Shore & Beach

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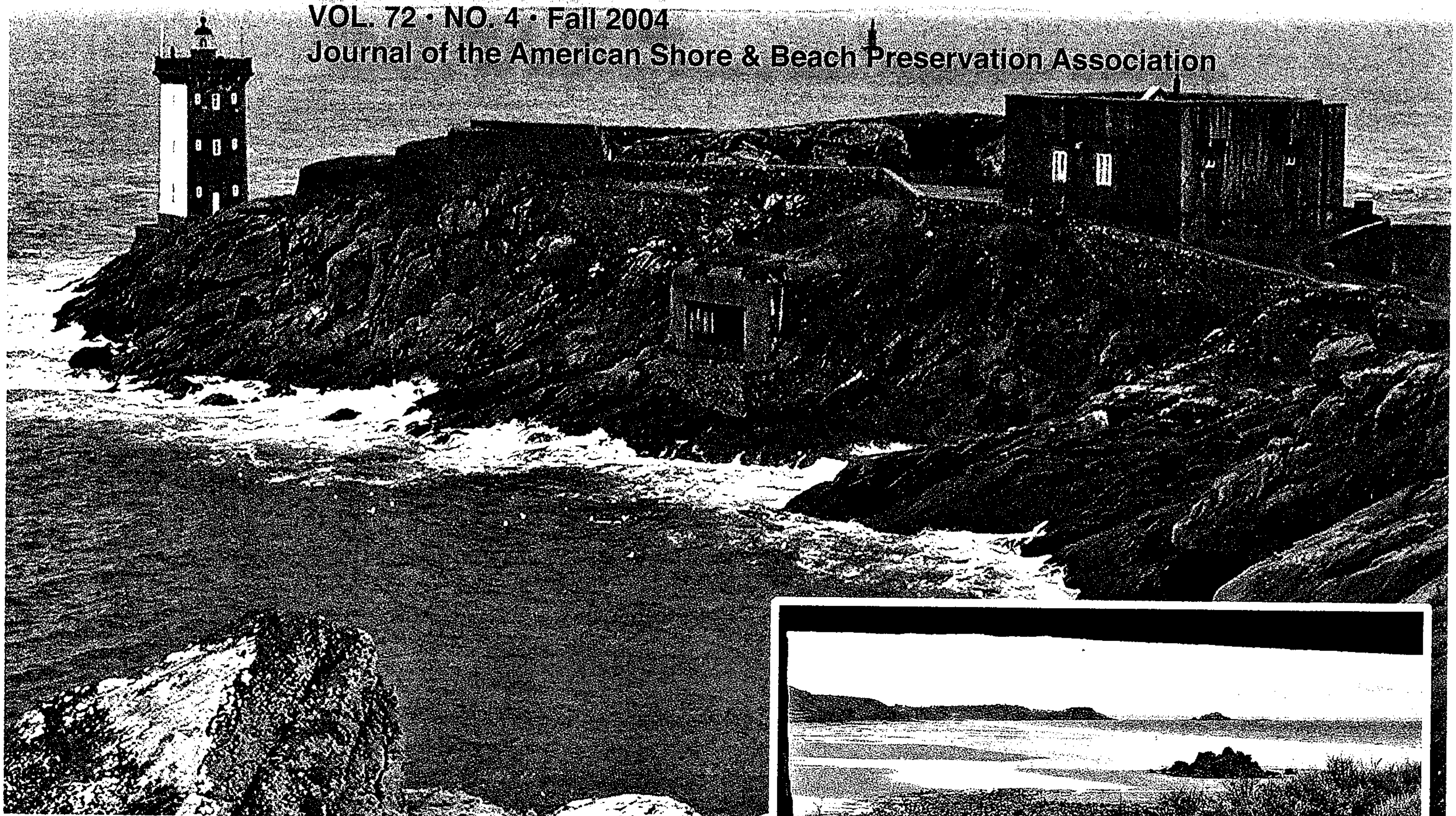

