First-Year Research in Earth Sciences: Dunes

Considering Management for a Blowout in Kitchel-Lindquist-Hartger Dunes Preserve

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Abstract

Active dunes can cause property damage if they move onto developed property. The south blowout in Kitchel-Lindquist-Hartger Dunes Preserve is suspected of posing a threat to two developments: an outdoor classroom in the preserve and the nearby North Shore Marina. To advise the management planning, we studied the current state of the blowout, including the dune features, the activity level, and current management. We inventoried dune features, gathering data about vegetation coverage and areas of bare sand. We surveyed topography to analyze the shape and structure of the dune. We used erosion pins on the windward and leeward slopes of the blowout to measure patterns of surface change. The dune is a 14-meter high trough blowout with a main axis that lines up with the outdoor classroom. Results from the erosion pin data show that the dune is active on both the windward and leeward slopes. Early-succession species on the slipface indicate more stability than the bare sand areas in the bowl of the blowout. A sand fence is doing some stabilizing of the middle windward slope, as demonstrated by the presence of beach grass near the fence. More sand fences, or the implementation of other barriers such as woody debris, could significantly stabilize the dune and would decrease the likelihood of any future threats to the nearby developments.

Introduction

Dunes can cause significant damage if they advance onto developed property. This is a reason for concern among dune managers who must balance managing dune activity versus letting processes occur naturally. Finding the right level of human intervention, as well as the most effective strategies, requires good information for decision-making. This investigation focuses on a blowout where dune advance threatens park infrastructure. To provide information that will help managers, this study focuses on collecting data about dune characteristics and activity.

Our research objectives were to:

1. Inventory the natural dune features,
2. Inventory the anthropogenic dune features, and
3. Investigate dune activity.

Background

Areas of bare sand that cut through otherwise vegetated dunes are referred to as blowouts (Bate and Ferguson 1996). The openings may be created by various types of natural or anthropogenic disturbance (Bate and Ferguson 1996), including wave erosion, wind erosion and flow over the dune, variable vegetation, climate change, and human activities (Hesp 2002). Bare sand enables strong winds to erode the exposed dune surface, and initial openings in vegetation tend to enlarge and extend downwind (Bate and Ferguson 1996). In contrast, dune surfaces that are sheltered by vegetation such as grasses or human interventions such as sand fences are protected from wind erosion.

There are numerous possible shapes of blowouts, but many can be classified into two types: saucer and trough blowouts (Hesp 2002). Saucer blowouts get their name from their appearance as shallow dishes, and they are semicircular or rounded in shape (Hesp 2002). Trough blowouts tend to be more elongated, have deeper basins, and have steeper and longer erosional sides of the deflation basin (Hesp 2002). The deflation basin is the depression or hollow where wind has removed sand. A downwind deposition lobe or area, which is the adjoining accumulation of sand to the windward deflation area, is normally considered part of the blowout (Bate and Ferguson 1996; Hesp 2002). Often there is a distinct dune crest to the blowout, which separates the windward deflation area from the leeward depositional area that forms the blowout slipface. When deposited sand reaches the bottom of the slipface (usually from a combination of wind action at the top of the slope and gravity further down the slope), the dune "advances" over nearby surfaces. The deep, elongated basins of trough blowouts provide a visual indicator of the blowout's orientation along the longest axis of the dune's shape. If the largest amounts of wind-blown sand move across the dune crest along the dune axis, then the axis can also represent the direction that the dune is advancing.

Blowouts of various sizes are common on the coast of Lake Michigan and have been included in studies of how windflow is affected by blowout shape (Fraser *et al.* 1998; Hansen *et al.* 2009). Hesp and Pringle (2001) investigated a New Zealand trough blowout to show that the orientation can impact the topographic steering, or the direction that the blowout is moving. As the wind entered the deflation depression, it was funneled in the direction of the main axis (Hesp and Pringle 2001). This drove the blowout in the direction that it was oriented by eroding the depression area and depositing more sand on the slipface (Hesp and Pringle 2001). Fraser *et al.* (1998) showed a similar pattern for a large blowout on the south shore of Lake Michigan, but different angles of wind approach could produce flows parallel to the access or flows that entered and exited the blowout across the dune arms. Hansen *et al.* (2009) did a similar study in a large trough blowout (transitional to a large parabolic dune) on the southeastern shore of Lake Michigan; they confirmed topographic steering but also found that the dune's ability to steer wind depended on the conditions. When winds approached the dune at an oblique angle, the high walls of the dune shielded the central deflation area and produced less sand transport (Hansen *et al.* 2009). Also notable from their study was the distinct seasonal pattern to sand transportation and deposition, with most occurring in the fall and winter during particularly strong storm winds (Hansen *et al.* 2009).

