

First-Year Research in Earth Sciences: Dunes



Interactions Between Dune Activity and Oriental Bittersweet on Castle Park Dune, Michigan

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ABSTRACT

The dunes along Lake Michigan are interesting sites for studying the interactions between invasive species and topography. This study explores the relationships between dune characteristics and the invasive species Oriental bittersweet on a 50-meter tall dune in Castle Park Preserve near Holland, Michigan. During the fall of 2011, the researchers investigated dune topography, activity, surface conditions and the locations of invasive species. Erosion pins and sand traps were utilized in the study to identify areas of dune activity, a total station was used to survey dune topography, and Trimble GPS units were used to map Oriental bittersweet. The Castle Park Dune is an active blowout with sand moving over the crest of the dune. More than 279 Oriental bittersweet plants were recorded, with most of them concentrated within 3 main areas on the leeward slope of the dune. The lee slope receives inputs of sand but is currently stabilized by the Oriental bittersweet. Management efforts to remove the Oriental bittersweet are underway, but our analysis of dune activity suggests the dune slope may become unstable without the plants. Dune managers could plant an appropriate native species in the place of the invasive species.

Key words: *Celastrus orbiculatus*; Oriental bittersweet; Invasive species; Dune; Castle Park.

Introduction

Few studies have been conducted on invasive species and dunes. This project addresses how the presence of the invasive species affects the characteristics of a Lake Michigan coastal dune. Castle Park Preserve possesses an active dune of interest because of the dense presence of invasive species: Oriental bittersweet also known as *Celastrus orbiculatus*. The Land Conservancy of West Michigan decided to remove *C. orbiculatus* from the dune to protect native species. Since the effect of the removal on the dune was unknown, an investigation of dune characteristics in relation to *C. orbiculatus* was conducted within Castle Park Preserve for the Land Conservancy of West Michigan.

Study Objectives

This study focuses on two main objectives: (1) to investigate dune characteristics including topography, dune activity, and surface conditions to further understand the dune environment at Castle Park and (2) to examine the interaction between the dune and the presence of *C. orbiculatus*.

Background

There are numerous studies that focus exclusively on invasive species and there are numerous studies that exclusively focus on dunes; however, there are few studies that focus both on dunes and invasive species. There are no studies that encompass this relationship from the state of Michigan. In Korea, a study concluded that increased disturbance on a dune favors the existence of invasive species (Kim 2005). A study conducted in the country of Mexico experienced similar connections between the presence of invasive species and a dune environment. This study observed that invasive species are more likely to invade an area that is disrupted (Castillo and Moreno-Casasola 1996). The two studies demonstrate that a disturbed environment is more vulnerable to invasive species than areas that are not disturbed. Other studies relating invasive species and dune environments have focused either on the threats invasive species pose on dunes (Lubke *et al.* 1995) or on the potential of a dune ecosystem to recover from invasive species (Marchante *et al.* 2004). Given the few studies that link dunes to invasive species, there is a substantial need for research on the relationship between dunes and invasive species.

C. orbiculatus (Oriental bittersweet) is an invasive species that exists as a vine-like form. *C. orbiculatus* moves rapidly into a natural area and overruns the native species within the vicinity by climbing, strangling, and uprooting vegetation in its path (fig. 1; Swearingen 2006). *C. orbiculatus* was originally introduced into the state of Connecticut for cultivation purposes from eastern Asia in 1860 (Dreyer 1987). The species has rapidly spread throughout the eastern portion of the United States and has advanced into the Midwest. Therefore, *C. orbiculatus* is not only present on a local scale at our study site, but it is common at a regional scale and occurs on a larger scale throughout the United States and in other countries such as China, Japan, North Korea, and South Korea.



Figure 1: This picture shows Castle Park dune and the debris left over from fallen trees.

C. orbiculatus is often identified by its twining vine, glossy round leaves, bright orange roots, and the fruit that it bears (fig. 2; IPSAWG 2005). Regularly this invasive species is confused with the American bittersweet (*Celastrus scandens*) which is a native species in the United States. While both species climb trees and other vegetation, the difference is that the native species, *C. scandens* climbs at a slower rate than the invasive species, *C. orbiculatus*. Additionally, *C. orbiculatus* is characterized by bearing a greater numbers of seeds but *C. scandens* possesses a fuller volume of fruit; this comparison has become a main identifier between the two species (Leicht-Young 2007). *C. orbiculatus* thrives in areas of land that are often disturbed in some way or another. This invasive species can also be found in fields, coastal regions, woodlands, forested areas and other similar areas of terrain (Swearingen 2006).



