Investigation of the Syndicate Park Dune Area

A Report to the Van Buren County Board of Commissioners

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REPORT SUMMARY

The Syndicate Park dune area is an active coastal dune area in Van Buren County located between the residences of the Syndicate Park Subdivision and Lake Michigan. Dune movement towards the subdivision threatens residential structures and property uses. In summer 2013, a team of researchers from Calvin College investigated the features, activity and influential variables of the Syndicate Park dune area. Specific study objectives were to 1) inventory the natural and anthropogenic features and activity of the Syndicate Park dune area, 2) investigate human interactions with the dune area, including patterns of human activity, demographics of visitors and neighborhood residents, and perceptions of visitors and residents with respect to the dune area, and 3) make recommendations about possible management strategies for stabilizing dune areas and reducing human impacts.

Our methods began with a field inventory of the site's natural and anthropogenic features using GPS to map surface cover (such as bare sand or vegetation communities), blowouts, and trails. We documented important characteristics of the dune features, such as dune activity levels and trail conditions. We also recorded locations of dune advance into the subdivision and used available air photo measurements to analyze dune advance rates. To investigate human interactions and influences on the dune area, we observed and recorded visitor activity in the dune area. By means of questionnaires, we asked dune visitors as well as residents of the Syndicate Park Subdivision about their visitation patterns, activities, and views of dune area problems and management. Finally, using our study results and an understanding of dune activity and management in other parts of the world, we developed some recommendations for managing the Syndicate Park dune area.

The study results show that the Syndicate Park dune area contains almost two kilometers of unmanaged trails and numerous active blowouts, including very-active blowouts which are causing the edge of the dune area to advance towards the Subdivision. The spatial patterns of trails and blowouts suggest that trampling and vehicle use on trails are contributing to the presence and activity of the blowouts. Questionnaire results show that Subdivision residents and visitors from elsewhere come to the dune area to enjoy the beach, and approximately 40% of visitors climb up into the dunes. Most residents oppose banning vehicle use within the dune area but they support other management actions such as planting vegetation or using sand fences to stabilize dunes.

We provide some examples of management strategies and considerations to assist Van Buren County with its challenge of managing the Syndicate Park dune area. Stabilizing the most active blowouts with sand fences and planting vegetation can slow or halt the dune advance into the subdivision. We recommend developing a managed trail system which can find a balance between decreasing human impacts on the dunes and providing some access to the dune crests which are a popular destination for visitors. If ATV use continues to be permitted, we recommend limiting it to the northern trail because ATV impacts at other locations are increasing dune activity and advance. Combining effective management strategies with stakeholder interests can produce a workable management plan for the Syndicate Park dune area.

INTRODUCTION

In Van Buren County, the active coastal dune area located between Lake Michigan and the residential neighborhood of the Syndicate Park Subdivision is a source of interest to a variety of people. Scientists appreciate the case study of interactions between natural processes and human actions resulting in the current landscape and activity of the site. Visitors enjoy the scenic environment for relaxation and opportunity for scenic views from the high dune crests. Nearby residents like the convenient access to the beach and dunes, but moving sand and advancing dunes threaten structures and property uses for the owners of property immediately east of the dune area. The majority property owner of the dune area, Van Buren County, faces the challenge of managing an area that draws such diverse interest from stakeholders.

In summer 2013, a team of researchers from Calvin College were commissioned by Van Buren County to investigate the features, activity and influential variables of the Syndicate Park dune area to provide information relevant to forming a management plan for the site. Specific study objectives were to:

1) inventory the natural and anthropogenic features and activity of the Syndicate Park dune area,
2) investigate human interactions with the dune area, including patterns of human activity, demographics of visitors and neighborhood residents, and perceptions of visitors and residents with respect to the dune area, and
3) make recommendations about possible management strategies for stabilizing dune areas and reducing human impacts.

This report describes the study and its results.

BACKGROUND

Coastal dunes, defined as wind-blown deposits of sand near oceans or large lakes, have a variety of types, shapes, sizes, and characteristics. The presence and activity of wind shapes the dunes, but wind patterns can vary with location, season, storms, and local influences. Surface characteristics such as sediment availability, sediment size, moisture, cementing agents, and vegetation influence whether the sediments are more or less susceptible to movement by the wind (Davidson-Arnott and Law 1996; Davidson-Arnott, MacQuarrie, and Aagaard 2005; Delgado-Fernandez and Davidson-Arnott 2011). Unlike drier desert environments, vegetation is often present on coastal dunes because of the availability of moisture to promote plant growth. The physical dune processes (erosion, sand movement, and deposition) interact with vegetation growth to 1) create distinct ecosystems because the spatial patterns of species are affected by local environmental conditions such as moisture and nutrient availability, and 2) create spatial patterns of dune activity related to the presence or absence of different types of vegetation. Human activities, including walking and driving on dune surfaces, constitute an additional set of influences on the dune behavior and features. Dune activity can also influence human interests, such as when moving sand and dune advance threaten valued anthropogenic features such as houses and roads. The environmental conditions, surface characteristics, dune processes and human activity at a particular location interact to produce a coastal dune landscape that is distinct from other locations. Therefore, although managing a coastal dune area may start with a broad base of knowledge (understanding coastal dunes in general, understanding dunes in the region), site-specific information is also required to understand important local influences and management needs.

Previous studies on dunes along the southeast coast of Lake Michigan have identified various dune types, histories and contemporary processes. The dunes formed after the region was deglaciated, with the largest dunes forming during or after the level of Lake Michigan dropped from a higher stand about 5900-5300 years ago (Arbogast, Hansen, and Van Oort 2002; Hansen et al. 2006; Hansen et al. 2010; Van Oort et al. 2001), and the smaller foredunes forming less than twenty years ago (van Dijk in press). Over the past centuries, the dunes have gone through periods of activity and stabilization, with soil forming during stable periods and dune advance (sometimes over the soils) during active periods (Arbogast, Hansen, and Van Oort 2002; Arbogast et al. 2004; Hansen et al. 2006; Hansen et al. 2010; Van Oort et al. 2001). Paleosols

(buried soils) are indicators that a dune surface was stabilized long enough for soil to form at some past date; radio-carbon dating of carbon in a paleosol can indicate how long ago that period of stability occurred. Investigations of wind-flow patterns and sand movement within large dunes (Hansen et al. 2009; Hansen et al. 2006) and the effects of storms (Yurk et al. in press) show that substantial dune change occurs during high-energy events in which winds can be steered and accelerated by the existing topography of the dunes. Studies of seasonal influences on contemporary dune change (Hansen et al. 2006; van Dijk 2004, in press) show that more dune change occurs during the fall and winter when there are stronger winds, but also changes to surface conditions such as rain, snow or freezing that make dune activity more complicated.

Lake Michigan coastal dune types include foredunes, dune ridges, blowouts of various sizes, and large parabolic dunes (Hansen et al. 2010). Foredunes are low elongated dunes that form along the inland edge of a beach where sand blown inland from the beach is deposited because of vegetation (van Dijk 2004, in press). These dunes are mostly vegetated with pioneering dune species such as *Ammophila breviligulata* (American beach grass, also known as marram grass). Additions of wind-blown sand can cause foredunes to grow wider (sometimes taking on hummocky surface topography) and/or higher. Formation of a new foredune lakeward of an existing foredune may permit ecological succession and surface stabilization on the older foredune. Blowouts are saucer-, cup- or trough-shaped depressions or hollows formed by wind erosion on preexisting sand deposits (Hesp 2002). Blowouts begin with some type of disturbance to the original dune—often a disturbance that damages or destroys vegetation stabilizing the dune surface. When wind moves sand from the disturbed area, forming a bare sand erosional area known as the deflation area, the sand is transported downwind and deposited where there is increased vegetation or a change in topography. The adjoining accumulation of sand, known as the depositional lobe, is normally considered part of the blowout (Hesp 2002). Parabolic dunes are U-shaped dunes with arms pointing upwind. Many parabolic dunes begin as blowouts that become active enough to advance or migrate beyond the pre-existing dune, leaving trailing arms behind that sometimes appear anchored to the original dune (Hansen et al. 2010).

Coastal dunes can be stable (inactive) or have levels of activity ranging from small amounts of sand movement to full-scale dune advance. Stabilization most often results from vegetation covering the dune surface and halting sand movement by wind. Over time ecological succession and soil formation occur on stable surfaces. Evidence for surface stabilization

includes indicators such as complete vegetation cover, climax vegetation communities (e.g., forests), leaf/organic litter on the surface underneath vegetation, no evidence of recent sand deposition on top of vegetation or organic material, and the presence of soils or soil forming processes such as sand discoloration. Evidence for dune activity include indicators of *erosion* such as bare sand areas, lowered topography (relative to surrounding surfaces), and exposed roots, posts or other previously buried features; *sand transport* such as visible sand movement or sand blasting of items near the ground; and *deposition* such as sand visible on top of vegetation, snow or leaf litter, and buried vegetation or posts. Active blowouts with visible deflation and deposition areas are obvious indicators that dune activity is present within a dune system. Dune advance occurs when enough sand is transported by wind over a dune so that sand reaches the bottom of the downwind slope (leeward slope or slipface) and the dune appears to move forward on the landscape. Dune advance can be slow (centimeters or less a year) to fast (a meter or more a year). Although dune advance rates of 15 meters or more per year have been measured in other parts of the world, the fastest documented advance rates in Michigan have been between 1 and 2 meters per year (Hansen et al. 2006).

There have been few studies of human impacts and dune management on Lake Michigan dunes (Amsterburg Jr. 1973; Reinking and Gephart 1978; van Dijk and Vink 2005), although studies of coastal dunes in other parts of the world provide valuable information. Coastal sand dunes are naturally popular locations for human recreation. A nearby large body of water is a focus for recreation and leisure traffic that brings people to the coastal environment, thereby giving them access to nearby dunes. People can also be attracted to the dunes themselves and the possible activities they offer, such as climbing to high points with scenic views, running down steep slopes, relaxing, viewing flora and fauna, etc. With increasing coastal popularity and leisure time, the anthropogenic pressure on sand dunes is steadily increasing (Boorman and Fuller 1977).

A significant impact by people on sand dunes is the disturbance of vegetation and other features that stabilize a dune surface. Dune visitor movement over vegetated dune surfaces, by walking, driving off-road vehicles (ORVs) or other recreational activities, causes impacts such as damaging vegetation and eroding topography. Both foot traffic (trampling) and ORVs affect dune vegetation by reducing plant heights, decreasing plant cover, decreasing species richness and diversity, and lowering soil organic matter content (Boorman and Fuller 1977; Hosier and

Eaton 1980; Kutiel, Eden, and Zhevelev 2000; Kutiel, Zhelevev, and Harrison 1999; Rickard, McLachlan, and Kerley 1994). Experimental and observational studies of trampling on dune vegetation (Boorman and Fuller 1977; Hylgaard and Liddle 1981; Kutiel, Eden, and Zhevelev 2000; Rickard, McLachlan, and Kerley 1994), including several Great Lakes' dunes studies (Bonanno, Leopold, and St. Hilaire 1998; Bowles and Maun 1982), show that vegetation cover is reduced to less than 50% after several hundred passages in a year and is reduced to less than 5% after a thousand or so passages in a year. Specific numbers depend on the type of vegetation that is being trampled as well as dune characteristics such as slope angle. For example, a study on outer dune heath in Skallingen, Denmark, demonstrated that 200 passages by one person over 4 months could create a new footpath that was 0.24 meters wide and 0.15 m deep with vegetation cover reduced by 50% and the number of species decreased by 75% (Hylgaard and Liddle 1981).

Off-road vehicles (ORVs) have similar impacts on dunes as foot traffic, but vehicles have a more severe effect because they produce significantly higher stresses on the landscape (Priskin 2003). Ten passages or less by vehicles can substantially damage vegetation, and 50 passages or less can produce trails with little or no vegetation cover and downcutting into the dune surface (Godfrey, Leatherman, and Buckley 1980; Hosier and Eaton 1980; Kutiel, Eden, and Zhevelev 2000; Rickard, McLachlan, and Kerley 1994). Some studies note that the first vehicle passages have the greatest impact on dune vegetation and subsequently a vehicle track will remain bare and open with minimal use (Godfrey, Leatherman, and Buckley 1980). If vehicle traffic is discontinued, natural recovery of vegetation takes several years at least, and ORV trails may be remain clearly visible after 8 years(Godfrey, Leatherman, and Buckley 1980). However, in comparison to foot traffic, vehicle traffic may be limited to routes through the dunes which are more accessible to vehicles(Ranwell and Boer 1986), and exploring pedestrians may be more tempted to leave existing paths than vehicle users (Rickard, McLachlan, and Kerley 1994).

Trampling and ORV use may produce individual trails or trail networks the reduce dune stability and change dune topography. *Unmanaged trails* (also known as "social" or "unregulated" trails) are the trails resulting from human impacts that are not an intentional part of a managed trail system or management plan for an area. Unmanaged trails over dunes between parking lots or road access and the beach are common (Bowles and Maun 1982; McDonnell 1981). Because trampling pressure may be greatest along these pathways, networks of small trails may be denser in these areas. Rickard et al (1994) also noted use unmanaged trail

patterns which had funnel shapes which narrowed at dune crests and flared out at the base of dunes. They attributed this pattern to pedestrians converging on the dune crest from different directions and then diverging to different destinations at the end of the pathway (Rickard et al 1994: 242). Furthermore, they described such trail use producing a characteristic 'notching' and lowering of the dune crest (Rickard et al 1994). Mt. Pisgah, a large and heavily-visited parabolic dune in Holland, Michigan, provides an example of this type of trail development leading to a notch at the dune crest (van Dijk and Vink 2005). Trails which expose dune sand to wind erosion in susceptible areas of the dunes such as windward slopes and dune crests may serve as the vegetation disturbance that can lead to blowout development. Hosier and Eaton (1980) recorded an increased number of blowouts in North Carolina dune areas that had ORV traffic present. However, they very clearly state that vehicle activity alone does not create blowouts; wind action is required (Hosier and Eaton 1980).

Managing dunes, whether for conservation, restoration or to change dune activity, has been described as a relatively unscientific activity where there is little evaluation of which approach to use or whether the chosen approach produced lasting change (Psuty 1989). Several decades later, there are more scientific studies on dune management strategies, although work on Great Lakes dunes remains limited to several studies on planting vegetation (Emery and Rudgers 2011; Maun and Krajnyk 1989) and unpublished reports (Bleeker et al. 2013; Parkin et al. 2012). Dune managers seeking to stabilize active dune areas can employ strategies such as using sand fences to slow down wind and reduce erosion or promote deposition (Grafals-Soto 2012), along with planting vegetation to stabilize the dune surface (Emery and Rudgers 2011; Maun and Krajnyk 1989). Where human impacts such as trampling and ORV use are making dune surfaces susceptible to wind erosion, reducing human impacts can be achieved by using fencing or regulations to exclude people from a vulnerable area (Santoro et al. 2012) or by using a managed trail system to limit the locations of the impacts (Carlson and Godfrey 1989). Boardwalks are a type of managed trails that use design features to mitigate the impacts of high numbers of visitors, such as keeping people from leaving the trail by using railings or enabling vegetation growth to continue by elevating the boardwalk (Carlson and Godfrey 1989).

STUDY AREA

The Syndicate Park dune area is located in South Haven Township in Van Buren County, Michigan, north of Van Buren State Park (Figure 1). We defined our study area as the unforested dune area between Lake Michigan and the Syndicate Park subdivision (Figure 2). Forested dunes formed the north and south boundaries of our study area.

Most of the Syndicate Park dune area is owned by Van Buren County. The dune area and the Syndicate Park subdivision to the east were part of a plot of land marketed by the Syndicated Press out of Chicago in 1910 (Southwest Michigan Planning Commission (SMPC) 2012). The 80-acre plot was platted into more than a thousand small lots with 20x100 feet dimensions; the lots were sold to people who bought subscriptions to the Chicago Tribune (SMPC 2012). People were expected to purchase multi-year subscriptions to obtain large enough lots for building residences. However, many owners did not receive contiguous parcels of land and the subdivision, which "pre-dates the adoption of zoning in South Haven Township", currently

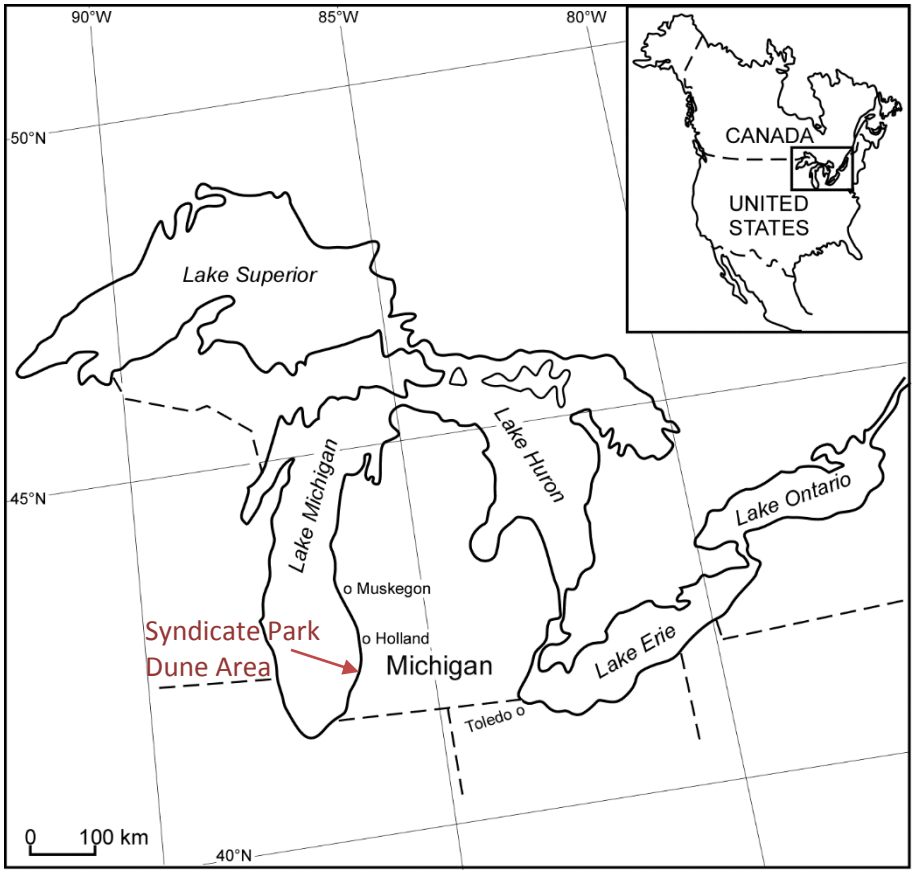


Figure 1. Location of Syndicate Park dune area and subdivision.

Figure 2. Syndicate Park dune area (outlined in blue) and Syndicate Park subdivision residences (outlined in red). Imagery from © 2013 Digital Globe, USDA Farm Service Agency and map data from © 2013 Google.

includes many small and/or non-conforming lots (SMPC 2012: 2-3). Although Van Buren County owns most of the parcels forming the Syndicate Park dune area, there remain small parcels of land within the study area boundaries that are privately-owned and undeveloped (SMPC 2012). The entire study area is designated as a Critical Dune Area under the Sand Dune Protection and Management Act (MDNR 1989).

A recent study by the Southwest Michigan Planning Commission describes the dune area as "shifting at an increasing rate" and "mostly devoid of stabilizing vegetation due to continued human impact" (SMPC 2012: 3). Analysis of air photos from 1938 to 2010 shows 129 yards (118 meters) of dune advance in 72 years along the line of Michigan Blvd (SMPC 2012). This averages to an advance rate of 1.63 m/year. Dune advance threatens several houses in the Syndicate Park subdivision and two houses have already been buried by the dunes (SMPC 2012).

The proximity of the Syndicate Park subdivision to the dune area promotes interactions between subdivision residents and the dune area. For this study, we are defining the Syndicate Park Subdivision as the properties identified in Figure 2. Residents gain access to the dune area, the beach and Lake Michigan via pathways between the subdivision and the dune area, such as the pathways extending west from Grand Avenue, Sheridan Avenue and Michigan Boulevard. Resident activities in the dune area likely contribute to the "continued human impact" described by the SMPC (2012) study. The high dunes are visible from many locations in the neighborhood, and residents along the west edge of the subdivision not only have a clear view of the eastern slopes of the dunes, but may observe changes to those slopes threatening their structures and property uses.

METHODS

Investigating Natural and Anthropogenic Features

We completed an inventory of the dune area including natural features, such as dune types and areas of activity, and anthropogenic features such as trails. We mapped features with a Trimble Juno GPS by recording *point data* to mark single locations of importance, *line data* to record extended lengths such as trails and *area data* to record closed areas such as blowouts. By setting up categories in the GPS for characteristics such as trail condition, we could use the GPS to systematically collect information about features (their attributes). We also took photographs of dune characteristics, collected two sand samples for grain-size analysis using dry-sieving technics, and used soil analysis techniques to investigate paleosol (buried soil) characteristics.

We mapped the entire dune area according to surface types of bare sand areas and vegetation communities. Bare sand areas included blowouts (described below) and other bare sand areas that showed no signs of erosion or deposition. From field observations, vegetation community categories were identified based on species present and vegetation density. The categories used for mapping were pioneering species, early successional species, and shrubby brush and/or occasional scattered trees. To reduce researcher impact on the dunes, existing trails were used to map the boundaries of vegetation types if possible.

We investigated dune activity patterns through direct field observations of dune characteristics and by using information from other sources. We looked for and recorded indicators of dune activity at the site, including locations and sizes of bare sand areas, evidence of erosion, locations of dune crests, evidence of deposition, surface and vegetation conditions, and other physical features. Mapping the current location of the base of dune slipfaces gave us a reference line for future monitoring, and we used field observations to assess whether there were structures or trees that could be used as reference points for monitoring dune advance. To classify dune activity levels, we used the categories of stable to very active as described in the Dune Features Inventory method (see Appendix A; Beachamp *et al.* 2009; Ferwerda and van Dijk 2010) . The calculations of dune advance in the SMPC (2012) study provided historical information which we analyzed to determine how dune activity may have changed between 1938 and 2010.

