Journal of Coastal Research	33	3	738–746	Coconut Creek, Florida	May 2017

TECHNICAL COMMUNICATIONS

Applications of Coastal Data Collected in the Texas High School Coastal Monitoring Program (THSCMP)

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ABSTRACT

Caudle, T.L. and Paine, J.G., 2017. Applications of coastal data collected in the Texas High School Coastal Monitoring Program (THSCMP). *Journal of Coastal Research,* 33(3), 738–746. Coconut Creek (Florida), ISSN 0749-0208.

The Texas High School Coastal Monitoring Program (THSCMP) engages students and teachers who live along the Gulf of Mexico in the study of their natural environment. Scientists from the Bureau of Economic Geology (BEG) at The University of Texas at Austin show middle and high school students and teachers how to measure topography, map vegetation lines and shorelines with GPS, and observe weather and wave conditions. The students are active participants in the research project, which has the dual benefit of enhancing their science education while providing valuable data on the dynamic coastline. Students collect critical scientific data that help scientists and managers address coastal issues and gain a better understanding of dune and beach dynamics on the Texas coast. Since the THSCMP began in 1997, data collected by students have been applied by scientists to investigate beach, dune, and vegetation-line recovery following several tropical cyclones, including Hurricane Ike in 2008. Student-collected data are used to monitor the effects of nourishment projects on South Padre Island, foredune changes on Mustang Island, geotextile tubes on Galveston Island, and jetty construction on Matagorda Peninsula. Student data are also used in verifying shoreline positions for updates of Texas' long-term shoreline change rates. Through these real-world examples of scientific observations, students gain a better understanding of environmental issues affecting their communities.

ADDITIONAL INDEX WORDS: *Student monitoring, coastal processes, beach, dune, Texas Gulf Coast, beach profiles*.

INTRODUCTION

The Bureau of Economic Geology (BEG) at The University of Texas at Austin serves as the State Geological Survey of Texas. In that capacity, the BEG has led major research projects on the Texas Gulf Coast since the 1970s, including studies of historical Texas gulf and bay shoreline change rates, the status and trends of coastal wetlands, submerged lands of Texas, storm impacts, and inlet dynamics. Coastal researchers at the BEG strongly believe in their obligation to support enhanced education programs based on research and to provide the public with unbiased information regarding coastal data and processes.

High school science courses with content that is interesting and shown to be relevant to human livelihood are crucial to encouraging students to pursue careers in science. For students not pursuing science careers, high school may be the last opportunity to learn and appreciate the scientific method, which governs the formation of much public policy. Furthermore, citizens are increasingly asked to vote on or get involved with environmental issues that are often framed in scientific arguments.

Educational resources to help encourage protection of the coastal environment are available on the Internet from Texas groups such as the Mission-Aransas National Estuarine Research Reserve (2016), which provides resources for use in the classroom or when visiting the reserve, and the Texas General Land Office (GLO) Adopt-a-Beach program (Texas Adopt-a-Beach, 2016), which provides lesson plans on marine debris and other coastal issues. The GLO program also sponsors coastwide beach cleanup days, which are opportunities for volunteers (*e.g.*, from schools, Boy and Girl Scouts, clubs, local communities) to work together to remove debris from Texas beaches.

Involving middle and high school students in scientific research takes a variety of forms nationally as well. "Connecting with the River" was developed to help participants have a better understanding of the Connecticut River and to expose students to earth science in general (O'Connell, Ortiz, and Morrison, 2003, 2004). A geoscience-themed outreach program in San Francisco (SF-ROCKS) introduces diverse students to earth sciences concepts applied to their own neighborhoods (White *et al.*, 2003, 2004). This program provides inquiry-based lesson plans, teacher training, graduate student mentors, and

DOI: 10.2112/JCOASTRES-D-16-00033.1 received 22 February 2016; accepted in revision 12 July 2016; corrected proofs received 25 August 2016; published pre-print online 9 November 2016.
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Table 1. *Schools involved in the Texas High School Coastal Monitoring Program.*

School	Location	Year Started
Ball High School	Galveston Island	1997
Cunningham Middle School	North Padre Island	2009
High Island High School	Bolivar Peninsula	2016
Palacios High School	Matagorda Peninsula	2006
Port Aransas High School	Mustang Island	1999
Port Isabel High School	South Padre Island	1999
Tidehaven Middle School	Matagorda Peninsula	2005
Van Vleck High School	Matagorda Peninsula	2005

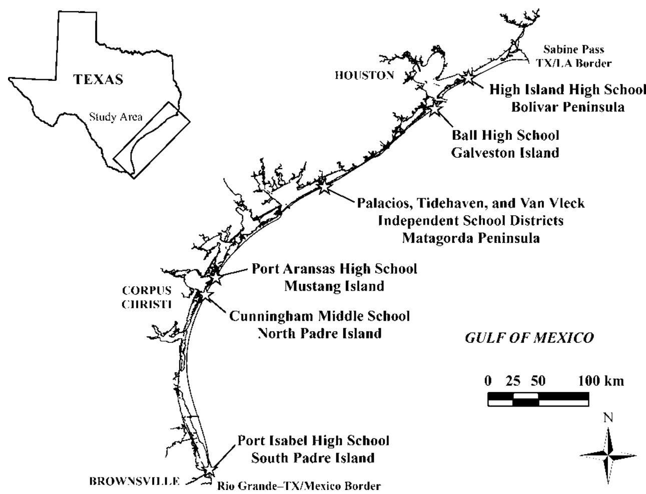

Figure 1. Location of sites (stars) monitored by schools participating in THSCMP.

summer institute activities. Other research and outreach activities involve university faculty and undergraduate and graduate students collaborating with educators and students in middle school and high school classrooms to (1) develop inquiry-based lesson material; (2) guide middle and high school students in conducting field research in areas such as water quality, atmospheric conditions, and ground temperature measurements; and (3) provide undergraduate classes, training, and field experiments for future coastal managers and geoscientists (Bell, Fowler, and Stein, 2003; Edwards, 2009; Esteves *et al.,* 2013; Klene *et al.*, 2002; Lee *et al.*, 2009; Maygarden, Egger, and Gill, 2011; Taylor, Dutton, and Poston, 2002; Trautmann and Krasny, 2006; Vinhateiro, Sullivan, and McNally, 2012).

