will impact future activities of the states/states' needs to be involved in this development. What is the role of Alabama going to be? -- Ernest Mancini

2. Long-Range Planning

   A. Establishment of long-term plans for the entire Mobile Bay and Delta, including the surrounding habitats. -- David Hayden

   B. Establish a comprehensive planning process for Mobile Bay area determining long-term development needs, areas for protection, and mitigation measures. -- Larry Goldman

   C. A long-range plan for assessment of cumulative impacts (both additive and synergistic) must be initiated now. -- Judy Stout

3. Directing Research to Meet Management Needs

   A. A task force should be assembled to define the scope and modelling needs to adequately understand and manage Alabama estuaries. This task force would interface with the scientific and management communities and seek funding from appropriate agencies and other sources. -- Judy Stout

   B. Increase resources allocated to environmental aspects of studies.- John Friend

   C. A compilation of existing data bases should be accomplished in one location. Critical data gaps must be delineated including the physical/chemical environment, biotic responses, and species specific life history requirements. A plan, with time lines, should be developed to fill the defined gaps. -- Judy Stout

   D. A number of detailed investigations need to be initiated or further developed (if already begun). The purpose of these studies is to provide the quantitive and other information necessary for a clear understanding of the characteristics of the natural systems and to complement the development of predictive models for management purposes. The topics of these studies are, minimally - circulation, flushing, pollutant and sediment transport, low dissolved oxygen phenomena, pollutant uptake effects on the biota (including man), sewage treatment and disposal for minimal environmental degradation and maximum economy, development of optimal dredge/disposal processes exhibiting minimal environmental impact and maximum economic benefit, and the development of a mechanism for comprehensive evaluation, including the synergistic aspects of all these research elements. -- James I. Jones

   E. Cumulative impacts must be addressed. -- John Friend

4. Initiation of Monitoring

A. A comprehensive monitoring program must be established to describe and evaluate the natural history and pollution characteristics of Mobile Bay. The purpose of this program is to provide the information necessary to develop and conduct management efforts appropriate to optimum non-destructive multiple-use of the system. This program, over a significant period of time (decades), will need to monitor the kind and amount of heavy metal pollution in the waters, sediments and biota of the system; the chemical and physical aspects of the water; the ecosystems floral and faunal characteristics; and the demographic qualities of the Mobile Bay area human population. -- James I. Jones

B. A monitoring program of indicator species and key systems should be implemented to provide real-time data on perturbations, changes and impacts, for short-term management as well as long-range planning. -- Judy Stout

I. Heavy Metals

a. There is a clear need to examine bivalves for heavy metal content, in light of Isphording's findings on high sediment concentrations of various metals and also his findings on zinc levels in oysters of Mobile Bay. The more common and toxic metals found by Isphording should be selected. -- Ken Marion

b. Determine impacts on biota of elevated levels of heavy metals present in Mobile Bay and Mississippi Sound. -- Larry Goldman

II. Organic Pollutants

a. Bivalves in Mobile Bay should be monitored for organic pollutant levels on a regular basis in the future (perhaps every five years). Now that we have done our study, this data can most usefully serve as a baseline to evaluate any potential future changes in bivalve contaminant content and, ultimately, water quality in Mobile Bay. It would allow one to determine if detrimental changes are occurring. Even though severe levels of pollution were not found, the wide variety of contaminants found serve as a clear warning that some impact is occurring. The current National Status and Trends Program of NOAA has urged that sampling of bivalves for organic contaminants take place at strategic locations and sensitive stations along the U.S. coast at least every five years to establish rates of change in estuarine habitats. I would strongly recommend that Mobile Bay be included in any future sampling program, whether through NOAA or any other agency. -- Ken Marion

b. A follow-up study to organic contaminant work presented by Dr. Marion and others should be conducted within 5 years. -- Larry Goldman

c. There is a need to monitor additional compounds not routinely investigated in our study. Several come to mind:

(1) dioxins - We looked for these in a couple of samples and found none, but they should be investigated more thoroughly.

(2) PCB'S - same as above. Considering their history of occurrence in the upper Coosa chain, these should be investigated in the future.

