First-Year Research in Earth Sciences: Dunes

Investigating a Boardwalk's Effect on a Lake Michigan Coastal Dune

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Abstract

Boardwalks are a management strategy that protect dunes from negative human impacts. There has been little study, however, of how boardwalks themselves may harm dune vegetation. We studied this at a boardwalk on a Lake Michigan coastal dune in P. J. Hoffmaster State Park, Michigan. We recorded boardwalk characteristics of the two sections that were built along the dune crest and arm in 1975, and of the section that was built up the slipface in 2016. Other methods included GPS mapping, measuring light intensity under the boardwalk, measuring surface soil moisture, and recording vegetation characteristics. The newer section of the boardwalk has effective signage and barriers to prevent people from leaving the boardwalk. The older sections have insufficient signage and barriers. There are unmanaged trails stemming from the older sections, but not the new section. The condition of vegetation generally improves as distance from the boardwalk increases. This correlates with light intensity and the height of the boardwalk above the dune surface. Therefore, while the boardwalk reduces trampling along the ridge, it does not fully prevent trampling on other parts of the dune surface and there is a narrow corridor of vegetation impairment along the boardwalk.

Introduction

Boardwalks can help prevent trampling of vegetation on the surface of dunes (Carlson and Godfrey 1989; Purvis *et al.* 2015; van Dijk and Vink 2005). Not much investigation has been done, however, on how the presence and construction of boardwalks may impact vegetation. This study seeks to determine the effects of a dune boardwalk and its recent construction on the surrounding vegetation.

The objectives of the study are to:

- Map the boardwalk and its characteristics.
- Measure vegetation characteristics.
- Map any unmanaged trails near the boardwalk.
- Analyze patterns to determine the boardwalk's impact on surrounding vegetation.
- Suggest improvements that would decrease the boardwalk's negative impacts.

Background

Boardwalks are a management strategy used in environments such as dunes which are vulnerable to the impacts of human activities. Managers may have different goals for employing boardwalks, including dune stabilization, decreasing erosion and surface change, protecting rare flora or fauna, and restoring impacted ecosystems. Boardwalks are often implemented with the goal of permitting high visitor rates to an area while simultaneously preserving the environment (Carlson and Godfrey 1989). Muñoz Vallés *et al.* (2011) state that boardwalks do not completely achieve the goal of a natural environment, because they often draw more people to the dune area. However, boardwalks are significant in moving towards a more natural environment (Muñoz Vallés *et al.* 2011). Boardwalks have been shown to be successful in rehabilitating beach and dune areas which have been impacted by human impacts such as trampling (Johnston and Ellison 2014). Community participation is important to the success of such projects (Johnston and Ellison 2014). Boardwalks also can enhance the visitor experience by providing easier access to scenic viewpoints (Williams *et al.* 2016) or providing a venue for exercising that will improve the health of visitors (Mangham and Viscount 1997).

How boardwalks are designed, such as how far from the ground they are, how much space is between boards, and what type of barriers and signage they have greatly affects their effectiveness (van Dijk and Vink 2005). Boardwalks can be placed directly on the dune surface or raised above the surface (Purvis *et al.* 2015). Elevated boardwalks can be less of an interruption to dynamic processes such as sand transport by wind (Carlson and Godfrey 1989), and they also reduce human impacts on dune characteristics and dynamics (Purvis *et al.* 2015). In South Carolina, the raised boardwalk (compared to sand paths) had increased vegetation cover and species diversity but decreased blowout formation (Purvis *et al.* 2015). Gaps between the floor-boards of a boardwalk, such as the 3-cm spaces in the R. T. Crane Jr. Memorial Reservation in Massachusetts, allow light to reach the ground beneath the boardwalk so that plants can grow there (Carlson and Godfrey 1989). Whether or not a boardwalk section has a railing and the ease with which visitors can get past the barrier to get onto the dune makes a difference to the amount of human trampling and formation of unmanaged trails in the dune environment. In areas that have been affected by human trampling, studies of barriers such as sand fences have shown increased in species diversity and vegetation percent cover (Santoro *et al.* 2012). Signs placed by viewing platforms or other areas of boardwalks can educate people about the dunes and discourage them from using unmanaged trails (Carlson and Godfrey 1989; Randall and Newsome 2008). Public education is important as people are more likely to comply with local rules if they understand why the rules are in place (Carlson and Godfrey 1989).