Wind erosion of dune surfaces, along with sand transport and deposition, can be altered or controlled by the placement of human-made structures on dunes. Fences, walls, and vegetative equivalents such as windbreaks and shelterbelts, are examples of these types of "boundaries" on dunes (Grafals-Soto and Nordstrom 2009). Many different designs, construction materials, sizes, and placements are possible, and their effectiveness also varies (Grafals-Soto and Nordstrom 2009). Investigators have noted that porosity, height, and placement are several factors that contribute to the success of sand fences as a dune management strategy (Dong *et al.* 2006; Grafals-Soto and Nordstrom 2009). Dong *et al.* (2006) identified a porosity of 0.3-0.6 as ideal for preventing erosion and sheltering vegetation. Higher fences present greater barriers to the wind, and shore-parallel orientations tend to be more compatible with natural processes (Grafals-Soto and Nordstrom 2009; Grafals-Soto 2012). The height of the fence may change over the course of its use as sand deposition partially buries the fence (Grafals-Soto 2012). Although most remnant fences do not directly increase vegetation diversity or density because the low fences cannot shelter the vegetation, the topography itself (which was likely a result of sand deposition when the fence was deployed) does affect vegetation distribution (Grafals-Soto 2012). Grafals-Soto (2012) suggested that multiple fence rows were effective, with a design that has fewer fences placed further apart representing a more natural topographic variation.

Use of sand fences on west Michigan dunes have been investigated in several recent studies (Bleeker *et al.* 2013; Gerber *et al.* 2015; Etienne *et al.* 2016). Bleeker *et al.* (2013) pointed out the challenges of employing sand fences on steep dune slopes where sand sliding down the slope may offset the deposition of sand downwind (which is upslope) of the sand fences. When a sturdier fence design was combined with planted vegetation at the same site, Gerber *et al.* (2015) measured decreased wind speed and increased sand deposition downwind from the fences in the planted vegetation. They concluded that a combination of planting *Ammophila breviligulata* (American beach grass) and using the sand fences could be the most effective management. Etienne *et al.* (2016) completed a broader investigation of sand fences in four coastal parks. They noted that the sand fences were effective for both increasing sand deposition and decreasing some human impacts on vegetation (Etienne *et al.* 2016). However, some of the unintended consequences were unmanaged trails near the fences where people trampled vegetation to walk around the fences (Etienne *et al.* 2016). Etienne *et al.* (2016) also pointed out that most of the fences they examined were damaged (missing or broken slats, fence falling over or detached from poles), which lowered fence ability to prevent human access to an area or slow down sand movement.

Study Area

Our study area is located in Kitchel-Lindquist-Hartger Dunes Preserve near Grand Haven, MI near the mouth of the Grand River (Fig. 1). The southern blowout (Fig. 2) was the focus of this study and is located next to the preserve parking lot, an outdoor classroom, and the North Shore Marina.

Some previous and concurrent research results are available for the south blowout (the focus of this study) and the neighboring blowout to the north. In fall 2012, Karsten *et al.* (2013) investigated patterns of vegetation and sand transport in both blowouts. The study measured more erosion and deposition in the south blowout compared to the north blowout; the study concluded that the south blowout was more active than the north blowout (Karsten *et al.* 2013). The study recorded sand deposition on the slipface that nearly reached the bottom of the slipface (Karsten *et al.* 2013). VanEyl-Godin *et al.* (2014) installed dune pins in the north blowout to test the use of photographic measurements of dune surface changes. An internal study commissioned by the KLH Dunes Preserve Board (Hicok 2018) used air photos from 1994, 1999, 2004, 2014, and 2017 to calculate the rate of blowout crest movement towards the outdoor classroom built