We identified all of the blowouts within the dune area, mapped them and recorded their characteristics. The general area, in square meters, along with the location was recorded by

walking along the outer edge of the blowout bare-sand areas with the GPS. Signs of recent human activity in the blowout such as fire pits, foot prints or tire tracks and the presence of organic litter were recorded, along with whether there is visible deposition around the feature.

We mapped and recorded the characteristics of all unmanaged trail segments in the dune area. A trail segment was defined as the visible path from one trail intersection to the next. We measured trail width in meters at three locations for each trail segment: a few meters in from each endpoint and once in the middle. We observed and recorded the density of vegetation for each segment using the categories of heavy, sparse and no vegetation. We also noted whether vegetation on a trail was trampled or not. Then we identified the observed use of each segment as either: walking, ATV, both (ATV and walking) and undistinguishable. We also looked for signs of recent human activity such as footprints or tire tracks.

To analyze the collected data, we downloaded and post-processed all line, point and area data collected with the GPS, and then imported the data into ArcGIS 10 (ArcMap). We mapped the data as layers which were superimposed on an air photo of the dune area. Each of the trail segments and blowouts were assigned numbers, and the attributes of the features were associated with those numbers. Using the GIS, we examined the data for spatial patterns of different features and their attributes. We analyzed vegetation and blowout patterns to locate the areas with the most sand transport as well as areas that are more stabilized.

Investigating Human Interactions with the Dune Area

During our field measurements, we directly observed visitor activities in the dune area. We recorded the activities we observed, where they happened and how many people participated. We analyzed the data to identify patterns of visitor activity, as well as the main access points to the dune area. We also compared the observed activities with the activities reported by visitors or Syndicate Park Subdivision residents on questionnaires.

We created and administered two questionnaires to investigate visitor and Syndicate Park Subdivision resident demographics, activities, and perceptions of the dune area and possible management of the dune area. These questionnaires were designed using similar questions to the study by van Dijk and Vink (2005) at Mt. Pisgah, with additional questions specific to the Syndicate Park dune area situation. Demographic questions focused on where visitors came from, how they got to the dune area, group sizes and ages. Respondents were asked to identify

the activities they participated in when visiting the dune area, as well as the season(s) in which they visited. Perception questions asked respondents to identify dune-related problems, their level of dune knowledge, their observations of dune changes, and their opinions of various dune management and interpretation activities. Before administering the questionnaires, both were approved by a Van Buren County Commissioner and the Institutional Review Board at Calvin College. The questionnaires can be seen in Appendix B (Visitor Questionnaire) and Appendix C (Resident Questionnaire).

The Visitor Questionnaire was given to visitors seen during pre-determined sampling periods. In order to get a representative sampling of visitors, a random stratified sampling method was used. A two-week period in July 2013 was stratified into the categories of weekdays (Monday through Friday) and the weekend (Saturday). The samples were further stratified into morning (8am to 12am), afternoon (12am to 4pm), and evening (4pm to 8pm) time periods. From the week days, two morning, two afternoon and two evening time periods were chosen randomly (using a random number generator). One Saturday was chosen and questionnaires were administered in the morning, afternoon and evening of that day. The Visitor Questionnaire was administered on the beach area on the western end of the dune area. Visitors were approached and asked if they would be willing to fill out a short survey. If there was a large group, a representative was asked to fill out a survey for the whole group.

The Resident Questionnaire was administered to 44 residences in the Syndicate Park Subdivision (as defined in Figure 2). These questionnaires were distributed door to door. If the resident was not home, a letter describing the study was left along with the questionnaire and return postage with instructions to send the completed questionnaire in the mail. To prevent possible duplication and submission of multiple responses, each survey had a unique number written on the back. Confidentiality was maintained by shuffling the questionnaires before administering them and after collecting them so that researchers could not match numbers with residences.

Completed questionnaires were analyzed by coding the responses and using spreadsheet software (Excel) for descriptive and comparative statistics as well as plotting the data. We compared similar questions in both the questionnaires to each other to investigate whether there were different perceptions between the visitors and residents. We also compared the reported activities with observed activities and evidence of human impacts on the dunes.

RESULTS

Natural and Anthropogenic Features of the Syndicate Park Dune Area

Dunes and Surface Characteristics

The Syndicate Park dune area contains a system of connected dunes rather than a single dune (Figure 3). At the lakeward (west) edge of the dune system is a sand and cobble beach that was roughly 6 meters wide in July 2013 as measured from the shoreline to the lakeward edge of the foredune. A foredune up to 3 meters in height is continuous along the north-south length of the dune area. The foredune is predominantly covered by grasses with a few trails cutting through the vegetation. East of the foredune is a small interdune area of gravelly sand and a sparsely-vegetated area at the base of the larger dunes to the east. The larger dunes have heights of 10-50 meters above Lake Michigan. They have a variety of shapes including mounds, ridges and blowouts, with vegetation cover ranging from none within active blowouts to full coverage by grasses and shrubs on more stabilized slopes and dunes (Figure 4). The sediment in the Syndicate Park dune area is a moderately-sorted fine sand that has a mean diameter of 0.23 mm and is strongly course skewed.

Figure 3. View from north looking southwest at dunes in the Syndicate Park dune area.

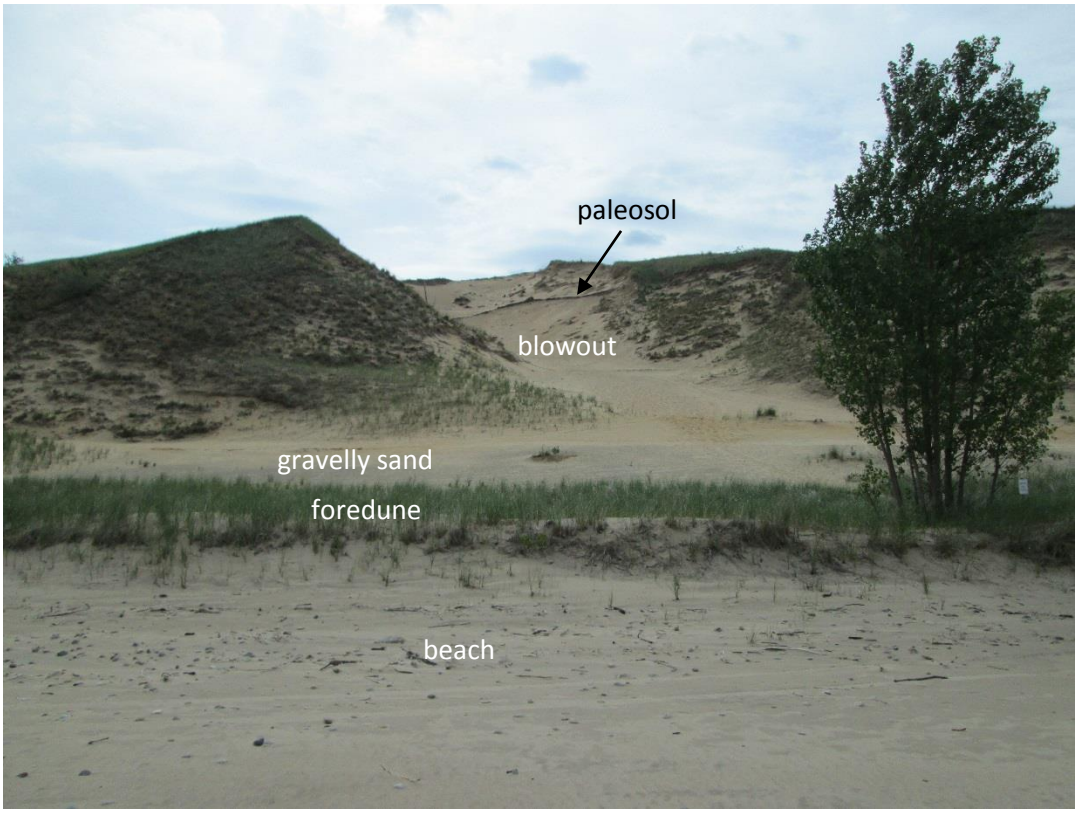


Figure 4. View from beach looking east at largest blowout (with paleosol).

Several paleosols (buried soils) are exposed in blowouts, such as the paleosol present approximately three-quarters of the way to the crest of the southernmost blowout (Figure 4). This paleosol had a profile (Figure 5) comprised of 4 major layers including a top layer of sandy clay loam (13 cm) above a layer of sandy loam (10 cm) above a layer of loamy sand (18 cm). The bottom-most layer of the plaeosol was sandy clay (7 cm) on top of slightly weathered dune sand. Other paleosols also had layers consisting of different textures of soil including sandy clay loam, sandy loam, loamy sand and sandy clay.

Surface cover across the dune area included bare sand areas and three different types of vegetation communities (Figure 6). Pioneering species consisting mostly of *Ammophila breviligulata* (American beach grass or marram grass) covered the greatest area (approximately 8000 m^2; see Table 1). A mix of early-successional species, consisting of grasses, wild grape and other herbaceous vegetation covered the smallest area at 2100 m^2. Vegetation including shrubs and scattered small trees covered about 7500 m^2. There were no forested areas within the study area boundaries, although forested dunes were present to the north and south. Bare sand

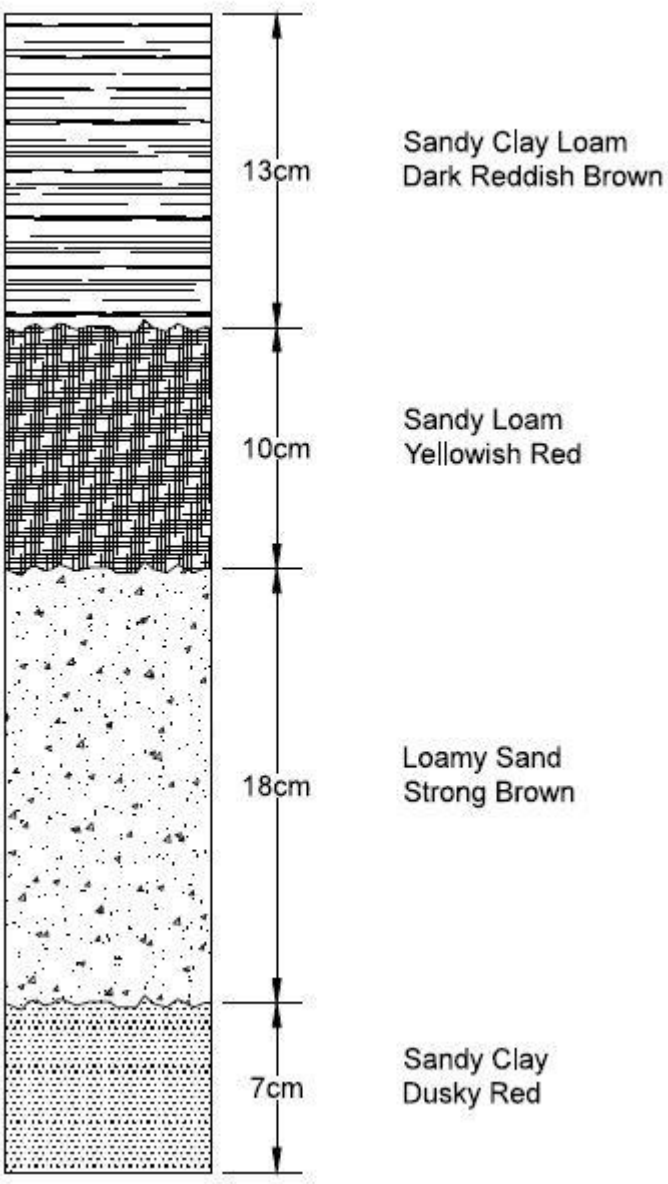
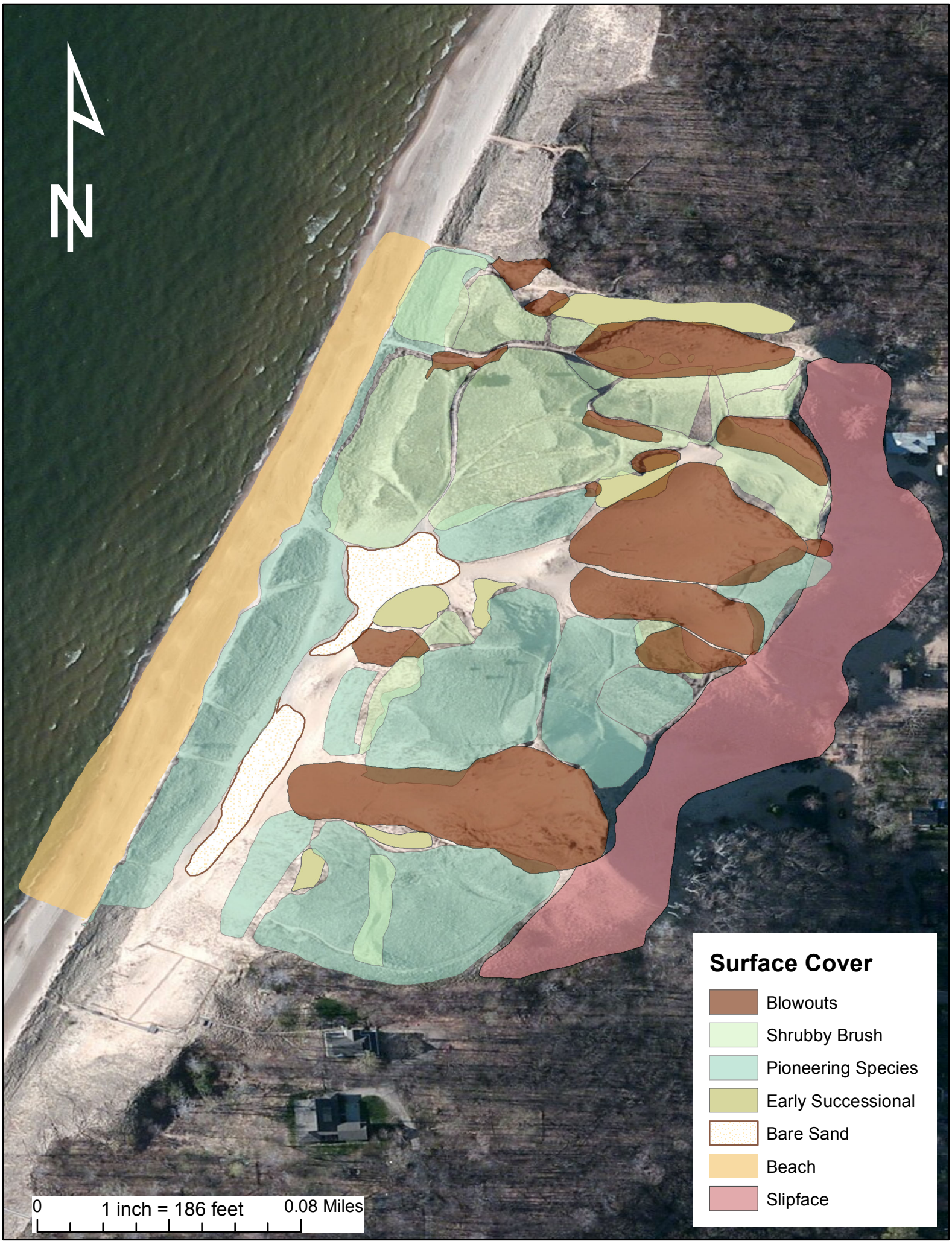


Figure 5. Profile of paleosol in blowout 1 (Syndicate Park dune area).

Figure 6 (next page). Types of surface cover in the Syndicate Park dune area. (Disconnected boundaries are a function of the mapping technique.)


N
Surface Cover
Blowouts
Shrubby Brush
Pioneering Species
Early Successional
Bare Sand
Beach
Slipface
0
1 inch = 186 feet
0.08 Miles

Surface Cover Type	Area (square meters)	Area (percent of total)
Bare sand – blowout	10,410	35%
Bare sand – not blowout	1,664	6%
Pioneering species	7,991	27%
Early successional species	2,461	8%
Shrubby brush and scattered trees	7,522	25%
Total Area	30,048	

Table 1. Types of surface cover mapped in Syndicate Park dune area.

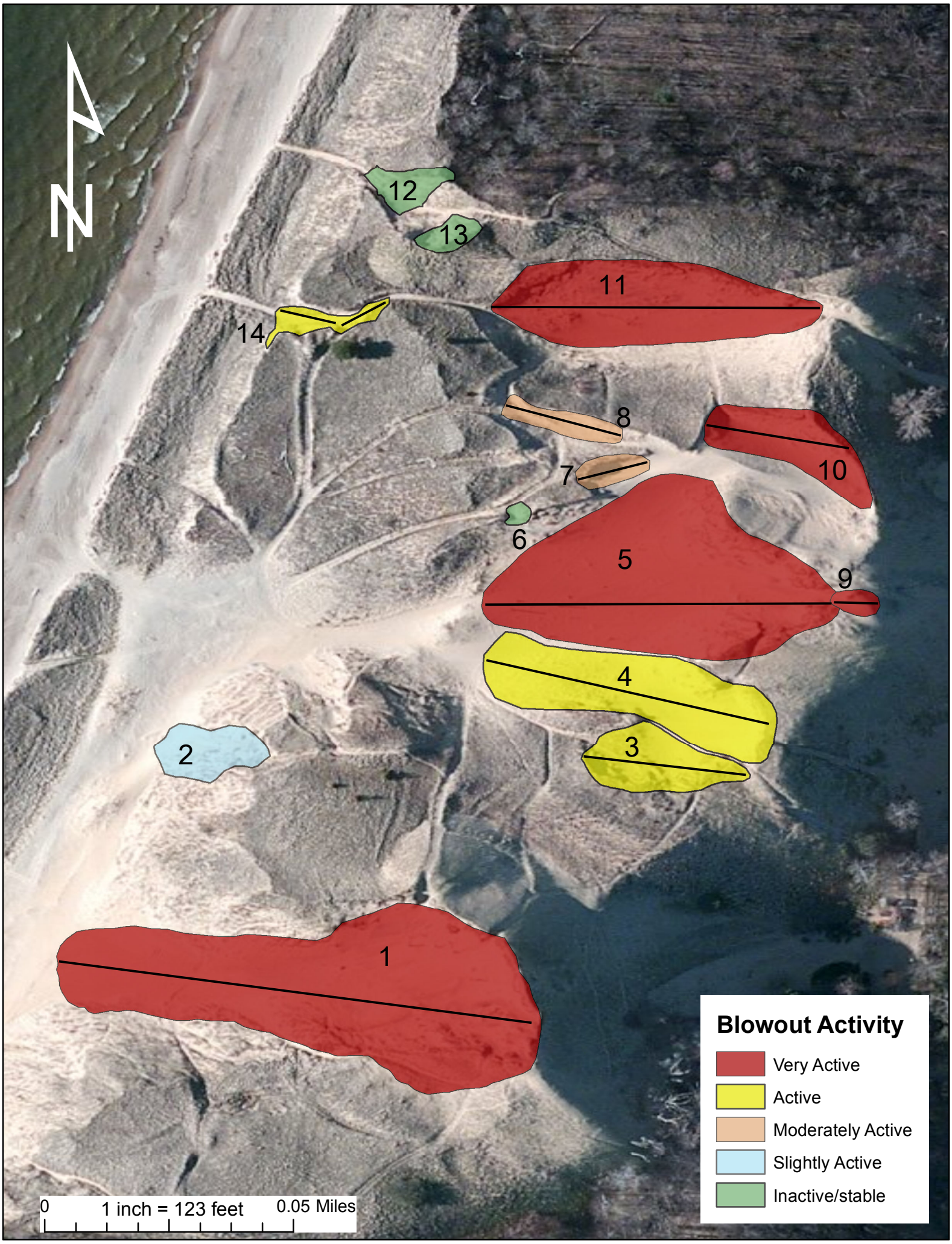
areas were classified as beach, areas of bare sand without visible signs of erosion or deposition, or blowouts. The beach forms the western boundary of the dune area and its mapped area is not included in the totals because the size depends on the level of Lake Michigan. Two areas of bare sand with gravel visible at the surface were present between the foredune and the larger dunes to the east. Together these bare sand areas covered an area of 1750 m^2. The bare sand (deflation) areas of blowouts covered 10,410 m^2 (or 35%) of the study area.

Blowouts

There were 14 different blowouts identified in the dune area (Figure 7). The sizes of their deflation areas ranged from 3272 m^2 to 32 m^2 (Table 2). Many of the deflation areas were bare sand or sparsely vegetated with scarps at the boundary between the deflation area and adjacent denser vegetation (Figure 8). Most of the blowouts were aligned in a similar direction with an east-west orientation.

Blowout activity ranged from inactive/stable to very active. Three blowouts were rated as *inactive/stable* because they were fully vegetated, had organic litter visible on the ground surface, and showed some evidence of soil formation. Three blowouts were classified as either *slightly active* or *moderately active* with dune surfaces stabilized by vegetation with some areas of bare sand and evidence of erosion—in other words, there were small blowout areas on a mostly stabilized dune. Three *active* blowouts had evidence of significant sand movement but had more vegetation cover than the very active blowouts. Five blowouts were classified as *very active* because they had little or no vegetation cover along with evidence of substantial wind

Figure 7 (next page). Blowouts in the Syndicate Park dune area.


N
12
13
11
14
8
10
7
6
5
9
4
3
2
1
Blowout Activity
Very Active
Active
Moderately Active
Slightly Active
Inactive/stable
0
1 inch = 123 feet
0.05 Miles

Blowout #	Area (m^2)	Activity Level	Visible Deposition	Visible ATV Tracks
1	3271	Very active	Yes	Yes
2	336	Slightly active	No	No
3	548	Active	No	No
4	778	Active	Yes	No
5	2801	Very active	Yes	Yes
6	585	Very active	Yes	No
7	76	Moderately active	Yes	No
8	32	Inactive	Yes	No
9	146	Moderately active	Yes	No
10	1328	Very active	No	Yes
11	143	Active	No	Yes
12	121	Inactive	Yes	No
13	193	Inactive	No	No
14	52	Very active	Yes	Yes

Table 2: Blowout characteristics

Figure 8. Blowout #3 is a very active blowout with a well-defined deflation area (bare sand) that has scarping along the edges where wind erosion is exposing roots of grasses holding the sand in place.

erosion and sand transport. Of the 14 blowouts, 8 had areas of visible deposition. All of the blowouts that were nearest to the homes in the subdivision had visible deposition on the slipface.

