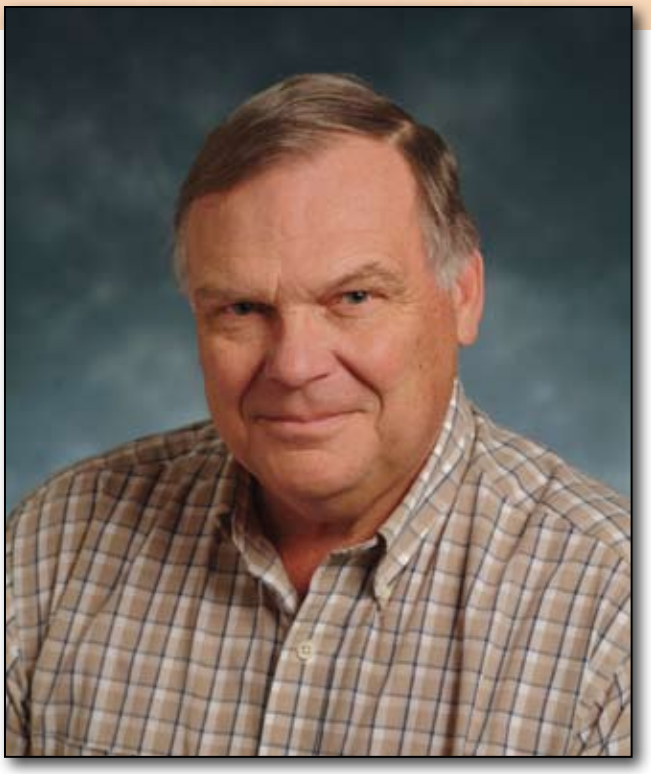
Sea Grant
TEXAS

coastal science serving texans

2006

from the director



Robert R. Stickney

The year 2006 was another busy one for everyone associated with Texas Sea Grant. Our extension and communications personnel worked on a wide variety of issues and projects, and the amazingly talented group of researchers that we support once again produced meaningful and useful results.

Summarized in the pages of this report are many of the outcomes they achieved. In addition, those associated with our program were involved in one-on-one contacts by the hundreds, reached thousands of people interested in the marine environment through our publications and workshops, worked with K-12 education, and were involved in many community activities. Sea Grant personnel and supported researchers attended a large number of meetings and served on committees, panels, boards, commissions and made additional contributions through their activities – far too many to chronicle here. Scientific publications were published, presentations were made at meetings, graduate students were supported, we had another highly successful year with respect to recruiting and placing Knauss Fellows... and the list goes on.

The Houston/Galveston population center of the Texas coastal region dodged a major bullet when hurricane Rita turned east in 2005, but our state was not entirely spared. There was bad news for coastal residents along the upper coast near the Louisiana border, including considerable impact on the property of Sea Grant country extension agent Terrie Looney and her family. Associate Director Ralph Rayburn has developed a plan whereby our coastal personnel can check in with the main office in College Station about their status following future storm events and that information can be passed to all Sea Grant personnel so we can account for their whereabouts and safety. We are also working on ways in which Sea Grant can become more prepared to help not only our own but also our coastal communities in the aftermath of storms. A regional Sea Grant research program on coastal resilience is planned for 2008-2010 and the Gulf Region Sea Grant programs are working on coastal hazards outreach and education with NOAA.

The good news in all of this is that one of our research projects that involved collecting historical beach profile information and comparing that with current conditions completed a LIDAR flight only days before Rita struck. As a result we have beach profiles before and after, which will be of significant value to those interested and involved with coastal erosion issues.

In 2005, Texas Sea Grant assumed responsibility for the northern Texas regional National Ocean Sciences Bowl (NOSB) competition. NOSB is patterned after the old College Bowl television program in which teams of students competed by demonstrating their knowledge on a variety of subjects. NOSB uses the same format with high school students, and the concentration is on marine science. Regional competitions, mostly in coastal and Great Lakes states, are held each year in February or March, with the winning teams from each region meeting for a national competition in late spring. Texas Sea Grant recruited graduate student Bianca Whitaker to coordinate the 2006 and 2007 competitions in our region. She did an outstanding job and our winning team from Langham Creek High School placed seventh out of nearly 30 teams that competed at the national

competition in Monterey, California, in May. The 2007 competition was held in College Station on Feb. 24.

In early 2006 we experienced a significant loss due to retirement and a major gain with the addition of a Research Coordinator. Amy Broussard, who was the Associate Director of Sea Grant and headed up the Marine Information Service, retired at about the same time we retained the part-time services of Dr. John Wormuth, professor of oceanography at Texas A&M University, who accepted the position of Research Coordinator for our program. He will play a major role in overseeing the proposal process that we go through in 2007.

With Amy Broussard's retirement, our program needed to find a graphic designer and layout editor for our publications and other communications products. We were very fortunate to find and hire Tanya Baker, who had been a graphic designer with the *Galveston County Daily News*. She is responsible for the design of this document, and she has produced a number of outstanding publications while still in her first year on the job.

Our two-year proposal cycle began on March 1, 2006. Again, we believe that the research that is being funded addresses significant issues facing our state. Even as the second year of that cycle is under way beginning in February 2007, we will be soliciting, reviewing and selecting research proposals for 2008 and 2009. A new wrinkle will be the commitment of $50,000 a year in the next cycle from each of the four Gulf of Mexico Sea Grant programs for a regional project. Details appear in our request for proposals, which was put on our web site in December 2006.

Finally, kudos go to assistant editor Cindie Powell for collecting the information in this annual report, distilling down and making understandable the scientific information, and writing the comprehensive document you see. She is but one representative of the fine Sea Grant staff with which I have the pleasure of collaborating.

Robert R. Stickney, Ph.D.
Director and Professor

Students compete in the 2006 National Ocean Sciences Bowl at Texas A&M University in College Station, Texas, which was hosted for the first time by Texas Sea Grant.

Contents

Photographs supplied by Tanya Baker, Mark Beal, David Bean, Sarah P. Bernhardt, Bill Harvey, Stephan Myers, John O'Connell, Cindie Powell, and Tony Reisinger.

success stories

For the past 35 years, Texas Sea Grant has provided leadership and expertise about marine issues through focused research, outreach to coastal communities and industries, and strategic communications and education efforts.

The Floating Classroom Program, coordinated by Texas Sea Grant Extension's William Younger, reached a milestone in 2006 when the number of students, teachers and others who have taken part in its vessel-based outreach and educational training reached 15,000.

Texas Sea Grant is part of a network of 31 university-based programs in coastal and Great Lakes states that make up the National Sea Grant College Program of the National Oceanic and Atmospheric Administration. For sustained excellence in marine research, education and extension services, the U.S. Department of Commerce designated Texas A&M University as a Sea Grant College in 1971, make it one of the first four state programs established under the National Sea Grant College and Program Act of 1966. The program is headquartered at College Station, Texas, in TAMU's College of Geosciences.

The approximately $1.9 million that Texas Sea Grant receives annually from NOAA is matched by about $600,000 from the state as a combination of special item funding from the Texas Legislature and support from Texas A&M University. Additional funding periodically comes from grants and contracts from NOAA, other federal agencies and state agencies.