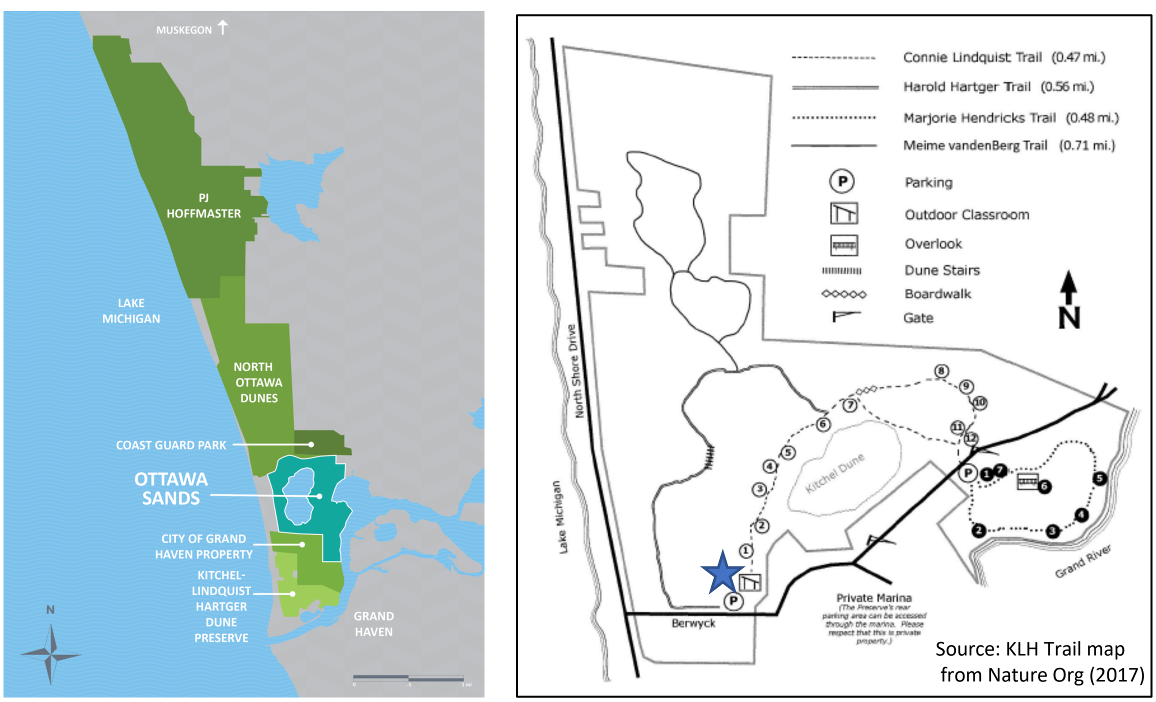

Figure 1. Location of Kitchel-Lindquist-Hartger Dunes Preserve north of Grand Haven and the study area location in the preserve (blue star).