Blowouts had a range of signs of human activity within the boundaries of the blowouts: 4 had footprints and 5 had footprints as well as ATV tracks (Figure 9). Nine blowouts also had trash or organic litter within the boundaries.

Figure 9. ATV tracks are visible in Blowout 1 on 19 June 2013.

Dune Advance

Field observations, confirmed by reported observations from subdivision residents, indicated that the base of the slipface mapped in Figure 6 is advancing eastward. The greatest visual evidence of advance occurs where the southern ATV trail comes out in to the neighborhood. Other locations with evidence of significant advance are where the three other trails descend the slipface and enter the subdivision—these are visible on Figure 6 as the places where the slipface extends further into the neighborhood.

Measurements from air photos (SMPC 2012) at Michigan Boulevard show that at this location the dune has been advancing eastward since 1938 (the earliest air photo date), with a total advance of 118 meters between 1938 and 2010. The rate of dune advance has not been consistent from one measurement interval to the next (Figure 10). Between 1955 and 1967, the advance rate was almost 5 m/year compared to approximately 0.6 m/year between 2005 and 2010.

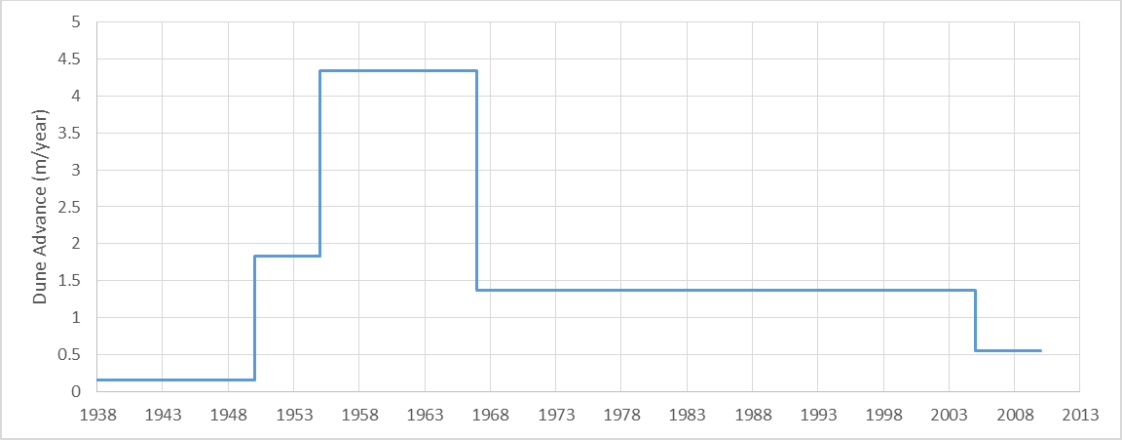


Figure 10. Dune advance rates (m/year) as measured from changes between slipface locations on airphotos from 1938-2010.

Trails

In the dune area there are 38 trail segments which combine to form a total trail length of 1.968 km (Figure 11). Trail widths ranged from a minimum of 0.23 meters wide to a maximum of 2.3 meters wide (see Appendix D). Over 90% of the trail segments had widths greater than 0.5

Figure 11 (next page). Trails in the Syndicate Park dune area.


N
0
1 inch = 180 feet
0.08 Miles
Types of Trails
Main ATV Trails
Unmanaged Trails

meters, and 50% of the trail segments had widths between 0.5 and 1.0 meters. Vegetation cover on the trails ranged from bare sand (no vegetation) to fully vegetated (Figure 12). The most common vegetation cover was sparse vegetation with 16 segments.

The two main observed uses of the trails were walking and driving an ATV (Figure 13). Of the 38 trail segments, 26 segments had evidence of walking as the only use. Five segments were used for both ATV's and walking and 7 segments only showed evidence of ATV traffic. The two trails that were most frequently used by the ATVs were the widest and had the least vegetation on the dune. Some sections of these main trails were incised more than 2 meters into the dune surface. At the eastern edge of the southern ATV trail there was a significant mound of sand at the bottom of the dune slope. Some areas along the edge of the trail had exposed roots and vegetation being eroded away (Figure 13b).

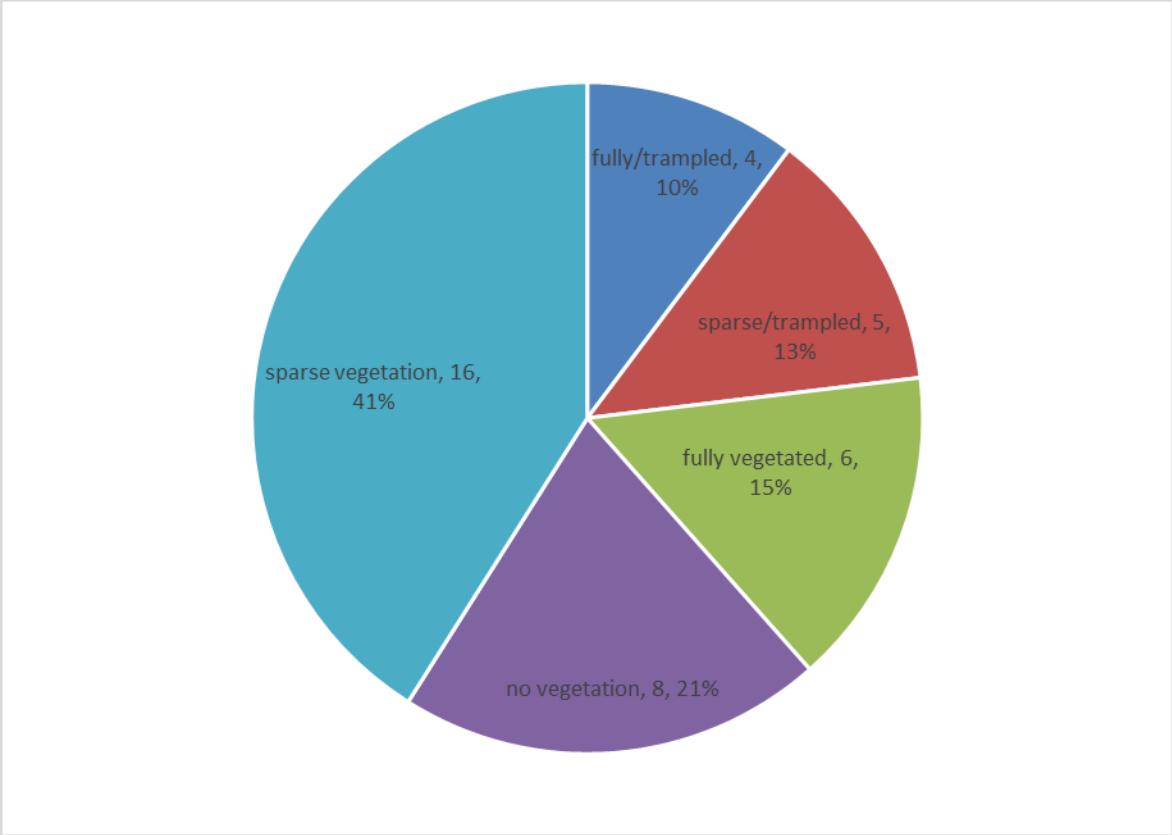


Figure 12. Types of vegetation cover on trail segments in the dune area. Numbers show the number of trail segments in the category (out of 38 total segments) followed by percentage of trails in the category.

Figure 13. Trail characteristics and uses include a) a network of interconnected trails used for walking and b) trails used by walkers and ATVs.

Human Activities in the Dune Area

During the 56 hours that we were at the dune area in June and July 2013, we observed a variety of visitor activities in the dune area (Figure 14). Most people that visited the dune area were walking on the beach, and the majority of the walkers did not climb up into the dune. The largest group of people that climbed into the dune consisted of at least 15 people that swam to shore from boats and climbed into the southernmost and largest blowout in the dune area. Another 10 people who did not come from boats were seen climbing up into the largest blowout. Approximately 10 people were seen walking through the forested area north of the dune area from the neighborhood to the beach. At least 8 different ATVs were observed in the dune area. All of the observed ATVs were being driven on the neighborhood-established ATV trails and on the beach. However, fresh tracks from ATVs were seen off these paths, specifically inside the largest blowout to the south (blowout 1).

Figure 14. Young dune visitors digging holes and playing in sand of Blowout #1.

Visitor and Resident Demographics and Perceptions

Visitor and Resident Demographics

During the 32 hours from July 2-20 when questionnaires were administered to dune area visitors, 34 were completed and 8 people declined to participate for a response rate of 81%. The 34 completed questionnaires represent 148 visitors to the dune area. Visitor participation was spread out evenly across the weekday sampling periods, with fewer visitors encountered on Saturday morning and afternoon but a larger number of visitors encountered on Saturday evening (Figure 15).

Out of the 44 Resident Questionnaires handed out, one was completed at the door and 26 were mailed back, giving a 61% response rate. The 27 completed questionnaires represent 74 people living in the subdivision.

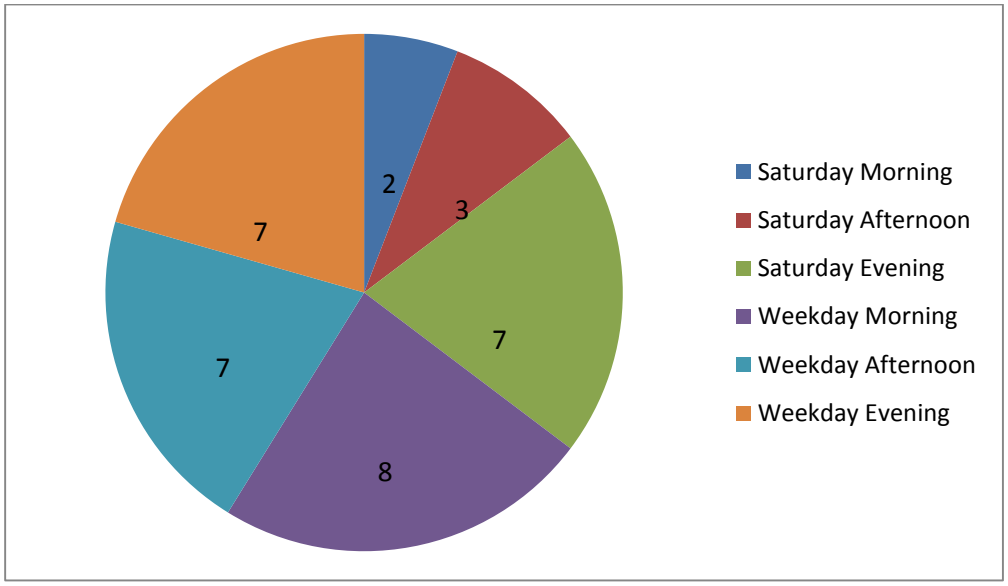


Figure 15. Timing of responses to Visitor Questionnaires. Note that each weekday time period shows the combined results from two days of questionnaire administration and the Saturday time periods represent one day of administering questionnaires.

Dune Area Visitation Patterns by Visitors and Residents

Most visitors got to the dune area by walking on the beach, but 11 people said that they had parked in the neighborhood and walked over the dune (Figure 16). Only two visitors reported getting to the dune area by boat; however, their reported group sizes reported were the largest of all the visitor groups encountered. In the "other" category, two visitors reported that they got to the dune area by ATV; one visitor reported driving, and another visitor reported "*Walked over dune from home*." Twenty-two out of the 34 questionnaires were filled out by people from Michigan, and a majority of those were from South Haven or Kalamazoo. In total, there were visitors from 7 different states, including some as far away as Oregon and Texas.

Almost 77% (26 people) of the visitors encountered in the dune area reported that they had visited the dune area before the current visit. All of the resident respondents reported that they had visited the dune area at least once. The reported frequency of visiting the dune area (Figure 17) shows that residents visit the dune area more frequently than visitors. The majority of visitors and residents visit the dune area several times a year to several times a month. All visitors were encountered during the summer, but roughly 45% reported also visiting the dune area in the spring and/or fall (Figure 18). Residents also visited the dune area most frequently in the summer (96%) and they visited the dune more frequently than visitors in other seasons. People reported visiting the dune area least often in the winter, with only 15% of visitors and 37% of residents reporting winter visits.

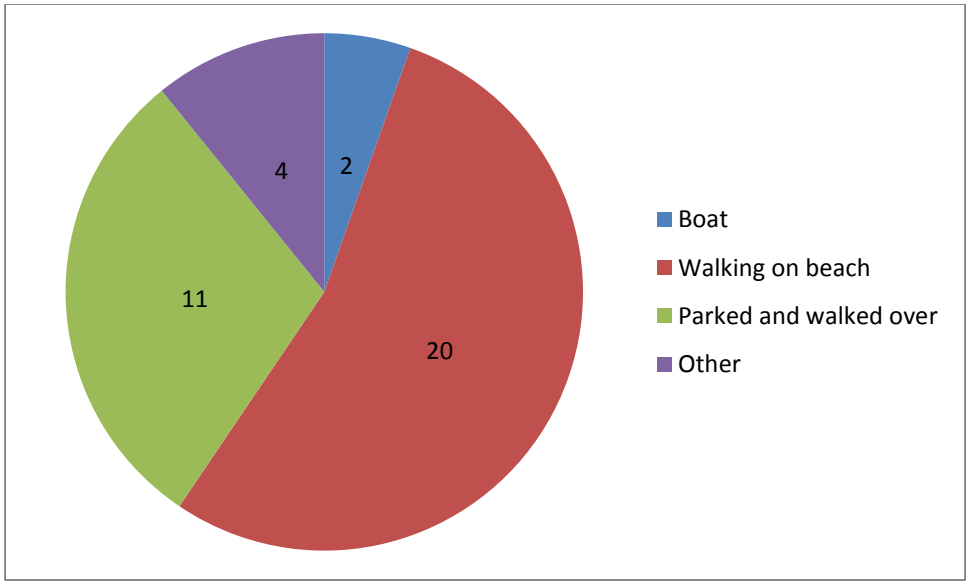


Figure 16. How visitors reported getting to the dune area.

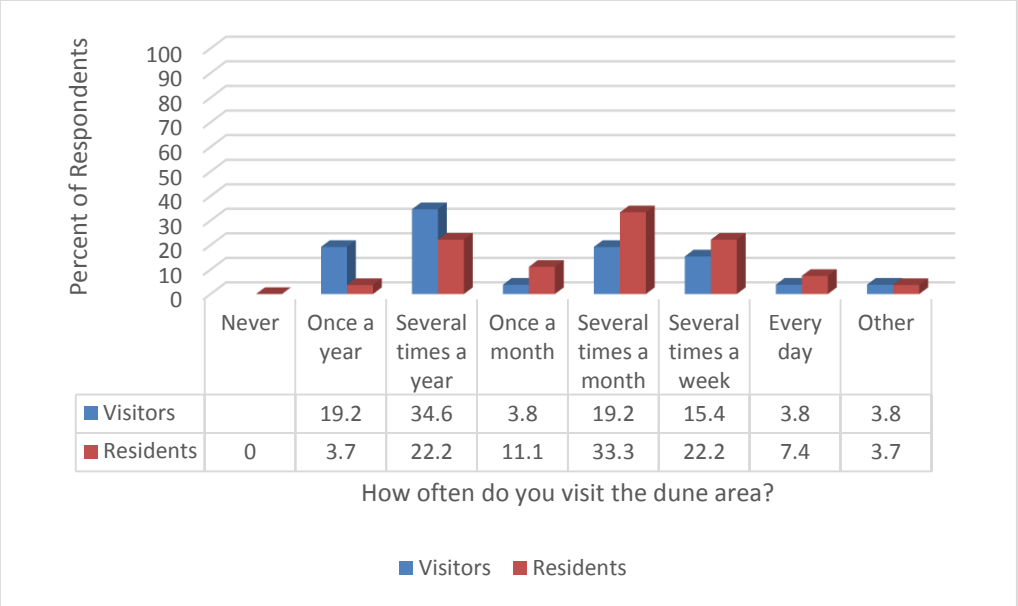


Figure 17. Frequency of visiting the dune area reported by returning visitors and residents.

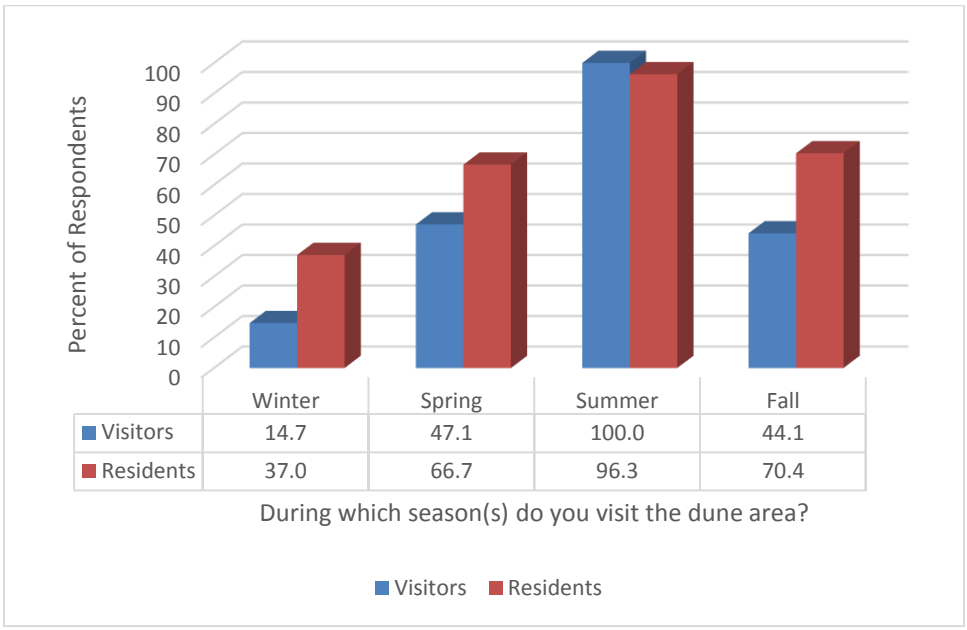
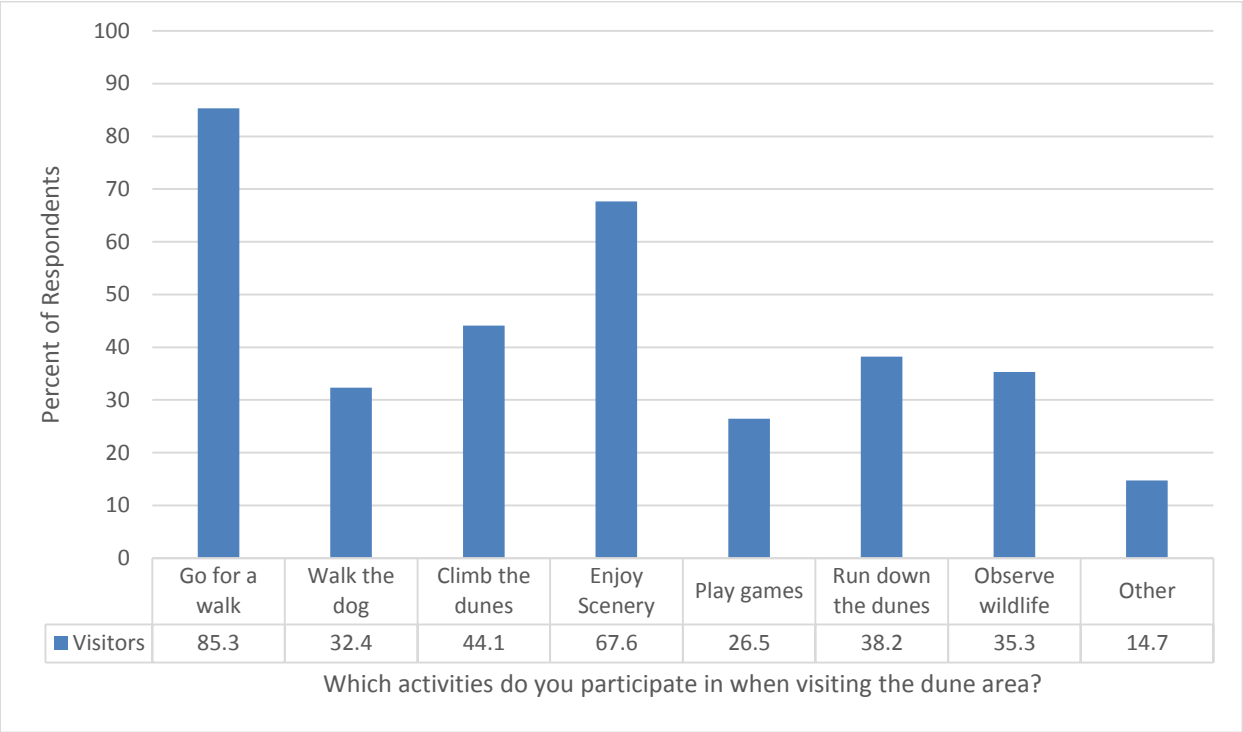


Figure 18. Seasons in which visitors and residents visit the dune area.

