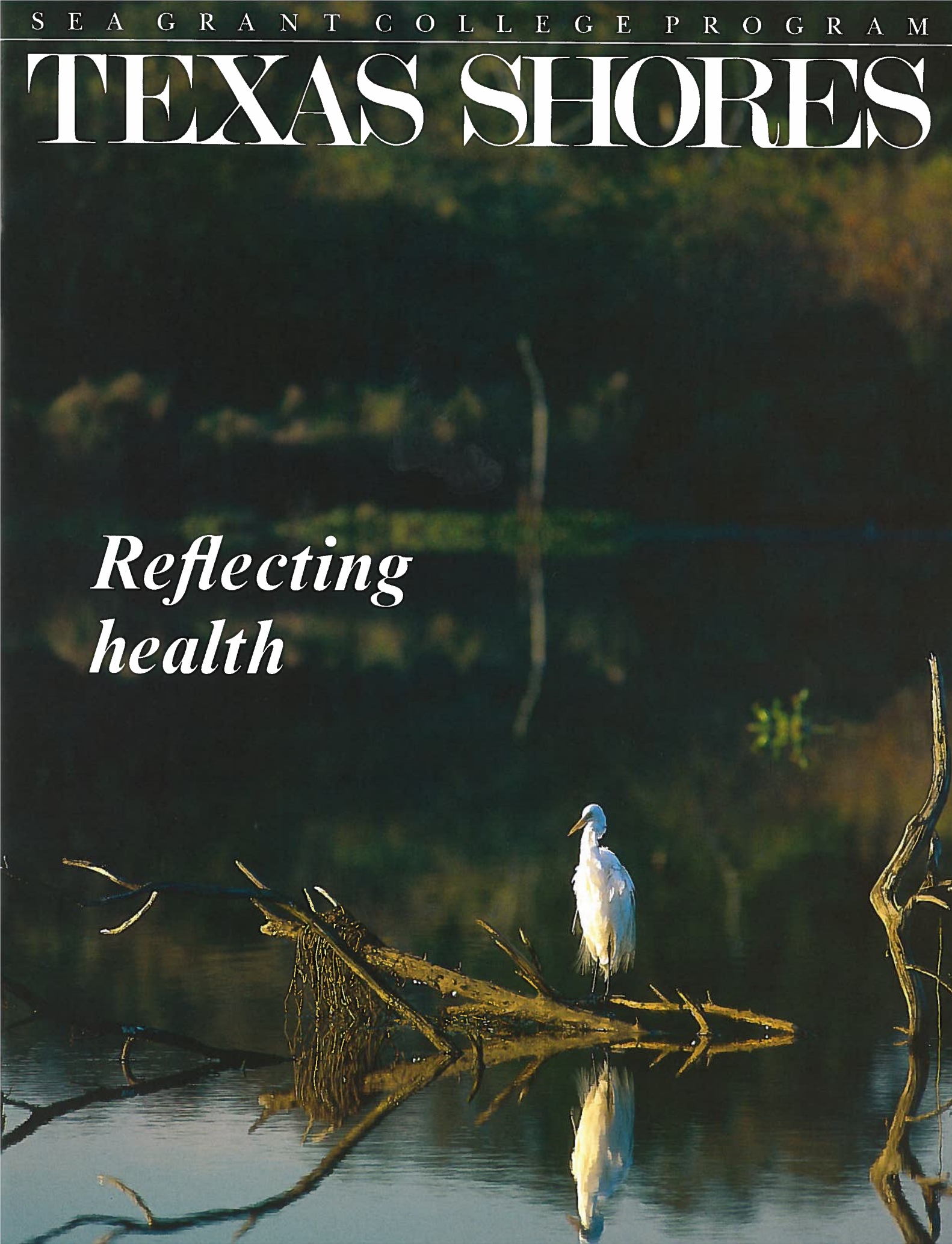
SEA GRANT COLLEGE PROGRAM

TEXAS SHORES



Reflecting health

NOTES

Texas Sea Grant to coordinate NOSB regional meet

COLLEGE STATION, TX — The National Ocean Sciences Bowl (NOSB) regional competition at Texas A&M University is under new management — the Texas Sea Grant College Program is taking on coordination of the event beginning with preparation for the March 4, 2006, meet.

The Dolphin Challenge, which is open to high school teams from the northern half of Texas, is held in College Station, while students in the southern part of the state can compete in the Loggerhead Challenge, hosted by Texas A&M University-Corpus Christi. Earlier this year, the previous coordinating department for the Dolphin Challenge, TAMU's Department of Oceanography, determined that it would be unable to coordinate the next competition.

"When we learned that the Department of Oceanography was having difficulty properly staffing the TAMU NOSB event for 2006, I thought the competition was so important that I volunteered Sea Grant to take it on," says Texas Sea Grant Director Dr. Robert Stickney. "Texas Sea Grant has been a supporter and has participated in the event in various capacities for several years. I've moderated in four of the past five years myself and thoroughly enjoyed interacting with the very bright students who will doubtless become leading scientists in the future."

Texas Sea Grant has hired TAMU graduate student Bianca Whitaker, who is pursuing a master's degree in wildlife and fisheries sciences, to coordinate its NOSB efforts, including planning the event and contacting high school teachers to generate interest in the competition.

"With Bianca Whitaker's enthusiasm and drive, I am confident that we will have another first-class event next March," Stickney says. "I also intend to make a long-term commitment by Texas Sea Grant to NOSB."

The NOSB is a college bowl-style competition that provides an opportunity for students to receive national recognition for excellence in math and science and stimulates their interest in marine science as a possible career. Teams of high school students compete by answering questions about the earth's oceans from a wide range of disciplines, including physics, geology, biology and the social sciences. Winners of the regional competitions go on to the national meet, which will be held in Monterey, Calif., in May 2006.

"NOSB represents a wonderful learning experience for the high school students who participate," Stickney notes. "It's also an opportunity for them to visit Texas A&M and get a flavor for our campus."

Up to 16 teams may participate in the Dolphin Challenge; the deadline to sign up for the 2006 competition is Nov. 1, 2005.

For more information on the Dolphin Challenge, contact Whitaker at whitakerb@tamug.edu or 979-204-2741. Additional information about the NOSB is available on its Web site at www.nosb.org.

— *Cindie Powell*

Ray to Congressional committee: Listing oyster as endangered would be 'biologically unjustifiable,' 'economically devastating'

Marine biologist Sammy Ray testified before the House Resources Committee July 19, opposing a petition to list the Eastern oyster (*Crassostrea virginica*) as an endangered or threatened species under the Endangered Species Act.

"I consider the petition to list the Eastern oyster as endangered to be biologically unjustifiable, procedurally inappropriate, politically unwise and economically devastating," he told the committee.

The professor emeritus at Texas A&M University at Galveston, who is considered one of the world's leading experts on oysters, explained that the Eastern oyster "is in no way a threatened or endangered species."

"Texas has landed a minimum of about 3 million pounds of oyster meat for the past 10 years," he testified, adding that Texas harvests in 2003 and 2004 totaled about 4.3 and 5.1 million pounds of meat, and the 2005 harvest is expected to exceed 5 million pounds.

The Eastern oyster is found in North American estuaries from the Gulf of St. Lawrence in Canada to the Yucatan Peninsula in Mexico. The proposal to list the oyster as endangered or threatened was prompted by its declining populations in Chesapeake Bay.

"Declaring the Eastern oyster as endangered throughout its broad range will do nothing to correct the environmental problems of Chesapeake Bay. If the proponents of this measure truly believe that cessation of oyster harvest will possibly promote its recovery, why not have the states of Maryland and Virginia halt all oyster harvesting from Chesapeake Bay and its tributaries?"

Ray noted that the most recent annual oyster harvest from the bay totaled about 50,000 bushels and suggested subsidizing the harvest there to avoid harming the "watermen" whose livelihoods depend on the oyster harvest.

"We pay farmers not to grow crops, I see nothing wrong with paying oystermen not to harvest oysters," he told the committee.

"Valuable, viable and sustainable oyster fisheries exist over much of the range of the Eastern oyster. Designation of the Eastern oyster as endangered would destroy successful oyster industries of the Gulf and Atlantic States without saving the industry of Chesapeake Bay."

Ray also cautioned that listing the Eastern under the Endangered Species Act (ESA) could jeopardize the Act itself.

"The ESA should be reserved for species that are truly threatened or endangered," he said. "If the Eastern oyster is considered endangered, then the designation criteria are so broad as to make the ESA biologically meaningless and politically vulnerable."

More recently, Ray says after reading about the pollution loads suffered by Chesapeake Bay, "I realize that

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FRONT AND BACK COVERS: PHOTOS BY STEPHAN MYERS

TEXAS SHORES is published quarterly by the Texas Sea Grant College Program in an effort to promote a better understanding of the Texas marine environment. Sea Grant is a partnership of university, government and industry focusing on marine research, education and outreach. Nationally, Sea Grant began in 1966 with the passage of the Sea Grant Program and College Act. Patterned after the Land Grant Act of the 1860s, the Sea Grant concept is a broad-based scientific effort to better the world for all those living in and out of the sea.

In 1968, Texas A&M University received the distinction of being named among the nation's first six institutional award recipients. Three years later the school was designated a Sea Grant College. The university has a rich heritage of oceanography research dating back to 1949 when the program began. In addition, there is an ongoing program to get marine information to the public.

Sea Grant is a matching funds program. The Texas Sea Grant College Program itself is made possible through an institutional award from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce, as well as appropriations from the Texas Legislature and local governments.

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TEXAS SHORES (ISSN 0747-0959), is published quarterly by the Sea Grant College Program, Texas A&M University, 2700 Earl Rudder Freeway South, Suite 1800, College Station, TX 77845. Subscriptions are free to Texas residents. The cost is $7.50 per year for out-of-state or foreign addresses. Periodical postage is paid at Bryan, TX and additional locations. **Postmaster**: Send address changes to the Sea Grant College Program, 2700 Earl Rudder Freeway South, Suite 1800, College Station, TX 77845. http://texas-sea-grant.tamu.edu.

Vital signs

By Jim Hiney

Did you hear the one about the guy who was not feeling particularly well, so he went to see his doctor?

A bit pale and listless, the man sat quietly while the doctor checked his pulse, blood pressure and temperature, listened to his heart and lungs, and checked his reflexes. The doctor then stood back and eyed his patient with a look of rapt contemplation.

"Give it to me straight, doc," the man pleaded. "Will I be able to play the violin?"

"With sufficient time, rest and proper treatment," replies the doctor, after a moment more of silence, "I believe you'll be able to play the violin."

"Great!!!" says the man, enthusiastically. "I could never play it before."

A marine ecosystem is not a person, but they have a lot in common. Both require adequate circulation, proper nutrition and vigorous filtration to ensure the entire entity remains healthy.

We cannot take an ecosystem to the hospital, so where do we find an ecological doc?

How do we know if our marine ecosystems will play the violin?

In light of recent reports that have sounded warnings about the deteriorating health of the nation's marine ecosystem, the federal Environmental Protection Agency (EPA) and state natural resource agencies are re-evaluating their approaches to environmental monitoring. Dr. Larry McKinney hates to use a hackneyed phrase, but there is not a better way to describe the effort to designate aspects of the natural world that give scientists a clue to ecosystem health.

"We have lots and lots of information about ecosystems, but how do we sort through this storm of data points to sort out what makes sense?" asks the Texas Parks and Wildlife Department's director of coastal fisheries. "There is a real desire to pick out — and I hate to use this old cliché — canaries in a coal mine. These are points that you can watch to give you an indication of

PHOTO COURTESY TEXAS DEPARTMENT OF TRANSPORTATION

how well or how poorly you are doing."

The "points" are called ecological indicators, and their development and use has been accelerated in recent years by researchers, resource managers and policy makers concerned with restoring, conserving and managing threatened marine resources — and there are few more threatened than the Gulf of Mexico.

In 2003, the EPA named the Gulf the dirtiest coastal body of water in the nation, noting that half of its estuaries show signs of degradation. The EPA's *2005 National Coastal Condition Report* states that water clarity is so poor in 22 percent of the Gulf's estuaries that less than 10 percent of sunlight penetrates to a depth of 1 meter. About 4 percent of the bottom waters in Gulf estuaries exhibit hypoxic, or low oxygen, conditions that are harmful to aquatic life.

Ecological indicators are "a way of determining the health of a resource," explains Dr. Jim Lester, director of the Environment Group at the Houston Advanced Research Center. "Most people like to think of things in terms of natural resources and human value. They have a concept of health. They may not know exactly how to measure health, but they know when they feel unhealthy."

The concept of ecological indicators is both old and new. Scientists have taken measurements of various aspects of marine ecosystems for decades, but the data from each source were usually analyzed independent of each other.

"TCEQ (Texas Commission on Environmental Quality) water monitoring was originally designed for enforcement of permits and they look at single contaminants that are permitted," notes Lester. "TPWD originally developed their monitoring program to manage the oyster and shrimp industries and the recreational fishermen."

Over the past decade there has been a movement toward ecosystem-based management, as highlighted in the U.S. Commission on Ocean Policy's report issued in September 2004.

"I think the indicators are more about how you manage the entire system," says Lester. "EPA is still trying to figure out how they will assess the status of the coastal areas and some of the things they developed for the East Coast do not work well along the Gulf Coast. I believe there is probably a role for national indicators, but there is also a need for indicators that recognize the uniqueness of a local ecosystem."

EPA has mandated that each of its 28 National Estuary Programs identify and develop ecological indicators tailored to their unique habitats and needs in order to "give the public and government officials a means to measure whether their investment in a national estuary program is producing results," says Doug Jacobson, an EPA coastal program manager. "We want to ensure that we are succeeding in our efforts to restore and improve the target areas as well as to carry out our fiduciary duty in spending taxpayer dollars on environmental restoration."