Figure 2: This picture shows *C. orbiculatus* found on the windward slope of the Castle Park dune.

The presence of vegetation on any dune affects the stability of the dune. When vegetation is present, the movement and migration of a dune slows down because vegetation acts as a barrier by absorbing and diminishing energy from transportation agents such as wind (Bruun 1998). Vegetation aids in stabilizing the dune and reducing the transportation of sand grains from the windward slope to the leeward slope of the dune (Abuodha *et al.* 2003). Plants, shrubs, and trees on dunes resist the energy from the wind and often create a stable, sheltered area where sand grains are deposited. Because dune surfaces are anchored by plants, the percent of the dune covered by vegetation becomes an important variable when understanding the activity of a dune (Seppala 1972).

Study Area

Castle Park Preserve is located in Holland, Michigan on the eastern coast of Lake Michigan (fig. 3). Castle Park, owned by the Land Conservancy of West Michigan, has implemented management strategies to preserve its natural state. As a result, the Land Conservancy decided to remove the *C. orbiculatus* from the dune.

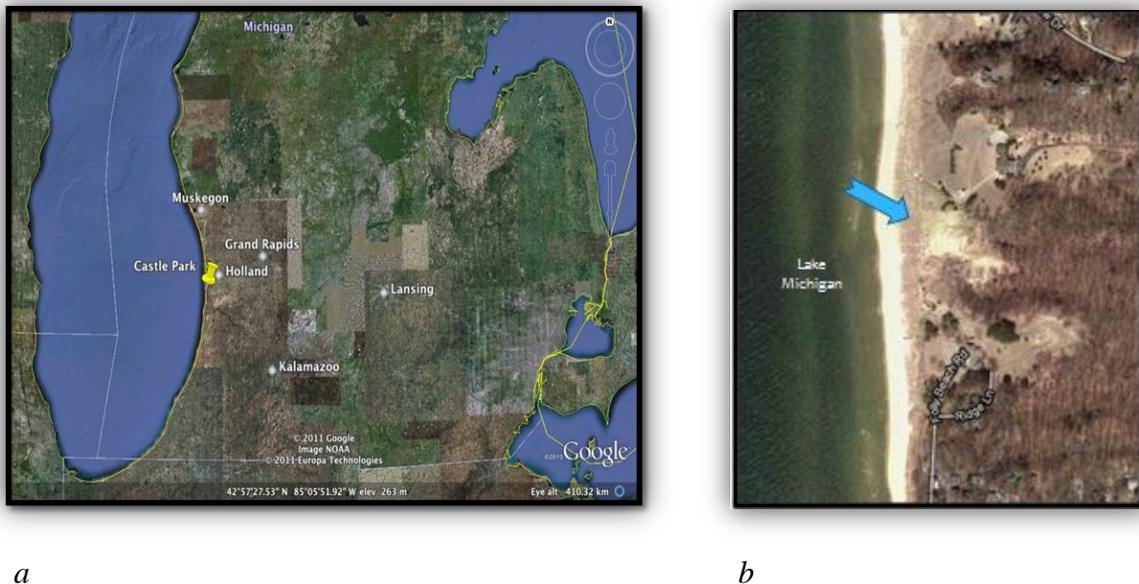


Figure 3: These images (a) show the location of Castle Park along the Lake Michigan coastline and (b) identify the general study area.

Methods

In order to carry out the study at Castle Park dune, background information about the human and natural characteristics of the dune needed to be gathered. Understanding how the dune functions is essential to understanding the relationship the dune has with the invasive species, *C. orbiculatus*. Methods such as surveying dune topography, monitoring erosion and deposition at erosion pins, examining sand grain activity through the use of sand traps, and using a Dune Features Inventory (DFI) were used to investigate dune activity and background characteristics of the dune. To further investigate *C. orbiculatus*, a spatial survey of the invasive species was completed using Juno Trimble GPS units.