(3) other insecticides/herbicides - We only looked at a few. The specific compounds locally applied on crops should be investigated. Kelthane is also commonly used now, and we did not look for it due to budgetary constraints. -- Ken Marion

III. Fisheries

a. Bivalves should be watched for abnormal numbers of lesions, growth problems, or unexplained population drops in certain areas. Although I am not expecting these to occur, these would be signs of severe problems. Local fisherman and the Conservation Department can probably monitor this. -- Ken Marion

b. If we are to make informed management decisions concerning our fishery resources, to conduct the appropriate fishery-related studies. Funding agencies must be prepared to put out the necessary funds to support such work and there is really no substitute for obtaining the necessary information. My second recommendation is actually an elaboration of the first, which stresses that appropriate fishery-related studies must be multi-disciplinary in nature if we truly are to apply the OSY principle of fishery management. -- Steve Malvestuto

c. Develop creel data update and specific fishery management programs for the Mobile Delta. -- Larry Goldman

d. Marine Resources Division should initiate/continue a tagging program for spotted seatrout and redfish to determine stock size, migration, fishery pressure, and other management-related information. -- Larry Goldman

IV. Seabirds and Reptiles

a. Institute a comprehensive survey and monitoring program of seabird and shorebird nesting sites in coastal Alabama to determine their longterm use and changes that impact such areas. -- Larry Goldman

b. Develop and institute a comprehensive colonial seabird survey and monitoring program. Baseline data on colonial seabird status and distribution in coastal Alabama is lacking. Reliable baseline data is needed if we are to assess any future changes in seabird status and distribution. A comprehensive survey and monitoring program to develop that baseline is absolutely necessary. -- Dwight Cooley

c. A comprehensive status survey to document the exsistence, distribution, habitat use, and population densities of coastal herptiles should be conducted. The resultant baseline information would be used to monitor population changes and assist the decision-making process of lawmakers, and environmental planners and managers. -- Steve Carey

V. Habitat

a. Establish a regular systematic assessment program for submerged aquatic vegetation that determines distribution in coastal Alabama (5 - 10 year update). Long range research should be undertaken to determine the factors affecting abundance and distribution of submerged grass. -- Larry Goldman

b. Establish a regular systematic wetland trend analysis program that is compatible with previous and ongoing efforts (update every 5-10 years). -- Larry Goldman

c. Continuation of various on-going monitoring programs and establishment of additional programs where needed and justified. -- David Hayden

Habitat Preservation, Mitigation and Restoration

I. Habitat Perservation

A. Acquisition by the Alabama Game and Fish Division or other conservation oriented entity of as much Mobile Bay and Delta wetlands as pratical and as soon as pratical. -- David Hayden

B. Continue and accelerate acquisition at Bon Secour NWR and State holdings in the Mobile Delta. As deemed pratical existing uses should be maintained. Important colonial bird nesting sites should be acquired. -- Larry Goldman

C. Institute an aggressive acquisition program aimed at protecting not only existing colonies but also traditional colony sites that have been abandoned. Many of the traditional and exisiting seabird colony sites are located in senitive areas that are subject to many development pressures. An acquisition program aimed at acquiring would insure that these sensitive areas were not developed and that the resource utilizing these areas remained in the public domain. -- Dwight Cooley

D. Highest priority areas to important sport fishery resources (redfish, spotted seatrout and others) should be maintained with no net habitat loss. Areas of particular importance are submerged grass beds and marshes, and passes or constructions with high current velocity. -- Larry Goldman

E. Protection from detrimental impacts (such as dredging, filling, and water pollution) to the greatest extent praticable. -- David Hayden

F. The acquisition and maintenance of habitat critical to the survival of many coastal herptiles should be continued. -- Steve Carey

G. Designate Gaillard Island a bird sanctuary and develop a protection plan for other colonial nesting sites. -- Larry Goldman

H. Designate Gaillard Island a Colonial Seabird Sanctuary. The importance of Gaillard Island as a seabird nesting area is unquestioned. The administration of the island at present is unclear and the potential for many impacts is great. Designation of the island as a Seabird Sanctuary would add some measure of protection and provide for continued colonial seabird use. -- Dwight Cooley

I. Develop a protection plan for existing colonial seabird resources. Over the past two decades, almost 50 percent of the colonial seabird colonies in coastal Alabama have been abandoned. The reason for this is not clear but all indications are that human disturbance was, in part, the reason. Aggressive enforcement of existing statues and posting of colony areas should reduce impacts considerably. -- Dwight Cooley

J. Promote colonial seabird use of traditional colony sites that have been abandoned. Enforcement of existing statutes should largely eliminate human-related disturbance in areas, such as the west end of Dauphin Island, that no longer support nesting colonies. Once human disturbance has been eliminated, these areas should be assessed as to their potential to support nesting populations. If this assessment reveals that the habitat is no longer suitable for nesting, measures should be initiated to improve the habitat. -- Dwight Cooley