EPA gives its estuary programs some guidance on their indicator projects, but for the most part the programs develop their own indicator plans.

"There are 28 programs around the nation, so there is not one set of indicators that will work for all of them, just as there is not one comprehensive management plan that would work for all of the programs," says Jacobson.

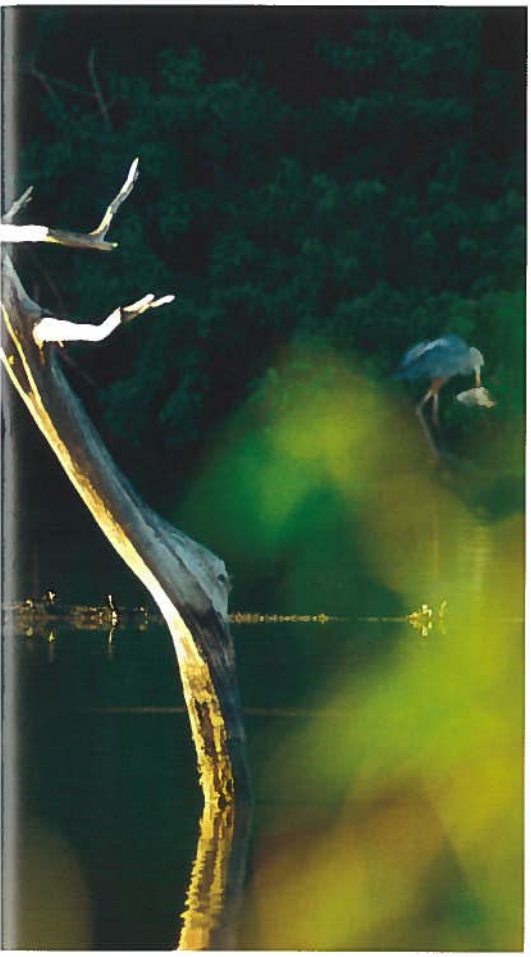
The Galveston Bay Estuary Program (GBEP) and the Coastal Bend Bays and Estuaries Program (CBBEP) are both part of the National Estuary Program and, as such, are required to develop indicator programs. GBEP issued its final report on its indicator project earlier this year.

PHOTO © CLIFF MEINHARDT

CBBEP Executive Director Ray Allen says he expects his program to complete its indicator plan by the summer of 2006.

"For the past couple of years we've accumulated the most current data because you don't just wake up one day and generate indicator reports," Allen says. "We have spent a significant amount of money looking at the issues of water quality and habitat, and working with our friends at Texas Parks and Wildlife to look at fisheries population trends.

"Our motivation is that without establishing benchmarks, how do you know what you are trying to manage for?" he asks. "We have to develop indicators, but we've got issues of water quality, fisheries populations, colonial water bird populations and seagrass coverage that are critical to us. We have not selected our final indicators, but I think those will be along the lines of the indicators we select."



Healthy ecosystems comprise many individual components, from wildlife (like the egret and heron pictured above) to water to specific plants and trees. There is a growing trend among scientists to study changes in some of these components to gauge an ecosystem's health.

Eye of the beholder

Allen chuckles slightly at the mention that many of the indicators CBBEP may select for its monitoring program are the same as those already chosen by GBEP.

"You really don't need to be a rocket scientist to figure this stuff out," he says. "The real challenge is to decide who the audience is. If you are choosing indicators for a technical group of people, you might have a more sophisticated suite of indicators. Here, we're trying to generate indicators and a scorecard to let the general public — the people who are managing local cities, counties and agencies — know what's happening. The indicators need to be fairly representative. We can't just say we want to talk about redfish and whatever redfish are doing, we draw conclusions from that. My philosophy is that if we can tell the fisheries story by talking about the recreationally and commercially important species, then that's what we ought to do."

Atlantic croaker is recreationally important as a baitfish, but that had little to do with the reason Dr. Peter Thomas chose it as an indicator species to detect ecosystem problems in Florida. For Thomas, a researcher at The University of Texas Marine Science Institute in Port Aransas, croaker was the best answer to the question of how to determine the effects of hypoxia on fish reproduction. Pensacola Bay is often subject to hypoxic conditions caused by large amounts of freshwater and nutrients washed into the bay system after heavy rainfall. The nutrients fuel algae blooms that consume much of the oxygen in the water as the organisms die.

"I chose a biological indicator that is very sensitive to environmental degradation," says Thomas. "Reproduction is a very complex process that is controlled by the endocrine system and is easily disrupted by environmental stressors. For example, many animal species can't be induced to breed under the unnatural and often stressful conditions in captivity. Another advantage of reproduction as an indicator is that the consequences of impairment in the individual can be understood at the population level under certain kinds of scenarios. If reproduction is impaired consistently, then we can expect to see population problems. We have developed models to predict the effects of impaired reproduction and reproductive physiology on population abundance.

"Croaker is a very good estuarine species to model because it comprises a major component of the population of free-swimming aquatic animals in the estuary, and because its reproductive physiology has been studied extensively over the past 25 years," says Thomas. "In addition, we have extensive informa-

Atlantic croaker

tion on how environmental stressors, particularly contaminants, affect the endocrine system controlling reproduction.

"So, we can understand, or at least partially understand, the consequences of a change in a particular reproductive endocrine parameter in croaker," he says.

Among the croaker populations in East Bay, a part of the Pensacola Bay System, Thomas found complete endocrine and reproductive failure in both males and females caused by hypoxia.

"The conclusion one can draw is that the fish from that particular bay system are not contributing to the spawning population that year," he says. "Reproduction in croaker is just one indication of the health of the ecosystem. A suite of indicators, perhaps involving different organisms or even different levels of biological organization, together would provide a more accurate overall assessment of ecosystem health. Atlantic croaker reproduction is a good model for an important component of the open bay ecosystem, the fish species that develop in the estuaries and spawn offshore."

Indicators need to be evaluated and chosen based on their purpose, suggests Thomas. Some are very specific about what they detect while others are more general in nature and convey less about the state of ecosystem health in broader terms.

"When you go from molecular level to ecosystem level indicators, there is a time scale involved," he says. "As the specificity of the indicator decreases, its relevance increases. But by the time you see something manifest itself as a population effect, you could be a long way down the road — it could be several years after exposure to the stressor. A molecular indicator can occur within a short time of the stressor, so there are tradeoffs you have to make when choosing an indicator."

The Texas Parks and Wildlife Department (TPWD) was in the process of converting to an ecosystem-based management system when the Ocean Commission released its report. The shift to ecosystem-based management has been decades in the making but is picking up momentum, says McKinney.

"Ecosystem-based management is something that academics recognized some time ago," he says. "But it takes some years in bureaucracies — both state and federal — to make a shift of this magnitude."

As part of this shift, TPWD has done away with its Resource Protection Division and allocated the division's responsibilities between the Coastal Fisheries and Inland Fisheries divisions.

"We are trying to take a look at how we are going to set our responsibilities in the future — trying to manage fish and wildlife," says McKinney. "Frankly, you can't do that unless you can have some influence on the ecosystem of which they are a part. The main things that are affecting those resources are water quality, loss of habitat and factors like that. We can implement bag and length limits until we are blue in the face, but that is not doing anything except cutting up the pie into smaller pieces. We have to do something about the pie itself — making sure that we maintain an ecosystem in which these species can survive.

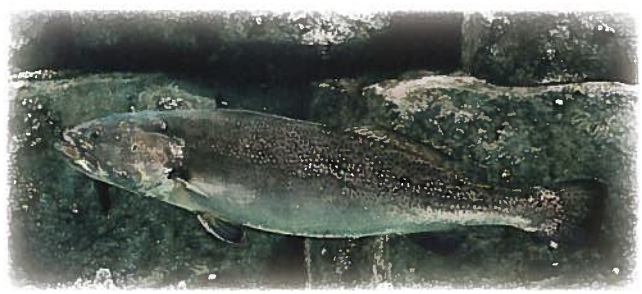
"Scientists have been talking about the need to look at ecosystems on an integrated level for about 10 years now and we are just now, from a management perspective, trying to do it, and it is pretty daunting," McKinney admits. "When I look at what NMFS and others call ecosystem management, I don't know if they really know what they are doing yet. That's not a knock on the federal government because I'm not sure I know what I'm doing yet. When you move beyond talking about it at an academic level and actually have to try using those tools in resource management, it is difficult because it is so overwhelming. We are all looking for things — ecological indicators — that will give us clues so we can measure our success."

McKinney and other TPWD managers have spent much time trying to identify indicators that will help them determine how well they are managing the state's varying ecosystems. Although the indicators will vary by ecosystem, they will share similar characteristics:

- It must have numeric values from actual data, not a model prediction. "Your indicator has to have a basis in real numbers, a numeric value you can apply," says McKinney.
- It must be applicable to a defined geographic area.
- It must reflect trends over time. "It must have a temporal aspect to it so you can look at trends over time," he says.
- It must be able to integrate underlying trends. "That is the canary in the coal mine part of it. It must be a trend that can reflect other trends happening at a lower level that you could not otherwise detect," says McKinney.

Three indicators with the required characteristics come quickly to McKinney's mind: spotted seatrout, fish kills and seagrasses.

TPWD has about 30 years of data on seatrout distribution, population changes and fish advisories along the entire Texas coast. The agency also



Spotted seatrout

UPPER PHOTO FROM SEA GRANT FILE; LOWER BY STEPHAN MYERS

has 7,000 to 8,000 data entries related to fish kills, which is a broader indicator than seatrout.

"If your goal is to manage to attain a certain level of ecosystem health, there are three components you must look at — chemical integrity, physical integrity and biological integrity. If you achieve the levels of physical, biological and chemical integrity that you have targeted, then you may have reached the level of ecosystem health you are looking for."

Spotted seatrout data tell McKinney that the species has been in trouble in the past, but the population is now increasing and seems to be doing pretty well, except in a few systems like the Laguna Madre, where the populations could be doing better.

Wetland grasses

"We have to be careful about drawing conclusions here because there are influences like fishing pressure that we must be aware of, but those are part of the system, too," he says. "It's not real straightforward, but at least the data is there and it gives us the basis for an analysis."

Spotted seatrout is at the top of its food chain, so its status gives scientists and resource managers an idea of what is happening within the resources upon which the fish depends, such as the shrimp and small fish it eats.

"Spotted seatrout can't stand alone as an ecological indicator," warns McKinney. "We must also look at habitat and water quality, and then look at how those three indicators fit together. We will fail in our mission if all we do is focus on spotted seatrout, red drum or any single species and assume that as long as we can regulate that population through bag limits, seasons and those sorts of things, then we will be successful. We have to look at the other connected issues, take them into account and, frankly, try to do something about them."

Resource managers use seagrasses as indicators by looking at their extent and species compositions — are seagrass meadows growing or shrinking? Are the types of seagrasses within an established meadow changing?

Some species are more sensitive to environmental conditions than other species. During the prolonged brown tide in the Laguna Madre in the 1990s, researchers saw a shift in the seagrass community from one dominated by turtle grass to one of eelgrass, which needs less light to grow and was better adapted to survive the brown tide's shading effect on the Laguna's floor.

"Of course, when you are in Galveston Bay and you've lost all of your seagrasses, that's a pretty good indicator that something is wrong," says McKinney.

Results of a fish kill

A large amount of fish dying at one time is a really good indicator that something is wrong within an ecosystem, but scientists must answer several other questions to enhance its capabilities as an indicator: Where was the kill? How many fish died? What species were involved?

"Location is the first clue," says McKinney. "If you see a concentration of fish kills occurring in one part of an estuary or a secondary bay, that gives you an indication something is going on there. The next level is cause. Was the fish kill caused by low dissolved oxygen or was it a contaminant?

"If you are going to use indicators, there is no stand-alone indicator. Instead, there are layers of them," he says. "You have coarse filters and fine filters. It is very much like diagnosing human health. When you go to see your doctor when you are ill, the first thing they do is check your temperature, your blood pressure and your pulse. Those are all basic indicators of human health. That's what we are talking about with ecological indicators. The population levels of spotted seatrout, distribution of seagrass beds and numbers of fish kills are pretty good indicators that something is happening. If you want to find out something more, you'll have to run more detailed tests. In humans, that might mean running blood work or taking a cardiogram."

McKinney feels indicators are most effective at the estuarine level. There are issues, like the hypoxic area off the Mississippi River and harmful algal blooms, that are applicable to the entire Gulf of Mexico, but resource managers can have their greatest effect on estuaries.

"I base that on my experiences in Texas dealing with freshwater inflows in the seven major estuaries," says McKinney. "I learned over time that every one of those systems is different. Trying to apply one solution

SEA GRANT FILE PHOTOS

to all of them is not practical. If you are going to affect the health of an estuary in a positive way, then you have to think of it as a single ecosystem."

The natural variability within ecosystems and man's relative ignorance of their natural cycles complicates things a bit, he adds.

"Coastal areas are so dynamic that the natural variability that occurs in any of these indicators can be so great that it can mask man-made changes," says McKinney. "And, there are very few databases that are continuous over long enough time periods to be very meaningful. Our 30-year database on spotted seatrout is probably one of the longest datasets in the world, if not THE longest. We don't know what meaningful is in terms of estuaries. Is it a year or 10 years? We don't know what the cycles are, but we know they are more than a few years. Databases that have long enough lines of data so you can really look at trends are few and far between.

"Even if you have long-term data, there is a question of its quality and standardization," he says. "Methodologies change. You can get radically different looking data from the same indicator, but it may be because whoever recorded the measurements used more sensitive instruments over time."

The technology of ecological indicators has come a long way. As McKinney points out, "At one time, people picked up a fish and ate it and if they got sick, they didn't do it again."

Technology has also proven to be a limiting factor in some ways. Decades of information that could have fed trend analyses have been lost to rapidly evolving computer software. Data stored in one format were not always upgraded to newer programs.