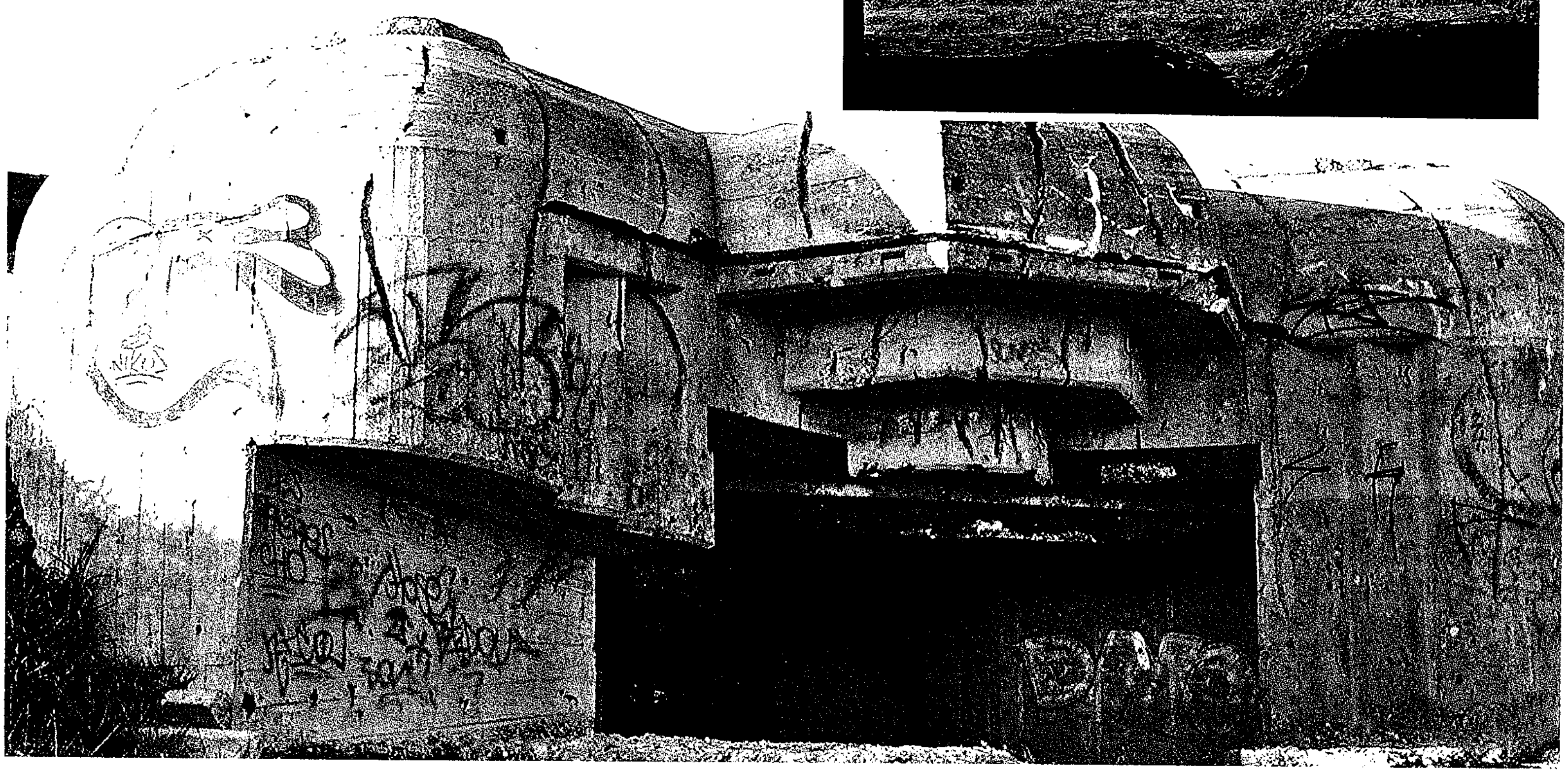

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Cover: Top Photo: Fort and Phare de Kermorvan, Le Conquet. Inset Photo: View of Plage de Saint-Pabu, Plage de la Ville Berneuf, Plage du Nantois and Plage des Vallées from a machine gun bunker protecting Plage de Saint-Pabu. Bottom Photo: Pointe du Petit Minou showing the 105 mm German gun bunker above the Phare and Fort du Petit Minou at the entrance of the Goulet de Brest. Photos: Hubert Chanson. For more information see Coastal Observations, page 10 of this issue.

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Tracking Post-storm Beach Recovery Using Data Collected by Texas High School Students

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ABSTRACT

The Texas High School Coastal Monitoring Program (THSCMP) engages people who live along the coast in the study of their natural environment. High school students, teachers, and scientists work together to gain a better understanding of dune and beach dynamics on the Texas coast. Scientists provide the tools and training needed for scientific investigation. Students and teachers learn how to measure the topography (beach profile), map the vegetation line and shoreline, and observe weather and wave conditions. By participating in an actual research project, the students obtain an enhanced science education. Public awareness of coastal processes and the Texas Coastal Management Program is heightened, and the students' efforts also provide coastal communities with valuable data on their changing shoreline.