There are few Michigan studies related to boardwalks. A study of Mt. Pisgah near Holland, Michigan, focused on dune visitor patterns and impacts that prompted a recommendation that a boardwalk would be an appropriate management action (van Dijk and Vink 2005). At that location, more than 3000 visits per year to the large parabolic dune were destroying vegetation in some areas which enhanced dune erosion and surface changes (van Dijk and Vink 2005). LePage *et al.* (2015) focused on a boardwalk in P.J. Hoffmaster State Park, Michigan, prior to planned changes to the boardwalk. The study methods included GPS mapping and field measurements to document boardwalk characteristics, dune environment characteristics near the boardwalk, and vegetation communities on the dune (LePage *et al.* 2015). The study recommended raising the height of the boardwalk, putting larger gaps between the boards, updating signage, and changing the boardwalk path to better direct visitors (LePage *et al.* 2015).

Study Area

Our research site is located at the boardwalk on a large parabolic coastal dune near the Visitor Center in P.J. Hoffmaster State Park in Muskegon, Michigan (Figure 1). Originally built in 1975, the boardwalk has undergone recent construction in which the "Dune Climb" portion was rebuilt in 2016 (Figure 2). Just to the northeast of the boardwalk is the Gillette Sand Dune Visitor Center.

Figure 1: Location of P.J. Hoffmaster State Park in Michigan. The boardwalk location is circled on the aerial image of the park.

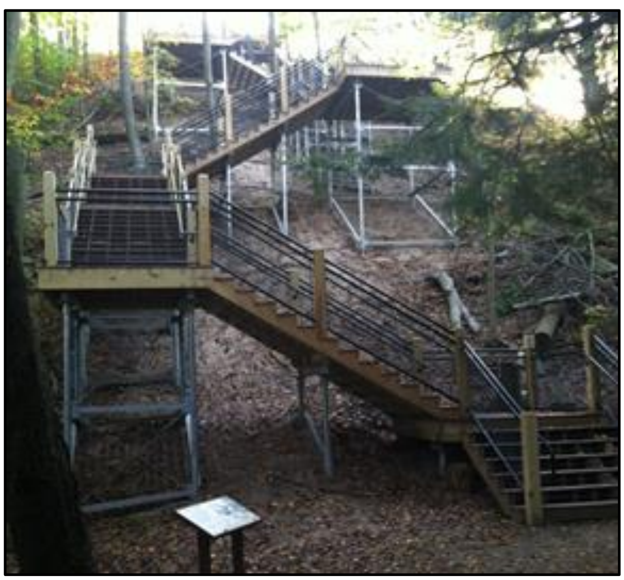

Figure 2: The Dune Climb boardwalk section after rebuilding in 2016.

Methods

Field data was collected during three site visits: on October 27, November 3, and November 10, 2016. We collected data on boardwalk characteristics, vegetation characteristics, and unmanaged trails (Table 1). GPS mapping was done with a Trimble Juno GPS.

	Variable	Methods
Boardwalk Characteristics	Amount of light reaching dune surface	Measured with a light meter
	Boardwalk's height above dune surface	Measured with a tape-measure
	Presence of signs	Mapped with GPS
	Presence of leftover construction material	Mapped with GPS
	Layout of boardwalk	Mapped with GPS
Vegetation Characteristics	Height of vegetation	Measured with ruler in selected quadrats
	Percent of vegetation cover	Estimated from observations at selected quadrats
	Number of species present	Counted in selected quadrats
	Soil moisture	Soil samples collected on-site and dried in lab oven.
Unmanaged Trails	Paths of unmanaged trails	Mapped with GPS
	Unmanaged trail entry points	Mapped with GPS

Table 1: Variables and methods.

Boardwalk Characteristics:

We started by classifying the boardwalk into three sections. We named the Dune Climb section 1, the east arm section 2, and the west arm section 3. We made basic observations on what types of materials were used, such as wood, plastic, or metal. We also observed how wide the gaps between the boards of the walking surface were. Using photographs, we compared the characteristics of the new Dune Climb with the pre-construction wooden stairway.

We measured the elevation in meters from the walking surface of the boardwalk to the dune surface. This was measured near the centers of the vegetation transects, which are described below. Using a Trimble Juno SB GPS unit, we collected GPS points for the location of each measurements, and we mapped the length of the boardwalk.

A LI-191R Line Quantum Sensor light meter was held just above the dune surface underneath the boardwalk to measure light passing through the walking surface of the boardwalk to the dune surface. GPS points were recorded for each of the locations where we collected this data. We also compared images of the old boardwalk with the new boardwalk.

Vegetation Characteristics:

To measure vegetation characteristics, transects perpendicular to the boardwalk were established at randomly-selected locations along the boardwalk (Figure 3). We entered the boardwalk length, in meters, into a random number generator to choose five distances from the center viewing platform at which to place transects. For example, section 3 of the boardwalk is 89 meters long, so we used the random number generator to choose 5 numbers between 1 and 89.

Figure 3: Transects (orange) extending from randomly-selected locations along the boardwalk.