K. The ecological requirements and limiting factors of many coastal herptiles are poorly known. Additional studies are urgently needed to insure the survival of Alabama's coastal herpetofauna. Funding forms of assistance should be made available in support of such studies. -- Steve Carey

L. Predator control may be necessary to insure the survival of some coastal herptiles. -- Steve Carey

M. Existing legislation protecting Alabama's coastal herpetfauna must be rigidly enforced. State protection should be extended to include all priority category herptiles. -- Steve Carey

N. State legislation banning the "gassing" of gopher tortoise burrows should be enacted. This barmful pratice, used to flush out rattlesnakes, is deleterious to the tortoises and their burrow associates (Speake and Mount 1973). -- Steve Carey

O. The use of turtle-exclusion devices by commercial shrimping and fishing trawlers should be changed from a voluntary to a mandatory basis. -- Steve Carey

2. Mitigation

A. Data and information should be obtained to compare natural and manmade wetlands in terms of their various functions. How much do we get back when a marsh is created as compared to a natural marsh. -- Larry Goldman

B. Stronger consideration should be given to preserving wetlands as a mitigation measure for permitting wetland lossess. -- Larry Goldman

C. A followup study should be conducted on mitigation projects plus a tighter rein should be placed on requirements for mitigation projects to assume proper construction efforts and satisfaction of permit requirements. --Larry Goldman

D. Further refinements are needed in methods used to determine the quality of habitat loss when a project is proposed. -- Larry Goldman

E. Consideration should be given to establishment of a mitigation bank or credit system. -- Larry Goldman

F. Procedural guides or manuals should be developed to describe when, where, and how wetland creation should be performed. This publication would explain important requirements for wetland development and growth, as well as functions sought through wetland creation. -- Barry Vittor

G. Oversight agencies should develop a joint plan for monitoring construction and success of wetland creation projects. Such a plan would consider soil characteristics, elevation control, hydrology, vegetation survival and growth, and faunal communities. -- Barry Vittor

H. Wetland creation banks should be considered as a means of providing mitigation for unavoidable wetland losses, in a carefully managed, demonstrably successful wetland creation program. -- Barry Vittor

3. Restoration

A. Establish enhancement programs after careful consideration of both short- and long-term benefits and the cost-benefit ratio. -- David Hayden

B. Selective habitat restoration efforts should be established. -- Judy Stout

C. Develop longterm dredge material disposal plans for areas in coastal Alabama and protection plans for known colonial bird nesting sites and rehabilitation plans for areas formerly used for nesting but now abandoned. -- Larry Goldman

LIST OF ATTENDEES

Alfredo Acoff
639 Azaela Rd. #86
Mobile, AL 36609

Geneve Adams
102 Glenwood Circle
Daphne, AL 36526

Merrilee B. Adams
Rt. 2, Box 255
Bon Secour, AL 36511

Geary Allen
Alabama Attorney General's Office
11 South Union Street
Montgomery, AL 36130

Eric Althouse
P.O. Box U 374
Mobile, AL 36688

Bob Andrews
5150 Pineview Lane
Mobile, AL 36608

Randy L. Austin
TAI Environmental Sciences, Inc.
1717 Old Shell Road
Mobile, AL 36604

David Barley
Alabama Dept. Economic Community Affairs
P.O. Box 2939
Montgomery, AL 36105

Ann Bedsole
Alabama State Senator-District 34
P.O. Box 16642
Mobile, AL 36616

Robert Beyers
Biology Department.
University of South Alabama
Mobile, AL 36688

Barbara Bitter
3074 Riverside Dr.
Mobile, AL 36609

Jenny Cook
Dauphin Island Sea Lab
P.O. Box 369
Dauphin Island, AL 36528

Dwight Cooley
U.S. Fish and Wildlife Services
P.O. Drawer 1190
Daphne, AL 36526

Ricky Corker
427 Myrtlewood Avenue
Chickasaw, AL 36611

George Crozier
Marine Environmental Sciences Consortium
P.O. Box 369
Dauphin Island, AL 36528

