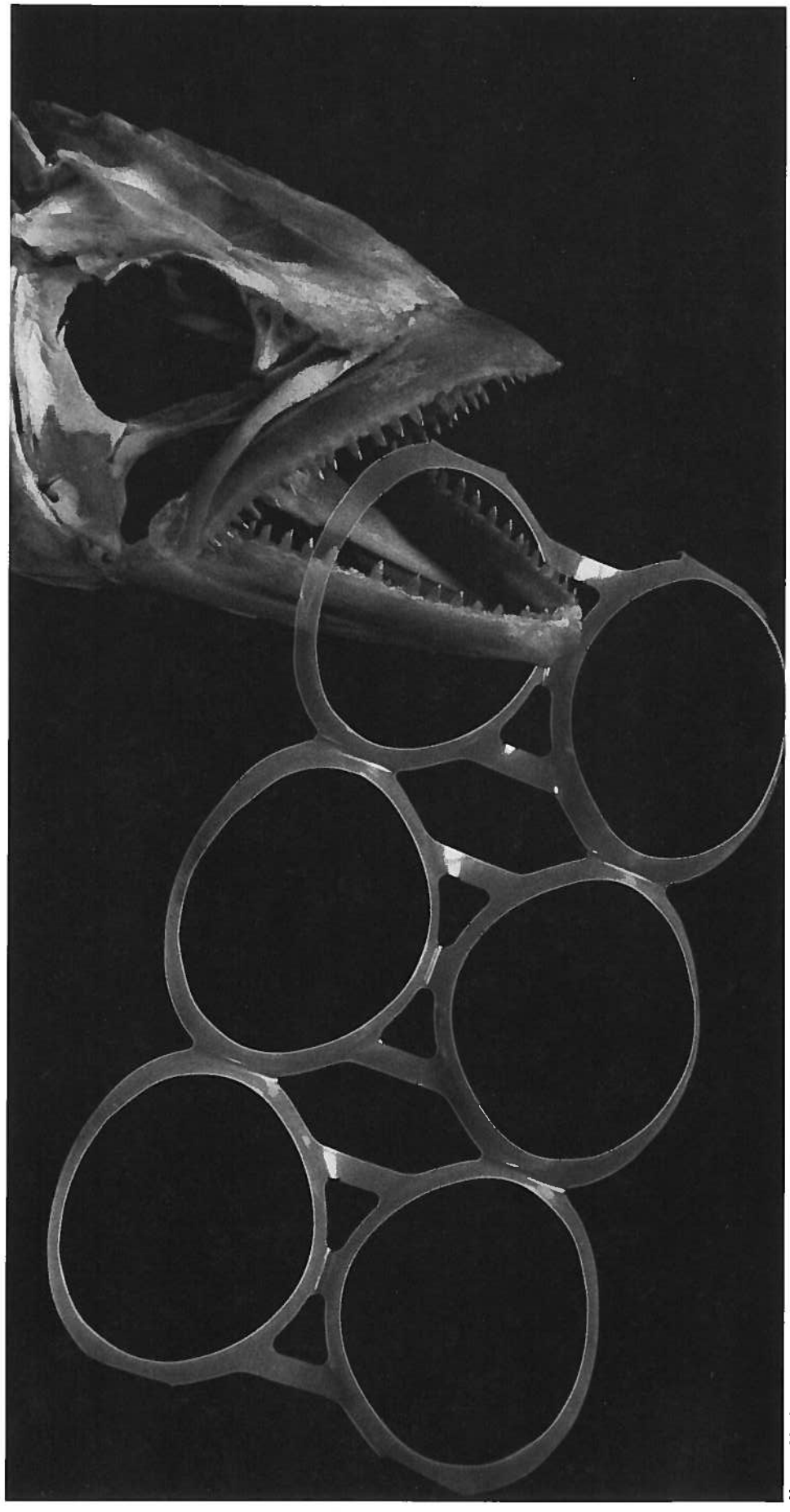
SEA GRANT COLLEGE PROGRAM

TEXAS SHORES

PLASTIC TRASH

Please don't test the waters.

Before you toss that six-pack holder overboard, stop and consider. That fragile-looking plastic ring can last 450 years. Plastics do not rot. They don't go out with the tide. They accumulate and they kill. Both fish and shorebirds get entangled in the mess. Some even mistake plastic for food. The result: thousands die needlessly. So, next time you take the plunge in the Gulf, stow the garbage or, at the very least, toss the degradable stuff and keep the plastics. We shore appreciate it.



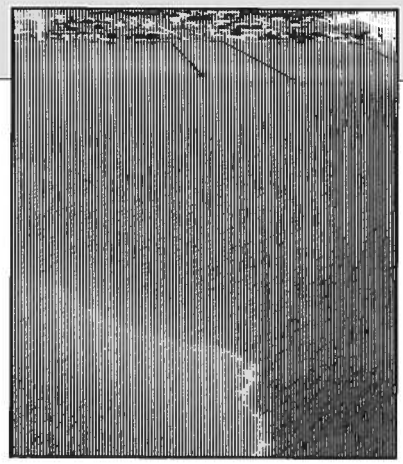
Norman Martin

Texas Sea Grant

An organization of professionals dedicated to the better understanding of our marine environment.

CONTENTS

Volume 19 **Number 4**



TEXAS SHORES

Red is such a nice color that we've decided to do another magazine with a red theme. As you may remember, last fall we tackled the redfish scene and its surprising future in Texas. Now we turn to another red, red tide. While we were touting the future of redfish, a huge killer red tide was forming off the Gulf coast. Eventually, it killed about 22.2 million fish and cost the state millions of dollars in lost tourism and oyster income. In this issue we examine how the tiny, toxic marine organism raked the western Gulf from near Galveston to Mexico. There is a review of the economic costs and future research needs of red tide in our state. In addition, we include a detailed examination of exactly what red tide is and how the fish killer came to our shores. And, finally, an historical view of the tide in Texas. Apparently, red tides have been unwelcome guests here before. Cover photo by James Bowman—Texas Water Commission.

***Texas Shores* is published quarterly by the Sea Grant College Program at Texas A&M University in an effort to promote a better understanding of the Texas marine environment.**

Dr. Tom Bright, *Texas A&M Sea Grant Director;* Amy Broussard, *Head of Marine Information Service;* Norman Martin, *Texas Shores Editor and Art Director;* Rhonda Snider, *Advisory Publications Editor;* Gary Hallbauer, *Distribution Manager;* Cindy Liles, *Production Assistant;* Jeanne Isenberg, *Editorial Assistant*; and Celia Jeter, *Graphic and Printing Consultant.*

Sea Grant is a partnership of university, government and industry focusing on marine research, education and advisory service. Nationally, Sea Grant began in 1966 with the passage of the Sea Grant Program and College Act. Patterned after the Land Grant Act of the 1860s, the Sea Grant concept is a practical, broad-based scientific effort to better the world for all those living in and out of the sea.

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

The effort is aided by seven county marine extension agents serving the nine coastal counties of Texas. These individuals are backed by a group of specialists in marine recreation, fisheries and business management, as well as sea food marketing and consumer education.

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

Change of Address, Subscription Information or Other Questions: *Texas Shores,* Sea Grant College Program, Texas A&M University, College Station, Texas 77843. Or call 409-845-7524. Please include old label when changing mailing address.

*Texas Shores (ISSN 0747-0959),*is published quarterly by the Sea Grant College Program, Texas A&M University, College Station, TX 77843. Second class postage is paid at College Station, TX. **Postmaster:** Send address changes to the Sea Grant College Program, Texas A&M University, College Station, TX 77843. □

SEA NOTES

Ocean drilling facility dedicated at Texas A&M

Texas A&M University has dedicated the world's largest, most sophisticated facility for storing and studying core samples taken from depths beneath the oceans' bottoms never before possible to reach.

The $4.5 million facility, which houses the core storage area, is the world headquarters for the Ocean Drilling Program (ODP), a $30-million-a-year activity supported by the U.S. National Science Foundation, Canada, the Federal Republic of Germany, France and Japan.

Officials predict oceanographers and scientists from around the world will come to the ODP building to study the thousands of core samples to be stored there. Construction for the 60,000-square-foot facility began in February 1985.

The ODP office building and its laboratory and repository facility were built by the university to house the more than 150 staff members and scientists who are working for the world's largest scientific ocean drilling program. The ODP, with its research activities, ranks in the forefront of the number of new jobs being created, Texas A&M officials say.

The manager of the ODP is Joint Oceanographic Institutions Inc., a nonprofit consortium of 10 major U.S. oceanographic institutions, and the Joint Oceanogaphic Institutions for Deep Earth Samples (JOIDES) is the international group of scientists that provides planning and advice for the program.

Texas A&M, as the ODP's science operator, is responsible for operating and staffing the program's drillship, the JOIDES Resolution, which retrieves cores from strategic sites beneath the world's oceans.

The university maintains sophisticated laboratories on the ship, provides logistical and technical support, and manages the scientific activities conducted after each cruise. These activities include serving as curator for the cores, distributing samples and publishing scientific results.

With its dedication, the ODP became the first tenant of the new Texas A&M University Research Park, a 434-acre facility designed to attract high-tech industry to the university community. The multi-million-dollar park is expected to appeal to private corporations involved in research and development activities that coincide with Texas A&M's research interests and strengths. □

— Jeanne Isenberg

Odd diet for sea animals discovered by scientists

Sea animals that live on methane, the main component of natural gas, may not be as rare as thought — just difficult to find and retrieve — say scientists.

Researchers at Texas A&M University and the University of California at Santa Barbara reported the discovery. Over the last 20 years, scientists have found a number of marine animals that subsist on unorthodox diets of sulfide and other chemicals, but the newly discovered mussels are the first with a proven ability to consume methane.

Retrieved during trawls 150 miles off the Louisiana coast during a Texas A&M cruise last February, the animals seem to live around undersea oil seeps.

"We are learning where to look for these creatures and improving our techniques for recovery," says Malon C. Kennicutt II, a Texas A&M chemical oceanographer. Also reporting in Science were Texas A&M oceanographers James M. Brooks and Robert Bidigare as well as UCSB biologists James Childress, Charles Fisher and Amy Anderson.

Kennicutt explains that the mussels thrive on the methane diet because of a mutually beneficial relationship with methane-eating bacteria living in their gills. Tests found that the mussel-bacteria team consumes large amounts of methane brought in through the gills.

Microscopic analyses of the gill tissue revealed the presence of bacteria congregating in tiny sacks at the gill surface, scientists report. Many of the mussels are still living on natural gas bubbled into the water of their aquarium at UCSB. □

— Jane Mills Smith

The krill of discovery leads team to Antarctic

A Texas A&M University oceanographer was among a group of scientists celebrating New Year's aboard a research ship off the tip of the Antarctic Peninsula looking for shrimp-like crustaceans known as krill.

Dr. John Wormuth, along with researchers from the University of Washington at Seattle, the National Marine Fisheries Service and Mosslanding Marine Laboratories in Monterey, Calif., were hoping to locate swarms of the elusive krill during the month-long cruise aboard the Polish research ship Professor Siedlecki.

In 1981, the scientists mapped a "superswarm" of krill near Elephant Island off the tip of the Antarctic Peninsula using high frequency acoustics. On a return trip in 1984, however, they found few krill and no swarms.

"We hope that this third trip may shed new light on the distribution and populations of krill," Wormuth says "At this point, with such sketchy information, it is difficult to make any valid judgments on using krill as a potential protein source for humans. We do know, however, that they are an important food source for whales."

On this third trip, the scientists took along a variety of instruments to measure swarms acoustically from aboard ship. They hope that comparisons of results from the various instruments will give a more accurate picture of the tiny creatures below.

They also took along improved netting systems that can be towed faster and, hopefully, will retrieve more live krill. Netting the tiny krill is difficult, even in a swarm, Wormuth says.

"In fact, we seem to net even fewer krill from a swarm than from low concentrations," he says.

After the 1984 trip when few krill were found, the scientists realized that a long-term study is needed to get a clear picture of the activities of krill. On their first trip, they thought they would find krill in surface patches, visible to the eye from shipboard. Such patches have been reported for many years by biologists who traveled through the area.

But they found instead, a "superswarm," many kilometers wide and long, up to hundreds of meters thick and invisible from the surface. Three years later, however, they found no swarms at all. "We have a new appreciation of the diversity of the Antarctic ecosystem," Wormuth says. "We feel a long-term study is essential." □

— Jane Mills Smith

Global ocean study ready for major push in 1990s

Even before the official experiment date of the 1990s, hardware and software development and strategic planning is taking place for U.S. participation in the World Ocean Circulation Experiment (WOCE).

A key element of the World Climate Research Program, WOCE will study the circulation of the oceans in an effort to model its present state and predict its evolution in relation to long-term changes in the atmosphere, explains Dr. Worth Nowlin Jr., head of the U.S. planning effort headquartered at Texas A&M University.

Nowlin, a Texas A&M professor of oceanography, says WOCE is the first serious scientific experiment to describe and understand global ocean circulation. The information obtained from the experiment may someday help scientists design an observation sytem that could predict climatic patterns, he says.

The National Science Foundation, NOAA and NASA are participating in the planning of the United States' role in WOCE. During its major operational phase, American expenditures on WOCE may equal $20 to 25 million a year.

"If you consider computer time, satellite costs and other important contributions, WOCE will probably ultimately be a $2.5 billion project," Nowlin says. "The experiment means new research dollars for oceanographers and a new way of pursuing oceanography."

During 1987, most sub-projects within WOCE will be determined and will include satellite data analysis, a WOCE ship operation to obtain a global suite of physical and chemical measurements, a subsurface velocity measuring project using drifters tracked by satellites, a data management unit, projects to determine exchanges between the atmosphere and sea surface, modeling projects and a project for worldwide monitoring of sea level changes, he said.

In 1988, the U.S. WOCE Planning Office will be replaced by a U.S. WOCE Project Office.

