Loss of Open Dune Habitat Along Southeast Lake Michigan shoreline: with Aerial Photographic Evidence

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Background

Our investigation of Lake Michigan coastal dune mobility was inspired by historical management techniques and the growing changes to management in response to potential overstabilization. In the early twentieth century, management of Lake Michigan's sand dunes was focused on demobilizing, concerned primarily with encroachment on cultivated farmlands and housing development (Clarke and Rendell, 2014; Amsterburg, 1973). Studies later performed by ecologist Henry Chandler Cowles on the Indiana Dunes Lakeshore however, revolutionized the outlook on open dune ecology. He was among the first ecologists to develop ideas on plant and ecological succession and the climax community, and understand the importance of dune mobility for the survival of uniquely adapted organisms. A large portion of open dune habitat's biodiversity are rare, threatened, and endangered plants and animal species.

Collaboration in England and Wales

As part of the project was inspired by a Welsh study in 2014 (K. Pye et. al 2014), our team traveled to the United Kingdom for three weeks to collaborate with and learn from current research on dune mobility. We worked closely with Liverpool Hope University professors Dr. Paul Rooney, Dr. Kevin Crawford, and Dr. David Chester, visiting several local coastal dune sites and the current management being performed there. We were also able to meet with Dr. Pye in Wales, and learn from his perspective on mobile dune analysis and management techniques. The K. Pye study specifically investigated historical changes in dune geomorphology using aerial photographs from the 1940s to the early 200s. This work was done in response to a growing concern that dunes were stabilizing due to decreasing wind speeds, longer growing season, warmer temperatures, greater nitrogen deposition, and strict dune management control over mobility. Their study revealed coastal open dune decline ranging from 41% up to a massive 97% loss (Pye et. al 2014).

Aerial Photography Preparation

Upon returning to Michigan, we prepared to follow the historical investigation techniques used by K. Pye's study by using aerial photography. Based on available budget, time, clarity, and availability of aerial photos, our study focused Allegan, Ottawa, and Muskegon counties. Of these three counties, we gathered imagery from 1938, 1965-1968 and 2005. The orthorectified 2005 photos were obtained from USGS Earth Explorer Website. The rest of the images were gathered from Michigan State University's Aerial Imagery Archive, and were georectified using ArcGIS. I researched, implemented, and taught other researchers how to georectify the images, and georectified 1938, 1965-1968, and 2005 images of Muskegon County.

To ensure a consistent area for our analysis, we outlined the base of inland dune ridges in ArcGIS. We used a topographic basemap as our reference for the ridge lines. The same outlines were used in all subsequent analyses. As with georectifying, I also outlined Muskegon county dune ridges for all analyzed years.

Aerial Photography Analysis

ArcGIS Method

Initially, our project was focused on using a strictly manual method of outlining open dune habitat. We defined open dune areas as predominantly covered by bare sand or grass. On ArcGIS, we outlined these areas using the polygon tool within their respective polygonal topographic areas. These open dune areas were then divided by the total area of the dune complexes to calculate the percentage of open dune habitat. I outlined Muskegon county images from 1938, 1965-1968, and 2005.