Dune topography was mapped through the use of the SOKKIA Total Station (fig. 4). This instrument was utilized to survey the elevation and topographic changes of the study area. The

surveying was done on three different site visits with two different total station locations to survey points over the entire dune: (1) at the crest and (2) at the bottom of slip face. Three benchmarks were installed (Appendix A); the benchmarks were surveyed each time the total station was set up to permit meshing the datasets. After post-processing the data to match the sets of data, a map showing dune topography was created using the Rockworks software.



Figure 4: A researcher is surveying with the total station at the location on the crest of the dune. Erosion pins are visible in the foreground of the photo.

The Dune Features Inventory (DFI) is a tool that aided in the investigation of dune activity along with human and natural features of the dune. The DFI is a systematic approach for the collection and analysis of qualitative and quantitative data through the means of a checklist (Beauchamp *et al.* 2009; Ferwerda and van Dijk 2010). The DFI is used to identify the characteristics of dune environments through measurements, surveying and observation, and covers various topics ranging from dune size to vegetation to human management and impacts. For this project, the DFI aided in recording essential characteristics of Castle Park dune to establish a solid set of reference information. Most importantly, the DFI enabled researchers to classify the activity level of the dune into one of five categories: inactive/stable, slightly active, moderately active, active, or very active.

Erosion pins in the form of wooden dowels were used to measure patterns of dune activity. Fifteen erosion pins were placed in a transect line along the center of the dune which included the windward slope, the crest, and the leeward slope (fig. 5). The erosion pins were placed every ten meters along the transect line. After the erosion pins were installed and heights

measured, the pin heights were measured weekly for two weeks to document erosion, deposition or stability at pin locations. The erosion pin locations enabled measurement of dune activity on the windward slope, the crest, the leeward slope, including sections of the dune that possess the invasive species, *C. orbiculatus*.



Figure 5: This aerial view of Castle Park dune shows the fifteen erosion pin locations (red dots) and the three Leatherman sand trap locations (yellow dots).

Leatherman sand traps were positioned at the crest of the dune to investigate whether sand grains were migrating from the windward slope to the leeward slope. The sand traps were positioned in a west-northwest direction to be parallel to the dune's central transect line; the traps were located at the inland edge of the blowout. After installing the sand traps, the trapped sand was collected weekly for two weeks, brought back to the lab, dried and weighed. The results were analyzed to determine patterns of sand transport at the dune crest.

To further investigate the activity/stability of the dune, soils were investigated. Several soil pits were dug on the leeward slope of the dune (fig. 6). The researchers also investigated the presence of soil by using a soil corer at other dune locations.



Figure 6: A researcher is digging a soil pit on the leeward slope of the Castle Park dune.

To investigate the relationship *C. orbiculatus* has with the dune, Juno Trimble GPS units were utilized. Before going to the field site, a data dictionary was created to permit recording the research locations and all the *C. orbiculatus* plants found on the dune. Three Juno Trimble GPS units were used to locate the *C. orbiculatus* plants, erosion pins, sand traps, and benchmarks on the dune. The researchers recorded individual points for all of the *C. orbiculatus* plants on the dune except for areas that were too dense to identify individual plants. Photos of the *C. orbiculatus* were also taken. Once all the data was collected, GPS data was post-processed and several maps were created within the program ArcMap 10.

Results

The distinctive topography of the windward slope and crest of the Castle Park dune is apparent on the topographic map from the survey data (fig. 7). Due to missing information, the data from the third survey which focused on the dune leeward slope is not included in the map. The dune is a blowout and reaches an elevation of 49.5 meters. The windward slope of the dune has a gentle slope angle at the bottom that changes to a much steeper slope angle in the middle to upper slope. The crest of the dune can be described as hummocky with an extended nearly flat area of more than 25 meters from west to east before the dune descends steeply on the leeward slope. The two high points on the dune crest occur closer to the windward slope and are split by a bare sand blowout which is clearly visible on a photo of the dune (fig. 8).