Reported Activities in the Dune Area

The reported activities of the visitors and residents can be seen in Figure 19. For both visitors and residents, the reported activities with the highest frequency were *going for a walk*



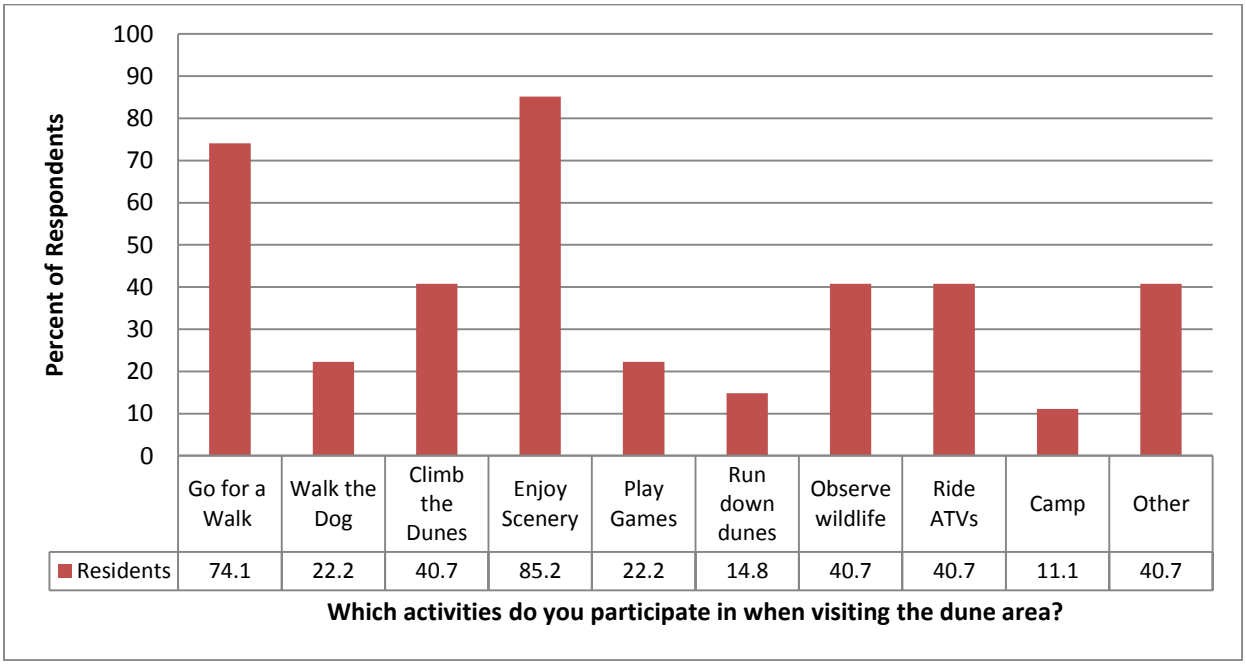


Figure 19. Activities in the dune area reported on Visitor Questionnaires and Resident Questionnaires.

and *enjoying the scenery*. The other category in the visitor data included swimming, rock collecting, jet-skiing, and riding ATVs. The other category in the resident data included the above things as well as enjoying the beach and picking up trash.

Visitor and Resident Perceptions

Residents report higher levels of knowledge about sand dunes compared to dune area visitors (Figure 20). On a 5 point scale with 1 indicating almost no knowledge and 5 indicating a lot of knowledge, the median response for dune visitors was a 3 and the median response for residents was a 4.

Both visitors and residents were asked to identify problems/annoyances on the dune from a list of ten items. The visitors mostly indicated that the listed items were either no problem or a minor problem, with only litter identified as a moderate-major problem by more than half of the respondents (Figure 21; additional data in Appendix E). Residents indicated that a number of the items were no/minor problem, but several items had a significant number of responses in the moderate or major categories (Figure 22). "Litter" was most frequently identified as a moderate problem, and 58% of the respondents identified litter as either a moderate or major problem. For both "Damage to dune" and "Dune advance", approximately 1 out of 5 respondents identified the item as a major problem.

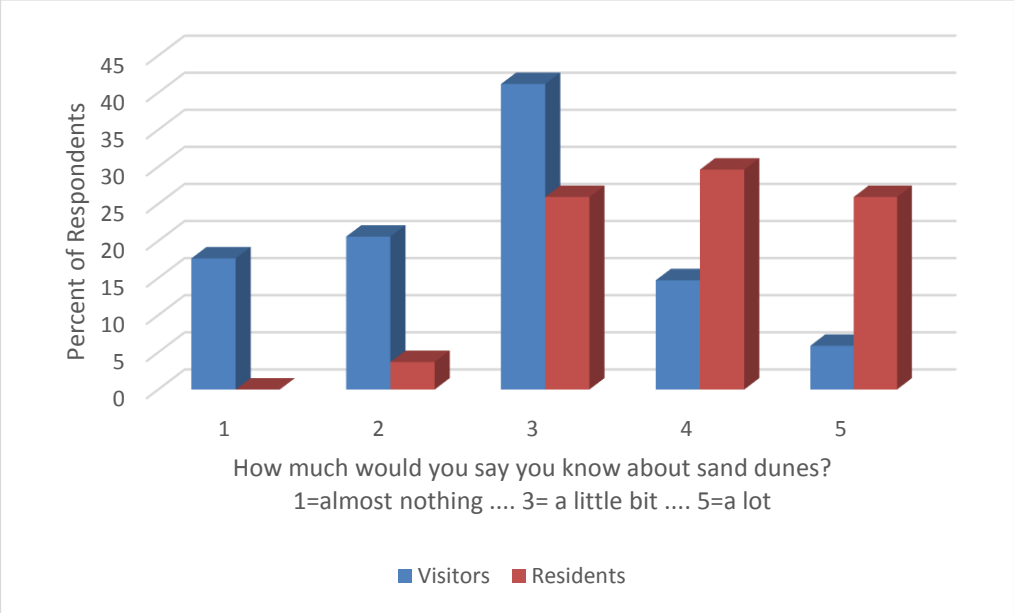


Figure 20. Self-identified amount of knowledge about sand dunes.

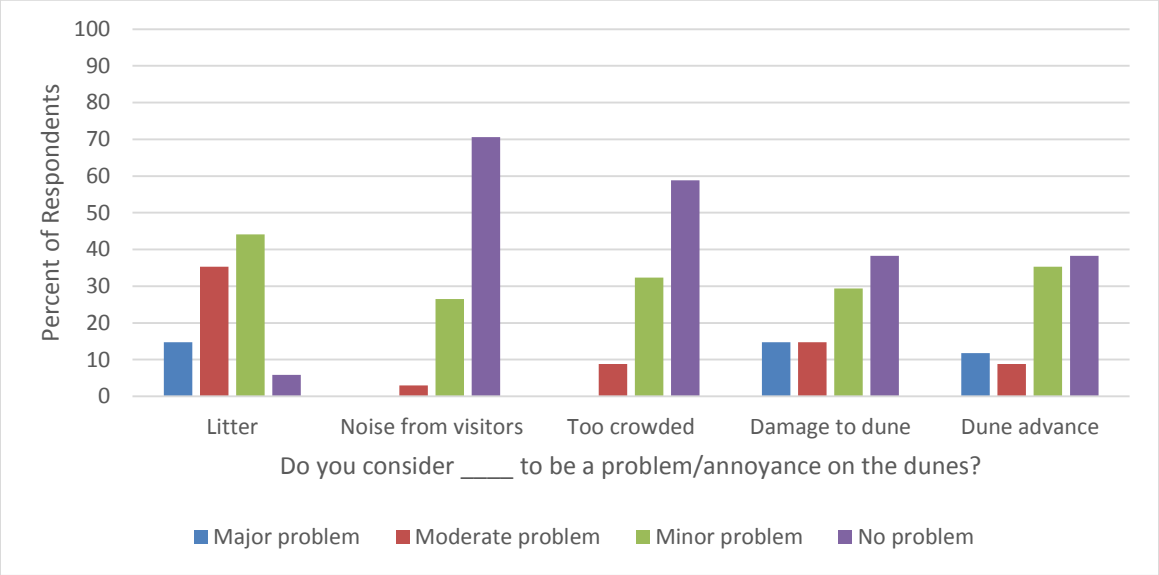


Figure 21. Visitor responses to the question "Do you consider the following to be problems/annoyances on the dune?"

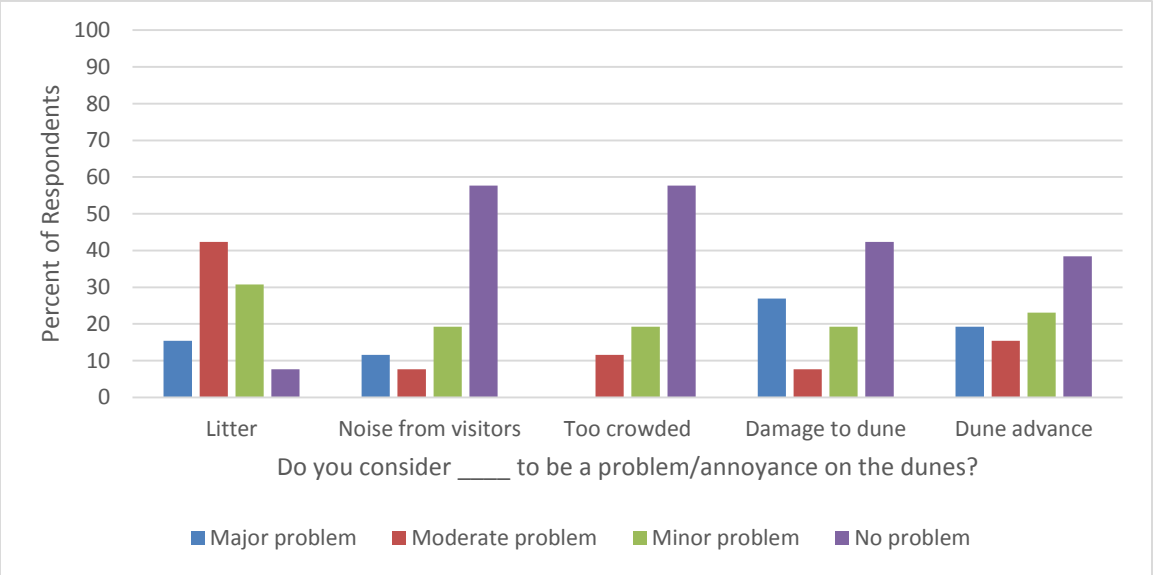


Figure 22. Resident responses to the question "Do you consider the following to be problems/annoyances on the dune?"

Residents indicated a variety of opinions on dune management and interpretation activities (Figure 23). The residents were mostly in favor of planting dune grass and installing sand fences on the dune surface. Almost 75% of the respondents said they either strongly favored or favored planting dune grass, and almost 60% said that they either strongly favored or favored installing sand fences. The responses indicated split opinions about the idea of building a boardwalk, with slightly more responses indicating opposition (48%). Responses to the idea of installing interpretive/informational signs were fairly evenly distributed from strongly favor to strongly oppose. Most resident respondents were neutral or opposed the idea of educational programs on the dune area. Resident responses were split towards the idea of limiting vehicle access, with almost equal numbers of responses opposing and favoring this idea. However 71% of resident respondents were opposed or strongly opposed to banning vehicle use.

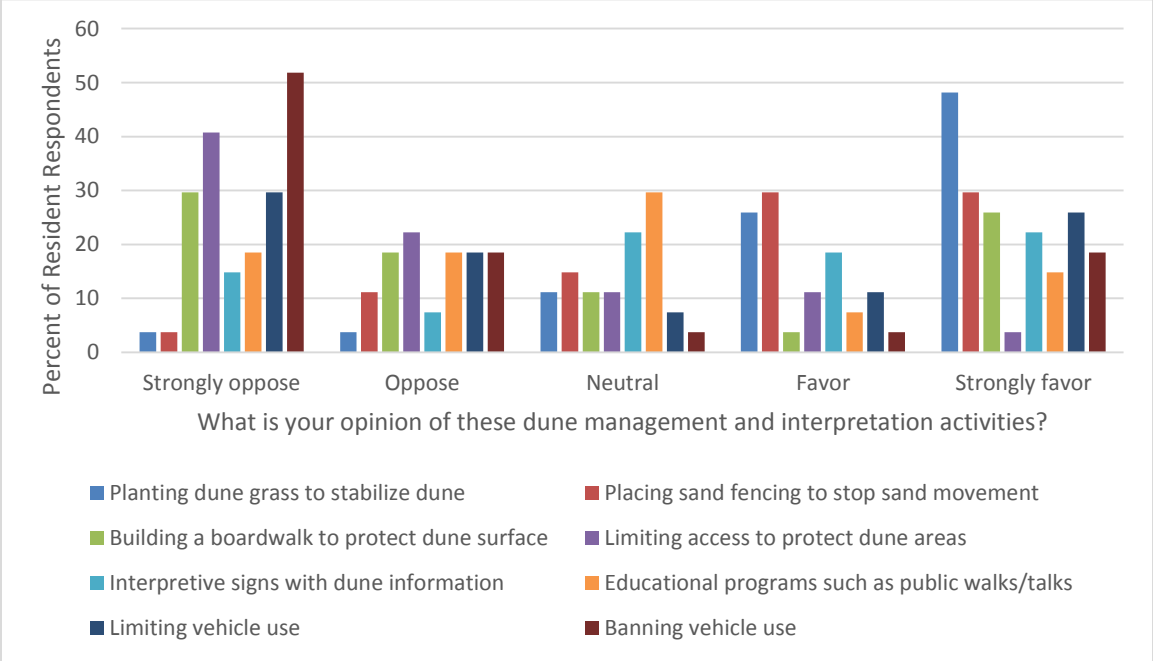


Figure 23. Resident opinions of dune management and interpretation activities.

More than 55% of resident respondents identified themselves (the Syndicate Park residents) as responsible for the dune area; and 48% identified the State of Michigan as the responsible body (Figure 24). Only 26% identified Van Buren County as responsible, although the County owns most of the land in the dune area. One person commented that responsibility was a combination of all options and that the implementation would depend on involvement in the community. A number of respondents picked more than one answer to this question. Responses were different for the question "who do you think will do the most work to make the management strategies happen?" (Figure 25). More residents identified Van Buren County (37% of respondents) compared to Syndicate Park residents (30%). Most of the "other" responses were explained as the respondent not knowing who would be implementing management.

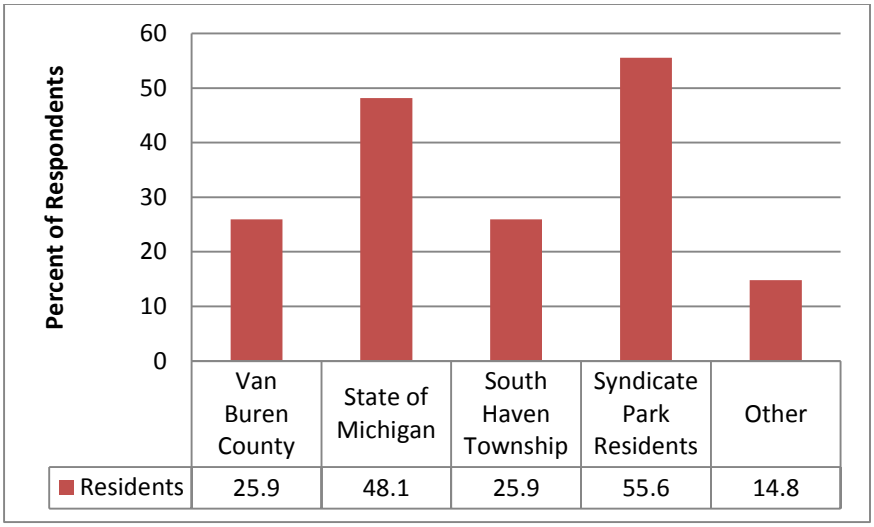


Figure 24. Resident perceptions of who is responsible for the dune area.

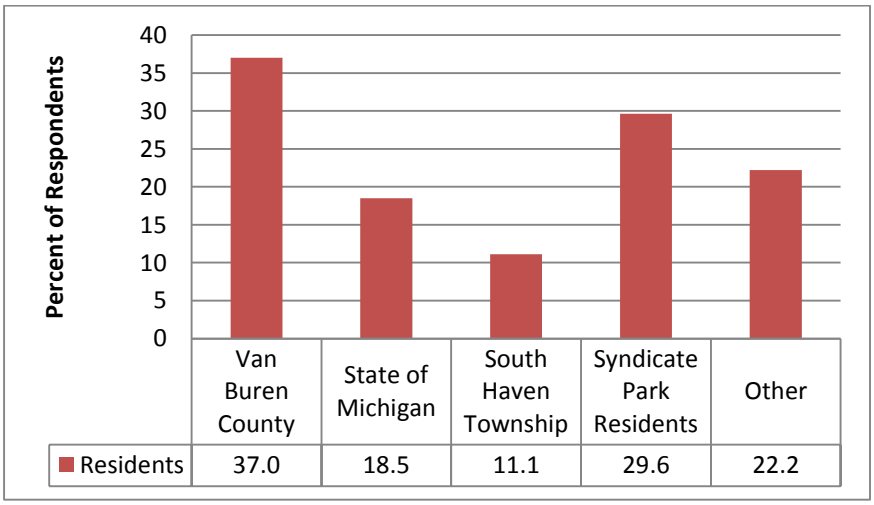


Figure 25. Resident responses to the question "Who do you think will do the most work to make management strategies happen?"

DISCUSSION

Natural and Anthropogenic Features of the Dune Area

Our study results provide many indicators that the Syndicate Park dune area can be described as active or even very active. Over 40% of the total area is bare sand, with 85% of the bare sand occurring in the 14 blowouts present at the site. Only 3 of the blowouts can be described as stable because they are completely vegetated. However, most of the vegetation in the dune area fits into the categories of pioneering species or early-successional species which indicate that the dune surfaces have not been stable long enough for later-succession vegetation communities to develop. The pioneering and early-succession species may also indicate that even vegetated parts of the dune area are experiencing some disturbance or sand movement by wind. Eight of the blowouts are classified as active or very active because of indicators of significant amounts of sand moving over the dune crest or dune advance. The large sizes of some of the blowouts combined with active/very active dune characteristics contribute to what may appear to be a continuous advancing slipface along the eastern boundary of the dune area. This part of the dune area is actually composed of the overlapping slipfaces of the active blowouts along with several less-active slipfaces that lack upwind source areas for wind-blown sand. Slipface edge measurements from air photos show variable but high rates of dune advance between 1938 and 2011 (mostly between 1 and 4.5 m/year). Variable advance rates are not unusual for dunes which are affected by changes in wind and weather from year to year. In fact, the long intervals between some air photo measurements are likely masking more variability in advance rate from year to year. In addition, the advance rates are likely to be variable along the edge of the slipface depending on which blowouts are most active at one time.

While the dunes are active and advancing because strong winds, most likely in fall and winter, move sand from bare-sand erosion areas over blowout crests to deposition areas where gravity moves the sand downslope, there are many indications that human impacts are contributing to dune activity. The locations of the furthest inland extensions of the slipface are all locations where there are trails connecting the subdivision with the dune area. A network of connected unmanaged trails within the dune area includes trails through many of the blowouts, where the trail appears to widen into the bare-sand erosion area of the blowout. Most of the trails are wider than would be needed for people walking single file along a trail, and most of the trails have no or little vegetation on them. The alignment and position of some trails and

blowouts that are closer to the homes in the subdivision suggest that sand leaving one blowout may be feeding a downwind blowout.

There were some patterns that appear to connect trail use with trail width or trail vegetation cover. Trails that had signs of ATV use were wider and had less vegetation cover than most trails that were only used for walking. The two largest trails on the dune area were the trails used as ATV trails to get to and from the beach. Both of these trails had a width greater than 2 meters and trail surfaces that were completely bare sand. Only one other trail on the dune area had a width of greater than 2 meters and this trail also showed evidence of ATV traffic on it. All except two of the trails that had signs of ATV use had sparse vegetation cover or less. Our results correspond to previous studies which indicated that vehicle traffic damages vegetation more quickly than foot traffic (Godfrey, Leatherman, and Buckley 1980; Priskin 2003). ATV use on trails also appears to be contributing to dune advance, as seen where the slipface has advanced the furthest toward the subdivision which corresponds to the trail used for ATV trips from the beach/dune area to the subdivision. Along this trail there is considerable bare sand as well as a mound of sand at the base of the slipface which suggests that ATV use is pushing sand down the slope.

The two largest trails also were located inside of the second and third largest blowouts by area. All of the blowouts that had the highest level of dune activity also showed the most signs of human interaction such as footprints, ATV tracks, and litter. These results suggest that more visitor activity in the blowouts is leading to increased dune activity.

Human Interactions with the Dune Area

Observations of visitor activity correspond well to questionnaire responses concerning visitor activity in the dune area. Based on the number of visitors we observed during our hours at the dune area, we can make a very rough estimate that 4000-5000 people visit the dune area during the summer. Roughly 40-45% of questionnaire respondents (visitors and residents) reported climbing the dunes as one of their activities in the dune area. We would have estimated slightly less than that percentage as most of the dune area visitors remained on the beach while we were observing. However, 40% of 4000 people produces an estimate of 1600 visitors who might climb the dunes during the summer. Although the visitors did not all go to the same locations in the dunes, some areas such as Blowout #1 were popular destinations for visitors.

The visitor numbers are well above threshold numbers needed to destroy vegetation along a common pathway or keep the pathway free from vegetation.

Consideration of four visitor management strategies described by Orams (Kindermann and Gormally 2010; Orams 1995) suggests that physical, regulatory and educational management strategies have some potential for the Syndicate Park dune areas. *Economic management strategies* have little relevance because charging fees for access to the dune is not currently done and would be impractical to administer with the variety of access points for visitors. *Physical management strategies* to limit or deny visitor access to sensitive areas could include a managed trail system that sets access routes to decrease human impacts to the dunes as well as fences to stop visitors from entering areas that are being stabilized. Questionnaire results suggest some objection to limiting access to current trails or dune areas. *Regulatory management strategies* (i.e., establishing rules for visitor behavior) would clarify what activities are permitted and where in the dune area, and the regulations would also give the appropriate authorities the ability to enforce the regulations. Again, some objection to regulations was expressed by residents in their questionnaire responses. *Educational management* in the form of providing information on the nature of the dune area, effects of people on the dunes, and threats of the dunes to local homes, can address issues of visitor actions resulting from lack of information or misinformation. A significant challenge of educational management is finding the appropriate ways to get the information to the audience.

An effective management plan requires clear identification of the goals for the management, along with stakeholder agreement or commitment with the desired outcomes. The SMPC (2012) report identifies "stabilizing the dune" as one of three goals contributing to a global solution for the entire Syndicate Park Subdivision. We suggest that "stop dune advance to protect houses/property" is a better-stated goal for neighborhood residents, because we saw no indication that stabilizing the entire dune area for the sake of stabilization was desired by residents. Conversations with residents and questionnaire responses also indicate significant support for a goal of "maintaining ATV access to the beach". Additional goals that had stated but less vigorous support include "keeping resident access to the beach/dune area", "reducing human impacts" and "keeping scenery beautiful".

