First-Year Research in Earth Sciences: Dunes

Interactions Between Blowouts and Trails in a Lake Michigan Coastal System

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1.0 Abstract

Previous dune research has shown that trails on dunes can influence blowout development, but there are no studies of the interactions between trails and blowouts on Lake Michigan dunes. In the fall of 2011, a study was undertaken to investigate relationships between trails and blowouts on a dune ridge in P.J. Hoffmaster State Park. We documented the characteristics of all trails and blowouts in a 1.2-km section of the dune ridge. Recorded blowout characteristics included height, length (parallel to shore) and width (perpendicular to shore). For each trail, we recorded vegetation density, average width and orientation. We mapped the locations of each trail and blowout using GPS, and visually represented the data using GIS software. Results show spatial patterns of trails and blowouts within the study area. There are 31 blowouts and 33 trails. Ninety-seven percent of blowouts are connected to at least one trail. The average trail orientation is 79 degrees east, which is perpendicular to the shoreline orientation of 155 degrees southeast. These results suggest that blowouts are more likely to occur where trail orientation makes the dune surface vulnerable to erosion by southwesterly winds. Understanding the relationship between blowouts and trails can help to identify potential areas where greater human impact can occur.

2.0 Introduction

Blowouts are distinctive features in coastal dune systems and can be viewed along the Michigan coast. Westerly winds blowing across Lake Michigan have created a dune environment that is receptive to blowout formation. P.J. Hoffmaster State Park, located on the east coast of Lake Michigan, is part of a series of large, active parabolic dune systems influenced by these winds. The dune system is a significant attraction due to its size and activity; because of its easy accessibility, many people visit the park. Due to human activity, unmanaged trails have developed, creating many disturbances in this particular dune system. Numerous blowouts have formed in and around the dune ridge area. Previous dune research has shown that increased anthropogenic pressures, such as unmanaged trails on dunes, can destroy vegetation and lead to the development of blowouts (Catto *et al*. 2002) but there are no studies of the interactions between trails and blowouts on Lake Michigan dunes. This study investigates whether relationships exist between trails and blowouts in the coastal dunes of P.J. Hoffmaster State Park.

3.0 Study Objectives

The objectives of our research on the coastal dunes in P.J. Hoffmaster State Park were to:

1) Document the characteristics of trails and blowouts.

2) Examine the relationships between trails and blowouts.

4.0 Study Area

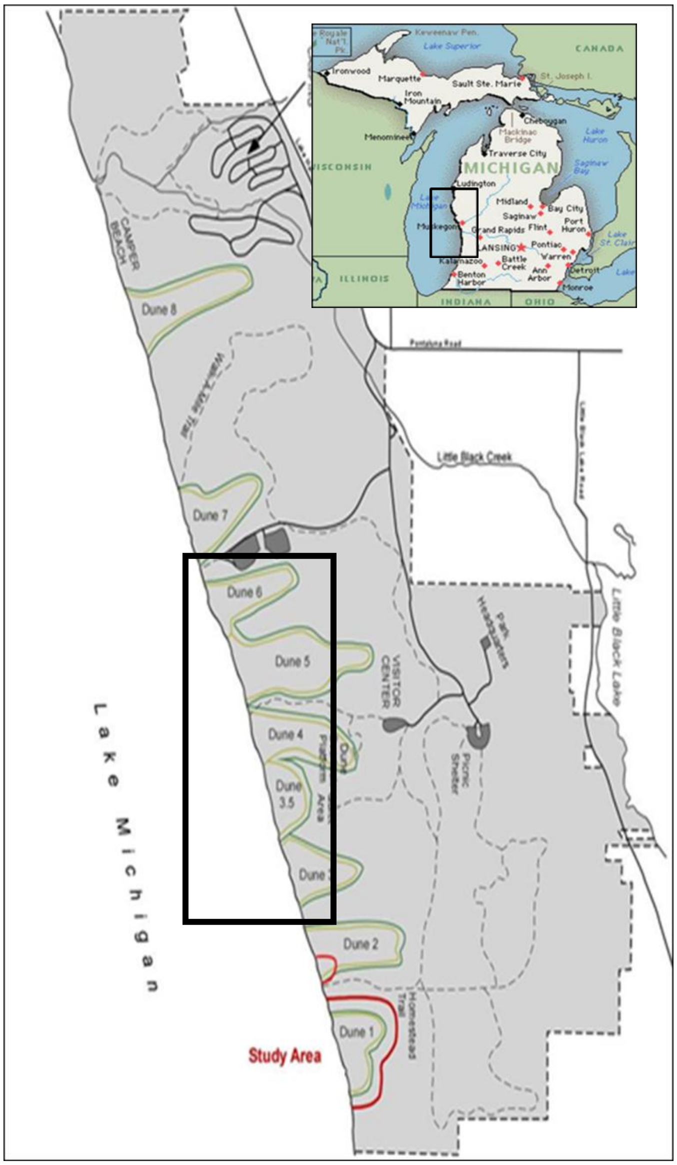

Figure 1. Study area location.
1a: Data was collected in a 1.2 km section of beach stretching from Dune 6 to Dune 3.
1b: Inset map shows location in Michigan.