The program awards about $800,000 annually in highly competitive grants to the best marine researchers at universities across the state. Current focus areas for research are coastal ecosystem health, coastal community and economic development, and marine education. Research proposals are ushered through a rigorous and thorough peer review process, and the number of projects approved is limited far more by the funds available for grants than by the quality of the proposals.

Texas Sea Grant also supports smaller research projects as funds allow. These Program Development Projects are designed to take advantage of opportunities that are not anticipated during the two-year major research funding cycle — opportunities for which limited amounts of funding may have significant results. They may be used to test concepts that could lead to development of larger proposals submitted to Sea Grant or other funding agencies, to support new faculty at Texas colleges and universities who are trying to initiate research programs, or to fund research demonstration projects for Texas Sea Grant Extension Program (TSGEP) agents and specialists.

In addition to overseeing the program's daily operations and awarding research grants, the ***Program Administration*** also hosts conferences, including the annual Researcher Conference, which brings together investigators from the program's funded research projects to share their results and build collaborative relationships with colleagues at other universities or state agencies.

The ***Texas Sea Grant Extension Program*** (TSGEP) is supported by Texas Sea Grant in cooperation with Texas Cooperative Extension, Texas A&M University, the Texas Transportation

Institute and the county commissioners' courts in several coastal Texas counties. Its seven county agents serve the needs of eight coastal counties, while its eight specialists in such areas as aquaculture, marine business, environmental quality, coastal community development, marine fisheries, marine education, marine policy, and seafood quality, marketing and economics. In addition, the National Sea Grant Ports and Harbors Specialist is also part of TSGEP.

TSGEP has helped the Texas shrimp industry meet the technical assistance training required for shrimp fishermen to obtain federal trade adjustment benefits. The fisheries specialist also conducted result demonstrations on technologically advanced trawl doors, called cambered doors, that initial findings show will reduce fuel usage in shrimp boats by 20 to 30 percent, which could save a typical Gulf of Mexico shrimp vessel from $25,000 to $35,000 a year.

Ongoing projects include coordination of the Clean Texas Marina and Clean Texas Boater programs, which reached the 100 mark in participating marinas during 2006, giving Texas the largest percentage of participation of any state, and the Floating Classroom Program, which has had more than 15,000 students and adults take part in its hands-on vessel-based educational training. Texas Sea Grant specialists also regularly coordinate a conference on the outlook for marine/offshore industries and conduct a short course on shrimp farming.

Extension personnel have trained and maintained a cadre of 448 volunteers through the Texas Master Naturalist Program, and one county agent coordinated members of the Rio Grande Valley Chapter of the Master Naturalists to be the first volunteer group qualified and utilized to conduct surveys and assessments of a red tide bloom and collect samples of the organisms for later analysis in the laboratory. These "Red Tide Rangers" relieved natural resource agency staff and university researchers from significant travel expenses during a red tide event along the lower Texas coast in late 2005.

Another effort that enlists the help of volunteers is the Monofilament Recovery and Recycling Program, coordinated by one of the county extension agents. Volunteers build and place collection bins at key high-traffic areas for recreational boaters, collect data and recycle the material, which is hazardous to marine life.

Linda McGonigle of South Padre Island is a member of the "Red Tide Rangers," a group of volunteers organized by Texas Sea Grant Extension's Tony Reisinger and trained by Texas Parks and Wildlife Department staff to survey and assess a red tide algal bloom and collect samples and prepare them for later analysis in the laboratory.

The program's marine business specialist administers fishing vessel drill instructor training. Texas Sea Grant, in cooperation with McMillan Offshore Survival Training, has trained 2,127 drill conductors through 100 course offerings

Texas Sea Grant Extension's John O'Connell is coordinating the Monofilament Recovery and Recycling Program, which collects used fishing line for recycling and keeps it from harming wildlife.

in 10 states. Drill conductors are trained to ensure effective approaches to safety at sea, relying on prevention, survival and self-rescue and search and rescue. With commercial fishing designated as one of the most hazardous professions in the United States, such training has proved critical to the fishing industry.

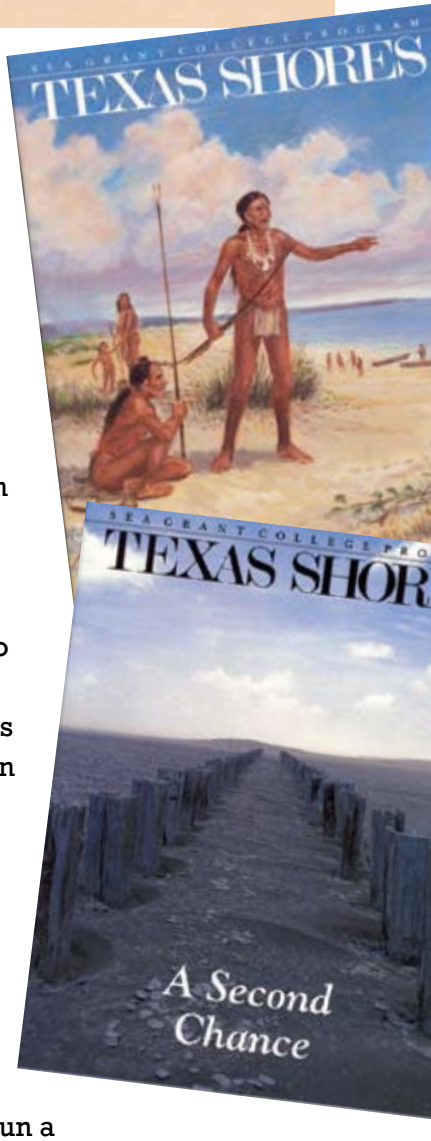
TSGEP personnel secured a $285,000 grant from the Texas General Land Office for Calhoun County to assemble a planning document to help communities there cope with the rapid conversion of traditional agricultural land to coastal residential development and the accompanying demand on infrastructure and public access to coastal resources.

Staff members helped organize the Houston Region Smart Growth Alliance, which is to be called "Livable Houston," in collaboration with the Bayou Preservation Association, Houston Preservation Association and the Gulf Coast Institute. The group has been significantly engaged in planning for the future growth and development of Houston. TSGEP also received funding from the Houston Endowment for three more years of support for the ongoing WaterSmart Landscaping for Houston Program. The new initiative is called "Habitat Highway" and will focus on watersmart landscaping in urban settings that provide habitat for wildlife and creates habitat corridors.

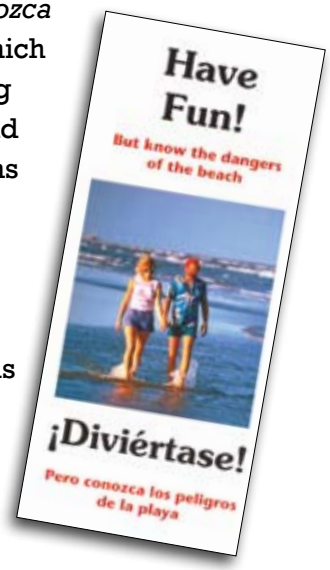
The National Sea Grant Ports and Harbors Specialist conducted research on U.S.-Mexico short sea shipping for the Gulf Ports Association. Findings from the study were used in evaluating opportunities and challenges created by this transportation methodology. The specialist also coordinated research on the effects of new security measures on port infrastructure planning and funding, and distributed the report to state ports for consideration in their security initiatives.