Mike Dardeau
Dauphin Island Sea Lab
P.O. Box 369
Dauphin Island, AL 36528

R. R. Darney
1404 Cadiz Street
New Orleans, LA 70115

David Dean
Biology Department
University of South Alabama
Mobile, AL 36688

Fred Delchamps
Mobile Area Chamber of Commerce
P.O. Box 1660
Mobile, AL 36633

Jim DeWit
P.O. Box 899
Saraland, AL 36571

John Dindo
Dauphin Island Sea Lab
P.O. Box 369
Dauphin Island, AL 36528

George Diogene
577 Hazeur Curve
Mobile, AL 36608

LIST OF ATTENDEES CONTINUED

Don Blancher
TAI Environmental Sciences Inc.
1717 Old Shell Road
Mobile, AL 36604

Carolyn Borom
P.O. Box 432
Fairhope, AL 36533

John Borom
Faulkner State Junior College
13 N. Summit
Fairhope, AL 36532

David Burford
BCM Converse, Inc.
108 St. Anthony Street
Mobile, AL 36612

Bobby Burk
Scott Paper Co.
P.O. Box 899
Saraland, AL 36528

Barbara Cadell
Mobile League of Women Voters
1321 Dauphin Street
Mobile, AL 36660

Steven Carey
Mobile College
363 South School Street
Fairhope, AL 36532

Jerome Carroll
U.S. Fish and Wildlife Services
P.O. Box 1650
Gulf Shores, AL 36542

Al Chamlee
Ciba-Geigy Corp.
4644 Channing Court
Mobile, AL 36608

Chuck Coker
6624 Autumn Ridge Drive
Mobile, AL 36609

Daniel Conner
Law Center
Mississippi-Alabama Sea Grant Consortium
University of Mississippi, MS 38677

Hugh Dowling
Dowling Environmental Inc.
P.O. Box 66003
Mobile, AL 36660

Roger DuMars
3906 BeBee Point Drive
Theodore, AL 36582

Dan Dumont
Gulf Coast Conservation Association
611 E. Barksdale Drive
Mobile, AL 36606

Brad Durling
Gulf Coast Conservation Association
2801 Pine Ridge Drive
Lillian, AL 36549

Arthur Dyas
Coastal Land Trust Inc.
P.O. Box 1029
Mobile, AL 36633

Joy Earp
6259 Lausonne Drive North
Mobile, AL 36608

Elaine Eutrekin
Mobile College
P.O. Box 13220
Mobile, AL 36613

Davis Findley
U.S. Army Corps of Engineers
P.O. Box 2288
Mobile, AL 36628

Robert Free
2355 Dog River Drive North
Mobile, AL 36605

Elizabeth French
36 Ridgeview Drive
Chickasaw, AL 36528

John Friend
Baldwin United
P.O. Box 622
Montrose, AL 36559

LIST OF ATTENDEES CONTINUED

John Fulton
P.O. Box 1650
Gulf Shores, AL 36542

Brad Gains
Alabama Dept. Environmental Management
2204 Perimeter Road
Mobile, AL 36615

Larry Goldman
U.S. Fish and Wildlife Service
P.O. Drawer 1190
Daphne, AL 36526

Judy Gooch
5958 Shenandoah Road South
Mobile, AL 36608

Derrek Griffey
52 Ann Street, Apt. C
Mobile, AL 36604

Patrick Hallett
BCM Converse Inc.
108 St. Anthony Street
Mobile, AL 36633

David Hayden
Game and Fish Div., ADCNR
4313 Mabson Drive
Montgomery, AL 36106

Steve Heath
Marine Resources Div., ADCNR
P.O. Box 189
Dauphin Island, AL 36528

Ken Heck
Marine Environmental Sciences Consortium
P.O. Box 369
Dauphin Island, AL 36528

Bob Henderson
6121 Palemino Drive
Mobile, AL 36609

Sherry Herron
1020 Mixon Avenue
Bay Minette, AL 36507

Robert Hodge
Fowl River Protective Association
Rt. 1, Box 343
Theodore, AL 36582

Gary Holcomb
Alabama Dept.Environmental Management
2204 Perimeter Road
Mobile, AL 36615

Tom Hopkins
Marine Environmental Sciences Consortium
P.O. Box 369
Dauphin Island, AL 36528

William Hosking
Alabama Sea Grant Extension Service
3940 Government Blvd. Suite 5
Mobile, AL 36609

Edgar Hughes
Mobile County Health Dept.
P.O. Box 2867
Mobile, AL 36652

Tom Hutchison
Coastal Land Trust
7 South Hathaway
Mobile, AL 36608

Tara Irwin
1861 Hunter Avenue
Mobile, AL 36606

Wayne Isphording
Geology Dept.
University of South Alabama
Mobile, AL 36688

James Jones
Mississippi-Alabama Sea Grant Consortium
P.O. Box 7000
Ocean Springs, MS 39564