Data collected by students in the program have been used to observe beach and dune recovery after Tropical Storm Frances caused significant damage to beaches along the southeast (upper) coast of Texas. The post-storm recovery of the beaches is compared to recovery following a category 3 hurricane 16 years earlier. The two storms were very different in duration and magnitude but similar in the amounts of beach erosion and storm damage. The volume of sand removed by Frances returned quickly to the beaches in the study area but dune profile and the vegetation line, both of which were severely impacted by the storm, have not returned to their pre-storm positions by the end of the five year study period.

Additonal Keywords: Texas, science education, beach profile, beach monitoring, post-storm recovery. *Article Received: 5/20/2004, Revised: 9/20/2004, Accepted: 9/20/2004*

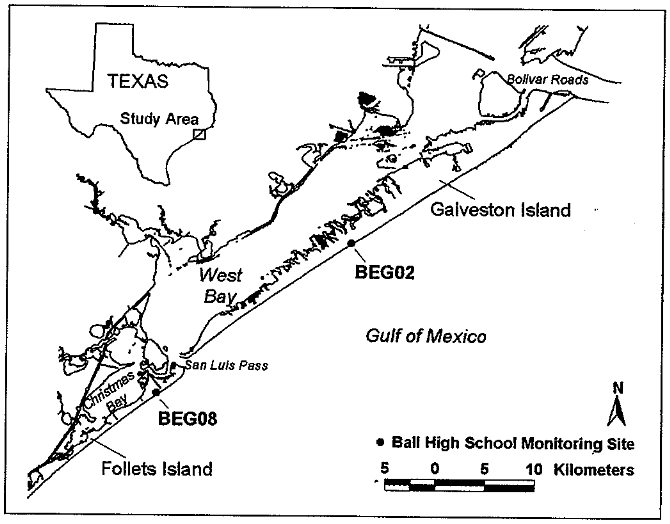

Figure 1. Ball High School students monitor two sites for the Texas High School Coastal Monitoring Program. BEG02 is in Galveston Island State Park and BEG08 is southwest of San Luis Pass on Follets Island.

INTRODUCTION

High school science courses with content that is interesting and shown to be relevant to our livelihood are crucial to encouraging students to pursue careers in science. For students not pursuing science careers, high school may be the last opportunity for learning about and appreciating the scientific method, which governs the formation of much public policy. Furthermore, citizens are increasingly asked to vote on or get involved in environmental issues that are often framed in scientific arguments. Coastal processes and public issues are an ideal venue for teaching high school students basic and applied science and illustrating the role science plays in making public policy decisions.

Most people enjoy going to the beach and experiencing the waves, wind, and sand. For high school students living near the coast, the beach may not be just a place for personal recreation but may also be an important part of their local economy. Motivating high school students to go on a beach field trip is not a problem.

This paper describes the program and research results through the sixth year at Ball High School on Galveston Island (Figure 1) and fourth year at Port Aransas on Mustang Island and Port Isabel in south Texas. To demonstrate the scientific usefulness of student-collected data, we have done a comparison of post-storm beach recovery at the two sites monitored by Ball High School students. Morton et al. (1994) conducted a 10 year study of the beaches of Galveston and Follets Island following Hurricane Alicia in August 1983. Two of their study sites, BEG02 and BEG08, are currently monitored by Ball High School. Morton et al. (1994) described four stages of post-storm recovery from forebeach accretion through dune and vegetation expansion following Hurricane Alicia. Although the storm that affected the upper coast of Texas in 1998 was not as strong as Alicia, damage to the beaches was extensive and the stages of recovery can be applied to the Ball High School monitoring sites.

Study Area

The study area for this project ranges from Galveston Island on the upper Texas coast to South Padre Island at the southern extent of the Texas coastline, a distance of approximately 460 km. While all of the sites for this project vary morphologically, they are very similar sedimentologically. The beaches of the Texas coast are composed of well-sorted fine to very fine sand that is mainly quartz with varying amounts of shell and heavy minerals.

The two sites monitored by Ball High students are located on Galveston and Follets Island (Figure 1). BEG02 is located in

Galveston Island State Park, about 10 km southwest of the southern end of the Galveston seawall. This site has an artificial dune that was formed by bulldozing washover sand following Tropical Storm Frances in 1998. BEG08 is located on the northeastern end of Follets Island, approximately 3.5 km south (downdrift) of a natural tidal inlet, San Luis Pass. This site is completely natural with very low (1 m) foredunes and is influenced by processes occurring at the inlet.