The ***Marine Information Service*** (MIS) is the communications arm of Texas Sea Grant, using media releases and publications, several of them bilingual, to disseminate beach and boater safety information, the results of research projects, curriculum materials and other information.

The most widely known Texas Sea Grant publication is *Texas Shores*, an award-winning quarterly news magazine that provides information on coastal issues, marine safety and marine education to interested readers throughout the state, region and nation. It has been integrated into the marine science curriculums in six Texas high schools and into the curriculum of a marine resource management class at Cornell University and an environmental law class at the University of Houston-Clear Lake. In 2005, Texas Sea Grant obtained a $20,000 grant from the Rowan Companies to increase readership of *Texas Shores*.



Texas Sea Grant has begun a collaboration with the Town of South Padre Island to inform visitors about the dangers of the beach. The town has requested 10,000 copies each summer of the Texas Sea Grant 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, condominiums and numerous retail establishments



As a partner in the national Rip Current Awareness campaign, Texas Sea Grant has printed and distributed in coastal communities thousands of bilingual posters and

table tents describing how to escape a rip current if swimmers are caught in one. News releases about rip currents were sent three times during the year to about 70 coastal and metropolitan newspapers; public service announcements in English and Spanish are sent twice a year to 42 coastal radio stations. One news release, sent out in March 2006, was also distributed to Texas college newspapers with the assistance of the Texas Intercollegiate Press Association. The program also publicized the results of a Texas Sea Grant-funded research project designed to determine if there is a link between meteorological and surf conditions, drownings and near drownings in South Texas. Results of the study of historical records from the past 20 years and surveys of beachgoers suggested that other factors, including the use of alcohol, may have more impact on incidences of swimmers in distress than rip currents.

Another MIS project is the archiving of Texas Sea Grant publications on CD-ROM. In fiscal year 2006 alone, 35 publications from 1971 and 1972, primarily books and marine advisories, were scanned and saved.

Other recent MIS publications and projects include the Armand Bayou Watershed Plan, produced in collaboration with the Armand Bayou Watershed Partnership, which comprises local, state and federal agencies, private businesses and non-governmental organizations, and editing a series of detailed bathymetric/topographic maps of the Texas and Louisiana coasts that were part of a Texas Sea Grant-funded research project. The maps will be combined with a geography curriculum, placed on CD and provided to Texas teachers. The information will also be distributed to emergency managers, and the CDs will be made available to the public and are expected to be very popular at the Houston Boat Show in January 2008. In total, MIS distributed more than 52,000 copies of 80 different informational publications and audio-visual materials during fiscal year 2006.

Armand Bayou

Crabbing along the Texas coast.

The population of Texas is projected to continue to grow at a rapid rate over the next few decades, with a high percentage of those coming to the state expected to establish residence in the coastal counties. Rich in natural resources, coastal Texas provides opportunities for fishing, hunting, bird watching, boating and many other forms of recreation. The Texas coastal region also provides jobs in a wide variety of businesses and industries. The challenge facing communities is how to maintain the quality of life while allowing business and industry to grow and prosper. The Texas Sea Grant College Program is helping coastal communities meet that challenge.

fellowships

Texas Sea Grant College Program fellowships at both the state and national levels offer outstanding opportunities for graduate students to gain valuable experience while providing expertise to government agencies to aid their marine policy or natural resource efforts.

Dean John A. Knauss Marine Policy Fellowship

The Dean John A. Knauss Marine Policy Fellowship was established by Congress in 1979 to give a unique educational experience to graduate students enrolled in marine or Great Lakes studies. The program is named in honor of a former NOAA administrator who was one of Sea Grant's founders.

Students apply to become Knauss Fellows through one of the 31 Sea Grant programs, which select candidates to sponsor. The final decision is made by a review panel convened by the National Sea Grant Office. While the number of fellowships offered varies with the availability of positions, the Texas Sea Grant College Program has had at least one accepted each year. Three fellows were accepted to participate in the program in 2006 and spent a year working for federal agencies in the Washington, D.C., area.

Silvia Cristina Urizar

Silvia Cristina Urizar received a master's degree in oceanography from Texas A&M University and was working on obtaining a graduate certification in Geographical Information Systems from the University of Houston when she received the Knauss Marine Policy Fellowship. She was headquartered at NOAA's Center for Operational Oceanographic Produces and Services, or CO-OPS, which is responsible for monitoring, assessing and distributing information about tides, currents, water levels and other coastal data.

Urizar was involved in multiple projects while at CO-OPS. In one, she compiled CO-OPS' water level data to define regions of adequacy and deficiency of data for the purposes of establishing new stations or new partnerships and for developing products.

"There are always places where we could have more stations, and one of my projects was to see where those locations are," she said. CO-OPS water level data is available on-line for use by other agencies and individuals.

Urizar also participated in a collaboration between many NOAA offices to produce a bi-weekly bulletin for the Gulf of Mexico Harmful Algal Bloom Operation Forecast System. In June 2006, she became one of the team's forecasters and during her fellowship produced more than 30 bulletins. The bulletins monitor the location, extent, and movement of harmful algal blooms caused by a microscopic algae, Karenia brevis, and forecast the possible impacts of the bloom on the coastal counties of southwest Florida. K. brevis, the organism that causes "red tide" algal blooms, is the most common harmful algae in the Gulf of Mexico. It produces a toxin that can cause respiratory irritation in humans, contaminate some shellfish, and affect the central nervous system of fish.

"The main readers of the bulletins are fisheries and oyster reef managers who can make decisions about closing fisheries, state and federal officials, and academic and research institutions," Urizar said.

Rachel Butzler, who received a master of science degree in wildlife and fisheries sciences from Texas A&M University, worked in the Partnerships and Communications Division of NOAA's Office of Sustainable Fisheries. The division is charged with creating partnerships with governmental agencies, commercial and recreational fishing communities and environmental groups, and also has an outreach and

Rachel Butzler

education mission. Butzler worked with a team that is creating a website, FishWatch, to communicate the status of fish stocks to the public. FishWatch is expected to be available to the public sometime in early 2007.

"We're targeting seafood consumers," Butzler said. "It's not recommending any fish, but really putting the information out there to promote informed decision making."

She also was part of the team building the Fisheries Management 101 module for the web portal for the Smithsonian Institution's upcoming Ocean Hall, created in collaboration with NOAA that is part of the Smithsonian Ocean Science Initiative. The hall is scheduled to open in 2008 on the first floor of the National Museum of Natural History.

"The module takes fisheries management and breaks it down into slightly easier to understand language, and that should be coming online sometime in 2007 also," she said.

Butzler described the Knauss Fellowship as a "great opportunity."

"My bosses have really encouraged me to take in the whole DC experience," she said. "We're not a major policy office, but they encouraged me to go down to the Hill and listen to hearings, go to policy seminars around Silver Spring, and I've met with people in the fishing industry, seafood producers and packagers, and with people in some of the conservation organizations."

Li Zhang, a native of China who received a Ph.D. from Texas A&M's Department of Oceanography, spent her fellowship year — which has been extended into 2007 — in the National Science Foundation's Division of Ocean Sciences, Biological Oceanography Program. With the goal of keeping the United States on the leading edge of scientific discovery, NSF is the funding source for about 20 percent of all federally supported basic research done in U.S. colleges and universities. Zhang has been helping to review research proposals. In addition, she worked on some research environmental compliance issues, including the National Environmental Policy Act, the Endangered Species Act and the Marine Mammal Protection Act.