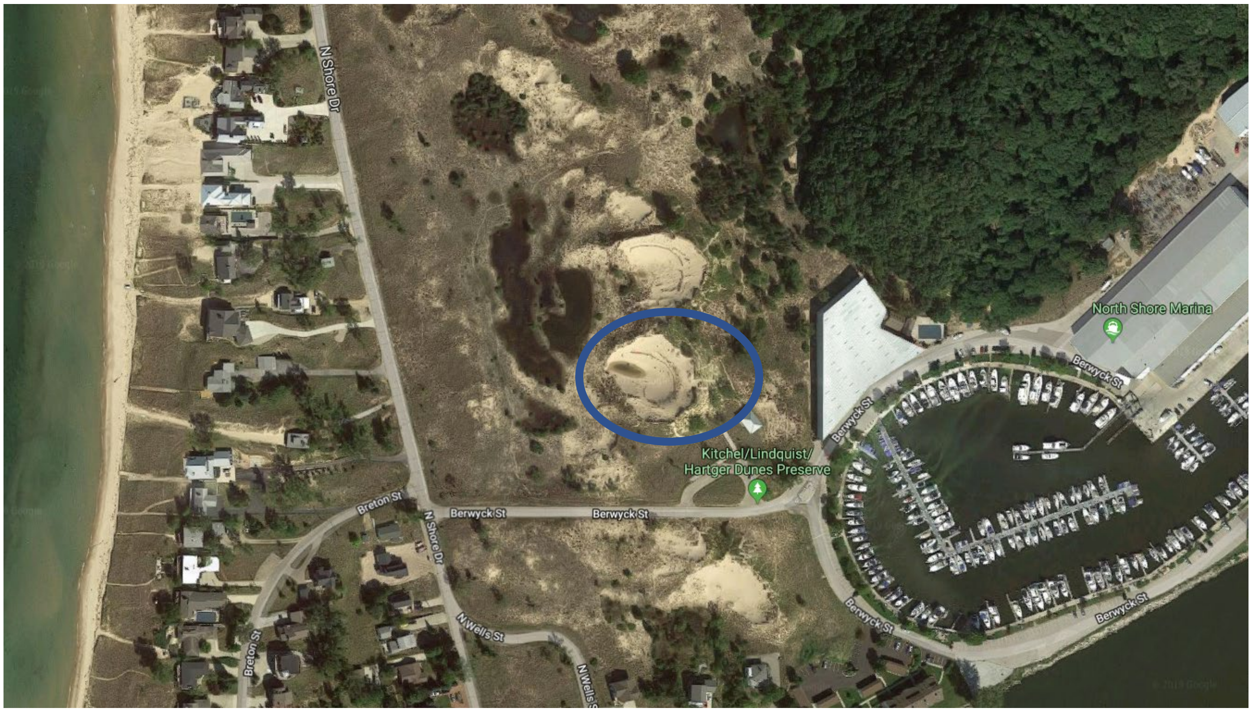

Figure 2. Aerial view of the south blowout (circled in blue) and its surroundings (Image source: Google Maps)

between 1999 and 2004. The study concluded that there was a trend of crest moving towards the classroom, but this might not represent dune advance (Hicok 2018). Measuring dune advance on the photos was not possible because of the difficulty in identifying the bottom slipface edge of the dune (Hicok 2018).

At the same time as our research project, another research team was studying the north blowout and the similarity of its characteristics with the south blowout (Leisman *et al*. 2019). The north blowout could become a potential control site for comparing blowout activity if the south blowout is the focus of future management interventions.

Methods

To gather data for our study we focused on recording the features of the dune as well as measuring the activity on the dune. Data was collected during a period of three consecutive Thursday site visits during the fall of 2018. The dates of our field data collection were October 25, November 1, and November 8, 2018.

Inventory Natural Dune Features

In order to document the natural dune features, we used a systematic checklist of Michigan dune features called a dune feature inventory (DFI). We used the checklist categories to record information about the different geomorphic areas of the dune and the different types of vegetation cover. Dune components we looked for included the deflation area, dune crest, deposition area, and dune wetland. Ecological communities we looked for included bare sand, beach grass/early colonizers, shrubland/early succession, forest, and interdunal wetland species. We photographed the distinctive dune features and vegetation communities.

Using Trimble GPS units, we collected location data for all these features, as well as our other measurement locations. We downloaded the GPS data using GPS Pathfinder Office and used the software to increase mapping accuracy with a differential correction using a base station along the lakeshore. Then we exported the data to ArcGIS, where we combined the data to produce maps and applied some of the measurement tools. Fig. 3 shows the locations of measurements described in the next paragraphs.

Figure 3. Measurement locations in the south blowout.

To investigate the shape and other physical characteristics of the blowout, we took a topographic survey of the dune area using a Sokkia SET530R Total Station. We set up the total station on the middle of the dune crest (see Fig. 3). We collected 300 separate data points of the topography and used specialized software (RockWorks 2017) to create a digital model that could be used to measure the physical dimensions of the blowout. From the topographic model, we were able to calculate blowout height, diameter, and slope angles.