Pamela James
P.O. Box 369
Dauphin Island, AL 36528

Laverne Jones
2208 Wagner Street
Mobile, AL 36617

Myrt Jones
Mobile Bay Audubon
P.O. Box 9903
Mobile, AL 36605

Nick Jongeblood
Rt. 1, Box 1274
Irvington, AL 36544

Marion Juzang
3655 Old Shell Road
Mobile, AL 36608

Sam Kayser
130 South McGregor Avenue
Mobile, AL 36608

Bill Kruczynski
EPA Laboratory
Gulf Breeze, FL 32561

Dennis Lathem
P.O. Box 4220
Montgomery, AL 36195

Skip Lazauski
Marine Resources Div., ADCNR
P.O. Box 189
Dauphin Island, AL 36528

Wally Lee
P.O. Box 1736
Mobile, AL 36608

Pat Leffingwell
Business College
University of South Alabama
Mobile, AL 36688

Tony Lowery
Alabama Sea Grant Extension Service
3940 Government Blvd. Suite 5
Mobile, AL 36609

Larry Ludke
National Wetlands Research Center
1010 Gause Blvd.
Slidell, LA 70452

Steve Mader
P.O. Box 8002
North Carolina State University
Raleigh, NC 27695-8002

Steve Malvestuto
Fisheries Department
Auburn University
Auburn, AL 36849

Ernest Mancini
Alabama Geological Survey
P.O. Drawer O
Tuscaloosa, AL 35486

Ken Marion
Biology Dept.
University Alabama Birmingham
Birmingham, AL 35294

John Marshall
Biology Department
University of South Alabama
Mobile, AL 36688

Tom Matthews
Dauphin Island Sea Lab
P.O. Box 369
Dauphin Island, AL 36528

Hugh McClellan
U.S. Army Corps of Engineers
P.O. Box 2288
Mobile, AL 36628

N. D. McClure
U.S. Army Corps of Engineers
P.O. Box 2288
Mobile, AL 36628

Ellen McDonald
65 South Layfayette Street
Mobile, AL 36604

Frank McFadden
1009 High Point Drive West
Mobile, AL 36609

Steve McMillian
Alabama State Representative-District 95
P.O. Box 337
Bay Minette, AL 36507

LIST OF ATTENDEES CONTINUED

Charles McNair
284 Old Bay Front Road
Mobile, AL 36615

Jim Meador
Bon Secour Fisheries
P.O. Box 644
Point Clear, AL 36564

Elizabeth Meek
College of Education
University of South Alabama
Mobile, AL 36688

Bill Menton
Alabama State Senator-District 35
Rt.2 Box 171
Irvington, AL 36544

David Miller
P.O. Box 61707
New Orleans, LA 70161

Laura Mitchell
P.O. Box 8002
North Carolina State University
Raleigh, NC 27695

Ack Moore
P.O. Box 203
Daphne, AL 36526

Adrienne Morgan
2410 Bragdon Avenue
Mobile, AL 36617

Ken Morris
Biology Department
University Alabama Birmingham
Birmingham, AL 35294

Lisa Myers
3105 Dauphin Street, B-12
Mobile, AL 36606

David Nadeau
Rt. 1, Box 807
Coden, AL 36523

Michael Nance
Thompson Engineering
53-A North Church Street
Fairhope, AL 36532

David Nelson
Biology Department
University of South Alabama
Mobile, AL 36688

Douglas Nester
U.S. Army Corps of Engineers
P.O. Box 2288
Mobile, AL 36628

Lynne Newman
P.O. Box 606
Theodore, AL 36590

Brenda Nickman
Rt. 1, Box 308-B
Fairhope, AL 36532

Joe Norton
Rt. 1, Box 88
Loxley, AL 36551

Warren Norville
327 Dalewood Drive
Mobile, AL 36608

Marie Patrick
Rt. 1, Box 176-A
Summerdale, AL 36580

Kenny Phillips
200 Mobile College
Mobile, AL 36613

P. Rawsonfer
Hillwood Road 56
Mobile, AL 36608

Susan Ivester Rees
U.S. Army Corps of Engineers
P.O. Box 2288
Mobile, AL 36628

LIST OF ATTENDEES CONTINUED

Andrew Rindsberg
5958 Shenandoah Road South
Mobile, AL 36613

Randy Roach
U.S. Fish and Wildlife Service
P.O. Box 1190
Daphne, AL 36526

Sherry Roberts
3768 Sheips Lane
Mobile, AL 36608

Pasquale Roscigno
National Wetlands Research Center
1010 Gause Blvd.
Slidell, LA 70458