Coastal processes and related public issues are an ideal realm for teaching pre-college-aged students basic and applied science and illustrating the role science plays in forming public policy. The Texas High School Coastal Monitoring Program (THSCMP) is an ongoing BEG research project that was designed to help students and scientists develop a better understanding of dune and beach dynamics on the Texas coast (Caudle and Paine, 2012; Hepner and Gibeaut, 2004). BEG researchers show high school and middle school students and teachers how to measure topography, map vegetation lines and shorelines using GPS instruments, and observe weather and wave conditions. As participants in a long-term research project, the students enhance their science education by gaining experience collecting data in the field while providing their coastal communities with valuable data on their changing shoreline.

Schools Involved and Study Area

In 1997, BEG researchers developed a pilot beach-monitoring program with Ball High School on Galveston Island (Caudle and Paine, 2012; Hepner and Gibeaut, 2004). THSCMP has since expanded several times to now include a total of eight schools (Table 1). Expansion of the program has not only increased the number of high schools in THSCMP, but also introduced middle school students, who make the same field measurements and observations as the high school students. Students in the program are enrolled in classes such as physics, environmental science, biology, aquatic science, and general science.

BEG researchers work with the same teachers each academic year. Researchers communicate directly with teachers to schedule field trips in the fall (September or October), winter (January or February), and spring (April or May). The teacher arranges transportation to the study sites (bus or sport utility vehicle, depending on class size) and a substitute teacher to cover his or her classroom for the day. In order to encourage school districts to continue participation in THSCMP, project support provides funding to cover the cost of student transportation and substitute teachers. A stipend is also provided to the participating teachers.

The most heavily used segments of the Texas coast are now monitored two or three times per year (Figure 1). Students monitor beaches, dunes, and vegetation lines from the following sandy barrier islands and peninsulas: Bolivar Peninsula, Galveston Island, Matagorda Peninsula, Mustang Island, and North and South Padre Islands. Staff from the Lower Colorado River Authority at Matagorda Bay Nature Park help facilitate field trips on Matagorda Peninsula.

Program Goals

The coastal monitoring program has three major goals. The first is to provide middle and high school students with an inquiry-based learning experience. Students make several field trips to their study sites during the academic year. Working in teams, 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. BEG researchers provide background information and guide inquiries about the data, but students are encouraged to form and test their own hypotheses. Through their collaboration with scientists on a research project, students gain an enhanced science education.

The second goal is to increase public awareness and understanding of coastal processes and hazards. The expectation is that participating students will discuss their experiences with their family and classmates, further expanding the program's reach. Presentations by BEG scientists at conferences and symposiums, student presentations within their local communities (such as the Winter Outdoor Wildlife Expo

Figure 2. Students using (A) a sighting level to determine vertical offset between Emery rods, and (B) a metric tape to measure horizontal distance.

on South Padre Island), and newspaper articles all increase awareness of THSCMP and Texas coastal issues. A website (http://www.beg.utexas.edu/coastal/thscmp/) containing the latest coastal information gathered by students is central to community outreach. On this site, coastal residents and general readers can view maps, graphs, photographs, and other data documenting the effects of storms that strike the coast. The website increases awareness and appreciation of coastal processes, shoreline changes, and future impacts.

The third goal is for coastal scientists to achieve a better understanding of the relationships among coastal processes, beach morphology, and shoreline change and subsequently make these data available for solving coastal management problems. The BEG has monitored shorelines and investigated coastal processes since the 1970s. An important part of this program is the repeated mapping of the shoreline position and measurement of beach profiles. Over time, these data are used to determine the long-term rate of shoreline change as well as shorter-term trends (Gibeaut *et al*., 2000, 2001; Morton, 1974, 1975, 1977, 1997; Morton and Paine, 1990; Morton and Pieper, 1975a,b, 1976, 1977a,b; Morton, Pieper, and McGowen, 1976; Paine, Mathew, and Caudle, 2011, 2012; Paine and Morton, 1989). One problem faced by scientists is the limited temporal resolution of Texas shoreline data. The beach is a dynamic environment where significant changes in shape, position, and sand volume can occur over periods of days or even hours. Tides, storms, and seasonal wind patterns cause large, periodic, or quasi-periodic changes in the shape of the beach. If coastal data are not collected often enough, short-term variations in beach morphology could be misinterpreted as long-term change. The THSCMP helps address this problem by providing frequent, repeated measurements at key locations along the Texas coast. These data are integrated into the ongoing coastal research program at the BEG and are made available to other researchers and coastal managers.

METHODS

The central element in the monitoring program is two to three class field trips during the academic year (weather permitting). During each trip, students visit several locations and apply established procedures to measure beach morphology and make observations on beach, weather, and wave conditions. These procedures, mirroring those applied by coastal researchers, were developed during the program's pilot year (1997–98) and are presented in detail on the THSCMP website.

