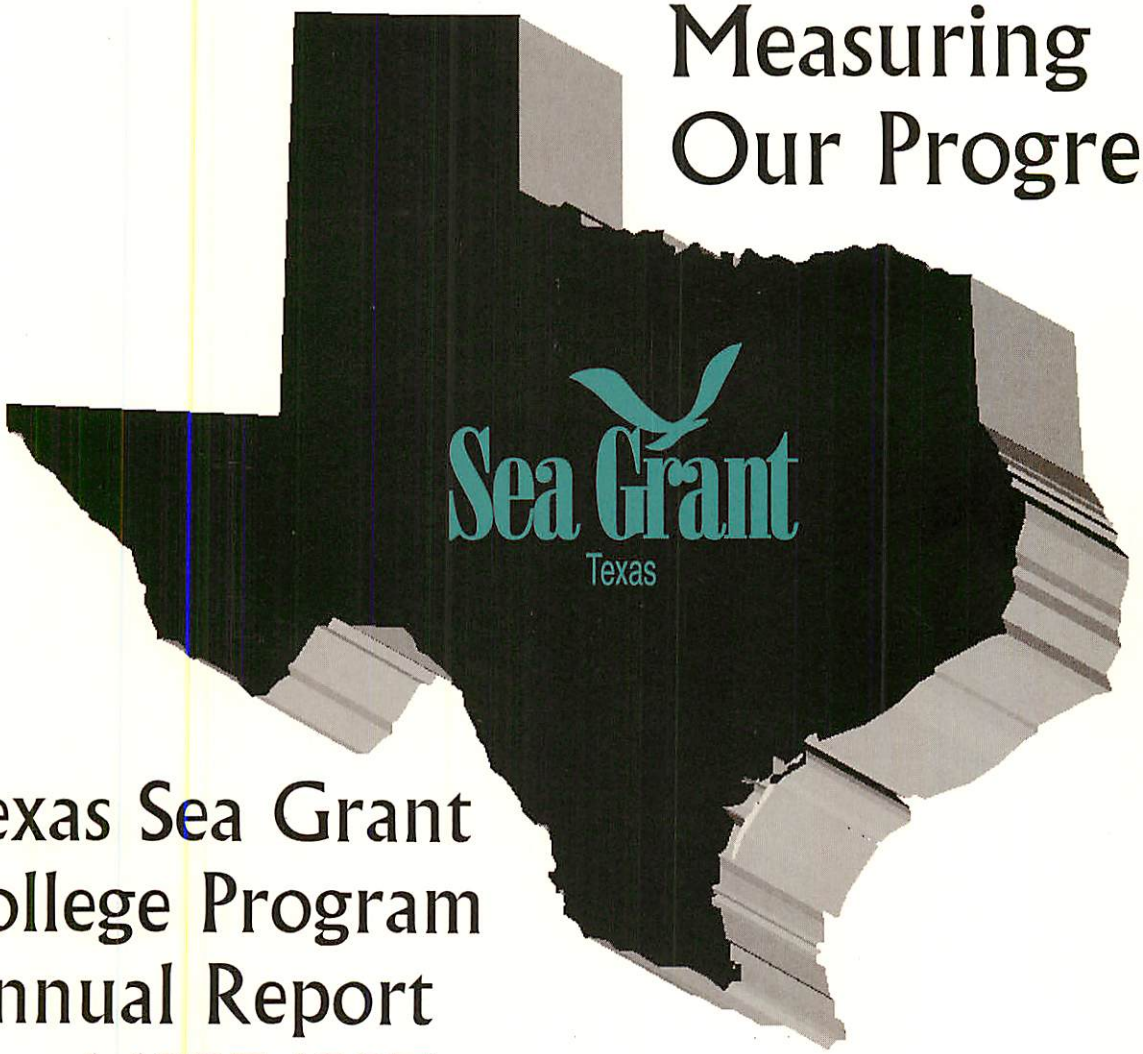
Measuring Our Progress



Texas Sea Grant College Program Annual Report Fiscal 1995-1997

Foreword

It was my distinct pleasure to join the Texas Sea Grant College Program in January 1996, the year the program celebrated its 25th year of operation. Early in calendar 1996, the program underwent a review by the National Sea Grant Office. Shortly thereafter, we began soliciting and reviewing proposals for a one-year cycle. Once the omnibus proposal was finalized and submitted in December 1996, planning began for a followup three-year proposal cycle. By March 1997, when the one-year cycle began,[1] we had developed the Request for Proposals in conjunction with the 1998-2000 budget cycle. The proposal solicitation, review and decision process was completed according to the schedule that was adopted and a three-year omnibus proposal was submitted to the National Sea Grant Office in December 1997.

This report covers activities associated with the State of Texas fiscal years 1996 and 1997 plus the period from September 1, 1997 through February 28, 1998, which coincides with the end of the one-year proposal cycle previously mentioned. In the future, annual reports will be prepared covering March 1 through February 28. Thus, in the future, information will be disseminated more rapidly than is possible through biennial reporting.

In 1996, Texas Sea Grant, utilizing its Advisory Committee of representatives from industry, agencies and academia, set new priorities for the program and attempted to find a theme for at least a number of the proposals that were funded. There were proposals funded in the areas of aquaculture and marine education, but (and this was not anticipated) many of the outstanding proposals related to the general topic of fishery recruitment. Summaries of work during the first year of the recruitment initiative are included in this report and are identified as such. The Advisory Committee re-evaluated research priorities in 1997 and concluded that the priorities developed the previous year had not changed. Some of the research initiated in 1997 received continued support in the 1998-2000 funding cycle after submission and review of new proposals, while several new projects that fell within the recruitment initiative were initiated in March 1998 with the start of the three-year cycle.

Summaries of projects that were funded outside of the omnibus proposal are included in this report. Some small projects were initiated with discretionary project development funds, while others were extramural with funding that passed through Sea Grant from NOAA, other agencies or private sources. None were part of the base budget of the Texas Sea Grant College Program.

We were pleased to have two Knauss Fellows appointed for one-year beginning in February 1997. Michael Coyne spent his year in Washington, D.C. working within the National Marine Fisheries Service, while Sean Powers was assigned to the National Science Foundation. Both men, who were Ph.D. students at Texas A&M University-Galveston in the final stages of their degree programs when awarded the Knauss Fellowships, reportedly performed exceptionally well and benefited greatly from the experience.

This report features summaries of the excellent research being conducted by the talented and dedicated marine researchers from various universities across Texas who were supported by this program. It also contains highlights of activities conducted within the Marine Advisory Service (MAS) and the Marine Information Service (MIS). Both of those entities are crucial to the Texas Sea Grant College Program as they work collaboratively in an effective manner to provide outreach and educational services.

Robert R. Stickney
Director

[1]For its 30-year history, Texas Sea Grant had a September 1 start date for its omnibus proposal. That changed to March 1 in 1997.

Administration

The Texas Sea Grant College Program administration offices are in Bryan, Texas a few minutes away from the campus of Texas A&M University. Some changes in staff occurred during the period covered by this report. A fulltime receptionist position was eliminated and fewer student workers are employed. These changes were made possible through some streamlining and improved efficiency that occurred as a result of upgrading computers and having a few holdouts become computer literate. Reducing staff was precipitated by the need to keep the research funding level as high as possible while maintaining the necessary level of financial support for MAS and MIS activities in the face of increased costs associated with salary increases to employees and a low, but not meaningless, inflation rate.

Debbie Hermann, administrative assistant to the Director, made the decision to return to school and complete her degree. Her long tenure and many contributions are gratefully acknowledged. Peggy Foster was recruited from International Programs as Debbie's replacement, bringing many talents that make her an excellent addition to the Sea Grant family. She came aboard in August 1997.

No changes in MAS administration occurred during 1996 or 1997, but there were additions to the field staff. John O'Connell became as county marine agent in Calhoun County in 1996, and John Jacob was hired as a new environmental specialist position. Jacob spent several months in Bryan and then moved his base of operations to the Galveston area. More details on O'Connell's and Jacob's activities and other MAS agents and specialists can be found in the Advisory section of this report.

There were some significant personnel changes in MIS. Jennifer Magee (now Jennifer Magee Toups) was employed as an editorial assistant in 1997 and was promoted to Assistant Editor when Phillip Sulak resigned to assume another position. Jenny has assumed primary responsibility for news release preparation and edited various publications, prepared contributions about the Marine Advisory Service for *Texas Shores* magazine (edited by Jim Hiney) and was responsible for developing the program and publicity associated with the Sharing Our Gulf conference planned for June 1998.

Eric Graham, MIS Distribution Manager, has become the computer expert within the Texas program. His original duties, which were primarily to maintain the inventory and distribution of publications, have changed dramatically. He developed the Texas Sea Grant College Program's web site (http://texas-sea-grant.tamu.edu) and continuously updates it with new information. He is also training to become a certified Apple technician. As his duties have changed, responsibility for mailing publications has been transferred to student workers.

Mike Hightower is Deputy Director and MAS Leader for the Texas Sea Grant College Program. He is assisted by Lynn Propes. There are two MAS specialists located in the Bryan offices: Dewayne Hollin (marine business) and Granvil Treece (aquaculture). Other MAS personnel include specialists William Younger in Palacios (education), Gary Graham in Palacios (fisheries) Russell Miget in Corpus Christi (environmental quality) and Michael Haby in Corpus Christi (seafood technology). Agents during 1996-1997 in addition to John O'Connell included Richard Tillman (Brazoria County), Tony Reisinger (Cameron County), Julie Massey (Galveston County) and Nancy Webb (Matagorda County).

Amy Broussard is Associate Director of the program and also holds the title of Publications Program Director. She and her staff, who have already been mentioned, publish a prodigious amount of material, while maintaining exceptional quality in all of their work.

Publications

Abstracts

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Stickney, R.R. 1997. Principles of salmonid culture. Edited by W. Pennell and B.A. Barton. Elsevier, Developments in Aquaculture and Fisheries Science, Volume 29, New York. **Prog. Fish-Cult**. 59:317-319.

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Marine Advisory Service

The Texas Marine Advisory Service (MAS) is the primary outreach and technology transfer component of the Texas Sea Grant College Program, working cooperatively with the Texas Agricultural Extension Service, commissioner's courts in seven coastal counties and four departments of Texas A&M University. The staff is composed of one program coordinator and six marine agents backed by seven marine specialists, each an expert in a particular marine subject matter area.

Over the last decade, it has been determined that the majority of issues and needs of constituents fall into one or more of six major subject areas. Each area — aquaculture, environmental quality, fisheries, marine business, marine education and seafood technology — is represented by a specialist with significant expertise in the specific field. This system has proven to be efficient, flexible and responsive to constituents and allows activities and results to be readily.

The MAS program is unique in that it uses a variety of disciplines and methods to meet the needs of a large number of constituents. A diverse group of audiences must be served; each with its own views about what constitutes acceptable performance. Constituent needs may be as simple as seeking general information over the telephone or as challenging as developing new methods or technologies that result in cost savings, revenues earned, development of recreational assets, etc. Many projects are best characterized as multi-year, applied research work designed to solve a particular problem. Still other activities focus on educating youth and adults — building human capital, in a sense — a difficult concept to quantify except through numbers of participants.

The process of identifying issues, programs and activities is continually evolving as local, state, regional and national conditions change. Issues are identified through work with the cooperating groups, from committee participation, various advisory committees, surveys of clientele, questionnaires from workshops and programs, discussions with key supervisors and unsolicited responses and comments from all sectors of the Texas coastal constituency. Also, Sea Grant conducts an annual workshop for all of the marine agents, specialists and administrators affiliated with the MAS Program where issues and programs are discussed and prioritized.

Selected Major Accomplishments

Overview

MAS directly reached more than 30,000 constituents from 1995 through 1997 through 350 workshops, seminars presentations and meetings; 55 field trips; and 26 demonstration projects. Representative topics by sub-program category are listed below, followed by short narratives for specific project examples.

Aquaculture: blue crab workshops, aquaculture economics, pond management, rules and regulations, offshore net pen culture, recirculating systems, shrimp farming technology, effluents and shrimp viruses.

Environmental Quality: recycling, non-point source pollution reduction, "Bay Friendly" landscapes, septic tank installation, dune stabilization, coastal erosion, toxic algal blooms, origins of beach trash, aeration in marina basins, marina sanitation and education, coastal hazards, composting, wetlands as biofilters and aquatic nonindigenous species.

Fisheries: turtle excluder devices, use and installation of bycatch reduction gear, fishing vessel fuel efficiency, fisheries regulations and policy, economics of commercial and recreational fisheries, fishing vessel safety, bottom obstructions and alternative fishing gear usage.

Marine Business: waste management, hurricane preparedness, recycling for ports and harbors, bay debris reduction, marina economics, best management practices for marinas, fishing vessel safety training, economics of marine and maritime industries and personal watercraft use and safety.

Marine Education: marsh ecology, dune ecology, beach safety, constructed wetlands as biofilters, fish and habitat identification and con-servation, water quality sampling, bay and beach ecosystems, turtle hatcheries, fish culture, youth sailing, water safety and recreational fishing.

Seafood Technology: proper handling of shellfish, brine freezing shrimp at sea, seafood processing, retail quality and safety programs, HACCP[2] requirements and training programs, fishery econom-

ics, seafood health and safety, seafood waste composting and value-added product development.

Selected Accomplishments, Programs and Efforts

Biofiltration of Aquaculture Pond Effluents

Effluents from coastal shrimp and finfish aquaculture pond operations are increasingly becoming a problem, not only in terms of the quantity of water, but more importantly, its quality. Concerns by regulatory agencies are directed toward the content of the effluent; specifically the levels of suspended solids, dissolved organics and nutrients. MAS and a commercial operator of shrimp and redfish aquaculture operations to address this issue by constructing additional ponds or basins, planting them with various marsh grasses, flowing effluents from the commercial aquaculture operations through the basins and monitoring the water quality of the effluent. The objective is to determine if bio-filtration by natural systems is effective in improving the effluents from coastal aquaculture operations prior to entering receiving coastal waters.

Moveable Aerators in Coastal Shrimp Ponds

Exchanging pond water in coastal shrimp operations to maintain water quality, regulate plankton densities and introduce supplemental food organisms has been an accepted management practice for shrimp farmers for the past two decades. Recently, however, there has been increasing criticism about the negative aspects of water exchange on receiving waters, release of shrimp pathogens and impingement and entrainment of indigenous organisms during source water pumping. MAS specialists designed, initiated and completed a demonstration project to evaluate the effects of moveable aerators on water/sediment quality of a shrimp pond that did not undergo water exchange. The pond was stocked with native white shrimp. The pond produced 750 pounds of shrimp, which was considerable higher than would be expected without the aerators.

aquaCalc 1.0 Software Development for Aquaculture

aquaCalc (version 1.0) is software that involves 12 preprogrammed calculators that do many of the basic calculations required to design and run an aquaculture facility. Funded by Texas Sea Grant, the software was developed by EcoMar Mariculture. The program is organized in three categories — design calculators, operations calculators and conversion calculators, and comes with a detailed user's manual. aquaCalc 1.0 is available in PC (Windows) and Macintosh formats. aquaCalc 1.0 has been tested and used by commercial aquaculture for the monitoring and daily control of important parameters such as oxygen, NH_3, feed rates, pH and alkalinity. aquaCalc software can also assist with converting a variety of units commonly encountered in aquaculture, such as biomass, productivity, energy, power, flow rate, nitrogen, oxygen, length, area, mass, temperature and volume. The user can quickly convert meters to inches or feet, or convert hectares to acres, liters to gallons or to cubic meters, temperature in ∞C to temperature in ∞F and others. aquaCalc includes conversions for shrimp such as count-per-pound of shrimp or carapace length. It also includes finfish conversions such as standard length or fork length to weight.

