First-Year Research in Earth Sciences: Dunes

An Investigation of the Relationship between Deer and Trails in North Ottawa Dunes

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FYRES: Dunes Research Report #12
June 2014

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Abstract

Although scientists have studied the impacts of deer browsing and trampling on coastal dune vegetation, few studies have been done on the impacts of deer on trails. We investigated the relationship between deer presence and trail characteristics in North Ottawa Dunes, Michigan over a three-week study period. We first recorded deer evidence (i.e. tracks and scat) on both an open dune area and a wooded dune area. At the same sites, we mapped trails and documented their features including width, slope, direction, length and surface condition. In the open dune area, we identified numerous trail segments and evidence of deer, with most of the deer evidence concentrated on the lower windward slope. In the wooded area, we also recorded the most trails and deer evidence on the lower slopes although the observed amounts were much smaller because of the thick leaf litter. The spatial pattern of trails and deer evidence indicates a positive relationship between deer presence and trail location. Our results suggest that deer activity contributes to disturbances such as trails that affect coastal dune dynamics.

Introduction

Although deer is a common habitant in the coastal dune environment along Lake Michigan, little is known about the impact of deer on coastal dunes. A number of studies have shown that deer contribute to the lack of vegetation, which can lead to increased or sustained dune activity (Anderson and Loucks 1979; Phillips and Maun 1996; Ashkannejhad and Horton 2005). However, other impacts of deer on dunes, such as trail development, have received little attention by scientists. In order to understand the relationship between deer activity and trails on dunes, this study investigates deer evidence and trails in a dune system on the coast of Lake Michigan. The objectives of this study are to:

- Map evidence of deer presence.
- Record trail characteristics and identify trails that can be attributed to deer activity.
- Observe patterns between deer evidence and trails.
- Build a digital elevation model (DEM) of the coastal dune.
- Distinguish the relationship between deer presence and topography of the dune.

Background

Introduction to White-Tailed Deer

The white-tailed deer (*Odocoileus virginianus*) is a keystone herbivore (Waller and Alverson 1997). It is the smallest member of the deer family commonly found from southern Canada to South America. When alarmed, white-tailed deer hold their tails erect, baring their white underside and white rump. Bucks (males) begin growing bonelike antlers early each summer and by early fall the antlers stop growing and harden (VerCauteren and Hygnstrom 2004). Female deer, called does, give birth to one to three young at a time, usually in May or June and after a gestation period of seven months. Young deer, called fawns, wear a reddish-brown coat with white spots that helps them blend in with the forest (Garrison and Gedir 2006). In the heat of summer deer typically inhabit fields and meadows using clumps of broad-leaved and coniferous forests for shade. During the winter they generally keep to forests, preferring coniferous stands that provide shelter from the harsh elements (Fergus n.d.).

White-tailed deer are herbivores, leisurely grazing on most available plant foods. Studies have shown that browse and forbs were the main component of deer diets (Ramirez *et al.* 1997). Occasionally venturing out in the daylight hours, white-tailed deer are primarily nocturnal or crepuscular, browsing mainly at dawn and dusk when the rate of deer-car collision is the highest (Allen and McCullough 1976).

Ecological Impacts of Deer on Dunes

Previous researchers studied deer activity in the coastal dune environment primarily from an ecological perspective. Phillips and Maun (1996) investigated the impact of white-tailed deer on *Cirsium pitcheri*, a threatened plant species endemic to the shoreline sand dunes of the Great Lakes. From a controlled experiment in a greenhouse, they concluded that deer grazing and trampling would cause a significant reduction in root biomass of *Cirsium pitcheri*. Suggestions for deer management, such as implementation of a late archery hunting period (Kilpatrick and Spohr 2000), have been made in order to protect vegetation.

Notwithstanding the results of the greenhouse experiment, the actual impact of deer on vegetation is debatable. Other researchers suggest that although the amount of shrubs increases as the deer population is reduced, the diversity and maturity of vegetation do not seem to be significantly affected (Royo *et al.* 2010). Warner and Cushman (2002) found that deer grazing does have a negative impact on the volume and growth rates of juvenile lupines as well as leaflet size, yet deer browsing on new shoots actually enhances flowering through the removal of apical meristems and subsequent growth of new shoots from lateral meristems. Another interesting study reveals that deer can help disperse viable spores of epigeous, wind-dispersed fungi (Ashkannejhad and Horton 2005).

Methods of Deer Observation

Although there has been research on the ecological impact of deer, fewer studies have discussed the method of counting and tracing deer activity. Brinkman *et al.* (2005) tagged deer and used radio collars to track deer movement, which they found was largely influenced by fluctuating weather and the highly fragmented landscape. Dzięciołowski *et al.* (1995) demonstrated how they numbered red deer in the Słowiński National Park in Poland; their method was significantly confined by time, weather, and technology. Generally speaking, deer tracing is a time-consuming and labor-intensive process and advanced technology is a key factor.

Effect of Deer Trampling on Dunes

Little is known about the relationship between deer activity and trails in a coastal dune environment. One study in Maine shows that deer do use snowmobile trails but usually for short distances (seldom following farther than 0.2 km) as they need to leave the trails to feed (Richens and Lavigne 1978). A study by Goddard (1992) shows that other smaller animals may use deer trails as “highways” in the woods.

To better understand deer’s impact on trails on dunes, it is helpful to look at how human and other animals’ trampling affects the coastal dune environment. Human activity has significant impacts on the dune, and trampling in particular has been found to cause bare ground in many dune studies (Boorman and Fuller 1977; Hylgaard and Liddle 1981; McDonnell 1981; Bowles and Maun 1982; Rickard *et al.* 1994; van Dijk and Vink 2005). Specifically, previous studies have shown that due to trampling: 1) trail widths increase slowly with increasing traffic; 2) a relatively narrow (1-2 m) band of vegetation at the trail side is affected, and 3) some plants disappear at trail sides, some are largely unaffected, and others invade the sites observed (Dale and Weaver 1974). Notwithstanding the natural and human factors previously studied, the science still lacks an examination of how deer activity may contribute to disturbances on coastal dunes such as trails.

