First-Year Research in Earth Sciences: Dunes

Impacts of White-Tailed Deer on a Lake Michigan Parabolic Dune System

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Abstract

White-tailed deer, *Odocoileus virginianus*, have a significant impact on environments in North America with many populations over the carry capacity of their habitats. This is the case in PJ Hoffmaster State Park, Michigan, where we investigated a large parabolic dune system to determine where deer have the most impact. We mapped individual tracks, scat and trails with Trimble GPS units, and areas were visually assessed for the impacts of deer. In areas with deer evidence, vegetation quality was noted within quadrats. The foredune had the most presence of deer as shown by scat and tracks going to and from Lake Michigan. Deer tracks on human unmanaged trails suggest that deer use these trails as well as creating their own trails. Vegetation results show deer have not significantly impacted the quality of American beach grass. With the low level of vegetation damage, sand movement has not increased beyond what is characteristic for this type of dune system. While the significant presence of deer is noticed—especially on the foredune—this study suggests no current concern for destabilization of the dune system.

Introduction

White-tailed deer, *Odocoileus virginianus*, have grown in population over the last century across the eastern United States (Russell *et al.* 2001). With populations in the millions, deer have had a big impact on different environments (VerCauteren and Hygnstrom 2011). Deer are labeled a keystone herbivore because of the large effect they have on their environment (Waller and Alverson 1997). There is evidence showing that in "some community types deer negatively affect the growth rate of tree seedlings and saplings, prevent adult recruitment into tree populations and alter species composition" (Russell *et al.* 2001: 1). The majority of studies done on deer take place in various forests throughout North America, and only a few focus on deer in dune environments.

Our study focused on how the presence of deer affect the stability of a parabolic dune system. Our study objectives were to:

- document and map deer impacts in the study area,
- assess quality of vegetation related to deer impacts, and
- assess the relationship between active deer trails and various areas of dune.

Background

About White-Tailed Deer

White-tailed deer came about their name because the underside of the tail is covered with white hair, and when the deer run the tail is often held erect so the white hair is visible (Fergus and Shope 2014). The species is the smallest member of the North American deer family, commonly found from southern Canada to South America (Fergus and Shope 2014). Deer are classed as ruminant animals, meaning the deer have four-chambered stomachs (Fergus and Shope 2014) which allow the herbaceous and woody species they eat to be digested easily. The average weight for deer varies depending gender and age but is typically between 50 and 136 kg (110 to 300 lbs) (National Geographic 2010). The average size of a deer is between 1.8 m to 2.35 m (6 to 7.75 ft) with the female deer (doe) typically being smaller than a male deer (buck) of the same age (National Geographic 2010). Bucks also grow antlers in the spring starting when the buck is about 10 months old (Fergus and Shope 2014). Towards the end of summer, the antlers begin to harden from the original soft tissue due to an increase of testosterone levels. After breeding season, the antlers are shed in late winter or early spring and the process begins all over again (Fergus and Shope 2014*).*

White-tailed deer coat color is reddish brown during the summer and grayish brown in the winter. During the summer, the coat has short, thin, wiry guard hairs with no underfur, but deer winter coats are long, thick, hollow guard hairs with soft, wooly, densely packed underfur (Fergus and Shope 2014*).* Fawns are born with reddish brown coasts dappled with white spots. This pattern helps camouflage the fawn when lying on the ground (Fergus and Shope 2014*).*

White-tailed deer are considered a keystone herbivore due to the large impact that deer have on their environment (Waller and Alverson 1997). Deer eat a variety of herbaceous and woody plants depending on the time of year. In the spring and summer, green leaves, herbaceous plants and new growth on woody plants are eaten (Fergus and Shope 2014). In late summer, fall, and early winter, both hard and soft fruits, such as apples, pears, and acorns, are consumed. In winter, evergreen leaves, hard browse (such as twigs), and dry leaves are eaten (Fergus and Shope 2014*).* In addition to the types of plants available for deer, the age of a forest determines the number of deer it can support. Studies done in Pennsylvania's mixed-oak and northern hardwood

forests show that seedling/sapling stands[1] can support the greatest number of deer (Fergus and Shope 2014*)*. A pole-timber stand—an area with trees at a diameter of 4" to 10" at 4 ½ feet above the ground[2] —can support few or no deer, and saw-timber stands—trees at a diameter of over 10"—can support a moderate number of deer (Fergus and Shope 2014*)*.