All but one of the key satellites necessary for WOCE have been approved, Nowlin says, including the European Space Agency's ERS-I, the joint U.S./French TOPEX/POSEIDON and the U.S. Navy's NROSS. Still needed is the NASA geopotential mission called GRM.

The National Science Foundation is accepting proposals. □

—Jane Mills Smith

William Clayton retires at Texas A&M — Galveston

Dr. William Clayton has retired as president of Texas A&M University at Galveston after 15 years as head of the programs there.

Clayton, who stepped down as president Jan. 1, will continue to serve as superintendent of the U.S. Maritime Service Program through the 1987 summer training cruise that concludes in August. At the completion of the cruise, which serves as required sea training for U.S. Merchant Marine officers, Clayton will retire from The Texas A&M University System.

System Chancellor Perry Adkisson says Dr. Sammy Ray, a renowned marine biologist and long-time member of the Galveston faculty and staff, will serve as acting president.

"We at the Texas A&M System are indebted to him for his great contribution," Adkisson said.

The chancellor also expressed confidence in Ray, saying he had a keen understanding of the university and a genuine investment in the programs he will administer.

"Dr. Ray will be an important part of this transition and we are grateful that he has consented to assume the acting president's position," Adkisson says.

Ray, 67, is a native of Mulberry, Kansas. He joined the Texas A&M faculty as an assistant professor of oceanography and meteorology in 1959 after serving as a research biologist with the U.S. Fish and Wildlife Service. He earned his bachelor's degree from Louisiana State University, and a master's and Ph.D. in biology from Rice University. □

A&M research team dives into Port Royal's past

Port Royal, Jamaica, may have been the most wicked harbor town in the Americas during the 17th century, and some might argue that the British outpost got what it deserved.

In June of 1692, an earthquake dropped two-thirds of the town into modern-day Kingston harbor, killing thousands outright or from the resulting pestilence. Texas A&M University researchers have resumed their long-range excavation of Port Royal's submerged ruins as they slowly unlock a time capsule of Caribbean island life.

It's possible that the nautical archaeologists will still be at work when the 300th anniversary of the disaster rolls around. "The research at Port Royal could continue for many years to come," says Texas A&M researcher Dr. Don Hamilton, director of the project and of the underwater archaeology field school conducted by Texas A&M and the Institute of Nautical Archaeology (INA).

INA is a nonprofit scientific group affiliated with Texas A&M and is considered the world's leading center for training nautical archaeologists.

"Although only a small portion of the submerged ruins have been excavated, it is clear that the potential archaeological importance of Port Royal is unparalleled by any other 17th century British site," says Hamilton.

Several summers of excavation, followed by more time spent studying a few artifacts more closely at the College Station campus, have already begun to document the importance of Port Royal to both geopolitical strategy and the calls of the flesh.

Pipes, liquor bottles, pewter mugs and signs of butchering — testimony to the city's importance as a source of fresh meat for British ships — have surfaced, as have other everyday and personal items. The good life was there for pirates, traders, sailors, soldiers, and the shopkeepers and tavern owners who could keep them happy, explained Hamilton.

After British troops laid claim to the former Spanish outpost, Port Royal became a haven for pirates and privateers including the likes of Blackbeard, Anne Bonney and Henry Morgan.

Although the presence of the pirates gave the town its wide-open reputation, historians credit their heavily armed ships with discouraging Spanish attempts to recapture Jamaica. □

— Ed Walraven

Just A Day At The Beach.

WITH TEARS RUNNING INTO HIS thick beard, Tony Amos clutched the wheel of his rocking pickup as another stinking dead fish exploded beneath his tires and ground into the white sand of Mustang Island.

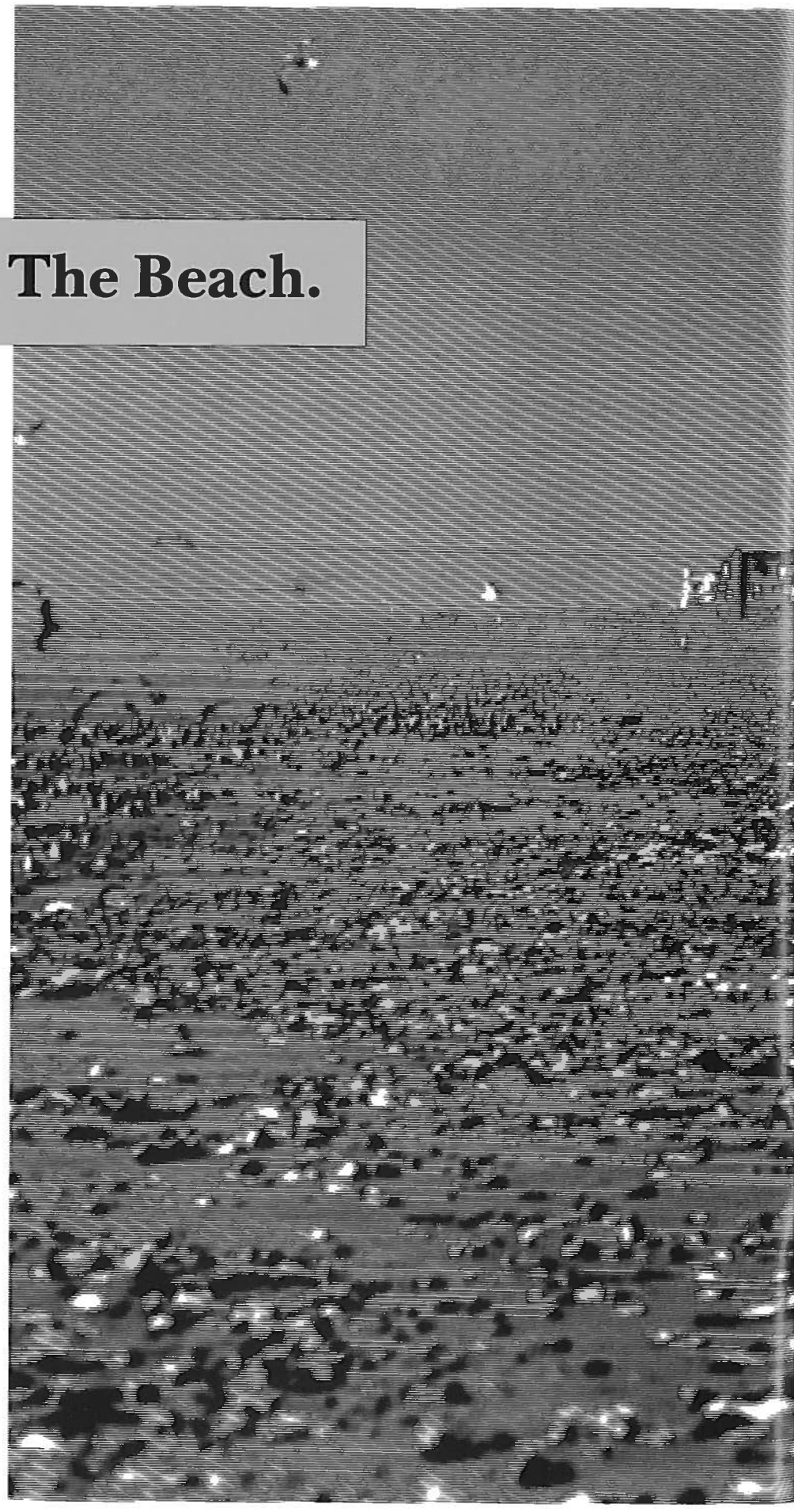
There was no way to avoid the rotting mounds. Millions of dead sea animals lay before the wheels of the lonesome Toyota, victims of a toxic red tide that had infiltrated Texas almost two months before. On the dune line, a huge mixture of sea birds fluttered and danced in the wind, glumly watching Amos' solitary scientific procession.

For nine years the broad-shouldered University of Texas Marine Science Institute researcher had driven this exact seven-mile stretch of beach, noting weather conditions, and counting birds, fish, even trash. It was an effort in which he took pride. In the middle of oil spills and hurricanes, he had collected his data. Today would be no different; yet in terms of carnage, this, indeed, was not a normal day at the beach.

On a portable computer that lay on his lap, Amos cryptically noted, "Most fish ever. Birds ignoring them. Starting to cough. County has dug trench along mid beach. Buried fish there. Nose hurts. This is really terrible."

The day was October 18, 1986. At the time Amos estimated more than 5 million dead fish lay in the sand and some 6,500 gulls came to see the awesome sight. "In 1,137 observations, it was by far the largest number I've ever seen. The interesting thing is that the birds were just sitting there, ignoring these millions of fish."

Further down the beach, workmen wore goggles and painters' masks to protect them from the noxious fumes emitted by the toxic red tide organisms as they cleaned fish from the white, sandy beaches. The stench and the government had already chased everyone else, coughing and wheezing, off the beach.



In October 1986, millions of dead fish lay in the sand near Corpus Christi.

BY NORMAN MARTIN

Tony Amos

ROLLING WITH THE RED TIDE

ROLLING WITH RED TIDE

During its fall rampage, the foul-smelling red tide caused millions of dollars of damage to the commercial fishing and oystering industries along the Texas Gulf Coast and is likely to add economic hardship for the state's tourist industry. An estimated 70,000 retirees, most of them elderly and susceptible to respiratory ailments, spend the winter each year in the semi-tropical Lower Rio Grande Valley.

The red tide, which one Texas oyster fisherman said "looks like you poured a gallon of red latex paint in a hog trough," spread 300 miles along the Texas coast and killed more than 22.2 million fish. The billions of plant-like dinoflagellate organisms making up the red tide thrive on sunlight, reproduce and grow rapidly in tepid saltwater, bloom, then die, giving off toxins that are lethal to fish and that irritate the eyes, nostrils and respiratory systems of humans.

Because of the breathing difficulties, red eyes and runny noses that the toxins induce in some people, health officials closed beaches in Corpus Christi and along the 63-mile Padre Island National Seashore, and because oysters, clams and mussels store the toxins in their systems, they banned the taking of shellfish along three-fourths of the Texas coast south of Galveston Island. And although health and wildlife officials stressed that the red tide wouldn't affect healthy fish caught on hook and line, it still caused millions of dollars in losses.

The red tide that blasted Texas in the fall actually began early in the summer far offshore. As the state baked under a typical screaming July sun, the red tide outbreak started as a war of sorts. And as wars do, the first battle began in a small way — literally — because the combatants were smaller than the head of pin. But before these tiny, pink fighters were through, they would send an economic torpedo into a struggling marine economy.

Dr. Edward Buskey, a specialist on red tides at The University of Texas Marine Science Institute in Port Aransas, says what touched off this explosion was a duel between dinoflagellates, called *Ptychodiscus brevis*, and their natural enemy, zooplankton. Zooplankton eat dinoflagellates.

From an evolutionary point, Buskey says it's clear the toxins in red tide didn't evolve to kill fish. Fish don't eat dinoflagellates. They didn't evolve to make human beings sick. The toxins simply evolved as a defense mechanism to deter zooplankton, the tiny animals in the water column that feed on dinoflagellates. Most of the time

In 1935 dead fish were "thick as seawee

ENCORE

THE HISTORY OF RED TIDE IN TEXAS IS NOT A WELL-detailed one. Marine experts say the organism's first documented appearance was in the fall of 1935, but speculation now suggests it may well have had a number of predecessors.

Dr. Henry Hildebrandt, a marine fisheries consultant who has looked extensively into the history of Texas red tide, says, "The one in '35 was the first to be definitely tied down, but I think there were others. There are many hints of others in articles before, but there just wasn't enough information to be certain about it until '35."

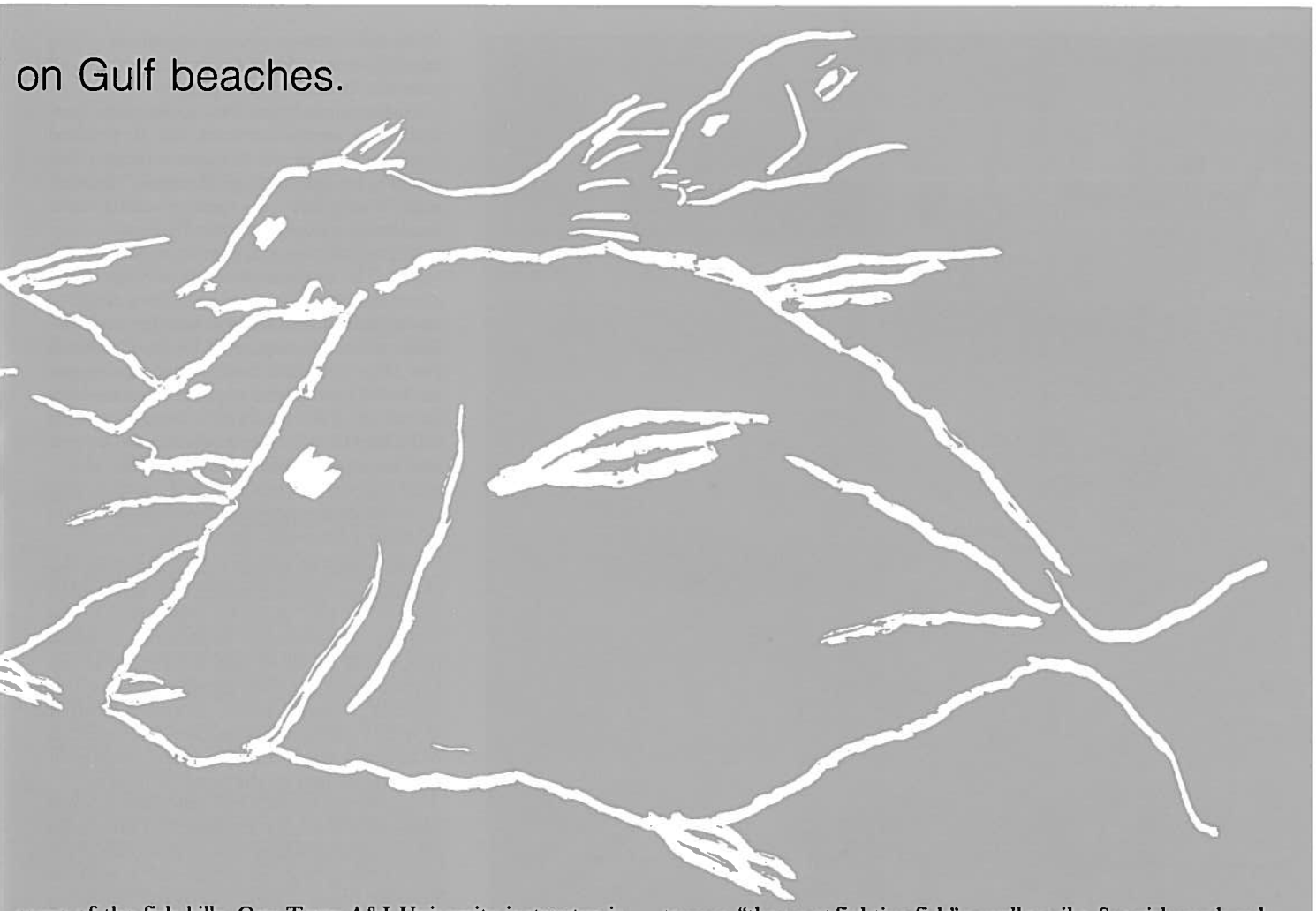
Hildebrandt says that first tide began at the end of June and lasted into October. The tide was not continuous throughout that time, he says, but rather, it covered different portions of the coast at different times, spreading from Sergeant Beach all the way down into Mexico.