At each transect, we tied flagging tape to the boardwalk as a reference point. Along each of these transects, we placed flags to indicate quadrat locations at 0m, 1m, and 5m from the boardwalk. We knew we would not be able to collect data at all of the quadrats because of time constraints. Therefore, we collected data at quadrats on the left side of the boardwalk at transects which were an even numbered distance from the center viewing platform, and on the right side of the boardwalk at transects which were an odd numbered distance from the center viewing platform. For example, on section 3 of the boardwalk we collected quadrat data on the right side of the transect that was 7 meters from the central viewing platform. A GPS point was recorded at each quadrat. When fieldwork was finished, we removed all flagging tape and flags from the study area.

Unmanaged Trails:

Using GPS, we mapped lines of unmanaged trails that appeared to be currently in use. We also mapped points for unmanaged trail entry points, where unmanaged trails connected with the boardwalk. We examined aerial imagery for visible unmanaged trails and we compared their characteristics (number, location) between photos of different dates and between photos and our mapped data. We looked for correlations between changes in the trails and the changes in the boardwalk, particularly its recent construction.

Park Staff Interview:

We interviewed Elizabeth Brockwell-Tillman, the park naturalist, to get an account of the boardwalk’s recent history. The types of questions we asked were about construction, how people have been interacting with the boardwalk, and about unmanaged trails.

Results

Boardwalk Characteristics:

The boardwalk has a total length of approximately 193 meters and is divided into three sections (Figure 4). Section 1 is the new Dune Climb, while the older sections 2 and 3 are built along the dune crest and north arm. The walking surface of section 1 is built with plastic or PVC composite decking boards, and there is more space between the boards. In contrast, the walking surface of sections 2 and 3 are wood boards.

Signage and barriers on the older parts of the boardwalk are scarce. The section with greater average height above the ground, section 2, has a higher light intensity beneath it (Table 2). There is a portion of section 3 which is so close to the dune surface that sand is sitting on the walking surface. Also along section 3, there are some sand fences that are placed along the side of the boardwalk. Upon comparing the older dune climb with the new one, we noticed much improved accessibility through design. Namely, the new Dune Climb has more even steps and improved handrails (Figure 5). It is also farther from the dune surface than the previous one.

Figure 4: Mapped boardwalk and features in the study area. Vegetation at 0, 1, and 5 meters from the boardwalk is shown in green.

	Boardwalk Height (Above Ground (m)		Light Intensity (W/m^2)	
Section	**2**	**3**	**2**	**3**
Average	2.16	1.45	12.66	6.03
Maximum	3.54	2.56	21.81	17.05

Table 2: Two variables at section 2 and 3. There is no corresponding data for section 1.

Figure 5: Old boardwalk (left) and new boardwalk (right). Note the changes in tree cover, with cut trees visible to the right in the photograph of the new boardwalk. (Image source for old boardwalk: http://www.lakemichigantowns.com/)

Vegetation Characteristics:

Section 1 runs through a forested slipface. Sections 2 and 3 are built over dune grass and bare sand. The height of vegetation, mostly dune grass, generally increases with distance from the boardwalk (Figure 6). Near the Dune Climb there were some trees which appeared to be cut down fairly recently (Figure 7). Other observed surface features included some unused boards and slumping on the dune's leeward slope. Soil moisture content ranged from 1.35% in section 3 to 15.51% in section 2. Our results showed no apparent relationships between vegetation and soil moisture patterns.

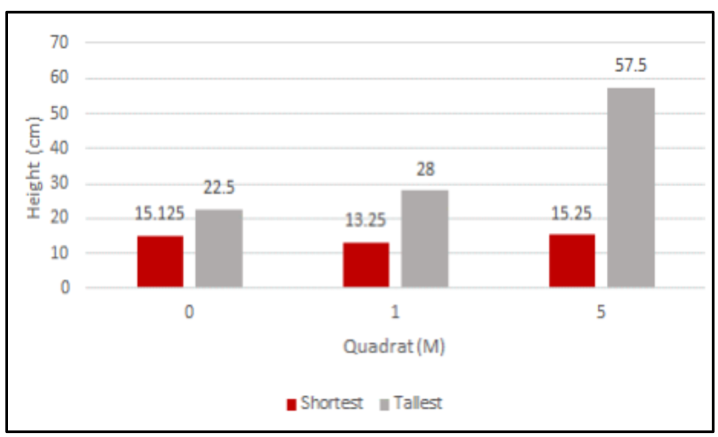

Figure 6: Average vegetation height at 0, 1, and 5 m from the boardwalk in Sections 2 and 3.

Figure 7: Recently-cut tree near new Dune Climb.

Unmanaged Trails:

There are three major unmanaged trails stemming from the ends of sections 2 and 3. On section 1, which has no unmanaged trails, there is mesh fencing and the boardwalk is higher from the dune surface. Aerial imagery showed more unmanaged trails than we recorded during our fieldwork. The analysis of aerial imagery did not indicate whether or not the Dune Climb's reconstruction had an effect on use of the unmanaged trails.