P.J. Hoffmaster State Park is located north of Grand Haven, MI and south of Muskegon MI, on the east coast of Lake Michigan (Figure 1). The park contains 1200 acres of land, including approximately 4 kilometers of Lake Michigan shoreline consisting of sandy beaches and a large, complex dune system (Michigan Economic Development Co. 2012). The coastal dune system is comprised of a series of dynamic dune features, ranging in size from a relatively small foredune to a larger series of active parabolic dunes inland. Further east of the active dune system is a large expanse of forested, stabilized dunes.

The Hoffmaster dunes are governed by a number of factors, including human activity, which shape dune systems in distinctive ways. The park is a highly visited location featuring recreational activities that entice people of all ages. The managed trail system provides access to many parts of the dune system. Many unmanaged trails have formed on the foredune and dune ridge.

This study focuses on a 1.2 kilometer portion of dune ridge in the park. Measurements were recorded on the dune ridge beginning at the northern boundary of Dune 6 and extending southeast ending at Dune 3 (Figure 1a). The study area is a segment of the NE-oriented dune ridge that runs parallel to the shoreline. Many blowouts and unmanaged trails can be found on the dune ridge.

5.0 Background

The dunes in Hoffmaster State Park form a small portion of a Lake Michigan coastline filled with sandy beaches and massive coastal dunes. Dune systems in Michigan are comprised of Holocene alluvium and Pleistocene-aged glacial deposited sands (Handy and Stark 1984), which have been redistributed by prevailing westerly winds. Glacial retreat in Michigan occurred 11,800 years ago (Drexler 1974), leaving behind ideal conditions for dune development (NPS 2005). Massive parabolic dunes formed approximately 3-5,000 years ago when high lake levels destabilized the existing shoreline and released immense quantities of sediment (Arbogast and Loope 1999). Strong winds, warm temperatures and low surface moisture contents are ideal conditions for movement of large amounts of sand on mid-latitude coastlines (van Dijk and Law 2003). The coastal dune system in Hoffmaster experiences these conditions periodically throughout the year (van Dijk 2004).

On Lake Michigan dunes, sand movement consists of the reworking of existing dune sediment, with local transport through the active foredune and over the crest of the dune ridge to the leeward depositional area further inland (van Dijk 2004). The Hoffmaster dune system is distinct in that lake level changes continue to change dune morphology. Close inspection of dune locations show that some dunes or dune-like structures would not have formed so far inland if lake levels existed as they do today (Hansen *et al*. 2010; van Dijk 2004). Over time, vegetation began stabilizing the foredune and dune ridge areas, although periodic disturbances by storm waves, high lake levels, mass wasting and anthropogenic activities allowed parts of these dunes to be reactivated. Currently, the dunes exist in various stages of activity and stabilization.

The dune ridge is located between the larger parabolic dunes inland and the lakeward foredune, and appears to be no more than five thousand years old (Hansen *et al*. 2010). The cycles of lake level changes on Lake Michigan suggest that the activity seen on the foredune and the dune ridge within Hoffmaster may continue to change as it has done in the past (Baedke and Thompson 2000) . The processes which actively shape foredunes are closely linked to beach activities, storm events and lake level changes (Hesp *et al*. 2005). The once active foredune may be short-lived, and the dune ridge may become an active coastal dune again. If Lake Michigan remains at or below its current levels (176.4 m above sea level in 2004), foredune growth will continue to grow larger (van Dijk 2004). The foredunes are both smaller and more recent features—in some cases these features are only a few years old and their life span can be measured in decades.

In Hoffmaster State Park, studies of contemporary dune processes have focused on a beach-foredune-dune ridge system at the south end of the park (van Dijk 2004). The dune system includes a saucer-shaped blowout on the dune ridge. Foredune growth has been measured at up to 5 m per meter dune-width per year (van Dijk 2004). Although the foredune was less than 10 years old, it was already large enough to cut off the aeolian transport of beach sediments to the dune ridge (Hansen *et al*. 2009). Activity on the dune ridge occurred as sand from the blowout was deposited on the lee slope of the dune ridge. The dunes will continue to change based on the varying local conditions, lake level fluctuations and available sand supply.