According to the notes of a Corpus Christi Caller reporter, it was on June 30, 1935, that fishermen first reported thousands of dead fish, "thick as seaweed," to be covering the Gulf beaches. The fish came in all shapes and sizes, the most common type being mackerel, kingfish, redfish, trout and flounder also were found in great numbers. One estimate in the reporter's notes suggests 100,000 tons of fish were covering the beach.

Hildebrandt says the fish mortalities that year were greater than those suffered on the Texas Gulf coast last year when some 22.2 million fish died.

The 1935 tide sparked many different theories regarding the

on Gulf beaches.



Norman Martin

cause of the fish kills. One Texas A&I University instructor is reported in the Caller notes to have attributed the deaths of the fish to a rift on the Gulf floor or a slight volcano that released a sulphur dioxide gas product.

The director of the Game, Fish and Oyster Commission, according to the Caller notes, suggested a sudden change in water temperature killed the fish, while the commission's report for fiscal 1934-35 showed it had no definite conclusions.

Still others suggest the kill could be attributed to fresh water flowing into the Gulf that affected the fish, or perhaps a submarine explosion in the Gulf caused the fish kills.

One source suggested the gills of the fish to be clogged with vegetation, and one man joked it must have been suicide.

Despite the vast amounts of dead fish washing up on the Gulf beaches, fishermen and fishing boast reported no out-of-the-ordinary decreases in their catch.

Hildebrandt says the tide of 1935 was not diagnosed as such until 1947, but there is "no doubt it was red tide." The "aerosol effect" was documented by the coastal residents — coughing, sneezing, red and watery eyes — and the water had a yellowish tinge to it.

The kill reported in September reportedly left not only a tinge to the water but heavy gases rising from the Gulf. Residents said they were coughing almost continuously. The dead fish first began drifting in Sept. 22, reaching their peak on the 23rd.

This time, the Caller notes report, the beaches were filled with tarpon, "the great fighting fish" as well as pike, Spanish mackerel, mullet and thousand of dead gar, which typically are freshwater fish.

Two researchers theorized the kill came from an unusual outpouring of fresh water into the Gulf, which caused a sudden temperature change, the Caller says. But, the notes add, large quantities of fresh water continued entering the waters of the Gulf but caused few fish to die. Fishermen began reporting the fishing to be the best in years in Laguna Matie, but this was attributed to the tremendous shrimp crop there.

After the fish kills of 1935, Hildebrandt says, the next documentation of red tide wasn't until 1955.

"I'm convinced there are outbreaks we don't pick up, however," he says, "which affect smaller areas of the coast."

In 1955, the red tide left most of its effects on Mexico, directly across the border, and at one time, it stretched all the way to the southern tip of the country at Vera Cruz. "This tide covered at least as much of the coastline as the '35 red tide," he says, "but it hit only a small part of Texas this time — down in South Padre.

"The organism was never picked up (in U.S. waters) because scientists didn't get there until after the outbreak began."

Hildebrandt says that if the fish already have begun washing ashore, it most likely is too late to obtain samples. The samples the U.S. scientists got were taken from waters in Mexico.

The tide spread only about 25 miles into Texas, but the fish mortality rate for Mexico in 1955 was extensive. ■

BY JEANNE ISENBERG

David Cortner — Brazosport Facts

these miniature wars go unnoticed. "You don't go out and see dead zooplankton all over the beach," Buskey says.

Unfortunately for Texas, the pint-sized upheaval works both at the individual level as well as on a massive scale. "It's really a unique biological event," Buskey says. "Imagine, one species taking over hundreds of cubic miles of water."

On top of this, the pace is frighteningly rapid. The organisms only have life spans of several days, yet can mount a massive biological phenomenon on the scale of Biblical locust plagues. The good news is red tides are rare here. Only two major outbreaks have been reported this century before, in 1935 and 1955. But all records indicated the latest episode was the largest and most severe in historical records.

September 1, 1986

Few could or would have predicted the coming devastation when the tide rolled ashore in late August. The first major flareup occurred on September 2 when thousands of dead fish littered Brazoria County beaches after dying in the Gulf of Mexico. Charles Moss, Brazoria County marine extension agent, says, "In the areas of heaviest concentration, there were easily 10 dead fish to the yard of beach."

Confirmation of a red tide outbreak still awaited laboratory analysis, but Moss says all the signs pointed in that direction. "We didn't have any evidence of a spill or leakage from a ship, or runoff from an industrial site."

"God, what a mess," Surfside Mayor Burt Strouse told a Brazosport Facts reporter. Surfside resident Wendy Loveless added, "The whole damn town is coughing, and it's not just the old people. The air tastes bitter."

Bess Williamson, owner of the Jettie Bait Camp, noted that a customer told her of seeing a 30-foot wide streak that appeared in the water off the jetties about 9 a.m. on August 31. When the streak came to shore about 3:30 p.m., "that's when the fish started going belly up." At the time there was no estimate of how many fish were involved, but Moss says the victims ranged from a 3-pound trout to half-inch Spanish sardines.

Red tide, which consists basically of a population of one-celled organisms, earns its name from the sometimes brownish-red sheen it gives the water. It is unpredictable and triggered by an unknown combination of factors.

Experts say red tide is caused by the rapid multiplication of a pinkish micro-

The stench and the government often chased everyone, coughing and wheezing, off the beach.

organism in warm, salty water. The microorganisms give off a toxin, poisoning the marine life that cannot get out of the way, and also robs the seawater of the available oxygen. It has occurred every month of the year in areas on the Gulf Coast, although September through February marks its usual season, with the highest incidence in November. Killer tides have been known to cover an area of water as great as 14,000 square miles.

Health officials say troubling symptoms can be triggered just by inhaling a sea breeze, which can contain mist contaminated by the toxin. Reaction to red tide varies with each individual. "Think of cigarette smoke and the way different people react to it - it's like that," says Texas A&M University at Galveston parasitologist Sammy Ray, a scientist who has been studying *Ptychodiscus brevis* since 1954.

Gordon McLerran, laboratory director for the Corpus Christi-Nueces County Health Department, adds that, in general, the *Ptychodiscus brevis* toxin affects the mucous membranes of humans, causing eyes to become irritated and noses to run. The symptoms, similar to the common cold, begin to disappear immediately when the person moves away from the source of the irritant, leaving no permanent damage.

By now everyone was getting mad. Mayor Strouse was peeved at Houston television reports urging people not to visit the beach. And some residents suspected something man-made killed the fish and fouled the air. Rumors abounded. Among the suspects were an oil spill, a broken

Peter Rocha — Brazosport Facts

Bulldozer drivers (above) wore goggles and painters' masks as they piled dead fish into trenches.

ROLLING WITH RED TIDE

underwater pipeline, and even radioactivity in the water. But biologists tried to point out that the tide was just part of the natural process, a deadly part for other marine life.

Red tides have a history of causing people problems as well as mass mortalities of marine life. More than 300,000 fish off the Brazoria County coast died in the first outbreak, which officials called the most serious in a decade. But on a positive note, scientists definitely knew what the cause was. The red tide was indeed *Ptychodiscus brevis* — a most toxic variety of the deadly bloom. It is the first time many state officials had ever faced this form of red tide, says Lloyd Crabb, director of the shellfish division of the Texas Health Department.

October 8, 1986

By October, the red tide began its first round of hide and seek. Environmental officials thought the fish-killing toxin had dissipated, but a week later it apparently reappeared, slaying thousands of fish in Matagorda and Espiritu Santo Bays on the Texas coast. Crews from the Texas Water Commission in a truck, a helicopter and a boat took water samples and noted the southerly drift of the lethal tide, as it

THE HALO EFFECT

Scare phenomenon touches entire seafood industry.

Even as the foul-smelling red tide roared down Texas' coastline last year, scientists say it left behind something besides rotting fish and sore throats. In all likelihood, researchers say, a halo effect was created that could well spell trouble for the state seafood sellers for some time to come.

Food scares, generated by botulism poisoning, pesticide residues, heavy metals and additives, to be sure affect foods other than those directly concerned. And, nowhere is the scare phenomenon more prevalent than in the seafood industry, particularly that segment that deals with shellfish, says Albert Jensen, now a retired member of the New York State Department of Environmental Conservation at Stony Brook, NY.

Among some scientists there is a growing conviction that news media reports linking shellfish and contaminated waters are at times blown out of proportion by rumors. All too often these fears are then intensified by screaming headlines and proclamations issued by public and private citizens overreacting to the situation.

When there is genuine reason to be concerned about the safety and wholesomeness of a shellfish product, Jensen says, a "halo effect" often touches seafood items remotely associated with the product in question.

Indeed, the impact of a red tide is not always restricted to the immediate area of the outbreak. For instance, the New England red tide caused by *Gonyaulax tamarensis* in September 1972, created havoc in the region's fishing industry. As a public health safety measure, shellfish from New England waters, including soft clams, hard clams, mussels and bay scallops were removed from the market.

But the halo effect of the outbreak hurt the seafood industry in other states, including New York. Although red tide did not bloom in New York waters, the publicity from New England created buyer resistance in New York to hard clams and other shellfish.

In the past, the halo effect touched almost all seafood as the buying public overreacted. Consumers avoided all sorts of items, including hard clams, both bay and sea scallops, lobsters and finfish. ■

— Norman Martin

ROLLING WITH RED TIDE

snaked its way through currents off the Texas coastline, leaving dunes of rotting fish carcasses.

"It's just devastating," Chip Volz of the Texas Water Commission told United Press International. "There's no way we can even begin to count them." Health officials started digging trenches and dumping the pungent fish remains in them.

On October 8, an extremely heavy concentration of red tide was observed just off the Port Aransas jetties, stretching up the Texas coast to Pass Cavallo and out at least 5 miles into the Gulf of Mexico. Smaller concentrations of the tide had been spotted in Aransas Bay a week earlier but nothing close to what was seen during the most recent flight over the Gulf.

Unofficial estimates now noted that hundreds of thousands of fish had been killed by a nagging red bloom that persisted in bay waters and off the Texas coast, particularly in Matagorda Bay and Espiritu Santo Bay. "We saw extremely heavy blooms from Port Aransas to Pass Cavallo," says Tom Heffernan of the Texas Parks and Wildlife Department.

"Along the Gulf beach, it's killing every fish that's in the surf zone — that's where the waves break," Volz added. He warned that if the red tide maintained its present course and speed, it could reach Corpus Christi. It did.

Meanwhile, health hazard warnings came into focus. There is no problem with eating fish caught in affected Gulf areas as long as they are "acting normal, biting normal." The same goes for shrimp and crabs. But people were cautioned not to pick up oysters anywhere in that area. Cooking does not destroy the toxins.

Eating shellfish contaminated with red-tide organisms could lead to poisoning. The symptoms of such poisoning usually occur 5 to 30 minutes after ingestion. A numbness occurs around the mouth and tongue, followed by disorientation, nausea, vomiting and abdominal cramps. If enough of a dosage is consumed, the toxin can be deadly, usually within 2 to 12 hours of consumption, health officials say.

October 11, 1986

Patches of the relentless red tide finally came upon the jewel of the Texas coast — Corpus Christi. In mid-October the tide tarnished pristine Corpus Christi Bay along Shoreline Drive and in the Corpus Christi Marina.

At the same time, Amos, the University of Texas scientist, was beginning to see the

RESEARCH RESCUE?

"We know nothing about this bug." But that may soon change.

Norman Martin

The red tide that waltzed down Texas' coastline last fall isn't likely to sidestep the state again. Indeed, all indications suggest marine scientists will have to tune up their red tide research base quickly before the red-streaked invader makes another devastating encore.

"We know nothing about this bug," says Stephen Indelicato, a biologist with the University of Houston Marine Science Program. "It is a different strain. Maybe it's more resistant to cooler temperatures or lower salinities, maybe it isn't." Indelicato was the first scientist to identify the red tide as *Ptychodiscus brevis* for state officials in early September.

In Florida, where red tide is almost an annual occurrence, red tide-causing organisms, especially *Ptychodiscus brevis*, have been studied extensively, but precious little evidence of the exact causes of their blooms has resulted. They have been able to document movement of the organisms and speculate on its life cycle.

Researchers agree, of course, there's much more to learn about the organisms making up red tides. Dr. Elenor Cox, a marine biologist and assistant dean of graduate studies at Texas A&M University, says three basic research areas need review.

"First, we must establish the life cycle of the organism," Cox says. It's assumed that *Ptychodiscus brevis* is like other dinoflagellates in that it has a resting cyst stage. But that stage has never been identified or described for the species.