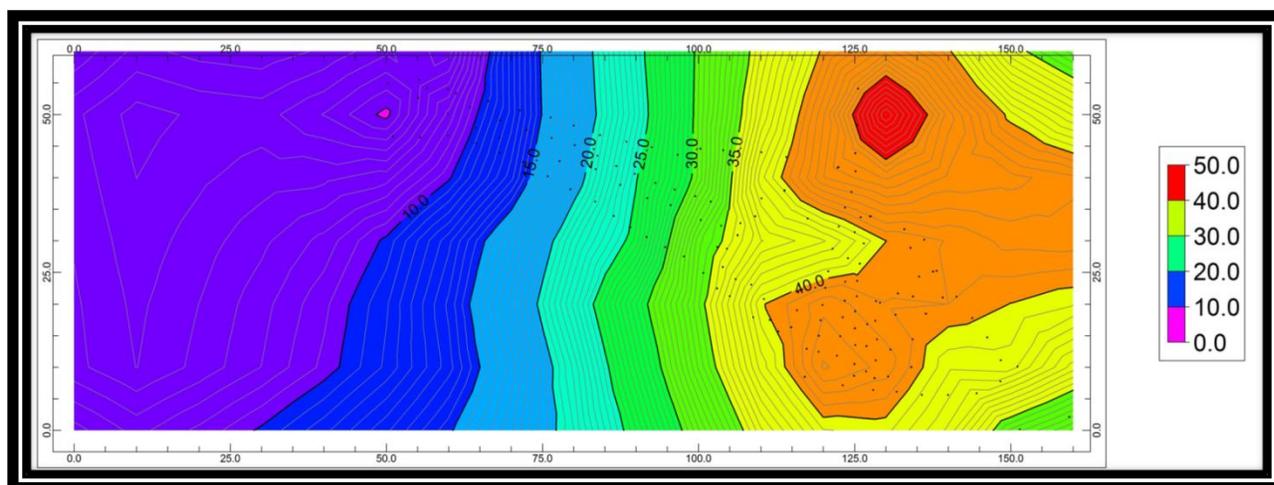


Figure 7: Topographic map of the windward slope and crest of the Castle Park dune.



Figure 8: Photo of windward slope of Castle Park dune (taken from the foredune) shows the highest point of the dune (top left), a second high point on the top right, and the blowout that splits the windward edge of the dune crest between the two high points.

The Castle Park dune is an “active” dune according to the classification of the Dune Features Inventory. Dune indicators for this classification included the following:

- a) the dune surface was not 100% vegetated,
- b) active blowouts were present,
- c) substantial areas of the dune were active,
- d) the dune is advancing, and
- e) surface composition includes bare sand, early colonizers such as *Ammophila breviligulata* on the windward slope, and shrubland/forest on the leeward slope.

The dune was not classified as “very active” because of the shrub and forest cover of the leeward slope; very active dunes typically have little to no vegetation or pioneering species on the windward slope. As well, the Castle Park dune did not show evidence of the rapid advance rates (> 1 meter per year) that are typical of very active dunes. The Castle Park dune did not fit the classification of a “moderately active” dune because moderately active dunes are not advancing, but the Castle Park dune has evidence of sand reaching the bottom of the slipface which is an indicator of dune advance.

Results from the sand traps, erosion pin measurements, and soil investigations document the spatial patterns of activity on the dune. Sand trap results show that sand is being transported over the crest of the dune (fig. 9). Some sand was collected in each trap during both weeks of measurement, with the greatest amount of sand transport measured during the November 3-10 measurement period. During several site visits, there was visible sand movement; sand transport was observed in the blowout on the windward slope and over the crest of the dune with deposition on the upper leeward slope of the dune.