Profiles measured by Port Aransas and Port Isabel students are only the fourth year in their time series. The selected profile sites for these schools represent a range of natural and human influenced environments. These sites were not previously monitored by scientists from the University of Texas. Future measurements will not only show change through time at each location but will also show spatial variation along the Texas coast. Through time the data collected from Mustang and South Padre Islands will help scientists establish a better understanding of the relationship between coastal processes, beach morphology, and shoreline change at these locations along the Texas coast.

PROGRAM DESCRIPTION

Goals

The THSCMP has three major goals. The first is to provide high school students with an inquiry-based learning experience. Students make several field trips to their study sites during the school year where they conduct topographic surveys (beach profiles) of the foredune and beach, map the vegetation line and shoreline, collect sediment samples, and observe weather and wave conditions. Back in the classroom, students analyze their data and look for relationships among the observed phenomena. University of Texas scientists provide background information and guide inquiries about the data, but students are encouraged to form their own hypotheses and to test them. Through their collaboration with working scientists on an actual research project, the students gain an enhanced science education.

The second goal is to increase public awareness and understanding of coastal processes and hazards. Participating students discuss the program with their parents, classmates, and neighbors, further expanding the reach of the program. Newspaper stories, television spots, and state-sponsored educational television programming have drawn attention to the program and coastal erosion issues. A World Wide Web site (http://txcoast.beg.utexas.edu/thscmp/) containing the latest information is central to the community outreach portion of the project. On the website, coastal residents can see the effects of a storm that strikes the coast and examine the recovery of the beaches and dunes. They can do this by viewing maps, graphs, and photographs acquired by the high schools. Hence, the website increases the awareness and appreciation of coastal processes and how future storms could affect their community. Also on the website are detailed descriptions of how to collect the data and field forms. This material encourages other groups or individuals to start a monitoring program of their own.

The third goal is to obtain a better understanding of the relationship between coastal processes, beach morphology, and shoreline change and make data and findings available for solving coastal management problems. The Bureau of Economic Geology (Bureau) at the University of Texas at Austin conducts research on coastal processes. An important part of our research program is the repeated mapping of the shoreline and measurement of beach profiles. Over time, these data are used to determine the rate of shoreline change, which is provided to the Texas General Land Office for management decisions and erosion mitigation planning. A problem we face is the limited temporal resolution in our shoreline data. The beach is a dynamic environment where significant changes in shape and sand volume can occur over periods of days or even hours. Tides, storms, and seasonal wind patterns cause periodic or quasi-periodic changes in the shape of the beach and position of the shoreline. If coastal data are not collected often enough, relatively short-term variations occurring over a few months to a few years could be misinterpreted as long-term trends occurring over decades. The THSCMP helps address this problem by providing additional scientific data at key locations along the Texas coast. These data are integrated into the ongoing coastal research program at the Bureau and are made available to other researchers and coastal managers.

Methods

The central element in the THSCMP is two to three class field trips during the academic year. During each trip, students visit several locations, apply scientific procedures to measure beach morphology, and make observations on beach, weather, and wave conditions. These procedures were developed during the program's pilot year (1997/1998) and are presented in detail on the website.

At each study site there are several measurements and observations that the students make. The key component for this study is the beach profile. The students employ the Emery method using a pair of graduated rods, a metric tape, and a hand level to accurately survey a shore-normal beach profile from the foredunes to the waterline (Emery 1965; O'Connell 2001) (Figure 2). The students begin each profile at a pre-surveyed datum stake so that they can compare each new profile with earlier profiles. Consistently oriented photographs are taken with a digital camera. The beach profiles provide detailed data on the volume of sand and the shape of the beach.