McKinney admits that at his home he has old computer card decks full of information that can no longer be retrieved. TPWD has recognized the data gap and has taken steps to make sure that it keeps data in forms that can be upgraded.

"Our 30-year database is in a continual process of being updated to a format that allows us to bring it into the next generation of technology," says McKinney. "We are also field testing a group of computer tablets that are basically shockproof, waterproof and salt proof. They can be submerged or dropped and they will keep working. If it works as we hope, our people in the field will be entering data directly onto those machines. There will be no more paper records. It may be that eventually all field data will go directly to headquarters via the Internet."

TPWD will also rely heavily on the environmental management wave of the future — geographic information systems (GIS) — to integrate data from its diverse set of indicators

"If we don't make use of GIS technology, we're dead," McKinney says bluntly.

In the simplest terms, GIS are tools used to gather, manipulate, analyze and combine information about virtually any aspect of the Earth's surface. The data take many forms, including maps, 3D virtual models, tables and lists.

"Almost all of the data we collect and analyze dealing with the natural and cultural world has a spatial component — it is based on location," says Dr. Kim Ludeke, TPWD's GIS lab manager. "A location is often a very important way of describing the data. GIS is a tool for integrating data by geography. GIS is a broad topic because it includes Global Positioning Systems (GPS), digital aerial photography and satellite remote sensing."

GPS, designed and controlled by the U.S. Department of Defense, is a satellite navigation system available to both the military and the general public primarily for determining precise locations anywhere on the planet.

Utilizing the geographic aspects of data is growing in popularity. Internet search engine giant Google Inc. recently hired Vinton Cerf, widely considered the "father of the Internet" for his role in developing TCP/IP standards — the basic way computers find and talk to each other over the Internet. Cerf said one of the ideas he wants to explore with Google is organizing information based on geography.

"More and more, location is becoming integral to understanding the world," believes Ludeke.

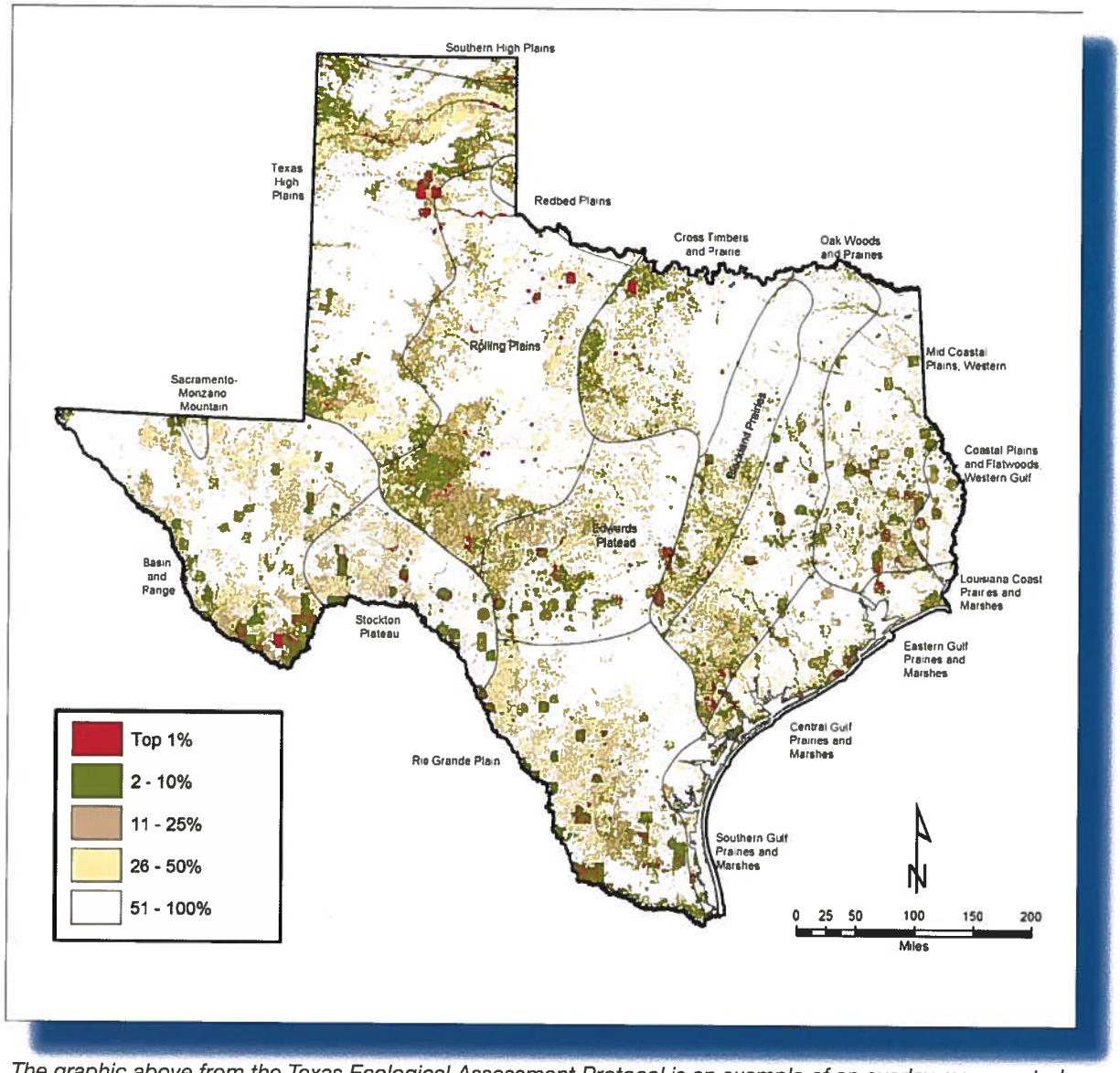
Rudimentary GIS, or rather the concept, may reach back 35,000 years. Cro-Magnon man drew pictures of his prey on the walls of caves near Lascaux, France. Near the pictures were lines believed to designate migration routes, marking the first known combination of graphics and a database, primitive though it was.

During the 1950s and 1960s, landscape architect Ian McHarg preached the need for urban planners to consider an environmentally conscious approach to land use. Until that time, the environment was lightly considered in planning and design because there was no efficient method of quantifying or displaying information about nature in relation to a given project.

McHarg breached the information gap through the use of map overlays printed on clear plastic sheets. He used overlays to great effect during a controversial road construction project on Staten Island, N.Y. Engineers had proposed that the most cost-efficient route for the parkway was along a 5-mile stretch of scenic park land, which would connect the two ends of the island along the straightest path.

McHarg approached the route with a view toward the benefits and costs to society of placing a major thoroughfare in the area. He considered factors such as water features, forests, wildlife, recreation areas, scenic areas, residential developments, industrial property and land values, and then created a map overlay for each factor, with the areas of greatest value denoted by dark tones and the area of least value denoted by light tones.

When all of the overlays were superimposed on a map, the darkest areas signified the land of greatest social value. McHarg then compared the social value map with composite maps he had done to show geologic and hazard considerations. The result was a highly precise map of the route the road should take to have



The graphic above from the Texas Ecological Assessment Protocol is an example of an overlay map created using GIS. The map shows the state's ecoregion boundaries and shows areas with the most diverse land cover, highest number of rare species and land cover types, and the areas that can best sustain ecosystems.

the least environmental impact.

In the end, neither McHarg's nor any other proposal was ever used, and the road remains unfinished.

Computer hardware development prompted by nuclear weapon research led to the first general-purpose computer mapping applications by the early 1960s, but the first truly operational GIS was developed in 1967 by Canadian geographer Roger Tomlinson.

Called the Canadian GIS, or CGIS, the program stored, analyzed, collected and manipulated data for the Canada Land Inventory — an initiative that mapped information about the country's soils, agriculture, recreation, wildlife, forestry and land use.

As the use of computers expanded, so did interest in GIS. As Ludeke puts it, "GIS is a technology that evolved with computers."

TPWD already utilizes GIS and GPS and remote sensing technology throughout the agency to, for instance, map the habitat for the lesser prairie chicken and to map prairie dog towns to find out if they have changed over time.

The Texas Environmental Resource Stewards Program, established in 2002 as a venue for state and federal agencies to identify collaborative ecosystem management opportunities, led to creation of the Texas Ecological Assessment Protocol. Under the protocol, Texas was divided into one-kilometer grid cells and each cell was assessed for its diversity of land cover, the number of rare species and land cover types, and sustainable ecosystems.

TPWD, working with the EPA and The Nature Conservancy, used GIS to produced a map showing the relative ecological value of each cell as a reference for future human development.

Game wardens routinely use GPS to establish crime scenes, "like

GRAPHIC COURTESY U.S. ENVIRONMENTAL PROTECTION AGENCY

TPWD plans database celebration

For two days in November, the Texas Parks and Wildlife Department's Coastal Fisheries Division will host a symposium in Corpus Christi celebrating 30 years of continuous monitoring of the state's marine fisheries and seeking input on how it should operate for the next 30 years.

Information from 60,000 bag seines, 50,000 trawls, 30,000 dredge samples, 20,000 gill net sets and 30,000 angler interviews collected over the past three decades generated millions of data points that make this TPWD database one of the longest, and possibly THE longest, datasets in the world, according to Dr. Larry McKinney, director of the Coastal Fisheries Division.

"Information we've gained from the database has been the basis for resource management decisions and regulations that have generated an economic impact of almost $2 billion annually in Texas," McKinney says. "We have also used this information in our successful fight to secure freshwater inflows for and to protect the water quality of our estuaries, which are critical habitats for our fisheries."

The symposium will feature panel discussions on lessons learned during the past 30 years, and challenges and issues facing Texas' coastal fisheries in the future. McKinney says information gained during the discussions will be incorporated into the Coastal Fisheries Division's new 30-year strategic plan.

The symposium will be Nov. 17-18 at the Omni Bayfront Hotel and is open to the public. Registration information will be available soon. For more information, contact McKinney at 512.389.4636.

pipes pumping something nasty into Galveston Bay, where a deer is poached, a body is found or a methamphetamine lab is located," says Ludeke. "The wardens get a GPS location and ask that it be plotted on a map. Through that they can establish property lines and determine that one man poached deer on another man's land. They can take that evidence to a judge.

"We had a case a year or so ago where people were shrimping in a no-shrimping zone," he continues. "We produced a (aerial photographic map) of the coast with the shrimping boundaries defined and the location where the boat was intercepted, which was clearly inside the no-shrimping zone boundary."

The agency is now embarking on a GIS project that could change the way wetlands restoration is conducted. TPWD has a contract to digitize the elevation contours in Harris County in one-foot increments based on surveys from 1916. The resulting digital map will show depressions where wetlands existed in Houston at that time. Using GIS, TPWD will be able to compare the 1916 map to what exists in those locations today.

Developers who destroy wetlands during construction projects are required to mitigate the damage by creating new wetlands. Once TPWD's project is completed, the potential will exist in Houston for developers to mitigate on the site of a previous wetland.

"If you strip the ground cover off one of those sites you may still have some classic wetlands soils there that lend themselves to restoration better than non-wetland soils," says Ludeke.

McKinney marvels at the monitoring technology available to resource managers. TPWD recently signed a contract with Dr. John Gold at Texas A&M University for a DNA mapping program involving red drum. Gold has been mapping DNA markers of brood fish kept in state-run hatcheries.

As he collects red drum caught in the wild, he will clip off a part of their dorsal fins and be able to tell not only in which brood tank the fish was spawned, but also the brood pair that produced it.

"We are going to answer the question in the next two or three years of just what contributions stock enhancements make to red drum populations," McKinney says excitedly.

Thomas' enthusiasm for indicators is a bit more tempered.

"There has been a lot of interest in indicators, but it has come and gone," says Thomas, who has worked with indicators since his graduate school days at Texas A&M University in the late 1970s. "There is always an indicator of the month and I think that's been a big problem. What we all have to do is to see if they really work in the field and determine if we can interpret their significance. If we don't do that, it just becomes research that builds on research."

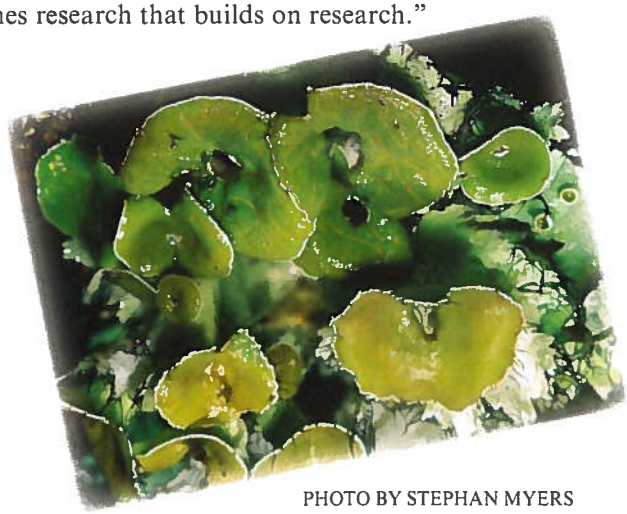


PHOTO BY STEPHAN MYERS

Leading indicators

The Galveston Bay Estuary Program (GBEP) is on the forefront among environmental organizations in the state seeking to identify and develop ecological indicators. In May of this year, GBEP released the final report of the Galveston Bay Indictors Project — an exhaustive two-year study that GBEP commissioned from the Houston Advanced Research Center (HARC).

The report (available online at http://galvbaydata.org/) details how the project's proncipal investigator, Dr. Jim Lester, and project manager, Lisa Gonzalez, narrowed a list of 350 potential indicators down to 28 that GBEP will use in the coming decades to judge the health of Galveston Bay and success of GBEP's actions there, and to bridge the information gap to the average citizen.

"Long term, we hope these indicators will tell us about the changes that are occurring in Galveston Bay and how successful our management actions are," says Helen Drummond, GBEP program director. "We're trying to come up with an integrated indicator system that allows us to look at multiple parameters and indicators that could be connected that will tell us more about the ecological aspects of Galveston Bay and not just one specific parameter. The bay is interconnected, so we're trying to get to the point of being able to understand that inter-connectedness. Right now, we are not there, but we hope indicators will eventually allow us to get there.