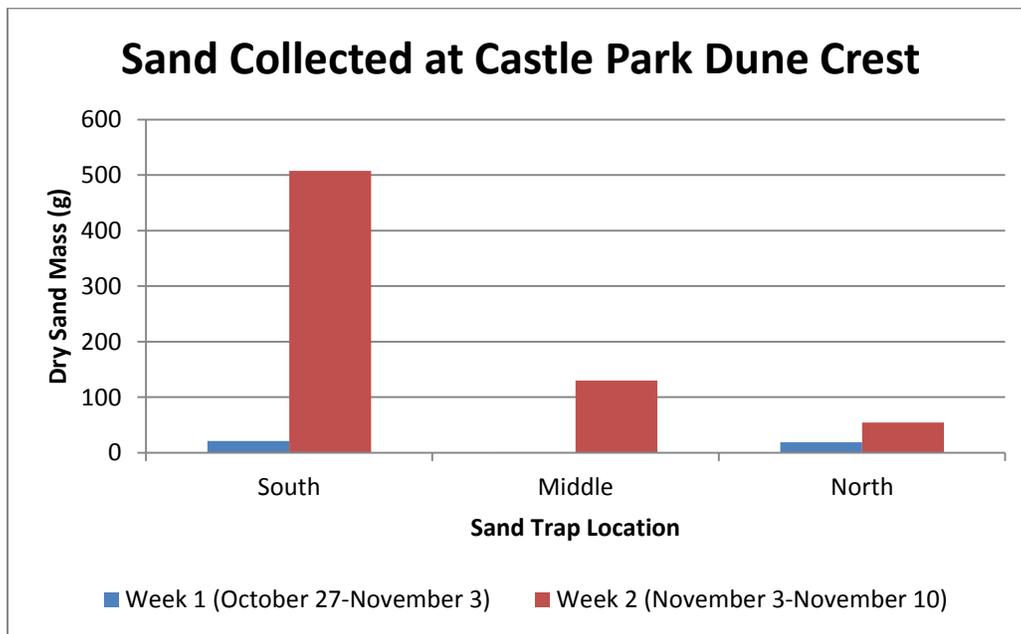


Figure 9: Amounts of sand collected at traps on the dune crest.

Erosion pin measurements show patterns of erosion, deposition and stability at different dune locations (fig. 10). The windward slope, where all pins were located in bare sand, was the site of dune activity including deposition at pin locations during the first week of measurements and erosion at the pins during the second week of measurements. Focusing on the second week of measurements, one sees that the amount of measured erosion increases towards the top of the windward slope. At and just inland from the dune crest, deposition was recorded at the pins 8-10. The pins on the upper leeward slope of the dune showed no surface change over the two weeks of measurements. Changes (mostly small amounts of erosion) were measured at the two pins on the lower leeward slope. During the study period, researchers observed no sand transport by wind or evidence of wind erosion at these pins which were located in an area of dense *C. orbiculatus*.