History of White-Tailed Deer in America

In 2011, an estimated 10 million deer inhabited the Midwest, which was more than any other region in North America (VerCauteren and Hygnstrom 2011). If one was to go back in history, the deer population was much smaller. When Europeans first immigrated in the 1400s, the white-tailed deer density has been estimated as 3.1-4.2 deer/km² (Rooney 2001). By the 1700s, the deer population started to decline because of overhunting by the colonists, as deer were used for food, clothing, and other personal uses. Widespread habitat modification following European settlement (Rooney 2001) included activities such as cutting down forests for agriculture, building materials, and fuel. Since deer use the forest as shelter, particularly during winter (National Geographic 2010), this left the deer without a major part of their habitat. Because of market hunting pressures (Rooney 2001), by the early 1900s, white-tailed deer were nearly extirpated from some regions of North America (VerCauteren and Hygnstrom 2011). In 1900 the Lacey Act was enacted to prohibit the interstate trafficking of venison and other wild game, and market hunting for white-tailed deer began to slow (VerCauteren and Hygnstrom 2011). In 1908, 41 states established departments of conservation to further protect the deer (HuntingNet Staff 2008). In the 1900s, as habitat conditions improved (eg. forests grew back) and predator numbers decreased, the deer population responded by growing (Rooney 2001). Rooney (2001: 202) estimates that in 2000, "deer exceeded…pre-settlement densities by a factor of 2-12 in the deciduous and mixed coniferous forests of northern Wisconsin". With increased population, white-tailed deer have expanded their range westward and now occupy areas of the Great Plains where they have never been before (VerCauteren and Hygnstrom 2011).

[1] A stand in forestry terms mean "A section of forest having relatively uniform composition in regard to species, size structure, and density; distinguishable from other stands by attributes such as these" (West Virginia Forestry Association 1998*)*.

[2] Pole timber diameters at breast height measurements defined by West Virginia Forestry Association (1998); metric conversions are 10 to 25 cm at a height of 1.37 m above the ground.

White-Tailed Deer Impacts on the Environment

Several studies have been done on deer and their effect on the environment around them. Averill *et al.* (2018) investigated the interactions between white-tailed deer and invasive plants in North American forests. With abundant large herbivores, plant community composition is altered by a lower density of flowering plants, reduced native plant richness and abundance, and increased cover of invasive plants (Averill *et al.* 2018). Invasive plants considered unpalatable by herbivores seemed to benefit under heavy pressure. "Deer are important agents of ecosystem change as their presence (i) reduces native biodiversity and (ii) increases the relative abundance of introduced plants, two of the major drivers affecting modern plant communities and ecosystems" (Averill *et al.* 2018: 18).

Frelich and Lorimer (1985) focused on how deer affect hemlock forests in Michigan's Upper Peninsula. The investigation found a trend between the increasing population of deer and the decreasing population of hemlock seedlings. Their results suggest that there is "likely to be some decline in the population of deer overwintering in the lakeshore area as hemlock disappears from the forest canopy" (Frelich and Lorimer 1985: 117). However, hemlock lives a long time, and in areas where the hemlock canopy is fully intact, long-term changes from 60 years of heavy browsing have barely begun. Therefore, it is possible to alter the trend of species conversion in most hemlock stands by controlling the deer population.

On Lake Huron sand dunes, Phillips and Maun (1996) concentrated on the effects of simulated herbivory by white-tailed deer on Pitcher's thistle (*Cirsium pitcheri*). Because of the rarity of Pitcher's thistle, seeds were collected from a healthy population and the seeds were grown under controlled conditions in a greenhouse. As the plants grew, the researchers simulated browsing by clipping treatments with different amounts — 25%, 50%, 75% and 100% — of the plant being clipped 1-3 times off different age groups (Phillips and Maun 1996). The study found the plants could recover from being grazed but those exposed to severe grazing often experienced an immediate reduction in root growth (Phillips and Maun 1996). The regrowth of shoots came at the expense of the root biomass, regardless of the amount of leaves removed. The greater the frequency of grazing, the greater was the decrease in root biomass of the plant (Phillips and Maun 1996).

Study Area

Our study location was at "Dune 2" in P.J. Hoffmaster State Park in Ottawa County, Michigan (Figure 1). This dune is a parabolic dune system with several blowouts on it (Figure 2). The foredune is heavily vegetated. A swale separates the foredune from the dune ridge. This swale has an unmanaged trail running parallel to the shoreline. The dune ridge is also vegetated but has several unmanaged trails on it and a blowout near the parabolic dune's south arm. For this study, "blowout crest" refers to the crest of the first blowout east of the dune ridge. The "second blowout" is located further east and slightly higher in the dune system. The "main deflation area" is the relatively open (not forested) mid-section of the windward slope of the parabolic dune.