Li Zhang

Zhang said her experiences at NSF have helped broaden her perspective.

"It has been a good experience for me to explore what's out there," she said. "It's not like when I did my Ph.D. and studied and focused on just one topic. I reviewed all the proposals and could see the whole spectrum of different research."

She said the experience with NSF also helped her understand how national policy decisions affect ocean and coastal resources and to make policy decisions on the basis of uncertain and incomplete scientific information under limited funding resources.

The next cohort of Knauss Fellows were selected in 2006 and began their fellowships in Washington in early 2007. Of those recommended by Texas Sea Grant, three were chosen: Lisa Iwahara, who has a master of science in ecology from the University of Houston, will be working in the office of Congressman Wayne Gilchrest (R-MD); Reagan Errera, who has a master of science in wildlife and fisheries management from Texas A&M, will serve her fellowship with the Office of Laboratories and Cooperative Institutes in NOAA's Office of Oceanic and Atmospheric Research (OAR); and Amy Wagner, who holds a Ph.D. in oceanography from Texas A&M, will be working with OAR's Climate Program Office.

Texas Fellows Program

In 2000, Texas Sea Grant launched a successful statewide fellowship program patterned after the Knauss Fellowship program. In 2006, Man-Seung Han was the fifth recipient of the Texas Sea Grant Fellowship. The native of Korea was headquartered at the Texas Parks and Wildlife Department (TPWD) in Austin, where he applied his background in natural resource economics — he is nearing completion of his Ph.D. in the subject at Texas A&M

— to the issues of interbasin water transfer.

"I had an opportunity to present to the TPWD staff my modeling work and its economic and environmental implications," Han said. "It was great to learn about the environmental impacts of freshwater inflows to Texas bays and estuaries. It helped me develop an idea and write another chapter about it for my dissertation."

Cindy Loeffler, chief of the Water Resources Branch at TPWD, was one of Han's supervisors during his fellowship.

"Interbasin water transfer and valuation of water…is something of interest to us in the Water Resources Branch because it also looks at the environmental costs of moving water from one river basin to another," Loeffler said. "That's being contemplated more and more in Texas where we have some water-short parts of the state…and what we call water-rich areas of the state in other places. Right now under the Texas Water Code, there are requirements for weighing impacts and benefits — impacts to the basin of origin versus benefits to the receiving basin.

"Even though more and more interbasin transfers have been contemplated, there haven't really been any since the law was changed in 1998," she said. "Han's proposal here was to look at ways of making those comparisons in a truly economic fashion and being able to include impacts to bays and estuaries, rivers and streams, and things of that nature."

Han also worked with TPWD's Science and Policy Branch regarding the nonmarket valuation of water, using survey and estimation techniques to provide the economic impacts of the change of water flow rates in river basins.

"I worked and am still working on the economic valuation for Texas anglers' recreational activities on Texas' rivers," Han said. "I and staff are developing a survey for economic modeling of Texas anglers' activities."

The survey, which is expected to be conducted withing the next year, will be mailed to fishing license holders in Texas, will solicit information about trips, particularly canoeing and other paddling trips, made in the previous 12 months and how much money was spent on the trips.

Man-Seung Han

"We also want to get their feedback on how different river conditions — if flow rates were higher or lower — would affect their choices about trips in the future," Loeffler said, adding that the survey also includes questions about the impact of water quality.

They expect to receive 500 to 600 completed surveys, and Han, who is continuing to work with TPWD, will analyze the survey results.

Loeffler said Han's specialized background in natural resources economics "opened our eyes about the possibilities."

"We have very limited access to economists here at Parks and Wildlife," she said. "Having someone who can look at the economic side of these kinds of tradeoffs is something that we're very interested in doing. Han was able to help us expand our horizons about looking at economic impacts regarding water development projects."

research

Texas Sea Grant awards about $800,000 every year to the best marine researchers in the state. The projects must fit within one of the program's three research priorities: coastal ecosystem health, coastal community and economic development, and marine education, with an emphasis on results that have practical, real-world applications.

Between 50 and 60 proposals are typically submitted for each two-year funding cycle. After a vigorous peer-review process, generally fewer than 10 are selected for funding approval, with the number limited only by funds available.

The next funding cycle will begin in February 2008, and renewal for funding in the second year is dependent upon significant progress being made in the first year.

Eight projects were completed in the fiscal year that ended at the end of February 2006, and they included studies focusing on inflows to Texas' bays and estuaries, coastal mapping and hatchery production, which are described below. Eight new projects were funded beginning in March 2006 and have already shown significant progress; they too are discussed below.

2004-2006 projects healthy bays and estuaries

Texas' bays are an important source for numerous marine species, including game fish and commercially important populations of shellfish. The health of these ecosystems has an important impact on coastal economic development. Five of the research projects in this funding cycle focused on the state's bays and estuaries; two examined the importance of freshwater inflow, an increasingly critical issue as human population and corresponding development increase along the coast and near the rivers that feed the state's estuaries.

Henrietta Edmonds of The University of Texas Marine Science Institute conducted a regional study to measure the amount of groundwater — and the chemicals contained in it — flowing into Nueces, Baffin and Mission-Copano bays (*Quantifying Groundwater Inputs to South Texas Bays Using a Multiple Tracer Approach*). The project started from the premise that, given the aridity of most of the Texas coast and the low amount of surface runoff, the effects of groundwater inflow may be particularly significant to the ecology of Texas' bays. Researchers sampled the bays multiple times using naturally occurring geochemical tracers, such as radium isotopes and methane, and measured flows directly using seepage meters. Sediment samples were also collected from all three bays; analysis of the samples is ongoing. In a closely related project, funded by the Geological Society of America through a research grant to a Sea Grant-supported doctoral student, investigators were able to locate two areas of brackish water discharge at the head of Nueces Bay. Additional information from this Texas Sea Grant project will be crucial to effective coastal management and for predicting the impacts of potential future changes in aquifer use or aquifer contamination.

As Texas' cities grow, the demand for freshwater increases, resulting in reduced freshwater available to flow into Texas' estuaries. Daniel Roelke and Steve Davis of Texas A&M University studied the effects of varied freshwater inflows in the San Antonio Bay system (*Freshwater Inflows, Productivity and Plankton Community Structure in the Guadalupe Estuary: Use of High-resolution Spatial Mapping and Fixed Station Sampling*). In monthly sampling trips, they measured several physical, chemical and biological characteristics that are linked to ecosystem health. They also used high-resolution spatial mapping to measure some of