SEA GRANT PHOTO

"We also believe these indicators will give us a simple way of displaying to the public what is happening in the bay system and some of the interactions between different parameters," she says.

The Galveston Bay Indicators Project grew out of GBEP's status and trends project — an ongoing assessment of the changes in physical, chemical and biological resources in Galveston Bay.

Gonzalez characterizes the indicators project as an "attempt to identify assessment questions, or questions that managers of Galveston Bay resources and the public might be interested in asking, and then identifying indicators and supporting data that could answer those questions to provide a broad picture of the overall health of the estuary and the surrounding watershed."

In simpler terms, "What are the questions people want answers to?" says Lester.

The indicators project began in the fall of 2003. Working with GBEP, Lester and Gonzales developed 16 questions they felt the bay's users and managers might ask, such as "Are finfish, shellfish and wildlife populations increasing or decreasing?" and "Are the values of competing bay uses changing?"

To find indicators that might answer the 16 basic questions, Gonzalez and Lester completed a literature and Internet survey reviewing the past 15 years of work on ecological and sustainability indicators used around the world, particularly those involving coastal areas. They compiled a list of almost 350 potential indicators that they submitted to a group of experts representing different disciplines — including ecology, water quality, economics and anthropology — at a December 2003 workshop.

Lester and Gonzalez left the workshop with a greatly abridged list of indicators — less than 100 — that they presented to the Galveston Bay Council (GBEP's governing body) and its technical subcommittees for further review to determine which ones had the most available data. "We wanted to get the list down to 20 indicators, but we didn't make it that far," says Gonzalez.

Using data routinely collected by the TPWD, TCEQ and the State Department of Health Services (formerly the Texas Department of Health), "We found we could answer standard questions like is seafood safe to eat, are we increasing or decreasing the abundance of fish that people want to catch or is the water polluted?" says Lester.

Other questions, such as whether the acreage of wetlands is increasing or decreasing, prove more difficult to answer, despite seemingly self-assured claims that scientists know the percentage of wetlands lost in the past 200 years.

"You can do remote sensing estimates of wetlands for the time period since remote sensing started, but a lot depends on the rainfall pattern and the particular time of the year when you took the satellite image," says Lester. "It is the best approach we have, but it tends to miss a lot of the small stuff."

One of the goals of the Galveston Bay Plan is to restore 14,000 acres of wetlands around Galveston Bay. The 14,000 acres was "just a number that a group of scientists decided on," says Lester, and was based on an estimate that more than 30,000 acres of wetlands have disappeared around Galveston Bay and the desire to try to restore about half of the lost acreage.

Lester had hoped that his research on existing data would answer the question of how much progress has been made toward the wetlands restoration goal.

"What we found out is that we really don't have a quality-controlled dataset that will allow us to answer that question," he says.

There were some people in the environmental community who wanted to see the bay's wetlands restored to the same acreage that existed before people settled in the area — an idea Lester says is impossible because no one knows how many acres of wetlands existed then.

"I just don't see any scientific methodology that would allow you to estimate

PHOTOS (1) BROWN PELICAN, (2) GREAT BLUE HERON, (4) GREAT EGRET, (5) BLACK SKIMMER COURTESY TEXAS DEPARTMENT OF TRANSPORTATION ; (3) GREAT EGRET © CLIFF MEINHARDT

the abundance of wetlands that long ago and that long before records were kept."

No single indicator is sufficient to answer all of the questions posed by the bay's users.

"There are many different user groups and each one has its own perspective of Galveston Bay," says Lester. "We developed indicators for fishermen, birders, people who are interested in the economy and we have indicators for people who are tourists. I think it is important to have indicators that are relevant to the way people relate to the resource."

Public input and a final workshop in December 2004 narrowed the list of indicators to the 28 featured in Lester and Gonzalez's final report. They divided the indicators into two groups — half describing the bay's physical attributes (such as the location and number of marsh restoration sites) and half connected to human uses of the bay (such as change in the public's perception of the value of the bay).

"You can't just look at the ecology of the environment itself. You must look at the economic and social value of the environment to the citizens," Drummond explains. "We are looking at the socio-economic indicators to give us a better understanding of how we use the bay and whether the bay is meeting those uses."

Socio-economic indicators are important, says the EPA's Doug Jacobson, but not every one of the 28 national estuary programs around the country will include them in their mandated indicators program. Making socio-economic indicators part of GBEP's project made sense because "a healthy environment is a measure of a healthy economy and the two go hand in hand in Galveston Bay, where the bay plays a large part in the economic base of the area," he says.

For instance, one of the economic indicators — change in waterfowl hunting and saltwater fishing licenses — conveys more information than just how many people are hunting and fishing.

"It tells us about the satisfaction of the user group," says Lester. "The number of fishing licenses issued has risen but waterfowl hunters as a user group has declined dramatically since 1998. We would assume from that decline that there was some sort of dissatisfaction among the user group with the way the resource is being managed."

Issues associated with shipping serve as indicators of bay health.

Figures from the TPWD show that the number of waterfowl hunting licenses sold fell from 12,822 in 1997 to 4,543 in 2004. During the same period, the number of saltwater fishing stamps purchased rose from 218,115 to 235,312

Lester is at a loss to explain why the number of waterfowl hunters is declining, exposing one problem with using indicators. "Indicators don't get into causation," he says.

The categories of indicators chosen to describe aspects of the bay's natural environment include:

- Water and sediment quality. Four indicators look at the concentrations of nutrients, contaminants and bacteria in water, sediment and seafood.
- Biological resources. Six indicators are used to detect trends in habitat change, population changes in oysters, colonial nesting birds and predatory finfish, and change in species diversity.
- Physical characteristics. Two indicators look at changes in freshwater inflows from the Trinity and San Jacinto rivers, and changes in the bay's average seasonal salinity.
- Social and economic. Two indicators track changes in land use patterns and in the human population of the five counties surrounding Galveston Bay.

Indicators describing human uses of the bay fall into the categories of:

- Seafood. Two indicators provide data on the status of seafood consumption advisories and changes in shellfish harvesting areas in the bay.
- Fisheries. Two indicators track change in commercial landings and commercial boat licenses, and changes in recreational landings.
- Water. Three indicators look at freshwater supply and demand in the state water planning region that includes the bay, annual gauged freshwater inflows compared to state recommended inflow amounts, and the change in the number of stream segments on the state's list of impaired waters.
- Shipping. One indicator focuses on trends in shipping traffic versus vessel fuel spills and vessel incidents, which include events like groundings and collisions.
- Boating. One indicator notes the change in number and location of marina pump out facilities.
- Other recreation. Three indicators track the change in the number of bay and tributary public access areas, change in the number of

PHOTO COURTESY PORT OF HOUSTON AUTHORITY

waterfowl hunting and saltwater fishing licenses issued and change in the amount of tourism dollars spent in the five counties surrounding the bay.

- Valuation. Two indicators that assess a change in the public's perception of the value of Galveston Bay, and the value of shipping cargo, recreational boating, energy production wells, commercial and recreational fishing, and nature tourism in the bay.

What do the indicators tell us about Galveston Bay? The following is a sample of information scientists and managers have gleaned from the data:

White ibis

The three species of colonial water birds pictured on this page are among the 11 species chosen by GBEP as indicators of water bird population health.

Great blue heron

Roseate spoonbill

Change in abundance of colonial nesting bird guilds:

"We are seeing a decrease in mostly the marsh edge wading birds like the Great Blue Heron, reddish egret and the tri-color heron," notes Lester. "There is no indication that the species they feed on are decreasing, so the next most likely factor is a loss of nesting habitat. People building nesting habitats out in the bay are finding that if they build the habitat, the birds will come. My assumption is that there has been a decrease in the quality or quantity of the nesting habitat."

Change in number and location of marina pump out facilities:

"This is an indicator of opportunity," says Steven Johnston, GBEP's monitoring and research coordinator. "A pump out is a place where boaters hygienically dispose of human waste removed from the toilets on their boats. If the number of facilities decrease, it suggests fewer people have access or opportunity to pump out their waste. It could also suggest negative effects on the bay with the fewer pump outs people do, but it begs the question of how much can you really say about the indicator? With some indicators we won't know for decades, perhaps, what the trends are. HARC's work is valuable in that it highlights the data gaps we need to fill."

Change in land use patterns: developed and undeveloped land:

"Some studies have shown increased human development leads to an increase in impervious (paved) surfaces, which potentially lowers water quality through increased pollution and thus lowers production from the bay," says Johnston. "We took land use patterns and superimposed them over land cover data to see that most land used for development is in Houston. We now need more studies to determine how development really affects the bay.

"Habitat fragmentation also comes along with development. Coastal prairie was vast at one point and now it has become very small. Right now there is only about 1 percent of native coastal prairie left, and that is not in the Houston region."

Lester adds that "the more people you get into an area, the less land you have available for all other uses. If you have more people moving in, you have less land for critters."

Land use is one of the indicators lacking sufficient supporting data. The Houston-Galveston Area Council is currently establishing a baseline through a land use classification study.

"We expect in five years to be able to compare some new numbers with that baseline," says Lester.

Change in abundance and size of oyster populations:

"If the physical size of the oysters that are harvested every year decreases, that says that the larger oysters are being taken out of the system somehow," says Johnston. "Oyster populations change based on fresh-

Tree frog

water inflows, so changes in freshwater or salinity patterns could wreak havoc on the larger individuals.

"Parasites increase when there is a lack of inflows and they will target the larger oysters. Most parasites live in higher saline water. Increased inflows reduce salinities while too much freshwater affects the oysters' ability to reproduce. That's why you find the best oyster beds in middle of the bay, where there is a balance between fresh and saltwater."

The Galveston Bay Indicators Project yielded some surprising information. Data showed higher than expected levels of contaminants, particularly the heavy metals lead and cadmium, in the sediments of Christmas Bay, long thought of as the most pristine water body in the Galveston Bay System.

"The indicators suggest that Christmas Bay is probably threatened almost as much as West Bay," says Lester. "We would like to believe that because it is out there at the end of the system and it is surrounded by some relatively undeveloped land that it is somehow protected, but it's not."

Christmas Bay is designated a coastal preserve and is home to some of the last remnants of seagrass meadows in the Galveston Bay System, says Gonzalez. "Residents in the area are concerned with the impacts of development in the watershed north of Christmas Bay, particularly along Bastrop Bayou. We have also seen increases in fecal coliforms in Bastrop Bayou, which is closely linked with Christmas Bay," she says.

Because indicators do not indicate causative factors, Lester refuses to speculate about where the contaminants are coming from — but it has to be from a source or sources that are relatively close.

"Heavy metals don't move that far," he says.

Data also show that the Galveston Bay System cannot seem to get rid of legacy pesticides — chemicals that persist in the environment and degrade very slowly. There are detectable amounts of Chlordane (a pesticide used on crops and termites until it was banned in 1988), DDT (also used on crops and to kill disease carrying insects until it was banned in 1972), DDE and DDD (both breakdown products of DDT) in the bay, particularly in the Houston Ship Channel.

"These pesticides haven't been for sale for a long time and yet they still show up," says Lester. "It is odd that after you ban something it doesn't necessarily go away."

Overall, the Galveston Bay Indicators Project report showed that:

- Water quality in general has improved since the 1970s and the inception of the Clean Water Act. Certain sub-bays, like Christmas Bay, and tributaries still show contamination problems.
- Areas of the bay open to shellfish harvest remain relatively stable.
- The bay appears to be sustaining recreational and commercial fisheries although the number of commercial licenses is declining.
- Indicators describing the ability of the watershed to sustain the demand for clean freshwater are mixed. The indicator that is based on the analysis of water demand shows a freshwater deficit in the future, but the indicator based on the gauged freshwater inflows indicates these inflows are not significantly different from the state's recommended inflows over the past decade. However, the number of stream segments on the state's list of impaired water bodies has increased.
- The rate of vessel fuel spills and incidents is relatively low compared with the amount of vessel traffic in the bay.
- The number of pleasure boat licenses issued and marina pump out stations available appears to be stable.
- The amount of money spent by tourists visiting the five counties surrounding Galveston Bay also appears to be stable.
- In general, the bay is becoming more valuable to the people in the surrounding communities.

"The critical issue will be how we communicate this information and trying to get it used," says Lester. "Lisa and I were both called by the General Accounting Office because they were doing a study of the usefulness of indicator projects. The federal government has been spending so much money on indicators projects that they were wondering if any of them were actually being used. I think their answer was 'not a whole lot.' The critical thing is to make the data useful.

PHOTO COURTESY TEXAS DEPARTMENT OF TRANSPORTATION

"There is a lot of monitoring, less analysis and even less effort to communicate the results of the analysis," he continues. "We must do a better job of making the scientific data more useful to the general public and the people who are involved in managing the resource. The real challenge is to simply state what we know in such a way that it is useable by interested folks. You can't make everybody interested in the health of Galveston Bay, but there are an awful lot of fishermen and people who want to go bird watching, sailing and participate in other activities, and most of them don't have a clue because nothing has ever been presented to them in a simple and straightforward way. These are very simply analyses. We tried very hard to keep the experts from pushing us in the direction of excessive analysis. These are very simple graphs and comparisons. If we could get it to a pie chart or a single line, we did that. We want to put the information out there and hopefully people will use it in making decisions. It has to be fairly simple to get it into wide use."

GBEP plans to make information from the indicators project available to the public through workshops, presentations and the mass media.

"Hopefully, we will help some of the people who don't think about Galveston Bay being right in their backyard to become more aware of this resource and how their actions and the things going on around them can impact the bay," says Gonzalez.