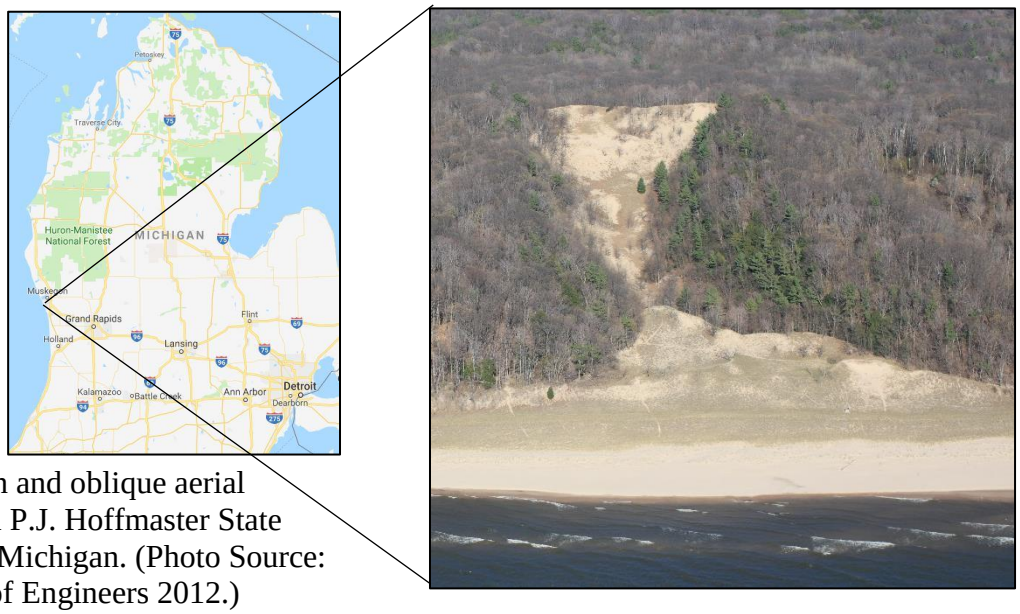

Figure 1. Location and oblique aerial view of Dune 2 in P.J. Hoffmaster State Park, Muskegon, Michigan. (Photo Source: US Army Corps of Engineers 2012.)

Figure 2. Geomorphic areas of beach-dune system shown on aerial view of study area.

Methods

Identifying and Mapping Deer Presence

We used Trimble GPS units to map trails — both unmanaged and deer—as well as scat, and single tracks as we explored the dune. Trails were categorized as unmanaged when there was evidence of human use and possibly animal use (Table 1). Deer trails were defined as several deer tracks forming a noticeable trail. Single tracks were identified as one or two hoof prints with no other prints nearby. By looking at the direction of the tracks, we could determine which direction the deer were heading. Deer tracks and scat provided visual evidence of deer presence at particular locations.

Variables and Relevant Definition(s)	Photo Example
Unmanaged Trail: Any trail which is not part of the managed trail system in the park. **Managed Trail**: A trail designated by park management for use; the trail is identified by inclusion on a park map, presence of park signs, or surface materials maintained by the park such as wood chips or boardwalk.	Unmanaged trail on ridge of dune. 
Deer Trail: A visible path (in contrast to an individual footprint on a dune surface) with evidence of deer presence but little or no evidence of human presence.	Multiple hoof-prints form a deer trail through the vegetation. 

Table 1. Variables investigated in the study. (Table is continued on next page.)

Variables and Relevant Definition(s)	Photo Example
Single Track: One or several deer hoof-prints without nearby hoof-prints or trampled vegetation to show a pathway.	Single deer hoof-print on dune. 
Scat: Deer droppings on dune surface.	Deer scat are distinct against the lighter sand. 

Table 1 (continued). Variables investigated in the study.

Assessing Vegetation Quality and Deer Impacts

We chose to divide the entire study area into smaller study areas for vegetation quality assessment. The study areas are the foredune, dune ridge, north dune arm, a blowout and the main deflation areatwo of the blowouts, the first blowout crest and first blowout slipface. Within each study area, we placed a flag at a random point, and then measured 1.2 meters in each cardinal direction to place flags at 4 corners of a plot. Within each plotted area, a 0.5m x 0.5m wood quadrat was thrown to identify a random sampling location for assessing vegetation quality. We observed how healthy the vegetation looked, the amount of dead plant stems, and how thick the vegetation appeared. To assess the impact of deer on the vegetation we developed a visual scale to define the level of damage ranging from no damage (1) to severe damage (5) within each study area (Table 2).