Study Area

Our study area is the North Beach dune and an adjacent wooded dune area located at the city of Ferrysburg in Ottawa County, Michigan (Figure 1). The North Beach dune is a large coastal parabolic dune with a height of 45 meters and an advancing speed of 0.67 m/year (Jamieson and van Dijk 2004). It is part of North Ottawa Dunes, a wooded-dune park managed by the Ottawa County Parks and Recreation Commission (OCPRC). In the last decade, OCPRC has implemented multiple management strategies on the North Beach dune, including boardwalks, sightseeing platforms, designated trail routes, direction signs, and sand fences, in order to protect the natural ecosystem and to stabilize the advancing dune (Figure 2).

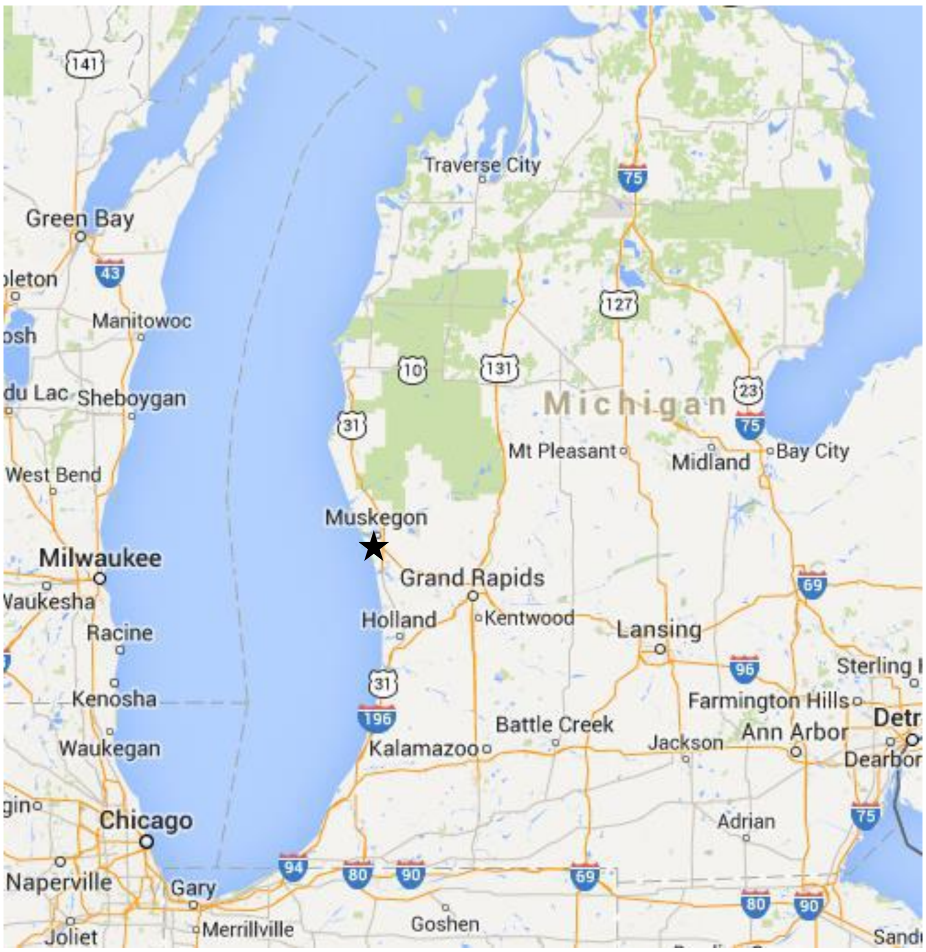

Figure 1. The study site is located in Ottawa County in western Michigan.

Figure 2. The windward slope of North Beach dune with signs of management.

The North Ottawa Dunes well represent the coastal dune environment where deer have an active presence. In 2007, Ottawa County and Grand Valley State University researchers installed a deer exclosure in North Ottawa Dunes to investigate the impact of high deer densities on the park’s ecosystem. The study’s conclusion, as stated by Melanie Manion who serves as the county’s natural resources management supervisor, was that “the number of deer was too high to sustain a healthy ecosystem” (Chandler 2012). Therefore, in the fall of 2012, OCPRC approved a managed hunt to help control the deer population in northwest Ottawa County.

Methods

Field Measurements

We investigated deer impacts on dunes by carrying out fieldwork at our study site on three dates: 10/24/13, 10/31/13, and 11/07/13. To investigate whether deer have different impacts on different types of dune areas, we chose two areas that are distinctly different from each other. We divided our study area into an open area on the windward slope of the dune and a forested area on the leeward slope of the dune. The forested area was further divided into a northern section and a southern section because the middle section was too steep for us to climb and survey. We recorded the dune environment characteristics at both sites.

Because of the exploratory nature of our study, our methods were refined from one site visit to the next based on the experiences of each site visit. The first visit was intended to familiarize ourselves with the local environment and to locate where deer evidence and trail segments were. We used the results from the first site visit to plan measurements during the second and the third visits. We also refined how we collected data between the second and third site visits. Because of the process of refining our methods, some trail characteristics were measured for a sample of the trail segments rather than all of the segments. Our data analysis and reporting of results account for the different sample sizes for the measured characteristics. The methods descriptions that follow represent our final study design including the improvements made during the process of investigation.