"When the cysts are identified, then their abundance in the sediment can be determined and the transport mechanisms can be identified." Currently, she says, it's not known what causes the organism to move. That is the second field wanting for examination.

Third is a history of the organism. Previous occurrences should be determined and researchers need to conduct oral histories with individuals involved in early red tide outbreaks. "If we see what's happened in the past, we can get a better idea of what is likely to happen," she says.

Cox believes, "If the cysts can be identified and the transport mechanisms are known, the bloom could be identified before it reaches land."

But uncertainties abound. Part of the reason apparently so little is known about the tide is that it's difficult to study. It is a fairly rare occurrence, and red tide is unpredictable when it starts to occur. Scientists even have difficulty in predicting how long the red menance will last.

Ely Marsh — Caller Times

There are political and legal implications for closing beaches and shellfish harvests, but University of Texas' Ed Buskey (left) believes more research data are required.

What's more, the recent red tide event brought to the surface a major research problem. Since the patches of red tide are floating here and there for a period of days, it is very difficult to obtain statistically reliable samples of the population.

"We ran into a lot of logistic problems," says George Guillen, regional chemist with Texas Parks and Wildlife's Resource Protection Division. Texas needs a system to gather data on long-term events like red tides or prolonged freeze kills. The fishery staff now has a fish counting procedure, but it has mainly been developed to handle one-time, short-term occurrences.

Another odd fact concerning the Texas tide is how potent the toxin in the tide has been, says Richard Thompson, director on shellfish sanitation for the Texas Department of Health. While scientists expected the toxin to dissipate in two to four weeks after the tide had passed, they were still finding "significantly high levels of toxin" six to seven weeks after the tide was past.

Now that red tide has established itself, Texas marine scientists may have ample opportunity to study this type of phenomenon. The red tide cells produce enormous amounts of cysts that drop out of the water current and settle into sediment. "When the conditions are right, you'll see this thing bloom up in the next few years," Indelicato predicts.

Indeed, there is precedent for a return performance. In Canada, red tide bloomed every few years, but in the early 1970s it drifted southward far enough to enter the Boston area. Once that New England connection was made, the red tide reoccurred every few years in the Massachusetts area.

Meanwhile, scientists are skeptical of any quick fix remedy to a red tide. Although preventing red tide outbreaks or controlling them from spreading has obvious benefits, it is impossible with current knowledge. Several substances are known to kill the red tide organisms, but treating red tide with chemicals is not feasible for several reasons.

One, red tide generally covers such large areas, both horizontally along the coast and vertically within the water column, that treating it before it spreads would be virtually impossible. Two, the substances (such as copper) to which the organisms are sensitive can be very expensive, especially in the large quantities needed to treat a red tide outbreak.

And, three, it's difficult to justify using chemicals because of their impact on other marine life. While killing *Ptychodiscus brevis*, the treatment also may kill other marine organisms or fish sensitive to the chemicals.

Biologist Vi Stewart of the Florida Department of Natural Resources' Bureau of Marine Research, recalls a red tide that lingered in the Gulf of Mexico near Florida for more than a year in the 1940s. Residents discovered that copper sulphate would kill the plant-like toxic dinoflagellate organisms, but they also discovered that the substance's damage to the ecosystem might be more extensive than the red tide itself.

"You can really upset the ecosystem (by using chemicals), because this organism is just one of hundreds of microscopic plants in the Gulf that comprise the base of the food chain for all practical purposes. If you try killing off this particular one, you'd better be sure you're not killing off the rest of them," Stewart says.

Indelicato agrees. "There is no known control over it, and I wouldn't imagine we could control something like this in the near future." Mel Russell, Galveston County Marine Advisory Service agent, adds, "The best you can do is look out for it."

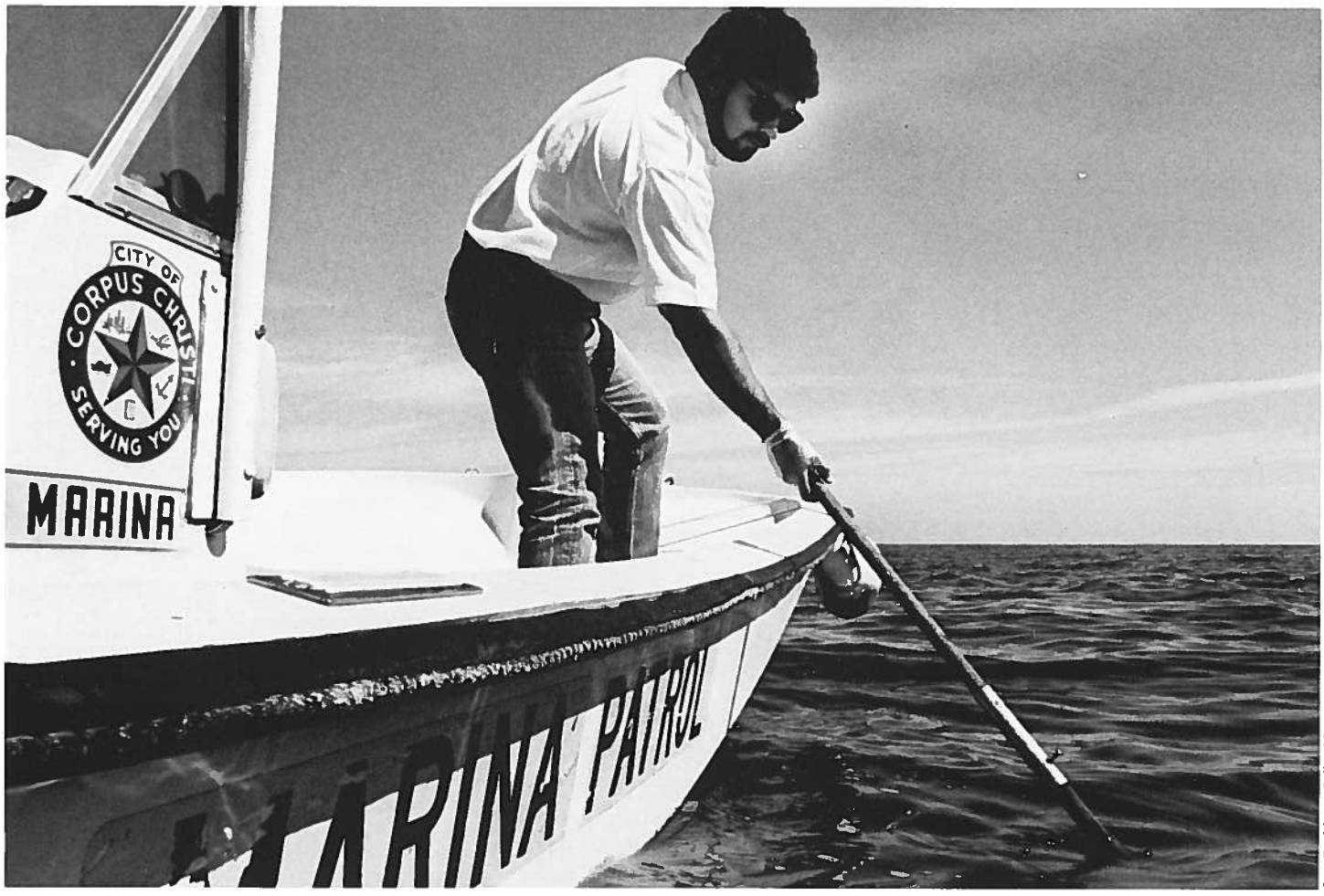
"We're going to have to treat it (red tide) like we do a hurricane or shark infestation," says Bob Conwell, president of the Corpus Christi Area Convention and Tourist Bureau. "It's just an act of God that's going to come from time to time." Thompson of the Texas Department of Health adds, "This is Mother Nature's ballgame and we're playing by her rules."

Meanwhile, the scientific community is adapting quickly to the chaos created by the red tide. Several options are already under investigation.

At present, prediction appears the best way to deal with red tide. Since the 1986 bloom, the researchers have begun a concerted effort to create an efficient red tide monitoring program for Texas. Mapping of resting cyst populations may give a better idea of when, and where, the organisms are likely to bloom.

In addition, regular water sampling and satellite monitoring will help locate red tides in their early stages. These methods for early detection should allow officials to warn

PLEASE TURN TO PAGE 23



Lee Dodds — Caller Times

State and local agencies monitored the tide as it snaked down the coastline.

first of many dead fish on his stretch of Mustang Island, near Port Aransas. Thousands of the victims of the microorganisms covered a 12-plus mile stretch of north Padre Island and Padre Island National Seashore beaches.

An overflight by scientists showed an extremely heavy, very dense, very long area of red tide in the Gulf stretching from the Colorado River south to Yarbrough Pass just beyond Malaquite Beach in the Padre Island National Seashore. The massive red patch stretched at least 6 miles into the Gulf.

The solid 4- to 10-foot-wide strip of dead fish continued unabated throughout the Padre Island National Seashore and south of Malaquite Beach. Heavy concentrations of the tide were still in Matagorda Bay, as well as in Espiritu Santo Bay, upper Aransas Bay and St. Charles Bay.

This type of fish-killing, shellfish-polluting red tide was last seen on the Texas coast in September 1955 off Port Isabel, but it only lasted a few weeks, Ray says. Red tide caused by the microorganism *Gonyaulax monilata* was reported along the Texas Coast in 1971, 1972 and two or three other times since then, he says. The latter type of red tide, though, kills shrimp and crabs as well. *Ptychodiscus brevis* does not.

Filter-feeding shellfish - such as oysters and clams - pose one of the most significant health threats regarding *Ptychodiscus brevis*, says Richard Thompson, director of the shellfish sanitation control division of the Texas Department of Public Health. Harvesting shellfish was now banned from Galveston Bay to the Rio Grande.

By October 16 the murky red tide had taken over Corpus Christi Bay, driving people out of the water. Health officials in Corpus Christi closed public beaches to swimming, surfing and sailboarding. The Texas Health Department also extended to the Rio Grande its ban on harvesting oysters, clams and mussels, which filter and store the toxins in their systems.

Marina Marshal Charles Fulton says the city's Marina Patrol Department placed "Beach Closed" signs along the shores of the affected area, warning people not to get into the water. To make matters worse, bright sunlight and temperatures in the 80s returned to South Texas, once more revitalizing toxic organisms.

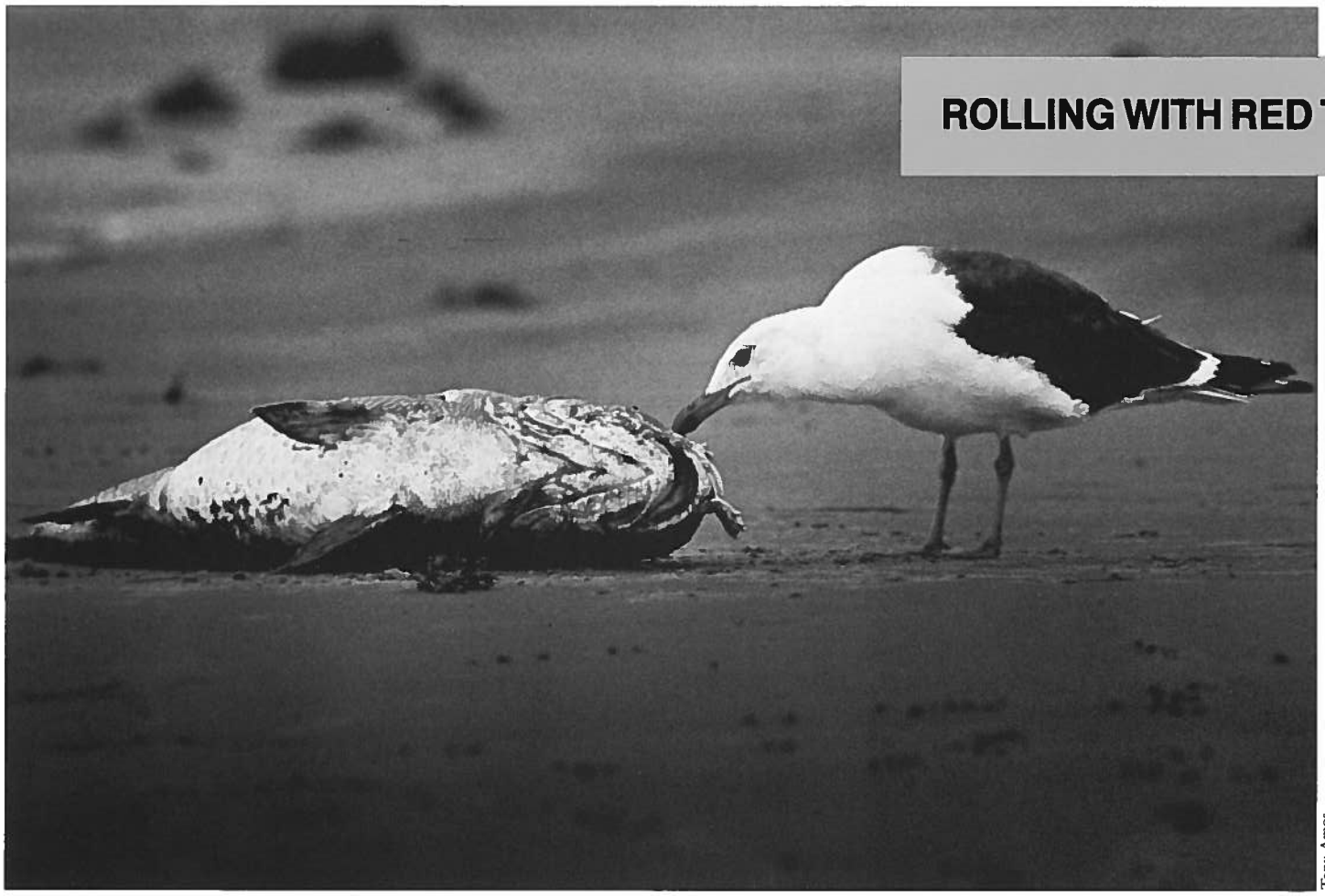
"It loves sunlight," says field investigator Buddy Stanley of the Texas Water Commission. Inspectors from the Texas Parks and Wildlife Department and Water Commission continued their flights along the coastline and sailed into bays to determine where the organisms were spreading.