Category	Damage Level	Description	Picture
1	No damage	Lush vegetation with no noticeable damage. No evidence of deer presence is observed.	
2	Little damage	Vegetation has some bare spots or noticeable damage. Some evidence of deer presence is observed.	
3	Moderate damage	Vegetation is sparser, with distinct bare spots and/or noticeably damaged plants. More evidence of deer presence is observed.	
4	Ample damage	Damage to vegetation is common, but vegetation also includes healthy stems growing. Frequent evidence of deer presence is observed.	
5	Severe damage	Few or no healthy stems of plants are observed; remnant stems are visible. A lot of evidence of deer presence is observed.	Not seen at study area

Table 2. Visual scale of deer impacts.

Collecting Context Information on Deer in Park

To gain more knowledge about the deer in Hoffmaster State Park, we interviewed Hoffmaster's Park Naturalist, Elizabeth Brockwell-Tillman. The interview format was semi-structured, with prepared questions to guide the conversation, such as: "Why did the deer hunts stop?" and "What impact on plants have you seen in the park?"

Results

Deer in Context

In Hoffmaster State Park, the carrying capacity for deer has been estimated by the Park Naturalist and biologists to be 65 deer (Brockwell-Tillman 2017). The actual deer population in the park is estimated at 3-4 times that many deer *(*Brockwell-Tillman 2017*)*. At one point, there were annual hunts to control the deer population, but hunters had reported complaints about the terrain and they would not hike back into the dunes (Brockwell-Tillman, 2017). Instead, hunters were hiking near the road, which was not safe, and they were running into each other while hunting. The kill rate was dropping as hunters came back unsuccessful (Brockwell-Tillman 2017). With the end of the annual hunts, deer population grew and with this growth the deer grazed the trillium flower to non-existence outside of deer exclosures. Similarly, at one point Hoffmaster State Park had sand cherry bushes, but now these bushes are not found within park boundaries (Brockwell-Tillman 2017).

Deer Presence in Fall 2017

On the dune, we found 25 samples of scat with 23 of the samples on the foredune (Table 3). The other two samples were found in the open area of the parabolic dune further up the windward slope. Single deer tracks were found in many dune locations with 22 tracks mapped. Five tracks were found on the foredune, seven

Dune Area	Scat	Tracks
Foredune	23	5
North arm	0	3
Dune ridge	0	1
First trough	1	2
Main deflation area	1	7
Forest	0	4

Table 3. Number of deer scat and deer tracks observed and mapped in different dune areas.

tracks were found in the main deflation area, four tracks were found in the forest, and the rest of the tracks where spread out in other areas of the dune.

Both deer trails and unmanaged trails are found in many areas of the dune. Several deer trails were mapped connecting Lake Michigan and various areas of the dune (Figure 3). Deer trails are found both on the forested arm and the open areas of the dune (Figure 4). Some unmanaged trails also had deer tracks on them. Several single tracks were found in the open areas of the dune near trails created either by humans or deer. The tracks head to and from Lake Michigan as well as between the forested areas of the dune.

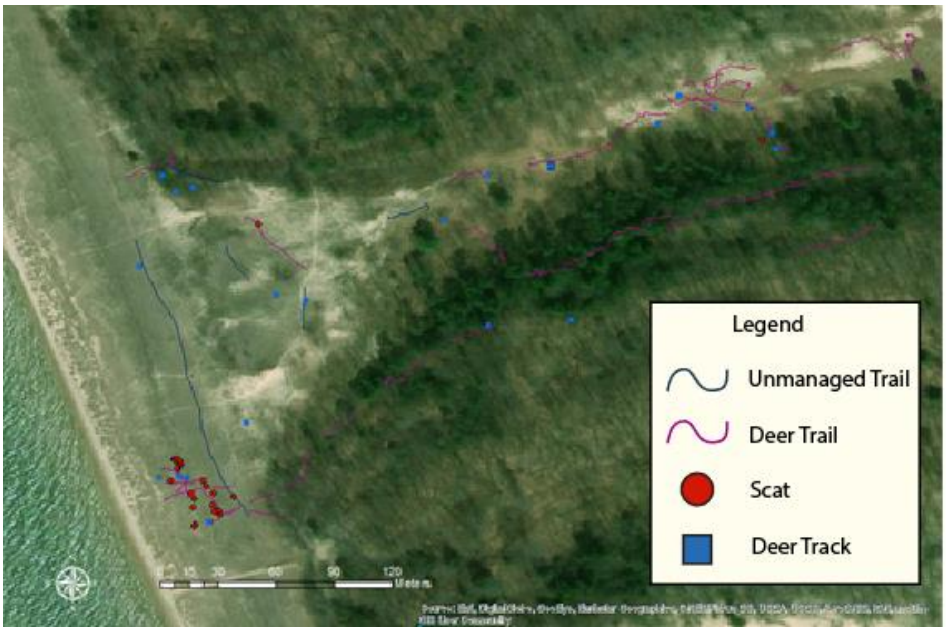

Figure 3. Mapped trails and deer evidence.