6.0 Methods

This study utilized two data collecting techniques. To document and compare the natural and human characteristics for blowouts and trails, a systematic data collection checklist was created. To map the spatial patterns of blowouts and trails, Juno Trimble GPS units were used.

6.1. Documenting Blowout and Trail Features

In October and November 2011, we documented characteristics of blowouts and trails in our study area using a modified version of the Dune Features Inventory or DFI (Beauchamp *et al*. 2009; Ferwerda and van Dijk 2010). Blowout and trail assessments were accomplished using a revised checklist, which we named the Blowouts Features Inventory (BFI). The BFI is a systematic data collection procedure that allowed for the documentation of blowouts and trails, which helped us compare the natural attributes of each blowout and trail characteristic—such as minimum, maximum and average height, length (meters parallel to shore) and width (meters perpendicular to shore) of blowouts, trail length, height and orientation and vegetation density (Appendix A). A blank BFI checklist was used to document each blowout at our site.

Each section of the checklist was completed through measurements and field observations. The surveying was accomplished by two two-person teams. After designating a starting position, the group traveled southeast along the dune ridge documenting each blowout and trail identified. Blowout width, length and height measurements were collected using a 50 meter measuring tape and hand level. Trail width and incision were measured using a Kenson foldable ruler. Once all questions from the BFI were answered, the group would move onto the next blowout and trail along the dune ridge. The data was then taken back to lab and assessed.

Analysis of the collected data was conducted using Microsoft Excel. A multi-page spreadsheet was produced to organize, sort and maintain the collected data.. Once all the data was transferred from our collected BFI's, the data in the spreadsheet was used to analyze trail and blowout characteristics and the relationships between trails and blowouts in our study area.

6.2. Collecting Geospatial Information

In order to determine if a correlation existed between blowouts and trails, Juno Trimble GPS units were used to map the spatial patterns of blowouts and trails in our study area. Before data could be collected in the field, the GPS units needed to be configured (Figure 2). A data

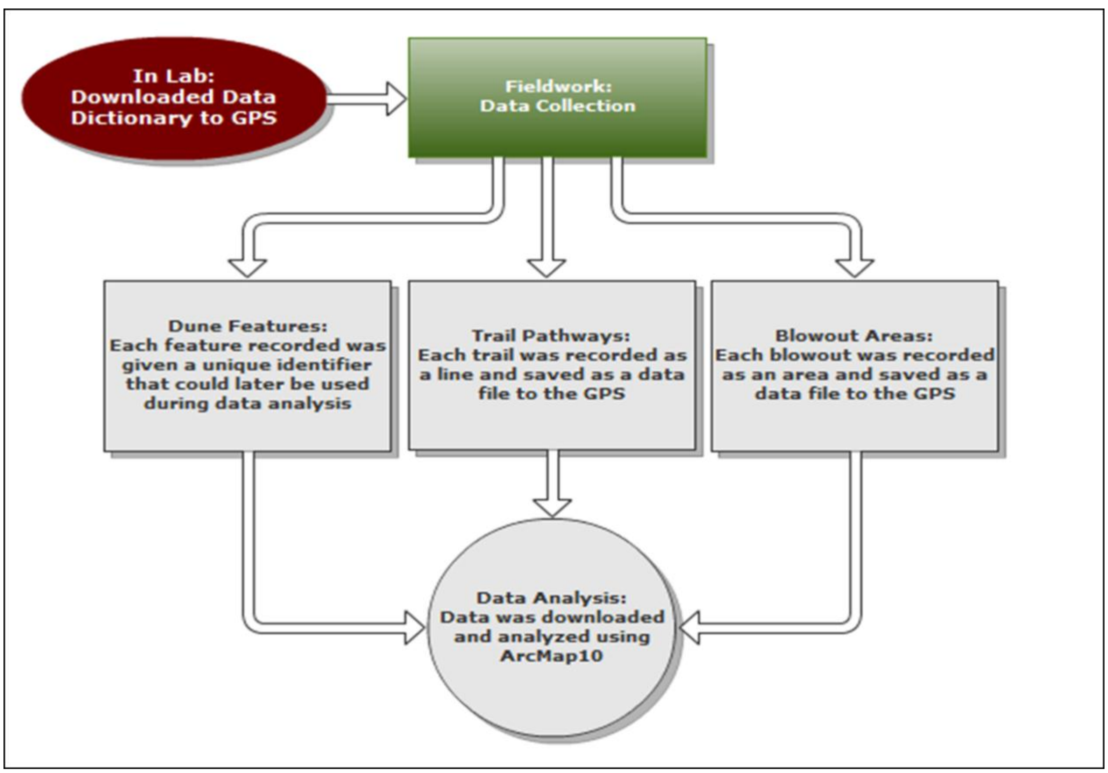

Figure 2. Flowchart explaining the process of data collection using the GPS units.

dictionary was created to control the data collection process in the field. The dictionary helps to define the data collection process through the creation of a preset attribute table, which is then filled out while in the field. The units were programmed to store three different data files: 1) dune feature indicators, which help correlate the GIS data with the specific BFI used at the dune feature; 2) a trail file, which would help record the GPS locations of trail pathways; and 3) a blowout file, which stored data concerned with blowout circumference. Once set up, the GPS units were ready to collect blowout and trail data.