Students make several measurements and observations at each study site. For the beach profile—a key component of the study—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 (Figure 2; Emery, 1961; Krause, 2004; O'Connell, 2001). Students begin profiling at a presurveyed datum stake so that they can compare each new profile with earlier profiles. They then take consistently oriented photographs with a digital camera. The beach profiles provide detailed data on the volume of sand and the shape of the beach.

Figure 3. Students (A) using a sighting compass to measure dune orientation, and (B) measuring how far along the shoreline the float (an orange) drifted to determine longshore current speed and direction.

Profile data are entered into the Beach Morphology and Analysis Package (BMAP). BMAP, software developed by the U.S. Army Corp of Engineers, is commonly used by coastal engineers and scientists to analyze beach profiles. Beach-volume calculations are made using BMAP, and shoreline and vegetation-line positions are determined from notes made by students and scientists while collecting data. For consistency with historical measurements, the shoreline is considered to be the boundary between the wet and dry beach or a berm crest (a prominent break in slope between the forebeach and back beach; Gibeaut and Caudle, 2009; Gibeaut *et al*., 2003).

In addition to measuring topographic profiles, students make observations on weather conditions, sea state, longshore current, and dune vegetation and map the position of the vegetation line (seaward limit of continuous vegetation) and shoreline (Figure 3). Students also 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, stopwatch, and tape measure. Using handheld GPS units, students map the vegetation line and shoreline for display on geographic information system software. A comparison of positions determined through GPS mapping over time allows students to calculate the rate of shoreline change.

RESULTS

Since 1997, the THSCMP has helped ensure that data at key locations on the Texas coast are collected on a continual basis. Ball, Palacios, Port Aransas, Port Isabel, and Van Vleck High Schools and Cunningham and Tidehaven Middle Schools annually contribute three new data sets to the beach-profile time series at their monitoring sites. Profiles, processes, and GPS data that students collected have been incorporated into the beach-profile database at the BEG. Scientists are using these data to investigate shoreline change, storm impacts and recovery, and beach and dune dynamics patterns due to human impacts (beach nourishment, construction, and beach maintenance practices).

Shoreline Change

Many BEG projects require updating of the long-term rates of shoreline change along the entire Texas coast based upon either the mapping of the shoreline position on aerial photographs or extraction of a shoreline proxy (elevation) from airborne light detection and ranging (LIDAR)–derived digital elevation models (DEMs). Updates of Texas' long-term shoreline-change rates (Paine, Caudle, and Andrews, 2013, 2014; Paine, Mathew, and Caudle, 2011, 2012) are widely used by public officials, corporations, and private citizens. Beach profiles and GPS-mapped shorelines (wet beach/dry beach

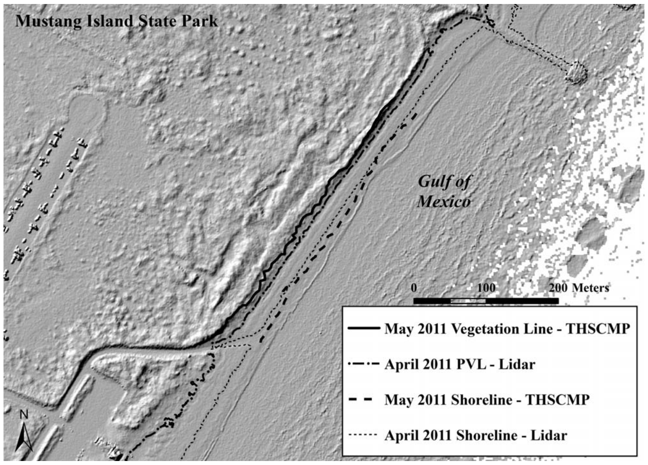

Figure 4. Shoreline and vegetation-line position comparison—student GPS-mapped positions and LIDAR-extracted elevations—at Mustang Island State Park (site MUI02).

boundary) collected by THSCMP students are used to confirm the shoreline position digitized on aerial photography or extracted from the LIDAR-derived DEMs. Student-collected data have proven to be invaluable in validating interpretation of the shoreline position on Galveston Island, Follets Island, Matagorda Peninsula, Mustang Island, and South Padre Island. At Mustang Island State Park (Figure 4), for example, the GPS-based wet beach/dry beach boundary and vegetation line mapped by students in May 2011 fall within a few meters of the same boundaries mapped from April 2011 LIDAR data. THSCMP data were used to verify the position of the shoreline mapped on aerial photographs and extracted from LIDAR DEMs for the 2007 and 2012 long-term shoreline change updates recently completed by the BEG (Paine, Caudle, and Andrews, 2013, 2014; Paine, Mathew, and Caudle, 2011, 2012).

Storms

The varying degrees of storm damage to beaches and dunes along the upper Texas coast are indicated by the landward movement of the shoreline and vegetation-line positions and decrease in sediment volume in the data profile immediately after storms (Figure 5). Recovery is indicated by the gradual seaward migration of the shoreline and vegetation-line positions as well as increase in sediment volume in the years between storms. Students from Ball High School have been collecting storm-damage data for the THSCMP at a site on Galveston Island (Figure 1), a sandy barrier island, since the program's inception; these data have increased scientific understanding of recovery of beaches and dunes following storms that have impacted the area.

Students documented Tropical Storm Frances (September 1998), which played a major role in reshaping the beaches on the upper Texas coast. Storm-surge flooding of 1.8 to 2.4 m (6 to 8 ft) lasted for 48 hours along the upper Texas coast (Lawrence, 1998). Frances caused significant damage to beaches that was comparable to that caused in 1983 by Hurricane Alicia (Gibeaut, Gutiérrez, and Hepner, 2002; Hepner and Gibeaut, 2004; Morton and Paine, 1985), a category 3 hurricane on the Saffir/Simpson scale (Simpson and Riehl, 1981). Student-collected data have also been used to study storm impact and beach and dune recovery following Hurricane Claudette (July 2003) and Hurricane Rita (September 2005), as well as tropical storms Allison (June 2001) and Fay (September 2002).

