Humans Alter the Sediment Budget for Beach-Dune Environments in West Michigan

Kei-Wing Wong, Caroline Komodore, Andrew Crago, Ty Nguyen and Deanna van Dijk

Calvin COLLEGE 1876

Abstract

Foredunes and beaches provide recreational opportunities and facilitate sediment storage and transport, but human activities also affect the sediment budget. Human influences on beach-dune sediment budgets are investigated at foredunes in Hoffmaster State Park and North Beach Park in Michigan. At each study area, we compared a human-impacted area with a nearby less-impacted area by measuring physical attributes (dune topography along a transect) and vegetation characteristics (plant height and density measured in random quadrats). Morphological and vegetation characteristics were obtained from field data and aerial photography. Foredunes in heavy-impacted areas had steep slopes flattened out and a reduction in vegetation density and height compared to the more natural areas. The impacted areas also had more litter and more management structures interrupting sand movement (sand fences). Our results suggest that human trampling leads to vegetation loss and amplifies the erosion in the foredune, while temporary physical structures increase the deposition on the beach. Sediment storage amounts in foredunes are significant because the dune is a buffer for extreme events (flooding and storms) and protects nearby private properties from damage.

Introduction

Beach-dune systems facilitate the storage, transport and exchange of sand, and they create buffers to protect adjacent properties from extreme events [1,2]. Human pressure on dunes has become more severe and diverse, especially in recent decades [2]. Human impacts can reduce vegetation cover, alter the rate of erosion and deposition, and affect paths of sediment transport [3]. This study investigates how different levels of human impacts shape the vegetation and landform characteristics in three different beach-foredune sites.

Objectives

- To document the human impacts on the beach-dune systems
- To measure the vegetation and landform characteristics in heavy, medium and low impact areas
- To identify human impacts on sediment movement

Study Area

We investigated 3 beach-dune areas which serve as recreational sites on the central east coast of Lake Michigan (Figure 1). Each location has a different recreational purpose and accessibility (Table 1).

Site	Location	Description	Accessibility
A	Hoffmaster State Park swimming area	Designated swimming beach area with nearby parking	~5 minute walk from parking lot
B	Hoffmaster State Park trail end at beach	Trail from Visitor Center reaches beach here	~15 minute walk from parking lot
C	North Beach Park	Popular coastal park includes swimming beach, picnic shelter, and playground	0 minute walk to enter beach and dunes from parking

Table 1: Locations and recreational descriptions of study sites.

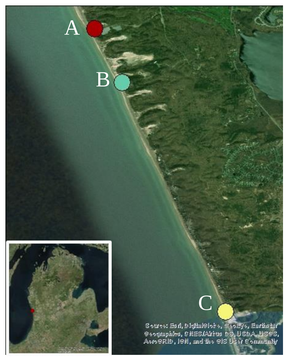

Figure 1: Study locations in Michigan (inset map) and relative to each other.

Methods

At each study area, we compared a human-impacted area with a nearby less-impacted area by documenting impacts, measuring vegetation and landform characteristics, and identifying effects on sediment movement (Table 2).

Objectives	Variables	Methods	Analysis
Document human impacts	Type of impact Location	Field observation GPS	AutoCAD drawing GIS mapping
Measure vegetation characteristics	Vegetation density Vegetation height	Count number of vegetation in quadrats Measure tallest plant in quadrats	Calculate from measurements
Measure landform characteristics	Elevation change along profile	Straight line survey of topography, perpendicular to the shoreline	Calculate amount of erosion
Identify human impacts on sediment movement	Net deposition Net erosion Other	Field observation Literature review	Interpret effect of human impact

Table 2: Research variables, methods and analysis related to study objectives

Results

Types of Human Impacts:

Dunes at Site C experienced the most diverse human impacts, including actions of park managers and visitors (Figure 2). Park management has introduced protection and recreation structures. The major visitor impacts are human trampling and litter. The foredune is entirely absent in the heavy-impact area.

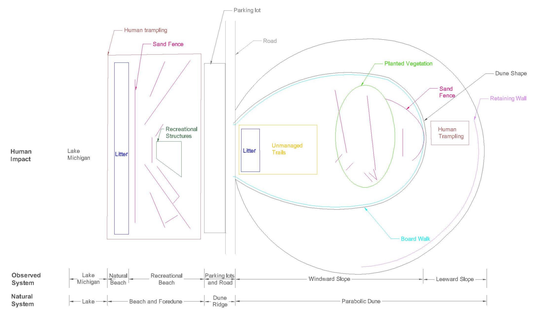

Figure 2: Human impacts on North Beach Park are identified by relative locations.

Vegetation Characteristics:

Locations without vegetation showed less sand accumulation compared to locations with vegetation (Figure 3). In heavy-impacted areas, vegetation density and height decrease compared to less-impacted areas (Figure 4).

Figure 3: Vegetation facilitates sand accumulation (A), compared to a nearby site without vegetation (B).