In the field, a researcher used the GPS unit to collect spatial data from each blowout and trail. The other researcher filled out the BFI to collect individual blowout and trail characteristics. Once both sets of data were collected for each dune feature, they were saved and archived as a data file. After completing the field work, the data files were extracted from the Trimble, downloaded and analyzed using ArcMap10. The units enabled us to collect field data on dune features, trail pathways, blowout areas and trail orientations.

7.0 Results

Blowout characteristics showed much variety in our study area. There are 31 blowouts in the 1.2 km study area. Blowouts had a wide range of sizes (Table 1; see Appendix B for collected data). The greatest blowout height was 10.6 meters; greatest width 92.7 meters; and the greatest length 90 meters. Of the 31 blowouts identified, 22 exhibited saucer-shape qualities, and 9 were classified as trough blowouts (Figure 3).

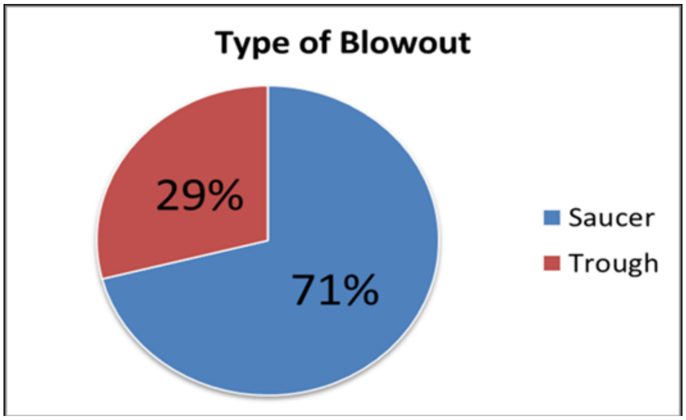

Figure 3. Almost three quarters of the blowouts were saucer-shaped.

Table 1: Blowout Characteristics			
	Maximum	Minimum	Average
Height (m)	10.6	0.1	3.1
Length (m)	90	0.65	15.1
Width (m)	92.7	1.6	15.1

Table 2: Trail Characteristics			
	Minimum	Maximum	Average
Width (m)	0.4	2.45	0.7
Orientation (N to S)	4 degrees N	155 degrees SE	79 degrees E

Trail characteristics showed similar variety. Trails within the study area included one Main trail and 32 Secondary trails. The Main trail traveled the length of the dune ridge in our study area, nearly parallel to the shoreline. The Secondary trails were the unmanaged trails that were in close proximity to the Main trail. Trails had a narrow range of sizes (Table 2). The greatest trail width was 2.45 meters; the smallest width was 0.4 meters; and the average width for all 32 Secondary trails was 0.70 meters.

Trails had a range of orientations. One trail had an orientation of 155 degrees, the exact orientation of the shoreline. Others had more extreme degrees that bisect the Main trail at a perpendicular angle. The smallest orientation measured 4 degrees north. Average trail orientation was 79 degrees east, which is approximately parallel to the shoreline at an orientation of 155 degrees southeast (Figure 4). Secondary trail orientations were not statically significant in determining whether orientation correlated with blowouts in these areas.

