A quantitative investigation of the role *Sargassum* accumulation plays in inhibiting sand erosion on Galveston Island's West-end Beaches

By

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Abstract

The impact of *sargassum* beach cast material was measured along the beaches of the west end of Galveston Island, Texas between February 2006 and January 2007. Six monthly cross sectional profiles were obtained by using theodolite and transit systems coupled with survey grade global positioning systems that measured latitude, longitude, and elevation from the toe of the dune or other limiting structure to the wetline. During the 12-month study period, the average elevation change for all study sites was -10 cm, and ranged from an independent site change of +4 cm to -26 cm. During the study period, one meter cores were extracted along the profile lines. Four sediment cores per site were collected in February, April, September, and November 2006. The approximate coring intervals were 10 to 13 m across-shore, starting from the toe of the dune/geo-structure and finishing at the wetline of the beach. Organic percentages ranged from 0.84% to 0.02%. The February cores contained the highest average organic percentage at 0.54%. The May cores contained the lowest at 0.25%. These monthly observations resulted in a time series of both profile and volume changes, thus enabling an analysis of beach change. Monthly monitoring at the six beach sites revealed that accumulation of beach cast was markedly seasonal with largest amounts observed during the months of June and July. At this point in our study, the analysis of the cores extracted and the temporal dataset profiles does not support a direct connection between *sargassum* beach cast and long-term (annual) beach influences on beach geomorphology. The accretion of sand during the height of *sargassum* casting was short-term (seasonal) and beach elevation returned to previous levels in subsequent months after the *sargassum* disappeared from the beach.

Keywords: Beach cast; *Sargassum*; Galveston; Theodolite; Wetline; Geomorphology; Temporal; Accretion

Introduction

The beaches of Galveston Island experience an annual beach cast of *sargassum* ("seaweed") during late spring/early summer, which is the height of the tourist season. Since tourism makes a significant economic input to the island and county, this accumulation of organic material inspires much debate among numerous stakeholders (including property owners, business owners, recreational fishers, tourists, and local, county, and state governmental entities). Several management options have been suggested, but to date, there is no holistic management program for the island. Many locations are raked or scraped (Pirates Beach), while other locations are left in their natural condition (Galveston Island State Park).

At this time, there appears to be no published scientific data regarding the impact of beach cast on the Gulf beaches of Galveston Island. There have been recent studies pertaining to these issues along the west coast of Africa, Eastern Indonesia, and Western Australia. The study in Kenya using rapid visual assessment technique, found that raking of beach cast had substantial impacts on the beach stability, thus increasing the possibility of beach erosion (Ochieng et al, 1999). In order to facilitate informed decision making regarding the management of the "sargassum issue", a study was undertaken by the Coastal Geology Laboratory at Texas A&M University at Galveston. The purpose of this plan is to quantify the influence of *sargassum* on beach morphology. This data will be of utility to the numerous stakeholders involved and assist in effective management of the island's beaches.

Sargassum

Sargassum gets its name from the small gas-filled bladders that help keep surface plants afloat. One of the first documented sightings was from Portuguese sailors sailing to the New World. They coined the floating plants salgazo because the round bladders reminded them of a small variety of grapes native to their homeland. Eventually scientists derived the common name for the genus of brown algae now known as *Sargassum*. The two most common species of floating *sargassum* are Sargasso natans and Sargasso fluitans. The two species are very similar, and many weed lines contain both species. The main source of the sargassum found floating throughout the Gulf of Mexico comes from the Sargasso Sea. Sargassum movement is controlled by surface currents. As sections break away, the currents and winds carry it in a multitude of directions. Some of these mats drift down through the Caribbean and are pushed down through the Yucatan Straits. The mats are then controlled by the Gulf of Mexico current. Gyres located within the current create unpredictable landings of the sargassum mats on Texas coastal shores. The earliest efforts of Galveston businesses to control excessive beach cast of sargassum date back to 1930 when a contest was held on what to do with the beach cast. A local gardener won the ten dollar prize for the idea of using sargassum for fertilizer around their pumpkins.