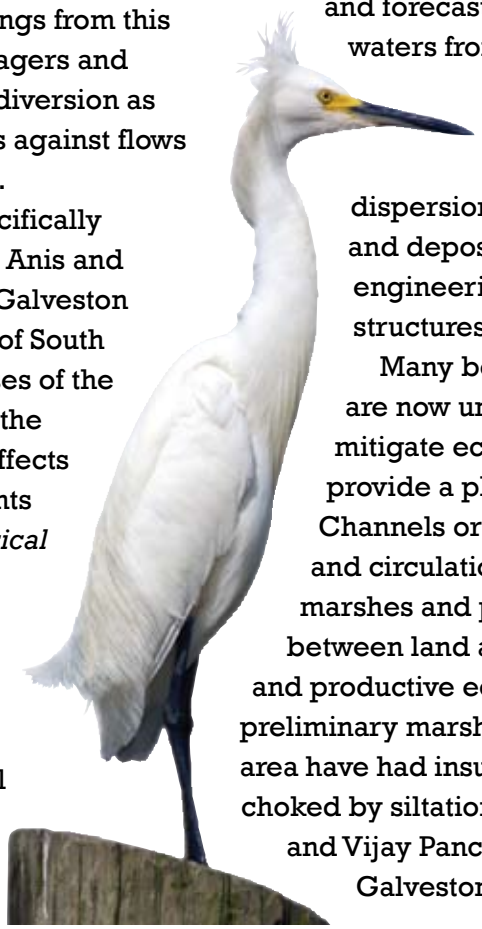
the same characteristics on a system-wide basis, and then generated maps for each parameter and documented the changes as a result of freshwater inflows — pulses of water flowing into the bays, typically caused by heavy rainfall upstream, that would decrease in frequency and size if the flow of water to the system decreased. The researchers also set up a sampling site to study water quality and nutrient loading into the head of the estuary along the lower Guadalupe River; they found ecosystem diversity and productivity corresponded with discharge patterns along the lower Guadalupe River.

To share their data with other scientists, resource managers and lay people, the researchers developed a web-based system (wfsc.tamu.edu/roelkelab/inflows.html) that shows the data in two formats that emphasize system-wide and fixed station spatial and temporal trends. The information can form another component of the Gulf Coast Ocean Observing System and has been expanded to another estuarine system, Galveston Bay. There is potential to expand this research approach to many other estuarine systems as well. Findings from this project will be valuable to water managers and state officials setting policy on water diversion as they work to balance human demands against flows needed to maintain ecosystem health.

Two additional studies focused specifically on Galveston Bay. In one project, Ayal Anis and Gary Gill of Texas A&M University at Galveston and James Pinckney of the University of South Carolina studied the physical processes of the bay — winds, waves and tides — and the impact those processes have on the effects of periodically high influxes of nutrients from the rivers entering the bay (*Physical Control of Nutrient Fluxes in Galveston Bay*). The impact of physical mixing is thought to be greater in Galveston Bay than in other bays in Texas because it is a much shallower bay system. The researchers conducted 11 sampling cruises through July 2005, taking physical, biological and chemical measurements. The

group compared the data from the cruises with modeled wave heights, period and directions, and found that, in cases when wind direction is steady, the models provide reasonable results; however, when there are abrupt changes in wind direction, the models have proved unreliable.

The researchers are continuing the project as they work to develop an improved empirical model that will account for wind direction and lag times between the wind and wave directions, and fine-tune the numerical model during changing winds. The goal is to improve on hindcasting and forecasting wave heights in shallow waters from knowledge of the wind speed, direction and bathymetry, with the potential for accurately predicting oil or other pollutant dispersion, sediment and wetland erosion and deposition, furthering the progress of engineering applications such as building structures and ecosystem habitats.



Many beneficial use islands and marshes are now under development in Texas to mitigate ecosystem losses elsewhere and to provide a place to deposit dredged material. Channels or creeks that allow the inundation and circulation of bay waters through these marshes and provide plenty of interface between land and water generate healthy and productive ecosystems. However, some preliminary marsh designs in the Galveston Bay area have had insufficient circulation and have been choked by siltation. Researchers Thomas Ravens and Vijay Panchang of Texas A&M University at Galveston completed a project to design

artificial channels in beneficial use marshes that better mimic the circulation in naturally occurring ones (*Design of Ecologically Rich and Sustainable Tidal Channels within Beneficial Use Marshes*). They developed, calibrated and applied circulation and sediment transport models for a naturally occurring reference marsh and for a constructed beneficial use marsh, tested sediment strength in the two marshes, did the preliminary design of the beneficial use channels, and collaborated with the Beneficial Uses Group (BUG), including the Port of Houston and the U.S. Army Corps of Engineers, who are managing the development of the beneficial use marshes in Galveston Bay. The results of their project are key components in designing tidal creeks for the Bolivar beneficial use marshes, just north of Bolivar Peninsula, with water velocities that are neither too fast — leading to excessive sediment erosion — nor too slow — leading to siltation of the channels.

Scott Socolofsky and Kuang-An Chang of Texas A&M University are using the Coastal Engineering Laboratory's shallow wave basin to further understanding about the mechanisms of water exchange through inlets between the open Gulf and bays and their impact on the water quality of Texas' estuaries.

In the Gulf of Mexico, estuarine niches provide critical habitat for more than 98 percent of the commercial fisheries catch. One of the most important processes influencing fisheries recruitment is the transport through tidal inlets of nutrients, sediments, pollutants, temperature, salinity, fish larvae and a host of other important substances and parameters. Transport in coastal waters is largely due to advection, and is dominated by the presence of large, two-dimensional coherent vortical structures. The goal of a study by Scott Socolofsky and Kuang-An Chang of Texas A&M University was to identify the mechanisms in tidal inlet flows responsible for the generation of the vortices and to incorporate their dynamics into two-dimensional coastal numerical models (*Laboratory Studies of Exchange Processes through Tidal Inlets on the Texas Coast*). The researchers used the shallow wave basin of the Reta and Bill Haynes '46 Coastal Engineering Laboratory at Texas A&M to investigate large-scale eddy formation and the resulting mixing in tidal inlets as influenced by inlet geometry. They analyzed the laboratory data from these experiments, made comparisons with a detailed coastal numerical model, made comparisons with the idealized simulations using ADCIRC, the widely applied numerical model for coastal engineering projects used extensively by the U.S. Army Corps of Engineers, and completed a new set of experiments involving tides. The analysis of the lab results will help coastal engineers and scientists understand the dominant mechanisms of exchange between open waters and estuaries, assist with fine-tuning of existing computer circulation models and help with predictions and control of such exchanges.

shoreline and shelf mapping

The combined effect of sea level rise and coastward population migration has made the Texas coast more vulnerable to coastal erosion, floods and frequent hurricanes and tropical storms. Two recently completed research projects focused on mapping the Texas shoreline and the Continental Shelf and nearshore land areas of Texas and Louisiana.

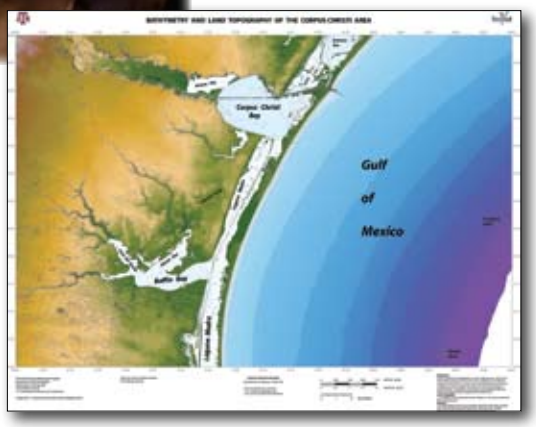
In one project, Hongxing Liu and Douglas Sherman of Texas A&M University developed algorithms and corresponding computer programs for measuring shoreline position and beach changes (*Quantitative Analysis of Short-term Shoreline Changes Using High-resolution Satellite Imagery and GIS Techniques*). They investigated short-term shoreline and coastal variations on the upper Texas coast by using multi-temporal airborne LIDAR data and high-resolution remote sensing imagery, and they also conducted beach profile surveys every two weeks at seven sites. In the process, they improved numerical algorithms for extracting shoreline information and developed methods for identifying and quantifying beach and coastal objects from digital image data and LIDAR data, and developed an object-oriented method for analyzing the volume of beach erosion and accretion. Based on repeat airborne LIDAR data, for example, they were able to derive two sets of tide-coordinated shorelines and quantify the shoreline changes for the upper Texas Gulf Coast.