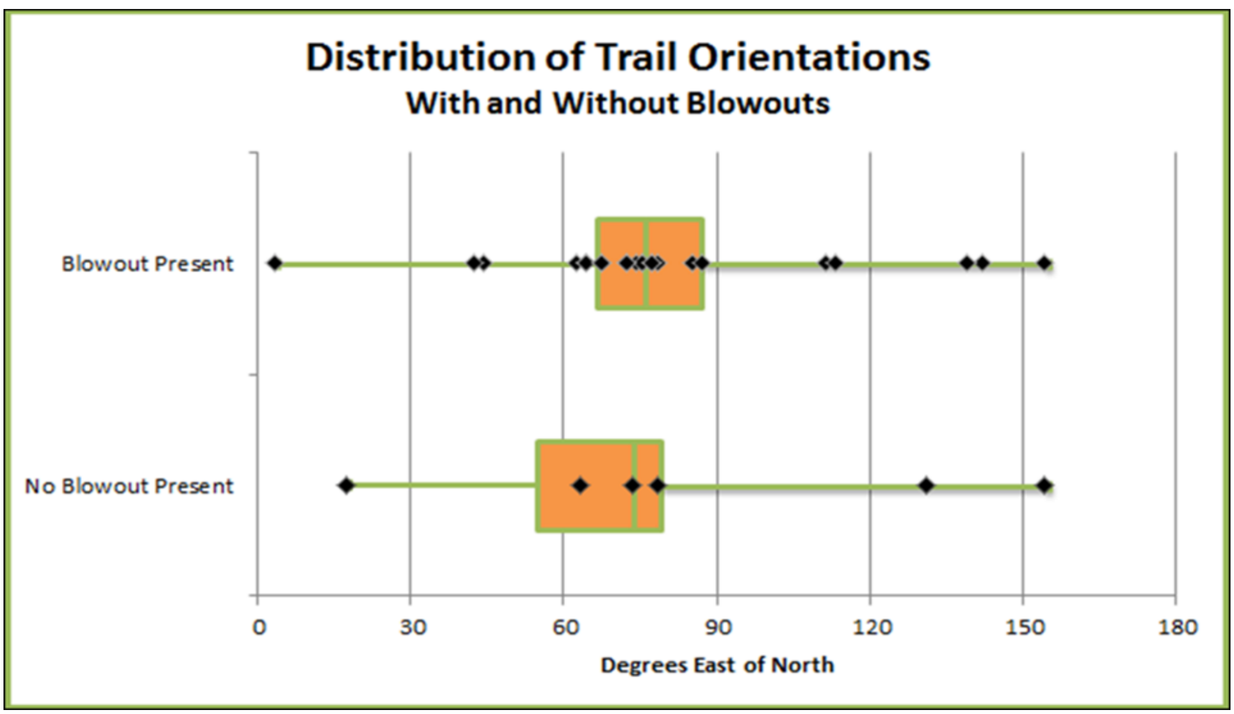

Figure 4. This graph depicts a boxplot of trail orientations grouped by trails with blowouts and trails without blowouts. The data points show the orientations of the trails.

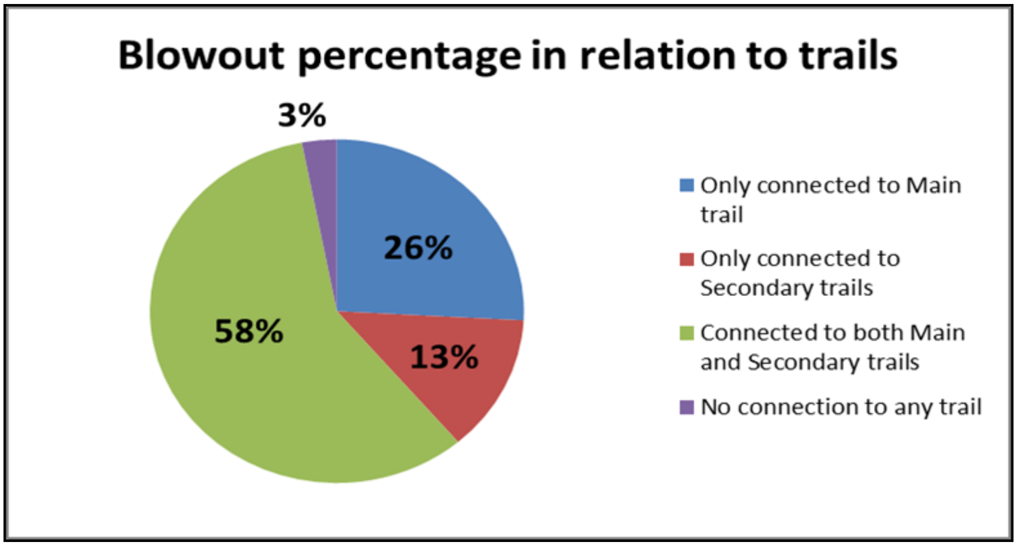

Figure 5. Over half of the 31 blowouts were connected to both Main and Secondary trails.

The relationship data recorded shows that a correlation exists between blowouts and trails. Of the 31 blowouts, 8 were connected to just the Main trail. There were 4 blowouts that were only connected to Secondary trails. Blowouts connected to both the Main and Secondary trails totaled 18. Only 1 blowout was not connected to either any trail (Figure 5).

Common trail characteristics included sparse vegetation and evidence of incision erosion into existing dune surface. Results show that most trails do not have vegetation on them. Accordingly, 56.6 percent of the trails were categorized as having sparse vegetation. Only 6.6 percent were completely covered with vegetation (Figure 6). Twenty-three of the thirty-two trails were incised more than 5 cm.