Their flights now indicated a half-mile ribbon of red tide — first discovered in late August near Freeport — was present along two-thirds of the 367-mile Texas coastline. Only about the lower 30 miles near the Mexican border and the upper 80 miles from Galveston to Louisiana were spared massive fish kills. Heavy concentrations of dead fish on beaches stretched more than 100 miles, starting at Malaquite, and heavy fish kills were observed in Matagorda Bay, Espiritu Santo Bay and on the east side of San Antonio Bay.

Meanwhile, Gene McCarty, director of the Gulf Coast Conservation Association/Central Power and Light John Wilson Hatchery at Flower Bluff, where up to 10 million redfish fingerlings are produced annually, said he was "pumping fast and furious" to fill up hatching ponds before the red tide could threaten the operation.

In addition, the irritating fumes and tire-puncturing bones left by thousands of decaying fish forced Padre Island National Seashore officials to close beaches there on October 17. A solid line consisting of

ROLLING WITH RED TIDE



Tony Amos

Thousands of sea birds came to see and poke at the piles of decaying fish.

millions of dead fish lay from Malaquite Beach south along the lower Texas coastline for more than 45 miles.

"This is not a panic situation. It is simply a time for awareness and caution," Corpus Christi Mayor Luther Jones told the public.

October 20, 1986

As the tide piled mounds of rotting fish along the Texas Gulf coast, it also threatened the livelihood of those who depend on seafood sales and tourism. "We can't sell because the public is scared," Corpus Christi fisherman Gabriel Bodukoglu told the Associated Press. "When I don't make money, I get angry. I have to eat."

In late October the Texas Department of Parks and Wildlife Marine Laboratory in Rockport reported the red tide was stronger than ever, and, in fact, showed signs of resurgence in areas where it had retreated. And while surgically masked crews cleaned the shoreline, nervous Gulf Coast tourists and consumers abandoned beaches and fish markets in droves.

At the end of October the tide was still visible in heavy concentrations in Nueces Bay and to a less degree in Corpus Christi Bay. "Unfortunately, the bottom line is the red tide isn't gone," Ed Hegen, regional director for the Texas Department of Parks and Wildlife, told the local newspaper.

For days there had been an absence in bay and Gulf of Mexico waters of the distinct coloration that marks heavy concentrations of the red-tide organism. Discoloration of waters occurs when blooms of the red tide float to near the surface. Depending on the type of organism, the discoloration could range from milkish-white to red. Waves of rotting dead fish continued to wash ashore in Corpus Christi. Gordon McLerran, City-County Public Health Laboratory director, recalls the city employees were picking them up as fast as they could.

Then, finally, the course of events turned. On October 30 the Padre Island National Seashore reopened. Heavy tidal action and a shift in winds had helped clean Padre Island beaches of the dead fish, as well as other beaches along the Texas coast.

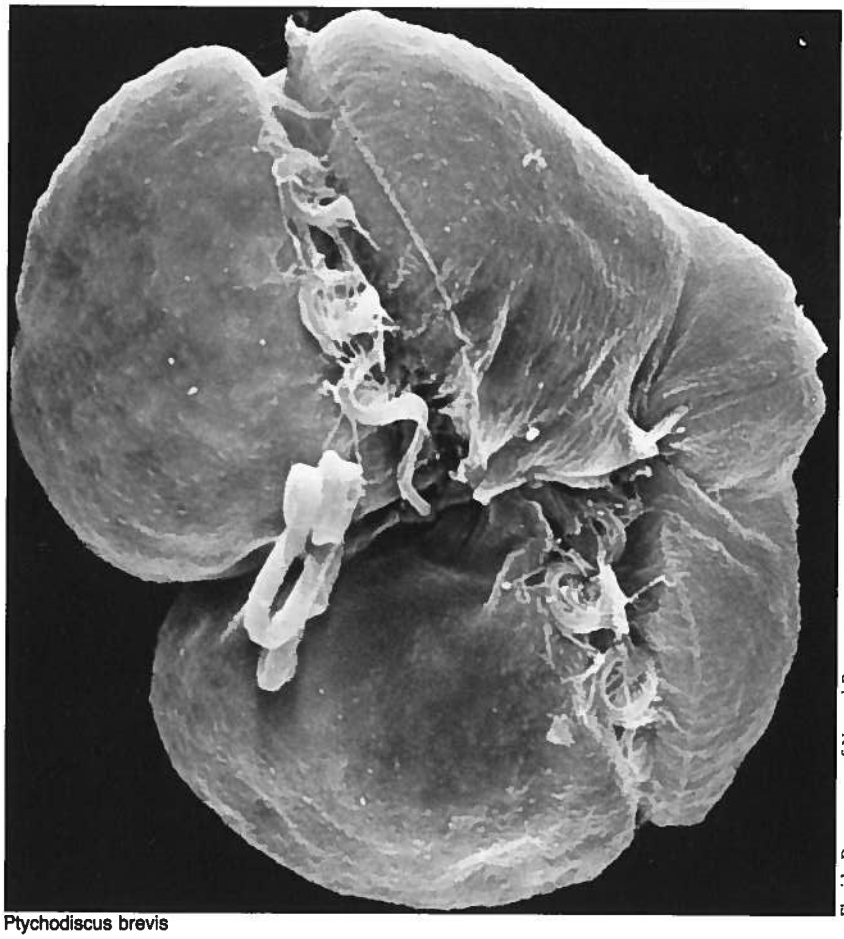
For more than two months, Texans had watched as the toxic red tide invaded the Gulf Coast. Now it finally dissipated in early November, thanks in large part to a frigid arctic cold front that swept through the area. It was the final hammer blow to drive the red tide organism away.

Now, of course, came the question, "Will it come back?" The answer to date appears to be that no one knows. Precious little is known about the red tide, about what triggers the appearance of the brick red-colored organism in coastal waters, although the salinity and temperature of water are believed to affect its concentrations and ability to grow.

"Basically, the answer is no. We won't be able to predict whether the red tide will return next year, or the year after, or in 10 years," says Hegen.

Hegen says that until scientists determine what triggers the red-tide organisms to bloom, they will not be able to predict an impending red-tide growth. Red-tide organisms can encapsulate themselves and burrow into the mud, where they can remain dormant for years.

But it's gone for now. To celebrate, a group of Port Aransas businessmen held a Red Tide sale the first week of December. And Tony Amos, the lone beach survey scientist, got back to the everyday business of counting an occasional bird or a bottle pushed to shore, and viewing his lovely, open, empty beach. ■



Ptychodiscus brevis

Florida Department of Natural Resources

SPECIAL REPORT: RED TIDE

What's killing the fish and causing the discolored water? the newspaper reporter asked. "Freshwater with alkali from the Rio Grande," guessed one citizen.

"Deep sea volcanic disturbances," replied another.

"Pockets of gas or gills clogged by vegetation," speculated a college professor, while a city official thought "It must have been something they ate."

"I have no idea," one humble soul told the reporter, "I think it will be years before the cause will be known."

Indeed, it was. These answers were reported in a 1935 edition of the Corpus Christi Caller during a phenomenon that tainted the local seawater and killed 2 million pounds of fish.

Scientists now know that the 1935 phenomenon was red tide, says Dr. Sammy Ray, marine biologist and interim president of Texas A&M University at Galveston. "It had to be red tide," Ray says, noting the similarities between the 1935 occurrence and the red tide that occurred on the Texas coast this past fall.

While scientists now understand much more than they did in 1935 about the organisms that make up the red tide blooms, they, like the man quoted in the newspaper, say it may be years still before the exact causes of the blooms are known.

What is known is that red tide is a naturally occurring bloom of tiny single-celled marine organisms called dinoflagellates. The organisms are only one-thousandth of an inch in diameter, but when an unusually dense concentration occurs, seawater sometimes appears reddish-brown, thus the name "red tide."

Red tides have been reported in various places throughout the world. The various species of red tide-causing dinoflagellates are native to particular regions. Major outbreaks in Texas have been caused by two organisms: *Ptychodiscus brevis* and *Gonyaulax monilata*.

Ptychodiscus brevis is the organism responsible for the 1935 outbreak, another in 1955, possibly a little known outbreak in the 1970s, and most recently, the 1986 bloom. *Gonyaulax monilata* has been documented six or seven times since 1935.

Although major outbreaks have been rare in Texas (with only 10 in the last 50 years), our Gulf of Mexico neighbors, Florida and Mexico, have a ed tide outbreak almost every year, says Dr. Karen Steidinger, Florida Department of Natural Resources's red tide specialist.

BY RHONDA SNIDER

Red tides are similar wherever they may occur, but each species of red tide dinoflagellates has its own particular set of characteristics. Some species produce toxins that kill shellfish as well as fish; others produce toxins that don't harm the shellfish but accumulate in them, causing illness occasionally when consumed by humans or birds. Some species produce an irritating aerosol that floats in the air. Some species are bioluminescent, creating flashes of light in and over the water where they have bloomed. Other species produce little visible evidence of their existence other than a slight discoloration in the water.

The "critters," or "bugs" as they are fondly called by Ray and others, have both plant and animal characteristics. They are photosynthetic (using light and chlorophyll to make food) and some are phototropic (moving or growing toward light). They move through the water by moving tail-like projections called flagella.

Dense concentrations of these organisms can appear in small patches or long streamers. Visible red tides have been reported to cover up to several hundred square miles.

Typically, the kind of red tide experienced in Texas in 1986 first appears several miles off the coast. Current, tides and winds may move it into the beach and bay areas where it will remain if favorable conditions exist.

The red tide also seems to "move" from one region to another, generally in a southwesterly direction with the coastal Gulf currents.

The 1986 outbreak was first sighted near Galveston and was last reported as far south as Mexico. "It's hard to tell whether the current was moving the organism," Ray says. "Or was it the 'conditioned water' that was moving? We don't know."

Steidinger believes the blooms occur in water masses, and it's the water mass that actually moves with the organisms in it.

Both *Gonyaulax monilata* and *Ptychodiscus brevis* tend to start blooming in the Gulf of Mexico in August and September. But red tide can occur anytime conditions are right for a bloom.

Red tide can last anywhere from one week to several months. Steidinger says the longest red tide on record is a bloom that in 1946 and 1947 lasted 11 months.

Ray disagrees with the common perception that red tides are happening more frequently than in years past. "People have said red tide seems to be occurring more in the last few years," Ray laments. "I don't think it's occurring more, but I think it's being identified and reported more."

Ray says a good example of the increase in reporting comes from Central and South America, where people are now culturing shellfish. Previous outbreaks probably went unnoticed, he says, but now that shellfish are being contaminated, "its effects are more obvious."

Shellfish are only one group affected by red tide. Probably the most obvious manifestation of red tide in Texas is the large numbers of fish it kills. Millions of fish can die during a red tide. Fish are killed in two ways: by toxins that are fatal to certain fish and by depletion of oxygen from the water.

Of the more than 60 species of dinoflagellates known to cause red tide, about 30 species produce toxins, says Steidinger. Both *Ptychodiscus brevis* and *Gonyaulax monilata* produce toxins.

Slow moving, bottom dwelling fish are usually the first to be affected by red tide. Nevertheless, nearly all inshore and nearshore fishes are susceptible, depending on the density of the bloom and the length of exposure.

In Texas, menhaden and mullet are the primary victims of red tide, according to

Tony Amos

Fish are killed in two ways: by a toxin that is fatal to certain fish and by depletion of oxygen from the water. Marine experts say Texas has only had 10 major outbreaks of red tide in the last 50 years.

reports from the latest outbreak. However, the organisms have killed many other species including redfish, mackerel, grouper, trout, ladyfish, rays, mudminnows, eels and more.

Ptychodiscus brevis has little effect on shrimp and crabs, unless oxygen depletion accompanies the bloom, and although the toxin accumulates in bivalves, such as oysters, clams and mussels, it doesn't kill them. *Gonyaulax monilata*, on the other hand, often kills invertebrates. Although shellfish will "close up" in an attempt to avoid filtering the *Gonyaulax monilata* organism, the toxins eventually enter the shell cavity killing them, Ray says.

Waterfowl also can be affected by red tide if they eat shellfish that have accumulated the toxin.

Although many fish are killed by red tide, fish, shrimp and crabs caught during a red tide may be eaten safely, Ray says. Very little, if any, of the toxin is absorbed by the muscle tissue. Therefore, unless the organs are eaten (as is the case with oysters, clams and mussels) the fish should not cause illness in humans.

The major health-related concern is Neurotoxic Shellfish Poisoning, which people contract by eating bivalves contaminated by the *Ptychodiscus brevis* toxin. The symptoms are similar to basic food poisoning. Few cases have been reported, and no known deaths have occurred.

NSP is sometimes confused with Paralytic Shellfish Poisoning, which can cause death in two to three hours after eating contaminated shellfish. PSP occurs worldwide, and has been documented in the *Gonyaulax monilata* organism. However, researchers in Texas say they know of no deaths connected to the PSP toxin here, while it has caused numerous deaths on the northeast coast of the United States.