Inventory Anthropogenic Dune Features

We documented anthropogenic features with field observations, GPS mapping, and photographs. We mapped the locations of the sand fences present on the dune and made some observations about their conditions. There were numerous unmanaged trails present within our study area, although we did not record the spatial data for all of them. We recorded other human impacts such as litter and measurement pins left behind by a previous study (VanEyl-Godin *et al.* 2014). After recording the impacts, we also collected the litter for disposal in trash cans, and we collected the measurement pins to return to Hope College.

Investigate Dune Activity

To measure the surface change, our team used 27 erosion pins set up in a line transecting the blowout (see Fig. 3). These pins were spaced 2 meters apart and were measured three times in total: once when they were placed, and then once each during our other two site visits. We compared the height of the pin above the ground surface between visits to see whether and how much erosion, deposition, or no surface change took place.

Results

Natural Dune Features

The topography shows a moderate-sized blowout with some areas of steep slopes (Fig. 4). The blowout measures 14 meters tall and has a roughly circular shape for its deflation area. The average diameter is 62 meters, with a primary axis oriented in a SE-NW direction. The leeward slope is steeper than the windward slope except for a small steep scarp at the very crest of the dune on the windward slope.

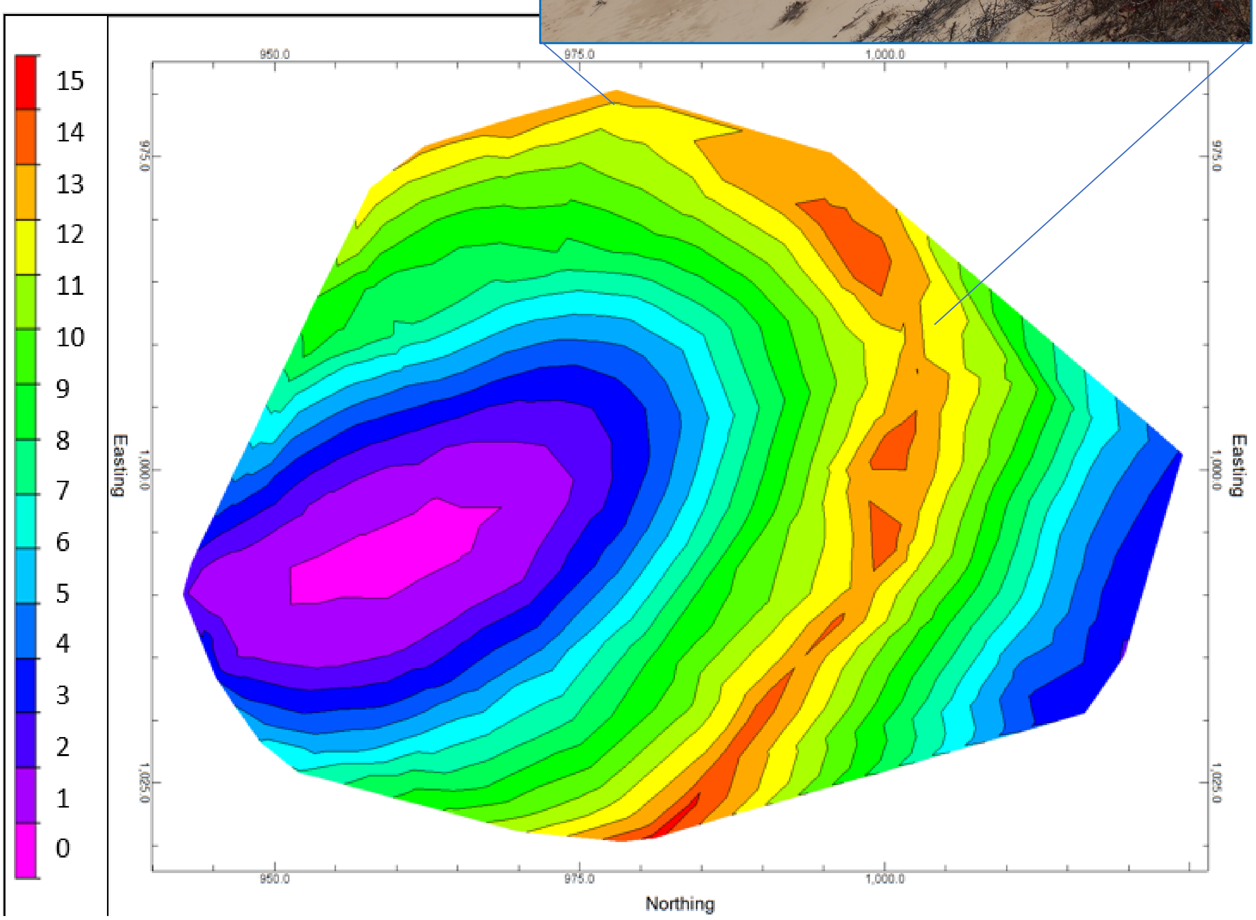

Figure 4. Topographic map of blowout, based on survey data, with photograph showing the steep scarp at the upper windward slope.