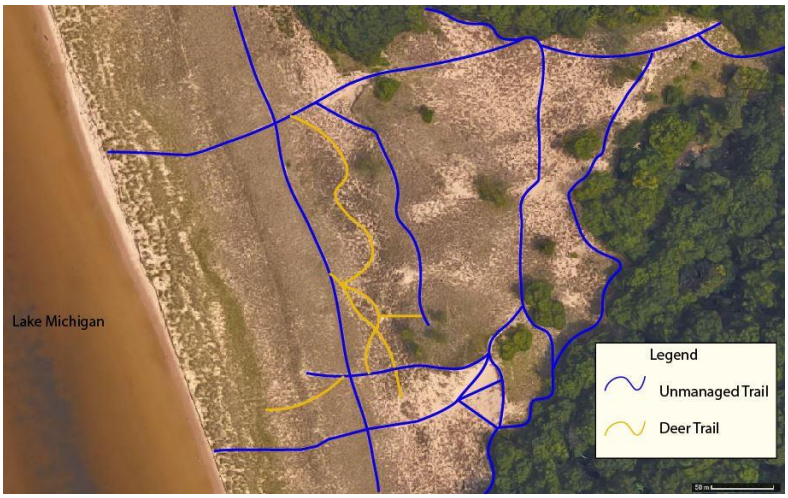

Figure 4. Unmanaged trails and deer trails in open dune areas at the site.

Deer Impacts and Vegetation Quality

Visual impacts from deer ranged from no damage (1) to ample damage (4) and scores were generally consistent across site visits (Table 4). The foredune is heavily vegetated (Figure 5) but scored higher because at close view, bare spots from grazed upon or dead grass are noticeable (Figure 6). The north arm of the parabolic dune had a deer-impact score of 1, although some of the trees are missing bark (Figure 7). The dune ridge crest scores for deer impact ranged from 4 to 2, due to the trails lining the crest. The blowout crest, main deflation area, and slipface of second crest all scored low (1-1.5) on the deer-impact scale because of the erosion and deposition that are typical of blowouts. The vegetation cover was sparse but healthy. A small amount of deer evidence was found in these areas.

Area of Dune	Visit 1	Visit 2	Visit 3
Foredune #1	3	3.5	2
Foredune #2	3	3	2
North Arm	1	1	1
Dune Ridge	4	2	2.5
Blowout Crest	1.5		
Main Deflation Area	1		
Second Blowout Slipface	1.5		

Table 4. Levels of deer impact observed for specific dune areas across 3 site visits.

Figure 5. Vegetated foredune.

Figure 6. Close up view of foredune surface.

Figure 7. Tree missing bark due to deer scraping antlers.

Discussion

The quantity of deer evidence and vegetation damage found on the foredune suggest that deer spend significant time in this dune environment and they are grazing on the American beach grass (*Ammophila breviligulata*). American beach grass on the dune has had some impact by the deer grazing. Nevertheless, the breach grass is still growing and doing well, as demonstrated by the vegetated foredune. We were unable to find published studies indicating whether beach grass is or is not a common food source for deer.

The various trees on the dune have had some impact from browsing and bucks scraping off bark by rubbing their antlers against trees, but the trees still appear to be healthy. The majority of trees on the dune are found on the arms of the parabolic dune. When comparing the arms of the parabolic dune to the foredune, the amount of deer tracks and deer scat found on the foredune is much larger than what was found on the arms of the dune. The arms of the dune had several deer tracks as well as trails, but little deer scat evidence.

With unmanaged trails found over the entire dune, it is hard to distinguish which trails are used only by deer. Deer tracks on unmanaged trails suggest that deer are using these trails as well as humans. From the direction of the tracks, deer use the trails to get water from Lake Michigan, forage on the foredune—as well as in the forest—, and shelter in various areas of the forest.

Overall, there is a low level of vegetation damage and abundant healthy vegetation in many areas of the dune. Wind erosion and sand movement do not appear to have increased beyond what is typical for this type of dune system.

Conclusions

Deer presence is seen over the entire parabolic dune system, but most evidence was found on the foredune. Vegetation has had some impact from the deer, but is still doing well. Trails made by people and deer have been found on the dune, with most of the unmanaged trails found in the open areas of the dune. Hoffmaster State Park is overpopulated by deer but at the moment there is no concern for destabilization of the dune system.

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