Marine Sanitation and Boater Education

The Environmental Protection Agency (EPA) recently designated Clear Lake, a secondary bay system adjacent to Galveston Bay, as a "no discharge area." Clear Lake is just south of Houston, adjacent to the NASA facility and has the largest concentration of marinas and coastal recreational boats on the Texas coastal area. Marinas with 10 or more slips were required to have pump-out stations for boats (sewage removal from the heads). MAS, with assistance from the Texas Parks and Wildlife Department, initiated an education program for boat owners and marina operators including potty training for boat operators; full demonstrations on the various systems available; water quality education; free pump-outs; and proper boat sewage collection and holding facilities.

Renovation of Dredge Material Disposal Sites

Dredge material disposal areas in South Texas are a continual source of airborne dust during periods of drought. The prevailing southeasterly winds dis-

[2]HACCP is the Hazard Analysis Critical Control Point system by which seafood processors identify the critical steps in their plants and monitor those steps to ensure the quality and safety of their products.

perse dust over the local communities. Also, vegetation is slow or unable to colonize the dredge material disposal areas because of soil composition (high clay content), high soil salinities and low nitrogen levels. A demonstration project was initiated in August 1996 using discarded shrimp shells from a local shrimp peeling plant. Shrimp shells were tilled into a disposal area in an attempt to add nitrogen and organic matter and to increase water percolation to reduce soil salinities. The preliminary results from this demonstration indicated that salinities were reduced, plant growth was greatly increased and there was a large increase in nitrogen after the addition of the shrimp shells.

Fisheries Bycatch Reduction

Finfish species that are incidentally harvested in shrimp trawls represent a major concern for marine resource users and fisheries managers. As much as 2.5 billion pounds of finfish bycatch are harvested in shrimp trawls each year. Recent amendments to the Magnuson Fisheries Conservation and Management Act have directed a substantial reduction of finfish trawl bycatch in the immediate future. MAS specialists, in cooperation with fishery management agencies and the shrimp industry, are actively addressing the bycatch issue. Efforts to date include: characterization of bycatch; testing and analyzing new bycatch reduction devices; underwater video analysis of bycatch gear under actual shrimp trawling operations; extensive data analysis; and numerous workshops, presentations and gear demonstrations. New gear has also been developed, tested, refined and is now being employed by the industry.

Standardized Performance Analysis for the Offshore Gulf Shrimp Fleet

A large proportion of Gulf shrimp boats are approaching 20 years of service. Operators will soon have to decide whether to replace their vessels or substantially refurbish them. Few operators can afford to finance the replacement exclusively with retained earnings, so external credit must be obtained and commercial lenders require financial information from prospective borrowers to evaluate their ability to repay the loan. Not only is financial information on individual producers needed by lenders, but industry-wide financial performance is also needed for comparative analysis. Without industry-wide profiles, lenders could conclude that a prospective borrower's profit margin or return was indicative of poor management when in fact the borrower's financial statements may reflect a leveraged position within the industry. MAS initiated a project in cooperation with Gulf shrimpers to develop performance measures, collect data from the industry and subsequently analyze, interpret and present financial profiles to financial institutions and industry members.

TEDs Management Alternatives

MAS is collaborating with industry and the National Marine Fisheries Service (NMFS) to refine and update information regarding the distribution and potential capture of marine turtles. Specialists are responsible for overseeing the deployment and data collection of 15 vessel observers who will be recording turtle captures on shrimp trawls with and without turtle excluder devices (TEDs) pulled at various depths and seasons. Emphasis will be placed on turtle abundance and distribution on the shrimp fishing grounds. Also, observers will be placed on a variety of vessels and evaluate sea turtle interactions on the basis of boat size and power, gear dimensions, and fishing strategies.

Nonpoint Source Pollution Reduction/Abatement

The Galveston Bay watershed is home to the world's largest chemical and refining complex and the third largest port in the nation. More than 650,000 people reside within two miles of the bay or its upstream tidal reaches. The population in the watershed has more than doubled within the last 30 years. Thus, residential, industrial and agriculture land uses are now beginning to overwhelm the filtration capacity of the watershed. MAS staff obtained funding from EPA for a three year project to develop, design and promote adoption of nutrient, soil and pesticide management best management practices (BMPs) that address primary water concerns. This project has five major program elements: create an agricultural watershed working group, identify subwatersheds to install multiple demonstrations involving BMPs, install six demonstration sites, design and implement educational programs, and publish a comprehensive resource guide and video.

Aeration of Marina Basins

Fish kills often occur during the warm summer months in backwater areas within marinas. The cause of fish kills is usually attributable to poor water circulation and low levels of dissolved oxygen. One recent fish kill on the upper Texas coast cost a marina operator $60,000 for cleanup. MAS staff in conjunction with state resource agencies and marina operators designed and conducted demonstration projects with various types commercially available aeration systems in an attempt to avert fish kills. The projects were a success and marina operators are being trained in basic water quality testing and are adopting the technology to solve fish kill events.

Constructed Wetlands for Treating Septic Tank Effluents

Marginal or failing septic tank systems in the coastal area near bayous and rivers are major contributors of fecal contamination into bays and estuaries. Constructed wetlands are being used in other states to handle wastewater in small rural communities where traditional treatment systems are too expensive or are not available. In many cases, constructed wetlands have proved to provide simple, effective and low cost wastewater treatment when compared to conventional systems. A two-year demonstration project was designed in conjunction with the U.S. Fish and Wildlife Service and the Brazoria National Wildlife Refuge for a recreational vehicle campsite in the refuge. Wastewater from the pads now drains into a septic tank and then into two constructed wetland cells planted with water-loving plants. Water that isn't absorbed by the plants is dispersed into a leach field containing 1,200 feet of perforated pipe laid into gravel-filled trenches adjacent to the wetland cells. The system, which could be applicable for other coastal counties, was designed to be low maintenance and low-tech.

Personal Watercraft Safety Operation Training Program

Personal watercraft (PWC) are continuing to grow in popularity and now account for 10 to 50 percent of new boat sales and registrations in some states. They are particularly popular in Texas where almost year round use of PWCs is common. With the popularity of PWCs has come a high number of accidents. More than 10 percent of the recorded fatalities associated with recreational boating in 1995 involved PWCs and 30 percent of all boating accidents involved PWCs. MAS, working with the Texas Parks and Wildlife Department, developed a PWC safety education training guide and additional training aids for both PWC owners and operators. A new state law, which became effective in September 1997, mandates that those between the ages of 13 and 15 can operate a PWC only after earning a certificate in a PWC safety education course. Young teenagers also must complete a boater education course or be accompanied by an adult. Publication of the final guide is expected within the next year.

National Sea Grant Marina Network (MarinaNet)

The Texas MAS program is participating in a national network for marinas and the marine-related trades established through the National Sea Grant College Program. This project has created a formal network of Sea Grant researchers and MAS staff working with marina operators as well as a system for the efficient exchange of information among academia, the marina industry, regulatory agencies and other marine-related organizations. MarinaNet has also established an on-line communication network, including a worldwide web site and e-mail discussion group. A biennial newsletter (MarinaNet News) provides information to the Sea Grant network about marine-related projects and issues.

Coastal Hazards

MAS recently joined in a collaborative effort with several other MAS programs to build a network known as HazNet to provide research, outreach and educational information for natural coastal hazard prevention and mitigation. This organization will share information, collect and distribute data, and identify gaps in current knowledge. Also, Texas MAS will specifically identify other Sea Grant/MAS staff active in hazards work and develop a list of available publications. All of the information will be posted on a web site for easy access.

Marine Education Initiative

A marine education facility at Palacios, Texas was designated by the Texas Legislature as the State Marine Education Center in 1995. MAS and Sea Grant staff conducted the original feasibility study for this center. In 1996, Sea Grant/MAS and the Texas Agricultural Extension Service signed a Memorandum of Agreement with Center participants for collaborative programs. Other participants included the Matagorda County Navigation District No. 1, the Palacios Independent School District, Wharton County Junior College and the Texas State Technical College. MAS has since located a marine education specialist and an assistant at the Center and extensive program development is now underway.

Aquatic Nonidigenous Species Educational Program

The incidence of aquatic nonindigenous nuisance species continues to increase as does the damage they inflict on both the environment and the economy. Zoogeographers suggest that the five Gulf states are part of the most naturally hospitable portion of the continent for introduced species. This area is especially vulnerable because of such natural dispersal factors as the Mississippi River drainage, port and shipping activities, cross-state recreational boaters, the mild climate and the Gulf Intracoastal Waterway that connects the five states. The Sea Grant MAS Programs in Texas, Louisiana, Mississippi, Alabama and Florida, with assistance from the National Sea Grant Office, have recently begun a two-year collaborative effort to increase awareness of the potential problems that can and have occurred as a

result of aquatic nonindigenous species in the Gulf region. The project is also intended to stimulate a common interest in the management and control of these species.

Keeping the Bait Alive

Recreational fishing along the Texas coast is a multimillion dollar enterprise. A large proportion of recreational fishermen prefer to use live bait. Bait stand operators have traditionally held the shrimp in suspended cages in or around marinas, but up to 50 percent of the shrimp often is lost prior to sale due to low oxygen levels, fluctuating salinity, sedimentation and contaminants in the water. MAS initiated an effort with bait stand operators to develop small, closed recirculating systems using readily available and relatively inexpensive materials to keep shrimp alive longer. The project was successful and workshops are being presented along the coast to bait stand operators, many of whom have adopted this system.

Brine Freezing Aboard Shrimp Vessels

Although brine freezing at sea should produce the highest quality shrimp, MAS agents and specialists found salty, tough shrimp to be a bit more prevalent in the market. The cause of these quality defects was improper charging and recharging of the brine systems. MAS conducted an assessment of current industry practices and industry management of brine refrigeration systems. Materials were then produced that outlined the correct, stepwise procedures necessary for optimal performance of the brine systems to produce high quality shrimp.

Crab Processing.

At the request of the crab processing industry and the Texas Department of Health (TDH), MAS evaluated current TDH requirements for picking crabmeat. A sampling and analysis protocol was designed to evaluate a mandated wash step after the crabs were steamed. With the assistance of an outside analytical laboratory, results demonstrated that this mandated step actually contaminated the crabmeat. A report was prepared, submitted to TDH, and as a result, the unnecessary and expensive mandated wash step was removed and the regulations were changed.

Improving the Quality, Safety and Profitability of Retail Seafood

In a 1987 study, the Food Marketing Institute reported that shrinkage (i.e., that portion of inventory purchased but not sold because of spoilage, etc.) emanating from retail seafood departments ranged from 10 to 15 percent of departmental sales. With seafood accounting for $12 billion in annual sales through retail food establishments, the shrinkage factor translates into a $1.2 to $1.8 billion loss to the grocery industry. To address this problem, MAS specialists in conjunction with NMFS and the Cooperative States Research Education and Extension Service of the U.S. Department of Agriculture developed manuals that have structured and effectively standardized operating procedures that are easily understood and time-efficient for employees to implement. In addition, the National Sea Grant Office has provided additional funding for fiscal 1999 to develop additional training programs and information dissemination that will lead to nationwide implementation of the program.

Seafood Safety

Recent mandatory regulations by the U.S. Food and Drug Administration are requiring seafood handlers and processors to develop and implement their own food safety programs using HACCP. Two MAS specialists became certified trainers and to date have trained more than 300 seafood handlers and processors on the new federal regulations and compliance procedures and on how to establish their own HACCP programs for their particular operations.

Marine Informaton Service

The Marine Information Service (MIS) works to increase awareness of and appreciation for the state's marine resources through an active, ongoing program of dissemination of research results and other information. MIS' five-member staff supports the Program through writing, editing, design, reproduction and distribution of printed materials; directing a concerted effort toward media relations; preparing reports and proposals; and assisting with seminars, workshops and exhibits.

The designation document signed in 1971 said that Texas A&M University is the Sea Grant College for Texas, although, in reality, the Program concentrates its efforts primarily in the Gulf Coast region — an area larger both geographically and in population than the combination of many other states' programs. Texas has 377 miles of open Gulf shoreline, 2,135 miles of bay-estuary-lagoon shoreline, and the longest barrier island system in the United States. About 4.5 million people live in the 18 Texas counties immediately adjacent to the Gulf of Mexico, drawn to the region by the mild climate, the benefits of waterfront locations, and the wealth of exploitable natural resources — fish and wildlife, oil, gas, other minerals and agricultural land.

Steady growth intensifies competition for limited coastal resources. Development is claiming land formerly devoted to agriculture. Shoreline development raises issues of beach and dune protection, preservation of open space, access, and private versus public ownership. Coastal fisheries compete for fresh water with upstream users and experience effects of wetland loss and contamination of habitat caused by human activities.

Although most of Texas Sea Grant's research and advisory efforts are focused in coastal areas, communications extends beyond the 100-mile boundary. Legislators, both federal and state, who affect Sea Grant's funding come from all parts of the state, and a Congressman representing a district in the Panhandle or West Texas may only be reached by a timely report or well-placed news release.

While Legislative interests are as varied as the Texas topography, coastal management, property rights, water rights and freshwater inflows, erosion, overfishing and toxic pollution have taken center stage in recent months. Texas finally achieved a coastal management program in 1996, a fact detailed in two issues of Sea Grant's *Texas Shores* magazine that the lead agency, the General Land Office, now uses in its educational program. *Texas Shores* also covered property rights versus endangered species, bycatch, the resurgence of the Kemp's ridley turtles and seafood safety during the grant period.

Apart from the magazine, the primary focus of the Marine Information Service has been media relations. MIS distributed 104 news releases from September 1995 through February 1998 to 43 newspapers — 17 dailies and 26 weeklies. All releases are posted on the Texas Sea Grant website and released through the Aggie Hotline, an electronic news listserv with approximately 1,000 subscribers.

Texas Sea Grant has always adhered to the policy that the Marine Information Service is a "news" provider, not a public relations medium. MIS' function is to keep its constituents informed of the issues, problems and opportunities associated with the coastal zone and the neighboring Gulf of Mexico. News stories or investigative pieces may refer to Sea Grant only as the provider of the article. Controversial issues such as bycatch or public versus private water rights required an informed decision-making process. MIS is recognized as the non-adversarial provider of that information.

Fulfillment of this role could take many forms, but MIS concentrates on its magazine, *Texas Shores*, the media relations effort and the website. The magazine format of *Texas Shores* accommodates an in-depth investigation of current issues and provides a forum for all sides to express their opinions on occasionally contentious matters. As of Feb. 28, 1998, there were 4,700 subscribers to *Texas Shores;* an additional 500 copies are sent to various state offices, aquaria and MAS offices.

The quickest and least expensive method of communicating with the general public has been through news releases but the advent of the electronic superhighway is changing this routine. MIS is not at a point of relying totally on electronic transmission and the worldwide web, because all

areas of its constituency are not linked to the web, but this could become the focus of future years.

Research results are reported by all three methods — magazine, news release, website — in articles designed for easy comprehension. While technical publications that allow scientists to converse exclusively with other scientists fulfill a purpose, they have less importance in communications programs with limited resources. MIS expenditures are geared toward the general public and the policymakers, most of whom are not scientists.

MIS, like Texas Sea Grant as a whole, believes little is accomplished in a vacuum, which is one explanation for the Sharing Our Gulf—A Challenge for Us All Conference that will take place in June 1998 at Texas A&M. This conference will be the culmination of nearly a year-long effort that began as a meeting on sea turtles and evolved into setting the stage for a dialog on the status of the Gulf itself and how interested people in the five Gulf states and Mexico can reach common ground.