During the 2008–09 academic year, the upper Texas coast was severely affected by the landfall of Hurricane Ike on Galveston Island (September 2008; Berg, 2009). Because of the size of the storm, impacts from this hurricane were seen along the entire Texas coast, despite Ike's classification as a category 2 hurricane at landfall (Simpson and Riehl, 1981). In addition to the severe storm effects on the upper Texas coast, dune erosion as a result of Hurricane Ike was also documented by students on the middle Texas coast at Matagorda Peninsula

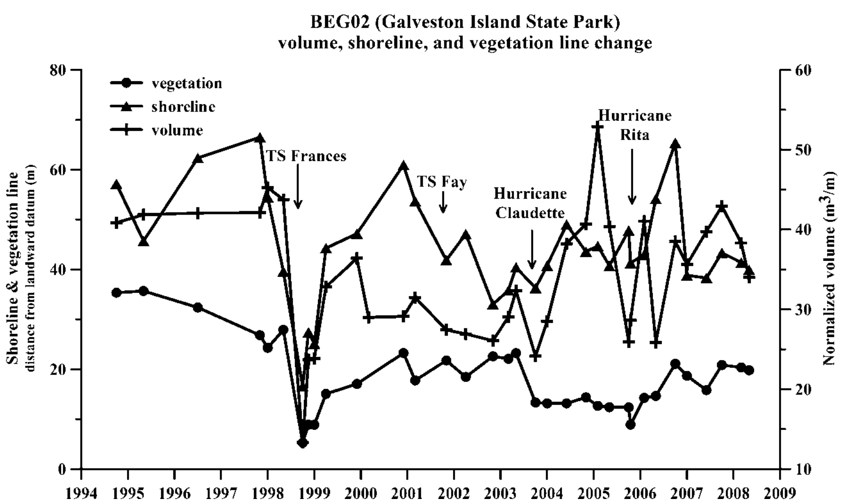

Figure 5. Profile volume, shoreline, and vegetation-line changes at Galveston Island State Park (BEG02), September 1994–April 2008.

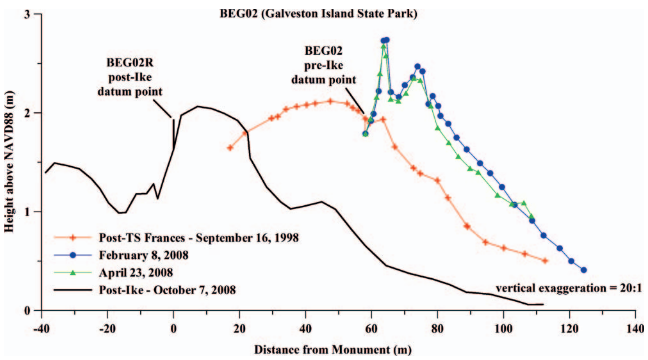

Figure 6. Beach-profile plots from Galveston Island State Park (BEG02) comparing post–Hurricane Ike profile with two prestorm profiles from early 2008 and post–Tropical Storm Frances profile from September 1998. The new datum point is 0.

(Palacios and Van Vleck High Schools and Tidehaven Middle School) and Mustang Island (Port Aransas High School).

Ball High School students from the 2007–08 academic year provided extremely valuable prestorm profile data on 8 February 2008, and 23 April 2008, which have been used to determine how much the beach and dunes changed before and after Hurricane Ike. Galveston Island experienced significant beach and dune erosion, as well as extensive damage to property and infrastructure, from Hurricane Ike. Ball High School students were unable to participate in the program during the 2008–09 academic year because of safety concerns about accessing their monitoring sites. The original datum marker at Galveston Island State Park (BEG02) was destroyed by the storm. A new marker was reset approximately 60 m landward of the old datum marker, along the same azimuth line. Reestablishing the marker allowed students to continue to monitor activities and storm recovery, and continue to compare pre- and post-storm profiles, at this location.

Comparisons of the pre-Ike profiles acquired by Ball High School students with post-Ike profiles measured on 7 October 2008 (Figure 6) show that the dune system at Galveston Island State Park was completely destroyed and that the shoreline (wet-dry line) moved 53 m landward between 23 April 2008, and 7 October 2008 (Figure 6); that the vegetation line moved 56 m landward; and that the old datum point was 1.14 m above the current surface of the beach. In Figure 6, the post–Tropical Storm Frances profile from 16 September 1998, is also plotted for comparison.

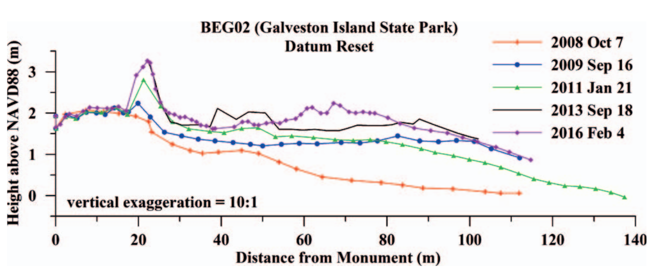

Figure 7. Post–Hurricane Ike beach and dune profile collected by Ball High School students at reset Galveston Island State Park (BEG02) marker. Students are monitoring recovery of beaches and dunes.