We mapped and recorded evidence of deer in both the open and wooded dune areas. We looked for various types of evidence including deer scat, deer tracks, marks of deer browsing and trampling on vegetation, etc. and then recorded their locations as point features in Trimble GPS handheld devices (Figure 3). We searched for deer evidence in the entire open dune area by having investigators walk in zig-zag patterns through the area so that they could directly observe all locations (Figure 4). This was also done in most of the wooded area, though sometimes we had to use remote observation from up to 10 meters away at places near the leeward slope where it was too steep to walk.

Figure 3. Trimble Juno GPS.

Figure 4. A researcher is looking for deer evidence on the open dune site.

In the open and wooded dune areas, we also recorded trail locations and their characteristics. We identified trail segments according to clear signs of flattening or demolition of vegetation in an elongated pattern. We collected data on the following trail characteristics:

We recorded trail location, length and orientation primarily using Trimble Juno GPS handheld devices. As we walked along trail segments, their spatial locations are stored in GPS devices as line features with auto-generated lengths. Trail orientations were identified later in ArcGIS by comparing the relative locations of the starting point and the ending point of trail segments.

We used a measuring tape and a Brunton compass (Figure 5) to measure trail width and slope respectively. For each trail segment, we measured width and slope data at the segment's starting point, ending point, and midpoint. We then calculated the average values for width and slope angle.

Figure 5. Brunton compass.

We measured sand compaction at the midpoint of trail segments using a qualitative scale in which different amounts of pressure were applied by hand to see whether the sand would give way (Table 1).

Apply pressure with:	Compaction level
Palm	Loose
4 fingers	Moderately Compact
1 finger	Compact

Table 1. Relative scale for sand compaction.

To determine the use of each trail segment, we visually looked for evidence that suggested whether the trail was used by deer, human, other animal (i.e., dogs, turkeys, etc.), or had mixed use (Table 2). For the surface condition, we used direct observation and categorized trail surface as bare sand, scattered leaves, or leaf covering (Table 3).

Trail Use	Observed Evidence	Width	Slope
Human	Footprints	Wide	Flat
Deer	Tracks and scat	Narrow	Steep
Other	Tracks	Narrow	Steep
Mixed	Various traces	Wide	Flat

Table 2. Different types of evidence that suggest the use of a trail.

Surface Condition	Leaf Appearance
Bare sand	No visible leaf litter on the trail
Scattered leaves	Sporadic leaves can be spotted along the trail yet not enough to cover it
Leaf covering	Trail completely covered in leaf litter

Table 3. Relationship between surface condition and leaf appearance on a trail.

Post-Processing of Data

We recorded the location and characteristic data in Trimble GPS handheld devices using Terrasync software. We downloaded the data to a computer using GPS Pathfinder Office software. Then, the data were rectified, projected into the WGS84 coordinate system, and mapped out in ArcGIS for Desktop 10.1. When post-processing our data, we compared trail data from all three visits and deleted duplicate records based on their length and spatial information.

As data of trail characteristics and deer evidence were transferred and mapped in ArcGIS, we used LiDAR data provided by the GIS Department of Ottawa County to build a digital elevation model (DEM) of the North Beach dune and the adjacent wooded dune area. The LiDAR dataset was acquired in 2004 and it consists of 349, 5229 laser points, each one containing its unique coordinate information in three dimensions. In order to create a DEM out of the LiDAR point cloud, we used spherical kriging as the method of interpolation. Kriging is an interpolation technique in which the surrounding measured values are weighted to derive a predicted value for an unmeasured location based on the assumption that the spatial variation is homogeneous. The general formula of kriging method is expressed as (Oliver and Webster 1990):

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i)$$

in which:

$Z(s_i)$ = the measured value at the *i*th location,

λ_i = an unknown weight for the measured value at the *i*th location,

s_0 = the prediction location, and

N = the number of measured values.

The spherical model of kriging we used is one of the most commonly used models. It shows a progressive decrease of spatial autocorrelation until some distance, beyond which autocorrelation is zero (Oliver and Webster 1990). In our analysis, we set the number of measured values (N) to 12 which essentially means that the spatial information of every interpolated point is determined by 12 nearby points. It took approximately 140 hours to run the kriging interpolation method on the LiDAR point cloud. Then, as the DEM was created, we generated a 10-feet contour map based on the DEM and overlaid it with the map of deer evidence in order to observe the relationship between deer presence and dune topography.

Results

Dune Environments

The open dune area of the North Beach dune is 23,276 m^2. It is located on the windward slope of the dune which rises in elevation from west to east and ends at the crest of 58 m above Lake Michigan. Dense vegetation comprised of dune grass is found in the lower, flatter part of the open area. In addition, there are clear signs of dune management in the open area including sand fences and fenced boardwalks. Signs warn people that entering the open area for recreational purposes is prohibited.

The forested dune area is 3,056 m^2 and it is separated from the open area by a boardwalk along the dune crest and arms. The forested area is located on the leeward slope of the dune along with nearby wooded dune slopes where there is a mixture of steep slopes and flat lands. Maples and birches are the primary types of vegetation grown in the forested area, especially on slopes. Consequently, the majority of the forested area is covered by a thick layer of leaf litter. In addition, concentrated herbaceous vegetation (e.g., dune grass) can be found in the southern section adjacent to the leeward slope. Compared to the open area, few signs of dune management were found in the forested area except for 5 wood posts for measuring dune advance rates.

Deer Evidence

In our study areas, we found evidence of deer in the form of deer scat and footprints. Deer scat often appeared as clusters of small, black balls (Figure 6) and deer tracks often appeared as distinct hoofprints in bare sand (Figure 7). A total of 17 individual deer tracks were

Figure 6. A cluster of deer scat.