Sharing Our Gulf is intended for government officials, researchers, regulators, those in the petrochemical industries, commercial and recreational fishermen, conservationists, teachers, students, and the general public. It is believed to be the first of its kind in the region, where the emphasis will be on an exchange of opinions rather than lectures by scientists.

While any true evaluation of MIS' efforts should be determined by the users of the material produced, peer recognition is often considered an indicator of success. *Texas Shores* was recognized by the Council for Advancement and Support of Education (CASE) in each of the three years covered by this report, 1995, 1996 and 1997, and current editor Jim Hiney was recognized in 1997. The magazine was similarly honored by the International Association of Business Communicators (IABC).

Either CASE or IABC also presented awards to The **Gulf of Mexico Repair Kit**, a joint project with the Gulf of Mexico Program that resulted in a flipchart now distributed in all five Gulf states, **Hurricane!**, a bilingual magazine-style preparation guide for Texas residents, and **Don't Pollute, A Potti-training Manual for Boats.**

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October 1995

Researchers hope to unearth benefits from dredge disposal. (Guillory)

Texas Shores — Taura virus. (Hiney)

November 1995

Stickney named new Sea Grant director. (Guillory)

Cost effective aquaculture. (Guillory)

December 1995

Shrimp release sign major restocking efforts possible. (Guillory)

Determining mussel makeup may help thwart invasion of nuisance. (Guillory)

January 1996

Texas Shores—Coastal Management (Hiney)

February 1996

Gulf of Mexico waste management education program included in environmental success index. (Hiney)

Marine Advisory Service, 4-H offer teachers training. (Sulak)

If everybody had an ocean, like Matagorda Bay .... (Sulak)

Emergency red snapper regs expected. (Sulak)

March 1996

Bycatch discussed at Galveston symposium. (Sulak)
Workshops scheduled for shrimpers. (Sulak)
Bilingual safety flip chart could save your life. (Heatherington)
Do you know all the dangers of the water? (Heatherington)

April 1996

New book lists more than 11,000 obstructions in Gulf. (Broussard)
Save the sea turtles, report sightings. (Heatherington)
Tillman named Brazoria County marine agent. (Sulak)

May 1996

Younger named marine education specialist. (Sulak)
Louisiana's southern flounder resource overfished. (Heatherington)
Texas Shores—Seafood safety. (Hiney)
Sea Safari seeking student artists. (Sulak)

June 1996

Webb named Matagorda County agent. (Sulak)
Tillman leads group to Watershed '96. (Sulak)
Catfish kill confounds coastals. (Sulak)
River Run '96 coming soon. (Sulak)

July 1996

Dolphin strandings on record pace for Texas coast. (Sulak)
Egging on the turtles at Padre Island. (Sulak)
Sargent citizens plant seeds of hope. (Sulak)
Gulf shrimp season off to slow start. (Sulak)
How to deal with stressed fish? (Sulak)
Clarification on dolphin release. (Sulak)
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August 1996

What to do in the midst of a Hurricane! (Heatherington)
Texas Shores—shipwrecks! (Hiney)
From bayous to bays: O'Connell named new marine agent for Calhoun. (Sulak)

September 1996

Sea Grant works for Cameron County (Sulak)
Sea Grant works for Brazoria County (Sulak)
Sea Grant works for Marine Industry (Sulak)
Sea Grant works for Galveston County (Sulak)
Sea Grant works for Commercial Fisheries (Sulak)
Sea Grant works for Seafood Industry (Sulak)
Sea Grant works for Matagorda County (Sulak)
Sea Grant works for San Patricio and Aransas Counties (Sulak)
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Advancing our Understanding of the Marine Environment (op-ed) (Stickney)
Coming to a modem near you (Sea Grant gets a Web Page) (Sulak)

October 1996

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November 1996

Catfish Kill Continues (Sulak)
No Miracle Cure for Whale (Sulak)

December 1996

Ahoy, Mates! (Heatherington)
Eating Raw Oysters: Are you at Risk? (Sulak)

January 1997

Texas Shores - Winter 1997 Press Release (Hiney)
Marine Advisory Service Adds Environmental Quality Specialists (Sulak)
Niña Sails into Palacios (Sulak)

February 1997

Sailing through the Mists to Palacios (Sulak)
Sea Grant Program Rated an Environmental Success (Sulak)
The Workshop You've Waited for with Baited Breath (Sulak)
Love Leads Education Assistant to Palacios (Sulak)
Boaters Get Chance to be a Part of History (Sulak)

March 1997

Stickney Announces Sea Grant to Texas A&M (Broussard)
Slow and Steady Wins the Race: Owens' Research Continues to Make Gains (Magee)
Safety Scores Points at Galveston Seminar (Sulak)
What's in the Future for the Offshore Industry? (Sulak)
Volunteers Needed for Duty Aboard the Niña (Sulak)
"The Return of the Kemp's ridley: New Documentary Chronicles Historic Comeback" (Magee)
Are You up to the Sail of the Century? (Sulak)
A Common Sense Prescription for a Healthier Gulf (Magee)
What If There Were a Major Oil Spill and Nobody Came? (Sulak)

April 1997

One-way Tickets: Houston Pollutants Don't come home from the Beach (Magee)
Workshop Can Help Avoid Fishing Tournament Troubles (Sulak)
Mussels Throwing Painless Punches at the Texas Coast-So Far (Magee)
Workshop Can Help Avoid fishing Tournament Troubles (Sulak)
Palacios to Host Elderhostel (Sulak)
Could the Rumbling in the Distance be a Second Oil Boom? (Sulak)
Symposium to Focus on Sea-librities (Magee)
Bycatch Rules to Take Effect in Fall (Sulak)
Texas Shores Spring 1997 Press Release - Brown Tide (Hiney)

May 1997

A Little Reading Can Make Everything Just Beachy (Sulak)

June 1997

Seafood Sizzles in the Summer (Magee)

Sea Grant Reauthorization Passes (Sulak)

Airing out a Smelly Problem (Sulak)

July 1997

Texas Shores Summer 1997 Press Release- Kemp's Ridleys' Return (Hiney)

Submissions Sought for Gulf Education Guide (Sulak)

Be Ready with "Hurricane" (Sulak)

Fishermen, Aquaculturists, Regulators, Environmentalists Give Testimony on Shrimp Viruses (Sulak)

Reviews Mixed on Gulf Shrimp Season (Sulak)

August 1997

4-H Fishing for a Few Good Folks for New Program (Sulak)

Conference Seeks Common Ground for Gulf Users (Magee)

September 1997

HACCP Spells Out Ways to Safer Food Supply (Sulak)

Red Tide Hits Texas Coast (Sulak)

October 1997

Texas Shores Fall 1997 - Press Release (Hiney)

Aggie Graduate Student to Represent Texas Sea Grant College Program in Washington (Magee)

December 1997

Marine Safety Conference Planned for March (Magee)

Marine Outlook Conference Looks to Future (Magee)

January 1998

Players in Red Snapper Debate to Air Differences in June (Toups)

Jefferson/Chambers Counties Get New Marine Agent (Toups

February 1998

Texas Sea Grant Receives $1.7 Million in Grant Funds (Broussard)

Congress Approves Renewal of National Sea Grant Program (Broussard)

Progress and Completion Reports for Grants Funded Prior to March 1, 1997

Aquaculture

Rearing of select *Penaeus vannamei* stocks to broodstock for incorporation into the U.S. commercial shrimp industry

Nature of the Problem and Approach

Taura syndrome, a viral condition in penaeid shrimp, is currently the most catastrophic threat to the U.S. commercial shrimp farming industry. Commercial shrimp farms do not have the facilities, in terms of manpower, space or time, to commit to developing select stocks for ultimate inclusion into their commercial broodstock programs. The Aquaculture Management Associates facility in Caldwell, Tex., isolated from the coast by 200 miles, is of an appropriate size and configuration to maintain the necessary environmental controls to facilitate continued growth throughout the winter months. This gave the U.S. shrimp industry the possibility of incorporating two different selected stocks of potentially Taura-resistant shrimp into commercial reproduction programs in the spring of 1997.

Results

At the time Sea Grant funding was requested (Fall 1996), Aquaculture Management Associates held approximately 500 juvenile shrimp (*P. vannamei*) in its Caldwell recirculating. The population consisted of offspring of survivors of an outbreak of "Taura" disease at the Harlingen Shrimp Farm the previous year.

Prior to the release of funds, a winter storm destroyed the plastic greenhouse-type cover over the shrimp rearing facility and with it, the shrimp then in culture. With the arrival of Sea Grant funds, a new cover was obtained and installed (February 1997). While the system was down, tanks were drained and cleaned, new synthetic seawater ("Bio-Marine Mix") was prepared and fresh shrimp feed (Rangen, 45 percent protein) was purchased and placed into cool storage. Subsequently, a supplement of fresh squid was used with the prepared feed.

In August 1996, the Oceanic Institute in Hawaii committed to supply AMA with 8,000 to 10,000 postlarval *P. vannamei* from its next successful hatchery production of specially-bred, "Taura resistant" shrimp. The anticipated date of shipment, September 15, 1996, was postponed several times until May 1997, when the first shrimp arrived. Each expected shipment date was postponed due to shortages at the hatchery. The shipment of shrimp, which arrived in May 1997, contained 1,600 of an expected 4,000 PLs. A second and final shipment of 2,200 postlarvae arrived in July 1997.

The two shipments of postlarval *P. vannamei* were reared for 6 weeks in the nursery system. At the time of transfer to the grow-out system, the two batches had survival rates of 85 percent (the batch of 1,600 PLs) and 72 percent (the batch of 2,200 PLs) and mean weights of 1.2 g and 0.8g, respectively.

The cost of maintaining the facility in readiness for the anticipated arrival of postlarvae, accompanied by the delay in receiving those shrimp stocks, shortened the project's working life. Soon after the transfer of the last shrimp from nursery to grow-out (mid-September 1997), Sea Grant funds were exhausted. Private funding supported the project through the winter season, 1997-1998, and continues to maintain the shrimp rearing program at a minimal level.

The final production, approximately 100 to 200 shrimp averaging 25-30g, will be transferred to the Harlingen Shrimp Farm or to another site.

The overall accomplishments of the project, while short of the stated objectives, were, nonetheless, successful in:

1. rearing the specially-selected shrimp for distribution to the U.S. commercial shrimp industry, and
2. continuing to demonstrate the technical feasibility of rearing *Penaeus vannamei* in a recirculating, synthetic seawater system.

The benefits derived from this project are:

1. providing an additional source of *P. vannamei*, specially-selected to be "Taura-resistant," and
2. support for the principle of rearing marine shrimp or other aquatic species in recirculating culture systems.

Publications and Presentations

None

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Automated Monitoring and Intelligent Control of Environmental Conditions and Water Filtration for Commercial, Recirculating Finfish Fingerling Production

Nature of the Problem

Intensive aquaculture systems are being used increasingly around the world, especially in developed nations. The availability of high-quality water is shrinking while the regulations on the quality of the discharged water are rapidly increasing. These trends indicate that recirculation of system water is inevitable for all intensive aquaculture systems. Despite the current need for improved recirculation, the cost of the best currently available filtration technology means that the profit margin of recirculating systems does not yet justify that technology except for very high-value species such as marine finfish fingerlings. The major problems associated with modern filtration technology include the need to develop cost-effective filtration of metabolic nitrogen waste products (NH_4, NO_2^- and NO_3^-) and particulates from uneaten and undigested feed that result in high BOD and COD levels.

Results

The original objective was to design a commercial control system for HarvestFresh Seafoods, Inc. However, frequent changes in their management staff (three different management changes occurred during the 24 months of the project) and a complete shift in culture philosophy pre-vented the installation of the fully integrated system although an automated spreadsheet system was installed. Effort on this objective focused on two subsystems, the first for management of indoor recirculating systems and the second for pond management.

For the indoor recirculating systems, a foam fractionator to aid in the removal of dissolved and particulate organics from the water was designed, constructed and installed. The fractionator also stripped CO_2. The stripping of CO_2 and removal of organics solved the pH drop problem in the indoor systems, allowing the operator to increase biomass without increasing the use of buffering chemicals. At the start of the project, the cost estimated to buffer the system was estimated at $200/raceway/week at operating biomasses above 45,000 lb/raceway. The farm was forced to operate at densities near 30,000 lb/raceway and to increase the rate of water exchange (>20 percent/day) because of this problem. During the course of the grant, densities at the farm were further reduced and water exchange increased to exceed 100 percent/day. In fact, the existing indoor filtration systems failed to the point where the tanks and raceways were operated totally flow-through. As remediation, it was the recommendation of the researchers to install a commercial upflow bead filter on one tank and to automate that filter's operation. However, the fish farm failed to install it as suggested and never did operate the tank in a recirculating mode. As a result, no effective improvements in nitrification using bead filters or denitrification using the bioreactor that was proposed could be made; essentially HarvestFresh abandoned the use of recirculating system technology.

For the pond management aspect of the research, the researchers designed a manual input feed management program to accommodate the objective of predicting feeding rates in each pond and to predict growth rates. Deviations from predicted values would be flagged and weekly reports prepared to understand feed utilization and cash flow. The situation was confounded when the manager for which this system was designed left the company and his replacement was not interested in the program. The researchers had also designed a pond aeration management system to maintain dissolved oxygen concentrations in the ponds and provided the design criteria to a vendor who prepared a very economical bid for them. The system would have reduced oxygen fluctuations, saved electricity and provided weekly and monthly reports on each pond. Those needs were identified by HarvestFresh's staff as key labor-saving management tools: however, management did not purchase the system or pursue the issue further.

Data to characterize and quantify the nitrogen waste outputs for commercial fingerling production system based on environmental and feeding management practices were collected on-site by HarvestFresh staff and by Marine Biological Institute (MBI) staff; however, the evolving nature of HarvestFresh's filtration system management resulted in incomplete data collection because of frequently changing operational procedures. The eventual change to flow-through operation effectively subverted this objective.

The next two objectives involved laboratory research at MBI to facilitate assessment of accomplish-

ments. An automated upflow bead filter was designed and fabricated. That filter has special insertion ports containing oxidation-reduction potential (ORP), dissolved oxygen and pH probes within the bead bed to assay the metabolic state of the aerobic nitrifying bacteria. The incoming data have been used to automate and to optimize backwashing of the bead filter, reducing water loss and maximizing nitrification rates. The prototype system was used for 18 months on a shrimp production system, operating at commercial densities (>100 shrimp/m^2). A patent application and scientific papers will follow.

A denitrifying bioreactor was added to the prototype upflow bead filtration system and Stella™ modeling software was used to interactively model the function of different nitrification filters and the denitrification bioreactor. In addition to the basic interactions between nitrifying and denitrifying filters, the effects of biomass and feed management were analyzed by the model. A version of the model was included in a patent application (Serial Number 08/881,718) and a submitted manuscript.

An objective to produce a CD-ROM complete with hypertext indexing to demonstrate the technology used in the commercial fingerling production system was to begin in Year 2 and continue into the out years (Years 3 and 4), culminating in a conference or workshop. That activity will not be completed due to the termination of the national funding initiative that supported the research.