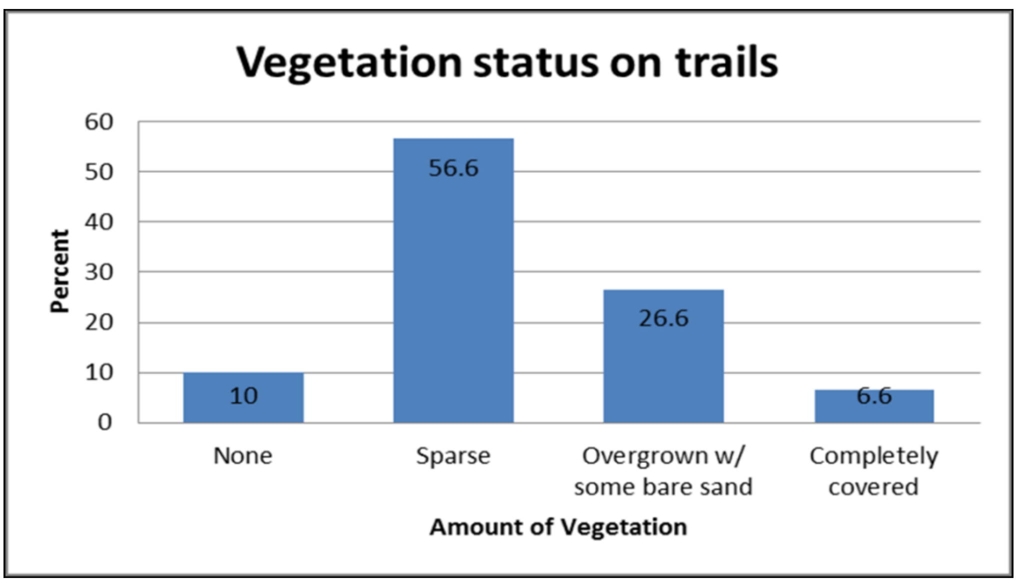

Figure 6. Trails were classified as either completely vegetated, overgrown, sparsely vegetated, or no vegetation present.

Spatial analysis of our study area shows a relationship between trail and blowout locations (Figure 7). Two blowout clusters can be identified where increased numbers of trails occur. The high intensity of blowouts around the Main trail shows a spatial correlation. If the study area is divided into 4 segments (quarters) along the Main trail and numbered 1-4 from north to south, then segments 2 and 4 show the highest intensity of blowouts and trails on the dune ridge. A high percentage of blowouts on the dune ridge that were connected to trails perpendicular to the shoreline were saucer-shaped.

Figure 7. Map of trails and blowouts within the study area.

8.0 Discussion

The two clusters of blowouts are located in areas where foot traffic and other disturbances appeared to be intensified. Other research shows that high foot traffic can create unmanaged trails (Bowles and Maun 1982), and those trails could aid in blowout development (Bate and Ferguson 1996). In Hoffmaster State Park we can see this pattern in Segment 4, where the greater number of blowouts seems to correspond with more traveled areas. The Main trail is a managed trail that is highly traveled, which may have led to a higher intensity of blowouts along the crest of the dune ridge. Dense vegetation landward of the Main trail in Segment 2 may have concentrated foot traffic around the Main trail, leading to more Secondary trails and more blowout development. These cluster patterns show that areas where increased human activity occurs are also areas where higher densities of blowouts develop. Many of the trails in our study area are still being traveled to access different parts of the dune system, therefore creating more disturbances on the dune ridge.

The similarities in average trail orientations where blowouts were and were not present would suggest that further research is needed to investigate correlations between trail orientation and blowout development. Continued research would help to understand whether the relationship between blowouts and trails are in fact impacted by the orientation of the trail. If a stronger correlation is discovered, managers of P.J. Hoffmaster Park can implement stabilization techniques on unmanaged trails that are orientated in a direction that most impacts blowout development. Artificial stabilization would prevent unwanted human activity from disturbing the dune ridge, and ultimately increase its stability. Since this study was one of the first to analyze the relationship between trails and blowouts, we hope that our research will act as a reference for future studies. This research can provide valuable insight to how human impacts change dune morphology.

9.0 Conclusions

This study was beneficial in documenting characteristics of blowouts and trials, and provided valuable data to understand the relationships between these two dune features. Application of the Blowout Features Inventory was a useful method for collecting data on blowouts and trails on Lake Michigan coastal dunes. This study documented 31 blowouts and 33 trails in our 1.2 kilometer stretch of dune ridge. The data collected shows that each blowout is distinct in its height, length and width. Trail characteristics are consistent but orientations show variability. Of the 33 trails, 32 were unmanaged and 1 was managed. GPS data identified distinct spatial patterns showing a relationship between trails and blowouts in the form of two blowout clusters where increased trail activity is present. The high intensity of blowouts around the Main trail does suggest that these features are connected.