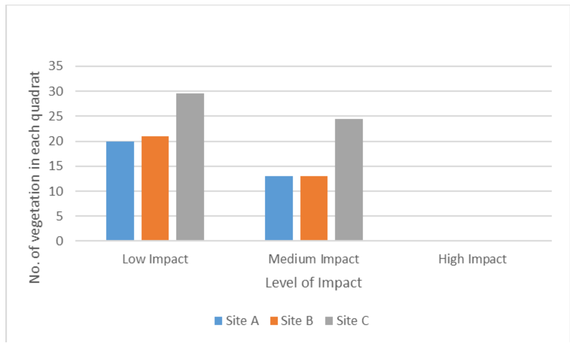

Figure 4: Vegetation density for different levels of human impacts. A similar trend was observed in vegetation height.

Landform Characteristics:

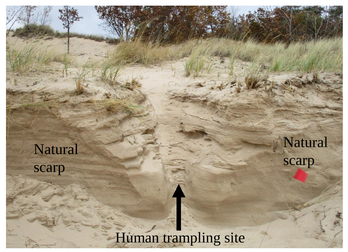

Figure 5: Erosion at human trampling sites compared to nearby vertical scarps.

Higher impacted areas showed more evidence of erosion and had flatter foredune slopes compared to the vertical scarps on nearby vegetated foredunes (Figure 5). Site A and B have higher depths of erosion, but Site C has the greatest volume of erosion (Table 3).

	Erosion from Human Trampling		
Location	Site A	Site B	Site C
Maximum depth of erosion	2.0m	1.5m	1.34m
Cross-sectional area	5.56m^2	5.37m^2	3.14 m^2
Volume of sand removed	244.64m^3	26.88m^3	824.77m^3

Table 3: Calculated amounts of erosion from human trampling in each location.

Discussion

Site C has the most diverse human impacts, which influence dune stability, erosion and deposition (Table 4). Most of the management impacts focus on increasing deposition—by altering wind and sediment paths—to prevent the dune from advancing.

Cause		Consequence			
	Class	**Erosion**	**Deposition**	**Features**	**Other**
Management Impacts	I. Sand fence		X	A single low narrow steep ridge [3]	
	II. Retaining wall		X		
	III. Recreational structures				
	IV. Boardwalk		X		Remobilize sand movement
	V. Parking lots and road		X		Highly efficient surface for aeolian and sand transport [3]
	VI. Tractor on the beach				Redistribute sediment to accommodate recreation [4]
	VII. Bulldozing at parking lots and roads		X	Artificial dune ridge tends to be more linear and steeper [3]	Pile up the sand at the edge of the road and parking lots to create artificial dune
	VIII. Planted vegetation		X	Sand accumulates downwind of objects	Stabilize sand
Visitor Impacts	I. Litter		X		
	II. Human trampling	X	X	Erosion at top of dune and deposition at bottom	Remobilize sand movement [4]
	III. Unmanaged trails			Walking tracks tend to fan out at the lakeward side of the dune [2]	Remove vegetation and destabilize the dune [1,2]
Other Impacts	I. Flotsam		X		

Table 4: Evaluation of human impacts on sediment movement

The results suggest that sites A and B have higher vegetation damage and erosion, but they have lower total volumes of erosion when compared to site C. We can conclude that the more centralized impact area creates more intense vegetation damage and erosion, but has less potential volume of erosion.

Our results represent 3 dune case studies, but the different types and levels of human impacts, sediment supply rates, sand grain sizes, and wind speeds may influence results at other locations [5].

Conclusion

Based on field observation and GPS mapping, the major human impacts are park management activities, human trampling and litter. All three heavy-impact sites have reduced vegetation density and height as well as significantly increased erosion.

Acknowledgements

- Many Calvin students for previously collecting data at North Beach Park.
- Department of Natural Resources and the Ottawa County Parks and Recreation Commission for allowing us to access to their parks.
- The Michigan Space Grant Consortium (NASA) and Calvin College for their financial support.

Works Cited

[1] Defeo, O., A. McLachlan, D. S. Schoeman, T. A. Schlacher, J. Dugan, A. Jones, M. Lastra, and F. Scapini (2009). "Threats to sandy beach ecosystems: a review." *Estuarine, Coastal and Shelf Science* 81: 1-12.
[2] Schlacher, T. A., R. De Jager, and T. Nielsen (2011). "Vegetation and ghost crabs in coastal dunes as indicators of putative stressors from tourism." *Ecological Indicators* 11: 284-294.
[3] Nordstrom, K. F., and S. M. Arens (1998). "The role of human actions in evolution and management of foredunes in The Netherlands and New Jersey, USA." *Journal of Coastal Conservation* 4: 169-180.
[4] Cabrera-Vega, L. L., N. Cruz-Avero, L. Hernández-Calvento, A. I. Hernández-Cordero, and E. Fernández-Cabrera (2013). "Morphological changes in dunes as an indicator of anthropogenic interferences in arid dune fields." *Journal of Coastal Research* 65: 1271-1276
[5] Saye, S. E., D. Van der Wal, K. Pye, and S. J. Blott (2005). "Beach–dune morphological relationships and erosion/accretion: an investigation at five sites in England and Wales using LIDAR data." *Geomorphology* 72: 128-155.