While the commercial results might seem disappointing at first, the actual final results are encouraging. The researchers were able to integrate an automated upflow bead filter (nitrification biofilter) with an automated denitrifying bioreactor and produce a model for their performance. This model has been used to design a commercial shrimp production system that is currently under construction. The commercial collaborators on this shrimp production system are spending more than $500,000 to install a biosecure, automated, closed, recirculating raceway system in greenhouses. That system would not be possible without the results from this Sea Grant project. The researchers were also able to secure several Texas Higher Education Coordinating Board technology grants to continue the research program on commercial recirculating systems.

The MBI is currently engaged in negotiations with a new start-up company, Aquatic Feeds and Filters, Inc, Galveston, Tex., for the license of the bioreactor and closed, recirculating system technology. Aquatic Feeds and Filters, Inc. is working in collaboration with Ortech Engineering, Inc., Houston, Tex., to design and manufacture the next generation of automated aquaculture systems based on fuzzy logic control paradigms. That research was funded by the Department of Commerce's Small Business Innovative Research Program. The technology with the most immediate promise is the denitrifying bioreactor that is estimatee to have a potential market of $20 to $45 million in the aquaculture and public aquarium industries. The home aquarium industry could easily add another potential $60 million market. The market beyond aquaculture in the drinking and wastewater industries is orders of magnitude greater. Aquatic Feeds and Filters, Inc. is also negotiating a collaborative relationship concerning the use of denitrification in potable water with EcoMat, Inc., Hayward, Calif., another company that markets denitrification systems. Finally, a commercial collaborator is using the closed recirculating technology developed by MBI to build a biosecure shrimp broodstock production system. That system will provide over 50,000 mature *Penaeus vannamei* for use as broodstock.

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Hyperintensive Production of Red Drum in Recirculating Aquaculture Systems: Optimization of Diet Composition and Feeding Regimes

Nature of the Problem

The research was designed to culminate in the development of optimized diet formulations and feeding strategies that would substantially improve the efficiency of production and nutrient utilization of red drum in intensive, recirculating aquaculture systems with a concomitant reduction in waste production. As a result, the scientific and technological basis for hyperintensive aquaculture of marine fish in recirculating systems would be strengthened so that commercial production can become economically viable and can be conducted in an environmentally sound manner.

Results

This project addressed various aspects of diet formulation and feeding strategies to support further development of hyperintensive aquaculture of red drum in recirculating systems. Digestible protein and energy requirements of red drum for maintenance and maximum growth were quantified in two different laboratory experiments using weight gain and body composition as response criteria. Knowledge of these metabolic requirements should allow diets and feeding regimes to be optimized for maximum production efficiency and nutrient utilization as well as minimum waste production.

Additional laboratory investigations were conducted to establish the effects of dietary energy on nitrogen excretion of red drum. Experiments are in progress to investigate the effects of dissolved oxygen on feed intake and nutrient utilization of red drum so that dissolved oxygen can be integrated into the development of optimal feeding schedules. Results from those studies are providing basic insights concerning nutritional and metabolic requirements of red drum leading to refined practical diet formulations and feeding strategies to improve the efficiency of red drum production and nutrient utilization in intensive, recirculating aquaculture systems with a concomitant reduction in waste production.

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Hyperintensive Production of Red Drum in Recirculating Aquaculture Systems: Optimization of Environment

Nature of the Problem

Optimization of recirculating-systems technology is vital for development of sustainable mariculture. Such optimization must begin with improved understanding of the joint effects of the dominant environmental variables: DO, temperature, salinity, and pH/alkalinity. The project was designed to capitalize on a new approach for estimating joint physiological effects on multiple environmental factors and on convergence of a complementary team of scientists and an innovative aquacultural producer.

The approach used represented a logical extension of F.E.J. Fry's metabolic-scope concept applied to formulate a model of the joint effects of dissolved oxygen, temperature, salinity, and pH/alkalinity on physiological performance of juvenile red drum, based on results of single-factor lab experiments. Subsequent to experimental validation of the model, predictions would be compared with actual performance of red drum in optimized hyperintensive production trials in recirculating systems at HarvestFresh Seafoods, Bacliff, Tex.

Results

Efforts were continued to: (1) evaluate the joint effects of dissolved oxygen concentration (DO), temperature, salinity, and pCO_2/pH/alkalinity on marginal metabolic scope, feed consumption, growth rate, and growth efficiency of juvenile red drum, and (2) model and communicate results of those studies, in the context of optimized regimes for hyperintensive commercial production of red drum in recirculating aquaculture systems.

Growth, feed conversion and the metabolism of juvenile red drum were measured as functions of DO, temperature and salinity in a series of experiments, each lasting eight weeks. Results to date suggest that the joint optima for those three environmental factors are: DO above 5 ppm, salinity near 10 ppt, and temperature near 28°C. An expected reduction in optimum salinity with increasing fish size was not observed when performance was compared over the weight ranges 3-60 g vs. 100-250 g. An additional experiment now underway will seek further resolution of temperature effects and provide an indication of the red drum's sensitivity to pH and related properties of the culture medium.

A conceptual model of metabolic scope, which integrates effects of environment variables on fish performance, has been put into mathematical form and tentatively parameterized for red drum. The quantitative model includes loading effects of salin-

ity, limiting effects of dissolved oxygen, and controlling effects of temperature (for the latter, both transient and steady-state). Planned subsequent experiments will serve to refine and validate the model.

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Environmental Studies

Vegetative Enhancement of Coastal Dredge Disposal Sites for Increased Forage Production and Amended Soil Salinity

Nature of the Problem

This pilot project was designed to help change private landowners'/ranchers' negative perceptions of dredge material as "spoil" to one in which the material would be viewed as a positive asset for enhancing forage production, thus increasing the acquisition of easements for disposal sites along the Gulf Intracoastal Waterway (GIWW). The project was designed to lay a foundation for further investigations on the beneficial uses of dredge materials and set the stage for similar demonstrations along the GIWW. The research involved soil sampling and planting to improve forage species on a site adjacent to East Matagorda Bay on which dredged material was pumped for routine maintenance dredging in 1986.

Results

Forage species were planted on the test plots in May and in the fall of 1997. Bermuda grasses have covered about 40 percent of the area and are growing well. Salt levels have been leached or reduced where forage species are growing very well. Of the species planted, Bermuda grasses sprigged into the area have grown better than seeded varieties especially while the salt levels were still high. Bermuda grass is a sod-type forage that produces both good quantity and quality livestock feed. It also produced good cover that prevents soil erosion and soil crusting. Soil crusting has prevented salt leaching over the years, and prevented plant establishment. The demonstration has been successful in obtaining grass growth. Yields and quality will be evaluated during the 1998 growing season and included in a publication being written on "Benefits of Dredge Material to Ranchers along the Intracoastal Waterway."

Soil salinity was reduced in the study area by various methods. Mechanical tillage, which broke the soil crust and allowed rain water to penetrate into the dredge material and leach salts, was very effective in reducing salt content. Salt levels in plots with mechanical tillage are now only 50 percent as high as sites outside the plots. Adding mulch to the tillage operation, and eventually obtaining grass cover, prevents the soil crust from reforming and will continue the leaching process. Plant species that would grow and accumulate salts for disposal with the plant material did not grow well. The salt level was still too high in the spring for a stands. The activity will be repeated in the early spring to measure the method with respect to salinity reduction. From the results obtained, it is clear that new disposal sites could be productive much earlier than previously thought.

The movements of salts in the dredge material remained higher closer to the GIWW and less at the edge with rain water leaching. The salt leached was a part of the standing water that accumulates on the low, flat soil next to the GIWW. This is a natural part of the ecosystem, and did not affect the adjacent saltwater tolerant native species. This will again be monitored next spring/summer.

The dredge material stayed within 1,000 feet of the GIWW where it was deposited by flow during the dredging operation. The small strip of dredge material close to the GIWW does not change the wildlife habitat or the overall ecosystem. In fact, there are benefits of the elevated dredge site (about 10 cm next to the GIWW) for both livestock and wildlife mammals. The elevated site provided a dry place for bedding of livestock and wildlife next to wet, muddy native pastureland. It also could be a place for hay feeding and supplemental feeding to reduce feed losses. This also causes better grazing distribution of the native forage by livestock due to the bedding site potential.

The original methodology that was delayed a year due to the 1996 drought is back on track. Results indicated good reduction in salt content. This has allowed forage species to be planted and produc-

[3]The work reported on in the three studies on hyperintensive aquaculture systems are part of a collaborative research effort involving the Marine Biomedical Institute of The University of Texas Medical Branch, Texas A&M University, Clemson University, Louisiana State University and HarvestFresh Seafoods to optimize technology for intensive aquaculture of red drum. Funding was through a national initiative administered from the National Sea Grant Office.

tion to occur. Benefits for livestock production, as well as for wildlife habitat have been noted and will be further appraised in 1998. Information is being put into educational materials for use in educating livestock producers along the GIWW about the potential benefits of dredge material.

Publications and Presentations

A publication entitled "The Benefits of Dredge Material to Ranchers along the Intracoastal Waterway" is being prepared for to landowners/ranchers along the GIWW. The only aspect that needs to be added to the draft is the 1998 yield and quality forage information and the wildlife habitat evaluation. Results of this project will be distributed through mail of the publication, through county educational meetings, and through media releases.

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Pollutant Metal Removal and Release via Reactions with Sedimentary Pyrite

Nature of the Problem

Sediments represent the major sink for toxic metals in Galveston Bay. The chemical speciation of toxic metals in sediments exerts a primary influence on their potential bioavailability. Resuspension of sediments via storms and human activities can result in reintroduction of toxic metals to the water column. Also, major seasonal variations in the redox conditions in the water overlying sediments may significantly alter the ability of sediments to sequester toxic metals.

Results

This report covers the fourth and final two-year period of a research project to determine the role that sedimentary sulfide minerals play in controlling the potential availability of toxic metals to organisms. Although this research has general applications to many coastal and estuarine environments, it focused on the Galveston Bay estuary and on Offatts Bayou in particular during this grant period.

The Offatts Bayou basin was created by use of the area as a borrow pit for land fill by the city of Galveston. Restricted exchange of water with the adjacent West Bay results in the basin having low oxygen and sometimes highly sulfidic conditions in its bottom waters during late summer. These conditions can result in the mass mortality of bottom-dwelling macroorganisms. Reactions of toxic metals with dissolved sulfide play an important role in limiting their bioavailability. If the fine sediments in this basin are resuspended at other times when oxic conditions are present, oxidation of the metal sulfides can cause toxic metals to become more readily available to organisms again.

In order to better understand these natural processes, laboratory experiments were conducted to further quantify the techniques used to determine the association of toxic metals with different sulfide mineral phases. An interesting finding of practical significance is that the metal sulfides of some metals, such as cadmium, lead and zinc, were easily extractable and can not be differentiated from oxides of those metals using available chemical leaching techniques, whereas the metal sulfides of mercury and copper can be readily discerned by leaching methods from their oxides. These results are consistent with a large number of measurements made earlier in this project on the Galveston Bay estuary and indicate that cadmium, lead and zinc are not significantly coprecipitated with the major and very insoluble iron sulfide mineral pyrite.

Earlier work on this project had indicated a rather peculiar behavior of some metals when sulfidic sediments were exposed to oxic waters, which can occur with storms, shrimp trawling and dredging activities. Consequently, further studies were made of this process as well. The general observation was that dissolved iron could substantially increase oxidation rates. The practical significance of this is that, during resuspension of sediments, the bioavailability of metals such as cadmium, lead and zinc are vastly more likely to be strongly influenced by oxidative processes than metals such as mercury and copper.

In summary, this project has demonstrated that interactions between toxic metals and sedimentary sulfide are important in the Galveston Bay estuary and play an important role in controlling the bioavailability of toxic metals. It has also shown that different metals can have very different behavior if either natural process or human activities cause them to become resuspended in oxic waters.

Human activities in the Galveston Bay estuary that lead to resuspension of sediments can result in the oxidation of toxic-metal sulfides into more bioavailable forms. Therefore, care should be taken in large operations such as dredging ship channels in contaminated areas. Experimental oxidation studies have shown that the rate of metal sulfide mineral oxidation closely corresponds to the solubility of the metal sulfide and can be catalyzed by the

presence of iron.

Offatts Bayou, which was extensively deepened, undergoes very wide changes in the redox conditions of its bottom waters that can significantly influence the chemistry of toxic metals on a seasonal basis. In some years, the deeper waters can even become sulfidic due to restricted circulation in this basin, leading to extensive sulfidization of metals and mortality of bottom dwelling macroorganisms.

A major effort was put into further refining and investigating techniques for determining the speciation of toxic metals in sediments, with particular emphasis on metal sulfides. This consisted of determining how pure metal sulfides (both commercially available and synthesized) extracted with different reagents under different conditions. Tests were also conducted using adsorbed and coprecipitated metals with the iron sulfide mineral mackinawite.

Apparently due to weather conditions during two summers, deep water in Offatts Bayou did not become sufficiently anoxic to reach sulfidic conditions as anticipated from earlier research. This points to the need for further research to establish predictive models for the environmental factors that can result in these extreme negative conditions.

Work was begun on a chemostated "gill" benthic chamber for long-term deployment, which is necessary to measure toxic metal fluxes from sediments to overlying waters. This resulted in further funding for this project from the Naval Research Laboratory and a proposal for application to the Texas Coastal region has been submitted to EPA.

The results of this research have been disseminated via technical journal articles and scientific talks at higher educational institutions and national scientific meetings. We are currently working with Sea Grant personnel to provide an article on Offatts Bayou for general consumption and a Ph.D. dissertation was completed largely through the support of this grant.

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Hydrodynamic and Circulation Data Set for Matagorda Bay

Nature of the Problem

Circulation processes are the basis for the distribution of parameters in an estuary, but useful measurements are rare because they are labor-intensive and must be sustained over a long period of time at many stations in the interior of the bay. A 1950s data set from Matagorda Bay was recently recovered that offers great potential value not only in explicating the mechanics of circulation processes in a Gulf bay, but in direct application to several environmental management problems specific to the bay, including the effect of a recent river diversion into the estuary, a proposal to deepen the ship channel, and remediation of mercury contamination.

The recovered data set relates to an extensive hydrodynamic survey of the bay system that included current measurements over many tidal cycles, salinity at a network of stations throughout the bay, and a system of eight consistently leveled tide gauges. The survey was carried out over a year, encountering a range of hydrometeorological conditions. The objective in this study was to digitize the data in permanent form for dissemination to estuarine scientists and to subject those data to preliminary analyses to determine the principal processes controlling circulation in the estuary.

Results

Objective (1): The task of digitizing the entire hydrodynamic data base is approximately 80 percent complete. In particular, all of the tide data have now been digitized (which was the major effort) and subjected to Q/A procedures. At present, key-

boarding is underway on the salinity data and a residual of miscellaneous field measurements.

Objective (2): Compilation into a comprehensive digital data base is estimated to be about 50 percent complete. When the proposal was originally submitted, the concept was to provide a data base to be disseminated on magnetic medium. In the interim CD-ROM technology has become very economical, and the plan has been altered to employ that medium for distribution of the database.

Objective (3): Clearly, the preliminary analysis of data must await completion of the digitization process. However, coding of several utilitarian vector and scalar display programs has been completed. Those programs will become much of the basis for analysis and will be included as a part of the final report to Sea Grant.

Since there is not yet a project report or digital data file available for dissemination, the outreach accomplishments of this project are minimal. However, some of the data compiled have been released to the project team for the Superfund project in Lavaca Bay, where they have benefited some of the analyses and modeling on that study.

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FISHERIES

The Reproductive and Migratory Biology of Sea Turtles in the Gulf of Mexico

Nature of the Problem and Approach

As recommended in species recovery plans, the habitat research effort on the endangered sea turtles of the Gulf of Mexico should be increased. This is important in improving ways to protect the turtles while at the same time minimizing impacts on fishing. To improve population models, conservationists need to know the rate of new female recruitment and the sex ratios of immature animals in all populations. The population genetics of most Gulf of Mexico sea turtles are also still largely unknown.