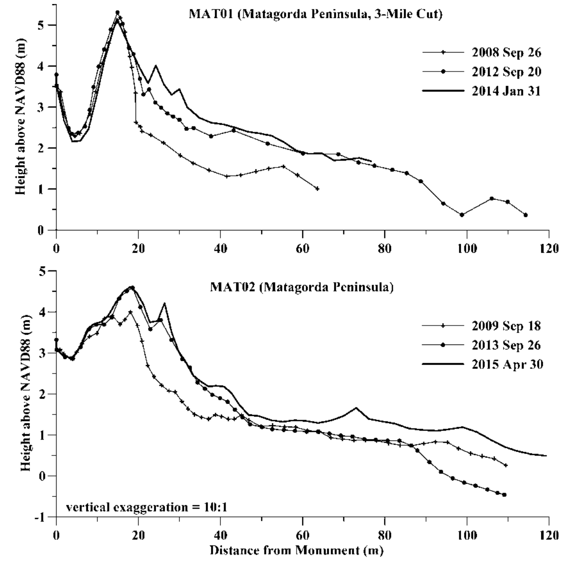

Figure 8. Post–Hurricane Ike monitoring of dune and beach recovery by Van Vleck High School (MAT01) and Palacios High School (MAT02) students on East Matagorda Peninsula.

Ball High School students have continued to collect data at Galveston Island State Park (Figure 7) to monitor the post-Ike recovery of the beaches and dunes. Between October 2008 and September 2013, the foredunes at site BEG02 have grown, and the volume of sand on the back beach has increased as part of the natural storm-recovery process.

Dune erosion due to Hurricane Ike was also documented on the middle Texas coast at Matagorda Peninsula and, to a lesser extent, on Mustang Island. Students from Palacios High School (site MAT02) and Van Vleck High School (site MAT01) have been monitoring the recovery of the dunes and the seaward movement of the vegetation line post–Hurricane Ike (Figure 8) on Matagorda Peninsula.

Human Impacts

The Ball High School site at Galveston Island State Park (BEG02) has been used by BEG scientists to study the effects of geotextile tubes—large, sediment-filled sleeves of fabric placed parallel to the shoreline at the edge of the back beach—that have been installed along some developed parts of the upper Texas coast in an attempt to protect beachfront structures. Galveston Island State Park is adjacent to a subdivision (Pirates Beach) where geotextile tubes had been installed. One of the observations made during this study compared beach width (distance from the vegetation line or base of dune to the waterline) in front of the subdivision geotextile tubes with the width in a natural beach area in the adjacent park. Beach width in the natural beach area was wider (average width of 45.7 m compared to 20.4 m in the subdivision) because the natural area allows for the landward migration of the dunes as the shoreline retreats. The geotextile tubes create a fixed

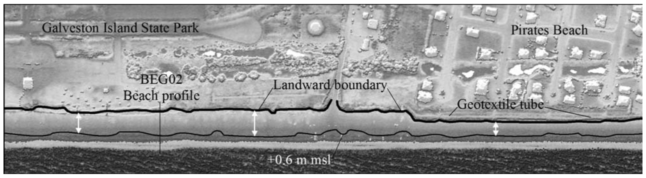

Figure 9. LIDAR topographic-relief image of Galveston Island State Park (leftmost two-thirds of image) and Pirates Beach subdivision (rightmost one-third of image). Note difference in beach width between natural beach and area in front of subdivision. Adapted from Gibeaut *et al*. (2003).

dune line that restricts beach width as the shoreline retreats landward (Figure 9; Gibeaut *et al*., 2003).

Brazos Santiago Pass, the southern border of South Padre Island, is dredged biannually. The pass serves as the southern Gulf of Mexico access to the Gulf Intracoastal Waterway and the Port of Brownsville. Dredged material is placed on beaches of South Padre Island; the three sites monitored by Port Isabel High School students are within these nourishment areas. The SPI02 monitoring site has been used by students and scientists to monitor the growth of dunes (sand volume) and shoreline movement. When SPI02 was established in August 2000, no dunes between the retaining wall and the waterline existed at this location. Since that time, profile data have been quantifying the effects of the installation of sand fences, the planting of vegetation, and numerous beach-nourishment projects (Figure 10).

Port Isabel data have documented an overall trend to shoreline advancement and sediment-volume increase throughout the study period (Caudle *et al*., 2014). The vegetation line had remained in a relatively stable position prior to 2012. Since that time, a push-up dune has been created by beach-maintenance practices (beach scraping to remove seaweed). The sand and seaweed scraped from the beach were placed just seaward of the vegetation line, and vegetation has begun to grow on the piled material.

The beach-monitoring activities of Port Aransas High School students have also provided beneficial information regarding the beach and dune system on Mustang Island. The dune system on Mustang is healthy, with tall (>3 m), wide foredunes along most of the island. The only breaks in the foredune system are at beach-access points and washover features. On

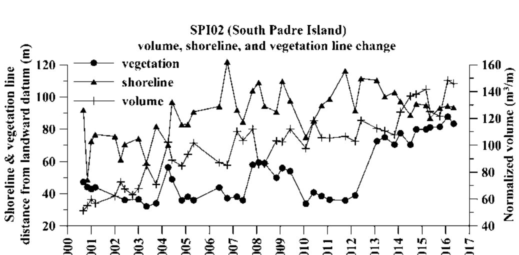

Figure 10. Changes on South Padre Island (SPI02) due to beach-nourishment projects, installation of sand fences, and beach-maintenance practices.