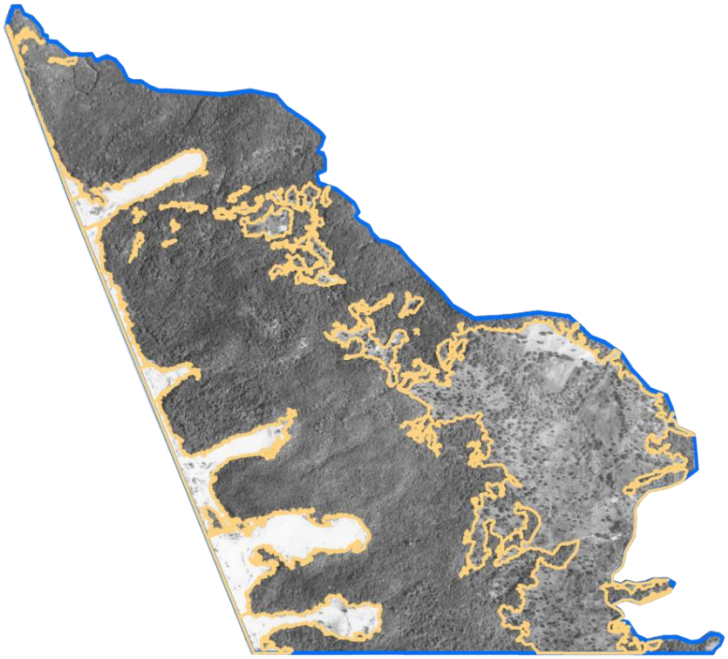


Figure 1. *Example of ArcGIS polygonal outlining method, dune habitat areas are outlined in yellow and the topographic area is outlined in blue.*

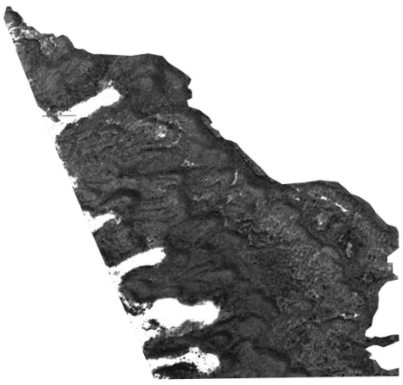
As we were developing this project, I wanted to know if there was a faster and potentially more accurate method of obtaining the open dune area. With my knowledge of ImageJ, a pixel counter used in biological studies, I chose to develop a method which implemented this program.

ImageJ Method

Because the pixel counter creates a black and white image, and counts the white pixels, I needed to ensure the dune complex images were void of extra area or of white pixels that were not open dunes. Thus, I exported images of the complexes from ArcGIS to Photoshop at 650 dpi

resolution TIFF images. In Photoshop, I cropped the images to only include the dune complex (Figure 2a). Light grey to white pixels which were human development or isolated light pixels in forested areas were blacked out manually so that ImageJ would not read them as open dune habitat (Figure 2b). I then determined the proper brightness threshold based on the edges of the open dune's location for each individual image. This varied due to the quality and brightness of the original photograph. The program then determined the area above the threshold by counting the white pixels (Figure 2c). With the same cropped and edited photograph, I created an inverted image in Photoshop and performed the ImageJ analysis with the inverse threshold. This inverse was used to calculate the area of human development and forested area. The sum of the inverse and original pixel count gave us our total area, from which we divided our original open dune pixel count for the percentage of open dune.

I conducted all ImageJ analysis for Allegan, Muskegon, and Ottawa counties. Preparation and analysis was significantly faster than the ArcGIS method, allowing me to perform it single-handedly. Although I did have to analyze each image in Photoshop to ensure the correct counting, I did not need to manually outline every section of open dune habitat. This was also beneficial because there was greater consistency between each individual dune area analysis.

a. 

b. 

c. 

Figure 2. *Example section of P.J. Hoffmaster state park (2005) images from ImageJ method: cropped original image (a), blacked out non-sand dune white pixels (b), and area (in red) selected by ImageJ above the set brightness threshold (c)*

Aerial Photography Results

Both methods showed a decline in open dune area between 1938 and 2005 from 32.87% to 76.36% (ArcGIS) or 42.48% to 61.79% (ImageJ). Both methods agreed that the percentage loss was the lowest in Allegan and the highest in Ottawa county, while Muskegon was midway between the other two counties.

ImageJ Analysis	
Muskegon	
Year	% Open Dune
1938	19.26
1965-1967	15.47
2005	9.49
Total Change	-50.73%
Ottawa	
Year	% Open Dune
1938	23.71
1965-1967	16.4
2005	9.06
Total Change	-61.79%
Allegan	
Year	% Open Dune
1938	29.94
1965-1967	20.46
2005	17.22
Total Change	-42.48%

ArcGIS Analysis	
Muskegon	
Year	% Open Dune
1938	28.49
1965-1967	26.19
2005	12.4
Total Change	-56.48%
Ottawa	
Year	% Open Dune
1938	46.44
1965-1967	24.42
2005	10.98
Total Change	-76.36%
Allegan	
Year	% Open Dune
1938	38.42
1965-1967	31.48
2005	25.79
Total Change	-32.87%