This research represents a continuation of field studies that have been underway at Rancho Nuevo, Mexico, in which laparoscopy, endocrinology and ultrasonography are used to determine if new Kemp's ridleys are recruiting into the population. Habitat studies at Rancho Nuevo and the Flower Gardens using radio and sonic transmitters to study movement, reproductive and feeding needs for green and loggerhead turtlesd were also proposed. Other objectives were to again use testosterone to develop sex ratio information on all species and microsatellite DNA and mtDNA to study population affinities.

Results

In terms of reproductive development both juvenile Kemp's ridleys (Sabine Pass and Padre Island) and loggerheads (Flower Garden Banks National Marine Sanctuary) are being studied. Reproductive development is clearly very slow and may take decades. Natural sex ratios are showing a tendency to be skewed toward females at two major sampling sites (Sabine Pass, Texas and Pamlico Sound, N.C.). Several collaborative projects are still in progress including work with Dr. André Landry at Texas A&M-Galveston and National Marine Fisheries Service scientists in North Carolina, Florida, Puerto Rico as well as several collaborators in other countries.

After two years of field work at Rancho Nuevo the ultrasound research evaluations of the ovaries are ambiguous in determining new recruits to the nesting population. None of the turtles we have ultrasounded appear to be clearly new recruits and yet it has been documented that the number of nesting turtles at Rancho Nuevo is increasing. Research on the Olive ridley in the Pacific was conducted in January 1998 (with support from sources other than Sea Grant) to determine if the confusion associated with the image data can be resolved.

Our graduate student Emma Hickerson fitted two loggerhead turtles with satellite transmitters at the

Flower Gardens. The first turtle (Triton) is one of the longest continuously tracked turtles ever studied. It and its fellow reef resident have both shown a surprising degree of site fidelity. They appear to forage in and around the reefs during the day in deeper water and rest at night in and on the reef. This result does not support the contention of offshore fishermen that sea turtles are not in those deeper habitats. Many other turtles, including hawksbills and a single Kemp's ridley, have also been documented at the Flower Gardens reefs on a more transient basis.

Samples have been collected from loggerheads, ridleys and green sea turtles for analyses which are still in progress. In addition this research is a component of the thesis of Kristine Kichler Holder who completed her degree in 1996. Her two major and important findings were that there is still a very high degree of genetic variability in the endangered Kemp's ridleys of the Gulf of Mexico. This is important since it refutes the suggestion that the species is doomed due to the hypothetical genetic bottleneck problem seen in other endangered species. The second important finding is that individual clutches of ridleys have multiple paternity. This is one of the first times this has been clearly documented in sea turtles and suggests that male numbers are adequate even though males are rarely seen.

As a bonus benefit for the Sea Grant program, three advanced sea turtle courses have been presented to U.S. and international graduate students, reaching more than 60 individuals from seven countries in the Americas. In addition, plans for a unique Symposium "Sharing Our Gulf: A Challenge For Us All" are well underway with the dates set for June 10-12, 1998, at the George Bush Library and Conference Center on the Texas A&M University campus.

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MARINE BIOTECHNOLOGY

Biotechnology of Gonad-Inhibiting Hormone to Improve Penaeid Shrimp Aquaculture

Nature of the Problem

To domesticate shrimp, it is important to develop animals that are adapted to aquaculture conditions. This can be accomplished by understanding the physiological bases for shrimp growth and reproduction. The sinus glands secrete a peptide hormone that inhibits gonadal maturation. Presently, one eyestalk is removed to eliminate one of the sources for growth inhibiting hormone (GIH), resulting in onset of reproduction. Sinus gland removal affects the health of the shrimp and results in uncontrolled reproduction with metabolic exhaustion.

Eyestalk ablation shortens the reproductive life of female shrimp and reduces overall fecundity and nauplius quality. It is essential to overcome the problem of stimulating reproduction without eyestalk ablation to preserve female shrimp for use in breeding programs for genetic improvement and adaptation. Therefore, it is essential to isolate and characterize GIH to devise peptide biotechnology strategies to suppress GIH effects. Because of the scarcity of adult female shrimp it is not possible to undertake GIH isolation from *P. vannamei* based on bioassays to identify hormone activity. Instead, all of the major peptides will have to be isolated from the sinus glands and based on general properties of several GIH's, isolated from other crustaceans, it should be possible to identify putative shrimp GIH's.

Results

Individual sinus glands were collected from shrimp eyestalks and the peptides extracted by acetic acid. The acetic acid-soluble peptides were separated by HPLC. The goal was to determine the molecular weights of each isolated HPLC peak by laser mass spectrometry. MIH/CHH/GIH-family peptides are all in the 7-9 kDa molecular weight range, and peptides of that size were the focus of amino acid analysis and sequencing.

Nine peptide components were isolated by HPLC that meet the criteria of being in the MIH/CHH/GIH peptide family based on molecular weights in the 7-9 kDa range and contain disulfide bonds. The most abundant of those peptides have been sequenced. Samples of the sequenced peptides were sent to Dr. Hans Laufer (University of Connecticut) for analysis in crustacean hyperglycemic hormone- and mandibular organ-inhibiting hormone (MOIH) assays. A MOIH assay was established using crayfish mandibular organs, and s similar assay is being developed for *Macrobrachium rosenbergii* mandibular organs. The MOIH assay may be used to analyze the isolated peptides, if Dr. Laufer is unable to perform the assays.

Four peptides of the putative MIH/CHH/GIH family have been sequenced in their entirety (PK20, PK26, PK27) or partially (PK28). Three of the peptides are unique (PK20, PK27 and PK28). PK26 is identical with PK27 except for missing six amino acids at the C-terminus of PK26. It is likely that PK26 is a degradation product of PK27. PK20 is blocked on the C-terminus. The *P. vannamei* peptides have been matched with sequences reported from lobster (*Homarus*) CHH-A and CHH-B, MIH, GIH and VIH and a reported *P. vannamei* MIH. The *Homarus* CHH and MIH have similarities to all of the shrimp peptides, but the putative GIH and VIH, although similar, also have distinct differences from the shrimp peptides. The isolation-sequence analysis studies have been terminated due to the departure of the, Dr. T.K. Hayes, co-principal investigator, from the project. However, sufficient sequence data were obtained to permit the research to move forward on the final objective of developing monoclonal antibodies to a peptide with potential GIH activity.

Of the *P. vannamei* sinus gland peptides that were sequenced, PK20 and PK27 were selected as having the greatest potential for GIH activity. C-terminal amino acid sequences of PK20 and PK27 were synthesized and conjugated to ovalbumin for use in preparation of monoclonal antibodies. The antibodies have been prepared. Three of the resulting monoclonal antibodies have monospecificity for PK27 and one crossreacts with both PK20 and PK27. The ascites fluid that is the last stage of the antibody development is being investigated.

Currently, 80 to 120 female *P. vannamei* are available for use in *in vivo* injection studies. The antibody will be tested by injection into intact, mature females. Controls will receive injections of nonspecific protein (bovine serum albumin or ovalbumin). Eyestalk ablated females will be used as positive controls to demonstrate the pattern and timing for maturation of oocytes in the absence of endogenous GIH, as induced by standard methods.

Recent studies in other laboratories suggest that methyl farnesoate (MF), a product of the crustacean mandibular organ (MD), may be essential for reproductive maturation of crustaceans just as its insect counterpart, juvenile hormone, stimulates ovarian maturation of crustaceans just as its insect counterpart, juvenile hormone, stimulates ovarian maturation in most insect species. A mandibular organ inhibiting hormone (MOIH) is known to be a member of the MIH/CHH/GIH family of peptides and may, in fact, be the putative GIH. As part of a

student dissertation problem, studies have been initiated to examine MOIH of *Macrobrachium*. Using bioassay with mandibular organs of crayfish, a rapid and nearly total inhibition of MF production occurred in isolated MO exposed to extracts of eyestalks or sinus glands from crayfish or *Macrobrachium*. The Sea Grant researchers are using this assay as a basis for separating the peptides of *Macrobrach-ium* sinus glands to identify the MOIH. If time permits, the isolated MOIH will be used to examine its ability to suppress reproductive maturation in eyestalk-ablated female *Macrobrachium*.

The most abundant peptides of the MIH/CHH/GIH family are identified from the eyestalk sinus glands *of P. vannamei* and their amino acid sequences determined. Although similar sequences are published from other crustacean species, information from this research will be published in a journal such as *Peptides* or *Aquaculture* to provide a baseline of information to be used by future aquaculture scientists interested in the endocrinology of *P. vannamei*. As aquaculture progresses and becomes increasingly successful, it will become essential to define and understand all aspects of the physiology of the most desirable aquaculture species, such as *P. vannamei*. Therefore, data obtained on the complement of peptide hormones in the sinus glands of *P. vannamei* will be useful to future investigators.

If the monoclonal antibodies have the desired effect of stimulating reproductive maturation in intact broodstock females, without the need for eyestalk ablation, the cell line will produce an infinite source of antibody that can be provided to aquaculture producers to stimulate reproduction without the negative effects of eyestalk ablation. However, the investigators caution that the selection of the peptides to use in developing the antibodies is based on their best evaluation from structural similarities with other peptides reported in the literature and that have not necessarily been demonstrative to be GIHs.

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Antagonism of Sulfide Intoxication with Marine Enzymes in Cell Carriers Systems

Nature of the Problem

A new conceptual approach is being developed to treat sulfide intoxication. This antidote is needed because there are no clinically useful antagonists to prevent and/or to treat sulfide poisoning. This will be accomplished by employing certain marine animals, which are resistant to sulfide (7.0 mM) because of their very rapid sulfide metabolism. The enzyme involved (sulfide oxidase) will be placed within carrier systems of animals in order to convert an animal, which is sensitive, into a sulfide-resistant animal.

Results

Most of the effort in this project has been focused on two things. First, the isolation of a fast enzyme to hydrogen sulfide. The investigators were able to employ various species of fish including the killifish, as it is a good source to sulfur oxidize. After discussing this matter with Dr. Vetters who made the original observation that sulfide oxidizing enzymes appear in fish, the researchers attempted to isolate the enzyme from killifish. Although a small amount of the enzyme was obtained from killifish, the activity of the enzyme was lower than expected. Isolation of the enzyme accomplished in subsequent purification. The purified enzyme was then encapsulated in resealed annealed red blood cells. Using sodium sulfide as a substrate it is possible to demonstrate that the enzyme encapsulated in red blood cells carriers can oxidize hydrogen sulfide. The research resulted in the development of a new conceptual approach to developing antidotes from sea animals.

The use of carrier systems for encapsulated enzymes has great potential and provides many benefits. It provides a method to develop an antidote, which currently does not exist. There are more than 200 occupations that utilize hydrogen sulfide. According to the combined data from the Texas Railroad Commission and the Texas EPA branch office, in the Texas petroleum industry alone there have been more than 130 accidents in one year with 17 fatalities and 37 individuals developing neuro-psychiatric disturbances and partial paralysis as a result of sulfide intoxication. Although no product is presently available for clinics and hospitals, the approach used in conjunction with this research provides is promising with respect to the potential for developing a new antidote fto hydrogen sulfide poisoning.

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Identification of the Ruffe Oocyte Maturation-inducing Substance and Characterization of Its Receptor[4]

Nature of the Problem and Approach

This work was designed to provide a rational basis for the construction and testing of molecular agents inhibitory to the reproduction of the Eurasian ruffe, thereby blocking the spread of the species throughout the Great Lakes region.

Results

Experiments conducted during the first two years of the project to identified the principal maturation-inducing steroid receptor in Eurasian ruffe. During the first year the dynamics of final oocyte maturation *in vitro* after stimulation with gonadotropin releasing hormone and *in vitro* after stimulation with gonadotropin were determined.

On the basis of those findings a series of *in vitro* final oocyte maturation (FOM) bioassays were conducted in year two. Long-term incubation with a wide range of steroids indicated that two progestins, 17,20ß-dihydroxy-4-pregnen-3-one (17,20ß-P) and 17,20ß,21-trihydroxy-4-pregnen-3-one (20ß-S) were the most potent in inducing oocyte maturation. Short-term assays confirmed that 17,20ß-P and 20ß-S were both potent inducers of FOM and likely candidates as maturation inducing steroids in this species. Measurement of 17,20ß-P and 20ß-S levels in the blood of fish undergoing FOM by radioimmunoassay showed that both steroids were present but that plasma 17,20ß-P concentrations were generally higher. The results suggest that 17,20ß-P is probably the MIS in the ruffe.

Established methods for measurement of the MIS receptor in fish ovaries were unable to detect binding in initial assay attempts. Development of the radioreceptor assay is continuing. Dr. Peter Sorensen with the University of Minnesota is close to completing the identification of the sex pheromone. Receptor assays will be conducted with that steroid in the near future. Once radioreceptor assay protocols for both receptors are established, xenobiotics will be rapidly screened for receptor binding in these assays.

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[4]This work was funded as a subcontract of a broader proposal entitled: Reproduction in the Eurasian ruffe, *Gymnocephalus cernuus*.

MARINE EDUCATION

Marine Field Experiences for Teachers and Students

Nature of the Problem

The project addresses the needs as outlined in the National Sea Grant Program vision statement in terms of understanding the natural earth system and teaching fundamentals of science and its processes. It also addresses the Texas Sea Grant College Program goals of providing marine field experience for primary and secondary school teachers with emphasis on the interdisciplinary nature of marine science.

Results

Twenty-seven teacher workshops hosted 1,148 teachers during the two project years. Eleven Sea Grant sponsored workshops held at The University of Texas Marine Science Institute (UTMSI) and The University of Texas-Pan American Coastal Studies Laboratory (CSL) hosted a total of 400 teachers. Sixteen non-project sponsored workshops held at UTMSI for whole school faculties and other sponsoring groups hosted an additional 748 teachers.

Three of the four scheduled workshops held at CSL were fully subscribed. The exception was the May 1997 Global Change workshop that was canceled after only three teachers signed up. The R/V *Katy* was at South Padre Island in late April/May 1996 and again in May 1997. The boat hosted more than 690 students for seagoing experiences. An additional 232 third grade students from Rio Hondo Elementary participated in a hands-on March field trip experience led by the project investigator. Nineteen K-12 field trip/pier lab follow-up activities were developed and pilot tested. They will be featured in a UTMSI workshop in April 1998.

More than 300 people attended presentations at six professional meetings, the National Science Teachers Association in 1996 and 1997, the Conference for the Advancement of Science Teachers in 1996, the National Marine Educators Association in 1996-1997 and the Texas Statewide Systemic Initiative. Another 250 Boy Scouts and their leaders participated in Oceanography Day held at UTMSI in April 1997, which featured presentations by UTMSI faculty and research staff as well as cruises aboard the R/V *Katy* and R/V *Longhorn*. The scouts collected plankton tows and trawl samples aboard the research vessels with follow-up lab sessions led by MES program staff. This qualified the scouts for their oceanography merit badge.

The handouts and activity outlines provided at each workshop were used to drive brainstorming sessions with the participants at the close of each workshop. This provided the teachers with the opportunity to break up into grade level teams to develop ideas about how to implement the material and information presented at the workshop into their classrooms. Each workshop focused not only on the science topic but also on interdisciplinary nature of marine science and its application across the curriculum. Surveys of the teachers at the end of each workshop also provided the ideas for future workshop topics.