The blowout has some variation in surface cover and distinctive features (Fig. 5). The windward slope is primarily bare sand with small patches of *Ammophila breviligulata*. At the very bottom of the deflation area there is a depression filled with water surrounded by a small dune wetland area (Fig. 6). On the leeward slope, the vegetation is primarily *A. breviligulata* with the addition of some shrubs and small trees on the south side.

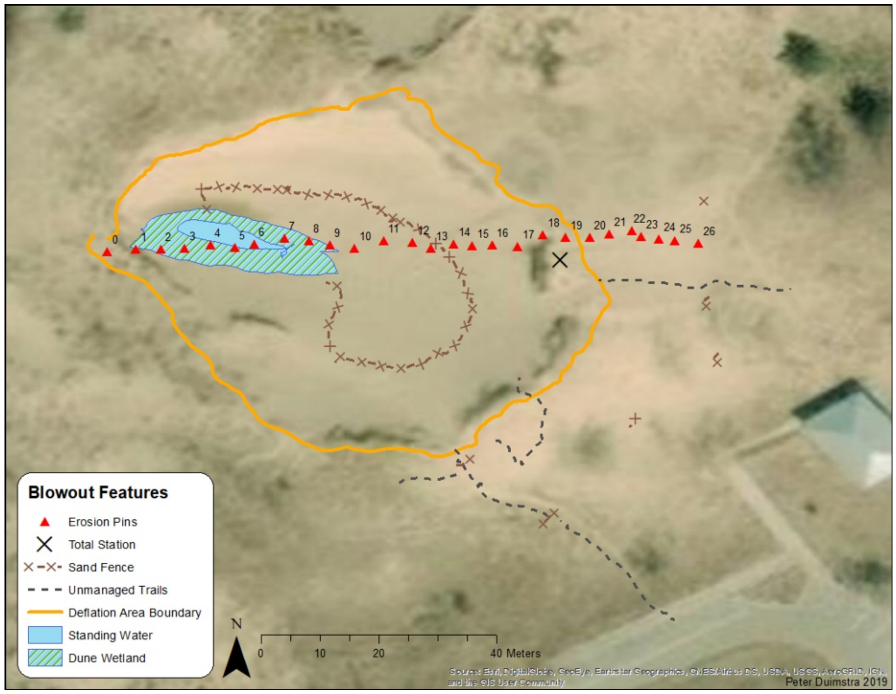

Figure 5. Natural and anthropogenic features of the blowout. (Measurement locations are included to permit comparison of data).

Figure 6. View from the dune crest shows the bare-sand deflation area with the small pond in a depression at the bottom of it.

Anthropogenic Dune Features

The blowout shows evidence of management in the form of several sand fences placed on the blowout (see Fig. 5). There is one main sand fence located at about the midpoint of the windward slope that stretches around the entire midsection (Fig. 7). However, the southern portion of this fence was collapsed, and some other parts were in disrepair as well. There were also five sand fences on the leeward slope positioned across unmanaged trails. The blowout had several signs directing people to stay off the dune surfaces.

There was evidence that people had been on the dune despite the signs telling visitors to stay off. We found several pieces of litter as well as some leftover erosion pins from a previous study (VanEyl-Godin *et al.* 2014). We recorded five unmanaged trails, with surface conditions ranging from dead/dying dune grass to bare sand, or a combination of the two. We observed more unmanaged trails within the study area, but we were unable to record these due to time constraints.