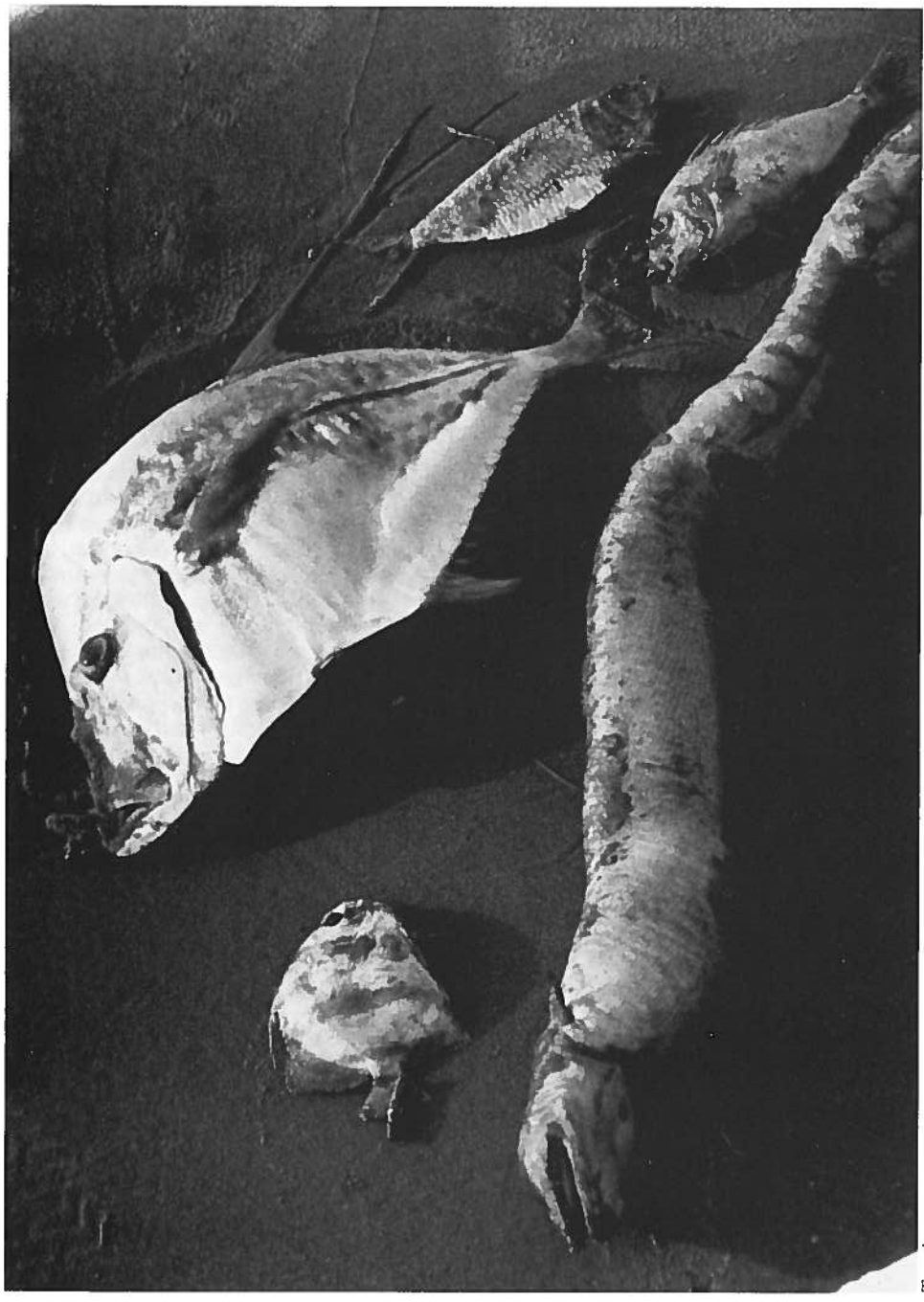
Ptychodiscus brevis also produces an "aerosol effect." In addition to the toxin released into the water, toxins are transmitted into the air via sea spray. When winds blow these particles into shore, people begin to cough, sneeze and wheeze.

While red tide researchers have identified many of the effects of red tide, they are still struggling to understand and document the life stages of the red tide dinoflagellates, especially *Ptychodiscus brevis*. Over the past 40 years, scientists have attempted to plot out the life cycle of these organisms, with a moderate degree of success.

"One of the most important things we've learned is the life cycle of other dinoflagellates," says Elenor Cox, marine biologist and assistant dean of graduate studies at Texas A&M. Florida scientists have established that *Gonyaulax monilata* and other dinoflagellates begin as cysts or "seeds." Making an analogy between *Ptychodiscus brevis* and the others, it is assumed that this organism also begins as a resting cyst, she says. And if it does, that leads to the probability of a "seed bed" on the ocean bottom.

Steidinger says it's also speculated that these seed beds are located offshore. "It (*Ptychodiscus brevis* red tide) has never actually started in the bays," she says.

Researchers have often been alerted to redtide offshore by reports from fishermen and divers of dead reef fishes and eels spoted floating offshore or dead on the bottom. Steidinger says a review of data off Florida for the 1960s and late 1970s blooms indicate that the initiation



Tony Amos

Tony Amos

Brazosport Facts

Nearly all inshore and nearshore fishes are susceptible, depending on the density of the bloom and the length of exposure. Waterfowl also can be affected if they eat shellfish that have accumulated the toxin.

zone for *Ptychodiscus brevis* blooms is 10-40 miles offshore.

Studies indicate that when certain conditions are right these dinoflagellate cysts will excyst and release motile cells into the overlying water. The exact conditions that prompt these blooms, however, are the most puzzling link in the life cycle of the organisms. Cox notes that while much has been learned about the organisms' life cycles and its cellular structure, "as for the exact causes of the bloom, we haven't learned anything really."

They do, however, have several ideas. Some of the theories are that the blooms are prompted by:

□ High salinity — "The organism grows better at higher salinities," Cox says. Normal salinity for the coastal Gulf of Mexico is 32 parts per thousand. When it begins to reach 35 or 36 ppt, the water seems to be more likely to support growth of the organism, Cox says.

□ Heat — "The organism (*Ptychodiscus brevis*) does not seem to grow at colder temperatures," Cox says. Temperatures in the 60s are the lowest that the organism has been exposed to in laboratory culture and survived. The higher temperatures seem to facilitate growth, Cox says. This probably explains why blooms usually occur in July, August and September in Texas.

□ Upwellings — Natural movements in water that bring deeper water to the surface also could bring the resting cysts to the surface, where, exposed to light and oxygen, they bloom, Ray says.

□ Entrainment — Steidinger says blooms can occur when initial low concentrations are entrained or restricted to a suitable water mass that allows their continued growth in the absence of predators.

□ Tying up of heavy metals — A theory for which there is less evidence to support lately once garnered much interest. It was once thought that the organism started to bloom when naturally occurring heavy metals in the seawater were tied up due to excessive humic acids from freshwater inflow. "The cause of the bloom is certainly not solely due to the tying up of heavy metals," Cox says.

Extending that thought a bit further she says the cause of the bloom is probably not solely due to any one condition. "I think

it's the combination of a lot of things," Cox says. "It's hard, when you're looking at nature, to isolate events." She says many elements may be working together to cause the organism to bloom.

Ray says he looks at the causes for the blooms differently than others do. Many people are looking for certain conditions or nutrients entering the water as the cause of the blooms. He believes researchers should be looking for the normally present conditions that keep it from blooming. "It's probably more likely that inhibitory factors keep it down most of the time," he says. When these inhibitory factors are removed or decreased, he says, that's when they bloom.

But whatever the causes, the organisms do bloom. However, the masses of ogranisms that make up the red tide are not the result of population explosions as many people think, Steidinger says.

"People don't see it out there," she says. "Then all of a sudden they see it. So they think it just rapidly exploded. But they're out there. They're out there slowly building up their population."

Steidinger says the creatures reproduce by dividing at an average rate of one division every two days. They continue at this rate prior to and during red tide. She says the reason they suddenly become apparent to the naked eye is because they are concentrated in one area. When the density of the organisms is great enough, the water begins to look off-color.

When the organisms reach a high density the toxins they produce begin to affect other creatures. Ray says scientists are not sure at what concentration the organism's toxins begin to kill fish. He says it's been documented that at concentrations of as few as 250,000 organisms per liter fish are killed. In 1986 the counts reached more than 100 million organisms per liter in some areas.

Why the toxin is produced is another unanswered question. Ray speculates it may be produced as a defense against the dinoflagellate's predators. Steidinger notes that some species of red tide dinoflagellates produce several toxins. *Ptychodiscus brevis*, for instance, can produce at least five different toxins.

These dense toxin-producing populations sometimes dissipate while still offshore; other times, currents, tides and winds bring them inshore. Once they begin to move into the beach and bay areas, humans begin to see and feel their effects. When the red tide begins to dissipate, the organisms may transfer once again to the resting cyst stage. It's also possible that the organisms die off as they dissipate having left cysts earlier in their life cycle.

Cox says they have no idea how many times or how often this cycle occurs. However often it may occur, she says, "the organisms are not present in superabundant numbers (off Texas) or red tide would occur more often."

Steidinger agrees, and theorizes that this is why Florida has red tide more often than Texas. "We believe ours (Florida's red tide organisms) are seeded right offshore," she says. "We seem to have certain centers of concentration." Thus, conditions such as current intrusions and upwelling can stimulate these offshore centers, she says.

It could be that *Ptychodiscus brevis* is seeded off the coasts of Florida and Mexico, she says, and every so often the coastal Gulf currents move the organisms over to the Texas coast.

Steidinger says Texas needs to discover the source of the blooms. "You need to know where your red tides are coming from," she says. By identifying the location of the organisms during their initial bloom stage, officials can begin to monitor the critters' movement and catch it in the early stages of its bloom. This early detection will allow coastal residents to be forewarned of an impending red tide.

Although there's nothing that can be done to stop an outbreak of red tide and a monitoring program will not lessen its effects, at least knowing more about the organism and its origins will allow people to prepare themselves for its arrival. ■

TO TELL THE TRUTH

Don't blame pollution, oil spills, toxic waste or nuclear fallout for red tide.

When the red tide came ashore last August near Freeport, just about every known man-made source was blamed for the kills, from remnants of the Chernobyl nuclear disaster to an oil tanker spill. "We had all kinds of reports," says James Kendall, a biologist with Texas Water Commission in Deer Park.

Evidently, some people just don't want to believe the truth. Because red tide is such a mystery among the general public, myths and fallacies abound about shellfish poisoning and the causes of red tide.

Although many people think pollution, war-time chemicals, oil spills, toxic waste or nuclear fallout are the catalysts to a red tide, it's simply not true. Red tide is sporadic, while the dumping of chemicals and pollutants into the water is a continuous occurrence. Also, red tide was documented long before these modern problems became prolific.

But, Kendall says the public didn't want to believe this. Explaining that the huge fish kills were caused by something called *Ptychodiscus brevis* was a real chore.

"There was a real public education problem," Kendall says. "If they couldn't understand it, it was wrong. Old timers on the beach said, 'I don't want to hear it's a red tide. It ain't no such thing.'"

Kendall says the public didn't want to hear about dinoflagellates. "They wanted someone to blame, whether it's Chernobyl or Exxon. People have to understand it's a natural disaster like a hurricane, tornado, earthquake or tidal wave. Mother nature did it. It's not anyone's fault."

Some of the older myths concern shellfish poisoning.

One of the most popular is that shellfish are safe to eat during months that have an "r" in them. The saying originated in Europe and was not based on red tide-induced shellfish poisoning. Shellfish are sometimes contaminated by red tide even during the "r" months in Texas.

Another fallacy concerning how to determine poisoning in shellfish is that if a silver spoon is put in a pot of cooking shellfish, it will tarnish if the shellfish are contaminated. If the shellfish are safe, the spoon will remain bright.

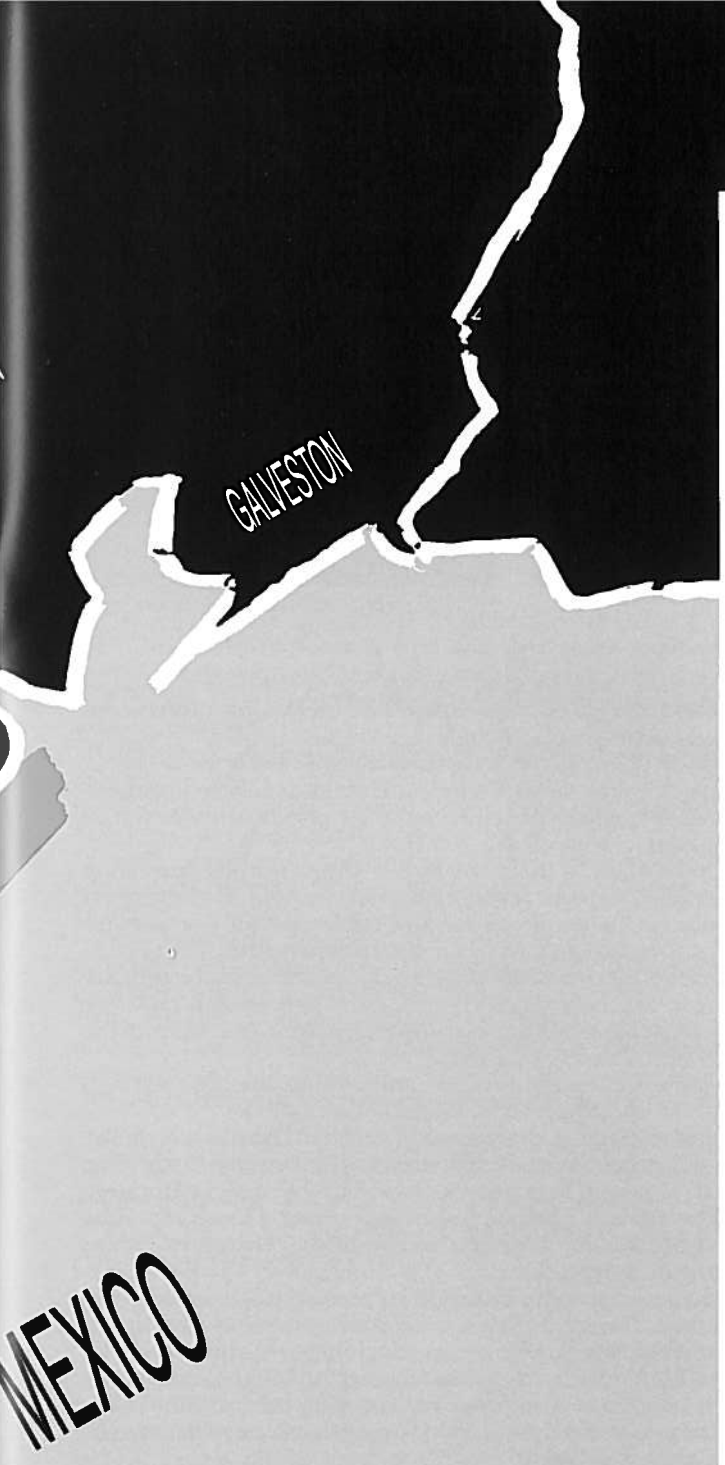
Actually, it is impossible to tell if a shellfish is contaminated without a chemical test. Also, normal methods of cooking may kill bacteria, but they will not destroy the toxins that cause shellfish poisoning.