Table 1. *ImageJ and ArcGIS method analysis results, comparing percentage of open dunes in 1938, 1965-67, and 2005 for Muskegon, Ottawa, and Allegan counties. Total change for each county and method shows the percent loss of open dune habitat from 1938 to 2005.*

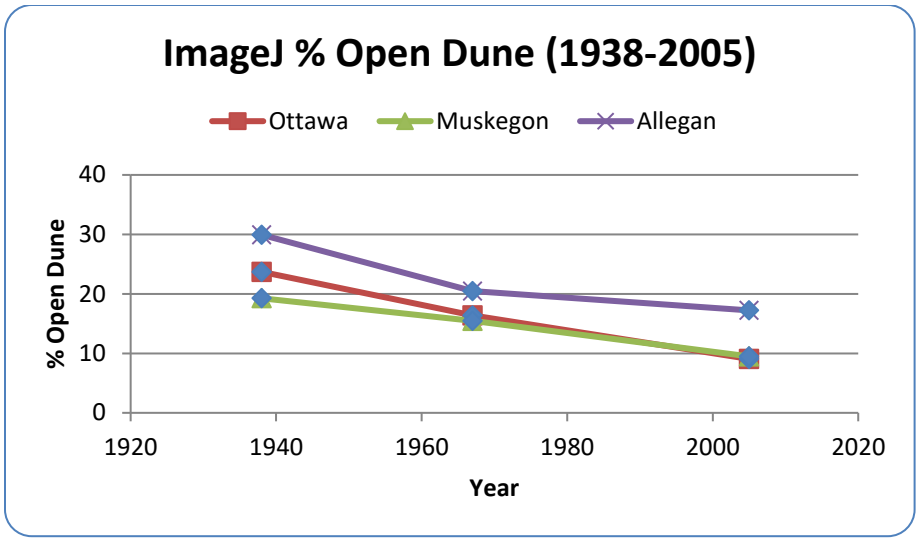


Figure 3. *Line graph of loss of open dunes between 1938 and 2005 in Muskegon, Ottawa, and Allegan counties using the ImageJ analysis.*

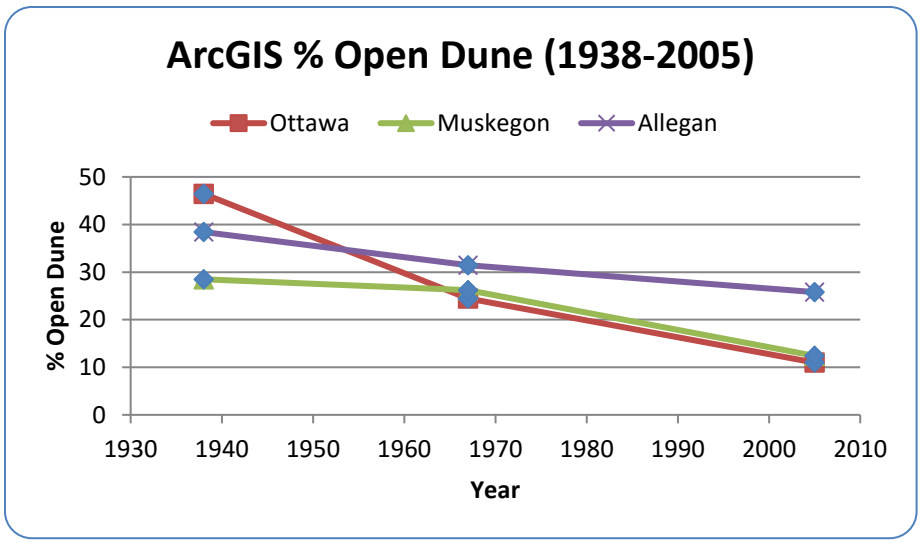


Figure 4. *Line graph of loss of open dunes between 1938 and 2005 in Muskegon, Ottawa, and Allegan counties using the ArcGIS analysis.*

The greatest agreement between results was found in Muskegon county (County (51 % decline by the ImageJ method vs a 56 % decline by the ArcGIS method) and the greatest discrepancy is for Ottawa County (62% decline by the ImageJ method vs a 76% decline by the ArcGIS method). The ArcGIS method consistently calculated a larger overall open dune habitat area than ImageJ. ArcGIS analysis also concluded greater percentage losses than ImageJ analysis for Muskegon and Ottawa, but this was not the case for Allegan county.