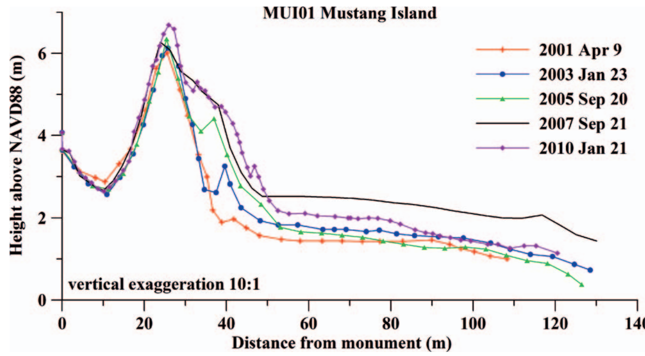

Figure 11. Foredune expansion on Mustang Island (MUI01) monitored by Port Aransas High School students.

Mustang Island, beaches are regularly scraped to remove seaweed. The sand and seaweed removed from the berm and forebeach are regularly placed at the seaward base of the foredunes. Since the beginning of the coastal monitoring program in 1999, Port Aransas students have been monitoring the growth of the foredune system at their profiling sites. Foredune expansion is evident at monitoring site MUI01 near Horace Caldwell Pier in Port Aransas (Figure 11). Note that the width of the dune has increased since 2001, although the shoreline has remained in a relatively stable position.

Tidehaven Middle School students collect beach measurements at Matagorda Bay Nature Park on Matagorda Peninsula (Figure 1). The park has several special circumstances that make this monitoring especially informative and important. A monitoring site (MAT03) has been established on the updrift side of the jetty at the mouth of the Colorado River. Impacts of coastal structures (jetties) are critical to coastal management. During the 2009–10 academic year, the U.S. Army Corps of Engineers began constructing a new east jetty at the mouth of the Colorado River. GPS-mapped shorelines from September 2009 (preconstruction) and September 2012 show a 40 m seaward movement of shoreline position at MAT03, east of the new jetty (Figure 12). Between September 2012 and September 2015, the shoreline moved an additional 30 m seaward. Student-acquired data at MAT03 will be used to continue monitoring the effects of the jetty on east Matagorda Peninsula.

DISCUSSION

The first goal of the THSCMP is to provide high school students with an inquiry-based learning experience, which is achieved by involving students in a real-world research project. BEG researchers emphasize to students that they are collecting critical scientific data that will help scientists address coastal issues affecting their community. Before and during each field trip, the similarities and differences between the sites they monitor and sites at other locations on the Texas coast are discussed with the students. Student-collected beach data are used by BEG researchers and students and teachers themselves to fulfill the other two goals of the THSCMP—increasing public awareness and understanding of coastal processes and hazards.

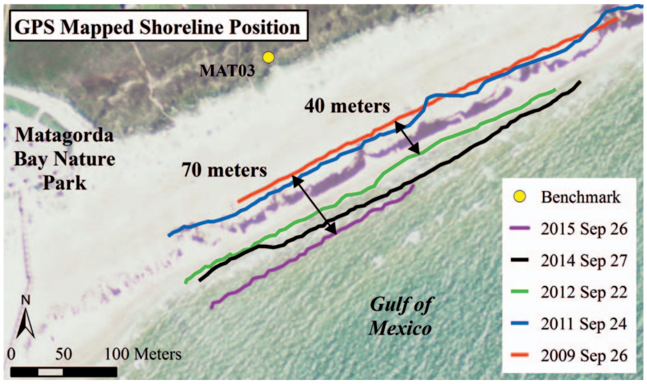

Figure 12. Shoreline position change monitored by Tidehaven Middle School students on East Matagorda Peninsula (MAT03).

All data collected by the THSCMP are integrated into the coastal research programs at the BEG. In support of coastal management issues, data collected by THSCMP students are clearly useful in explaining beach cycles and defining short-term versus long-term trends. Defining these trends is important in decision making regarding coastal development and beach nourishment. Scientists, managers, decision makers, and the public have gained a better understanding of the dynamic Texas coastal zone because of the continuous monitoring activities of the middle and high school students participating in THSCMP.

Increasing public awareness and understanding of coastal processes and hazards is accomplished through several avenues that reach different audiences. An annual report is published for the Texas GLO detailing the activities of each school and scientific analysis of the data collected. This report is available through the THSCMP website (http://www.beg.utexas.edu/coastal/thscmp/), which is instrumental in extending the reach of the program and in increasing public awareness of coastal processes by sharing data, pictures, scientific information, and educational resources. The monitoring program and data analysis have been presented in talks or posters at national conferences, workshops, and symposiums. Students from Port Isabel High School have demonstrated data-collection techniques to participants in the Winter Outdoor Wildlife Expo on South Padre Island. Newspaper articles have also helped increase public awareness.

CONCLUSIONS

The THSCMP provides middle and high school students with a real-world learning experience outside the classroom. The program provides not only hands-on education, but also valuable data for coastal researchers and regulatory and coastal-stewardship agencies. In the 19 years since the inception of the THSCMP, work by students at Ball, Port Aransas, Port Isabel, Palacios, and Van Vleck High Schools and Cunningham and Tidehaven Middle Schools has been beneficial to BEG researchers and coastal managers in several research projects. Analysis of the data has been used to investigate storm effects and recovery; to investigate impacts to the beach and dune system due to beach nourishment, construction of jetties, and beach-maintenance practices; and to verify shoreline positions for calculating change rates. Availability of data through the THSCMP website allows access by both coastal managers and the public. Scientists, students, and the public gain a better understanding of coastal processes and shoreline change along the Texas coast through this long-term student research program.

Future measurements by all schools involved in the THSCMP will show not only change through time at each location but also spatial variation along the Texas coast. Data collected from Galveston Island, Matagorda Peninsula, Mustang Island, Bolivar Peninsula, and North and South Padre Islands will help scientists better understand the relationships among coastal processes, beach morphology, and shoreline change at these locations.