The context for producing a management plan includes some constraints and challenges. The dune areas to be managed are classified as Critical Dunes (MDNR 1989) under

Michigan state law, and there is a regulation and permitting process that will affect any management strategies that include putting structures on the dunes (such as boardwalks) or changing dune contours. Our results point to diverse opinions and knowledge of Syndicate Park subdivision residents with respect to changes in the dune area and dune management. This suggests that education should be a component of future planning, with education including information on dune activity and the problems that are prompting the development of a management plan, the goals of the management plan, and changes to visitor activities (such as the protection of specific dune areas for stabilization) that may result from the plan. In practical terms, visitors are more likely to participate if they know what they are being asked to do, and studies show that visitors are more likely to participate in resource management if the visitors understand the reasons for requested behavior (Carlson and Godfrey 1989). Because limiting or restoring areas of human impacts is an important component of dune stabilization, non-compliance with management efforts and dune-area regulations is a potential challenge to future management efforts. Good communication with stakeholders throughout the management planning process will be helpful. Through our conversations with residents and in the responses to the questionnaires, we note that residents are thoughtful in their views and care deeply about the dune area. If commitment to a common management direction can be obtained, then the participation of the nearby residents will positively affect the success of the management plan.

Management Recommendations

In making recommendations, we intend to describe a range of options applicable to the Syndicate Park dune area so that the Van Buren County Commissioners, in collaboration with other stakeholders, have information needed to develop an effective management plan. The report by SMPC (2012) provides high quality recommendations and information related to zoning and related issues encompassing the dune area along with the residential neighborhood, so we focus our recommendations on management of the dune area itself. We also note that many details of implementation are outside the scope of our expertise and we expect that Van Buren County would work with engineers, architects, builders, or other appropriate professionals as needed to develop the details of the management plan and its implementation.

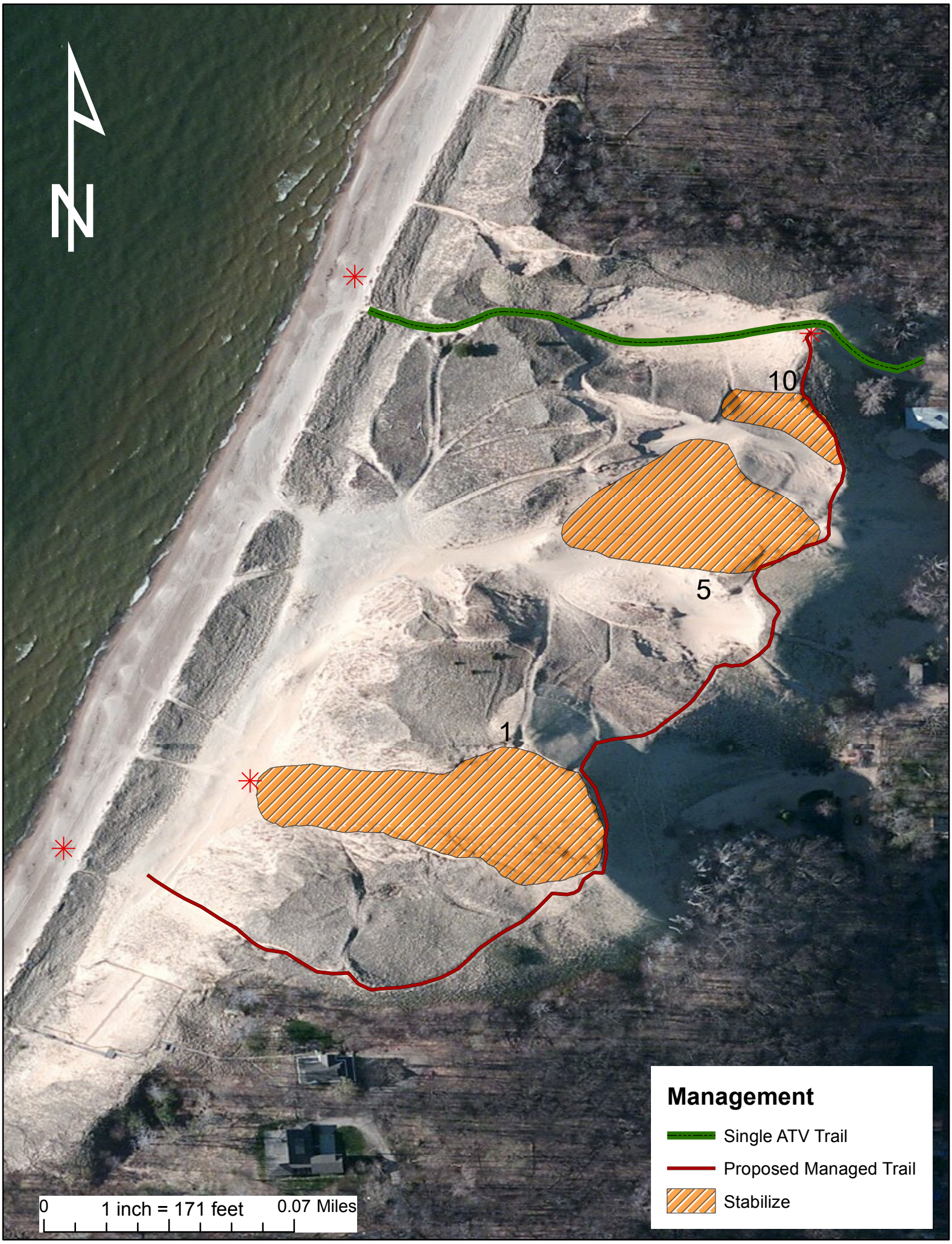
Stabilize active dune areas

We recommend that Van Buren County stabilize several very active blowouts in order to reduce dune advance towards houses and properties in the Syndicate Park subdivision. Specifically, we recommend stabilizing blowouts 1, 5 and 10 (Figure 26) because these are very active blowouts on the eastern edge of the dune area. Each of these blowouts contributes sand to the advancing slipfaces. Techniques for stabilizing the blowouts can include restricting visitor access to the blowouts, installing sand fences to slow wind-blown sand movement, and planting vegetation to hold loose sand in place as well as reduce wind erosion. Other methods of surface stabilization, such as netting, straw mats, debris or straw bales are also options towards quicker or more comprehensive stabilization.

Some considerations related to these management strategies are:

1. Because of the nature of how blowouts change, stabilization efforts will be most effective if they focus on the windward slope first (or at the same time as other slopes); stabilization efforts will be least effective if they focus on the slipface without changes to other slopes. In blowouts, wind moves sand from the windward deflation area and blowout crest to the deposition area. If the deposition area is a high slipface, then much of the wind-blown sand is deposited on the upper slipface and gravity brings the sand towards the bottom of the slope, both readjusting the slope angle and causing dune advance. Stabilization efforts on the slipface alone will fail if large inputs of sand continue to move from the windward slope or crest of the dune. However, cutting off the sand supply from the source areas by stabilizing the windward slope and dune crest will eventually result in natural stabilization of the slipface.
2. Sand fences installed for surface stabilization work by slowing down the wind at that location, thereby reducing wind erosion downwind of the fence and causing deposition of sand that is being transported by the wind from upwind locations. Barriers change the windflow to distances about 10x the height of the barrier, so several sand fences may be needed in larger blowouts. The fences will be most effective if installed perpendicular to the direction of the strongest winds. Installing the fences perpendicular to the main axis of the blowout is likely to be effective in Michigan dunes where there are variable wind directions and the dune topography itself can influence the wind direction.

Figure 26 (next page). Locations of example management recommendations.


N
10
5
1
Management
Single ATV Trail
Proposed Managed Trail
Stabilize
0
1 inch = 171 feet
0.07 Miles

3. Planting vegetation is most effective if it takes into account the type of vegetation and the best environmental conditions for vegetation. In the Great Lakes region, *Ammophila breviligulata* (American beach grass) is commonly used for plantings because it is a pioneering dune species that can thrive in the harsh conditions of areas needing stabilization or restoration. But it should be noted that *Ammophila* grows and spreads best in conditions of some sand burial and it does not do well at locations with stable surfaces (no burial), erosion, or very high rates of sand burial. Studies have shown that *Ammophila* thrives when sand deposition rates per year range between a few cm and 60 cm or so, and it can survive deposition of greater than 1 meter per year (Maun 1984). *Ammophila* plantings will not thrive in dune areas where net erosion occurs; in those areas the plants' survival may depend on their ability to trap moving sand to form a local deposition area. Thus, simply planting *Ammophila* in an active blowout may result in numerous plants not surviving or very slow growth and spread of the plants. However, a combination of sand fences which cause sand deposition combined with *Ammophila* plantings downwind of the sand fences can be very effective.

4. In active dunes where human activities (walking, ORV use) are contributing to dune activity by damaging or destroying vegetation, stabilization efforts such as planting vegetation will not be effective unless the human impacts are removed.

5. As dune stabilization occurs, management strategies can change focus from beginning the stabilization to maintenance and a more natural system. Sand fences can be removed when vegetation takes over, but in practice sand fences are often left in place because of the difficulties of removal if a fence has been partially or mostly buried along with the disruption that removal causes to the dune surface. Biodegradable barriers (either fences made of biodegradable materials, or woody debris on the dune surface, or straw bales, or used Christmas trees, etc.) can be an environmental alternative to the most commonly-used sand fences which are wood-slats kept together by metal wire. As the *Ammophila* colonizes the dune surface and sand movement is reduced, managers can plant successional species in an attempt to speed up the ecological succession process, but more commonly managers allow ecological succession to take place naturally after the sand movement halts.

6. Over time, manager vigilance is needed to make sure that human impacts do not increase to the pre-management levels that caused or contributed to the blowout activity before management.

Develop a managed trail system

We recommend that Van Buren County plan and implement a managed trail system within the dune area. Managing the trails can meet dual goals of reducing human impacts (thereby contributing to stabilizing the dunes) while maintaining a desired level of visitor access to the dunes, such as access to scenic views and access to the beach. The parameters of the managed trail system need to be decided on during the planning process. Some questions that need to be addressed are:

- What level of visitor access is desired?
- How should the managed trails be indicated to visitors and trail surfaces maintained or improved?
- Are there resources available to upgrade trail surfaces (such as building boardwalks or viewing platforms)?
- Should ORV use be permitted? If so, how much ORV use?

We present an example of a managed trail system that provides limited access to the dune area, would benefit from some upgraded trail surfaces, and permits a limited amount of ORV use. The example maintains a few managed trails that provide access to the beach and scenic views, closes down existing unmanaged trails particularly in areas vulnerable to wind erosion, and limits ORV use to a single trail providing access to the beach (see Figure 26).

Some considerations for setting parameters and developing a managed trail system are:

1. An important component of trail management is deciding where to place the trails. Existing unmanaged pathways indicate that enough visitors have been interested in going along those routes to create trails by repeated trampling. Our recommendation selects some of the existing pathways to provide a) access from the subdivision to the beach, and b) access to the scenic views along the crests of the dunes. Although the crest trail brings people to some vulnerable dune areas, we expect that not providing access to the crest may result in non-compliant visitors and the creation of more unmanaged trails as visitors seek ways to reach the tops of dunes. Our recommendation cuts off access to a number of smaller trails that may be contributing to movement of the very active blowouts.
2. Trail characteristics can be managed to reduce impacts of trampling on the dunes, but some of the most-effective methods have higher costs. To reduce trampling impacts, visitors should be encouraged to stay on designated trails, which should be constructed to minimize the impacts of

use by many people, such as trail erosion (downcutting) on steep slopes. In stable dune areas, many pedestrians and even ORVs should have little impact on the vegetation away from the pathway as long as the users do not leave the pathway. On steeper slopes, pedestrians and vehicles on bare sand trails will push movable sand downslope. A less-movable trail surface, such as a boardwalk or stairs, will protect the underlying dune surface from erosion. Boardwalk and trail surface design can reflect the management needs of an area. Wood or other materials placed directly on the dune surface reduce footstep erosion (and make walking easier) and provide a visual reminder that visitors should stay on the pathway. A railing or fence along a path or boardwalk provides a physical barrier to visitors leaving the pathway; the increased cost may be offset by the benefit of reducing trampling impacts in areas of rare vegetation or dune surfaces prone to destabilization. An elevated boardwalk allows sand to move under the boardwalk; this may be most useful in places where pathways cut across areas of dune activity (such as at the active crest of a dune) or in areas where sand burial of the pathway will increase maintenance costs. An elevated boardwalk which includes gaps in the floor design so that light can reach the dune surface will not only permit sand movement to continue but also allows vegetation to grow under the boardwalk.

3. Good communication is needed to encourage visitor participation in using the managed trail system rather than leaving the trails to wander over other dune areas. An essential element of communication is ensuring that visitors know where the managed trails are. Trail maps in pamphlets, online or on signs posted at access points to the dune area can inform visitors of the trail system and enable them to make decisions about desired routes. Clear and visible designation of the managed pathways themselves will prevent visitors from wandering off the pathways out of confusion. Clear designation can be by trail characteristics (the trail is visibly different than the surrounding area) or by signposts. Boardwalks, groomed trails (such as wood chips or mowed grass), or edged trails (such as trails with a wooden or rock edging) are examples of visible trails. Bare sand pathways are visible where they are surrounded by vegetation, but the possibility for confusion arises where the pathways go through blowouts or where animal trails or unmanaged people trails leave the managed pathway.

4. Where the intent is to halt use of unmanaged trails, managers need to consider how to prevent the continued use and whether to actively restore the trail. Options for preventing trail use include signs directing visitors not to use the trail and physical barriers such as woody debris or

fences. Because visitors determined to continue trail use will ignore signs and go around single barriers, some managers have put multiple fences across trails for which they are particularly eager to discontinue use. Without continued trampling, a trail will over time become naturally re-vegetated as nearby species spread into the trail area. This process will take months to years depending on how wide and bare the trail is at the beginning of the recovery period. Managers could plant vegetation on the trail to speed up the process, but this appears to be rarely done.

5. Regarding off-road vehicle (ORV) use on the dune area, the optimal management strategy for reducing human impacts and stabilizing vulnerable dune areas is to make the area off-limits to ORV use. Off pathways, ORVs contribute to dune activity by damaging or destroying vegetation, moving sand around, and eroding dune surfaces. On existing pathways, the ORVs contribute to pushing sand downslope on sloped areas of the path, as well as lowering the dune surface along the path to create notches in dune slopes and crests. All of these impacts of ORVs enhance the formation and continued activity of blowouts by creating or maintaining bare-sand erosion areas and transport pathways over dune crests which may funnel wind and sand to deposition areas. We recommend at the very least that ORVs not be permitted off pathways in the dune area.

6. Given resident interest in using ORVs to get people and belongings from the subdivision to the beach and back, we recognize that dune-area managers may want to maintain an ORV access route. We could not find an alternative route to the currently-used ATV pathways that would appear to have less impacts on the dune area, unless there would be a way to construct an ATV pathway through the forested dunes north of the site. However, we do recommend that ORV use be restricted to the northern trail; we recommend that ORVs not be allowed on the southern trail because their impacts are enhancing blowout activity and advance. Stabilization of this blowout will be very difficult if not impossible as long as ORVs continue to cause erosion. We recognize that the recommendation of a single ORV trail poses logistical challenges for managers and residents, and we applaud residents for already exploring ways to make possible a 2-way “one-lane” ORV trail which includes several crests that obscure driver visibility of vehicles approaching from the other direction.

Regulation

We recommend that Van Buren County develop and communicate a clear set of regulations for the Syndicate Park dune area. Clear regulations can meet dual goals of reducing human impacts (thereby contributing to stabilizing the dunes) while maintaining a desired level of visitor activities on the dunes. Many of the items to be addressed in regulations have been described in previous paragraphs, such as:

Should visitors stay on managed pathways or be able to walk wherever they want on the dunes?

Should ORVs be permitted in all of the dune area or restricted to one or two pathways (or not be permitted at all)?

Additional items that managers may want to consider are activities such as fires and camping; currently these activities do not appear to be contributing to the activity of the most-active blowouts.

Because visitors gain access to the dune area through four main access points/areas, we recommend posting the regulations at four different locations (see Figure 26): the subdivision end of the northern ORV trail, the north and south ends of the property along the beach, and at the beach end of the trail leading up to the largest blowout. A clear (and posted) set of regulations will provide backing to managers and subdivision residents wishing to inform dune visitors that they are participating in an activity that is not allowed on the dunes.

Managers should also consider what enforcement strategies are possible to encourage compliance with the regulations. Fines for offenders may provide a source of revenue for some management activities. However, fines also require an administrative and enforcement structure to impose the fines and collect them. Round-the-clock patrols by a "park warden" are likely to be cost-prohibitive and not warranted by the numbers of visitors present much of the time. But a clear set of regulations may enable law enforcement or government agency personnel to take additional steps towards enforcement when they see people breaking the rules.

Education

We recommend that Van Buren County include visitor education (public outreach) as part of the management plan for the Syndicate Park dune area. The goal of visitor education is to provide dune visitors with information that will make them more likely to participate in

management efforts. Three types of content would be helpful to inform visitors of the need for management and how they can contribute to effective management:

1. Information about the problems of the dune area, such as dunes advancing towards houses, and how planned management activities address the problems.
2. Information about how visitors have contributed to the problems (visitor impacts) and can contribute to recovery (what are low-impact activities?).
3. Information about changing policies and regulations.

Questionnaire results showed little interest in making the dune area a destination site for public education about dunes.

One method of presenting information to dune visitors who access the site occasionally is to post signs in the dune area. As described in the section on "Regulation", four locations where visitors access the dune area would be good locations for overview signs for visitors. Smaller signs could be used to target specific problems/items, such as signs indicating that visitors should not use a specific path or enter a specific area. Best practices for using signs in environmental management suggest that positive messages (*Please stay out of area*) are more effective than negative messages (*Do not enter*), and regulatory signs which include explanations (*Dune restoration in progress*) are more effective than regulatory messages without explanations (Carlson and Godfrey 1989).

Signs contain limited information, and more detailed information can be presented in a pamphlet, information sheet, or using other media such as a website. In any of these formats, the detailed information can be given to all of the residents of the Syndicate Park subdivision. A community meeting is another way of providing information, including an opportunity for questions and answers, to interested dune-area neighbors. Dune visitors could also be given access to the detailed information if boxes are installed at the sign locations to hold copies of the pamphlets or information sheets.

Monitoring

We recommend that Van Buren County develop a monitoring plan for the Syndicate Park dune area. Monitoring dune activity (including rates and changes) will enable Van Buren County to keep track of existing problems, identify new problem areas quickly, and assess the effectiveness of management activities. Table 3 shows different on-the-ground measurements

Dune activity/ characteristic	Methods	What monitoring can indicate*	Appropriate measurement intervals
Blowout activity	Classify activity level with the Dune Features Inventory method (Appendix A).	Decreasing levels of activity (such as changing from "very active" to "active") indicate the dune is becoming more stable.	multi-year (recommend 5 years)
Size of bare sand area (amount of vegetation cover)	Compare photographs. Measure dimensions. Map with GPS.	Smaller areas of bare sand suggest the dune is becoming more stable.	annual to multi-year
Type of vegetation cover	Make direct observations or compare photographs.	Progression from pioneering species through successional dune ecological communities indicates increasing or sustained stability.	multi-year
Presence of erosion, sand transport, and/or deposition	Make direct observations or look for evidence (indicators) of activity.	Decreasing evidence for erosion/transport/ deposition indicates increasing stability.	annual to multi-year
Amounts of erosion or deposition	Measure surface changes at erosion pins.	Decreasing amounts of erosion and deposition indicate increasing stability. (But amounts of deposition may increase initially where there are stabilization efforts such as planted vegetation.)	weekly, monthly, seasonal, annual, multi-year
Presence of dune advance	Observe whether new sand deposits reach bottom of slipface.	A "no" indicates a less active dune than a "yes".	annual
Amounts of dune advance	Compare measurements of slipface edge position relative to a fixed reference point such as a monitoring post or corner of building.	Decreased rates of dune advance indicate increasing stability.	Annual over a number of years recommended. There is a seasonal pattern to dune advance, so measurements over short time intervals in the "wrong" season may falsely indicate no advance.

Table 3. Ways to monitor dune activity and characteristics.
*Descriptions of "what monitoring can indicate" focus on changes towards stability. Results could also show increasing activity or no change in activity level.

appropriate for the types of information about dune activity that would be relevant to monitoring the activity of the Syndicate Park dunes. Most of the measurements are fairly straightforward and inexpensive and could be carried out by Van Buren County staff, subcontractors, volunteers, or college/university students. Mapping with GPS requires access to appropriate equipment, software and training.

Specifically, we recommend a monitoring plan that includes the following components.

1. Measure rates of dune advance at 5 or more locations along the eastern edge of the dune area. Begin by either installing monitoring posts or identifying existing fixed reference points. At least once a year, preferably in May or June, measure the distance from each reference point to the slipface edge. Compare measurements to identify the rate of dune advance.
2. Measure dune activity at a suitable multi-year interval, such as every five years, with a focus on dunes of particular interest such as blowouts 1, 5 and 10. Use the Dune Features Inventory method to classify and compare activity levels, assess and compare bare sand areas, assess type of vegetation cover, and look for indicators of erosion or deposition.
3. If more detailed measurements of activity in specific blowouts are of interest, then use erosion pins to measure erosion and deposition. Pins can be placed at individual sites of interest or in a line or grid pattern to provide information on patterns within a dune. Measurements can take place regularly over a number of years (such as every 3 months), or more frequent measurements can take place over shorter time periods (such as monthly or weekly for a season or year).

CONCLUSIONS

The Syndicate Park dune area is a 0.3 km^2 (74-acre) area of active dunes including a sand-cobble beach, active foredune, and rolling dune topography with many active blowouts and varying heights up to 50 meters. A high percentage of bare sand areas susceptible to wind erosion (35% of the total dune area), visible deposition downwind of the deflation areas, vegetation comprised mostly of pioneering and early-succession species, and dune slipfaces which are advancing inland are all evidence of a substantial level of dune activity. The advancing dunes already threaten the use and structures on four residential properties immediately east of the dune slipfaces.