Study Site

The Home Owners Associations of the beach communities of Pirates Beach and Pirates Beach West provided the funding and are therefore important sites in the study. Further, these locations are representative of the subdivision density along the eastern portion of the west-end and, as such, are valid locations for study. Galveston Island State Park was chosen due to it being adjacent to Pirates Beach West. It is a relatively large section of the beach, 2.43 kilometers and is devoid of geo-structures and receives no raking, scraping, or sand nourishment. Beach Pocket Park #3 is a frequently raked non-residential site, thereby allowing a comparison with residential raked areas and a contrast to residential non-raked beaches. Sea Isle Beach was chosen to provide spatial separation which is required to remove homogeneity in the study. This is a residential area further west along the beach and receives little/no-vehicular traffic, is non-raked, and experiences less foot traffic.

Figure 1. Galveston Island, Texas West End Study Area

Methods

The permanent benchmark, located on the Galveston Seawall at 61st Street, was selected for a primary base station. The primary base station serves as a point of reference elevation datum for the study. The horizontal coordinates of the benchmark were established by traditional geodetic methods (Ground speak Incorporated 2006; National Geodetic Survey 2006) and adjusted by the National Geodetic Survey in February 1996. The orthometric height was determined by differential leveling and adjusted by the National Geodetic Survey in March 1997. The Laplace correction (National Geodetic Survey 2006) was computed from DEFLEC99 derived deflections. The geoid height was determined by GEOID99. The dynamic height was computed by dividing the NAVD 88 geopotential number by the normal gravity value computed on the Geodetic Reference System of 1980 (GRS 80) ellipsoid at 45 degrees latitude (G = 980.6199 gals.). The modeled gravity was interpolated from observed gravity values. The benchmarks located on the Seawall have historically held a true position and elevation (Groundspeak Incorporated 2006).

From this permanent benchmark a dense network of six geodetic control monuments were established prior to the start of the project. Monuments were located at each line at the toe of the dune or some type of geo-structure and marked with 1 m long rebar driven into the ground so the top of the rebar was at ground level. These monuments were established by the survey grade GPS receivers set in static mode to establish new benchmarks with an accuracy level of Horizontal: 0.005 m + 1 ppm, Vertical: 0.010 m + 2 ppm, Azimuth: <1 arcsecond. Observation Time: Ranges from 180 to 360 minutes depending on distance between GPS receivers and other environmental factors. The survey grade GPS Surveying System utilizes integrated WAAS/EGNOS aided navigation to locate the survey point and collect GPS data with the receiver's on-board software systems.

The beach profile survey produced a monthly set of data-points on the six specified cross section beach surveys established along the shore at specified sites. Profile transects were measured using a combination of a field tape measure and a rod and transit system. The elevation was measured with reference to a benchmark with a known vertical datum. These two surveying data sets were combined to provide a complete bathymetric profile of the beach.

Each profile was 30 to 40 m long with data points set at 2 m fixed intervals. The distance was measured from a control point located on the toe of the dune or other limiting structure to beyond the wetline in the seaward direction. The wetline is the furthest point of wave run-up on the beach. The data was edited to remove spurious data points, entered into Microsoft Excel©, and combined with the elevation data from the survey grade GPS. Using Microsoft Excel, graphs were prepared for analyses.

At each site, four sediment cores at approximate intervals of 10 to 13 m were collected, extending from the toe of the dune/Geo-structure out to the wetline of the beach. A complete set of 99 cores were collected during the months of February, April, September, and November 2006.

All cores were cut lengthwise, photographed, and visual descriptions of the sediment lithology and Munsell color were recorded. One-half of the cores were archived for future reference and one-half subsampled for water content, organic content, and grain size analysis. Water content sample data were used for ancillary analyses. Water content samples were placed in pre-weighed tins and placed in the oven to dry. Dried samples were weighed and water content calculated.

Preparation for grain size analysis started with dry sieving each sample though a #45 (355µm) sieve. The sieved samples were weighed separately from the contents retained in the sieve. The retained contents were used to determine the percent shell content of the sample. A portion of the sieved material was then added to a vial and weighed. Grain size was determined for each sample using a Malvern Particle Size Analyzer. The Malvern is a laser instrument used to analyze sediment between 0.2-2000µm in a liquid medium. A sample from each vial was added into the Malvern's water bath until the obscuration reading was in the "green" range on the instrument display. Obscuration is the measure of the range of laser light lost due to the introduction of sample. The instrument runs three 12 second measurements and then calculates an average. Upon completion of grain size analysis, the Malvern software reports the grain size in microns (µm). The mean grain size of each core was calculated by averaging the mean grain size of each of the two samples taken from the core.