Comparisons of data from different years also showed shoreline accretion and erosion at several locations, including beach profiles impacted by Hurricane Rita that caused a 20- to 30-meter-wide and up to 0.5-meter-deep erosion zone in many parts of the upper Texas coast. Quantitative information about shoreline position and its change is essential for nautical navigation and coastal resource management and planning. This research has demonstrated that by using airborne LIDAR data and high-resolution image data, beaches can be numerically delineated as discrete objects and their size, shape, surface geometry, and other morphological and biological properties can be derived. With repeat airborne LIDAR data, erosion and accretion regions in beaches can be identified, and the location, size and volume of erosion and accretion can be precisely quantified. This information may become increasingly important as it provides a baseline from which to detect changes in beach profiles as a result of sea level rise and as storm impacts modify the shoreline.

In another study, researchers Troy Holcombe and William Bryant of Texas A&M University combined decades of digital bathymetric data and a smaller number of paper records to produce the first detailed, easily readable bathymetric maps of the Texas-Louisiana continental shelf and upper continental slope (*New Bathymetry of the Texas-Louisiana Continental Slope: Education, Research, Engineering, Decisionmaking*). They produced a CD-ROM of bathymetric images of those Texas and Louisiana shelf-edge banks that have been subjected to multi-beam bathymetric surveys, an introductory text, an index map that is linked to each image, and a gazetteer of names of undersea features. The CD-ROM is available for applications in ocean engineering and construction, coastal zone planning, environmental decisionmaking, storm impact forecasting, the monitoring of transport/deposition of toxic wastes and the regulation of fishing. The information is also available on the Texas Sea Grant website.

Co-investigator Sarah Bednarz, also of Texas A&M, prepared a set of laboratory investigations for study of offshore bathymetry and geomorphology

in Texas and Louisiana schools: "Bathymetry: Understanding the Floor of the Gulf of Mexico," "Modeling Landforms on the Floor of the Gulf of Mexico" and "Landform Building Processes on the Floor of the Gulf of Mexico." The laboratory exercises, keyed to Texas and Louisiana target science and social studies standards and assessment projects, are being provided by Texas Sea Grant to teachers in grades 6 through 12.



Troy Holcombe and William Bryant of Texas A&M University have combined years of digital and paper bathymetric records to produce detailed bathymetric maps of the Texas and Louisiana continental shelf. The maps, which are being combined with topographic data on nearshore areas, will supply important information for those doing ocean engineering and construction, storm impact forecasting and coastal zone planning.

Map courtesy Troy Holcombe

After the main project ended in spring 2006, Holcombe continued the project through the rest of the calendar year by preparing a series of 19 seamless bathymetry, land topography and shoreline maps for the entire Texas-Louisiana coastal and continental shelf area, including a map of the Houston-Galveston area that has been distributed to several science teachers in the region and will be helpful in facilitating storm surge predictions in low-lying coastal areas. The primary end-product containing the maps/images will be a CD-ROM, but all the items are suitable for printing; the companion final product will be a wall-size printed map of the entire region.

Several entities have expressed an interest in incorporating the bathytopographic maps of the Texas coast into their activities. Good bathymetry is an essential component of baseline studies for measuring future impacts of changes in climate, oceanographic parameters and rising sea level, and can be used with respect to marine fisheries to better quantify the carrying capacity for fish that occur in depth-dependent habitats, helping to prevent over-fishing. The Texas Parks and Wildlife Department is interested in using the bathytopographic maps of the Texas coast to aid their efforts to quantitatively assess the habitat of the brown shrimp, which spawns in the marshes and in very shallow water in Texas bays and estuaries. New bathymetry of the northwestern Gulf of Mexico is a valuable planning document for scientific expeditions to further study the biology, geology and history of shelf-edge banks. For example, the Harte Research Institute for Gulf of Mexico Studies at Texas A&M University-Corpus Christi is using the bathymetric maps to plan topographic highs/submerged bank biological research of the South Texas banks. The information will also be valuable for the oil and gas industry, which have already depended on the maps of the continental slope to help them site offshore drilling platforms and the paths of their pipelines through the maze of salt domes and deep depressions that occur in areas that are to be transversed by those pipelines. New and detailed bathymetry, along with information on the physical properties of the sea floor, will be useful as planning documents for continuing ocean engineering and construction, and the Minerals Management Service uses bathymetry to regulate these activities in the northwestern Gulf of Mexico.

enhancing hatchery production

Annually since the mid-1980s, about 30 million juvenile red drum have been grown in hatcheries operated by the Texas Parks and Wildlife Department (TPWD) and released into Texas bays in an attempt to maintain the stock of this important sport and food fish. Among the most difficult problems of juvenile production is exhaustion of forage in the hatchery ponds, leading to the need for premature release of undersized fish that have relatively low survival rates. William Neill and Delbert Gatlin of Texas A&M University and Robert Vega of TPWD conducted experiments to test predictions from Ecophys.Fish, an ecophysiological simulation model developed with support of previous Sea Grant projects, about the effects of environmental variation and feed quality on red drum growth and health (*Effects of Environmental Variation and Feed Quality on Juvenile Red Drum Performance*). Laboratory and pond experiments provided additional support for the hypothesis that it is metabolic capacity that tends to limit growth of juvenile red drum at lower temperatures, but that it is feed energy-density that tends to limit growth of juvenile red drum at higher temperatures. In the same experiments, low dissolved oxygen (DO) concentrations also tended to limit growth at higher temperatures, presumably by reducing metabolic capacity. However, neither a diurnal variation in temperature and DO, nor dietary supplementation with brewer's yeast, nucleotides or the commercial prebiotic GroBiotic® produced much benefit in performance. It was possible to account for much of the variation in juvenile red drum performance in pond experiments via simulation with the EcoPhys.Fish model, but model inputs need refinement via data analysis that is ongoing. The results of this project will benefit state and federal agencies responsible for managing marine resources, commercial red drum producers, the scientific community and the public. In fact, Ecophys.Fish, which was further refined by this study, has been adopted by TPWD's Marine Enhancement Program as a key tool for better managing and evaluating red drum stock enhancement. The red drum enhancement program has produced and released almost 500 million juvenile red drum since 1983, in an effort to support Texas' $1 billion per year recreational fishery for red drum and other marine fishes. As additional fish species such as spotted sea trout and southern flounder are produced for stock enhancement, successors of Ecophys. Fish will be of increasing usefulness to TPWD.

Sea turtles are being satellite-tagged and tracked after release to increase what is known about how long turtles spend in particular estuaries and in specific habitats within those estuaries to help with species recovery efforts.