Human activities are contributing to the level of activity and advance of the Syndicate Park dunes. Our observations suggest that at least several thousand visits are made to the dune

area each summer. From questionnaires and observations, we know that the visitors come both from the Syndicate Park subdivision and beyond. Most of the visitors stay on the beach, but up to 40% may climb up into the dune area, and some of the visitors use ATVs on informal access trails to go to and from the beach. Including the main access routes, there are approximately 2 km of unmanaged trails in the dune area, some of which are more than 2 meters wide and some of which have substantially eroded into the dune topography. The spatial patterns of trails and blowouts suggest that trampling and vehicle use on trails are contributing to the presence and activity of the blowouts.

Van Buren County faces some management challenges with the Syndicate Park dune area. Although curtailing the impacts of foot and vehicle traffic will promote dune stabilization efforts, questionnaire responses show resident interest in keeping ATV access to the beach as well as continuing access to the dune area. Management strategies that have more support among residents include planting vegetation and employing sand fences for dune stabilization. Our report provides examples of management strategies such as stabilizing several active blowouts, developing a managed trail system providing limited access to dune crests, and eliminating ATV use on the southern trail which has become a location for very fast dune advance. While Van Buren County needs to work out the goals and framework of a management plan with interested parties, we have included a number of items to consider for different management strategies. While developing a management plan will be challenging, we hope the result will be continued mutual enjoyment of the Syndicate Park dune area by Van Buren County, the residents of the Syndicate Park subdivision and other visitors.

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Appendix A. Dune Features Inventory (DFI) Checklist - Activity

D. Natural Features: Dune Activity

1. Is the dune 100% (or almost entirely) vegetated?
☐ Yes ☐ No

2. Are active blowouts present?
☐ Yes ☐ No

3. Are substantial areas of the dune active?
(Ex. large blowouts, sand moving over dune crest, etc)
☐ Yes ☐ No

4. Is the dune advancing?
(Evidence of sand deposits reaching bottom of slipface.)
☐ Yes ☐ No

5. Is the dune surface mostly composed of bare sand and early colonizers?
☐ Yes ☐ No

6. Classify dune activity level (see DFI Guide)
☐ Inactive/Stable
☐ Slightly Active
☐ Moderately Active
☐ Active
☐ Very Active

7. Classify foredune activity (see DFI guide)
☐ Active ☐ Stable

From the Guide to Completing the DFI: D. Natural Features: Dune Activity

Active blowouts have an area of bare sand (the deflation area) which serves as the area of wind erosion. You may also see a downwind area of sand deposition. Bigger or very active blowouts may have a visible slipface; for smaller or less active blowouts, the sand may be deposited on the slopes/vegetation downwind of the blowout.
Substantial areas of dune activity include:

- one or more large blowouts (10s of meters in size)
- a large number (>5-10) of small blowouts (<10 m in length or width)
- evidence that sand moves over the crest of the dune: this includes a bare sand area on the (upper) windward slope of the dune, bare sand areas on the dune crest, and a deposition area on the (upper) slipface of the dune
- evidence that sand has moved a significant distance from a sand source: deposition area of blowout(s) extends more than 10 meters from the blowout, fresh deposition on slipface reaches at least half-way down the slope or more.

Evidence of dune advance includes fresh sand deposits reaching the bottom of the slipface (ie without leaf litter or soils on the surface of the sand) and/or burial of vegetation/leaf litter/soils at the bottom of the slipface.

Level of Foredune Activity	Responses to Questions 1-5	Description of Dune Characteristics
Active	1. No or Yes 2. No or Yes 3. No or Yes 4. No or Yes 5. Yes	Active foredunes have evidence of sand movement (vegetation burial, fresh sand deposits, leaf/plant litter is buried by sand) and vegetation consists of pioneering species that may not completely cover the dune surface. Scarping of the windward foredune slope is an indicator of recent wave erosion.
Stable (Inactive)	1. Yes 2. No (possibly Yes) 3. No 4. No 5. No	Stable foredunes may have more complete vegetation coverage, less vigorous pioneering species (eg. duller color), greater species diversity from plant succession, and leaf/plant litter on ground beneath active plants. Another dune between the foredune and the beach is often an indicator of stability.

Classifying Dune Activity for dunes other than foredunes

Level of Dune Activity	Responses to Questions 1-5	Description of Dune Characteristics
Inactive (Stable)	1. Yes 2. No 3. No 4. No 5. No	Inactive (stable) dunes are fully vegetated with no locations of sand movement by wind. Dune surfaces have soils and leaf litter on them. Vegetation may be a climax forest community.
Slightly Active	1. No 2. Yes 3. No 4. No 5. No	Slightly active dunes have mostly stable (vegetated) surfaces with localized areas of sand movement. Sand movement occurs from small blowouts with sand deposition occurring within several meters of the blowout.
Moderately Active	1. No 2. Yes 3. Yes 4. No 5. No	Moderately active dunes have stable (vegetated) surfaces with substantial areas of activity in the form of large blowouts and/or sand moving over the crest of the dune. Deposition occurs on the slipface, but sand does not reach the bottom of the slope to cause dune advance. A dune may also be considered moderately active if it contains a very active nested dune on an otherwise stable surface.
Active	1. No 2. Yes 3. Yes 4. Yes 5. No	Active dunes show signs of substantial sand movement (large blowouts, sand moving over the crest of the dune) and the dune is advancing over the underlying landscape (shown by fresh sand deposits reaching the bottom of the slipface). Active dunes often have significant portions of the windward slope with little or no vegetation.
Very Active	1. No 2. Yes 3. Yes 4. Yes 5. Yes	Very active dunes have little or no vegetation and evidence of significant sand movement including significant dune advance. The windward slope and crest of the dune have substantial unvegetated areas for wind erosion and sand transport. The slipface shows many signs of activity (fresh sand deposits reaching the bottom of the slope, burial of vegetation, colonizing species of vegetation). Very active dunes will have rapid advance rates (> 1 m/year).

Appendix B: Syndicate Park Dune Area Visitor Questionnaire

Please answer these questions in regards to the Syndicate Park dune area. You do not need to write your name on this questionnaire, and your answers will not be used to identify you personally. You may choose to answer all, some, or none of the questions. The results from this questionnaire along with other data gathered from the sand dune will be incorporated into a final report which will be presented to Van Buren County Commission. The report may be obtained upon request. This study is being done by James Karsten, a geology major from Calvin College, and Lucas Vander Bilt, a geology and environmental studies major from Calvin College, with faculty advisor Deanna van Dijk.

1. Have you visited the dune area before? (*Please circle one.)* Yes No

2. If yes, how often do you visit the dune area? *(Please check the corresponding box.)*

- ☐ 1. Once a year
- ☐ 2. Several times a year
- ☐ 3. Once a month
- ☐ 4. Several times a month
- ☐ 5. Several times a week
- ☐ 6. Every day
- ☐ 7. Other _____

3. Which activities do you participate in when visiting the dune area? *(Please check all that apply.)*

- ☐ 1. Go for a walk
- ☐ 2. Walk the dog
- ☐ 3. Climb the dunes
- ☐ 4. Enjoy scenery
- ☐ 5. Play games
- ☐ 6. Run down the dunes
- ☐ 7. Observe wildlife
- ☐ 8. Other (*please specify*) _____

4. During which season(s) do you visit the dune area? *(Please check all that apply.)*

- ☐ 1. Winter (Dec-Feb)
- ☐ 2. Spring (Mar-May)
- ☐ 3. Summer (June-Aug)
- ☐ 4. Fall (Sept-Nov)

5. How much would you say you know about sand dunes? *(Please circle a number.)*

I know almost nothing		I know a little bit		I know a lot
1	2	3	4	5

6. Do you consider the following to be problems/annoyances on the dunes?
(Please circle the corresponding number for each item.)

	Major problem	Moderate problem	Minor problem	No problem
1. Litter	1	2	3	4
2. Noise from vehicles	1	2	3	4
3. Noise from visitors	1	2	3	4
4. Dune climbers	1	2	3	4
5. Dog waste/noise	1	2	3	4
6. Too crowded	1	2	3	4
7. Damage to dune	1	2	3	4
8. Management efforts (eg., fencing, signs)	1	2	3	4
9. Noise from boats	1	2	3	4
10. Dune advance	1	2	3	4

7. Where are you from? (*City, State/Province, Country)*_____

8. How did you get to the dune area today?

☐ 1. Boat

☐ 2. Walking on the beach

☐ 3. Parked in the neighborhood and walked

☐ 4. Other (please specify)_____

9. How many people on the dune are in your group? _____people

10. What are the age categories of the people in your group?
(Please fill in the blanks with the number of people in each age category.)

____0-16 yrs ____17-25yrs ____26-40 yrs ____41-55 yrs ____55 yrs and older

Appendix C: Questionnaire for Residents of Syndicate Park Subdivision

Please answer these questions in regards to the Syndicate Park sand dune area. You do not need to write your name on this questionnaire, and your answers will not be used to identify you personally. You may choose to answer all, some, or none of the questions. The results from this questionnaire along with other data gathered from the sand dune area will be incorporated into a final report which will be presented to the Van Buren County Commission. The report may be obtained upon request. This study is being done by James Karsten, a geology major from Calvin College, and Lucas Vander Bilt, a geology and environmental studies major from Calvin College, with faculty advisor Deanna van Dijk.

A. Questions regarding the Syndicate Park sand dune area

1. How often do you visit the dune area? *(Please check the corresponding box.)*

- ☐ 0. Never
- ☐ 1. Once a year
- ☐ 2. Several times a year
- ☐ 3. Once a month
- ☐ 4. Several times a month
- ☐ 5. Several times a week
- ☐ 6. Every day
- ☐ 7. Other _____

2. During which season(s) do you visit the dune area? *(Please check all that apply.)*

- ☐ 1. Winter (Dec-Feb)
- ☐ 2. Spring (Mar-May)
- ☐ 3. Summer (June-Aug)
- ☐ 4. Fall (Sept-Nov)

3. How much would you say you know about sand dunes? *(Please circle a number.)*

I know almost nothing		I know a little bit		I know a lot
1	2	3	4	5

4. Which activities do you participate in when visiting the dune area? *(Please check all that apply.)*

- ☐ 1. Go for a walk
- ☐ 2. Walk the dog
- ☐ 3. Climb the dunes
- ☐ 4. Enjoy scenery
- ☐ 5. Play games
- ☐ 6. Run down the dunes
- ☐ 7. Observe wildlife
- ☐ 8. Ride off-road or all-terrain vehicle
- ☐ 9. Camp
- ☐ 10. Other (*please specify*) _____

5. Do you consider the following to be problems/annoyances on the dunes?
(Please circle the corresponding number for each item.)

	Major problem	Moderate problem	Minor problem	No problem
1. Litter	1	2	3	4
2. Noise from vehicles	1	2	3	4
3. Noise from visitors	1	2	3	4
4. Dune climbers	1	2	3	4
5. Dog waste/noise	1	2	3	4
6. Too crowded	1	2	3	4
7. Damage to dune	1	2	3	4
8. Management efforts (eg., fencing, signs)	1	2	3	4
9. Noise from boats	1	2	3	4
10. Dune advance	1	2	3	4

6. In your opinion, while you have owned property near the dunes, has there been an increase or decrease in the number of people visiting and climbing the sand dunes? *(Please circle the corresponding number)*

Decrease		Stay the same		Increase
1	2	3	4	5

7. In owning property near the dunes have you noticed any physical changes to the shape, size, and height of the dunes? *(Please circle one.*)

1. Yes 2. No

If yes, please explain below:

8. What is your opinion of these dune management and interpretation activities?
(Please circle the corresponding number.)

	Strongly oppose	Oppose	Neutral	Favor	Strongly favor
1. Planting dune grass to stabilize the dune	1	2	3	4	5
2. Placement of sand fencing to stop sand movement	1	2	3	4	5
3. Building a boardwalk to protect dune surface	1	2	3	4	5
4. Limiting access to protect dune areas	1	2	3	4	5
5. Interpretive signs with dune information	1	2	3	4	5
6. Educational programs such as public walks/talks	1	2	3	4	5
7. Limiting vehicle use	1	2	3	4	5
8. Banning vehicle use	1	2	3	4	5

Please comment below *(optional).*

9. Who do you think is responsible for the dune area?

- ☐ 1. Van Buren County
- ☐ 2. State of Michigan
- ☐ 3. South Haven Township
- ☐ 4. You (the residents)
- ☐ 5. Other *(please specify)* _____

10. Who do you think will do the most work to make the management strategies in question 8 happen?

- ☐ 1. Van Buren County
- ☐ 2. State of Michigan
- ☐ 3. South Haven Township
- ☐ 4. You (the residents)
- ☐ 5. Other *(please specify)* _____

11. Comments: Please feel free to express any thoughts, ideas or observations in regards to the dune area in the space below.

B. Personal Information

12. How long have you owned property in Syndicate Park? _____ years

13. Do you own an all-terrain or off-road vehicle? *(Please circle one.)* No Yes

14. How many people live in your household? _____people

15. What are the age categories of the people in your household?
(Please fill in the blanks with the number of people in each age category.)

____0-16 yrs ____17-25yrs ____26-40 yrs ____41-55 yrs ____55 yrs and older

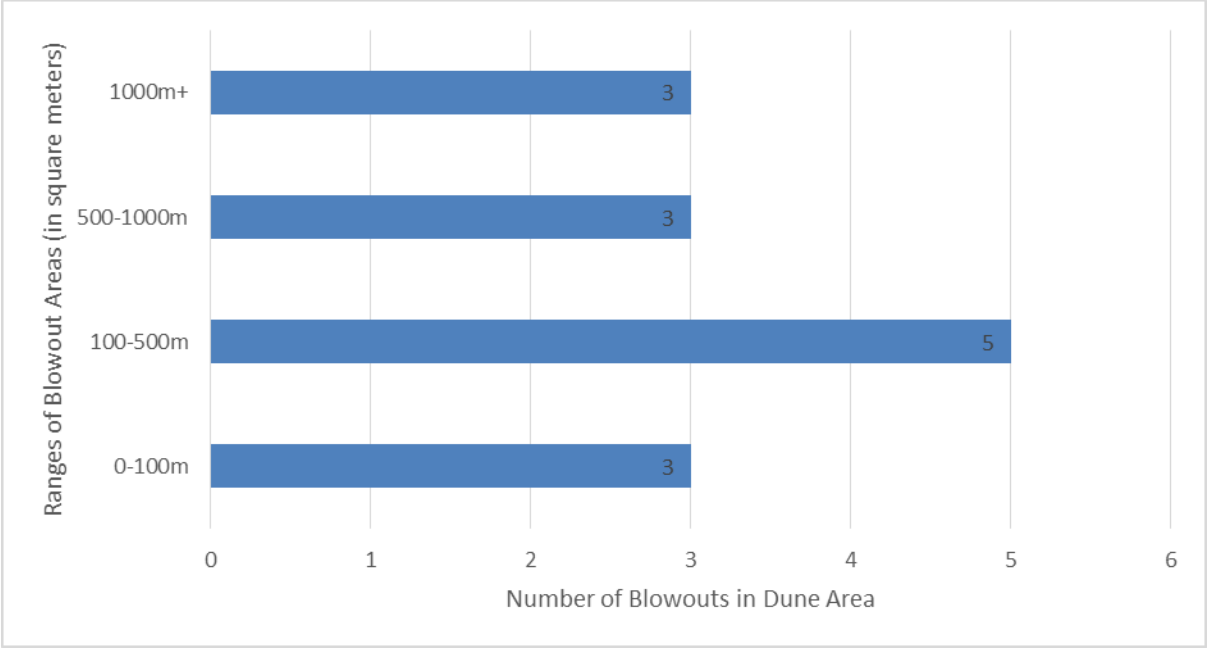
Thank you for taking the time to answer these questions. We appreciate your input!

Appendix D. More Results for Syndicate Park Dune Area Characteristics

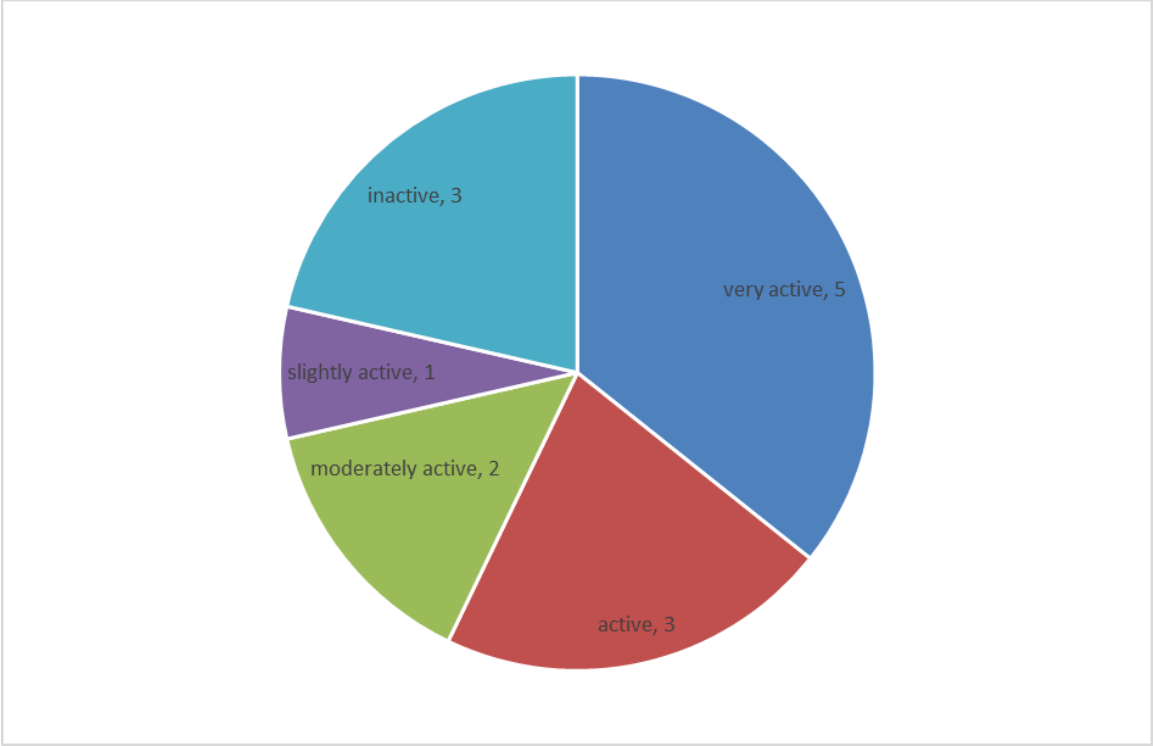
D-1. Table of data collected for each blowout in the dune area.

Blowout #	Area (m2)	Signs of human activity	Organic litter?	trash?	Visible deposition	Activity level
BlwOut1	3271.74	foot/OTV tracks	organic litter	trash	yes	very active
BlwOut2	335.59	none			no	slightly active
BlwOut3	547.83	footprints	organic litter		yes	active
BlwOut4	778.07	footprints	organic litter	trash	yes	active
BlwOut5	2801.29	foot/OTV tracks	organic litter	trash	yes	very active
BlwOut6	585.14	footprints	organic litter		yes	very active
BlwOut7	76.42	none			yes	moderately active
BlwOut8	31.57	none			no	inactive
BlwOut9	145.9		organic litter		no	moderately active
BlwOut10	1327.98	foot/OTV tracks	organic litter	trash	yes	very active
BlwOut11	142.61	foot/OTV tracks	organic litter	trash	no	active
BlwOut12	120.95		organic litter	trash	no	inactive
BlwOut13	192.5	footprints			no	inactive
BlwOut14	51.48	foot/OTV tracks			yes	very active

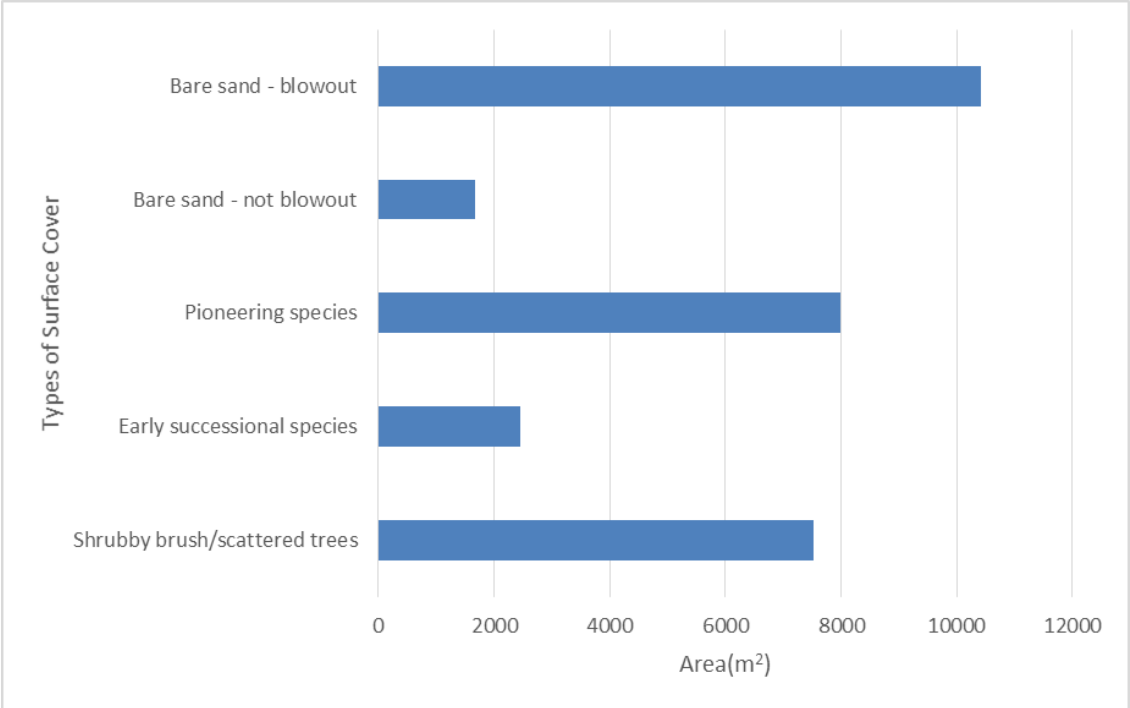
D-2. Graph showing how many blowouts fall into different categories for blowout areas. The areas are the measured bare-sand areas in m^2.



D-3. Number of blowouts in different categories of blowout activity level (inactive to very active).



D-4. Different types of surface cover and the area for each type (m^2).



D-5. Table of data collected for each trail segment in the dune area.