Approximately 60 g of oven-dried specimen was placed in a muffle furnace. The temperature of the furnace was set at 440^{o} C for the duration of 20 minutes per specimen to insure complete conversion to ash. The temperature was set at 440^{o} C to insure that all cellulose matter was converted to residue, which consists of carbon dioxide, carbon monoxide, and water vapor. Each specimen was then weighed to calculate loss of organic matter.

Results

The four sediment cores per site were collected in February, April, September, and November 2006. The approximate coring intervals were 10 to 13 m across-shore, starting from the toe of the dune/geo-structure and finishing at the wetline of the beach. In addition, 12 monthly shore-perpendicular profiles were conducted in order to observe elevation fluctuations throughout the study period. Standard surveying techniques were utilized and this procedure recorded the elevation and contours of the beach along the same transect during each survey. These monthly observations resulted in a time series of both profile and volume changes, thus enabling an analysis of beach change.

Figures 2 and 3 depict levels of organic carbon content for each sample. Organic carbon content ranged from 0.84% in Pirates Beach at 30 m extracted at the toe of the geo-structure to 0.02% in Galveston State Park, 13 m from the dune line. The February coring cycle recorded the highest average organic carbon content at 0.54%. The May coring cycle recorded the lowest at 0.25%. The September Pirates Beach wetline core contained 0.29% organic carbon. The Pirates Beach West wetline core contained 0.32% organic carbon.

The samples collected during the study period varied from 150µm to 191µm and the grain size distribution documented that the sand was well sorted. The mean grain size for the toe of the dune for all sites was 165.77µm, while the mean grain size for all of the wetline cores was 169.77µm. When taken together, the Stewart Beach samples had an average grain size of 156.57µm, while Sea Isle samples had an average grain size of 175.83µm.

During the 12-month study period, the average elevation change for all study sites was -10 cm. Galveston State Park that recorded a +4 centimeter change in elevation during the same period and was the only site where the elevation increased. Pirates Beach recorded the greatest elevation loss at - 26 cm. Table 2 shows the volumetric measurement of sand loss per kilometer of beach shoreline for each site.

Discussion

Large volumes of *sargassum* mats periodically wash ashore during the summer months along the beaches of the Galveston Island. Similar accumulations of seagrass and other marine macrophyte material on beaches have been reported in other locales. Our study was to compare various attributes and properties of four sets of twenty four 1 m long cores collected during a 12 month period from the beaches of Pirates Beach, Pirates Beach West, Galveston Island State Park, Sea Isle, Stewart Beach Park, and Pocket Beach Park #3. Based on these results, there does not appear to be any correlation between bulk organic carbon content and the rate of erosion at each site. The organic carbon content did not increase in the September cores, which were collected just after the summer beach casting. This observation suggests that there is no evidence of appreciable *sargassum* material within these samples.

Galveston beaches generally contain fine-grained sands. The samples collected during the study period varied from 150µm to 191µm. Mean grain size of Texas native beach sand typically increases from High Island to Surfside (Morton et al, 1995). Grain size also decreases across-shore towards submerged areas. Some of these trends were evident in the data. Stewart Beach, the closest study area to High Island, had an average grain size of 156.57µm, while Sea Isle, closest to Surfside, had an average grain size of 175.83µm. The toe of the dune areas' grain size average for all sites was 165.77µm, while the wetline grain size was 169.77µm. There appears to be no correlation between periods of sargassum mats on the beach and grain size as evident in Figures 4 and 5.

The 12 months of short-term fluctuations in the elevations of the profiles recorded on Galveston Island suggest a variety of physical processes, such as *sargassum* casting and flooding, were responsible for variations to the beach elevation. The February through May 2006 profiles produced very little change in elevation at all profile sites. During the months of June and July, there was an increase in elevation at all sites with the exception of Pirates Beach, due to the accumulation of sargassum beach casting. These areas returned to previous elevation marks during the months of August and September, with much of the *sargassum* mats either decomposed or carried back to the surf with high tides. The sargassum observed in the surf area had lost their grape air bladders and were no longer buoyant.

There was a high tide flooding event on October 16, 2006. The Galveston Pleasure Pier tidal gauge at 25th Street and Sea Wall Blvd. recorded a 1.25 m above mean sea level (NOAA, 2006). Pirates Beach West and Pirates Beach experienced considerable erosion of approximately 13 cm (figures 6 and 7). Galveston State Park experienced a 6 cm increase in elevation during this event. All areas have experienced partial recovery through the January 2007 profiles. There were temporary increases in elevation during the presence of the *sargassum* castings. Our, single, 12-month investigation found that presence or absence of *sargassum* on the beach had no long-term influence on the position of the wetline, which is a proxy for shoreline position.