Park Staff Interview:

On November 10, 2016, we interviewed Elizabeth Brockwell-Tillman, Park Naturalist. She told us that since the reconstruction of the Dune Climb, more people have been visiting the boardwalk. One of the unmanaged trails is largely from a senior citizen hiking group, who made the trail by regularly hiking along the ridgeline. She also told us that some of the sand fences located along section 3 were placed there to hide extra boards lying underneath the boardwalk, which are left for future repair.

Discussion

The decrease in the overall height of vegetation near the boardwalk suggests that the boardwalk has some negative effect on the amount and health of the surrounding vegetation. Because the Dune Climb is on the leeward side of the dune where vegetation other than trees is scarce, this increased spacing does not result in more abundant vegetation below and near this section of the boardwalk.

Since the new Dune Climb has been built, more people have been visiting the boardwalk, and in turn the dune, than ever before due to improved design and accessibility. There are now more landings on the Dune Climb for people to rest at, as well as some benches on some landings. Additionally, the composite boards are more level than the older wooden ones, preventing tripping, so people can run up and down the Dune Climb for exercise more safely and easily than before.

While boardwalks can have some negative impact on vegetation, the human impacts on the dune surface would be greater if the boardwalk was not present. However, as other studies have shown, there are management techniques that could be used, namely the following. These recommendations are listed in the order of what could be the best balance between cost investment and effectiveness.

Recommendation 1: Remove the sand fences that are only serving the purpose of hiding extra boards.

These sand fences are not currently meant to serve any practical purpose, apart from hiding spare materials. They may be preventing the movement of wind and sand, so removing them would benefit the dune. Sand fences which have been placed for reasons other than aesthetics should not be removed.

Recommendation 2: Improve barriers at the origin points of unmanaged trails.

The boardwalk can provide an origin point for unmanaged trails. Because more people are visiting the boardwalk than before, there are now more people that could potentially leave the walking surface of the boardwalk (Figure 8). Some of the decreased vitality of vegetation along the boardwalk could be due to trampling originating from the same points. Improving the barriers would prevent people from leaving the boardwalk. The leftover boards that are laying on the dune surface could be used if they are long enough. However, mesh similar to what is present on the Dune Climb would be more effective and more durable than horizontal wood boards.

Figure 8: Unmanaged trail entry point, with leftover construction material visible.

Recommendation 3: Install educational signage with positive language discussing how human traffic affects dune health.

This recommendation also seeks to reduce trampling impacts on vegetation. During our study, there was only one sign at the bottom of the Dune Climb that advises people to stay on the boardwalk. By the time people get to the top, they may need a reminder. Positive signage, such as “Please stay on the boardwalk to protect the delicate dune environment” has been shown to elicit a better response than negative signage, such as “Do not leave the boardwalk” (Carlson and Godfrey 1989). Installing such signage at the top of the dune climb and at the origin points of unmanaged trails would help keep people off the dune surface.

Recommendation 4: Plant trees of native species where trees were cut down during construction of the dune climb.

Replanting trees would help mitigate the slumping that might be related to trees being cut down. While the goal of dune management is not necessarily stabilization, the dune should have the same stability that it had before the reconstruction of the dune climb. The species that are planted should be native to the park, and they would ideally be located near the stumps of the trees that were cut down.

Recommendation 5: Increase the size of the spaces between the boards of the boardwalk, or replace the boards with metal mesh.

Increasing gaps in the boardwalk floor would allow light and water to better reach vegetation underneath (Carlson and Godfrey 1989). If wood boards are used, care must be taken to avoid treated wood that may introduce harmful chemicals into the dune environment. Whether replacing the walking surface with wood boards, Trex/pressed plastic boards, or mesh, updating the walking surface should be possible with minimal trampling. If the boards are removed starting from the two far viewing platforms, toward the middle viewing platform, then the new material is placed in the reverse direction, there should be minimal need for stepping on the dune surface.

Recommendation 6: Refurbish or raise the portion of section 3 that is on the dune surface.

Raising the boardwalk section would allow sand and wind to pass underneath the boardwalk without getting caught by the boardwalk.

Conclusions

The 193-m long boardwalk in P.J. Hoffmaster State Park provides access to the crest and arms of a large parabolic dune. Compared to two older boardwalk sections, the newly-constructed Dune Climb has a better design for human use and reducing impacts on the dune environment. Vegetation characteristics and the presence of unmanaged trails show that there are still some impacts from visitors. Overall the boardwalk is an effective management tool for protecting vegetation and encouraging visitor enjoyment. However, improvements to signage, barriers, and material could be made that would make it better serve both of these purposes.

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