PHOTO © CLIFF MEINHARDT

Call to action

Ecological indicators can do more than just mark a snapshot in time or lend themselves to an analysis of trends, says Dr. John Jacob, coastal community development specialist with the Texas Marine Advisory Service. Indicators can also point out the need for fundamental shifts in the way people do business.

"Biological indicators are important because we need to keep track of what is going on in the bay, as long as we realize what the drivers are for the indicators," says Jacob. "Indicators are one thing, drivers are another. What's causing something to happen?

"Scientists measure and look at the indicators just like a doctor measures a patient's blood pressure and pulse," he continues. "That's all well and good, but if all you know are the indicators and you don't know why, say, the patient's blood pressure is going down, then all you know is that you are going to watch him die."

Jacob believes human development is the major driver of degradation within the Galveston Bay watershed. Simply put, "If we weren't here, it wouldn't be screwed up. That's the bottom line," he says.

PHOTO © STEPHAN MYERS

This section of Charleston, S.C., was built before the invention of automobiles. It can support 20,000 people per square mile in the same pedestrian-friendly manner as New Orleans' French Quarter.

Jacob contends that many people involved in studying and managing the state's natural resources assume that human development is an inevitability, so they focus their attentions on measuring parameters within coastal ecosystems without spending much time thinking about coastal development.

"I feel Hurricane Katrina is a watershed event for us — pun fully intended," says a noticeably incensed Jacob. "There is a question of failure up and down the line. Short-term planning — emergency planning — went to hell. What about long-term planning? What about building in vulnerable areas? Were the right decisions made? Obviously they weren't.

"What about over here in Houston? Have we made the right decisions? We're about to put thousands of new homes in Galveston County. What is that going to do for emergency planning? That should be on our minds," he fumes. "To me this says that it's time for us to stop pussyfooting around and start talking more seriously about land use planning. We have always been afraid to talk about it. We've always said that is not part of our culture and we shouldn't be involved in it because it's just not Texas. Well, that is garbage. We're going to have to stand up now and say this is a public responsibility."

Regulators have already dabbled in land use planning by decreeing that people cannot build in flood plains. The logical extension is to question whether people should be allowed to build in other vulnerable low-lying areas, or to destroy other valuable ecological areas that are critical to our future.

"Land use planning is not anti-free market," Jacob contends. "It's the community asking, 'What are the bounds of that market?'"

For instance, New Orlean's French Quarter did not suffer as much damage as the rest of the city because it was built about three feet above sea level, as opposed to the rest of the city, which was built below sea level. Most of the structures in the French Quarter were built before the levee system was put in place — during a time when periodic flooding was part of the Mississippi River's life cycle. Many of the buildings are masonry structures, and the district itself is built in a pedestrian friendly manner that encourages resiliency, says Jacob.

Masonry houses are expensive, but if they are built in areas that encourage walking over driving, people can re-direct their transportation costs into building sturdier homes, says Jacob, exhibiting his predilection toward "smart growth" development.

Smart growth champions town-centered development reminiscent of the way communities were built before automobiles became the transportation mode of choice. It favors dense population centers, like the 15,000 people per square mile French Quarter, designed to provide for most of the residents' needs, versus the typical suburban subdivision, which has 3,000 to 4,000 people per square mile.

Jacob points to smart growth as one way to improve one of GBEP's chosen indicators — changes in land use from undeveloped to developed property.

"When you pave something over, it no longer acts like a natural area," Jacob reiterates. "Water becomes very flashy and runs off quickly. The more impervious surface you have, the worse it is. As imperviousness increases, stream quality — water quality and biotic indicators — declines. Studies indicate that there are thresholds of imperviousness. Once you get above 25 percent imperviousness, you are pretty much in a degraded shape. It doesn't necessarily mean you've gone to hell in a hand basket, but the system is not in good shape."

By comparison, an area that features less than 10 percent impervious surfaces is considered relatively pristine.

"These are broad thresholds," says Ja-

PHOTO BY JOHN JACOB

cob. "You can still have somewhat healthy streams in some developed areas. What the data say is that we should be preserving larger areas and save those watersheds that are still below 25 percent imperviousness and especially those below 10 percent. Those are the areas that are going to have the highest quality of life in the stream and the best water quality."

Jacob produces data on rainfall runoff taken from residential and commercial areas that show the more developed an area becomes, the more polluted the runoff. As the density of human population increases, the quality of the runoff decreases due to increased impervious surfaces.

The data seem to contradict Jacob's contention that building more densely populated communities is environmentally friendly, until Jacob presents the bigger picture. Begin with a large, unpopulated watershed and build a smart growth community that is home to 30,000 people. The development maximizes the amount of impervious surfaces in one location, but the amount of impervious surface per capita drops dramatically when you figure in the amount of non-impervious surfaces throughout the rest of the watershed.

"It's good to find a few summary indicators that the public can latch onto," Jacob believes. "What should be the indicator for Clear Lake? Could it be in the name? I think it could. Clear Lake used to be clear and there are old timers who remember when it was. There is an indicator that something is screwed up. Clear Lake does not live up to its name.

"We must be careful when focusing on indicators," he continues. "They are important but we can end up contemplating our navels. We know that natural areas work well — they work better than anything we know how to put together. They have evolved over eons, so it is the prairies and the forests that we need to preserve. We may not understand all of the ways they work, but we know those systems are critical to our survival. We don't have to know all of the answers. It is simple enough to say that if we pave something over, we screw it up. Nevertheless, we absolutely need indicators because we need to pay attention to approaching thresholds.

"The real message from Katrina is it's time to speak out more forcefully," Jacob contends. "Those of us in this field, the holders of the knowledge, can't be passive. We are the responsible ones. If we don't take action, what is the next generation going to say to us? We can't twist people's arms, they are going to do what they're going to do, but we had better try to get the word out."

People who build homes and businesses close to the coast are living in harm's way.

PHOTO © STEPHAN MYERS

PHOTO © CLIFF MEINHARDT

The final analysis

What does the future hold for the indicators movement? Is it here to stay or just a passing scientific fad?

The EPA's Jacobson believes resource managers will use indicators in every situation they possibly can "because of the need to disseminate information to the public. There is a large hunger for environmental information from citizens, non-governmental organizations and definitely government managers. As we become more accountable as an agency to Congress and the public as to how we spend our money, these indicators are extremely important."

McKinney sees a long and increasingly important future for indicators because they give resource managers the ability to head off environmental problems before they get out of hand.

"If you are going to manage a resource, you must have the ability to make predictions about the future, otherwise you are just reacting," he says, relying on many years of experience. "The reaction mode to management is not where we need to be. That leads to disaster. We must be more proactive in our management and the only way we can be proactive is to use indicators to tell us where we may be headed as we go down the road."

Allen foresees using indicator data for more than educating the public about ecosystem health. It can also be used to form public policy and generate public will to act.

"The data could be used to generate public support for taking a particular action. Instead of having a technical report on a shelf that talks about the statistical trends in whooping crane or blue heron populations, wouldn't it be nice to get that out to the general public because it is a concept they could easily understand?" asks Allen. " If your redfish and trout populations are increasing, it is one thing to say that is good, but it is another thing to say where they need to be."

In order for indicators to become the monitoring tool that many hope they become, resource managers must first answer a fundamental question: What do you manage an ecosystem for?

"If you are going to manage a bay for oysters, the decisions you make are different than if you are managing for natural patterns," says Allen. "That is a different goal entirely.

"We can't go back to the way these ecosystems were before European development began here. We've already got dams on the rivers that take out water, nutrients and sediments," he concludes. "Whether we like to say it or not, we are managing these ecosystems pretty aggressively. Saying we won't manage an ecosystem and will just let nature take its course is not an acceptable answer anymore. We have to understand what it is we want to see accomplished. We may want to see a lot of natural variability out there. The bays are not fish farms and the goal isn't just to raise redfish. The goal is to maintain habitat diversity and a diverse species composition." ■

At home with nature

By Jim Hiney

Dr. Connie Arnold with two of his six miniature donkeys.

Dr. Connie Arnold stops for a moment to greet six miniature donkeys that roam part of his 110-acre ranch about 20 miles north of Goliad. The animals gather around him like loving children around a doting father.

"Molly Ann is a nibbler," he says of the youngest donkey as he deftly keeps his fingers away from her teeth while stroking her nose.

Faith Ann, Rosie, Blossom, Gracie and Gabby push and nudge each other's heads as they vie for Arnold's attention.

The donkeys are "kind of a novelty," he says, adding that their gentle nature make them ideal animals for people with a few acres in the country who want to keep livestock. "The popularity of miniature donkeys is rising quickly. I see ads for them in the paper and by the time I call, they are already sold."

A few minutes later, Arnold shows off his garden of lavender bushes — a crop he plans to sell for use in potpourri, cooking and as a medicinal and aromatic oil.

All around the area just outside his fully restored 1930s vintage home (moved in from a location near the neighboring town of Weesatche), Arnold points out a mixed bag of plants he is growing all around his lush yard and he plays tour guide in one of the three cottages that comprise Three Oaks Guest Ranch (which has just two of its namesake trees remaining after Arnold was forced to cut one down when he discovered it was dead and threatening to fall on his home).

Back in his house, Arnold relaxes in a chair and gazes through a window and across his porch to a vast open field that vanishes in the distance into a thick tree line.

"Every morning I get up and it is a new world," he says quietly, with a serene smile on his face. "When you get to be my age, just being here is a real thrill. I get up every morning, sit on the porch, have my coffee and watch the world wake up. It's very nice."

If not for the brightly colored replicas of tropical fish and ocean related decorations that dominate his self-described "marine room" just off the kitchen, there would be no indication that Arnold, who turns 72 in November, was ever near the ocean or is one of the most respected marine scientists in the nation (with 111 scientific papers published between 1961 and 2004) and the man widely considered the father of Texas' saltwater sport fish restocking, or enhancement, program.

As far as anyone can determine, Arnold was the first person to successfully spawn spotted seatrout and red drum, also called redfish, in captivity. He did so by mimicking their natural spawning conditions — water, temperature, and periods of light and dark.

PHOTOS BY JOHN WOELKE

"He had the imagination that allowed him to conceive of bringing in large marine fish into a laboratory and essentially trick them into spawning," says Dr. Joan Holt, who worked under Arnold at The University of Texas Marine Science Institute (UTMSI) at Port Aransas. "He did so not only in the season when they would normally spawn. They would spawn in December or in the summer when we were using this simulation. He had fish spawning every month for two years solid — that was unprecedented at the time."

The time was the mid-1970s, and it was not a pleasant period for the commercial red drum fishery. There was a movement within the state government to make redfish and seatrout exclusively recreational species.

"The commercial fishermen were not happy, and you can understand why," says Arnold. "They were being forced out of business. For some of them, their daddies and granddaddies had been catching redfish in gill nets for years and years."

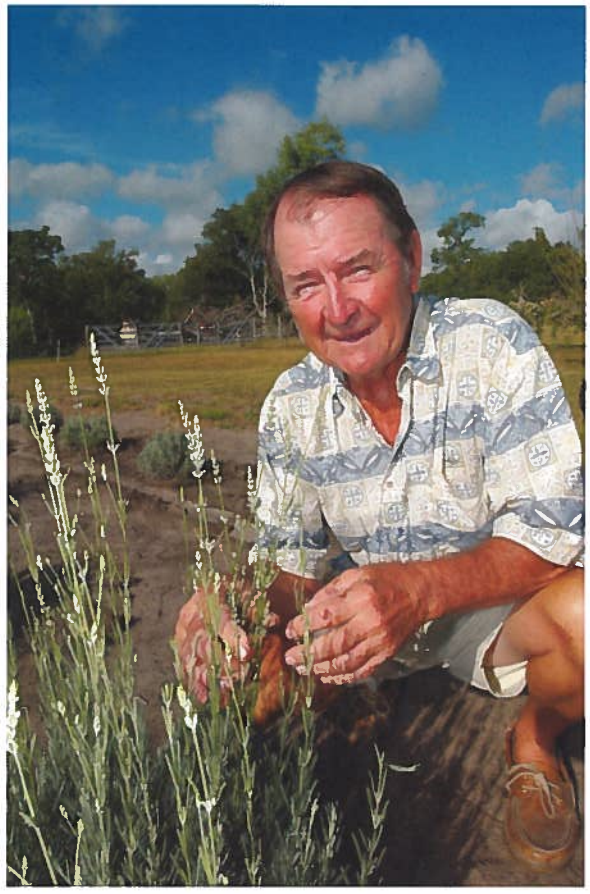
Restaurant owners were equally worried that they would not be able to obtain supplies of one of their most popular entrees. If the state wanted to ban commercial red drum fishing, it needed the restaurant industry on its side, Holt recalls.

"Restaurant people wanted to know how they would get their redfish," she says. "Connie talked with them about producing redfish in captivity and told them they could grow a food fish that we didn't have to catch in the wild. It was an important part of the conversation."

The state did ultimately ban commercial redfish and seatrout fishing, and then employed Arnold's spawning methods to ensure that recreational fishermen would always have enough of both to catch.

"The development of our stock enhancement program would have been delayed by many years without Connie Arnold's work," says Dr. Robert Vega, head of the Texas Parks and Wildlife Department's stock enhancement program. "He was at the forefront of developing spawning and maturation procedures that we have been able to adapt and utilize. His initial work was the foundation for the current brood fish program that we have in place."

Just since 2000, TPWD has produced more than 153 million redfish and more than 14.6 million seatrout that have been released into Texas' coastal waters.



Arnold examines one of his lavender plants.

Following spawning of the first seatrout and redfish, Arnold and those who have continued his work at UTMSI successfully spawned southern flounder, spotted seatrout, yellow tail snapper, black drum, croaker and cobia.

"Spawning large marine fish seems easy now. A lot of people are doing it," marvels Holt, who took over as head of UTMSI's Fisheries and Mariculture Lab after Arnold retired. "I can't imagine how he conceived of the fact that you could bring yard-long fish in, put them in a tank and expect that they would spawn. Anyone who writes a paper now about spawning large marine fish has to reference Connie because he probably did it in the late 1970s and early 1980s."