Coastal dune systems are dynamic, and the Hoffmaster dunes reflect changing stages of activity and development. Due to these fluctuations, consistent monitoring of the dune system will be able to better understand how blowouts and trails operate and interact with one another.

10.0 Acknowledgments

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Appendix A: Blowout Features Inventory (BFI) Checklist

A. Site Information

1. Dune Name: ____
(Dune number or description of location Ex. Dune 6 or between Dune 4 and Dune 5)

2. Blowout Letter: ____________________ 3. Trail Number: ______________________

B. Field Data Collection Information

1. Observer(s): ____

2. Date: __________________ Time In: ____________ Time Out: _____________

4. Weather conditions:

Wind speed (avg): Wind direction:

C. Natural Features: Geomorphology

1. Site has:
☐ Blowout ☐ Trail ☐ Both

2. Number of blowouts at site: ___________

3. Type of blowout:
☐ Trough ☐ Saucer

4. Number of trails at site:______________

5. Orientation of trail: _____________
(If sinuous, take multiple measurements)

6. Average width of trail (m):____________

7. Height of blowout (m): ______________
(Measure from lowest point to highest)

8. Width of blowout (m): ______________
(Measurement perpendicular to shoreline)

9. Length of blowout (m): ______________
(Measurement parallel to shoreline)

10. GPS data collected for:
☐ Blowout (polygon) ☐ Trail(s) (line)

D. Natural Features on Blowout: Ecology

1. Ecological communities (check all that apply)
☐ Bare Sand
☐ Beach Grass/Early Colonizers
(Ex: American beach grass)
☐ Shrubland/Early Succession
(Ex: sand cherry, juniper, aspen, cottonwood)
☐ Forest/ Late Colonizers
(Ex: pine, red oak, aspen, red maple)

2. Locations of vegetation on blowout:
_________________________ (Description)

5. Density of vegetation on the dune ridge:
☐ High (75%-100% vegetation cover)
☐ Moderate (25%-75% vegetation cover)
☐ Low (0%-25% vegetation cover)

E. Human Impacts: **Unmanaged Trails**

1. Are unmanaged trails present?
☐ No (*if no skip to next section*)
☐ Yes

2. Describe the intensity of the trail system
☐ Low- 1 or 2 trails on or leading to blowout
☐ Intermediate
☐ High- interconnected network of trails on blowout

3. Vegetation on trails (check all that apply)
☐ No vegetation on trail
☐ Sparse vegetation on trail
☐ Trail overgrown with bare portions visible
☐ Trail completely vegetated

4. Are any trails incised greater than 5 cm?
☐ Yes ☐ No

5. Is litter present along the trails?
☐ No
☐ Scarce (e.g. 1 piece of litter approx every 50 m)
☐ Moderate amount (between scarce and common)
☐ Common (e.g. one piece of litter every 5 m)

F. Management: Managed Trails

1. Are managed trails (excluding boardwalks) present?
☐ No (*if no skip to next section*)
☐ Yes

G. Management: Boardwalks

1. Is a boardwalk present?
☐ No
☐ Yes

Appendix B: Collected Data (Selected Items)