Another item that sometimes confuses people is the absence or presence of discolored water. Although the presence of red tide is a warning that oysters, mussels and clams may be contaminated, the absence of discolored water does not mean they are safe to eat. These bivalves filter dinoflagellates out of the water for food.

Because they can filter large quantities of water, they can consume enough *Ptchodiscus brevis* to become contaminated in some cases even when the density of the organisms is not high enough to form a visible red tide. ■

— Rhonda Snider


TEXAS
SAN ANTONIO
AUSTIN
PORT O'CONNOR
FREEPORT
CORPUS CHRISTI
LAREDO
BROWNSVILLE
MEXICO
GULF OF



BITTER HARVEST

Red tide rips Texas tourism and oyster industry.

In the past few months tourism experts, state officials and marine scientists have been tapping on doors, asking questions and making the rounds like salesmen testing a new product. They search for an answer.

Why did the red tide come knocking last year and what effects did its call have on the Texas marine scene? In general, the answer is no lasting damage, but some segments of the state's marine industry were severely hurt, if not crippled. The event killed some 22.2 million fish and cost the state millions of dollars in lost tourist, recreation and oyster income. Texas' recovery is now dependent on perseverance, luck and aggressive marketing, experts say.

The red tide's impact focused in two areas — tourism/recreational services and the commercial oyster industry — with the latter receiving the brunt of the blow.

For example, in early December business activity at coastal Calhoun County's oyster and seafood processing plants roared downward more than 98 percent. One plant that processed $1.3 million worth of seafood in 1985 did $2,000 in 1986 before the state finally opened the San Antonio Bay in late December. Based on the 1985 oyster harvest for November and December, Dewayne Hollin, a Texas A&M University Sea Grant marine business management specialist, says the state lost at least $1.4 million in oyster production with a total economic impact to the state of more than $3.7 million.

State officials say Texas produces $8.6 million in oysters annually, and for every dollar of production, there is approximately $2.70 in statewide impact. The bitter part of this news is that the state was in a position to capture a large part of the national oyster market because of supply problems in other regions, says Richard Thompson, director on shellfish sanitation for the Texas Department of Health.

On top of this, the Texas Department of Health closed some 300 miles of inshore and offshore waters to the harvesting of

BY NORMAN MARTIN

Norman Martin

Good news finally came (above), but red tide hurt Texas' tourism and oyster industries.

Norman Martin

"Fortunately people's memories are short," says tourism expert, Ede Day.

shellfish, which include oysters, clams and mussels from near Galveston to the Rio Grande River. About the only other times Texas has had such extensive closure of shellfish harvesting waters is during a hurricane. "Even then, I can't recall such a large area being impacted," says Garry Phillips, a research scientist with the Texas Department of Health.

For those living in small coastal communities, heavily dependent on fisheries, the hardship was devastating. Especially hard hit by a stubborn sense of gloom were small towns like Port Mansfield, Seadrift, Port O'Connor, Rockport and Fulton. "They were really looking forward to a good oyster season," Phillips says. "This year there wasn't much production out of the northeast coast and they were going to be relying heavily on Texas oysters."

Tony Reisinger, Cameron County Marine Advisory Service agent recalls, "Even before the tide got here, we were hurting. Charter fishing fell drastically. People just weren't coming down here." Several families in this deep South Texas region, who work in the oyster picking business, were also severely affected. "They were out of business for at least six weeks and that made for a pretty tough Christmas."

The 1986 red tide struck south of Galveston in late August, eventually killing millions of fish, mostly menhaden and mullet, during a two-month southern charge down the Texas coastline. And due to breathing difficulties and huge mounds of dead fish associated with the red tide, health officials closed beaches in Corpus Christi and along the Padre Island National Seashore.

"It killed about every type of species imaginable," says George Guillen, regional chemist with Texas Parks and Wildlife's Resource Protection Division. "It got everything from mackerel to sharks to offshore reef fish. Nothing was spared."

Despite the massive fish kills charter fishing guides along the coast report recreational fishing is still good for most of the sought after game species. "The fish kill itself hasn't really impacted that much," Hollin says. "A lot of those 22 million fish were trash fish."

What has hurt, though, was apparently just the idea of red tide. Often the perception of danger is as economically lethal as the actual problem. For instance, several years ago the New England clam fishery suffered a $7 million loss due to red tide. "Even after the health department gave them the all clear, people would no longer order clams in restaurants or buy them in the market. The reason was the adverse publicity they (the industry) received," says Mel Russel, Galveston County Marine Advisory Service Agent.

Charles Moss, Russell's counterpart in Brazoria County, says the red tide could well have similar adverse economic results. Minor effects are anticipated for the shrimp and fishing industries. But, he says, "Harvesting of shellfish is going to suffer from guilt by association. There'll be some resistance to Texas oysters, even though they are fine oysters."

Since then, officials have been trying to assess the impact of the tide on the state's marine community, as well as investigate possible methods of improving their performance in future episodes, if the red tide returns.

Mike Haby, a Texas A&M Sea Grant seafood marketing specialist, expects few lasting effects to the Texas seafood industry. The product most affected by red tide — the oyster — is already regulated by the health department. The department decides when the toxin is reduced and when the beds are safe to harvest oysters. Oysters, clams and mussels can store the toxic plant-like dinoflagellate organisms that make up the red tide for two to six weeks.

Indeed, Haby predicts the oysters will be fine. "In a red tide, fish die and oysters live. Oysters don't care."

But marketing problems still remain. Haby says a similar analogy could be made to a situation in the early 1980s when several people became sick from eating oysters in Houston. "That was a significant marketing problem in terms of pricing and demand for Texas seafood products," Haby says. "It was difficult to sell products."

Improvements in health warning methods are also being studied. During the latest event state agencies received good cooperation from wire services, various newspapers and radio and TV stations along the coast, says Lloyd Crabb, a sanitarian with the Texas Shellfish Sanitation Control Division. "They gave us a lot of help, as they normally do in cases where public health is concerned."

Yet, all the warnings didn't help some bent on bending the rules. Several individuals waded out on the shallow reefs at low tide to pick oysters. The public reefs were not open, and were not due to be opened until the first of November for harvesting.

"Several went ahead and ate oysters from the affected areas and they were very sick," Crabb recalls. "It wasn't a case of them not knowing. They had been informed. They just didn't believe."

Health officials also warned against picking up dead fish, not because of the toxin carried by the fish, but because of decomposition. "The dead fish might look good, but there is no telling how long that it had been dead."

Crabb says a Federal Food and Drug Administration official in Brownsville even called, concerned some might try to gather dead fish from Mexican beaches and ship them across the border for sale in Texas. "Anybody who buys fish knows how to recognize quality. There was no special public health problem presented there with the dead fish."

Another basic problem under review is the massive media coverage the red tide event brought to Texas. Unfortunately, there is now a connection in the public's mind between Corpus Christi and red tide, says Ede Day, director of public relations for the Corpus Christi Convention and Tourist Bureau.

The image of dead fish was burned into the national consciousness — in every big city in the country, in newspapers and even on network television. And when the television networks spoke of the red tide, they often targeted Corpus Christi, and a few smaller coastal communities.

As a result, a number of the tourism-related business people were upset about what they viewed as distorted coverage in the national media, she says. "TV networks would show mounds of fish, where perhaps that was the most dramatic shot. I understand that, but still, it really hurt fishing guides, restaurants, fishing boats, hotels and motels."

Clifford Hillman, owner of Hillman Seafood in Galveston, says, "For John Q Public it (red tide) is a scary situation. Sometimes the news media seems to thrive on sensationalism, and that can have a negative effect by helping to eliminate or weaken a market."

Of course, if there were any positive aspect to the red tide's appearance, it was that red sludge showed up in October, an historically poor tourism month for the Texas Gulf Coast. "It didn't have any great effect on tourism at the time," says Bob Conwell, president of the Corpus Christi Area Convention and Tourist Bureau. "Not many people use the beach in October."

How long what scientists call the "halo effect" lasts is difficult to determine. Corpus Christi has faced similar natural disasters in the past and come through unscathed. In the 1970s, the city was on the national stage following an invasion of sharks. Later that decade, the remnants of the Ixtoc oil spill rolled ashore.

"Fortunately people's memories are short," Day says. "We can just hope they will have forgotten the red tide by next summer's tourist season."

In terms of tourism, the Texas Highway Department reports that ferry crossings to the popular Port Aransas recreational area during October and November declined more than 19,000 vehicles, a 9.4 percent decrease from the year before. Still, overall, tourism was not affected on the scale of oysters. Most tourist areas don't depend exclusively on one type of industry.

Hollin points out that the economy for many Texas coastal communities was down in the first place, well before the red tide struck. Sales tax figures for 10 affected coastal counties were down by 5 percent overall for the first 11 months of 1986 compared to the year before. But for the first nine months the total was already down 4.2 percent. For the two months that were impacted most by the red tide — October and November — the change was down 8.2 percent.

"There was an acceleration in the decline in those counties," he says. The figures don't prove that red tide caused the decline, but it could be a contributing factor, he says.

Preliminary data suggest coastal regions most affected were Calhoun, Cameron and Aransas counties and on a limited basis, Matagorda County. In interviewing more than 80 businesses along the Texas coast, Hollin discovered several pockets of severe economic strain. For example in Cameron County:

- A fishing pier owner said business was down 19.5 percent for October and November against 1985 figures.
- One hotel in the area projected losses of between $95,000 and $125,000 directly linked to the red tide.
- One marina reported 1986 activity down 75 percent during October and November.
- And, a South Parde Island bay charter service's 1986 business dipped 31 percent, while another offshore charter service fell 87 percent in October and November. ■

RESEARCH RESCUE?

CONTINUED FROM PAGE 11

people of the health-related problems that may come with an impending red tide outbreak.

Cox compares monitoring programs for red tide to that of hurricane awareness programs. Hurricanes can't be prevented. Even the best specialist can't predict exactly when or where it will begin or hit land. However, it can be monitored once it begins. People can be warned when it's about to occur and what is likely to happen when it does.

Another technique is the sharing of information. The Texas A&M Sea Grant Program brought together state and federal agencies, in addition to university researchers for an all-day symposium in December to assess the event and examine its impact to the Texas coast.

At the same time, marine experts contacted by Texas Shores say more cooperation is needed at the top agency level of state government. Apparently, field operations are not the core problem, since notes and data are exchanged frequently.

Experts want to move on other fronts, too. There was a genuine lack of understanding in Texas about the human health problems associated with red tide. For example, Dr. Edward Buskey, a specialist on marine algae at The University of Texas Marine Science Institute in Port Aransas, says when the red tide first appeared scientists were asked what should be done.

"We went basically on what we had heard from the people in Florida," he says. "There are some respiratory problems associated with red tides there, but they don't routinely close down beaches and eliminate all water sport activities."

Because of dead fish, breathing difficulties, red eyes and runny noses the toxins induce in some people, health officials closed beaches in Corpus Christi and along the Padre Island National Seashore, and banned the taking of shellfish along three-fourths of the Texas coast south of Galveston Island because oysters, clams and mussels stored the toxins in their systems.

Certainly, there are political and legal implications for closing beaches and shellfish harvests, but Buskey believes more research data are required. "We need to draw all this information together and get a good information pack available in Texas. If this ever occurs again, we need to be ready," Buskey says.

Buskey adds, "We really don't even completely understand what impact red tides have on the marine system." There are certain indications from Florida, he says, that after a red tide like the massive Texas event with its big fish kill, shrimp catches go up and sport fishing actually improves.

Some marine scientists theorize the red tides essentially "shake up the population," allowing a switch from the domination of larger or older fish. The younger fish may then have more food and this could lead to a more vigorous population. ■

— Norman Martin

MARINE ADVISOR
BY RHONDA SNIDER

Coastal communities must develop tourism

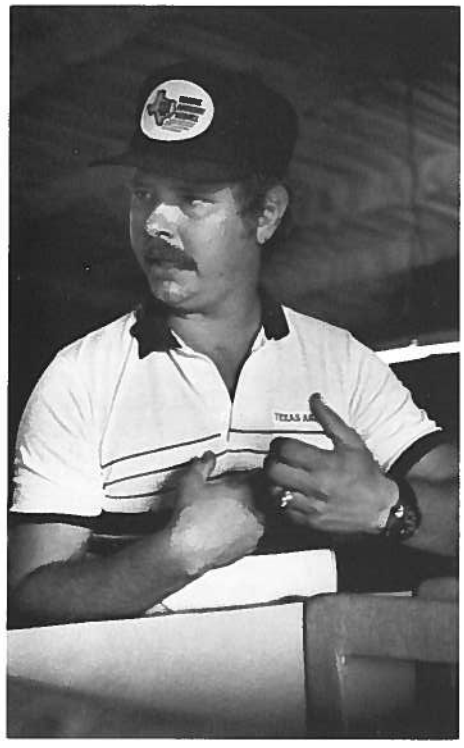
Many small Texas coastal communities are attempting to tap a new source of revenue to beat these hard economic times — a source that larger coastal cities such as Galveston and Corpus Christi have drawn on for decades: tourists. Marine Recreation Specialist Ken Pagans works with interested communities to establish game plans for developing the towns to attract tourists.

The Rockport-Fulton area took advantage of Pagans' community development expertise, recently. The leaders of Renaissance '86, a goal-setting program aimed at renewal of the area, asked Pagans, a specialist with Sea Grant's Marine Advisory Service, to be chairman of the development program. As chairman, Pagans provides impartial guidance in implementing the program and is responsible for initiating and enforcing the ground rules of the organizations' meetings.