Vega adds, "He had a green thumb when it came to spawning large marine fishes."

TPWD still uses Arnold's basic methods of spawning and rearing popular sport fish, says Vega. The agency's fisheries managers closely monitor the state's coastal waters and they decide the species and quantity that need to be spawned based on population trends.

Vega says TPWD will next use Arnold's methods to produce tarpon. The finfish

aquaculture industry is also greatly interested in Arnold's legacy, especially Holt's success spawning cobia. Cobia have great potential as a farm-raised species because they grow very fast (one can grow to 6 pounds in a year) and are very hardy.

"Before Connie developed his methods for spawning, people would have occasional spawns here and there," says Granvil Treece, aquaculture specialist with the Texas Marine Advisory Service and one of Arnold's former staff members. "They couldn't determine how many spawns they would have or how consistent it would be. With the thermal manipulation and the photo season, it was much more dependable. You could depend on it and set your watch by it. You could depend on a certain number of eggs being produced.

"You can go look at a fairly new commercial red drum aquaculture operation — Lone Star Aquafarms in Palacios, one of three commercial red drum operations in the state — and you see that it is basically Connie's concept."

In 2004, the state's redfish farms produced about 3 million pounds of fish valued at $6.2 million.

"I had the privilege of presenting Connie with a lifetime achievement award from the Texas Aquaculture Association when he retired in January of 2001," says Treece proudly. "He was very deserving of it."

To this day, Arnold seems unfazed by the enormity of his contribution to Texas' recreational fisheries and redfish aquaculture — a reaction that does not surprise his friends.

Arnold (left works with a small redfish at UTMSI in the early 1980s and (below) peers through a microscope in his lab in the early 1970s, when it was still operated by NMFS.

"He is one of the most low-key people you will ever meet," says long-time friend Dr. Gil Rowe, head of the Marine Biology Department at Texas A&M-Galveston. "There are a lot of people who are out there, preaching their gospel of the type of science they do, but Connie never did that."

Rowe tells a story from Arnold's first (but failed) attempt to spawn cobia. Rowe recalls looking into a very large brood tank and seeing a fish that Arnold had grown to more than 100 pounds.

"To me, it was unbelievable that he could do that, but he acted like it was just something he did, almost like an afterthought," Rowe says in amazement. "It was almost as if everything he did was just like a hobby, yet standing back from it, his work was very impressive."

Arnold shrugs his shoulders and agrees, "I don't get very excited about things. I try to keep everything in perspective. Usually, there is always a way out if you are in a jam, you just have to figure out how to do it."

Connie Arnold was born in Wewoka, Okla., to a homemaker mother and a father who worked in the oilfield industry. His family, which included two brothers and one sister, lived on a farm — the place Arnold says he first developed his love of nature.

He was about 13 when his father was transferred to Gainesville, Tex. After graduating from high school in Gainesville, Arnold joined the U.S. Navy, where he spent 41 months as an electrician aboard the *USS Algol*, a troop transport and supply ship.

"I was introduced to the marine environment while I was in the Navy," says Arnold, explaining how a farm boy from Oklahoma became interested in ocean science. "I traveled all over the Pacific. The ship I was on was never in one place for very long. We went to Japan, Korea, Viet Nam and the Philippines. I did a lot of diving in the Philippines and I got to really liking the marine environment from the diving. I decided that was what I wanted to do."

While he was serving in the military, Arnold married the love of his life – Aggie – and the couple welcomed the first of two daughters. Academic life attracted Arnold when he left the service, so he moved his wife and daughter to Southwest Texas State University (now Texas State University) in San Marcos.

Four years later, Arnold graduated with a master's degree in biology and a job teaching at Uvalde Junior College.

"I quickly decided that teaching wasn't for me," Arnold remembers. "I decided to go back to school at Texas A&M University in the Oceanography Department."

Rowe met Arnold at Texas A&M, when both were graduate students

PHOTOS COURTESY G. JOAN HOLT

in the mid-1960s. He still laughs about a research trip the pair took with another graduate student to collect coral samples near one of the small islands of the Campeche Banks in Mexico.

Arnold's job was to analyze the coral's organic breakdown products.

"Even though he trained as a biologist at Southwest Texas State University, he went into marine chemistry," says Rowe as an aside. "I believe that was the basis of his being good at raising fish, because he knew so much about the chemistry and plumbing of big fish tanks."

The three students collected samples by day and slept in a tent at night. Before the trip ended, the normally unflappable Arnold became... well... flappable, says Rowe.

"Connie has very pink skin and he ended up getting sunburned through his shirt," Rowe snickers. "He hated the wind. I think he still hates the wind. He missed Aggie. He can't stand to be without her.

"I don't believe he was very happy there," Rowe laughs a little more heartily.

Arnold received his Ph.D. from Texas A&M and joined the U.S. Fish and Wildlife Service (USFWS), where one of his first assignments was to help open a new laboratory in Narragansett, R.I.

Early in his career, Arnold laid the foundation for his groundbreaking work spawning big marine fish, albeit in an unintentional way.

"When I first went to Rhode Island, I was really interested in larval fish," he says. "I realized real fast that you couldn't go out and capture larval fish and do any work with them because they are just too fragile. I thought, 'Well, maybe I had better just bring in some fish and try to spawn them.' I got a couple of the local fish there and was able to spawn them, so we had a supply of eggs and larvae to work with. I didn't realize what it was going to lead to. I never even thought about it."

Arnold (front row, second from right) sits on the steps of the UTMSI Fisheries and Mariculture lab with his graduate students, including Joan Holt (standing, second from right), Scott Holt (second row at left) and Peter Thomas (second row, middle).

A little more than three years later, Arnold moved to Port Aransas. Now working for the National Marine Fisheries Service (NMFS), he was sent to the Texas Gulf coast to open a lab intended for larval fish physiology study. As a result, he was able to get funding to build large brood tanks. Just about the time he got his system set up, NMFS began closing down its fisheries laboratory in Port Aransas. Faced with the choice of moving to an NMFS office in Miami, Galveston or Washington, D.C., Arnold talked with administrators at UTMSI, which was negotiating with NMFS to take possession of Arnold's lab.

"I made a deal to work for UTMSI and I stayed for about 28 years," smiles Arnold, who was named the first Perry R. Bass Chair in Fisheries and Mariculture at the Institute in 1998.

He was always interested in working with seatrout and redfish, he says, and spawning them was the best way to ensure he would have sufficient numbers of larval fish to study. He spawned seatrout first and then moved to redfish, bringing the first adults from the surf to the lab in an ice chest.

Arnold is notoriously handy and he built many of the large spawning tanks still operating at UTMSI, including the one used to first spawn redfish. He built in controls that allowed him to manipulate the water temperature and photoperiod in the tank to simulate fall, the red drum's normal spawning season. About a year after he put the fish in the tank, they began changing colors and making their characteristic drumming sound late in the evenings.

"I knew something was going on," says Arnold. "Finally, they spawned. They spawned every day for 45 days. We had so many eggs that we took them out and let them loose in the bays."

Arnold decided to mimic natural conditions in the tanks because "the only other alternative is to catch a fish that is close

to spawning and you inject a hormone that forces a spawn. That is tricky because if you don't inject at just the right time it forces them to dump eggs that are not ready for fertilization. The only other way to do it is to get them to spawn naturally. They are cued to spawn by temperature and photoperiod, so we tried to set up a photoperiod system that would cause them to spawn naturally."

At the Three Oaks Ranch, Arnold is very much at home with nature.

Holt was fresh out of graduate school when she met Arnold. He was director of the NMFS lab and Holt interviewed for a job there.

"He had longish hair at that time, but it was in the late 1970s," she remembers. "My first impression was that he was a really nice person and thoughtful about fish and fish conservation. He is still the most relaxed and laid-back person you'll ever meet.

"I really wanted to work with him, but he told me about problems with the government not funding the lab and not having money and those sorts of things, so as it turns out I went to work at the Marine Science Institute instead," she says. "Within a year, National Marine Fisheries had pulled out of this lab and because of some political moving, it was leased to The University of Texas, and Connie stayed here."

Not long after UTMSI took over the NMFS lab, Arnold asked Holt to work for him. Like Arnold, Holt was interested in studying larval fish. At the time, getting the seatrout and redfish to survive their early stages was posing more of a problem than getting the adults to spawn.

"Connie wanted me to raise the larvae and do whatever studies were needed to find out about their life history," she says. "It took me a full year before I got them through the early stages. Now, it is so easy that anyone can do it."

Arnold mentored some of today's leaders in fish research and aquaculture — people like Treece, Holt, Holt's husband, Scott, and Dr. Peter Thomas. The Holts and Thomas remained at UTMSI and developed a long-lasting friendship with Arnold.

The three families at one time shared a hunting lease near the town of George West, which is not far from Lake Corpus Christi. Joan Holt fondly remembers hiking out into the lease at night with Arnold, who would make calls imitating prey animals in distress to attract predators like bobcats, coyotes and foxes.

He learned the calls as a student at Southwest Texas State, where he joined a group interested in learning animal cries.

"We all spent many a night out there calling up animals," Holt says, smiling broadly.

"We never killed them," Arnold says quickly, when asked about his nocturnal habit. "We just called them up."

Arnold also enjoyed driving his old Ford pickup through the lease, sometimes at the expense of whoever was riding in the passenger seat.

"I remember when the new director of UTMSI, Bob Jones, came on and Connie invited him up to the deer lease. He took Bob driving through the brush and up and down hills and dales. Bob Jones' eyes were about like this the whole time," says Holt, laughing as she holds her hands to her face, using her index fingers and thumbs to mimic Jones' wide-eyed expression. "Bob got back to the office and said, 'Now, I think I've seen South Texas.' That sort of thing is typical of what Connie would do."

Arnold's affinity for nature was evident in the lengths he went to in order to study it.

"Connie is a birder and one year as he drove over the causeway from his home in Aransas Pass to Port Aransas, he picked up every dead bird he found," Holt says. "He made a list of the species he found and said it told him when the migrations were occurring. Talk about road kill," she chuckles.

Arnold's greatest gift to his students was letting them grow as scientists in their own way instead of demanding that they fashion themselves professionally in his image.

When she first went to work for him, Holt feared Arnold might force a production quota on her, like demanding that she produce 100,000 small fish within a certain time period.

"I went to Connie and asked him when

PHOTO BY JOHN WOELKE

I would be required to produce something. He said, 'You do what you do. You are a scientist and that is what you do,'" she says, easing back in her chair. "That was a great relief to me because I wanted to be a scientist. I didn't want to have to come up with a production run and do what I did, which was to learn how the larvae grew, what they needed, what their environmental demands were and what their physiology and ecology were.

"One of the amazing things that Connie did for me, Peter Thomas and many of us was that he brought us on staff and gave us a lot of support and allowed us to grow in our research and our science, and become what we've become today," says Holt gratefully. "He made a big, big difference. Connie is a legend because what we do now — our production and productivity — is a result of his mentoring."

Arnold semi-retired from UTMSI in 2001, working halftime for the next year. In 2002, Arnold and Aggie moved permanently to the Yorktown property that they had bought a couple of years earlier.

"I always wanted my own place like this," he says. "When I got the place, there was nothing here but old cattle pens. We had the house moved in and then totally remodeled it. We also wanted to put some cattle on the place, so now we have 15 cows and one bull, and we sell the calves."

He built two of the three cottages so his daughters and their families, including three grandchildren, have their own places to stay when they visit. When they are not occupied by family, the cottages serve as a respite for urbanites from city living.

"We don't do any business from people traveling down the highway," says Arnold. "People who live in the cities and want to get out and spend a few days out in the country come here. There is no traffic noise. The only noise you hear at all is an airplane flying over and the coyotes calling at night."

The property features a hot tub and swimming pool, a barbeque shack where guests can cook their own meals and a fire pit where guests can gather at night to enjoy the country quiet.

Three Oaks Guest Ranch (http://www.goliad.net/-30aks/index.html) also offers a magnificent opportunity to observe many different species of birds, including green jays, which are not normally found much north of the Rio Grande Valley.

Several pair of binoculars hang just inside his porch door, ready for their daily use.

"We have a big view (from the porch) and a lot of animals come across out there. Every morning, turkeys come up by the pond and out into that field eating grasshoppers," he says, motioning to a large open area outside the window. "In that group there are three hens and about 20 babies. Well, they're not babies anymore. They are now pretty good size."

Arnold pauses for a moment before confirming why he is utterly content here. "If you like nature, why, this is a pretty nice little place."

Arnold published 111 scientific papers during his research career.

As he continues talking about all the beauty that surrounds him, it becomes readily apparent that Arnold is not the master of his domain. Rather, he is a part of it. To a certain extent, his connection with this piece of land dulls the roar of the Gulf's surf in his ears.