Figure 7. Sand fence wraps around the upper slope of the deflation area. One section (visible in center of photo) has collapsed and is resting on the dune surface.

Dune Activity

Erosion pin measurements showed sand movement over the entire length of the blowout (Fig. 8). The most significant erosion occurred at the windward edge of the blowout, just below the sand fence on the windward slope, and at slipface locations. The most deposition occurred at the dune crest and on the upper windward slope above the sand fence. Erosion was also observed at some locations without erosion pins, such as under the scarp on the upper windward slope.

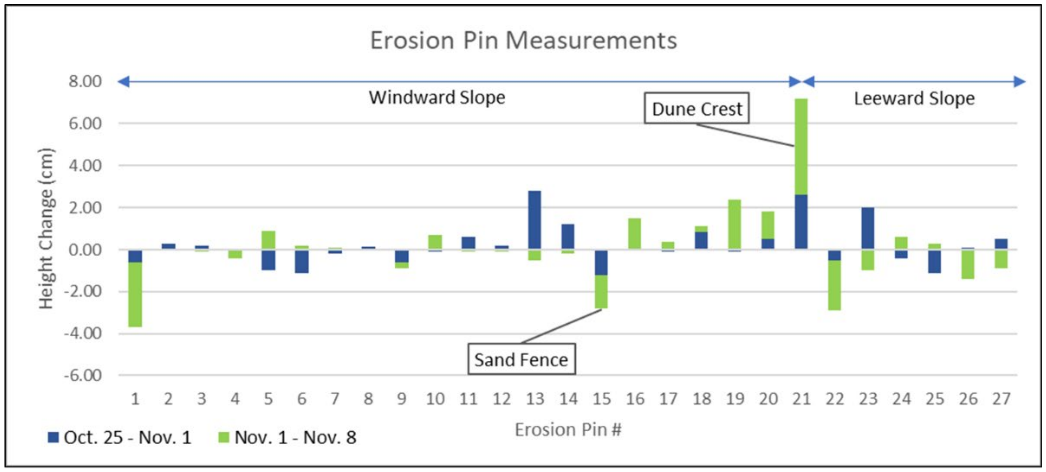

Figure 8. Surface changes as recorded at erosion pins between October 25 and November 8, 2018.

The measurements and observations of this study took place in the context of several strong wind events (Fig. 9). Wind energy was strongest during the week of November 1-8. These wind patterns fit into the normal autumn wind patterns for the Lake Michigan coast.

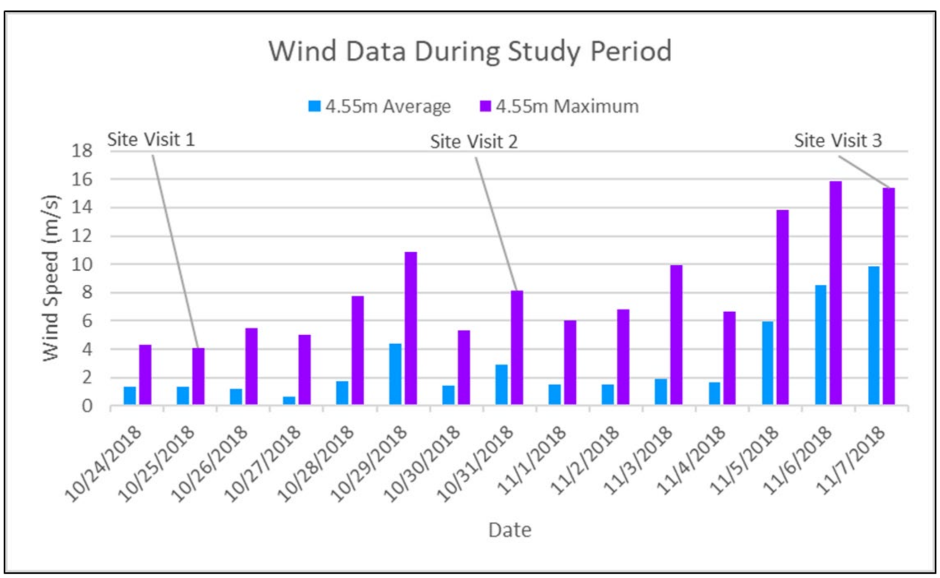

Figure 9. Wind velocities measured at reference dune site (Hoffmaster State Park) north of our study area.