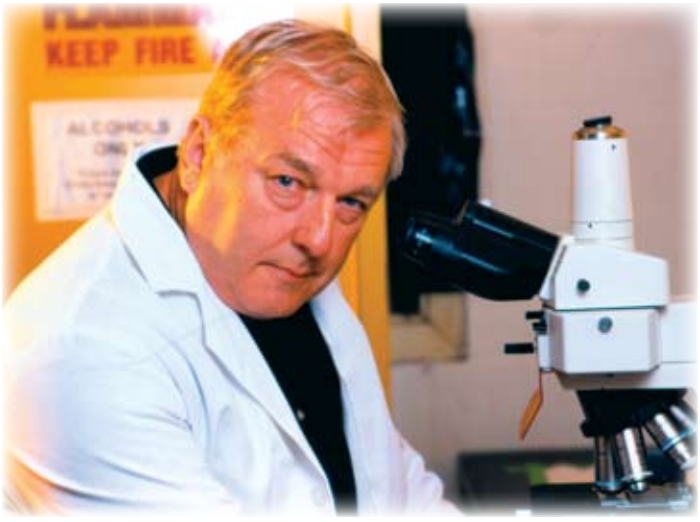
2006-2008 Projects Estuarine Habitats and Species

Six of the eight research projects that began in March 2006 focus on Texas' bays and estuaries or on the species that inhabit these ecologically rich areas.

André M. Landry Jr. of Texas A&M University at Galveston is directing a survey of the sea turtles found along the Texas coast (*An Assessment of Sea*

Turtle Assemblages in Texas Estuaries). Ongoing recovery efforts for the Gulf's five protected sea turtle species must be based on a thorough understanding of the role Texas' estuaries play in their life cycle, including identification of habitat critical to their foraging, as well as the overall health of the state's inshore ecosystems. This project will compare the species, abundance and sizes of turtles in the upper versus lower coast of Texas. Animals for this study are being collected via direct capture with entanglement nets and from capture for Texas Parks and Wildlife Department surveys, accidental catches by recreational fishermen, and stranding reports and access to animals in rehabilitation facilities. Selected turtles from each estuary are being satellite-tagged to track their movements to increase knowledge about their residence times in particular estuaries and their habitat preferences to lead to the identification of "hot spots" where data generation can be maximized for use by regulatory and resource management agencies.

Species that are subjected to the chronic effects of multiple sublethal environmental stressors can be used as sentinel species — early warning indicators for effective management of coastal ecosystems. They can also be used as the basis for predicting the impacts of environmental degradation on the species at the population and community levels. Peter Thomas of The University of Texas at Austin Marine Science Institute is measuring reproductive endocrine and histological indicators in the males and females of one sentinel species, Atlantic croaker, after exposure to the combined stress of hypoxia and organic chemicals that activate the aryl hydrocarbon receptor (AhR), also known as the dioxin receptor (*Evaluation of Atlantic Croaker Indicators of Estuarine Condition*). The individuals exposed to the stressors will be compared to fish from sites without the stressors and to individuals from the laboratory to determine whether reproductive responses in croaker are sensitive to estuarine degradation from multiple stressors. Thomas is also examining a protein that responds to the availability of oxygen in the cells to determine whether it is can be a useful indicator of hypoxia exposure and is attempting to determine if the effects of exposure to the organic chemicals under investigation are weakened by concurrent exposure to low oxygen levels. The results will be entered into physiological and population models to predict fecundity and population responses. The reproductive responses will be evaluated for their utility as ecological indicators and the findings communicated to state agencies for potential use in their monitoring programs.



Peter Thomas of The University of Texas Marine Science Institute is studying Atlantic croaker and its usefulness as a sentinel species for environmental stressors in coastal ecosystems.

Access to high-quality estuarine habitats via tidal inlets can play a major role in determining the dynamics and structure of marine fish populations. Many economically and ecologically important fish species use shallow estuarine areas as nurserygrounds, and their young rely on particular habitat types within estuaries for survival and growth. Understanding how young fish access high-quality habitat is fundamental for sustainable fisheries, but despite the recognition of the importance of estuarine habitat, there are significant gaps in knowledge about the specific spatial patterns of habitat use for many important fishery species. Gregory W. Stunz of Texas A&M University-Corpus Christi and Scott Holt of The University of Texas at Austin Marine Science Institute are using red drum as a model species to assess how tidal inlet dynamics affect the congregation and movement of estuarine-dependent fishes (*Recruitment, Spatial Distribution*

and Fine-scale Movement Patterns of Red Drum (Sciaenops ocellatus) *through Major and Shallow Passes in Texas*). Based on the data collected, the researchers will prioritize what habitats and spatial locales within an estuary are most critical to recruiting estuarine-dependent fishes. Successful completion of the objectives of this research will provide important information needed by managers to make informed decisions concerning conservation and management of estuarine-dependent fisheries.

Another research project is evaluating the breakdown of dioxins by microbes in the sediment in an estuary known to have these persistent environmental contaminants, which bio-accumulate in the aquatic food chain and pose significant and persistent risks to human health (*Factors Regulating Microbial Degradation of Dioxins in Estuarine Sediments: Houston Ship Channel and Galveston Bay, Texas*). The Houston Ship Channel and upper Galveston Bay are polluted with dioxins derived primarily from industrial, municipal and agricultural effluents and runoff. Peter H. Santschi, Robin Brinkmeyer and Kevin M. Yeager of Texas A&M University at Galveston are leading the collection and analysis of sediment core samples from known contaminated sites, sites within "hot spots" such as dredged areas, and background or control areas, as well as from biologically productive areas suspected to serve as dioxin "sinks" because of their geochemical conditions, high biodiversity and biomass. The analysis of the samples will build a data set that the researchers will use to develop laboratory experiments to evaluate dioxin degradation rates under controlled conditions, resulting in a comprehensive understanding of the processes that increase or decrease the breakdown of dioxins by microbes in the sediment. The researchers expect to be able to determine estimated dioxin microbial degradation rates under different conditions and assess the potential for natural remediation of dioxin-contaminated sites. This information will be shared with government agencies and stakeholder groups to help them develop new or modify existing best management practices with respect to dioxins.

Most natural and created salt marshes in Galveston Bay and elsewhere are suffering erosion due to wave action, relative sea level rise, limited sediment supply/deposition and other factors. Restoration projects are currently under way to stop the erosion processes. Thomas M. Ravens and Vijay Panchang of Texas A&M University at Galveston are working to determine the dependency of marsh erosion rates on these various factors (*Design of Erosion Resistant Salt Marshes*). The researchers are doing a detailed examination of an eroding marsh, the Galveston Island State Park in West Galveston Bay, which has been "restored." The study is examining the causes of the marsh loss as well as the role played by the geotube breakwater and the terrace field (created marsh) design in the state park, which are common features of restored marshes. This study is also determining whether these features are likely to promote sustainability and if there are low-cost but effective ways to protect against erosion. Preliminary results indicate that the primary cause of marsh loss in West Galveston Bay is insufficient sediment supply relative to the relative sea level rise. Waves appear to be playing a

Eddie Seidenstick, a soil conservationist with the federal Natural Resources Conservation Service, stands in a created salt marsh on Atkinson Island, located along the Houston Ship Channel.

relatively minor role. These findings led to the design of a submerged sacrificial sand berm to replace the geotube. The sacrificial berm will provide some wave protection, but it will also be a significant source of sediment to the marsh. By incorporating a sacrificial berm or some other sediment supply mechanism, restoration projects could become more effective and sustainable in the long term, given continued sea level rise.