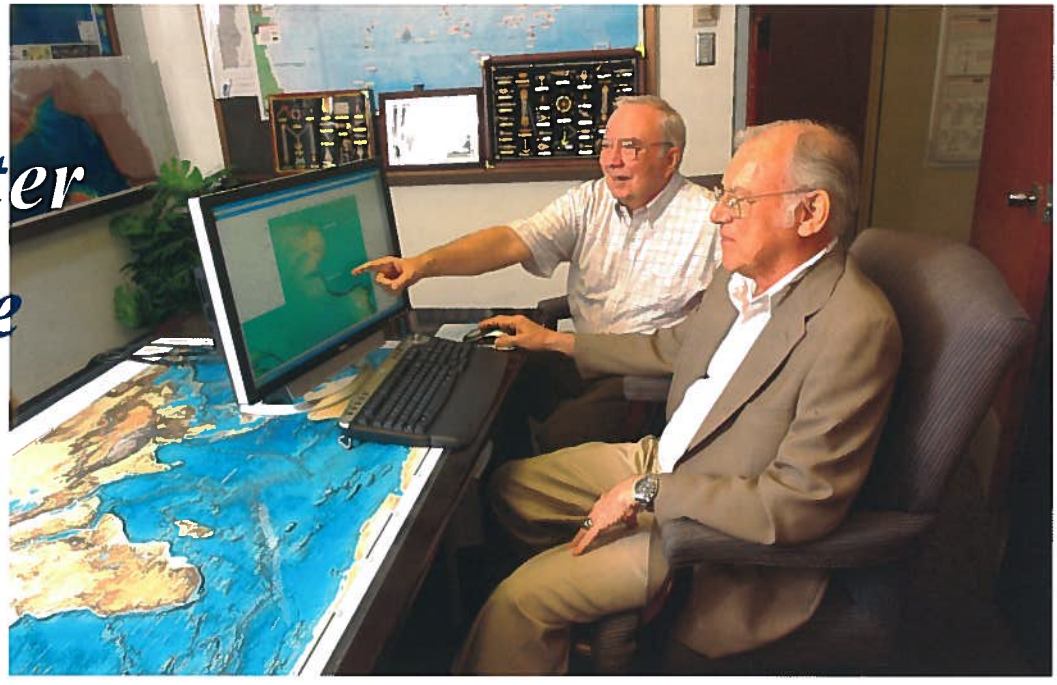
"I miss it somewhat," he says, pointing to the marine-related decorations on the surrounding walls, "but I am so occupied up here that I don't really have much time to dwell on it. I play golf two or three times a week, and then there is always work to be done around here. As a matter of fact, this morning I put the hay hauler on the tractor. I've got a field full of hay out there I've got to haul in and stack up. There is always something to do that keeps you busy all of the time. You never catch up. There is never a time when there is nothing to do. I don't have time to sit around and think about the past. I enjoyed it and I wouldn't trade the experiences I've had for anything, but I'm happy doing what I'm doing now, which is something entirely different."

Asked to quantify the impact of his work and the scientists he trained on the field of marine science, Arnold remains quintessentially Arnold.

"I was just doing what I liked to do," he says nonchalantly. "As it turned out, some of it was pretty good." ■

PHOTO BY STEPHAN MYERS

Bathymetry project reveals underwater landscape



Drs. Troy Holcombe and William Bryant look at a computer image of bathymetry showing Bouma, Bryant, McGrail, Rezak and Sidner banks.

by **Cindie Powell**

As restoration efforts continue along the Gulf coast in the wake of the devastation of Hurricane Katrina and Hurricane Rita, researchers at Texas A&M University are finishing a project that may someday make it easier to model the overwhelming storm surge that is part of such major storms.

The researchers are pulling together data from a patchwork of soundings — literally millions of data points collected by the U. S. Coast Survey during surveys spanning the past 100 years — from throughout the Texas-Louisiana continental shelf and upper continental slope, including bays and estuaries, to create the first detailed, easily readable maps of bathymetry, the topography of the land under water.

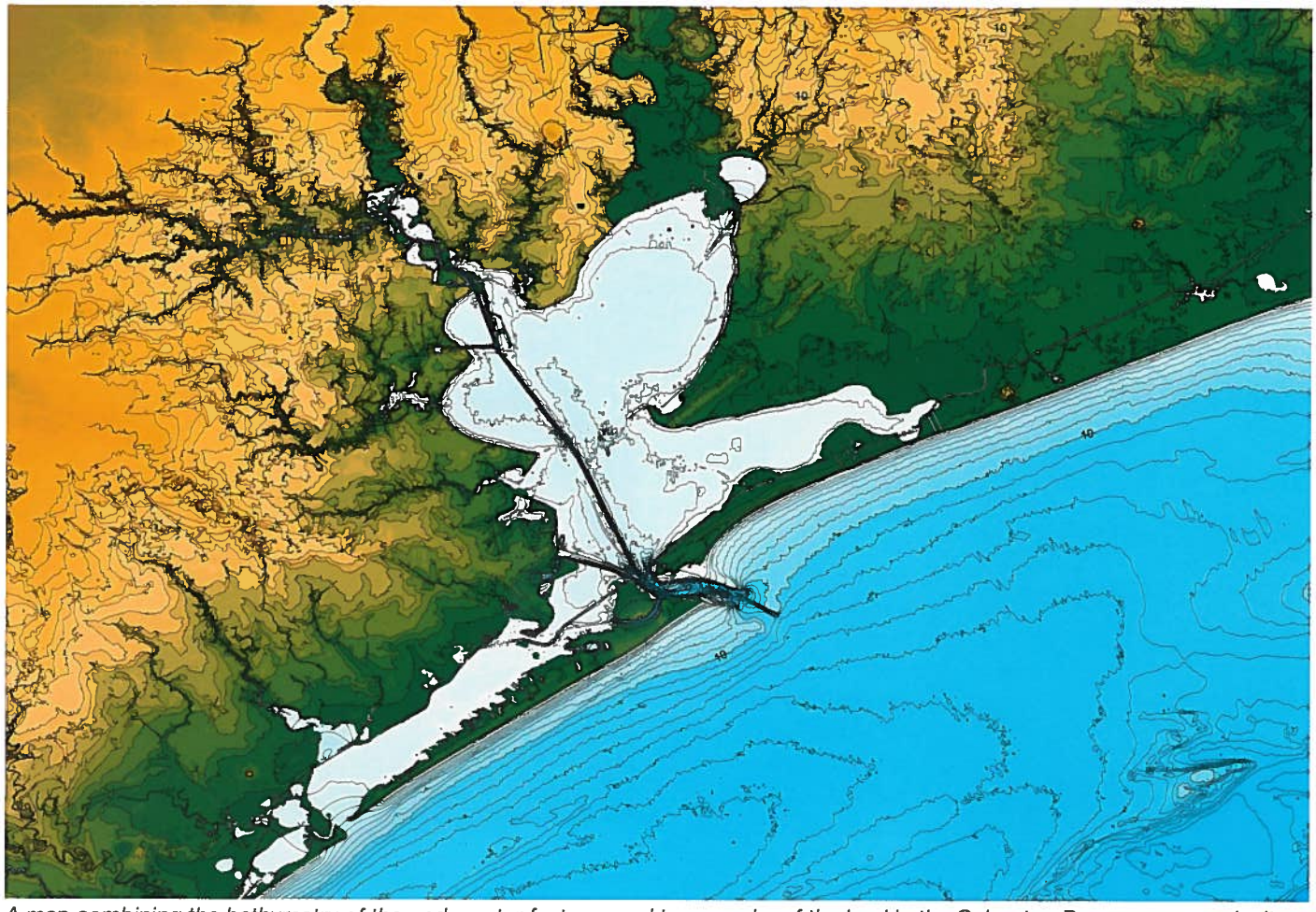
The two marine geologists, Dr. Troy Holcombe and Dr. William Bryant, are completing the bathymetry portion of the project, while geographer Dr. Sarah Bednarz is synthesizing their results to create curriculum items for teachers in grades 6 through 12 in Texas and Louisiana to use in the classroom.

The continental shelf is a gently sloping extension of the coastal plain. Along the northwest Gulf of Mexico coastline it extends 170 to 400 km out to a depth of 90 to 150 meters. At the edge of the shelf, at a marked break in the angle of descent, begins the continental slope, a steeper drop to the deeper waters of the Gulf.

Much of the commercial activity of the Gulf — oil platforms, pipelines, fishing — takes place along the shelf, and Texas and Louisiana have one of the most intensely used shelf areas in the world.

"Bathymetric maps are very useful for ocean engineering and construction — people who are deciding about laying a pipeline need good bathymetry maps of the shelf area to go along with information about the character of the bottom sediments," Holcombe says. "Also, if you're going to anchor a drilling platform, you need good bathymetry along with the information about the strength of the sediments in the area in order to build a safe platform and to

PHOTO BY MARK BEAL



A map combining the bathymetry of the underwater features and topography of the land in the Galveston Bay area may make it easier to model the storm surge in tropical storms and hurricanes.

decide where the best place to locate it will be."

"On the other end of the spectrum you have the fishing folks, who like to have bathymetry, particularly in the search for species whose habitat is depth-dependent," he adds. "On the Gulf coast shrimp are found mostly out to 50 meters, so there's not much point in trawling for shrimp if you're deeper than that. Other fish hang around reefs and banks on the outer shelf, so good maps of those are useful for fishermen."

Bryant notes that recreational users, including fishermen and divers, also value good bathymetry.

"A lot of sports fishermen like to fish on bathymetric highs like the Flower Gardens, which are known for the community of fish they attract. And the corals around and on the highs attract more and more people for recreational diving," he says.

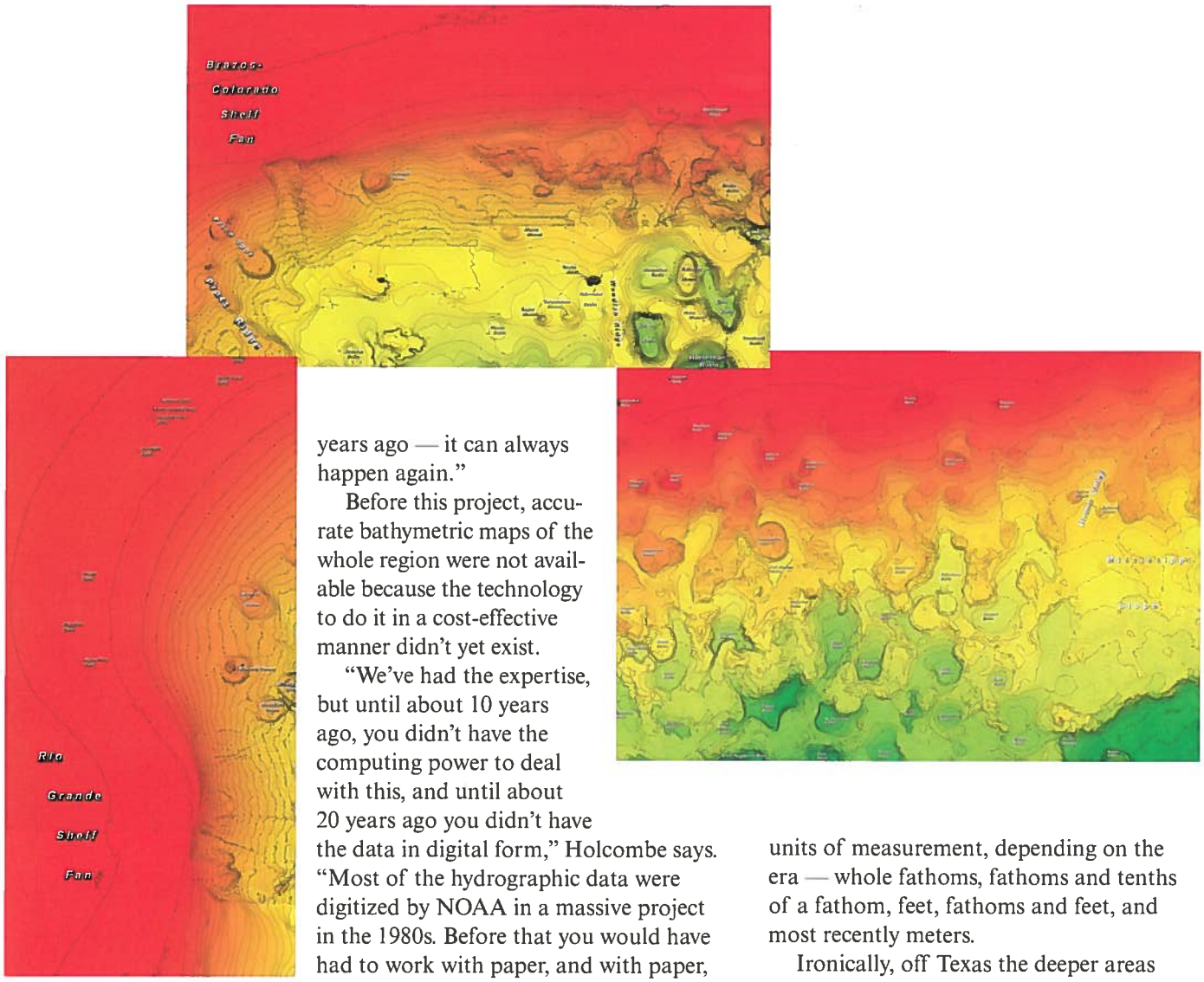
The combination of the bathymetry with existing maps of land topography along the coast also has potential applications for those who model storm impacts, especially the storm surge from a hurricane or tropical storm.

"That's probably one of the most important aspects of the whole study," Bryant says. "To determine how high the surge will get, to determine how far the water is going to run up on the land, you need to know the bathymetry plus you need a good map of the land topography." Holcombe explains that such storm surge models have never used bathymetry in this detail, because before now such bathymetry has not been available. "I predict that once they have it they will figure out a way to make their models use it. This would be a case where you have a hurricane coming in from this position in this direction at this speed, and with your model you run it across the shelf right into a bay and up the estuary, and you see what happens to the storm surge," he says. "It's not just hurricanes, it's other storms, too. This may turn out to be one of the most important uses for new bathymetry."

Bryant says that tsunamis present another danger that could send a large runup of water from the Gulf onto the coast.

"There's not a lot of seismic activity within the Gulf of Mexico, but there are indications from the bathymetry that large landslides have occurred in the past along the shelf edge. There are large masses on the continental slope and the Sigsbee Escarpment that have failed, and if they fail at the right time and the right place they can create a tsunami," he says. "This has occurred on the Mississippi fan, which may have created quite a tsunami tens of thousands of

ALL BATHYMETRIC IMAGES COURTESY OF TROY HOLCOME AND WILLIAM BRYANT



Sections of the outer continental slope: (clockwise from lower left) the upper continental slope off South Texas, upper continental slope off East Texas, and the main area of the northwestern Gulf of Mexico.

years ago — it can always happen again."