Conclusions

At this point in our study, the analysis of the cores extracted and the temporal dataset profiles does not support a direct connection between *sargassum* beach cast and long-term (annual) influences on beach geomorphology. The accretion of sand during the height of sargassum casting was short-term (seasonal) as beach elevation returned to previous levels in subsequent months.

Analysis suggests that anthropogenic methods, such as raking and/or grooming to remove debris from the beach do contribute to beach erosion. Pirates Beach, which experienced frequent raking of the beach during the summer months, lost approximately 15% of its aerial beach from February 2006 to January 2007. During the same period, adjacent Pirates Beach West, which does not rake, lost approximately 12% of its aerial beach. An additional contributing factor for this level of erosion at both sites is the geo-structures that were exposed to the surf at high tides. During the severe flooding on October 16, 2006, scouring developed along the base of the geo-structures causing substantial erosion. During the same period, the adjacent Galveston State Park, which has natural dunes instead of geo-structures, received sand accretion to its beach. Beach Park #3 shore face experienced extensive raking and incurred a loss of approximately 6% of aerial beach (figures 8 and 9). Differentiating the impact of the raking from the presence of a geotube is not possible from our data set. However, antidotal evidence suggests that the raking of the beach breaks the hard crust, and substantially decreased the critical shear stress of the sand, making it more susceptible to erosion.

As with most preliminary studies, the initial data set generates more questions than answers. Three questions beg from these preliminary conclusions. They are: 1) what percentage of erosion can be contributed to the effort of raking *sargassum* from the wetline of the beach; 2) although the sargassum does provide temporary armoring of the beach and appears to provide temporary accretion, during the 2006 field season there were no significant tropical storms in the Gulf of Mexico and the raking period coincides with the first half of the hurricane season, therefore the question is, “how much additional protection does the sargassum provide during a tropical storm;” 3) if the sargassum is piled up at the base of the dune or geo-structure, does this provide any benefit to the beach? We propose to refine our field and research methods to address these questions during the 2007 field season.

References

Groundspeak Incorporated 2006. Copyright © 2000-2007 Groundspeak Inc. <http://www.geocaching.com/.>

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Table 2.
Elevation and Volume measurements for February, 2006 thru January, 2007

SITE	Av. Elev. Feb. 2006	Av. Elev. Jan. 2007	m^3 sand per km of beach Feb. 2006	m^3 sand per km of beach Jan. 2007
Beach Pocket Park #3	1.25m	1.20m	37450.28m^3	35912.94m^3
Pirates Beach	1.15m	0.89m	31300.91m^3	26659.27m^3
Pirates Beach West	1.24m	1.10m	37320.00m^3	32896.10m^3
Galv. Island State Park	1.07m	1.11m	32055.00m^3	33284.19m^3
Sea Isle	1.28m	1.17m	38356.88m^3	35096.30m^3

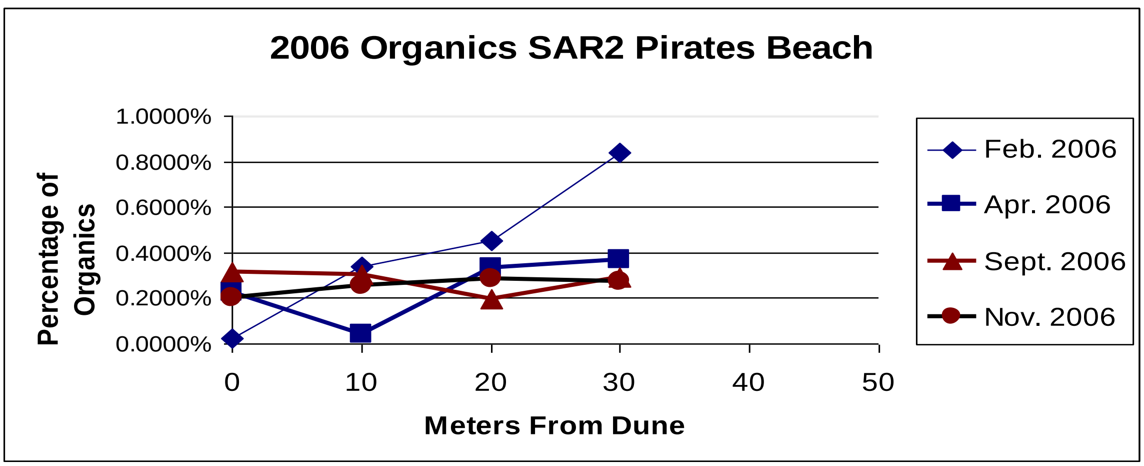

Figure 2. Percentage of organic material found in coring samples at Pirates Beach.