Figure 7. Deer tracks on bare sand.

recorded, including 10 found in the open area and 7 in the forested area (Figure 8). In addition to the individual deer tracks, we also identified three zones of dense deer tracks which we did not individually map because numerous deer tracks were clustered and overlapped with one another. Two of the deer-track zones were in the forested area and one in the open area. We found 35 clusters of deer scat in total and 32 of them were in the open area. Most of the deer scat was concentrated in the lower section of the open area where the slope angle is relatively small. Although we found a few marks of deer browsing and trampling on vegetation, we could not distinguish whether they can be attributed to deer.

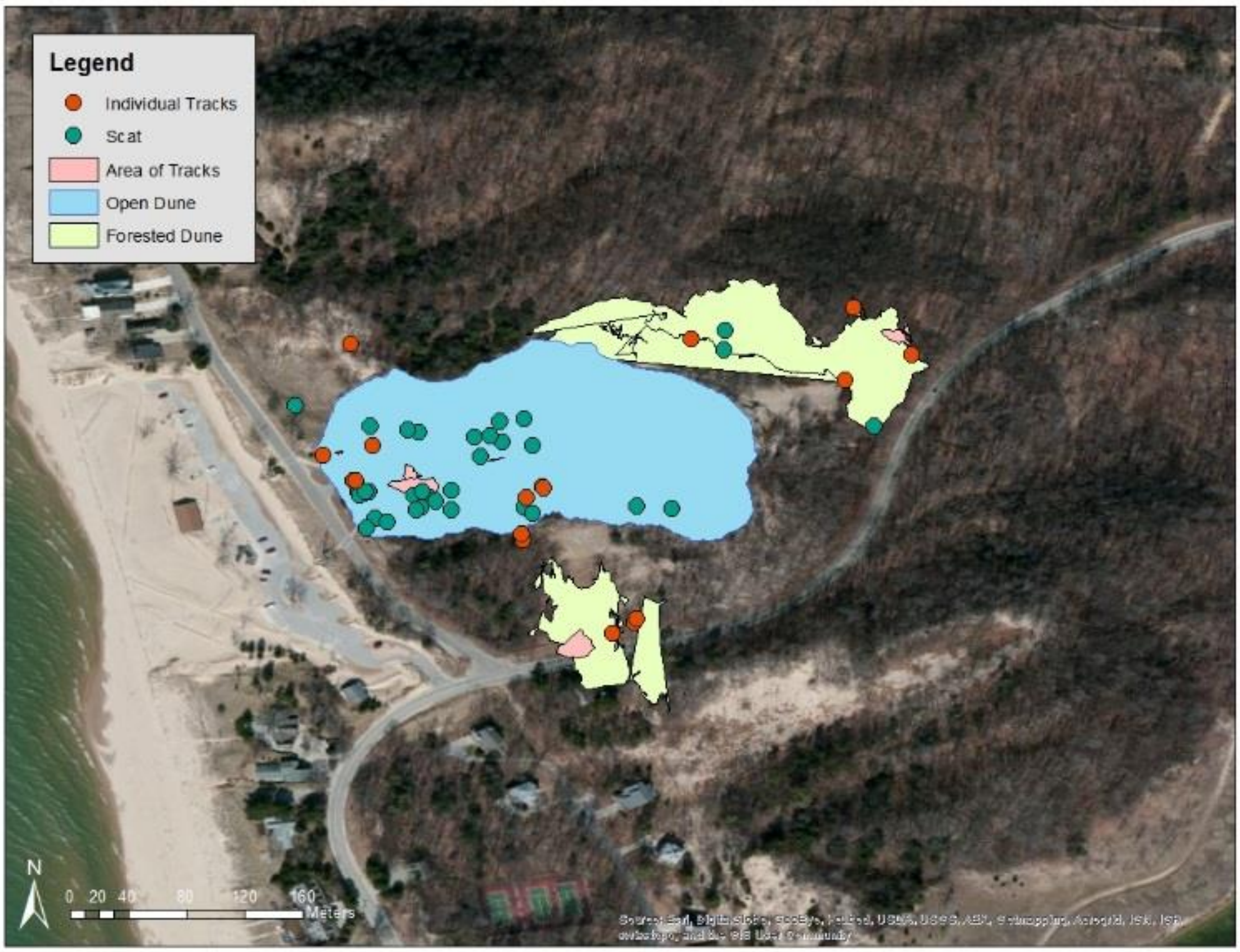

Figure 8. A map showing the spatial distribution of deer evidence. The blue area is the open dune site and the green area is the forested dune site. Green dots stand for clusters of deer scat and red dots stand for individual deer tracks. The pink areas are zones of dense deer tracks.

Trail Characteristics

We recorded a total of 29 trail segments, with 24 of them found in the open dune area (Figure 9). In general, trail segments appear to be more fragmented in the lower part of the dune and more continuous as the topography elevates.