Before this project, accurate bathymetric maps of the whole region were not available because the technology to do it in a cost-effective manner didn't yet exist.

"We've had the expertise, but until about 10 years ago, you didn't have the computing power to deal with this, and until about 20 years ago you didn't have the data in digital form," Holcombe says. "Most of the hydrographic data were digitized by NOAA in a massive project in the 1980s. Before that you would have had to work with paper, and with paper, differences in units, scales, projections and so on are major headaches and costly as far as the work they create."

Reconciling more than 120 million data points to produce the first continuous map of the bathymetry of the Texas-Louisiana continental shelf and upper continental slope has been far more involved than simply entering a series of numbers into a computer and hitting the "print" command.

"Some of these soundings were taken 100 years ago, so to merge those data with recent data is extremely tedious. We have millions of soundings, and those all have to be judged and verified, and matched with some datum such as the sea level that we choose," Bryant says.

Holcombe and Bryant have had to deal with a wide range of data types with technological sophistication ranging from dropping a weighted line overboard in the 1930s to digital soundings from just a few years ago. The surveyors also used different units of measurement, depending on the era — whole fathoms, fathoms and tenths of a fathom, feet, fathoms and feet, and most recently meters.

Ironically, off Texas the deeper areas of the shelf and slope have better data. In deeper waters, NOAA and the U. S. Geological Survey have collected data using multi-beam systems. Ships doing a multi-beam survey send out, and receive echoes from, a fan-shaped sound beam, which Holcombe describes as similar to a tractor plowing many rows in a field. The slightly different angle and echo time using this technique provides up to 100 or more different depth readings from each pulse.

Reconciling the data is further complicated by the different "zero points" used. All the NOAA surveys used the Mean Low Water (MLW) point as zero until about 1980, when it was switched to the Mean Lower Low Water (MLLW) datum, which is slightly lower than the MLW. The MLW and MLLW points are determined at tide gauges along the Texas and Louisiana coast, usually from 20 years of readings.

A third zero point, the one used for the land topography, which the researchers are

including in the map, is the North American Vertical Datum 1988, or NAVD88, which is indexed to actual mean sea level at one particular tide gauge in North America – in Quebec. The NAVD88 datum, in combination with the best geodetic signature or shape of the earth, defines the mean sea level throughout North America. There are, therefore, differences between the NAVD88 mean sea level, and mean sea level defined at local tide gauges.

The researchers also have had to cope with a sinking coastline. Subsidence occurs when the sediments along the shoreline compact and are not supplemented by new layers of sediment, typically because human activities have diverted the natural flow of water and sediment from the land, and removed water and petroleum from the subsurface.

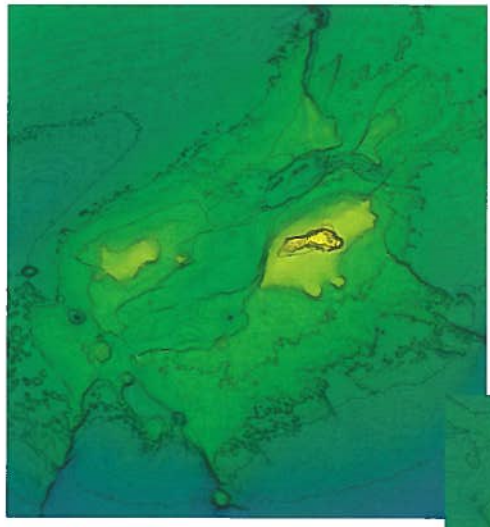
"There's been a lot of subsidence along the Texas and Louisiana coast, maybe half a meter in the last 50 to 60 years, and this subsidence is recorded at a good many of the tide gauges," Holcombe says. "The land has come down and the sea has come up, consequently the MLWs and MLLWs used for surveying have been periodically redefined. This causes data that are old do not match up with new data. A survey done now would not agree with one done in 1935."

There are also differences caused by coastal erosion — less widespread than subsidence, but in the localized areas where they occur, such as near jetties and other man-made structures, the differences are greater — up to two meters over a 20-year period in some places.

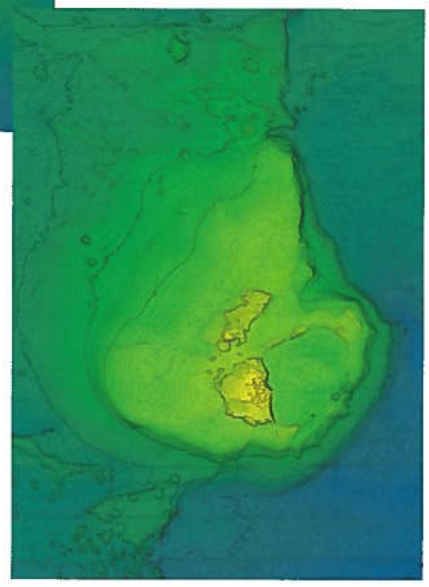
"We correct for everything that you can correct for, where you have the information, and what you're left with is the question, 'Does it match up or not?' Most of the time it does. If not, then you just do the best fit to make it match up," Holcombe says.

Holcombe says the researchers are within six months of completing the project. The bathymetry from Brownsville to Lake Charles has been completed, with work remaining on the stretch from Lake Charles to the mouth of the Mississippi.

In addition to the curriculum materials being designed by Bednarz, the study will yield one or more CD-ROMs of bathymetric images, including a continuous map with 1-meter contours of the Texas-Louisiana continental shelf and upper continental slope that also includes land topography and shoreline details. They have completed some larger panels of bathymetry at half-meter contour intervals showing more detail of features such as the reef terraces at Flower Garden Banks and the nearshore areas. The maps will be available for download from the Texas Sea Grant website at http://texas-sea-grant.tamu.edu/pubs/Bath.php; some images are already available at the gallery there. The images will be freely available to researchers, government agencies, coastal resource managers, educators and the public.



West Flower Garden Bank



East Flower Garden Bank

After they have completed this bathymetry project, the researchers say they would next like to map the shelf and upper slope for the rest of the states along the Gulf of Mexico, now that the technology exists to make it a reasonably cost-effective process.

"We're closer to having the bathymetry faithfully reproduce the bottom today than we ever have been," Holcombe says. "In the past, with a pencil and a bunch of soundings on a sheet of paper, there was a big gap between the data on the one hand and the bathymetry on the other. But that gap now has been narrowed a great deal. With better data and evolving technology, we're able to get credible bathymetry out of the sounding data without resorting to elaborate interpretation in many areas."

"There is much interest in having a good map of the bathymetry. It provides a base map for further studies of everything that involves the ocean environment on the shelf."

Educator's challenge: making bathymetry exciting

Dr. Sarah Bednarz's challenge is to transform the bathymetry of the continental shelf and upper slope being developed by Dr. Troy Holcombe and Dr. William Bryant into a form that Texas and Louisiana teachers can use in the classroom.

"I began by looking at the curriculum in science and social studies for Texas and Louisiana — where are the opportunities for teachers to use this information?" Bednarz says. "Too much curriculum material is developed on esoteric things that aren't relevant to what teachers are going to teach about. They're great materials but they're never implemented. So as much as possible I wanted to find a niche for this material, a way to combine it with what's going on in the curriculum."

She has designed several lessons that can be used in grades 6 through 12, and expects to have six or seven lessons by the end of the project. They are being "field-tested" by College Station teachers as part of a program funded by a separate grant she received from the National Science Foundation.

"We'll also put it up on the web to get comments and revise as we go."

The lessons Bednarz has developed include an example of bathymetry that students can model with clay or paper constructs that connects the bathymetric data to a hands-on understanding of the underwater landscape.

"When kids see the ocean they just see the top of the water, and they do not understand that there's anything under the water," she says. "They know and have experienced the shore — it's flat and sandy — but they don't understand that deep down underneath the ocean there are landforms, and the processes that created those landforms underwater are related to the processes on land. There's a whole rich geography of what goes on under the water, and the first activity is to introduce students to the idea of bathymetry and what the bathymetric map is all about."

Other lessons incorporate computer programs and PowerPoint presentations about the Gulf of Mexico, including one developed by Holcombe showing how coral reefs are formed on salt domes. Another lesson focuses on the importance of underwater salt domes in oil production.

Ann Linsley-Kennedy, a teacher at Bellaire High School in the Houston Independent School District, has used contour mapping in the Gulf of Mexico in lessons with her 11th and 12th grade students.

"I think that understanding the depths of the water levels helps to cultivate an understanding of the marine environment as well as the terrestrial environment," she says.

Linsley-Kennedy, who is also a graduate student at Texas A&M University pursuing a second master's degree in geography and oceanogra-

(Continued on NEXT PAGE)

Dr. Sarah Bednarz shows off a paper model of bathymetry that students can make to get hands-on understanding of the landscape beneath the surface of the water, represented here by the blue plastic.

PHOTO BY MARK BEAL

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phy, says bathymetry is a good jumping off point for students to learn about a wide variety of subjects.

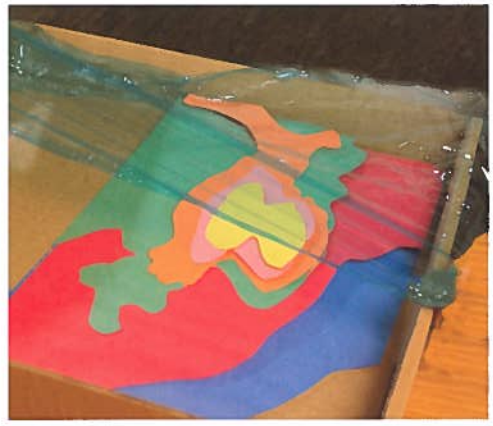
"My kids benefit from a better understanding of geologic history, the resource allocation that comes from oil and gas, the differences in fishing grounds — deep water fish versus shallow water fishing — and the income source from marine resources."

Bednarz says the greatest challenge in creating the lessons was making the information relevant, "trying to make it exciting to normal students, trying to find the hook that's going to interest them."

"Making it relevant to everyday life, that's an important part of what we need to do as people promoting science — too many kids see it as just something that's a school subject that doesn't relate to anything.

"Students need to understand how the world they live in works — on land, at sea, in the air," she says. "As ocean levels rise, and they will with global climate change, if we give students an understanding of the processes from the past, they are going to be better able to understand and cope with what's happening in the world now and in the future." — *CP*

NOTE: The curriculum items Bednarz has developed will be available online soon at http://texas-sea-grant.tamu.edu/pubs/education.php.



Paper, cardboard and plastic become a model of underwater contours.

Oysters

(Continued from inside cover)

there is no quick fix for its restoration and reasonable recovery of the Eastern oyster."

He notes that Chesapeake Bay oystermen prefer drought conditions because wet years provide increased pollutant input and stratification.

"My prayer is the direct opposite: Please give me rain," Ray says. "Rain lowers the water salinity, which in turn moderates the loss of oysters to oyster drills and Dermo disease."

Millions and perhaps billions of young Eastern oysters are present in Chesapeake Bay, but few survive the three to four years necessary to reach harvestable size because of two oyster diseases, Dermo and MSX. Until oyster strains resistant to the two diseases are developed, he says, the return of commercial-sized Eastern oysters will require reduced water salinity, especially during warm seasons.

Ray says he has a proposal of his own to possibly enhance the oyster population in Chesapeake Bay.

"I have a hunch that pollutants enmeshed in the silt have overburdened the bay bottoms and many oyster reefs, rendering them unsuitable for recruitment and survival of the Eastern oyster," Ray says.

His plan is to charter the 20 largest oyster lugger vessels from Texas and Louisiana, with two dredges each, minus the webbing, to go to Chesapeake Bay and "plow" the major oyster bars during the cool season to loosen the overburdened, highly organic material in the hopes that it would be flushed out into the Atlantic Ocean. He estimates that his proposal would cost about $2 million, "much less costly than previously failed approaches."

"Also it will cause less damage to the national oyster industry than the proposal to list the Eastern oyster as endangered throughout its range," he says.

— *Cindie Powell*

Texas Sea Grant, South Padre Island partner for beach safety awareness

Visitors to South Padre Island are finding it easier to learn more about the dangers of the beach, thanks to an arrangement between the Town of South Padre Island and the Texas Sea Grant College Program.

Texas Sea Grant is responding to a request from the town for 10,000 copies of its bilingual beach safety publication, "Have Fun: But know the dangers of the beach/*Diviértase: Pero conozca los peligros de la playa*," which the town began distributing in summer 2005 to hotel and motel rooms, condos, and numerous retail establishments. Plans call for the city to distribute 10,000 copies each summer.

South Padre Island Mayor Robert Pinkerton Jr. says the brochures are given to everyone who checks in, "and they walk away reading it."

"It is our intention to make this brochure readily available to tourists and other beachgoers throughout the year as part of our effort to communicate effectively with the public, in this instance by providing preventive information about beach safety and thus hopefully decreasing the number of occurrences where medical attention might be needed," Pinkerton says.

South Padre Island City Manager Dewey Cashwell says the publication "helps us do a better job of letting folks know the whole picture of the environment here, and the things that you need to be careful about."

"The brochure captures the message that we need to convey to our guests and visitors — the beach is a wonderful place to recreate and to enjoy the sun and the surf, but with respect for all of the animals and the environment in order to fully have a good time," Cashwell says.

"I just got off the phone with one (hotel manager) this morning who expressed his appreciation for the fact that we've taken such an initiative. The folks at the front desks of the hotels have a good deal to learn as well, and this brochure is extremely helpful for them as well as the visitors. They can learn about the subject matter...and be able to answer questions as well as hand out the material to the people who come to the desk."

The brochure is available free from Texas Sea Grant at 979-862-3767, by fax at 979-845-7525, at sgpublications@tamu.edu, or with the order form available online at http://texas-sea-grant.tamu.edu/pubs/pubcat/catalog.php.

— *Cindie Powell*

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