Pagans sees this area and others like it as having much unrealized potential. The Rockport area, which promotes itself as "The Toast of the Coast," is northeast of Corpus Christi. It is in one of Texas' three major coastal tourist havens, Pagans says. These areas include Galveston Island, the Aransas and Nueces Counties area, and South Texas' Cameron County.

"This program is a good example of what should be going on," Pagans says. Rockport and Fulton are "way out in front" of other communities in terms of the grassroots level enthusiasm and support for the improvement of the community, he says. The cooperation between the public and private sectors is also a plus for the Renaissance project.

"What Renaissance can do is tell you what the major issues are, through the goal-setting process," Pagans says. To identify the issues in their community the Renaissance leaders held public hearings and distributed questionnaires through the schools and local grocery stores.



Shrimp farm short course sows new ground in Texas

Sea Grant was co-host to a successful Shrimp Farming Short Course in October. The 10-day program, coordinated by Granvil Treece, Marine Advisory associate, provided in-depth shrimp farming information and practical training in the latest shrimp culture methods for 18 participants.

"I was pleased with it," Treece says. "I think it was successful. We got a lot of good feedback." The short course, conducted at the Marine Science Institute at Port Aransas, spawned shrimp farming ventures by several participants and employment for two others.

The course curriculum covered everything from the economics of shrimp farming to marketing of shrimp after growout. Lectures covered the life history and biology of shrimp, as well as possible diseases, and maturation, spawning and larval rearing technology.

Texas A&M study targets redfish market position

A questionnaire designed to discover more about the seafood industry's purchase and distribution of redfish has been sent out to 430 seafood distributors, wholesalers and retailers.

Mike Haby, a Texas A&M Sea Grant seafood marketing specialist and author of the questionnaire, says as of the end of 1986 more than half the surveys had been returned. Redfish have gained a great deal of popularity among seafood consumers in recent years, but little has been documented about the seafood industry's preferences for type, size, market form and price of the fish.

"We wanted to get a good idea of how the industry as a whole views redfish," Haby says. "This is very important from an aquaculture standpoint."

Haby says the budding redfish farming industry needs to know the preferences in the seafood market so that it can set standards for sizes to grow out redfish. Redfish caught by commercial fishermen typically are in the 3 pound to seven pound range.

"We (current consumers) pretty much use a good size redfish," Haby says. "One option in farming of redfish is to sell fish at 3/4 to 1-1/2 pounds, most likely pan-ready. But we want to find out if there's a market for this size fish."

The survey asks questions concerning the way wholesalers and retailers currently utilize redfish, including the price paid, the purchased market form (gutted, head on, steak, fillet, etc.), the sold market form, quantities purchased and sold and their level of satisfaction. The survey also asks similar questions about their preferences for price, market form, quantities available and quality.

A summary of the results of the questionnaire should be available this spring. Further information on the summary or the questionnaire may be obtained by writing Haby at P.O. Box 158, Port Aransas, TX, 78373.

■**ADMINISTRATION** ■ **Marine Advisory Project Supervisor:** *Donn Ward;* 442 Kleberg Center; Texas A&M University; College Station, Texas 77843; (409) 845-8557. ■**COUNTY EXTENSION AGENTS - MARINE** ■ **Aransas and San Patricio Counties:** *Richard Tillman;* 953 N. Commercial; Aransas Pass, Texas 78336; (512) 758-0001. **Brazoria County:** *Charles Moss;* Rt. 2, Armory; Angleton, Texas 77515; (409) 849-5711, ext. 1564 or (409) 265-4261, ext. 1564. **Calhoun County:** *Joe Surovik;* P.O. Box 86; Port Lavaca, Texas 77979; (512) 552-9747. **Cameron County:** *Tony Reisinger;* County Building; San Benito, Texas 78586; (512) 399-2448. **Chambers and Jefferson Counties:** *Robert Nailon;* Courthouse Annex, 225 Main Street; Anahuac, Texas 77514; (409) 267-3185. **Galveston County:** *Mel Russell;* 5115 Highway 3; Dickinson, Texas 77539; (713) 534-3413; Houston: (713) 337-2575, ext. 296; Galveston: (409) 94822581, ext. 296. **Matagorda County:** *Willie Younger;* County Courthouse, Room 326; Bay City, Texas 77414; (409) 245-8415. ■**SPECIALISTS** ■ **Business:** *Dewayne Hollin;* Marine Business Management Specialist; Sea Grant College Program; Texas A&M University; College Station, Texas 77843; (409) 845-3854. **Recreation:** *Ken Pagans;* Marine Recreation Specialist; Texas A&M Research and Extension Center; Route 2, Box 589; Corpus Christi, Texas 78410; (512) 265-9203. **Seafood:** *Michael Haby;* Seafood Marketing Specialist; P.O. Box 158; Port Aransas, Texas 78373; (512) 749-5207. *Annette Reddell Hegen;* Seafood Consumer Education Specialist; P.O. Box 158; Port Aransas, Texas 78373; (512) 749-5207. **Fisheries:** *Gary Graham;* Marine Fisheries Specialist; Rt. 2, Armory; Angleton, Texas 77515; (409) 849-5711, ext. 1564 or (409) 265-4261, ext. 1564. *Russell Miget;* Marine Fisheries Specialist; Texas A&M Research and Extension Center; Route 2, Box 589; Corpus Christi, Texas 78410; (512) 265-9203 or (512) 749-5207. *Thomas Linton;* Marine Fisheries Specialist; Department of Wildlife and Fisheries; Texas A&M University; College Station, Texas 77843; (409) 845-5794l

PUBLICATIONS

The following publications are available from the Marine Information Service, Sea Grant College Program, Texas A&M University, College Station, TX 77843. Prices quoted are for single copies. Write for prices for multiple copies. Request publication by both title and TAMU-SG number, and send a check payable to Texas A&M University.

Sea Sources: Bibliographic & Resource Material About Children's Literature of the Sea. *Bagnal.* TAMU-SG-79-402. $4.

Hurricane Message Enhancement. *Ruch, Christensen.* TAMU-SG-80-202. $5.

Marine Organisms in Science Teaching. *Hunt.* TAMU-SG-80-403. $4.

Shrimp in Microwave Cookery. *Reddell.* TAMU-SG-80-505. $2.

Guidelines for Establishing Open-Water Recreation Beach Standards-Proceedings. *McCloy, Dodson (ed).* TAMU-SG-81-116. $5.

Mini-Learning Station Set I; Language Art I. *Hunt.* TAMU-SG-81-401. $5.

Fairy Tales of the Sea (Reader). *Cowan, Davis.* TAMU-SG-81-402. $4.50.

Fairy Tales of the Sea (Teachers Guide). *Wiseman.* TAMU-SG-81-403. $2.

Whales and Dolphins Off the Texas Coast (Poster). *Broussard (ed).* TAMU-SG-84-505. $3.

Whales and Dolphins Off the Texas Coast (Fact Sheet). *Broussard (ed).* TAMU-SG-84-401. Single copies free.

Fishing the Texas Surf. *Fedler.* TAMU-SG-79-605. Single copies free.

Freezing Fish and Shellfish. *Nickelson & Hegen.* TAMU-SG-77-503. Single copies free.

1986-1987 Texas A&M Sea Grant College Program Directory. *Broussard (ed).* TAMU-SG-87-602. Single copies free.

Safety and Quality Aspects of Oysters, Mussels and Clams. *Haby.* TAMU-SG-85-503. Single copies free.

Red Tide in Texas: An Explanation of the Phenomenon. *Snider (ed),* TAMU-SG-87-502. Single copies free.

Aquatic Science - Marine Fisheries Biology. *Davis & Lightfoot.* TAMU-SG-79-405. Single copies free.

Children's Literature - Passage to the Sea. TAMU-SG-80-401. $2.

Cutting Fuel Costs: Alternatives for Commercial Fishermen. *Hollin & Windh.* TAMU-SG-84-504. Single copies free.

Proceedings of the Tenth Annual Tropical and Subtropical Fisheries Conference of the Americas. *Ward, Treece.* TAMU-SG-86-102. $15.

Proceedings of the Eighteenth Dredging Seminar. *Herbich.* TAMU-SG-86-105. $10.

Proceedings of the Shrimp Yield Prediction Workshop. *Landry, Klima.* TAMU-SG-86-110. $10.

Marine/Offshore Outlook 1986. *Hollin.* TAMU-SG-86-111. $5.

Economics of Harvesting and Market Potential for the Texas Blue Crab Industry. *Miller, Nichols.* TAMU-SG-86-201. $5.

Nonparametric and Parametric Estimation of Wave Statistics and Spectra. *Yamazaki, Herbich.* TAMU-SG-86-202. $10.

Hurricane Relocation Planning for Hardin, Jasper, Jefferson, Newton and Orange Counties. *Ruch.* TAMU-SG-84-620. $5.

Understanding Involved Fishermen: A Survey of Members of the Gulf Coast Conservation Association. *Ditton, Holland.* TAMU-SG-84-623. $2.

Airphoto Analysis of the Impact of Hurricane Alicia on Galveston Island. *Broussard (ed), Benton.* TAMU-SG-85-201. $2.

Nocturnal Activity of Birds on Shrimp Mariculture Ponds. *Beynon, Hutchins.* TAMU-SG-85-805. $1.

Economics of Harvesting and Market Potential for the Texas Blue Crab Industry. *Miller, Nichols.* TAMU-SG-86-201. $5.

Bird Island Basin-An Environmental Study Area. *Harris.* TAMU-SG-86-401. $2.

Hurricane Relocation Planning for Cameron and Willacy Counties. *Ruch.* TAMU-SG-86-601. $8.

Sea Grant Aquaculture Plan. *Jennings.* TAMU-SG-82-114. $5.

Proceedings of the Second Annual Tropical & Subtropical Fisheries Technological Conference. *Nickelson.* TAMU-SG-78-101. $10.

Proceedings of Third Annual Tropical & Subtropical Fisheries Technological Conference of the Americas. *Nickelson.* TAMU-SG-79-101. $10.

Proceedings of the Fifth Annual Tropical & Subtropical Fisheries Technology Conference of the Americas. *Nickelson.* TAMU-SG-81-101. $10.

Proceedings of the Sixth Annual Tropical & Subtropical Fisheries Technology Conference of the Americas. *Nickelson.* TAMU-SG-82-101. $10.

Proceedings of the Seventh Annual Tropical & Subtropical Fisheries Technology Conference of the Americas. *Nickelson.* TAMU-SG-82-110. $10.

Hangs & Bottom Obstructions of the Texas/Louisiana Gulf-Loran C (3rd Rev). *Graham.* TAMU-SG-81-501. $5.

Summary of Shrimp Mariculture Production Data at Texas A&M, 1968-78. *Johns, Holcomb, Griffin, Hutchins.* TAMU-SG-81-603. $5.

Hurricane Relocation Planning for Brazoria, Galveston, Harris, Fort Bends & Chambers Counties. *Ruch.* TAMU-SG-81-604. $5.

Predicting Marine Recreational Fishing Patterns from Boat Characteristics & Equipment. *Ditton, Grefe, Fedler.* TAMU-SG-81-814. $1.

Nutritional Response of Two Penaeid Species to Various Levels of Squid Meal in a Prepared Feed. *Fenucci, Zein-Eldin, Lawrence.* TAMU-SG-82-813. $1.

Generalized Budget Simulation Model for Aquaculture. *Griffin, Jensen, Adams.* TAMU-SG-83-202. $5.

User Guide for General Bioeconomic Fisheries Simulation Model (GBFSM). *Adams, Jensen, Griffin.* TAMU-SG-832204. $5.

Marine Education: A Seagoing Experience. *Tinnin.* TAMU-SG-83-401. $1.

Life On Board An American Clipper Ship. *Schultz.* TAMU-SG-83-402. $1.

Bibliography of Maritime & Naval History Periodical Articles Published 1978-79. TAMU-SG-83-602. $5.

Computer Accessible Annotated Bibliography of the Corpus Christi Bay Estuary. *Flint.* TAMU-SG-83-605. $5.

Saltwater Fishes of Texas: A Dichotomous Key. *Murdey.* TAMU-SG-83-607. $7.

Microbial & Chemical Changes During Storage of Swordfish (Xiphias gladius) Steaks in Retail Packages Containing CO2 Enriched Atmosphere. *Finne, Hanna, Vand, Nickelson.* TAMU-SG-83-808. $1.

1984 Deep Sea Roundup: An Analysis of Participant's Characteristics, Attitudes and Expenditures. *Ditton, Arneson.* TAMU-SG-86-203. $5.

Readership Survey of Marine Education. *Gresham, Bush.* TAMU-SG-86-204. $2.

Monthly Wave Characteristics National Oceanographic Data Center - Vol. I, II, III. *Yamazaki, Herbich.* TAMU-SG-86-205. $25.

Bird Island Basin—An Environmental Study Area. *Harris.* TAMU-SG-86-401. $2.

An Annotated Guide to the Barnacles of the Northern Gulf of Mexico. *Gittings, Dennis, Harry.* TAMU-SG-86-402. $3.

12 Pound Test: A Dozen Checkpoints for Avoiding Snags in Your Fishing Tournaments. *Younger.* TAMU-SG-86-502. Single copies free.

Texas Coast Hurricanes. *Broussard & Martin.* TAMU-SG-86-505. Single copies free.

Keeping Fish "Tournament Fresh". *Russell.* TAMU-SG-86-504. Single copies free.

Hurricane Relocation Planning for Cameron & Willacy Counties. *Ruch.*TAMU-SG-86-601. $8.

Fishing Tournament Information and Retrieval System. *Bartley.* TAMU-SG-86-603. $5.

Effects of Seismic Sounds on Marine Organisms: An Annotated Bibliography & Literature Review. *Linton, Hall, LaBomascus, Landy.* TAMU-SG-86-604. $3.

SEA GRANT COLLEGE PROGRAM
TEXAS A&M UNIVERSITY

WINTER 1987

Norman Martin