Segment #	Width 1	Width 2	Width 3	Average Area	Veg. cover	Use
seg1	0.44	0.72	0.49	0.55	sparse/tramp	walking
seg2	0.72	1.18	0.69	0.86333333	sparse	walking
seg3	0.8	0.58	0.47	0.61666667	trampled	walking
seg4	1.29	0.63	0.67	0.86333333	trampled	walking
seg5	2.85	2.73	1.4	2.32666667	none	ATV/walking
seg6	1.09	1.54	1.13	1.25333333	sparse	walking
seg7	2.79	2.55	1.98	2.44	none	ATV
seg8	0.73	0.62	0.49	0.61333333	sparse	walking
seg9	0.77	0.62	0.47	0.62	sparse/tramp	walking
seg10	0.78	0.72	0.64	0.71333333	sparse	walking
seg11	1.08	0.63	0.63	0.78	sparse	walking
seg12	0.62	0.66	0.53	0.60333333	sparse/tramp	walking
seg13	1.8	1.7	1.4	1.63333333	sparse	ATV
seg14	1.51	1.52	1.86	1.63	fully/trample	walking
seg15	1.64	1.7	1.75	1.69666667	none	walking
seg16	0.43	0.58	0.56	0.52333333	sparse	walking
seg17	0.6	0.57	0.92	0.69666667	sparse	walking
seg18	0.62	0.61	0.89	0.70666667	sparse	walking
seg19	0.75	0.71	1.15	0.87	sparse	walking
seg20	1.44	1.52	2.24	1.73333333	none	ATV/walking
seg21	0.64	0.32	0.2	0.38666667	fully	walking
seg22	1.79	1.83	1.84	1.82	none	ATV/walking
seg23	1.36	1.75	1.6	1.57	none	ATV/walking
seg24	0.26	1.07	0.58	0.63666667	fully/trample	walking
seg25	0.49	0.35	0.85	0.56333333	sparse/tramp	walking
seg26	0.34	0.59	0.93	0.62	sparse	walking
seg27	0.28	0.31	0.95	0.51333333	sparse	walking
seg28	0.86	0.56	0.53	0.65	sparse	walking
seg29	0.27	0.3	0.31	0.29333333	sparse	walking
seg30	0.6	0.49	0.54	0.54333333	fully	walking
seg31	1.09	1.66	2.74	1.83	fully	walking
seg32	1.9	1.56	2	1.82	fully	ATV
seg33	0.4	0.16	0.36	0.30666667	fully	walking
seg34	0.91	1.43	0.89	1.07666667	sparse	ATV/walking
seg35	1.85	0.91	0.9	1.22	none	ATV
seg36	1.59	1.41	1.17	1.39	sparse	ATV
seg37	2.13	2.26	2.11	2.16666667	none	ATV
seg38	1.24	1.38	1.33	1.31666667	fully	ATV

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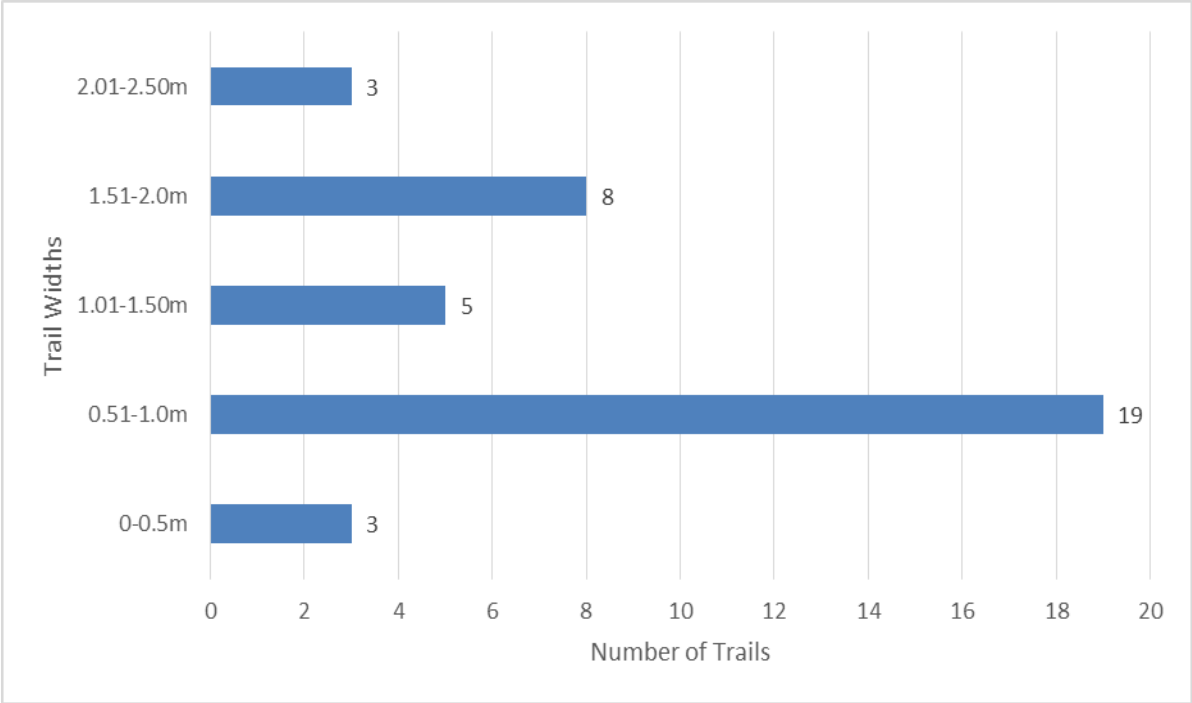
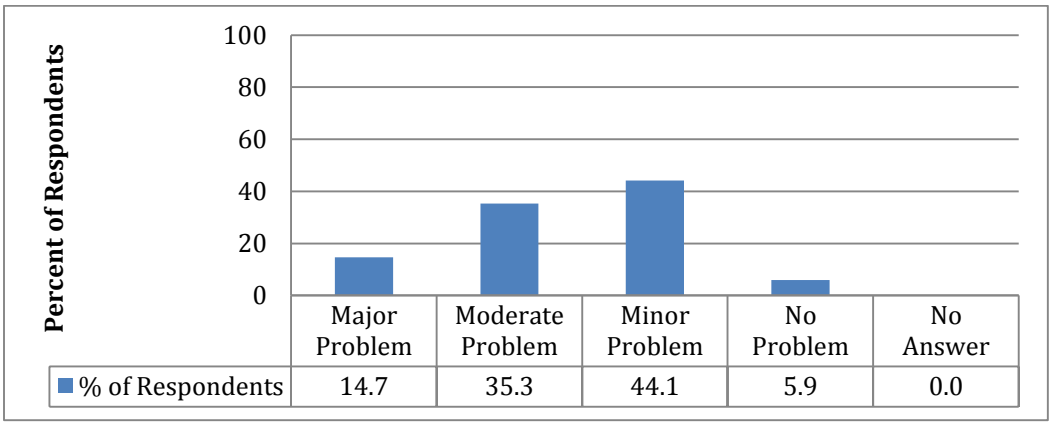
D-6. Graph showing the number of trails in different categories for trail width.



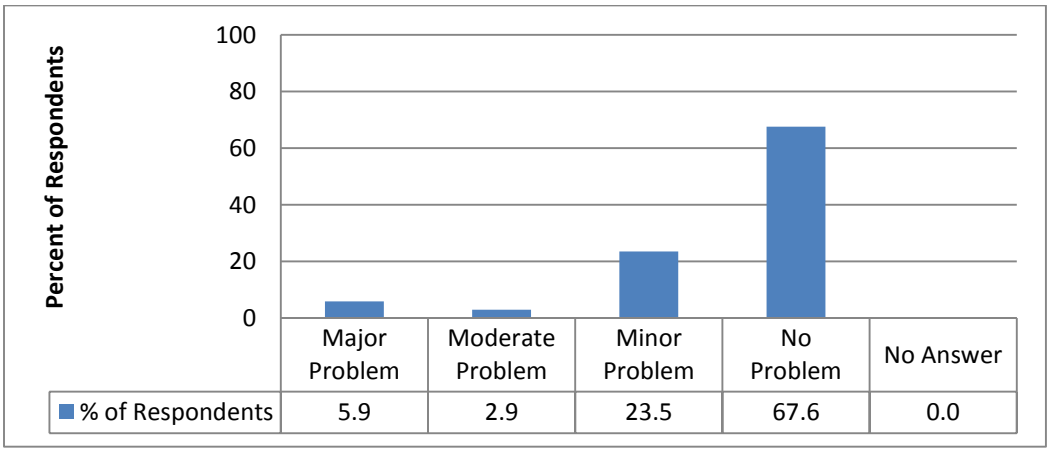
Appendix E. More Questionnaire Results

E-1. Visitor responses to the question "Do you consider the following to be a problem/annoyance on the dunes?"

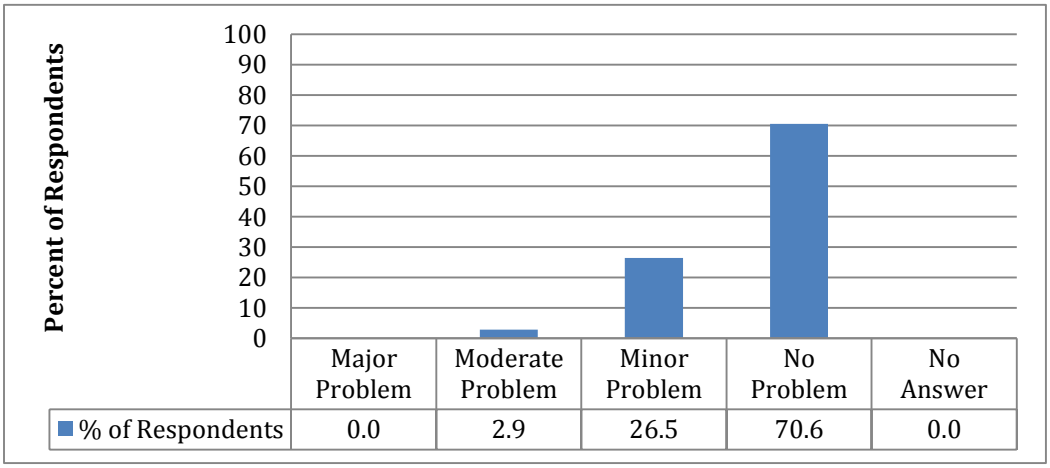
Litter



Noise from vehicles

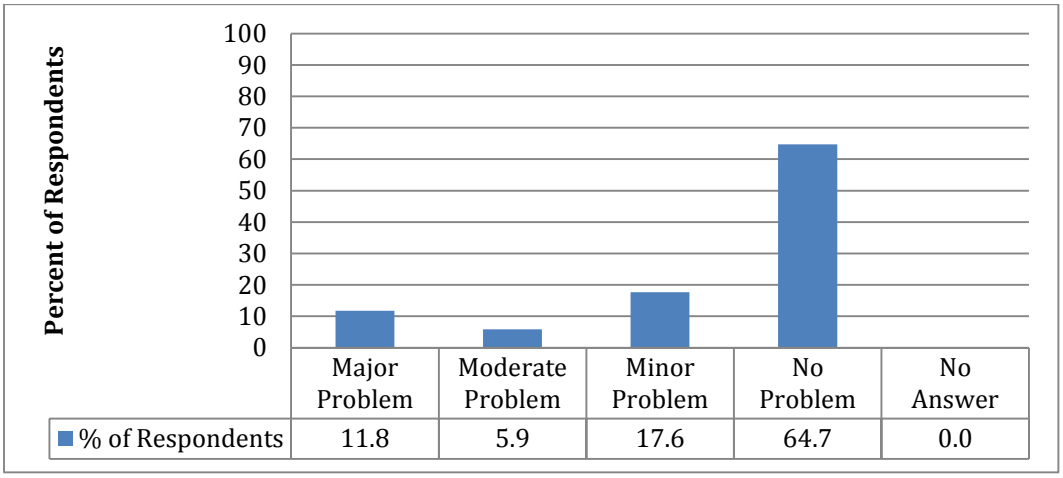


Noise from visitors

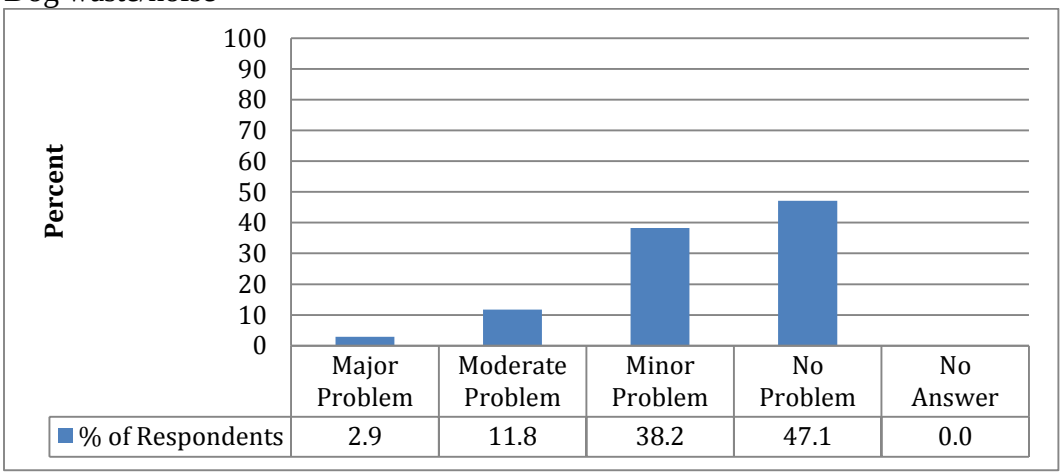


E-1 (continued). Visitor responses to the question "Do you consider the following to be a problem/annoyance on the dunes?"

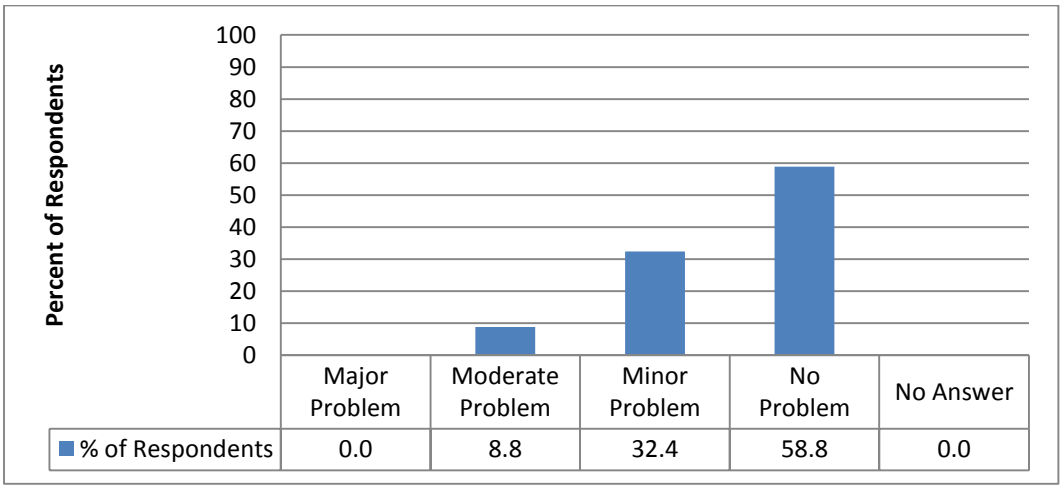
Dune climbers



Dog waste/noise

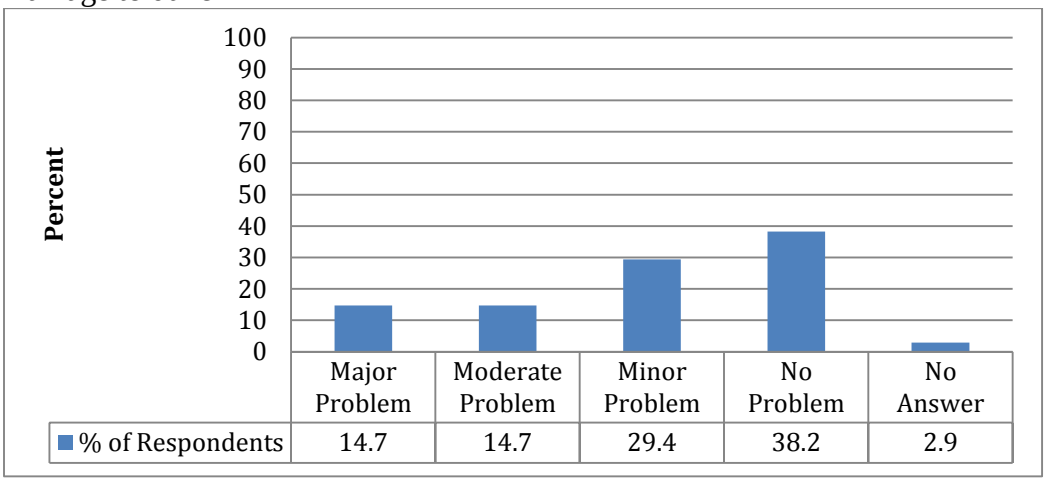


Too crowded

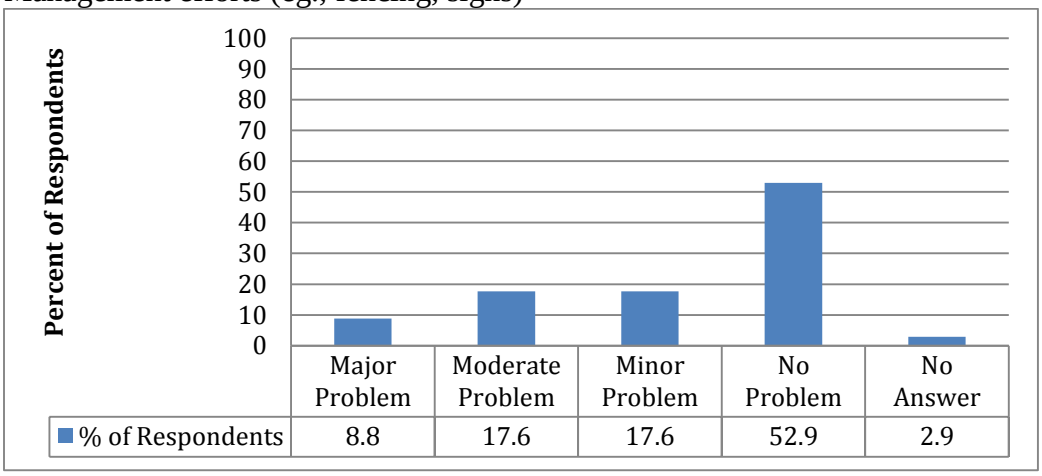


E-1 (continued). Visitor responses to the question "Do you consider the following to be a problem/annoyance on the dunes?"

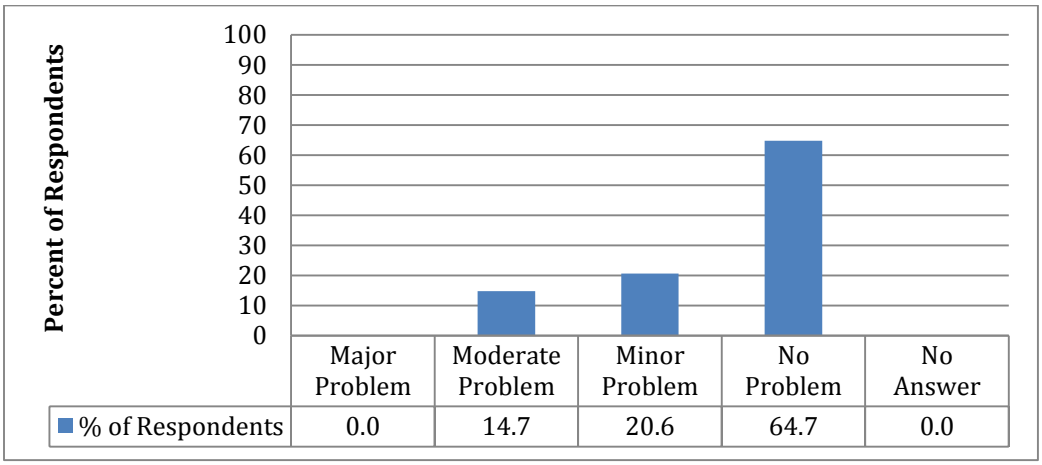
Damage to dune



Management efforts (eg., fencing, signs)

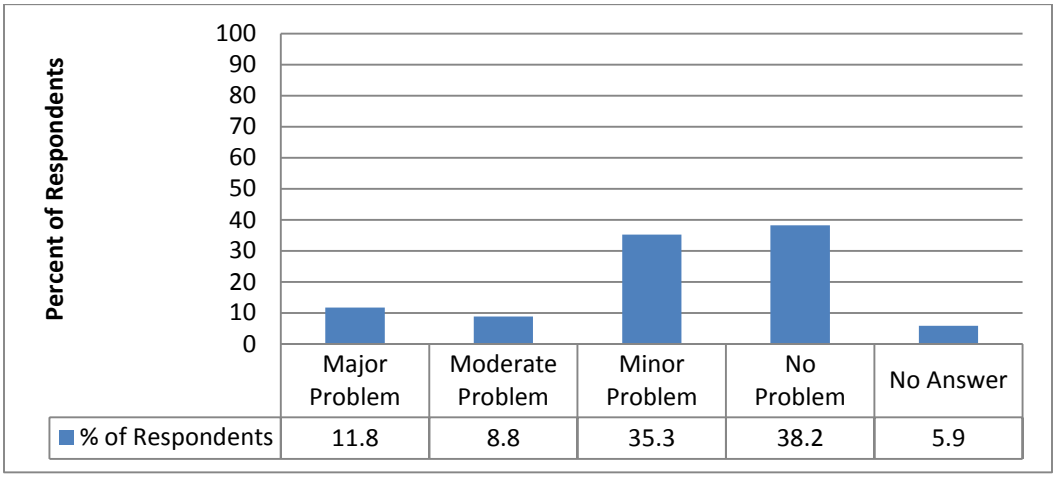


Noise from boats



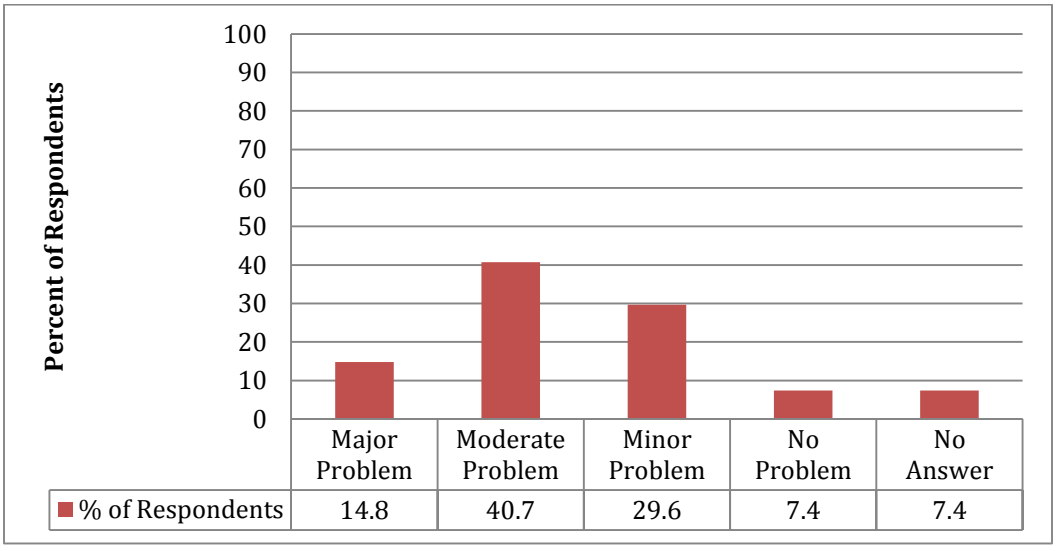
E-1 (continued). Visitor responses to the question "Do you consider the following to be a problem/annoyance on the dunes?"