Scott Socolofsky and Kuang-An Chang of Texas A&M University are combining laboratory experiments with numerical models to build on their 2004-2006 research project and advance the understanding of the important processes affecting chemical transport in the coastal zone (*Laboratory Studies of Mixing Processes in Estuaries and Coastal Flows on the Texas Coast*). Shallow flows are known to generate large-scale, two-dimensional coherent vortical structures that can dominate mixing. Because of the three-dimensional nature of the formation of these vortices, typical estuary models that are depth-averaged do not accurately capture their formation and growth. To correct this problem, this project proposes a series of laboratory experiments to obtain detailed velocity and concentration data for typical coastal flows. The experiments will include the effects of obstacles, variable bottom roughness, surface waves and alongshore currents. Advanced state-of-the-art and state-of-the-practice numerical models will be compared to the laboratory data, and the validated numerical model will be applied to the Texas Sea Grant priority of evaluating salinity regimes in Trinity Bay and East Galveston Bay. By comparison to depth-averaged simulations, the importance of the two-dimensional vortices will be evaluated. Through a series of "what if" scenarios, feasible design alternatives (addition/removal of groins, jetties, channel deepening, etc.) will be evaluated and recommendations will be summarized for improving water quality in the bays.

Hurricanes are just one hazard that coastal communities must keep in mind when planning new development. Texas A&M researchers are using Texas Sea Grant funding to build an online, interactive coastal communities planning atlas to help predict the effects of different development scenarios and direct growth to the most desirable areas. *Sea Grant file photo*

coastal communities

One research project is designed to help local planners in coastal communities understand the implications of development decisions and plan appropriately for the future (*Developing a Coastal Communities Planning Atlas as an Educational Tool for Decision Makers and Local Residents*). Samuel D. Brody, Douglas Wunneburger, Walter Peacock, Forster O. Ndubisi and June Martin of Texas A&M University are building an online coastal communities planning atlas to provide an easily accessible, graphically represented, interactive database that will allow users to identify and visualize critical "hot spots" related to environmental degradation, natural hazard risks and significant changes in land use patterns. In addition, users will be able to query data and create custom maps based on multiple development scenarios. The researchers have already created a template website and collected several datasets. The project will include the 30 coastal counties at the Census block and block group level; in addition, Galveston County datasets will be refined down to parcel-level data. Communities will be able to use this educational

tool to guide future decisions on growth in a sustainable manner so that the need for economic development is balanced with priorities associated with environmental protection and human health, safety and welfare. The system will also help address important research questions related to where future growth will occur in the Texas coastal zone, the impacts of this growth and the usefulness of WebGIS in facilitating sustainable planning.

public health and safety

As a biomedical model, sea urchins (*Lytechinus variegates*) are ideal organisms for learning how genes and proteins regulate growth and development with potentially profound implications for understanding human biology. Additionally, these animals are approved by the U.S. Environmental Protection Agency and the U.S. Geological Survey Agency for use in bioassessment of environmental hazards and status of bays and estuaries. The major impediment to urchin model development is a lack of nutritionally complete, commercially available diets. Addison Lee Lawrence of the Texas Agricultural Experiment Station, Port Aransas, and Stephen A. Watts of the University of Alabama, Birmingham, are conducting a study to determine the dietary nutritional requirements of urchins (*Dietary Nutrient Requirement Determination and Feed Development for Sea Urchins for Biomedical, Ecotoxicological and Educational Models*). The researchers are also experimenting to develop purified, semi-purified and practical feeds that will promote gonad production and provide a predictable supply of quality gametes, larvae, juveniles and sub-adult urchins ideal for medical, ecotoxicological and educational uses as well as those in the business of the production of juvenile urchins for stock enhancement.

mini-grants

The Texas Sea Grant College Program uses Rapid-Response Mini-Grants and Texas Sea Grant Extension Program Mini-Grants to fund smaller, short-term projects that cover topics that were not anticipated during the approval process for the two-year research funding cycle. They allow the program to respond quickly to problems or opportunities in which a small amount of funding can leverage significant results, including larger research studies in the future.

No such projects were funded during the fiscal year that ended in March 2006, but two projects began later in 2006; both focus on the Houston area.

Houston's Midtown has all the elements in place for transit-oriented smart growth, in particular a new light-rail line down Main Street, yet no new major developments have begun since the rail line opened over a year and a half ago. Growth is occurring in all of the Houston suburbs, suggesting the overall financial environment is favorable, and market studies suggest immediate demand for more than 100,000 new households in the Midtown area. Virtually all of the major non-profit organizations involved with Midtown (Main Street Coalition, Midtown Management District, the Midtown Redevelopment Authority) strongly

Texas Sea Grant Extension's John Jacob talks to Houston Midtown stakeholders during a Sea Grant -U.S. Environmental Protection Agency technical assistance team workshop in July 2006 to help spur compact development along the light rail line there.

support smart growth in Midtown, however, indications are that city policies, or lack thereof, may not be conducive to fostering the kind of investor confidence needed to support large-scale transit-oriented development. The Midtown area is the best opportunity for smart growth in the Houston region, and it is imperative that it be successfully implemented here before it can spread to other parts of the region.

Texas Sea Grant, led by John Jacob of Texas Sea Grant Extension, partnered with Houston's Main Street Coalition and the Gulf Coast Institute to request a U.S. Environmental Protection Agency technical assistance team that analyzed the policy and regulatory environment in the Midtown area, particularly around the Houston Community College/ Ensemble transit stop on Main Street (*Houston's Midtown: A Transit-oriented Community*). The team, which held a two-day workshop in July 2006 on Main Street near the transit stop, produced a report that sketched out a general vision for the community and suggested strategies and key policy and regulatory changes needed to bring about that vision.

Houston's Midtown, especially the area around the Ensemble/HCC transit stop on Main Street, is the best opportunity for resource-conserving smart growth in the metro area. Texas Sea Grant is working with local, regional and national partners to help build a vision for the community and suggest strategies and regulatory changes needed to bring about that vision.

With four million people expected to move to Houston in the next 30 years, demands for services and space will increase and further stress this urban watershed. There is already a demand for infill development in Houston, but there are considerable policy and cost barriers that make such development more difficult. Houston's Midtown could receive hundreds of thousands of new residents and be one of the most vibrant neighborhoods in Houston – a hub for creativity and commerce.

Under the second grant, Texas Sea Grant staff members are working with physical oceanographers David Brooks, William Bryant and Troy Holcombe of Texas A&M University and in partnership with emergency management agencies, Sea Grant programs in North Carolina and South Carolina, the National Severe Storms Laboratory in Norman, Okla., and the University of Oklahoma to link storm surge models to rainfall/flood models for the Houston-Galveston area (*Introduction of Precipitation and Storm Surge Models to the Houston-Galveston Watershed of Texas*). The models will be used to predict storm surge inundation and flooding from heavy rainfall events in the Galveston Bay area as well as predicting runoff patterns that may contribute to water pollution. The ability to precisely predict storm events and the likelihood of flooding will help emergency management agencies better determine which areas should be evacuated in advance of storms.

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