In addition to measuring topographic profiles, the students make observations on weather conditions, sea state, longshore current, and dune vegetation and map the vegetation line and shoreline. Students measure wind speed and direction, estimate the width of the surf zone, and observe the breaker type. They note the wave direction, height and period, and estimate the longshore current speed and direction using a float, stop watch, and tape measure. The students take sediment samples along the beach profile at the foredune crest, berm top, and beach face. They then sieve the samples and weigh the grain size fractions. Using a differential GPS unit, students walk along the vegetation line and shoreline, mapping these features for display on

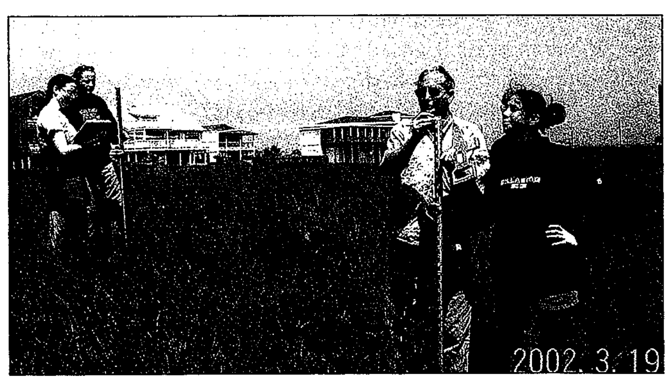

Figure 2. Port Aransas High School teacher demonstrating to students how to conduct topographic surveys using the Emery method.

Geographic Information System software. The GPS mapping provides measurements of the rate of shoreline change.

Effects on Science Curriculum

The THSCMP addresses several National Science Education Standards (National Research Council 1996). The program is relevant in the following categories of content standards: (1) unifying concepts and processes in science, (2) science as inquiry, (3) physical science, (4) earth and space science, (5) science and technology, and (6) science in personal and social perspectives. Standards related to applying scientific methods in field and laboratory investigations in these categories are well covered in the THSCMP. Specific requirements, such as (1) collecting data and making measurements with precision, (2) analyzing data using mathematical methods, (3) evaluating data and identifying trends, and (4) planning and implementing investigative procedures, are an excellent fit with the THSCMP. Standards that require students to use critical thinking and scientific problem solving to make informed decisions are also well served. Furthermore, teachers and scientists can use the program to illustrate to students the role science could, should, or does play in developing public policy. A case study of a local erosion problem could be used as an example.

General Recommendations for High School Coastal Monitoring Programs

We consider the THSCMP a successful student monitoring program and offer the following recommendations for those interested in initiating a similar program. Emphasize to the students that they are working on a real research project and are collecting scientifically valid data that will appear in scientific publications and help in making decisions about beach management. Clearly inform the students about the specific scientific problems being addressed, but also emphasize that they are gaining experience not just in how to measure beaches but how to conduct scientific field research in general. Survey at least two beaches to provide a balance between scientific research and science education. The number of official field trips depends on the class, but a maximum of four trips is reasonable. When adding additional schools to the program, a two to three day seminar before the school year, including all teachers, is desirable. A website adds an important dimension to the project for exchanging observations between the schools and increasing public awareness of coastal processes.

CASE STUDY OF BEACH AND DUNE RECOVERY ON GALVESTON AND FOLLETS ISLANDS

Hurricane Alicia struck the southern end of Galveston Island on August 18, 1983. The hurricane reached a category 3 on the Saffir-Simpson scale with wind speeds of 115 mph and a minimum central pressure of 963 mb. The maximum storm surge of 3.8 m lasted for 3 hours causing severe beach and dune erosion (U.S Army Corps of Engineers 1983). According to Morton and Paine (1985), 1.5 million cubic meters of sand were eroded from the southwestern end of Galveston Island. The foredunes on Galveston Island and Follets Island were destroyed by the storm surge.

Morton et al. (1994) described four stages of post-storm recovery from beach profile data collected following Hurricane Alicia. The stages include (1) rapid forebeach accretion, (2) backbeach aggradation, (3) dune formation, and (4) dune expansion and vegetation recolonization. This study found that the post-storm recovery of the beaches of Galveston Island and Follets Island affected by Hurricane Alicia lasted between 4 and 5 years. After this time period the beaches reverted to long-term patterns of beach response.

The above model for post-storm beach and dune recovery was developed from quarterly beach profile surveys conducted at seven locations from 1983 through 1985 following Hurricane Alicia. From 1985 to 1997, however, the beaches had been surveyed on an irregular schedule about once per year. The THSCMP at Ball High School began in 1997 and has measured two key locations approximately three times per year (Figure 1). These student measurements have enabled a test of the beach and dune recovery model for the period following Tropical Storm Frances in 1998.