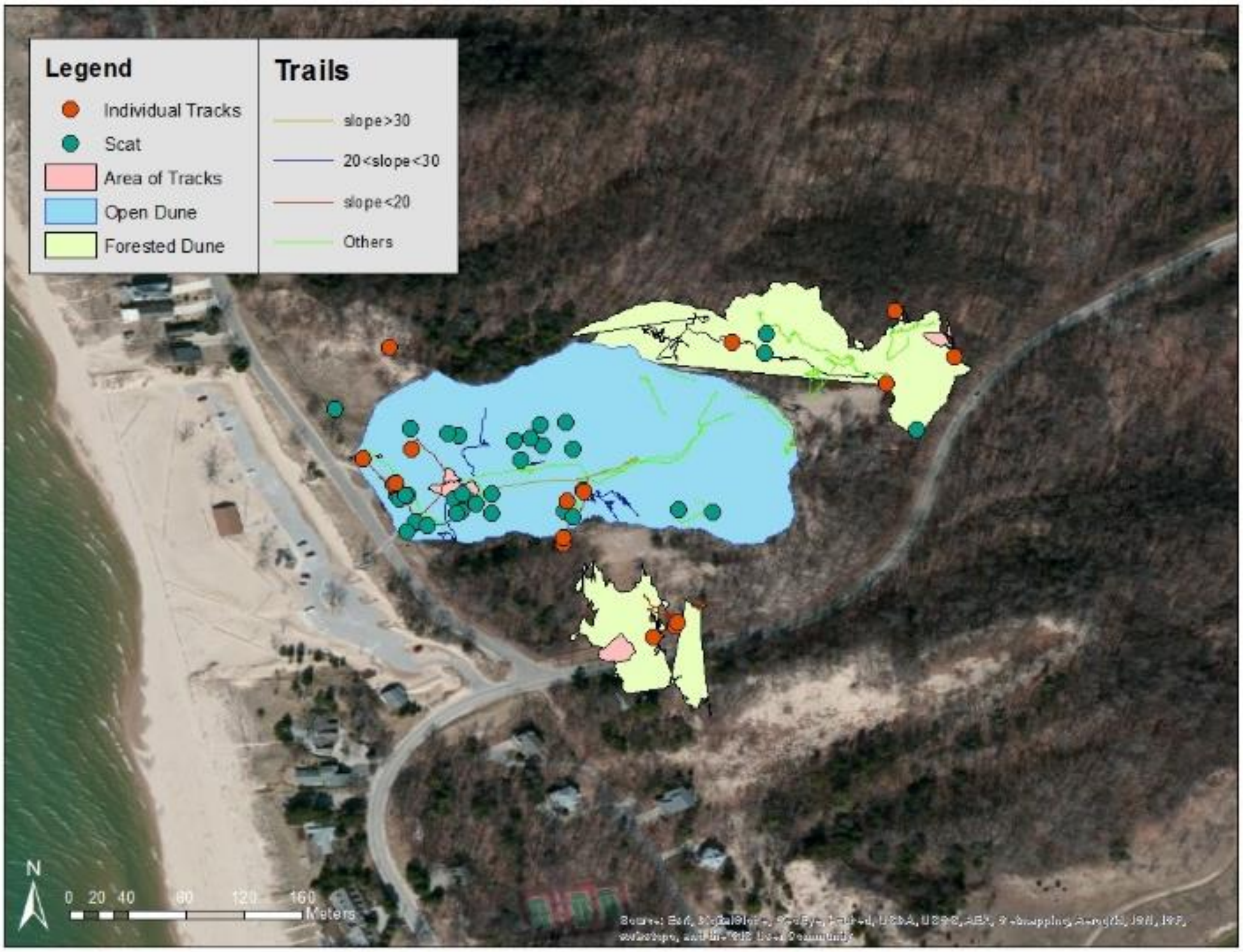

Figure 9. A map showing the spatial relationship between deer evidence and trail segments. Trail segments are classified by slope angle.

Trails in the forested area are longer than trails in the open area on average (Table 4). In addition, trails in the forested area tend to be larger in width and smaller in slope angle compared

	All				Forested Area				Open Area			
	Trails Counted	Avg.	Min.	Max.	Trails Counted	Avg.	Min.	Max.	Trails Counted	Avg.	Min.	Max.
Length (m)	29	82	15	199	5	135	80	199	24	77	16	175
Width (cm)	17	58	25	83	4	74	70	78	13	56	25	83
Slope (degree)	14	21	4	43	4	10	9	11	10	23	4	43

Table 4. Length, width, and slope of trails on North Beach dune.

to trails in the open area. Trails of various uses existed in both the open and the forested areas (Figure 10). The majority of trails appear to be used by a mixture of deer, human, and other animals.

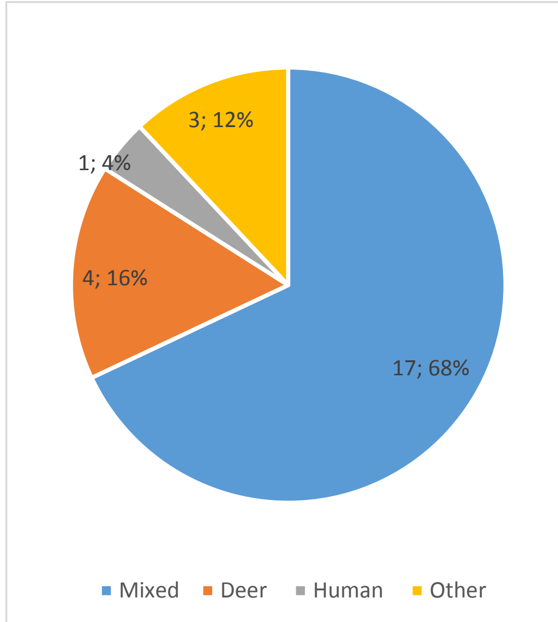

Figure 10. Use of trails. Each pie segment shows the number of trails (out of 25 measured trails) followed by the percentage of the total number of trails.

Most trails had a N-S orientation which was perpendicular to the axis of the parabolic dune; only 5 trails had an E-W orientation (Figure 11). We also found some trails with a NE-SW or NW-SE orientation and they were all located in the open dune area. Four out of the 5 trails in the forested area had a N-S orientation and one of them had an E-W orientation.