This program impacted a total of 21,645 students and teachers. During the 1995-1997 project years, 27 teacher workshops hosted 1,148 teachers. Eleven workshops were project sponsored and 16 were whole faculty in-service or for other sponsoring groups. An additional 690 Rio Grande Valley students participated in a visiting class research cruise aboard the R/V *Katy* while it was in the Rio Grande Valley in support of the teacher workshop programs. An additional 232 third grade students from Rio Hondo Elementary participated in a marsh field trip led by the principal investigator. Six presentations at professional societies hosted 300 people. An Oceanography Day held at UTMSI hosted more than 250 Boy Scouts and their leaders. Each year, more than 10,000 students from 350 school districts participated in shipboard experiences aboard the R/V *Katy* through the Visiting Class program.

No one else in Texas is providing the quality and quantity of marine field experiences to Texas teachers and students. Demand far exceeds the available dormitory space and boat use opportunities available at UTMSI. The Marine Educational Services program currently accepts only six out of every ten groups that request participation in the programs. Teachers who have participated in the weekend workshops have arranged for their whole faculties to attend in-service programs tailored to their needs. Participation in the workshops expanded the participants' knowledge of the interdisciplinary nature of marine science and exposed them to classroom and laboratory exercises and techniques that they can share with their students. Teachers gained valuable field-trip experience and confidence in their ability to work in the field and use their experience as a tool to enhance classroom activities.

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SOCIAL, ECONOMIC, LEGAL AND POLICY STUDIES

Biological and Economic Impacts of a Limited Entry Program in the Texas Bay and Bait Shrimp Fishery

Nature of the Problem

The 1995 Texas Legislature gave the Texas Parks and Wildlife Department (TPWD) authority over Texas inshore shrimp fisheries, which included limited entry through license limitation. The first fishery to experience the effect of limited entry was the bay and bait shrimp fishery. The TPWD agreed to evaluate the biological and economic impacts of the limited entry plan within four years. To evaluate the biological and economic impacts of the limited entry plan requires a model that includes both a biological and economic component.

The general bioeconomic fisheries simulation model (GBFSM) is a sophisticated policy analysis model developed specifically for the Gulf of Mexico shrimp fishery. Prior to this research the model was composed of a biological and an economic sub model. This project proposed developing a processing sub model, a community impact sub model, and a limited entry sub model and to link each sub model into GBFSM.

Results

Quantitative specification of components of the limited entry license sub model are being developed to account for license buy back, capital stuffing and a license pricing mechanism. Once those quantitative specifications are complete the sub model will be programmed into GBFSM.

The biological sub model has been updated with more recent biological information from the National Marine Fisheries Service and has been tuned to provide an accurate simulation of biological conditions in the fishery.

An econometric model capable of estimating major fishing cost components has been developed to estimate fuel, maintenance and supply, crew share and overhead costs. The model was developed to better understand cost dynamics in the fishery under changing conditions such as limited entry licensure.

Fifteen coastal counties have been identified and aggregated into a coastal regional economy for analysis by IMPLAN, which is the input/output model that will be used to assess the impact of the limited entry license model on regional and state employment and income. In addition to the overall effects of the program on employment and income, eight additional sectors of the economy have been developed from among the 528 sectors available in IMPLAN. These aggregated economic sectors are: shrimp landings sector inputs, shrimp processing sector inputs, common inputs, landing sector outputs, processing sector outputs, local shrimp outlets, community growth and maintenance and local government expenditure.

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AQUACULTURE

The Utilization of Artificial Diets in Intensive Culture of Fish Larvae: Ontogeny of digestive enzymes

Nature of the Problem

The development of sustainable rearing techniques for marine fish larvae is one of the most critical factors influencing the successful production of marine fish species. The survival of marine fish larvae under culture conditions greatly depends on meeting their nutritional requirements through exogenous feeding. Larvae must first ingest food, then digest it by means of enzymatic processes and finally absorb the required essential nutrients for proper development. A better understanding of the digestive system and its functional capabilities in relation to ontogenic processes will be a significant contribution to the progress of marine fish larval rearing techniques. The successful replacement of live food with artificial microparticulate diets is largely dependent on such a knowledge.

Results

The researchers were successful in determining that the digestive enzymes lipase, protease and amylase were present at first feeding in larvae, remained low until larvae reached 4 mm standard length (day 10 post hatch) and increased thereafter. Feeding microparticulate diet (MPD) or live food had no effect on the activity of the digestive enzymes suggesting that dietary regime, availability of prey and possible effects of exogenous enzymes did not significantly influence enzyme activity. Larval size had the strongest influence on digestive enzyme activity; linking enzyme activity with growth and development rate.

Research to determine the role of intracellular digestion on macronutrients by larval red drum is in progress and initial results have been obtained and and frozen samples are ready to be analyzed to complete the work. Intracellular enzyme activity (leucine alanine hydrolase) was found to be present at day 3 (first feeding) and diminished by day 8, while the brush border enzyme (leucine aminopeptidase) associated with extracellular digestion increased from day 3 to day 8. This suggests a shift in emphasis from intracellular to extracellular digestion after the first week posthatch, similar to results from mammals and other vertebrates. The role of diet (live vs. MPD) on these enzymes and changes through day 18 are being evaluated.

Information generated from this research was presented in a session on *Recent Advances in Larval Fish Nutrition* at the World Aquaculture Society conference Aquaculture '98. A manuscript from the first study has been submitted for publication.

The research thus far has found that exogenous enzymes potentially provided by live prey do not increase enzyme activity in larval red drum, thus eliminating one of the suggested values of live prey for growing larvae. Indications are that intracellular enzymes are more important at first feeding than the enzymes in the gut. This result may provide insight into why larvae are not able to grow and develop on MPD during the early stages and will lead to development of diets specific to this life stage with emphasis on ingredients for intracellular digestion.

Publications and Presentations

J.P. Lazo, G.J. Holt and C.R. Arnold. Ontogeny of digestive enzymes in larval red drum *Sciaenops ocellatus* . **Aquaculture Nutrition**. (Submitted for publication.)

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RECRUITMENT INITIATIVE PROJECTS

Recruitment Success of Estuarine-Dependent Marine Fishes: Growth and Natural Mortality of Larval and Juvenile Recruits

Nature of the Problem and Approach

Fisheries management decisions are often confounded by high variability in recruitment (i.e., year-

class strength). An increased knowledge of the potential causes of this natural variability will aid in providing more enlightened management. Resource managers can generally only directly regulate fishing mortality but other management practices can regulate other biotic and abiotic conditions in the environment. This study provides a basis for potential management of non-fishing mortality through an understanding of the sources of variability in growth and mortality in the nursery habitat.

Results

An epibenthic sled was used to collect recently settled red drum (5 to 10 mm) from nursery sites composed of pure strands of *Thalassia* and *Halodule* seagrass to estimate growth and mortality rates for those fishes. Atlantic croaker larvae and young juveniles were removed from those samples for comparative analysis. Both age-based (from otolith microstructure analysis) and length-based methods were employed to estimate growth and mortality of Atlantic croaker from each site.

One objective of the study was to estimate the growth and mortality rates of young red drum in estuarine seagrass habitats. Excellent estimates of growth and mortality were obtained. Growth averaged 0.58 to 0.62 mm d^{-1} for 20- to 40-day-old larvae for the 1994 and 1995 year-classes. Interannual variability was minimal for both parameters. Mortality rates ranged from 12.5 to 13% d^{-1} and varied little between years.

A second objective was to determine the effects of season, cohort, ontogenetic stage, and habitat on growth and mortality rates of red drum.

Growth rates varied considerably among cohorts but not between the two seagrass habitats. Growth rates were highest for the most abundant cohorts, suggesting nursery areas resources (e.g. space and food) are not limiting red drum growth. Mid-season cohorts showed higher growth rates than either early or late season cohorts.

The project also involved estimating mortality rates due to predation on red drum under varying conditions (e.g. ontogenetic stage, habitat complexity) using *in situ* experimental manipulations. Red drum predation by pinfish predators was significantly higher on mud bottom than in seagrass habitats but did not differ between two seagrass habitats of differing complexity.

Evaluation of the performance of length-based methods against age-based methods for estimating parameters of natural mortality and growth for red drum was also a research objective. The researchers were delayed in obtaining length-based growth analysis software and that analysis is still underway.

Two ancillary projects were completed as part of the funded project. One was a study of annual patterns of recruitment of sciaenid larvae to several seagrass meadows and the other was a comparison of food habits of co-occurring red drum and Atlantic croaker larvae in the seagrass nursery areas. Both studies resulted in publications (listed below). The food habit study produced a master's degree thesis. In addition to a total four publications relating to the primary and ancillary research, 12 presentations based, at least in part, on results of the current project were made at regional and national scientific and technical conferences.

This research produced the first data giving quantified estimates of mortality rates for small red drum in seagrass nursery sites. The information will be beneficial for resource managers in assessing population changes and evaluating stock enhancement programs. The growth rate and predation rate results showed the value of seagrass meadows in the early life of red drum and did not support any suggestion that one species of seagrass was better habitat for red drum than another (specifically, widgeon grass compared to turtle grass).

Publications

Rooker, J.R. and S.A. Holt. 1997. Utilization of subtropical seagrass meadows by newly settled red drum *Sciaenops ocellatus*: patterns of distribution and growth. **Marine Ecology Progress Series** 158: 139-149.

Soto, A. M., G.J. Holt, S.A. Holt, and J.R. Rooker. 1998. Food habits and dietary overlap of newly settled red drum (*Sciaenops ocellatus*) and Atlantic croaker (*Micropogonias undulatus*) from Texas seagrass meadows. **Gulf Research Reports** 10:41-55.

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Recruitment and Post-Recruitment Mortality on Red Drum in Galveston Bay: What Nursery Habitats are Critical

Nature of the Problem

Red drum support an impressive recreational fishery in Texas that has a large economic impact on Texas coastal communities, especially in Galveston Bay which has three times higher fishing pressure than other Texas bays. Despite its economic importance we know little about red drum nursery grounds in bay systems, like Galveston Bay, that do not have seagrasses. Project results will identify essential habitat of young red drum, and provide information critical to the management of red drum and their critical habitats

Results

Intensive field censuses in Galveston Bay using an epibenthic sled designed for this project indicate that newly recruited red drum primarily utilize seagrass and marsh-edge habitats. However, very low cover of seagrass in Galveston Bay prevents this habitat achieving importance as a nursery ground as it has in other locations. Rather, the data demonstrate that red drum utilize the emergent marsh consisting of *Spartina alterniflora* as the primary recruitment habitat in Galveston Bay. Densities of red drum on unvegetated substrate decreased as distance from the marsh edge increased. In controlled mesocosm experiments, red drum preferentially selected habitats with complex structure. Red drum preferred oyster over seagrass, seagrass over marsh and marsh over unvegetated bottom. These patterns of habitat preference were altered by the presence of a predator in a particular habitat. Moreover, hatchery reared fish displayed none of the habitat preferences observed in wild caught red drum.

Growth rates were assessed using otolith microincrement analysis as well as growth in field enclosures. Otoliths of several hundred juvenile red drum were extracted, cleaned and analyzed using an image analysis system. Microincrement analysis indicated there were no significant differences among the growth rates among the various habitats. Preliminary enclosure experiments also indicated that the growth rate among the various habitats were similar. Moreover, the addition of food had no effect on growth rates. Additional growth experiments are planned in order to unequivocally demonstrate that the ultimate cause of differential habitat use is not habitat differences in post-settlement growth.

Mortality rates were assessed using field predator enclosures as well as examining age structure in fish from the various habitats. Our initial experiments indicated that mortality as a consequence of predation by adult pinfish did not vary among seagrass, marsh and unvegetated habitats. However, the manner in which the habitat affects predator-prey associations appears to depend on the predator species used in the experiment. As a result, a series of experiments has been designed to determine precisely how different predators impact red drum in varying habitats.

Given the ambitious nature of this project, relatively few problems were encountered. Preliminary work allowed the investigators to foresee and avoid many logistical and experimental problems. One significant problem involved the construction of field enclosures. In particular, there was concern expressed that all fish placed in enclosures would be recovered. Given the small size of the fish (10-20 mm), this turned out to be a difficult task. To solve this problem, a drop sampler just larger than the enclosure was developed, which formed a seal and allowed the water to be drained and the fish to be recovered. An additional problem emerged when predation rates predation rates were examined. That experiment will be repeated with different types of predators to accurately test the hypothesis that mortality rates vary in the different nursery habitats. To address the above problems a no-cost extension has been requested to provide another sampling season when newly recruited red drum will be available.

This research on red drum nursery grounds in Galveston Bay represents the first intensive effort to understand the habitat needs of this valuable species in locations were seagrasses are absent or rare. The work to date clearly identifies marsh edges as critical habitat in Galveston Bay and it is believed that this information as well as the habitat-specific demographic rates being obtained will be extremely useful to resource mangers. In addition to understanding the processes impacting juvenile recruitment in red drum, collaboration with Marc Mangel at the University of California has allowed for the creation of a series of models based on the red drum data. The models provide a new tool for evaluating the relative importance of different processes impacting exploited stocks, and thus provide insight as to the usefulness of different management options. The models indicate that in addition to the well-documented overexploitation of red drum, habitat degradation in Galveston Bay and elsewhere contributed significantly to the demise of the fishery. Moreover, the models indicate that stocking efforts in locations with compromised nursery grounds will meet with minimal success.

Publications & Presentations

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The Effect of Prey Densities and Nursery Habitat Quality on Penaeid Shrimp Recruitment Success

Nature of the Problem

The influence of densities of march-dwelling macroinvertebrates on attracting and providing food for postlarval shrimp and fish is not well understood. Nor is the influence of variation in salinity at a given location on promoting or inhibiting shrimp recruitment well understood. This research was designed to provide synoptic data that will ultimately permit creation of a predictive model.

Results

The project protocol called for sampling 10 randomly selected sites each collecting trip from among 30 that had previously been established. The winter of 1996 was unusual in that frequent cold fronts came through the Texas coastal zone and the resulting wind blew water out of Galveston Bay and made some sites inaccessible. In trying to maintain the protocol, if sites were inaccessible, the trip was cancelled and the researchers returned to home base. This resulted in almost no collections between January and April 1996. It was then decided that the approach was totally impractical, and thereafter, sampling stations were will sampled randomly, but if upon arrival a site was inaccessible, a substitute sampling station that was accessible was used an alternate. This resulted in some stations being sampled much more frequently than others, but it was the only way to gather data.

This project was intended to provide data for Master of Science student Heather Spivak, and she conducted most of the sampling. Ms. Spivak announced she was pregnant in late 1996 and that her doctor would not allow her to continue sampling. Subsequent sampling was undertaken by the Principal Investigator.

In early 1997 Ms. Spivak decided to quit the graduate program. Another graduate student, Ms. Zuzan Pool, was recruited for the. She arrived on campus and participated in the final few sampling trips. Since beginning in Fall 1997, Ms. Pool has completed analysis of about 6 collections. Sample analysis is still in progress.

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A New Molecular and Statistical Approach to Measure Anthropogenic Impacts

Nature of the Problem

This research is an extension of previous studies that have demonstrated that harpacticoid genetic diversity can detect long-term, sublethal impacts due to proximity to hydrocarbon production platforms in the Gulf of Mexico. Matching funds are sought to apply a new monitoring technique to a sediment quality assessment commissioned by the Corpus Christi Bay National Estuary Program (CCBNEP). Previous studies demonstrated low genetic variability near hydrocarbon production. Development of a new monitoring tool would be useful to a broad range of environmental scientists and managers at the state and federal levels.