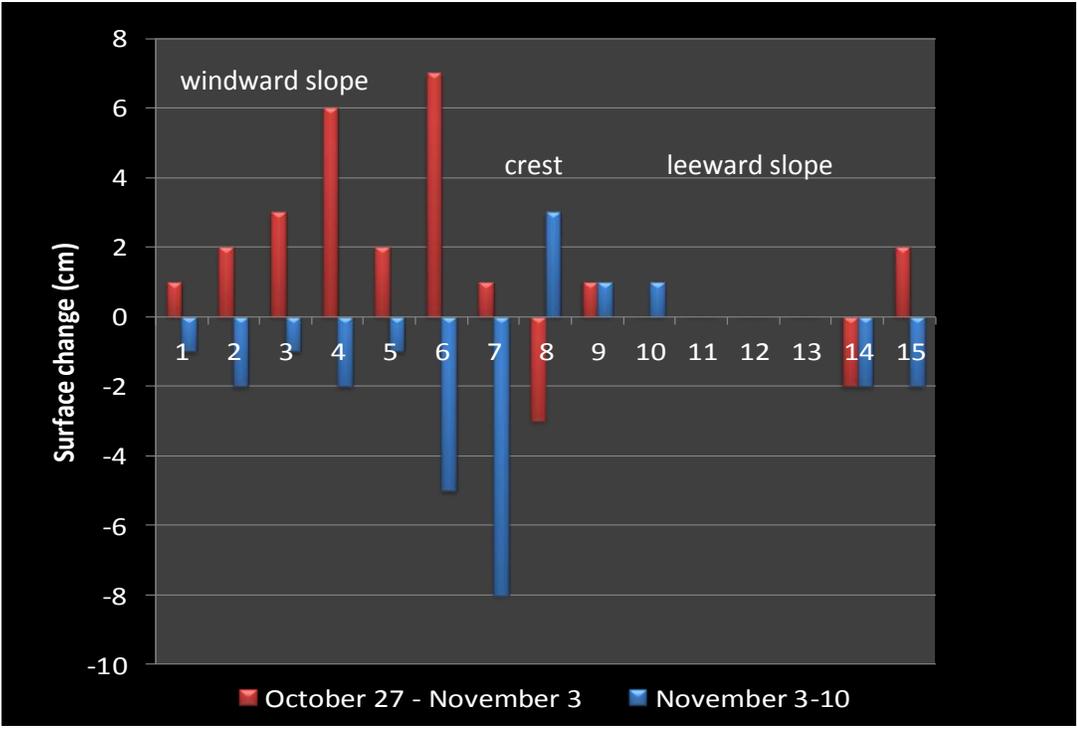


Figure 10: Surface change measured at Castle Park dune erosion pins in 2011.

The investigation of soils in the study area indicates a pattern of increasing soils on the leeward slope of the dune (fig. 11). The exposed windward slope of the dune was a bare sand surface with no change in visible sediment characteristics from the surface downward. At sampling locations on the dune crest, coring and shallow soil pits also indicated minimal soil development with small amounts of organic material present at the ground surface and a little discoloration of sand in the top centimeters of cores/pits. Figure 11 shows a soil pit on the lower leeward slope of the dune. Here a soil is present, with an organic horizon topped by leaf litter at the dune surface, a distinct A horizon of dark organics mixed with the sand minerals, and a subsoil layer (the B horizon) visible in the photo as a discolored sand layer below the A horizon. The material below the B horizon appears to be unaltered dune sand.



Figure 11: This soil pit on the leeward slope of the dune displays distinct soil horizons.

The spatial patterns of *C. orbiculatus* on the Castle Park dune include three areas of dense plant presence on the leeward slope of the dune (fig. 12). Some individual plant locations were recorded in these areas, but generally the plant density was too high to record all the plant locations. Outside of the three dense areas, all of the other individual plants are recorded on the map. There are a total of 279 dots on the map representing individual *C. orbiculatus* plants; an estimated total for the site could be 400+ plants. The *C. orbiculatus* were mostly present within the forested areas of the dune which correspond with the leeward dune slopes.