Tropical Storm Frances struck the southeast (upper) Texas coast September 7 through 13, 1998 causing extensive beach and dune erosion and damage to structures. The storm surge peaked at only 1.4 m above mean sea level, but extreme water levels, defined as more than three times the standard deviation above the mean from 1993 to 1998 (>0.78 m), lasted for 64 hours. Peak wave height was 4.09 m during the storm with extreme wave heights (>2.3 m) lasting for 73 hours. Water level data are from the Pleasure Pier open-coast tide gauge on Galveston Island. Wave height information is from a moored buoy operated by the National Data Buoy Center, offshore Galveston Bay. Frances caused 15 to 25 m of vegetation line retreat, and at the two Ball High School study sites, the foredune was completely eroded and washover sand was deposited landward (Gibeaut et al. 2002).

Post Tropical Storm Frances Recovery

Beach and dune recovery following Tropical Storm Frances in 1998 was interpreted from beach profiles and onsite observations. Profile data collected by the high school students is entered into the software package called "Beach Morphology and Analysis Package" (BMAP). BMAP Version 2, developed by the U. S. Army Corps of Engineers, is commonly used by coastal engineers and scientists for beach-profile analysis. Beach-volume calculations were made using BMAP. The volumes for BEG02 and BEG08 were calculated from the benchmark to a closing height 1.5 m below the elevation of the benchmark or to approximately mean sea level. Profiles that did not extend to the closing elevation were extrapolated. Shoreline and vegetation

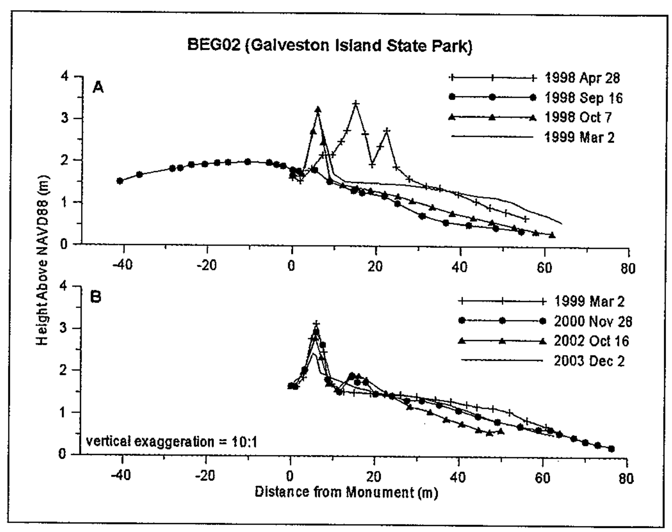

Figure 3. Selected profile plots from BEG02. A) Profile plots from April 1998, representing pre-Frances topography, through the end of the first winter of recovery. B) Continuation of beach and dune recovery at Galveston Island State Park.

line positions were determined from field notes of students and scientists and GPS positions.

BEG02. During Frances, the beach at Galveston Island State Park (BEG02) lost 42 m³ of sand per m of shoreline. Before the storm, this beach had a prominent foredune and a smaller incipient foredune (Figure 3A). These dunes were completely removed with a portion of the sand deposited landward. During the storm, the shoreline retreated 39 m, and the vegetation line retreated 21 m (Figure 4). Recovery of the beach proceeded quickly, however, with a steady return of sand over the winter. By March 1999, the beach had regained 88 percent of the volume eroded by Frances (Figure 4). Post-storm recovery proceeded during the first winter after the storm as the shoreline advanced steadily and regained its pre-storm position (Stage 1) and the back beach aggraded (Stage 2). The vegetation line moved only 10 m seaward, aided by a human-made foredune that consisted of bulldozed washover sand (Stage 3-dune reconstruction). The bulldozed washover sand also contributed to the volume recovery of the beach/dune system.

Recovery continued from summer 1999 through early 2001 when volume and shoreline position stabilized near the pre-storm figures (Figure 3B). From March 1999 to July 2001, the vegetation line moved another 2 m seaward. In November 2000, scientists and students noted a secondary vegetation line and a small set of incipient dunes seaward of the foredunes (Stage 4). This secondary line was the seaward boundary of a recovery area stretching landward to the vegetation line monitored in Figure 4. The vegetation in this area was in small patches (<30% vegetation cover overall) and was often discontinuous due to landward embayments caused by elevated water levels. By the end of 2000, this section of beach had evolved through all four stages of beach recovery. Stages 3 and 4, dune formation and dune expansion and vegetation recolonization, were completed much earlier then would have naturally occurred. The end of 2000 marked the end of the beach recovery period at BEG02. The vegetation line remained stable until early 2003. Since 2000, there has been a slight trend of shoreline retreat and volume loss that is consistent with the long-term trend for this site.