The research was designed to: (a) measure meiobenthic abundance and community structure at selected sites; (b) measure environmental parameters affecting meiobenthos; (c) measure harpacticoid genetic diversity; (d) employ multivariate statistical techniques to assess sediment quality; and (e) employ multivariate statistical techniques to determine the best method for monitoring change.

Results

Higher taxonomic identification of meiofuana has

been completed. Harpacticoid species identification has been completed for 47 percent of the samples collected. Preparation for genetic analysis has been completed for 34 percent of the samples collected. Thus far, genetic variability is higher in estuarine populations than offshore populations.

The Sea Grant project is an extension of a CCBNEP project, which has been completed. A sediment quality triad (SQT) study was conducted at 36 sites in the CCBNEP study area. The majority of the sites were located near stormwater outfalls, but other sites of concern (e.g., industrial and domestic outfalls and dredging activity) and reference sites were included for comparison.

Synoptic sediment samples were collected and analyzed for physical characteristics (grain size, total organic carbon), contaminant concentrations (metals, PAHs, PCBs, and pesticides), toxicity using a suite of tests (amphipod and mysid solid-phase, and sea urchin pore water fertilization and embryological development tests), and benthic macrofaunal community structure. This large data matrix was reduced using multivariate analysis to create new variables for each component representing overall means. The new variables were used to conduct the correlation analysis and used to assess ecological health. Two sites were ranked poor for all three components of the SQT, which indicates contaminant-induced degradation. Fourteen sites were good or moderate for all three components, which indicates no contaminant-induced degradation. The remaining 20 sites were ranked poor for toxicity, chemistry or benthic communities, but not all three, which indicates contaminants may be stressing the system, or unmeasured contaminants or other conditions were causing degradation.

Major problems with the genetic techniques applied were not encountered. The researchers had performed 1,800 analyses, and for some unknown reason, were unable to get a reaction to work for nearly six months in 1997. The problems were resolved by replacing all chemicals, pipets, and reoptimizating the DNA extraction and PCR reaction conditions. The original plan was to amplify the 16S gene, but better success was obtained with the CO-I gene.

The project is incomplete,[5] but the approach developed is having an impact on risk assessment. The general statistical approach has been completed, and is being used in other programs to integrate data to assess sediment quality and ecological integrity. The statistical approach was used in an undergraduate honors thesis by Julie Beck, who graduates with a B.S. from The University of Texas at Austin in May 1998. The title of her thesis is: "The effects of storm water outfalls on the benthic macrofauna of Corpus Christi Bay."

[5]Anticipated completion will be prior to the end of calendar 1998.

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Tower-Based Conditional Sampling to Monitor the Impact of Freshwater Management on Coastal Wetlands

Nature of the Problem

Maintaining and improving the condition of coastal wetlands is critical for fisheries in Texas and the United States generally. Many of these ecosystems are deteriorating due to consumption and diversion of freshwater destined for wetlands and estuaries and introduction of nutrients. This research is designed to develop innovative methodology for long-term monitoring of the condition of coastal wetlands, and to develop a better understanding of the mechanisms by which freshwater inflow affects productivity of phytoplankton, zooplankton and emergent plants that are key to recruitment and survival of finfish and shellfish larvae.

Results

Measurements of net carbon exchange (NCE) between the atmosphere and coastal wetlands were used to monitor the impact of freshwater on primary productivity, essential for survival of finfish and shellfish larvae. NCE was measured using conditional sampling, in which carbon exchange is determined from the difference in CO_2 concentration between updrafts and downdrafts in the atmosphere. The methodology was be employed in the Nueces River Delta, near Corpus Christi, Tex., at a location in the estuary where treated municipal wastewater is being used as a source of freshwater to increase primary productivity and at a nearby control site not influenced by the wastewater discharge.

With conditional sampling, 30-minute averages of NCE were obtained 24 hours a day from differences in the CO_2 concentration between updrafts and downdrafts in the atmosphere above the marsh. A conditional sampling system has been in operation in the Nueces River Delta since late June 1997.

Measurements in the Nueces Delta showed that

NCE increased in response to freshwater inflow due to enhanced photosynthesis by emergent plants and phytoplankton and decreased loss of respiratory CO_2 from soil to the atmosphere. Detectable increases in photosynthesis occurred within one day of freshwater inflow. The continuous nature of the NCE measurements allowed dynamic events such as algal blooms to be detected almost immediately.

Conditional sampling measurements of NCE provide a large-scale estimate of total carbon flux and storage and primary productivity. Studies will be conducted in 1998 to determine the contributions of emergent plants, soil and the water column to total NCE.

The only major problem encountered has been associated with the electrical power to the conditional sampling system. The system is powered by 12V batteries charged by solar panels. During the winter power was lost several times due to extended cloudy periods and short day lengths which reduced the effective charging period by the solar panels.

Results to date have provided new information on the dynamics of the response of coastal wetlands to freshwater inflow. Of particular note is that the measurements show when freshwater inflow would be most beneficial for restoring productivity of degraded wetlands systems.

Because of dams and channelization, the Nueces River no longer inundates its delta and estuarine marshes with freshwater, except during floods. As a result, salinity in the delta is high and net primary productivity is low. Two pilot studies dealing with restoration, one involving discharge of treated municipal wastewater into the delta and the other involving diversion channels to direct flow of the river into to delta are underway. Conditional sampling measurements are providing quantitative information on the impact of water management on marsh productivity and on timing of freshwater inflow to achieve greatest benefit.

Publications

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Simulation of Larval Transport from the Texas Coastal Ocean to a Bay

Nature of the Problem

Recruitment of larvae to bays estuaries from their planktonic phase floating in the coastal zone is important for the maintenance of animal populations. An understanding of what controls larval recruitment will provide information required to minimize the deleterious environmental impacts of changes in the coastal environment and maximize the beneficial effects. Such knowledge and practice will provide valuable tools that can be used to sustain important coastal and estuarine fisheries.

Results

The goal of this research is to develop a computer model of coastal currents and larval transport to predict the movement of larvae from the coastal ocean outside of Aransas Pass, Tex., to settling grounds in the Corpus Christi Bay and Aransas Bay region. Physical and biological data (including larval density and distribution, bathymetry, shoreline configuration, water level, salinity, freshwater inflows, wind speed and direction, and current measurements) were compiled. The information was obtained for this modeling study from numerous sources including the Louisiana-Texas Shelf Physical Oceanography Program, Texas Coastal Ocean Observation Network, U.S. National Geophysical Data Center, National Ocean Service, Texas Water Development Board, Texas Automated Buoy System, and The University of Texas Marine Science Institute.

To provide the physical component for a coupled bio-physical model, a three-dimensional finite-element hydrodynamic model developed by the Numerical Methods Laboratory, Thayer School of Engineering at Dartmouth College was applied. Input files for the hydrodynamic model that incorporate the bathymetry, shoreline configuration, and boundary conditions were generated, as was a linear finite-element mesh to represent the study area which encompasses Corpus Christi, Nueces, Redfish, Aransas, Copano, Mission, and St. Charles bays and extends offshore to the 50 m depth contour. The mesh consists of approximately 12,000 nodes and 21,000 elements with a minimum nodal spacing of about 80 m to adequately represent the complex bathymetry of the study area, including the numerous small islands and intersecting channels.

Hydrodynamics of the study area are dominated by subtidal (time scales longer than tidal) variations in water level and currents in the study area associated with the wind regime and offshore changes in sea level. To incorporate the wind forcing and low-

frequency water level variations, the numerical model was modified to include time-dependent water level and wind forcing.

Model calibration for the conditions measured in the summer and fall of 1994 is being performed. Passive-particle tracking has been incorporated into the model to simulate the transport of inactive larvae. To facilitate the dissemination of study results an Internet web page (http:/www-ocean.tamu.edu/~ecomodel/Research/Larval/larval.html) was established which will be augmented as the study progresses.

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A Rapid Quantitative Method for the Measurement of Growth Rate in Marine Ecosystems

Nature of the Problem

This proposal addresses Sea Grant priorities related to environmental health, fisheries management and aquaculture. The measurement of growth rate is a fundamental aspect of determining ecosystem productivity, organism condition, and recruitment in marine systems. Current measurement techniques are often difficult to interpret. The long-range goal of this study is to develop a tool that can be used by the research and natural resource regulatory communities to measure instantaneous growth rate with a single sample.

The measurement of mitosis promoting factor (MPF) activity in all species studied followed procedures developed by the researchers. Species evaluated came from plankton tow samples from the Galveston Bay area and university fish hatcheries in College Station and Galveston. In order to test the feasibility of using MPF activity in mixed assemblages of organisms, fertilized ponds with plankton blooms were sampled. Correlation of oyster growth with MPF activity is being conducted by collecting samples over an extended time period.

Results

Progress has been made in addressing each of the objectives of the research. The first objective was to detect MPF activity in plankton tows from oceanic and estuarine systems. Species sampled included rotifers and copepods along with blue crab, shrimp and oyster larvae. MPF activity was detected in each species. Further refinements of the assay will be required to reliably measure MPF in planktonic communities as the data indicate a large variability between sample replicates. It is suspected that there are enzymes present in homogenates that are not completely inhibited by the standard inhibitors present in the homogenation buffer and that those enzymes deactivate the MPF during the homogenation and storage stages of sample preparation.

The second objective of this research was to measure the MPF activity in planktonic communities from fertilized pond compared to unfertilized ponds. That experiment has been tried once thus far. The results indicate a very large difference in MPF activity between two treatments. However, the samples suffer from the variability mentioned above. Replication or further development of the entire planktonic focus in the proposal will have to wait for further developments of the assay.

The final objective was to correlate MPF activity in growing oysters with known growth rates. Using the samples above, kinetic analyses of oyster MPF have been initiated. This is a necessary step to validate the assay for use in the growth study. The analysis should be completed by June 1998. Spawning has been delayed in 1998 because of cool spring weather, but will be conducted when the oysters become ripe. The minor delay will not affect the scheduled completion date for the research.

Results from a previous NSF grant on the development of a red drum assay were presented at the International Marine Biotechnology Conference'97. Results from the initial detection experiments were conveyed in an associated workshop at that same conference. As a result, several collaborations have been initiated that should widen the application of this growth measurement tool in aquaculture and fisheries management. Dr. Joseph Quatro is interested in pursuing the method to evaluate pH effects on fish among habitats. A collaboration with Dr. John Benzie has been established to utilize the assay for shrimp culture in Australia. A collaboration with Dr. Tom Soniat has been established to use the assay to quantify the effects of parasite loads on oyster growth and mortality in Galveston Bay. Finally, a collaboration with Dr. Marco Saroglia has been establish to investigate growth rates in net culture of Sea Bream in Italy.

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ENVIRONMENTAL STUDIES

Development and Use of an Immuno-Fluorescent Probe for the Texas Brown Tide Alga

Nature of the Problem

An improved method for the identification and enumeration of the Texas brown tide alga is a prerequisite for definitive studies of the ecology of this bloom-causing organism. The optimization of probe specificity and signal will be determined empirically. An optimized protocol will be used in conjunction with a field sampling program to determine the geographic distribution of the Texas brown tide.

Results

The project was terminated and funds returned to Sea Grant. As the project was undergoing the review process, and prior to the allocation of money, a probe was developed for the Texas brown tide organism by independent investigators. Those investigators did not have to adhere to funding demands requiring projects using live animals to undergo approval of sacrificing animals. The current project had been initiated before the investigators learned of the existence of the other probe, which was also developed and tested in Texas waters. Sea Grant was notified about the fact that the current project would duplicate completed work and unexpended monies were returned.

Availability of funds to co-investigator Deyoe was delayed until late March, which slowed progress on the project. Also, Dr. Deyoe was relocated to a new building during the summer of 1997 so his laboratory had to re-established. Despite those factors, the following project activities were completed or in progress at the time of project termination:

- Purchasing: The selection and purchase of the filtering equipment necessary to concentrate cells for use in making the probe and especially for applying the probe to cultured and natural samples of the brown tide was completed. Axenic strains of the brown tide were also purchased.
- Brown tide culture: Brown tide culture and protocol for preparation of the brown tide cells for anti-serum production were in progress at the time of project cancellation. Different formulations of culture media for the brown tide were evaluated to optimize growth rate and yield. The goal was to produce several grams of stabilized brown tide cells in good physiological condition to be used in the production of anti-serum.
- Protocol development: A variety of cell preservation and hybridization protocols were investigated that might improve the sensitivity and specificity of the probe.
- Isolation and culture of endemic algae: Preliminary attempts were made to isolate endemic algal species for use in specificity checks of the probe.

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FISHERIES

Marine Turtles: Symptoms of an Education Necessity

Nature of the Problem

The purpose of this project was to organize, plan, and conduct a symposium on natural resources issues in the Gulf of Mexico. A Sea Grant committee was the core of a larger interdisciplinary organizing committee, which developed a "Symposium Plan" for 1998. Top scientists in the country were recruited in economics, biology, education and conservation to refocus the need for and propose new strategies for problem solving.

Results

The symposium "Sharing Our Gulf: A Challenge For Us All" has been organized and will take place at the George Bush Presidential Conference Center from June 10-12, 1998. More than 120 participants are expected from all the Gulf states, Mexico and the Washington D.C. area. A special mitigation meeting facilitator (Mary Jane Naquin) has assisted the Sea Grant staff and the project investigator in organizing a truly unique strategy for the symposium. The intention is to "roll our sleeves up" and take a hard look at the past, present and the future of marine resource utilization and conservation. The purpose is not to dwell on any one issue (organizers have discovered there are many issues) but rather to evaluate how conflicts are addressed and to come up with new models based on the successes of the past. This meeting will be a first step in establishing a better protocol for integrated conflict management in the future.

The project began with the development of a series of "Status Reports," which are short summaries of a given topic such as whooping cranes, Kemp's ridley sea turtles or Galveston Bay. These are being reviewed by several teachers at this time. Ultimately, they will be incorporated into a set of marine exercises keyed to the Texas Essential Knowledge and Skills series. The entire program is being developed as a web page and/or hard copy series for use in middle school and high school classes. Three graduate level short courses have also been completed in Mexico on the biology and conservation of sea turtles (also part of the project reported in the preceding year).

Several long-term studies are now being completed. Loggerhead sea turtles have been tracked continuously at the Flower Garden Banks National Marine Sanctuary for more than two years. A student, Pam Plotkin, has just published a review on the interaction between behavior of sea turtles and the performance of satellite transmitters. Papers dealing with hibernation and reproductive biology of sea turtles in the Gulf of Mexico are in the final editing stage. Several additional papers have also been published in the past year. A review of the role of endocrinology in the life history of sea turtles was also published in 1997 and a review of techniques for the study of reproductive cycles and endocrinology of sea turtles is in press. Studies on the mating problems in captive sea turtles and the development of a vitellogenin radio immunoassay in sea turtles are being completed.

New Research Directions

As mentioned, a series of studies to develop a vitellogenin assay for marine turtles has been initiated. The basic yolk material is interesting because it has been shown in some juvenile animals to be responsive to "environmental endocrine disrupters." One of the most serious problems being evaluated today in environmental science is the possibility that low levels of pollutants are subtly impacting the reproductive development, maturation and productivity of various vertebrates.

Ancillary Research Topics

A forthcoming Marine Turtle Survival Manual will include a chapter on "Reproductive Cycles and Endocrinology" written by the investigator. A detailed study of the sex ratios and reproductive development of sea turtles in Pamlico Sound, N.C., also has begun in collaboration with the National Marine Fisheries Service.