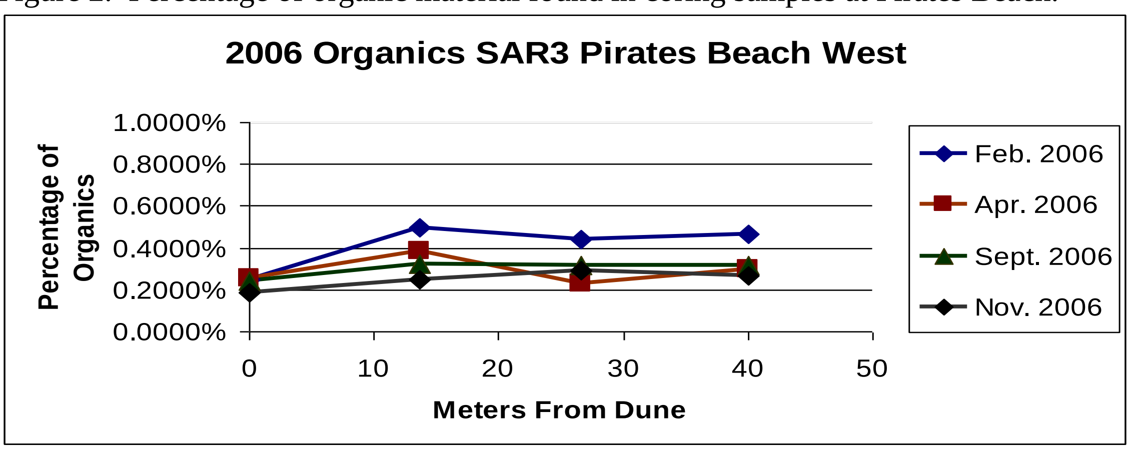

Figure 3. Percentage of organic material found in coring samples at Pirates Beach West