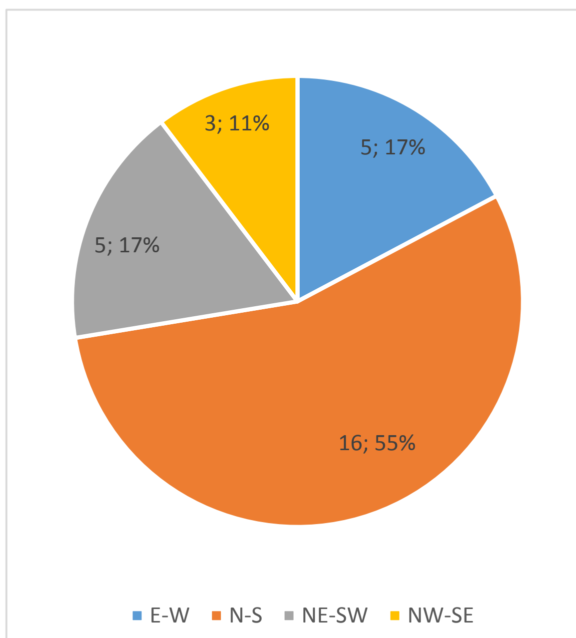

Figure 11. Orientation of trails. Each pie segment shows the number of trails (out of 29 measured trails) followed by the percentage of the total number of trails.

Most of the trails had bare sand surfaces, but there were some trails that were sporadically or entirely covered by leaves (Figure 12). Four out of 5 trails with leaf presence were found in the wooded area. Using our qualitative scale of sand compaction, we identified almost 60% of the trail segments with compact surface (Figure 13). Both the forested and the open dune areas had one trail each with a loose sand surface.

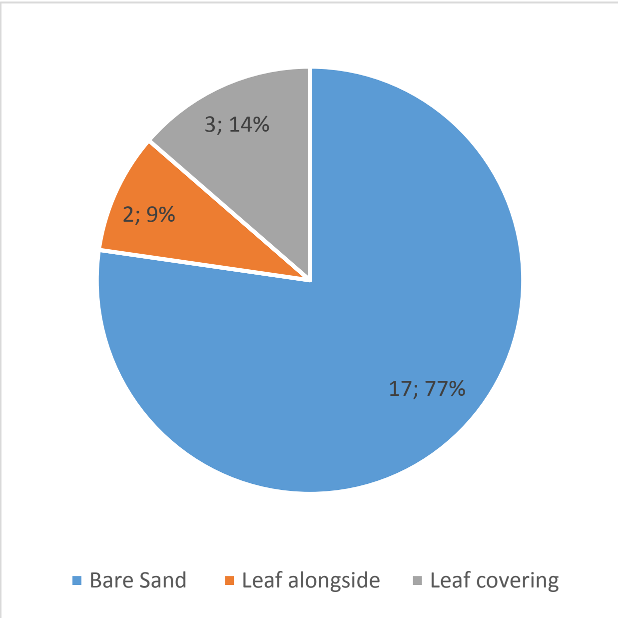

Figure 12. Surface condition of trails. Each pie segment shows the number of trails (out of 22 measured trails) followed by the percentage of the total number of trails.

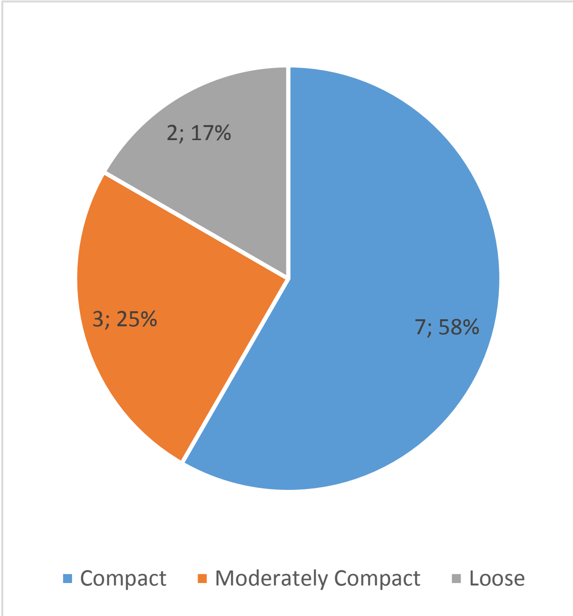

Figure 13. Sand compaction of trails. Each pie segment shows the number of trails (out of 12 measured trails) followed by the percentage of the total number of trails.

Digital Elevation Model (DEM) of the North Beach Dune Area

The DEM accurately delineates the topography of the North Beach dune as well as two other parabolic dunes adjacent to it (Figure 14). The crest of the North Beach dune is 58 meters above Lake Michigan and the change of elevation in the open area is much greater than in the forested area (Table 5). The DEM shows that in the open area, deer evidence is concentrated below the elevation of 192 m (630 feet); in the forested area, deer tracks and scat are sporadically distributed at various elevations (Figure 15).