Discussion

We categorized the blowout as “active” based on the presence of bare sand in the deflation area and visible deposition around vegetation on the slipface. The erosion and deposition measurements along the main axis of the blowout are additional evidence that the dune is active. The erosion and deposition results fit with the autumn storm winds that we observed over the course of our study period. Some of the erosion pin measurements may have been affected by human disturbance from walking near the pins. Future measurements that include a longer measurement period and/or more pin locations would be helpful in providing more detail about the amounts and patterns of sand movement.

To measure how quickly the blowout is advancing toward the outdoor classroom, we recommend establishing a program of direct measurements of dune advance. Because of some study logistics, our team did not measure the distance from the outdoor classroom to the edge of the dune’s slipface. This type of direct measurement, repeated at intervals such as yearly, is the most effective way to measure the rate of dune advance. The calculation is simple: the change in distance between a fixed reference point (such as a corner of the classroom) and the dune edge divided by the length of time between measurements equals the rate of dune advance (in feet or meters per year). Measurements from several points along the dune edge to fixed reference points can help to identify the direction of the greatest advance. Existing fixed features can be used as reference points, such as structure corners, sign-posts, or sturdy trees. For more control over the quality, ease, and location of measurements, managers can install some reference posts; a distance of about 2 meters beyond the edge of the dune is ideal because the distance is easy to measure with a folding ruler or measuring tape and the post can be used for at least 8 years if the advance rate is less than 0.5 m/year. Many types of posts will work for the measurements, but we recommend the 4x4 wood posts installed by Ottawa County Parks staff at North Beach Dune and Department of Natural Resources staff at Mt. Baldy in Hoffmaster State Park.

The main axis of the blowout is pointing towards the location of the outdoor classroom, which could suggest the dune is advancing in that direction (Hesp and Pringle 2001). According to the calculations of Hicok (2018), the dune may be advancing at a rate of 0.1 meters per year. The leading edge of the blowout is about 25 meters from the outdoor classroom. If these rough calculations are correct, damage from the blowout moving into the space of the outdoor classroom is unlikely in the near future. However, management actions to slow down the dune advance would reduce future risk.

Our study results show some evidence that management is effectively stabilizing parts of the blowout with sand fences. In the deflation area, the sand fence has stabilized a section of the blowout enough to allow *Ammophila breviligulata* to grow downwind (upslope) from the sand fence. The beach grass needs some burial by sand to thrive and it does not do well in erosion areas which are more typical of the upper windward slopes of blowout deflation areas. Sand fences that are effective at slowing down the wind will create deposits of sand downwind from the fence. The presence of *Ammophila* is an indicator that there is enough deposition produced by the fence to allow early colonizers to grow.

Additional management in the form of sand fences or other barriers such as woody debris could lead to further stabilization of the windward slope. The managed stabilization would be aided by the continued growth of dune grasses, because the grasses, when established, act as natural barriers to wind flow and sand transport. If blowout stabilization is something the managers want to accomplish, we believe it is an achievable goal.

The shorter sand fences on the blowout's outer arms and slipface are unlikely to slow down sand movement by wind, but they are positioned correctly to reduce human impacts. Multiple overlapping trails on some slopes (Fig. 10) suggest that there are enough people walking on the slopes to damage vegetation and create pathways. While some of these slopes are facing directions that make them unlikely to become big sources of sand moved by wind, the reduced vegetation makes the slopes more vulnerable to different types of erosion. Finding more effective ways to keep visitors off the slopes will contribute to increasing dune stability.

Figure 10. Blowout slope behind research team shows multiple lines where vegetation has been damaged by people walking on the dune.

Conclusions

The moderately-sized trough blowout shows widespread signs of activity. The main axis of the dune and presumed direction of advance is in the direction of the outdoor classroom. Current management is stabilizing the upper windward slope and preventing trampling on the leeward slope with the use of sand fences. Additional fences or other barriers could increase stabilization and decrease future problems from dune advance.

Acknowledgements

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