George Rush
P.O. Box 56
Daphne, AL 36526

Whitney Rustand
2727 Scenic Highway
Pensacola, FL 32503

Al St.Clair
Mobile Area Chamber of Commerce
P.O. Box 1243
Mobile, AL 36633

Tim Savage
Alabama Dept.Environmental Management
308 Barnhill Drive
Daphne, AL 36526

William Schroeder
Marine Environmental Science Consortium
P.O. Box 369
Dauphin Island, AL 36528

Lloyd Scott
Environmental Studies Center
P.O. Box 1327
Mobile, AL 36633

Lisa Shanahan
5701 Freeman Drive
Mobile, AL 36609

Kevin Shaw
P.O. Box 6647
Mobile, AL 36660

Robert Shipp
Biology Department
University of South Alabama
Mobile, AL 36688

Steven Sikes
Biology Department
University of South Alabama
Mobile, AL 36688

Jay Simmonds
P.O. Box 1691
Mobile, AL 36633

Tim Simmonds
Baldwin United
P.O. Box 700
Montrose, AL 36559

Hattie Smith
South Baldwin Chamber of Commerce
P.O. Box 1117
Foley, AL 36536

Doug Staub
P.O. Box 1691
Mobile, AL 36633

D. E. Stearns
Dauphin Island Sea Lab
P.O. Box 369
Dauphin Island, AL 36528

Julian Stewart
Vittor and Associates Inc.
8100 Cottagehill Road
Mobile, AL 36609

Lynn Stewart
3425 Terry Lane
Mobile, AL 36605

Robert Stewart
National Wetlands Research Center
1010 Gause Boulevard
Slidell. LA 70458

LIST OF ATTENDEES CONTINUED

Judy Stout
Marine Environmental Sciences Consortium
P.O. Box 369
Dauphin Island, AL 36528

Marie Sweeney
Mobile Area Chamber of Commerce
P.O. Box 2187
Mobile, AL 36652

Morgan Swift
360 Tatum Avenue
Mobile, AL 36609

Hugh Swingle
Marine Resources Division, ADCNR
P.O. Box 189
Dauphin Island, AL 36528

June Taylor
P.O. Box 200
Foley, AL 36536

Alan Temple
Dauphin Island Sea Lab
P.O. Box 369
Dauphin Island, AL 36528

Ellen Thomasson
Gulf Coast Conservation Association
P.O. Box 16987
Mobile, AL 36616

Bruce Trickey
Consulting Associates, Inc.
314 Dalewood Drive
Mobile, AL 36608

Bill Tucker
Game and Fish Div., ADCNR
P.O. Box 245
Spanish Fort, AL 36527

Garry Tucker
Rt. 1, Box 91
Summerdale, AL 36586

John Tyson
600 Bel Air Boulevard
Mobile, AL 36606

Kenneth Valco
P.O. Box 978
Gulf Shores, AL 36542

Mark Van Hoose
Marine Resource Division, ADCNR
P.O. Box 72
Dauphin Island, AL 36528

Richard Wallace
Alabama Sea Grant Extension Service
3940 Government Blvd. Suite 5
Mobile, AL 36609

Sharon Walker
Mississippi-Alabama Sea Grant Consortium
P.O. Box 7000
Ocean Springs, MS 39564

Lewis Waller
1717 Old Shell Road
Mobile, AL 36604

Sandra Wanner
2254 Beau Terra Drive West
Mobile, AL 36618

Mary Watkin
National Wetlands Research Center
1010 Gause Boulevard
Slidell, LA 70458

R. D. Wells
51 Rickarby Place
Mobile, AL 36606

Greg Whitendorfer
Rt. 1, Box 88
Loxley, AL 36551

Karen Williams
U.S. Army Corps of Engineers
P.O. Box 2288
Mobile, AL 36628

Mave Wilson
Dauphin Island Sea Lab
P. O. 369
Dauphin Island, AL 36528

LIST OF ATTENDEES CONTINUED

Patricia D. Wilson
284 Old Bay Front Road
Mobile, AL 36615

Nelson Wingo
P. O. Box 543
Robertsdale, AL 36567

James A. Yance
P. O. Box 66705
Mobile, AL 36660

Joe Zolczynski
Game and Fish Division, ADCNR
P.O. Box 245
Spanish Fort, AL 36527