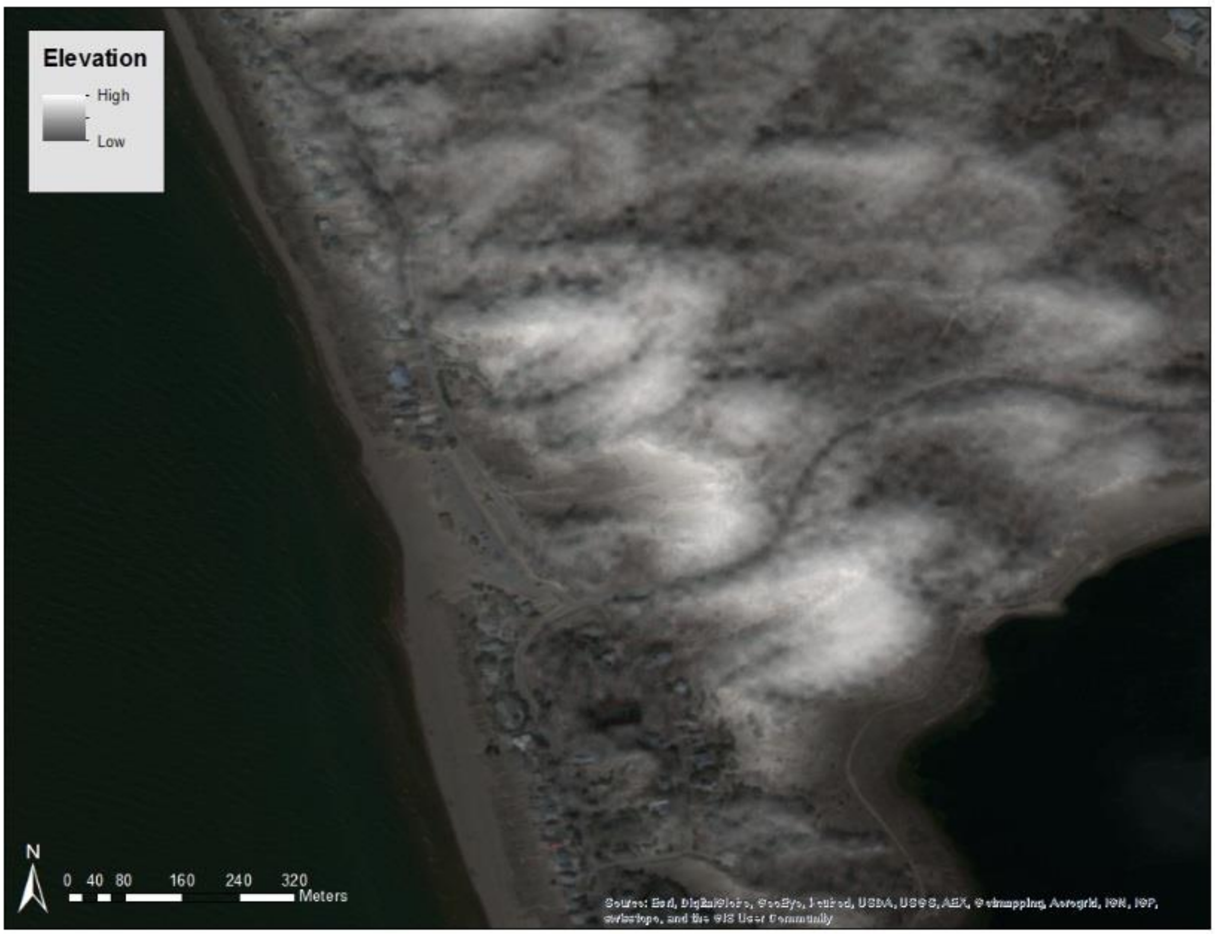

Figure 14. DEM created for the North Beach dune. Brighter areas indicate higher elevation.

Minimum	Maximum	Average	Change in elevation	
			Open area	Forested area
180m	238m	189m	52m	24m (both in northern section and in southern section)