Discussion

Both ImageJ and ArcGIS methods exhibit clear open dune decline for all three counties analyzed (Table 1). The ArcGIS results indicated a higher percentage of open dune habitat loss in two out

of the three counties, and larger calculated open dune areas than ImageJ. The ArcGIS method included single trees growing within the open dune habitat and assumed an outward growth along the forest edge. This addition adds more overall area to the dune habitat calculated. ImageJ effectively excludes single trees within the open dune pixel count. Therefore the two methods represent two different types of open dune habitat characterization, but the same general conclusion.

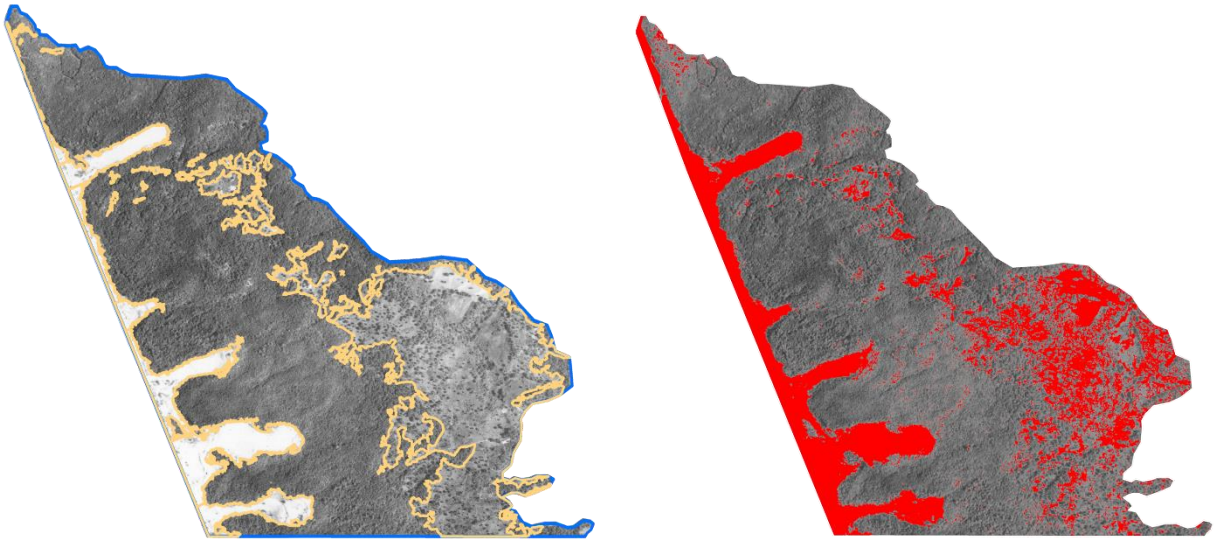


Figure 5. *Comparison of the two methods for P.J Hoffmaster State Park (2005). ArcGIS shown is shown on the right and ImageJ on the left.*

Potential sources of error could come from using older and lower resolution photos. Some photos from 1938 and 1960s were more difficult to interpret because of overexposure or low resolution. This made it particularly difficult to accurately decide whether an area was open dune or human development, or where the forest edge was located.

Both ImageJ and ArcGIS analysis relied on human judgement. However, ImageJ limited human judgement to blacking out white pixels that would have otherwise been read as human development or forested area, and choosing the proper threshold. ArcGIS relied on human judgement to define the edges of an open dune habitat and what trees to omit or keep. Thus ImageJ is more easily kept consistent in analysis, but excludes area that are still considered part of the open dune habitat due to small patches of larger vegetation.

Conclusions

Although both methods provide somewhat differing quantitative results, they both indicate significant decline in the open dune environment. Thus stabilization may be leading to the loss of distinctive open dune geomorphology and unique flora and fauna. We may need to change the focus of our dune management from demobilization to preserving dune mobility to preserve these unique geological features.

References

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