Trail ID	Blowout ID	Trail Orientation	Average width of trail (m)	Vegetation cover on trail	Incised more than 5cm?
ST1PT1	none	74 degrees NE	0.8	Sparse	yes
ST1PT2	ST1PB1	4 degrees N	0.71	None	yes
ST1PT2	ST1PB2	4 degrees N	0.71	None	yes
ST1PT2	ST1PB3	4 degrees N	0.71	None	yes
ST1PT3	ST1PB4	112 degrees SE	0.44	Sparse	yes
ST1PT4	ST1PB5	79 degrees NE	0.51	Sparse	yes
ST1PT5	ST1PB6	76 degrees NE	0.7	Sparse	yes
ST1PT6	ST1PB7	75 degrees NE	0.52	Sparse	yes
ST1PT7	ST1PB8	68 degrees ME	0.48	None	yes
ST1PT8	ST1PB9	63 degrees NE	0.71	Sparse	yes
ST2PT9	ST2PB 10	73 degrees NE	0.46	Overgrown	yes
ST2PT9	ST2PB11	73 degrees NE	0.46	Overgrown	yes
ST2PT10	ST2PB12	86 degrees E	0.63	Overgrown	yes
ST2PT11	ST2PB13	114 degrees SE	0.68	Overgrown	yes
ST2PT12	ST2PB14	143 degrees SE	0.46	Overgrown	yes
ST2PT13	ST2PB15	65 degrees NE	0.62	Sparse	yes
ST2PT14	ST2PB 16	45 degrees NE		Completely	yes
ST2PT14	ST2PB17	45 degrees NE		Completely	yes
ST3PT15	ST3PB18	76 degrees NE	0.85	Sparse	yes
ST3PT16	ST3PB 19	65 degrees NE	2.45	Sparse	yes
ST3PT16	ST3PB20	65 degrees NE	2.45	Sparse	yes
ST3PT17	ST3PB21	78 degrees NE	0.76	none	yes
none	ST3PB22				yes
HR1PT1	none	79 degrees NE	0.96	Sparse	yes
HR1PT2	none	132 degrees SE	0.5	Sparse	yes
HR1PT3	none	18 degrees NE	0.45	Sparse	no
HR1PT4	none	64 degrees NE	0.4	Sparse	no
HR1PT5		19 degrees NE		no data	
HR1PT6	none	55 degrees NE	0.68	Sparse	no
HR1PT7	none	76 degrees NE	0.38	Sparse	no
none	HR1PB1				yes
HR1PT8	HR1PB2	78 degrees NE	0.64	Sparse	yes
none	HR2PB3			no trail	no
HR2PT9	HR2PB4	155 degrees SE	0.9	Overgrown	no
none	HR2PB5				no
HR2PT10		155 degrees SE		no data	
HR2PT11	HR2PB 6	68 degrees NE	0.66	Sparse	no
HR2PT11	HR2PB7	68 degrees NE	0.66		
HR3PT12	HR3PB 8	73 degrees NE	0.61	Completely	no
HR3PT 13	HR3PB 9	43 degrees NE	0.73	Overgrown	yes
HR3PT14	HR3PB 10	88 degrees NE	0.57	Overgrown	no
HR3PT15	HR3PB 11	140 degrees SE	1.11	Overgrown	no

Trail ID	Blowout ID	Height of blowout	Width of Blowout	Length of blowout	Type of Blowout
ST1PT1	none	0	0	0	none
ST1PT2	ST1PB1	0.3	5.3	4	saucer
ST1PT2	ST1PB2	0.15	33.5	4.4	saucer
ST1PT2	ST1PB3	0.3	2.82	2.94	saucer
ST1PT3	ST1PB4	2.4	9.7	6.85	saucer
ST1PT4	ST1PB5	1.01	7.32	3.6	saucer
ST1PT5	ST1PB6	1.01	0.65	0.65	trough
ST1PT6	ST1PB7	0.35	9.05	0.8	trough
ST1PT7	ST1PB8	2	1.87	2.2	trough
ST1PT8	ST1PB9	4.27	4.31	10.3	saucer
ST2PT9	ST2PB 10	4	19.4	23.4	trough
ST2PT9	ST2PB11	4.3	2.6	0.97	saucer
ST2PT10	ST2PB12	3.2	24.5	16.5	saucer
ST2PT11	ST2PB13	5.45	2.12	3.6	trough
ST2PT12	ST2PB14	10.6	7.3	11.7	saucer
ST2PT13	ST2PB15	7.7	1.6	7.6	trough
ST2PT14	ST2PB 16	3.9	23.1	21.1	trough
ST2PT14	ST2PB17	0.85	7.2	1.61	saucer
ST3PT15	ST3PB18	2.2	2.6	12.1	saucer
ST3PT16	ST3PB 19	5.35	92.7	90	saucer
ST3PT16	ST3PB20				saucer
ST3PT17	ST3PB21	3.82	20.3	24.6	saucer
none	ST3PB22	4.05	25.1	20.8	saucer
HR1PT1	none				
HR1PT2	none				
HR1PT3	none				
HR1PT4	none				
HR1PT5					
HR1PT6	none				
HR1PT7	none				
none	HR1PB1	1.98	17.62	18.9	saucer
HR1PT8	HR1PB2	1.43	19.35	9.36	trough
none	HR2PB3	1.95	12.71	8.64	saucer
HR2PT9	HR2PB4	7	16.75	45.85	saucer
none	HR2PB5	2.4	14.95	8.83	saucer
HR2PT10					
HR2PT11	HR2PB 6	0.65	8.7	3	trough
HR2PT11	HR2PB7	1.9	10.4	5.75	saucer
HR3PT12	HR3PB 8	2.94	27.34	36.23	saucer
HR3PT 13	HR3PB 9	6.25	23.1	45.4	saucer
HR3PT14	HR3PB 10				
HR3PT15	HR3PB 11				