Table 5. Elevation and relief of the North Beach dune

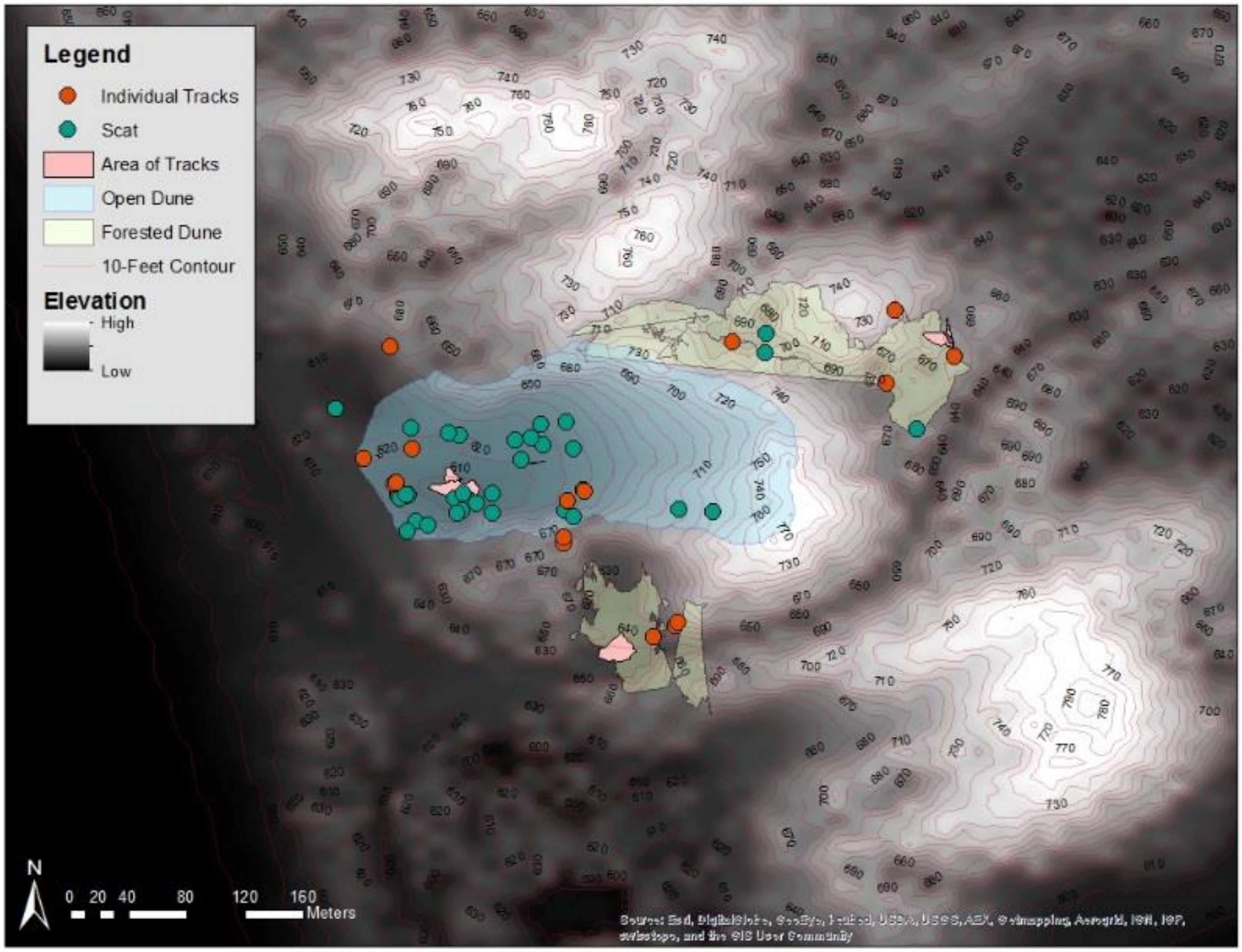

Figure 15. A map showing the spatial relationship between deer evidence and dune topography.

Discussion

As illustrated by the map results, the majority of deer evidence was found in the lower, flatter part of the open area. However, we cannot conclude that deer are more active in the open area because our observation was limited in the forested area due to the thick leaf litter. In fact, as 2 out of 3 zones of dense deer tracks were found in the forested area, deer are probably more active in the forested area. Practically, it is easier for deer to find shelter and food in the woods rather than on bare sand, which is consistent with previous findings (Reynolds 1966; Fergus and Shope 2007). Signs of dune management such as boardwalk and sand fences do not seem to hinder deer activity in the open area. The map results also indicate that individual deer tracks were more spread out than deer scat in the entire study area. Limited by time and professional knowledge, we were not able to conduct further study on this interesting phenomenon. Future researchers can certainly look into this and identify a behavioral pattern of deer activity in the coastal dune environment.

Topography of the dune is an important factor which influences deer activity. The DEM of the North Beach dune shows that deer tend to avoid areas with a great change in elevation because all three zones of dense deer track are located at topographically flat area. In addition, most deer scat were found in the lower part of the open area. Compared to deer scat and zones of dense tracks, individual deer tracks are distributed more sporadically in the entire study area regardless of topography. For example, we distinguished a “deer corridor” located on a relatively steep slope. It connects the southern end of the open area and the southern section of the forested area where several deer tracks, scat, and fragmented trail segments were found. We infer that deer frequently commute through this corridor to get to their bedding or feeding places which are located at lower and flatter areas. Our suggestion can be supplemented by Richens and Lavigne’s study (1978) on the traveling pattern of deer among different feeding places.

As for the spatial relationship between deer evidence and trails, we noticed that trail segments in the lower part of the open area appear in a radial pattern which center on a dense zone of deer tracks and scat. In the middle part of the open area where the terrain starts to elevate, trails tend to be longer and run parallel to the parabolic dune, especially along preexisting sand fences. Based on these findings, we suggest that deer may use the lower part of the open area as a primary feeding zone (Reynolds 1966).

Trails on the North Beach dune have diverse characteristics. Although the majority of trail segments were found in the open area, trails in the forested area tend to be longer, wider, and flatter which indicates longer time of formation and more frequent use. Also, there is clear evidence showing that the majority of trails (68%) are used by a mixture of deer, human, and other animals, which is corroborated by previous studies (Richens and Lavigne 1978; Goddard 1992). However, we are not able to discover the specific mechanism of how deer trampling changes trail characteristics.

Considering the lack of previous research on this topic and the limitations of our observation, this study is preliminary and exploratory in many aspects. One limitation of our study is the short time period that we had available for field measurements. The study would yield more accurate and meaningful results had it been conducted over a longer time span. In addition, we regret not being able to find a deer in the study area during our visits. Future researchers may consider using trail cameras or IR cameras in order to trace deer activity in the coastal dune environment.

In general, the map results suggest a positive relationship between deer evidence and unmanaged trails particularly in the lower open dune area which is relatively flat, sandy, and proximate to water. However, because of our limited observation, it is hard to determine how deer trampling in specific influences trail characteristics, especially in the forested area. We did find sporadic deer tracks and indistinct trails in the forested area regardless of the thick leaf litter, while a spatial relationship between deer tracks and trails is hard to determine. Nevertheless, our results suggest that deer activity contributes to disturbances such as trails that affect coastal dune dynamics.

Conclusions

In this study, we mapped a significant amount of deer evidence and trail segments in North Beach dune and an adjacent wooded dune area. Various trail characteristics were recorded and they demonstrate a clear distinction between the open dune site and the forested dune site. We also created a DEM of our study area and delineated dune topography. Based on our findings, a positive relationship between deer activity and trail segments is most distinct in the lower open area, while patterns are harder to distinguish in the forested area.

Acknowledgements

We would like to thank the Ottawa County Parks and Recreation Commission for allowing us access to the dune for our research. Funding for this research was provided by the National Science Foundation (Grant #0942344) and the Michigan Space Grant Consortium. We would also like to thank and acknowledge Deanna van Dijk for all her invaluable help and support. The digital elevation modeling and analysis in this project was part of Chengbi Liu’s work towards the honor’s requirements of his degree. Chengbi gratefully acknowledges the mentorship and technical assistance of his honor’s advisor, Jason VanHorn. We would also like to acknowledge the Innovation and Technology Department of the County of Ottawa, Michigan for the access and use of the point-cloud LIDAR data. Specifically the GIS Supervisor, Mr. Shane Pavlak was very helpful towards the success of this research endeavor.

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