The increase in shoreline retreat and loss of volume in late 2002 and again in mid 2003 is due to additional tropical storm activity. Tropical Storm Fay in September 2002 and Hurricane Claudette in July 2003 both made landfall on the central Texas coast. At the end of the monitoring period, recovery from these two storms was still in an early stage (forebeach accretion and backbeach aggradation). Following Claudette, a significant volume of sand was lost from the dune system (Figure 3B) and the vegetation line retreated 10 m. At the end of the monitoring period, the vegetation line was 13 m landward, the shoreline was 15 m landward, and the volume was 13 m³/m less than the pre-Frances values.

BEG08. At this location on Follets Island, southwest of San Luis Pass (Figure 1), Frances eroded 33 m³/m of sand. The foredune was removed, leaving a former secondary dune as the foredune (Figure 5A). Only a small amount of washover sand was deposited through low areas in the former secondary dune. The shoreline retreated 50 m, and the vegetation line retreated 42 m (Gibeaut et al. 2002). As at Galveston Island State Park, this beach began recovering soon after the storm with 57% of the sand eroded returning by October 22, six weeks later (Figure 6). By March 1999, the beach contained the same amount of sand as before the storm. The shoreline also advanced to its pre-storm position, but the vegetation line had only moved 18 m from

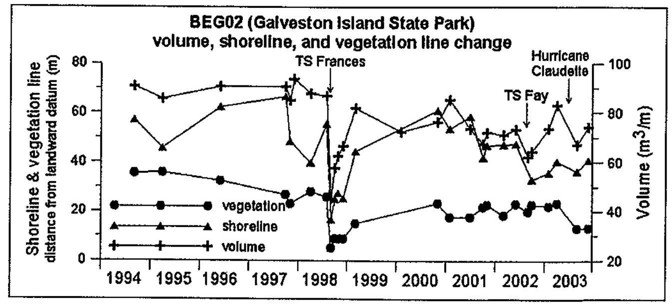

Figure 4. Profile volume, shoreline, and vegetation line changes at Galveston Island State Park.

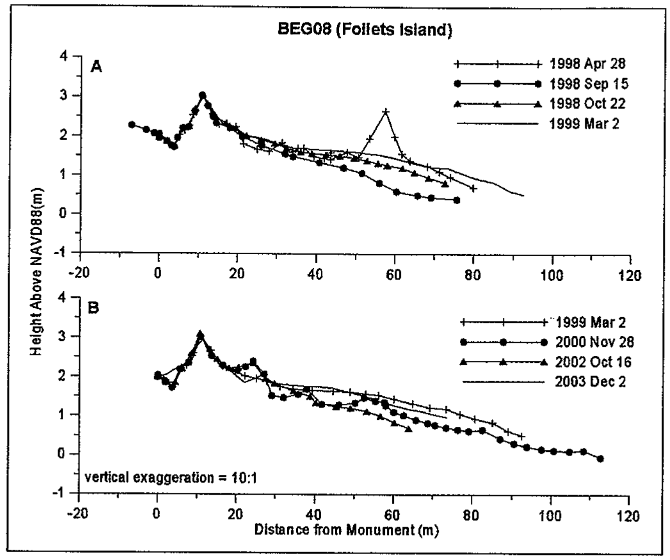

Figure 5. Select profile plots from BEG08, Follets Island. A) Profile plots from April 1998, representing pre-Frances topography, through the end of the first winter of recovery. B) Continuation of beach and dune recovery on the northeast end of Follets Island.

its post-storm position. BEG08 moved through Stage 1, rapid forebeach accretion, and Stage 2, backbeach aggradation, in just six months. The recovery of volume and shoreline position at BEG08 was similar to the recovery at Galveston Island State Park. By February 2001, the volume and shoreline had stabilized near the pre-storm values and a secondary vegetation line was recognized. The position of this discontinuous vegetation line was in approximately the same location as the pre-storm vegetation line. Figure 5B also depicts small amounts of sand being deposited seaward of the present foredunes but further inland of the pre-Frances foredunes (Stage 3 and beginning of Stage 4). This site has been allowed to recover naturally with no intervention by humans.

From 2001 to 2003, the volume and shoreline exhibited an erosional trend. As at BEG02, there was a decrease in volume and substantial landward movement of the shoreline following Tropical Storm Fay in September 2002. The vegetation line was also impacted by Fay, but returned to its pre-storm (Fay) position, 26 m landward of the pre-Frances position.