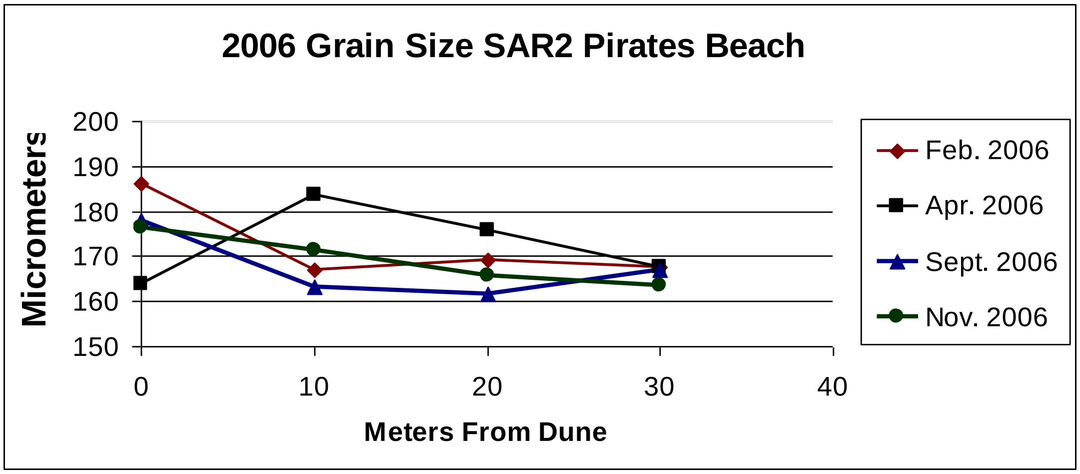

Figure 4. Grain size analysis of samples of cores extracted from Pirates Beach

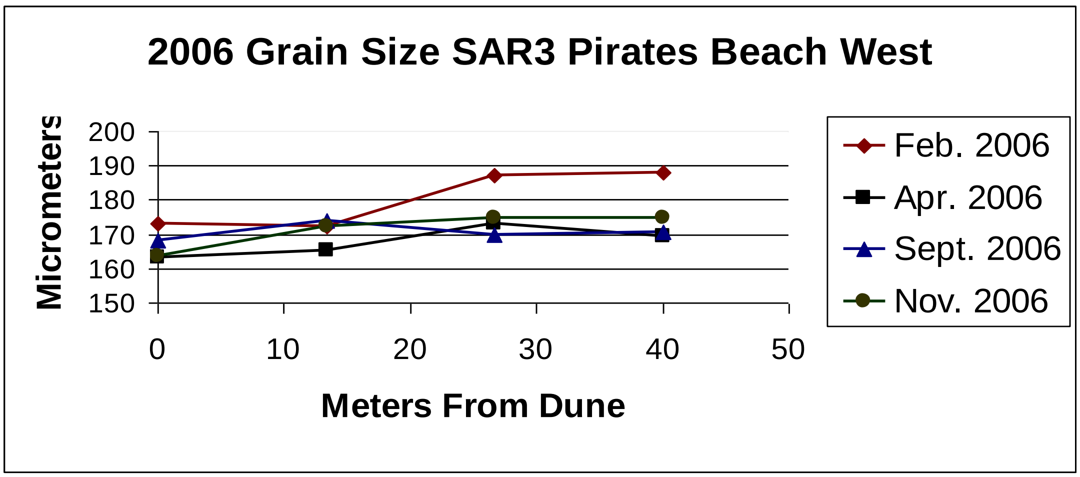

Figure 5. Grain size analysis of samples extracted from Pirates Beach West.