Technology and Information Transfer

In addition to the traditional publications listed below three Marine Turtle Reproduction and Conservation Workshops were conducted in Mexico in collaboration with the Instituto Nacional de la Pesca. The most recent workshop was held on the Pacific coast in the southern state of Oaxaca (January 1998), with the previous two courses taking place in the spring of 1996 and 1997.

The principal investigator was chosen president of the annual sea turtle symposium. In March 1999 approximately 700 people interested in sea turtle biology and conservation will come from all over the glove to converge on South Padre Island, Tex., for a week of meetings. There will be public lectures, newspaper and television and radio coverage as well as a particular boost for organizations such as Ila Loetscher's Sea Turtles, Inc. (which is trying to build a new museum/holding facility), the Gladys Porter Zoo in Brownsville, Tex., and universities within Texas.

Publications and Presentations

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Hickerson, E., D.W. Owens. 1998. Tracking a subadult *Caretta caretta* through puberty. 18th Annual Symposium on Biology and conservation of Sea Turtles, Mazatlan, Mexico.

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Population Status and Ecology of Kemp's ridley Sea Turtle in a Gulf of Mexico Index Habitat

Nature of the Problem

This research responds to Kemp's ridley Recovery Plan mandates and recommendations by the Turtle Expert Working Group by: (1) continuing long-term, at-sea research identifying abundance over time and detecting changes in size composition with implications for recruitment to the breeding stock; (2) defining the "lost year" or time spent in the pelagic phase; (3) determining the time and size/age at which post-pelagic ridleys invade coastal waters and become vulnerable to fishing activities; (4) identifying age and mortality of the wild stock; and (5) characterizing population dynamics of adults (especially males) off the nesting beach.

Results

The objective aimed at documenting survival, distribution, age and growth in hatchling and post-pelagic life stages was successfully completed through the in-water capture and analysis of 100 sea turtles from the upper Texas coast in 1997. In-

cluded were 94 Kemp's ridleys, 3 loggerheads, 2 hawksbills and 1 green sea turtles.

The objective to characterize the status and population dynamics of juvenile-adult assemblages utilizing nearshore habitat of the western Gulf was also successfully completed. An age-class analysis was conducted with of the aforementioned 94 Kemp's ridleys, which ranged in carapace length from 20 to 60 cm and were utilizing nearshore habitat along the upper Texas coast.

Another goal of the research was to conduct an exploratory assessment of adults (especially males) off the Rancho Nuevo nesting beach. Collaboration with permit specialists at the U.S. Fish and Wildlife Service, biologists with the Kemp's ridley Working Group, and Dr. David Owens at Texas A&M University facilitated this assessment and set the stage for in-water capture operations to be conducted as early as Spring 1999.

To better assess chemical/biological dynamics of trace-metal loading in ridley population constituents a comparison of mercury levels found in the blood and carapace tissue of Kemp's ridleys captured in 1997 was made.

No new research directions were pursued during the course of the project. However, project results have led the principal investigator to solicit funds to: (1) assess population status of the endangered Kemp's ridley in nearshore habitats east of the Sea Grant study area; (2) determine the impact of capture in TED-equipped shrimp trawls on the potential for subsequent multiple capture and survival of this species; and (3) begin research on reproductive ecology to better understand the seasonal use of nearshore waters of the Gulf by older subadult and adult ridleys.

One ancillary research project associated with the Sea Grant study was related to investigating the impact of hypoxic zones on sea turtle distribution in the northern Gulf of Mexico. This has led to an invited presentation at a workshop entitled "Effects of Hypoxia on Living Resources in the Northern Gulf of Mexico" held in Baton Rouge, La., in March 1998. The principal investigator's technical abstract entitled "Sea Turtles and Hypoxia in the Northwest Gulf of Mexico: Any Cause for Concern?" was included in the workshop proceedings.

Information generated by the Sea Grant study of Kemp's ridleys was disseminated in several venues. The principal investigator's research program and findings were highlighted in the Summer 1997 edition of the Texas Sea Grant College Program's *Texas Shores* magazine. That issue entitled "Rebirth of a Nation" contained two articles – "A Long Swim Back" and "Modern Technology Meets Ancient Creature" — that gave an overview of the principal investigator's research on Kemp's ridleys in nearshore waters off Sabine Pass, Tex.

Results of the research also were presented to the Kemp's ridley Working Group meeting held in Brownsville, Tex., in March 1998. A similar presentation entitled "Southeast Sea Turtle Population Trends: A Review of Recent Data" was delivered to regulatory personnel, fisheries biologists, gear specialists, university researchers and fishing industry representatives at the TED Testing Technical Review Committee Meeting in Pascagoula, Miss., in November 1997. Another presentation on sea turtle population dynamics was delivered to scientists and regulatory personnel attending the aforementioned workshop on hypoxia held in Baton Rouge, La., in March 1998. Lastly, an overview of sea turtle stocks of the Gulf of Mexico will be presented at Sea Grant's "Sharing Our Gulf" Conference in June 1998.

This project represents pioneer research on the life history of the Kemp's ridley in nearshore waters of the northwestern Gulf of Mexico. It has generated information on population abundance, size structure, habitat preference, spatial and temporal distribution, migration and foraging strategies, sex ratio and reproductive condition. These findings have identified nearshore areas such as Sabine and Calcasieu Passes as major developmental habitats for an increasing population of post-pelagic and juvenile ridleys. This information has been critical to policy making regarding the management of this stock and the habitats these turtles depend upon for their recovery. Consequently, this project's results are being used in decisions concerning whether nearshore passes and shallow Gulf waters (<20 m) should be closed to shrimping during months of peak sea turtle occupation. The at-sea captures accomplished during the project are being used with sea turtle stranding data and shrimping pressure information to develop new fishing regulations that reduce turtle mortality, facilitate recovery of ridley stocks and resolve conflicts between sea turtle conservation efforts and the shrimp fishery. Research findings are being used by National Marine Fisheries Service, U.S. Fish and Wildlife Service, Texas Parks and Wildlife Department, and Texas Shrimp Association personnel.

Socioeconomic gain beyond that related to the accomplishments summarized above will likely result when the conflict between sea turtle conservation and the shrimping industry is resolved. This project's results will go a long way in facilitating future resolution of the conflict. Resolution will pro-

vide the shrimping industry with a clear set of fishing regulations that should provide socioeconomic gain to the industry's constituents. Quantification of this gain will be possible only after the shrimp fishing regulations are established.

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NONINDIGENOUS SPECIES RESEARCH

Physiological Tolerances and Nonchemical Control Strategies for the Recently Introduced Macrofouling Brown Mussel, *Perna perna*

Nature of the Problem

The brown mussel is a known biofouler of raw water-using facilities. Heavy infestations of brown mussels resulting in serious flow blockage of cooling water systems have caused frequent power station outages in its native range. Brown mussels have been continuously invading new areas, including some estuarine habitats, since first being discovered in 1990. An understanding of environmental variables that affect byssal thread production are of paramount importance if nonchemical control strategies are to be developed.

Results

The objectives were to (1) detail the brown mussel's physiological tolerances to the major physio-chemical parameters likely to influence its colonization of North American coastal waters, and utilize the results to (2) predict its potential spread in North America, and (3) provide data on which nonchemical control technologies for mussel macrofouling in raw water systems could be based.

Mussels survived and maintained normal activity (i.e., byssal thread production) during prolonged exposure (30 d) to salinities ranging 15 to 50 ppt, temperatures from 7.5 to 30°C, and to ambient oxygen levels >10 percent of air O_2 saturation. Emersion tolerance was negatively correlated to air temperature, with 50% mortality after 24 h at 35°C versus 132 h 15°C. Relative humidity was positively correlated with emersion survival particularly at lower temperatures (i.e. 15°C), where survival times were extended. *P. perna* is sensitive to freezing in air. Total mortality occurred after 2 h at –7.5°C.

The data suggest the *P. perna* could eventually inhabit U.S. coastal waters from southern Texas to Cape Hatteras, N.C. Discrete linear logistic models were developed from the data collected that predict times required to mitigate mussels exposed to lethal levels of the above physiological parameters, incorporating exposure level, prior acclimation experience and animal size. The models can be used in habitat risk assessment, and to design efficacious nonchemical treatments for mussel macrofouling.

The research did not deviate from the original research plan, nor were there any unresolved problems with the experimental protocol. Other research projects resulting from this study include investigations of byssal thread strength and production, cytogenetic research of nonindigenous brown mussels and studies of aspects of mussel invasion on native marine fauna.

Sea Grant support allowed the Center for Coastal Studies, Texas A&Muniversity-Corpus Christi and the Center for Biological Macrofouling Research, The University of Texas at Arlington to document the invasive history, biology, ecology and physiology of the brown mussel since its discovery in the Gulf of Mexico. Seven papers describing aspects of this research have been presented at scientific meetings. Past and current Sea Grant funding of *Perna*-related projects have directly or indirectly supported master's theses by R.R. Smith (1995), S. Alvarado (1995), M.

McGrath (in progress), and N. Sohn (in progress) and Ph.D. dissertations by B.S. Holland (1997) and D.W. Hicks (in progress). The mathematical models risk assessment profiles developed for the brown mussels as a consequence of this research will aid industrial and resource managers in making decisions regarding the likelihood of invasion of their waters by this species, and in the development of appropriate nonchemical controls for its macrofouling.

Publications and Presentations

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MARINE ECONOMICS

Impacts of Recreational and Commercial Fishing and Coastal Resource Based Tourism on Regional and State Economics

Nature of the Problem

This study was designed to provide information critical for planning, managing and preserving coastal wetlands. The Texas Parks and Wildlife Department, Texas Water Development Board, Texas Natural Resource Conservation Commission, Galveston and Corpus Christi Bay National Estuary Programs, and Texas Marine Advisory Service specialists all indicated a need for this information. This study will enhance the understanding of the economic value of the natural marine environment.

Results

Total impacts of water-related recreational activities and commercial fishing were estimated for the six Texas bay and estuary systems and the Texas Gulf Coast. Eight input-output models were developed for this analysis using IMPLAN (IMpact analysis for PLANing). These included one regional model for each of the six bay and estuary regions, one regional model for the 26 Texas coastal counties, and one economic model to capture statewide impacts.

In general, recreational activities had a much greater employment impact on the regional and state economy than did other sectors. Sectors where recreational travel expenditures are spent consist of largely service sectors, which generate large employment impacts. The Trinity-San Jacinto estuary region had the largest total impact for all economic impact variables for both recreation-related sectors and commercial fishing. Employment impacts of recreation and tourism-related sectors ranged from 283 (Guadalupe) to 16,500 jobs (Trinity-San Jacinto). An important contribution of this study was the estimation of tourism multipliers for each estuary region.

Since no survey was conducted, recreational fishing could not be separated in the impact estimation. Trends in data examined indicate that participation in recreational fishing is growing along with other recreational activities. Secondary impacts of the sport fishing activity were not estimated separately although they are included in the economic impact estimates for all recreational activities.

Direct impacts of commercial fishing were estimated using data from TPWD and the NMFS. Those impacts were then used to estimate total impacts at the regional and state level using input-output models.

Direct impacts of bay and estuary-related recreational activities were estimated using data from the

Texas Department of Commerce (TDC) and the travel surveys conducted by D.K.S. & A. Ltd. Bay. Estuary-related recreational expenditures were derived from a 1987 study by Fesenmaier et al. The impacts were then used to estimate total impacts at the regional and state levels using input-output models developed for each bay and estuary and the Texas Gulf Coast using IMPLAN.

Relative impacts of industry, manufacturing, agriculture, government, recreation-related sectors, and commercial fishing were estimated for the Corpus Christi Bay National Estuary Program region, which includes the Nueces-Mission-Aransas and Upper Laguna Madre bay and estuary systems. Results were compared and contrasted for the region and the state. While petroleum and chemical industries had a much larger output impact, employment impacts were largest for tourism-related sectors.

Given the time frame and the impossibility of conducting a survey, the direct impacts of expenditures were estimated from an earlier study (Fesenmaier et al., 1987) in conjunction with data from the TDC. To estimate allocation of expenditures, data from D.K.S. &. A Ltd. were used.

Major problems encountered during the course of the study were lack of data, particularly on new bay and estuary-related activities such as windsurfing. Participation and expenditures for visitors engaged in diverse recreational activities are lacking. New surveys are needed.

This project has resulted in several developments that have affected marine resource management and behavior of user groups. Included are:

- The project provided seed money for additional research funding from the Texas Water Development Board (TWDB) and CCBNEP ($70,000) and the Army Corps of Engineers ($95,000).
- Results of the research have been incorporated into the CCBNEP Coastal Bays Plan for marine resource management within that region.
- Results became an integral part of the TWDB overall water management plan that ensures freshwater inflows to coastal bays and estuaries.
- To date, one scientific paper has been developed for presentation at the Southern Regional Science Association Meetings. This paper advances knowledge about the differential impacts of tourism as compared to other industries.

This research sets out a methodology to estimate multipliers for tourism for a given region. Tourism multipliers at the regional level can potentially be beneficial for small communities seeking to estimate potential impacts of tourism development.

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MARINE EDUCATION

Development of Middle School Marine Education Resource Manual

Nature of the Problem

This project was intended to fill the void in the availability of marine education curriculum materials in the middle schools. The manual being produced as a result of this project will be a resource for the middle school teachers who, in Texas alone, teach approximately 795,000 students. The manual will provide teachers and students with an understanding of marine environment and resources in order to develop "marine literacy." The examples in the manual will emphasize the Gulf coastal region.

Results

This report covers the first year of a three-year project that has the following objectives: (1) to develop a marine education resource manual for use in traditional science courses and integrated science courses but also in language arts, social studies and math courses or interdisciplinary thematic units in the middle school, grades 6-8; (2) to provide middle school teachers with current in-depth information and resources for classroom use that pertain to all aspects of the marine environment, with emphasis on the Texas coast, that will promote marine literacy and meet the Texas Essential Knowledge Skills and the national standards in science, mathematics, social studies and language arts; and (3) to provide teachers with strategies for teaching marine education that reflect the national teaching standards and are based on current research on effective teaching and learning. Since all three objectives of the project are interrelated and overlapping, they are addressed together here.

Existing resources have been reviewed, evaluated, and collected to provide information for the resource manual. Current research findings have also been reviewed for utilization and incorporation into activities and lessons. This process is on going.

The process of developing lessons from the information and materials collected is continuing. Many of the lessons for the marine education manual

are still in the process of being developed. Forty new lessons have been completed; some have been sent to teachers to review; and others are in various stages of completion.

The development has progressed much slower than anticipated for a number of reasons, not the least of which is that there are so many aspects of the marine environment that need to be addressed in order to provide teachers with the knowledge and tools they need to develop marine literate citizens. This also makes it difficult to determine what should be included and what can be left out.

Teachers were questioned to determine the marine topics that should be included in the marine resource manual. Many of the responses were that any materials or topics related to the Texas coastal zone would be helpful since there were no such resources available. Others only cited topics with which they were familiar, such as sea turtles and whales. Questioning the teachers was not as beneficial as hoped. The responses were not always helpful in determining specific focus areas.

A workshop for middle school science teachers was presented at CAST'97, the state science teacher's conference, using activities and lessons that had been developed. The comments were very favorable. The question that all asked was when and how could they obtain the manual. Participants at the presentations and teachers who have reviewed some of the lessons felt that the strategies utilized were strategies that they would use, would involve their students and would challenge the students to use higher level thinking skills as they learn.

The plan is to complete field testing by early Fall 1998, which should provide sufficient time to have the manual printed in time to be released at CAST '98 conference in Corpus Christi in November 1998.

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