DISCUSSION

Hurricane Alicia moved quickly causing elevated water levels due to storm surge to last only three hours (U.S. Army Corps of Engineers 1983). Tropical Storm Frances was a much weaker storm than Alicia but its slow movement caused elevated water levels for over 2 ½ days and generated large waves that lasted

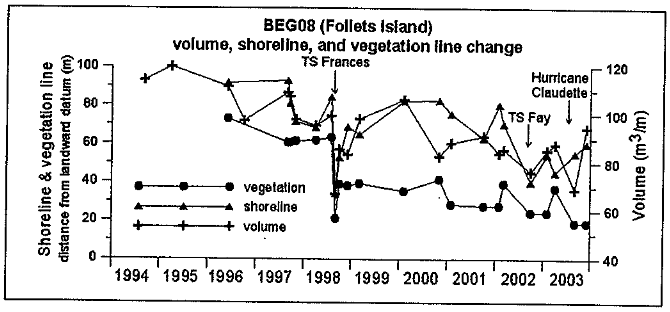

Figure 6. Profile volume, shoreline, and vegetation line changes on the northeast end of Follets Island.

for three days. At the BEG02 and BEG08 study sites, the erosion of the beaches and dunes was similar for the two storms. At BEG02, Tropical Storm Frances removed the foredune and returned the profile to its post-Alicia shape. Sediment volume and dune recovery at BEG02 following Tropical Storm Frances progressed as it did after Alicia but at a more rapid pace. Following Alicia, berm reconstruction and seaward advancement of the shoreline occurred quickly but was eroded again during a winter storm passage. This cycle continued until the end of the second year when the beach moved into the 3rd and 4th stage of beach recovery (Morton et al. 1994). In contrast, the beach progressed through the first three stages of beach recovery within six months of Frances. The difference in the recovery rates is because Alicia probably transported more sand farther offshore or alongshore than Frances and because of the effectiveness of rebuilding the foredune using washover sand and the installation of sand fencing after Frances.

Following Alicia, BEG08 completely recovered its pre-storm morphology and sand volume and began dune expansion and vegetation recolonization (Stage 4) three years after the storm (Morton et al. 1994). Frances removed the foredunes, but left the secondary dunes, and eroded a large volume of sand. Stages 1 and 2 of post-storm recovery progressed in the same time frame after Frances as it did following Alicia. However, Stage 3, dune reconstruction, and Stage 4, dune expansion and vegetation recolonization, had not been completed at BEG08 by a time five years following Frances. It is hypothesized that Alicia transported sand alongshore from the San Luis Pass ebb-tidal delta and deposited it offshore of the BEG08 site. Following Alicia, this sand was transported onshore (Morton et al. 1995). Frances, on the other hand, was a storm energetic enough to erode beaches and dunes but did not cause massive alongshore transport from the ebb-tidal delta. The foredune at BEG08 is also recovering more slowly than at BEG02 partly because there has been no human manipulation.

CONCLUSIONS

Ball High School students from Galveston, Texas, working with scientists from the Bureau of Economic Geology at the University of Texas at Austin, have been taking scientific measurements on the beaches of Galveston and Follets Islands since 1997. During this time, the students have been collecting data that is recording the recovery of the beaches following Tropical Storm Frances. This monitoring is allowing scientists at the Bureau to compare post-storm recovery from a tropical storm with that of a category 3 hurricane. The two storms differed greatly in magnitude, but the changes in morphology and position of the beaches as well as the stages of recovery are comparable.

Most of the sand removed by Frances returned to the beaches during the following winter, but the post-storm profile morphology of BEG02 and BEG08 still had not completely recovered (Figures 3 and 5) five years later. Dune formation and seaward advance of the vegetation line may take several more years, and in some areas, the vegetation line may not return to its pre-storm position before long-term erosion begins again. Tropical Storm Fay in September 2002 and Hurricane Claudette in July 2003 also impacted the area. The effects of these storms were much less severe than Frances. Continued monitoring of BEG02 and BEG08 by Ball High School will provide insight into the processes of natural and enhanced post-storm beach recovery for various levels of storm impacts.

Continued data collection by students from Ball High School, as well as Port Aransas and Port Isabel High Schools, will help scientists, students, and the public gain a better understanding of coastal processes and shoreline change along the Texas coast. Although it will take time to incorporate the data into products that support coastal management, it is clear that the data will be useful in explaining beach cycles and defining short-term versus long-term trends.

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