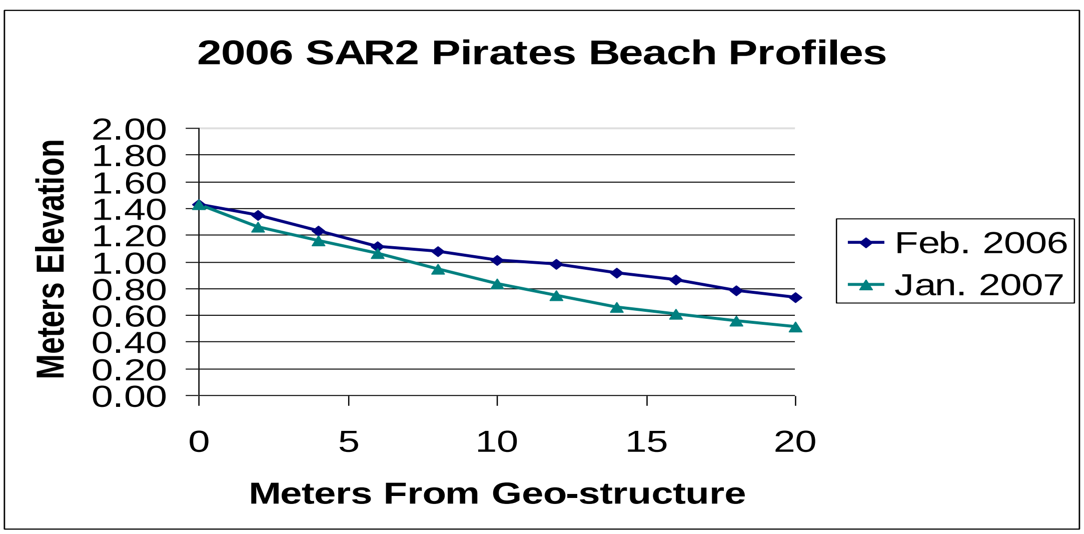

Figure 6. Elevation change based upon mean sea level for Pirates Beach

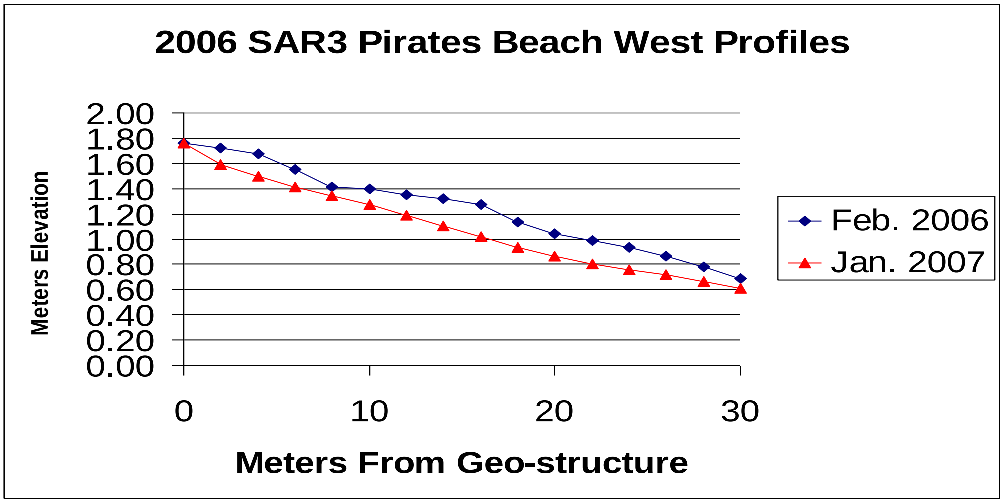

Figure 7. Elevation change based upon mean sea level for Pirates Beach West

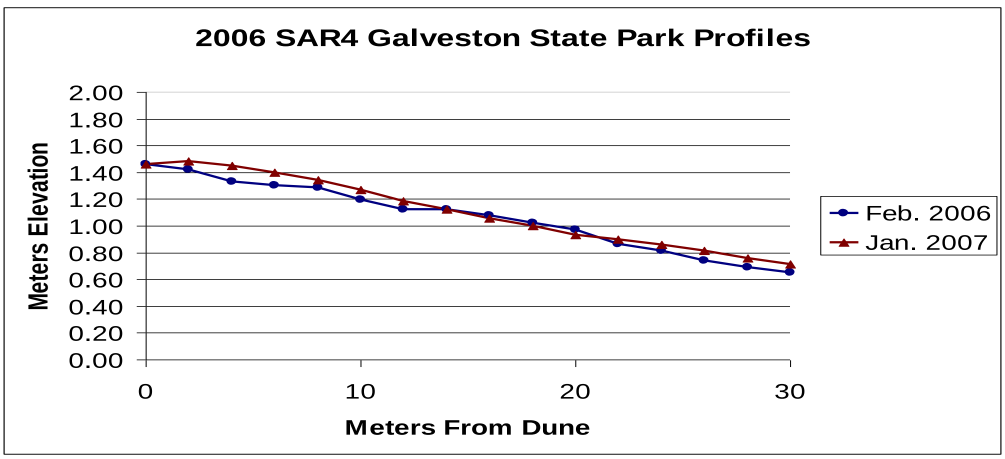

Figure 8. Elevation change based upon mean sea level for Galveston State Park

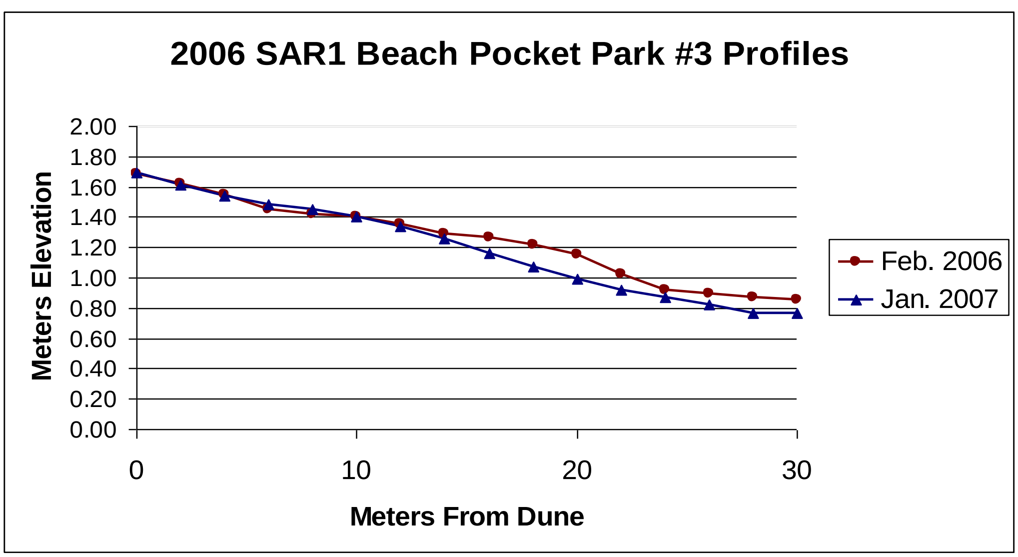

Figure 9. Elevation change based upon mean sea level for Beach Pocket Park #3.