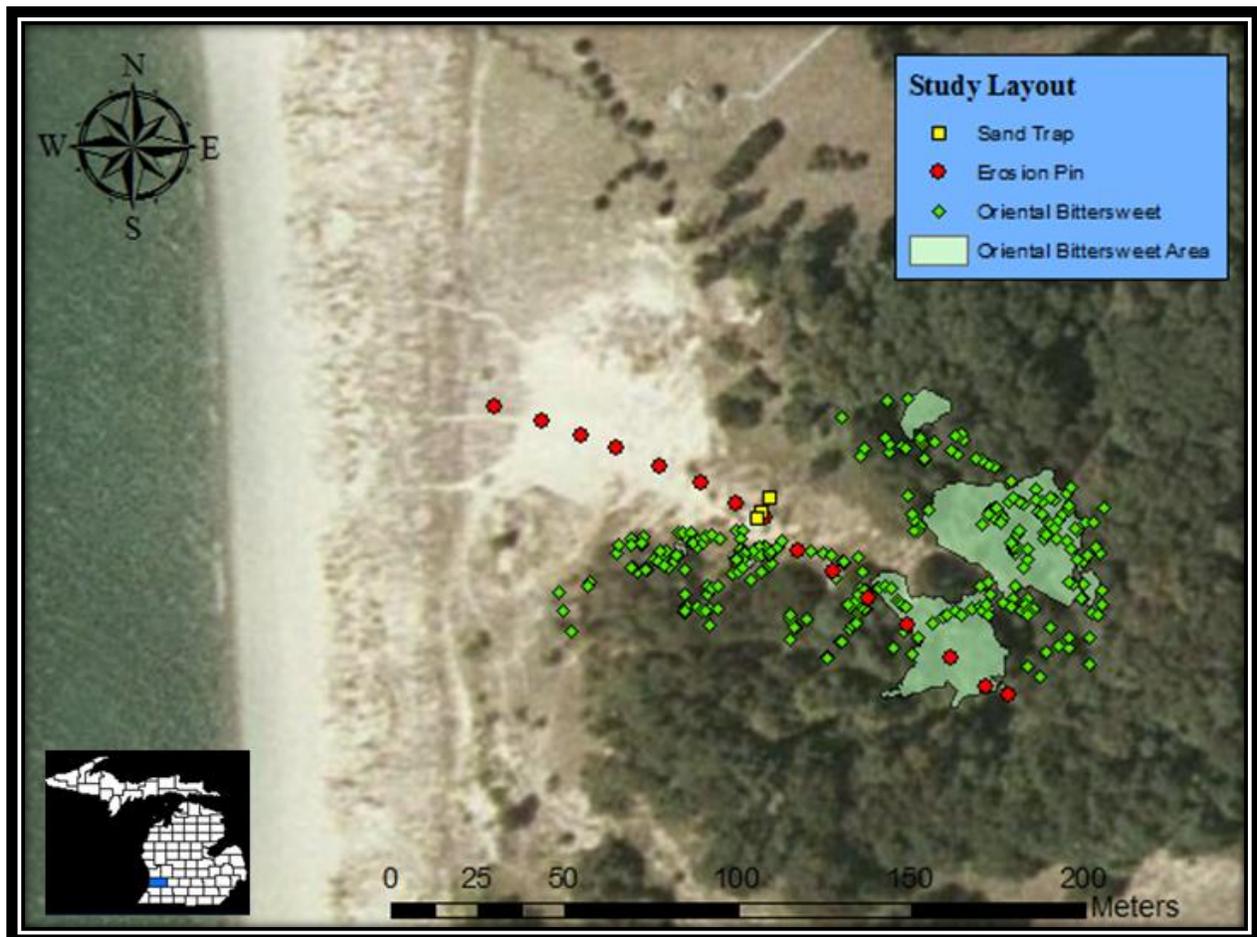


Figure 12: Spatial patterns of *C. orbiculatus* plants on the Castle Park dune. Locations of sand traps and erosion pins provide some reference points.

Discussion

The topography of Castle Park dune does not lead to an easy classification of the dune type. The dune does not have the classic u-shape of a parabolic dune, nor does it have the simple elongated, alongshore length of a dune ridge that has formed parallel to the shore. Complex and interesting shapes of dunes can indicate a variety of past influences on dune topography, such as wind direction, availability of sand to be moved, stabilization of parts of the dune surface by vegetation, etc. As dune topography develops, it also interacts with wind processes to cause areas of greater or lesser wind that can affect future dune development (Hesp *et al.* 2005; Hansen *et al.* 2009). In fact, one dune study notes that “microenvironmental differences dictate that even adjacent dunes will not be exactly alike” (David *et al.* 1999: 227).

The blowout on the windward slope of the dune is a significant component of the dune topography. A blowout is a “saucer-, cup- or trough-shaped depression or hollow formed by wind erosion on a preexisting sand deposit” (Hesp 2002: 255). Blowouts form as a result of some disturbance to a dune surface, such as animal or human activity, weather variations, or changes to vegetation (Hesp 2002). On the Castle Park dune, the blowout is cutting into the windward edge of the dune crest, resulting in a split crest effect with high points to the north and south of the split. The pattern of the blowout, combined with the unmanaged trails observed on the dune, suggest that there is a significant amount of human impacts such as people walking up or running down the dune slope. A study of pedestrian impacts on South African dunes reported that

Pedestrian pathways typically have a funnel shape, being narrow on dune crests and flaring out at dune bases. This reflects the use patterns of pedestrians who converge on the pathway from different areas and then diverge to different destinations at the end of the pathway. Intense continued use of a single pathway by pedestrians can result in characteristic ‘notching’ and lowering of dune crests and, ultimately, can cause dunes to split, thus significantly altering the topography. (Rickard *et al.* 1994: 242)

One can see this pattern of converging pathways in the air photo view of the Castle Park dune (fig. 12). Elsewhere in Michigan, van Dijk and Vink (2005) noticed a similar pattern of pathways converging and a notch forming at the dune crest at Mt. Pisgah in Holland.