ACKNOWLEDGMENTS

The THSCMP is funded under Coastal Management Program grants made available to the State of Texas by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, pursuant to the Federal Coastal Zone Management Act of 1972. Additional funds have been provided by the State Energy Conservation Office, the Lower Colorado River Authority, the Meadows Foundation, Conoco, the Trull Foundation, the Ed Rachal Foundation, the Exxon Foundation, and the Wray Family Trust. Publication was authorized by the director, Bureau of Economic Geology, The University of Texas at Austin.

LITERATURE CITED

Bell, W.H.; Fowler, E.M., and Stein, J.A., 2003. Coastal seas as a context for science teaching: A lesson from Chesapeake Bay. *Marine Pollution Bulletin*, 47(1–6), 253–259.

Berg, R., 2009. *Hurricane Ike (AL092008). Tropical Cyclone Report*. Miami, Florida: National Oceanic and Atmospheric Administration, National Hurricane Center, 55p.

Caudle, T.L. and Paine, J.G., 2012. Pre-college student involvement in Texas coastal research. *Gulf Coast Association of Geological Societies Transactions*, 2012, 27–38.

Caudle, T.L.; Tremblay, T.A.; Paine, J.G.; Andrews, J.A., and Saylam, K., 2014. *Beach and Dune Analysis Using Chiroptera Imaging System, South Padre and Brazos Islands, Texas Gulf Coast. Final Report to the Texas Coastal Coordination Council and General Land Office, Contract No. 13-030-000-6895*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, 68p.

Edwards, W.A.D., 2009. Using the geology of your neighbourhood and city for geoscience outreach. *Geoscience Canada*, 36(3), 124–127.

Emery, K.O., 1961. A simple method of measuring beach profiles. *Limnology and Oceanography*, 6(1), 90–93.

Esteves, H.; Ferreira, P.; Vasconcelos, C., and Fernandes, I., 2013. Geological fieldwork: A study carried out with Portuguese secondary school students. *Journal of Geoscience Education*, 61(3), 318–325.

Gibeaut, J.C. and Caudle, T.L., 2009. *Defining and Mapping Foredunes, the Line of Vegetation, and Shorelines along the Texas Gulf Coast. Final Report to the Texas Coastal Coordination Council and General Land Office, Contract No. 07-005-22*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, 30p.

Gibeaut, J.C.; Gutiérrez, R., and Hepner, T., 2002. Threshold conditions for episodic beach erosion along the southeast Texas coast. *Gulf Coast Association of Geological Societies Transactions*, 52, 323–335.

Gibeaut, J.C.; Hepner, T.; Waldinger, R.; Andrews, J.; Gutierrez, R.; Tremblay, T.A., and Smyth, R., 2001. *Changes in Gulf Shoreline*

Position, Mustang and North Padre Islands, Texas. Report to the Texas Coastal Coordination Council and General Land Office, Contract No. 00-002r. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, 30p.

Gibeaut, J.C.; Hepner, T.L.; Waldinger, R.L.; Andrews, J.R.; Smyth, R.C., and Gutierrez, R., 2003. *Geotextile Tubes along the Upper Texas Gulf Coast: May 2000 to March 2003*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Report of the Texas Coastal Coordination Council and General Land Office, Contract No. 02-493R,* 37p.

Gibeaut, J.C.; White, W.A.; Hepner, T.; Gutierrez, R.; Tremblay, T.A.; Smyth, R., and Andrews, J., 2000. *Texas Shoreline Change Project: Gulf of Mexico Shoreline Change from the Brazos River to Pass Cavallo. Report of the Texas Coastal Coordination Council and General Land Office, Contract No. NA870Z0251*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, 32p.

Hepner, T.L. and Gibeaut, J.C., 2004. Tracking post-storm beach recovery using data collected by Texas high school students. *Shore and Beach*, 72(4), 5–9.

Klene, A.E.; Nelson, F.E.; Nevins, J.; Rogers, D., and Shiklomanov, N.I., 2002. Permafrost science and secondary education: Direct involvement of teachers and students in field research. *Geomorphology*, 47(2–4), 275–287.

Krause, G., 2004. The "Emery-Method" revisited—Performance of an inexpensive method of measuring beach profiles and modifications. *Journal of Coastal Research*, 20(1), 340–346.

Lawrence, M.B., 1998. *Tropical Storm Frances (AL061998). Tropical Cyclone Report*. Miami, Florida: National Oceanic and Atmospheric Administration, National Hurricane Center, 55p.

Lee, M.; Wolf, L.; Hardesty, K.; Beasley, L.; Smith, J.; Adams, L.; Stone, K., and Block, D., 2009. Water education for Alabama's black belt (WET): A hands-on field experience for middle school students and teachers. *In:* Whitmeyer, S.J.; Mogk, D.W., and Pyle, E.J., (eds.), *Field Geology Education: Historical Perspectives and Modern Approaches:* Boulder, Colorado: Geological Society of America, *Special Paper 461*, pp. 253–259.

Maygarden, D.F.; Egger, H.L., and Gill, I.P., 2011. Inquiry-based field science education at UNO's Coastal Education and Research Facility (CERF). *Geological Society of America Abstracts with Programs*, 43(3), 33.

Mission-Aransas National Estuarine Research Reserve, 2016. http://missionaransas.org/education/teachers.

Morton, R.A., 1974. *Shoreline Changes on Galveston Island (Bolivar Roads to San* Luis Pass)*, and Analysis of Historical Changes of the Texas Gulf Shoreline*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Geological Circular 74-2*, 34p.

Morton, R.A., 1975. *Shoreline Changes between Sabine Pass and Bolivar Roads*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Geological Circular 75-6*, 43p.