All of the dune activity measurements in this study suggest that sand is being moved by wind from the blowout area onto and over the dune crest. The southern sand trap, located within the central pathway of the blowout, was the site of the highest amount of sand transport during

this study. These measurements are consistent with wind being funneled along the trough blowout and accelerating near the dune crest (cf. Byrne 1997). Deposition takes place either on the extended dune crest or the top of the leeward slope of the dune. Researchers noted small amounts of sand deposition at the bottom of the leeward slope and beyond, suggesting that during the strongest wind events, sand is transported far into the dune system. The presence of soils and forest on the leeward slope indicates that deposition rates on the lowest leeward slope are likely to be small (certainly less than a cm/year and more probably on the order of a mm/year). Although sand at the bottom of the leeward slope indicates the dune is advancing, the rate is likely to be very slow (again on the order of less than a cm per year). This study covered only a very short time period within the yearly activity patterns of the dune; better measures of deposition rates and dune advance can be obtained by repeated measurements over longer time periods.

The leeward slope of the dune is where *C. orbiculatus* is interacting with dune characteristics and activity. Mapping the presence of this invasive on the dune (fig. 12) shows a clear spatial pattern of species presence. The pattern suggests that the conditions in other areas of the dune might not be favorable for *C. orbiculatus*; such as greater amount of exposure to sun and wind, along with increased amounts of erosion on the windward slope and substantial amounts of sand transport on the dune crest. Locations of *C. orbiculatus* correspond with dune locations where there is greater surface stability, soil development, and shrubs or forest. As the dominant vegetation in some of these dune areas, the invasive plants are themselves contributing to dune surface stability and protection from wind erosion (via both the root system of the plants and the surface cover of the vines and leaves). The plants are contributing to soil-forming processes by providing organic material (leaf litter and twigs) and root activity.

Managing the *C. orbiculatus* by killing the plants is likely to have an effect on the dune, although the greatest effects may not be realized immediately. Because the plants are contributing to slope stability, their removal makes the dune slopes more susceptible to erosion. The type of erosion is unlikely to be wind erosion because of the plant locations in areas which are sheltered from the wind by dune topography. Slope processes (sliding and flowing of sand) and water erosion are the more likely results if stabilizing vegetation is removed from steep dune slopes. However, killing the plants and leaving the debris in place (as is the current Land Conservancy of West Michigan strategy) provides some measure of continued protection. The

stabilizing influences of the debris will decrease as the plant materials decompose. Ideally, other vegetation will grow to replace the decaying vegetation and will take on the role of stabilizing the slope. If the Land Conservancy of West Michigan would like to accelerate the revegetation process and encourage native dune species to return, species which will thrive on leeward dune slopes with relatively low amounts of sand deposition by wind are recommended. For example, Red Oak (*Quercus rubra*) and Basswood (*Tilia americana*) are two native species which thrive in these dune environments.

Conclusions

The investigation of the Castle Park dune reveals that the dune can be classified as an active dune with sand moving from the windward blowout over the crest of the dune and some limited dune advance. The invasive species *C. orbiculatus* is located on the leeward slope of the dune where there are more than 300 plants in both dense concentrations and some dispersed plant presence. The invasive plants are interacting with dune activity: the plants appear to thrive in the mostly stable and sheltered areas of the leeward slope and the plants contribute to slope stability and soil formation. The management of the invasive species by killing the plants but leaving the debris in place will continue to provide a measure of slope protection that will lessen as the plant remains decompose. Other plants may move into the area naturally, or managers can plant species which are well-suited to the dune environment and conditions. Because there are so few studies of the interactions between coastal dunes and invasive species, continued monitoring of the Castle Park dune is recommended.

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Appendix A: Benchmarks at Castle Park Dune

Benchmarks were placed on three trees on the leeward slope of the Castle Park dune (fig. A-1). They were placed here to account for referencing for our survey as well as future surveys conducted on the dune. The coordinates for the locations are as follows:

Point 1: Latitude: $42^{\circ}45'12.62''\text{N}$ Longitude: $86^{\circ}12'22.50''\text{W}$

Point 2: Latitude: $42^{\circ}45'12.30''\text{N}$ Longitude: $86^{\circ}12'22.42''\text{W}$

Point 3: Latitude: $42^{\circ}45'12.35''\text{N}$ Longitude: $86^{\circ}12'22.13''\text{W}$



Figure A-1: Benchmark locations at Castle Park dune.