Morton, R.A., 1977. Historical shoreline changes and their causes, Texas Gulf Coast. *Gulf Coast Association of Geological Societies Transactions*, 27, 352–364.

Morton, R.A., 1997. *Gulf Shoreline Movement between Sabine Pass and the Brazos River, Texas: 1974 to 1996*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Geological Circular 97-3*, 46p.

Morton, R.A. and Paine, J.G., 1985. *Beach and Vegetation-Line Changes at Galveston Island, Texas: Erosion, Deposition, and Recovery from Hurricane Alicia*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Geological Circular 85-5*, 66p.

Morton, R.A. and Paine, J.G., 1990. Coastal land loss in Texas: An overview. *Gulf Coast Association of Geological Societies Transactions*, 40, 625–634.

Morton, R.A. and Pieper, M.J., 1975a. *Shoreline changes on Brazos Island and South Padre Island (Mansfield Channel to Mouth of the Rio Grande), an Analysis of Historical Changes of the Texas Gulf Shoreline*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Geological Circular 75-2*, 39p.

Morton, R.A. and Pieper, M.J., 1975b. *Shoreline Changes in the Vicinity of the Brazos River Delta (San Luis Pass to Brown Cedar Cut)*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Geological Circular 75-4*, 47p.

Morton, R.A. and Pieper, M.J., 1976. *Shoreline Changes on Matagorda Island and San Jose Island (Pass Cavallo to Aransas Pass)*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Geological Circular 76-4*, 42p.

Morton, R.A. and Pieper, M.J., 1977a. *Shoreline Changes on Mustang Island and North Padre Island (Aransas Pass to Yarborough Pass)*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Geological Circular 77-1*, 45p.

Morton, R.A. and Pieper, M.J., 1977b. Shoreline Changes on Central Padre Island (Yarborough Pass to Mansfield Channel). Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Geological Circular 77-2*, 35p.

Morton, R.A.; Pieper, M.J., and McGowen, J.H., 1976. *Shoreline Changes on Matagorda Peninsula (Brown Cedar Cut to Pass Cavallo)*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Geological Circular 76-6*, 37p.

O'Connell, J., 2001. *Beach and Dune Profiles: An Educational Tool for Observing and Comparing Dynamic Coastal Environments*. Woods Hole, Massachusetts: Woods Hole Oceanographic Institution Sea Grant Program, *Marine Extension Bulletin*, 6p.

O'Connell, S.; Ortiz, J., and Morrison, J., 2003. Connecting with the river. *Geotimes*, 48(9), 14–17.

O'Connell, S.; Ortiz, J., and Morrison, J., 2004. Connecting urban students with their rivers generates interest and skills in the geosciences. *Journal of Geoscience Education*, 52(5), 462–471.

Paine, J.G.; Caudle, T., and Andrews, J., 2013. *Shoreline, Beach, and Dune Morphodynamics, Texas Gulf Coast. Final Report Prepared for Texas General Land Office, Contract No. 09-242-000-3789*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, 64p.

Paine, J.G.; Caudle, T., and Andrews, J., 2014, *Shoreline Movement along the Texas Gulf Coast, 1930s to 2012*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Final Report Prepared for Texas General Land Office, Contract No. 09-074-000*, 52p.

Paine, J.G.; Mathew, S., and Caudle, T., 2011. *Texas Gulf Shoreline Change Rates through 2007*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Report Prepared for Texas General Land Office, Contract No. 10-041-000-3737*, 38p.

Paine, J.G.; Mathew, S., and Caudle, T., 2012. Historical shoreline change through 2007, Texas Gulf Coast: Rates, contributing causes, and Holocene context. *Gulf Coast Association of Geological Societies Journal*, 1, 13–26.

Paine, J.G. and Morton, R.A., 1989. *Shoreline and Vegetation-Line Movement, Texas Gulf Coast, 1974 to 1982*. Austin, Texas: The University of Texas at Austin, Bureau of Economic Geology, *Geological Circular 89-1*, 50p.

Simpson, R.H. and Riehl, H., 1981. *The Hurricane and its Impact*. Baton Rouge, Louisiana: Louisiana State University Press, 398p.

Taylor, S.B.; Dutton, B.E., and Poston, P.E., 2002. Luckiamute River watershed, upper Willamette Basin; an integrated study for K–12 educators. *In:* Moore, G.W. (ed.), *Field Guide to Geologic Processes in Cascadia: Field Trips to Accompany the 98th Annual Meeting of the Cordilleran Section of the Geological Society of America*. Boulder, Colorado: Geological Society of America, *Field Guide 36*, pp. 167–186.

Texas Adopt-A-Beach, 2016. http://www.glo.texas.gov/adopt-a-beach/.

Trautmann, N.M. and Krasny, M.E., 2006. Integrating teaching and research: A new model for graduate education? *Bioscience*, 56(2), 159–165.

Vinhateiro, N.; Sullivan, K.A., and McNally, C.G., 2012. Training for the next generation of coastal management practitioners. *Journal of Coastal Research*, 28(5), 1297–1302.

White, L.D.; Grove, K.; Dempsey, D.; Garcia, O.; Garfield, N.; Kheradyar, T.; La Force, M.J.; Pestrong, R., and Thorp, B., 2003. Reaching out to communities and kids with science. *Geotimes*, 48(9), 18–19.

White, L.D.; Grove, K.; Dempsey, D.; Garcia, O.; La Force, M.J.; Pestrong, R.; Davis, J., and Snow, M.K., 2004. SF-ROCKS: Reaching out to communities and kids with science in San Francisco. *Geological Society of America Abstracts with Programs*, 36(4), 88.