Dune advance



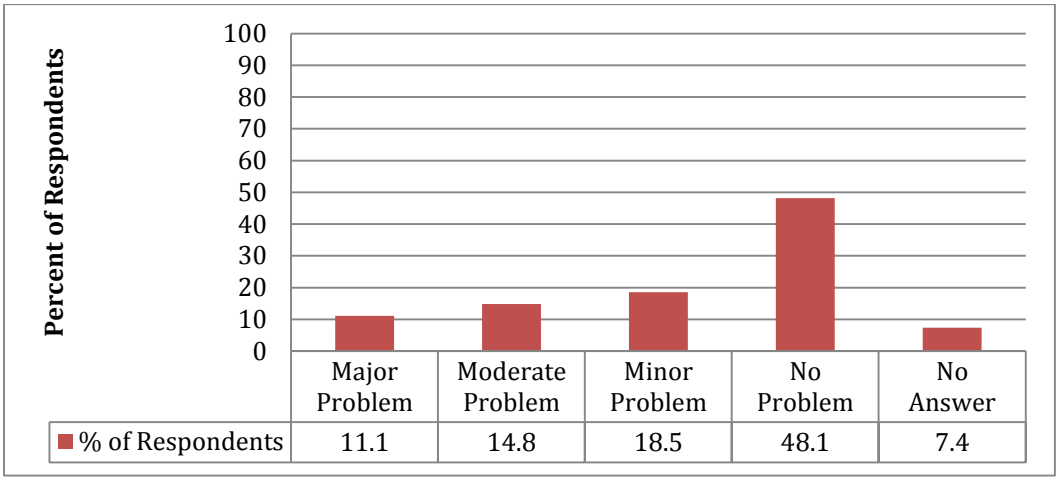
E-2. Resident responses to the question "Do you consider the following to be a problem/annoyance on the dunes?"

Litter

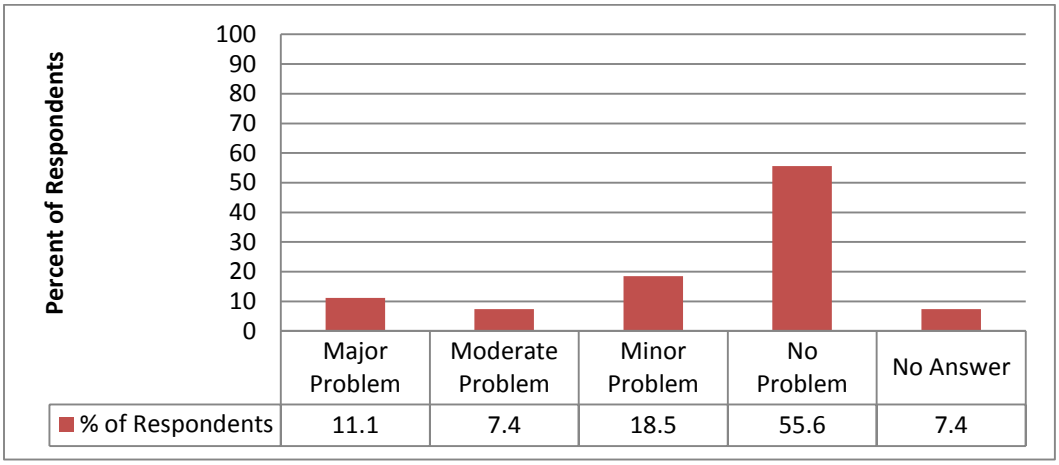


E-2 (continued). Resident responses to the question "Do you consider the following to be a problem/annoyance on the dunes?"

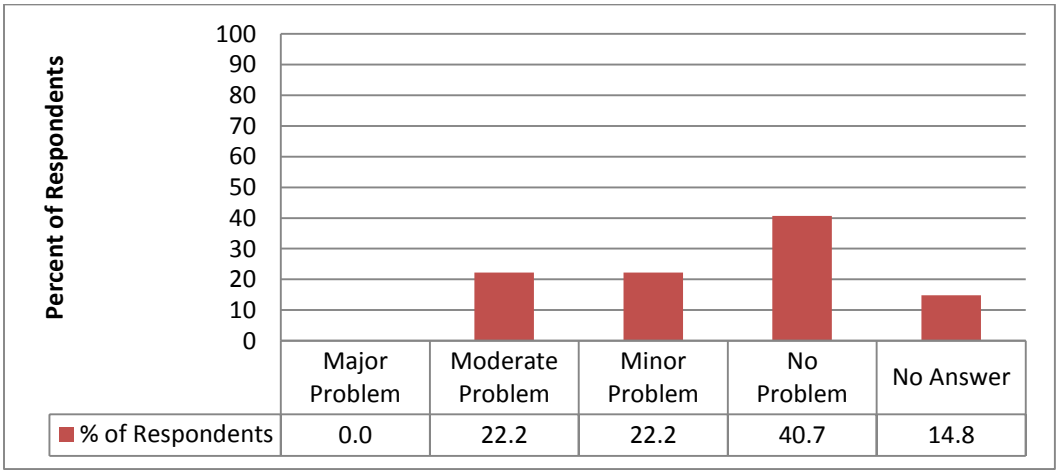
Noise from vehicles



Noise from visitors

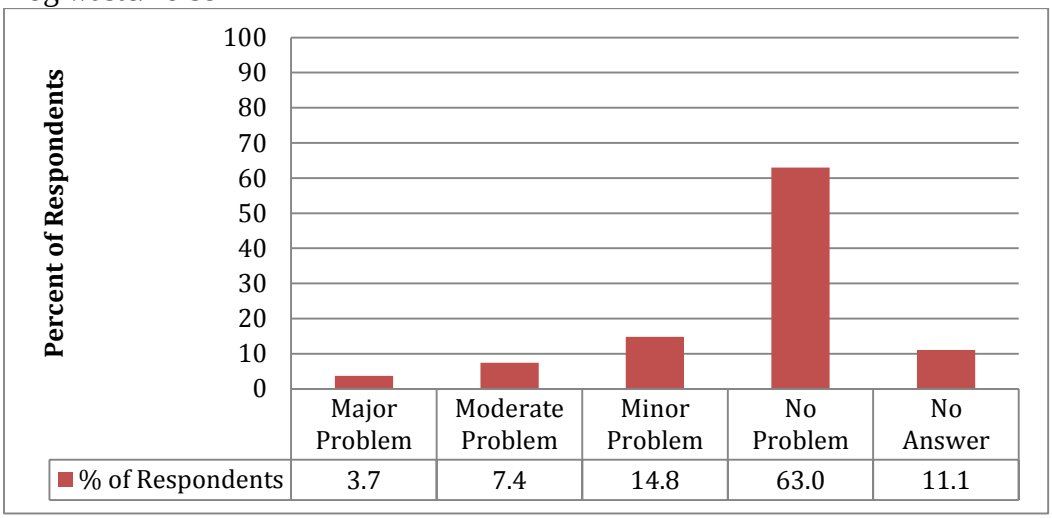


Dune climbers

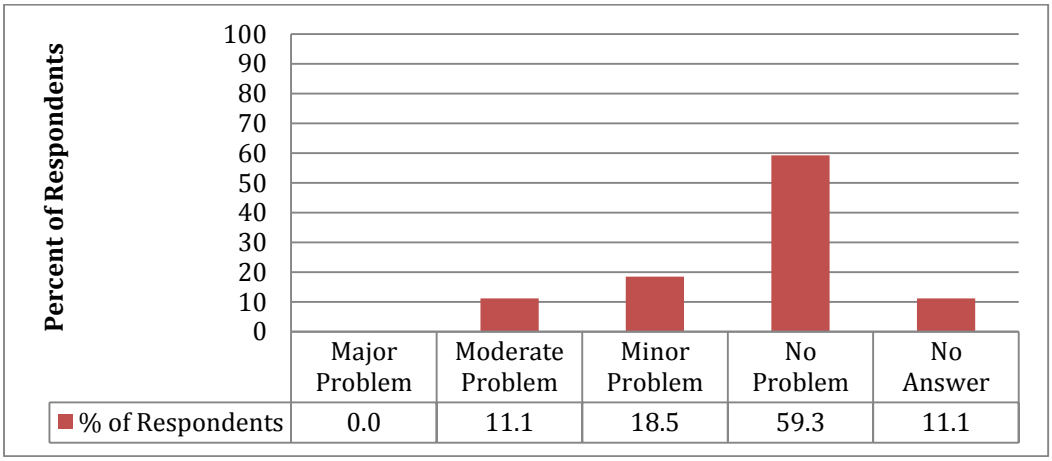


E-2 (continued). Resident responses to the question "Do you consider the following to be a problem/annoyance on the dunes?"

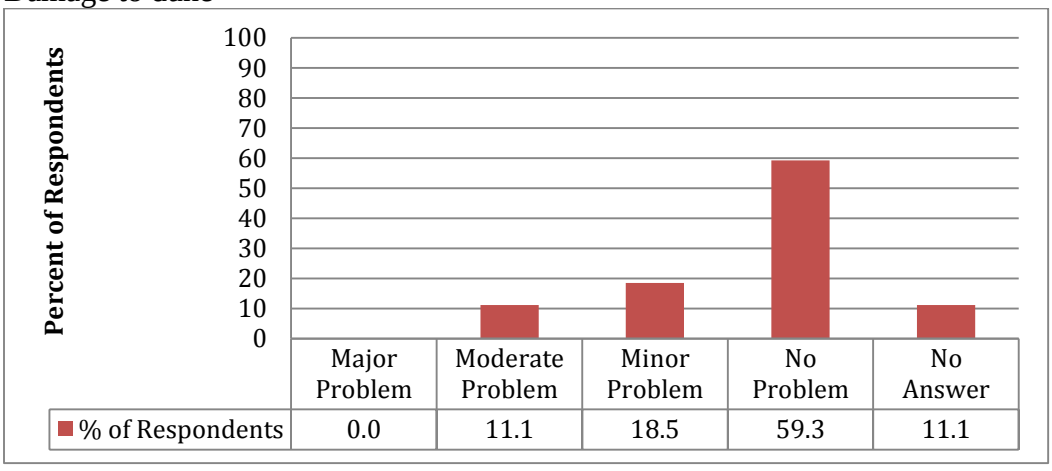
Dog waste/noise



Too crowded

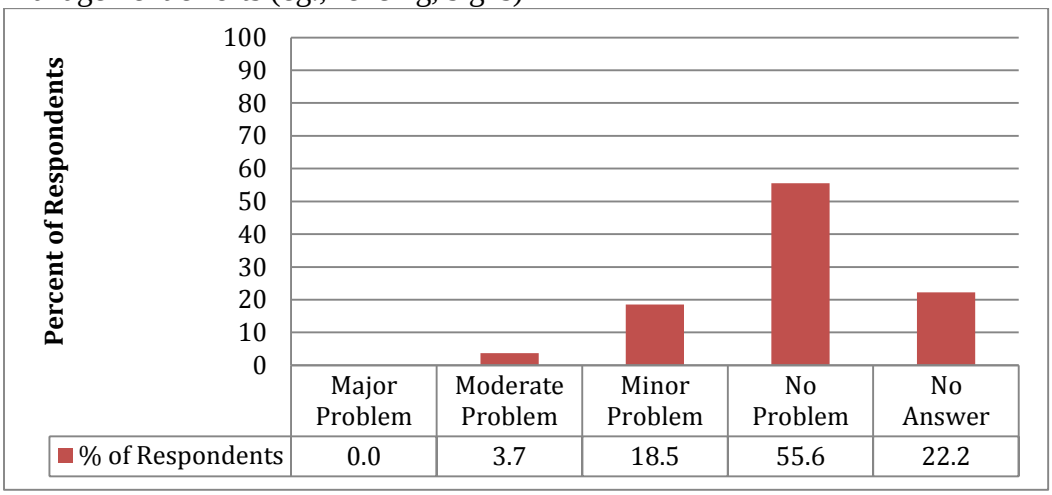


Damage to dune

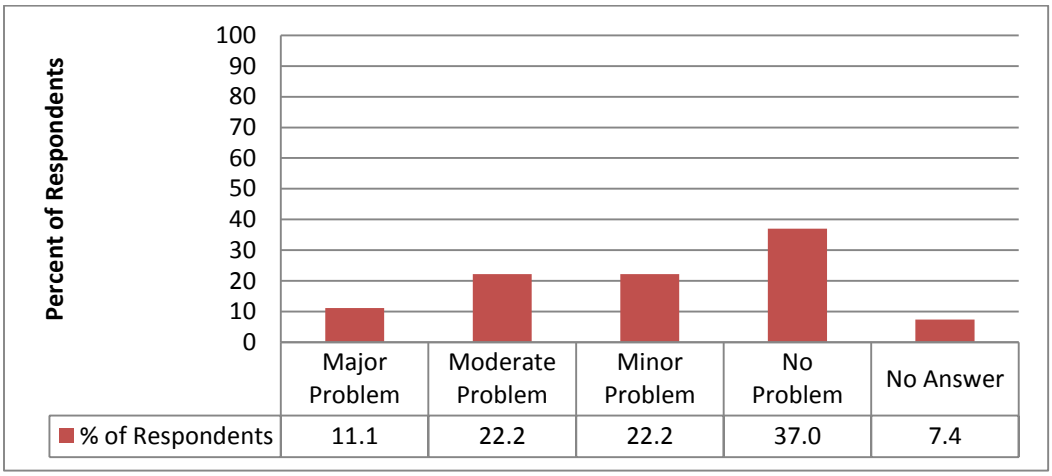


E-2 (continued). Resident responses to the question "Do you consider the following to be a problem/annoyance on the dunes?"

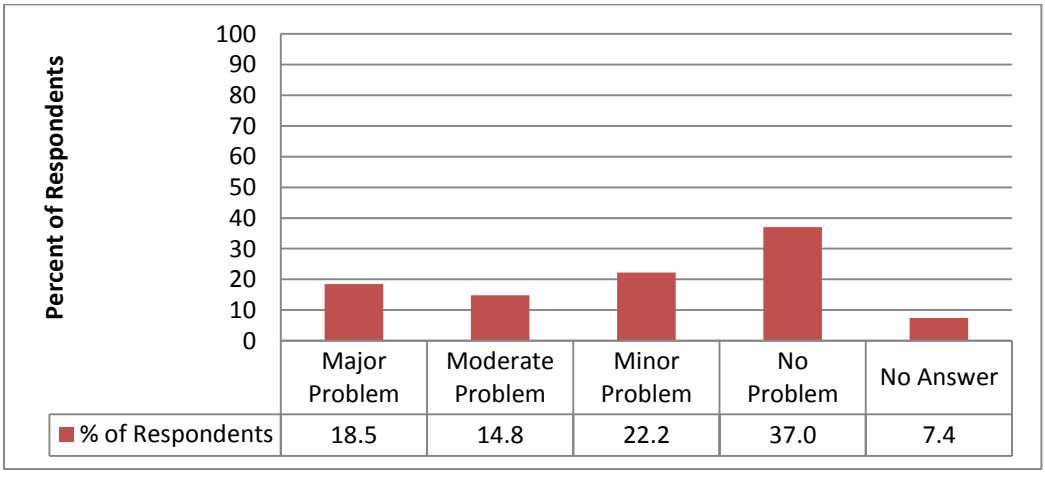
Management efforts (eg., fencing, signs)



Noise from boats

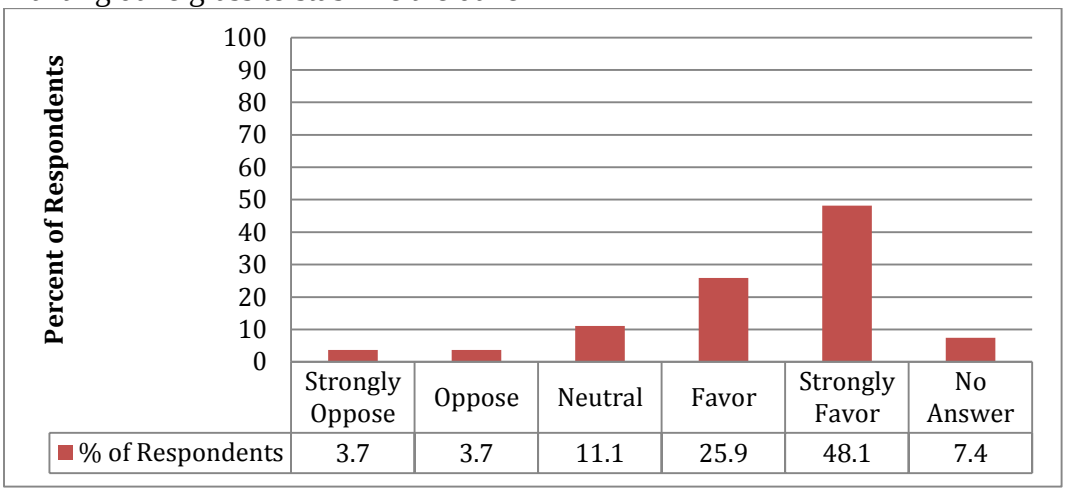


Dune advance

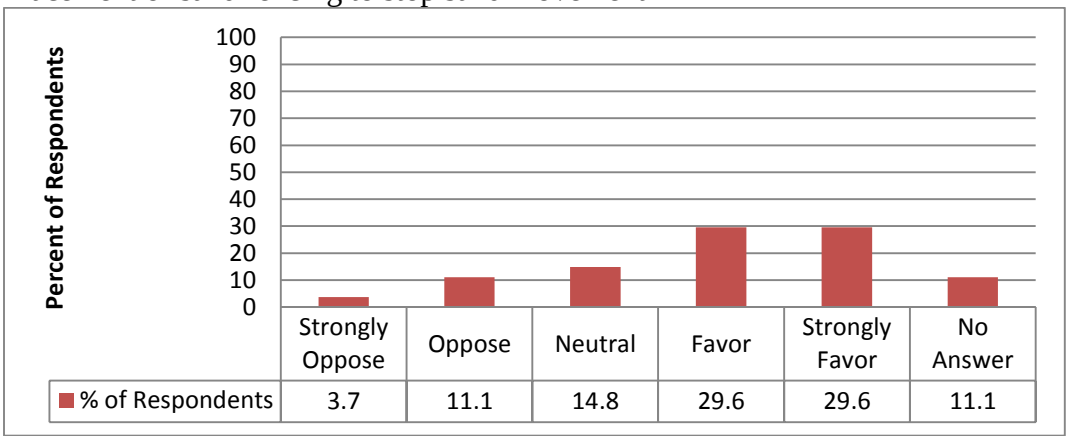


E-3. Resident responses to the question "What is your opinion of these dune management and interpretation activities?"

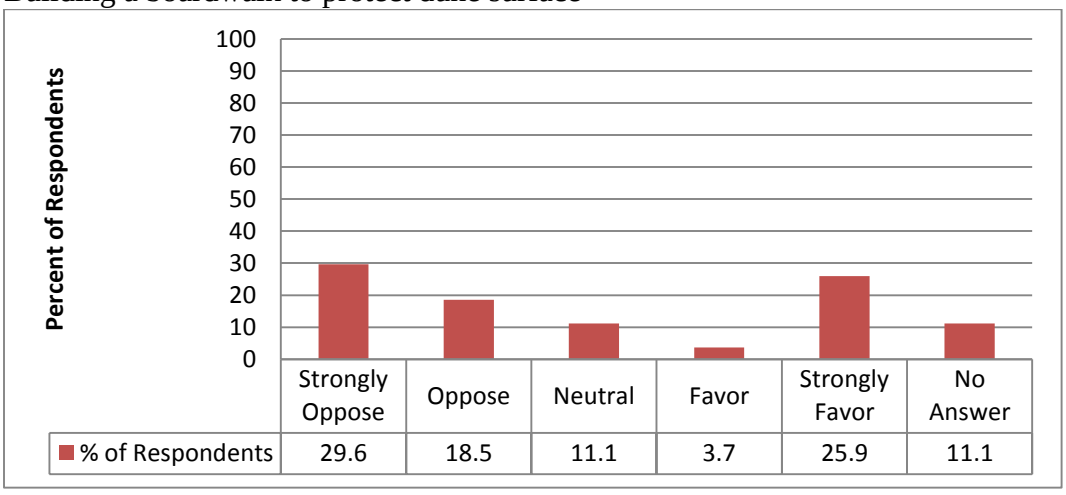
Planting dune grass to stabilize the dune



Placement of sand fencing to stop sand movement

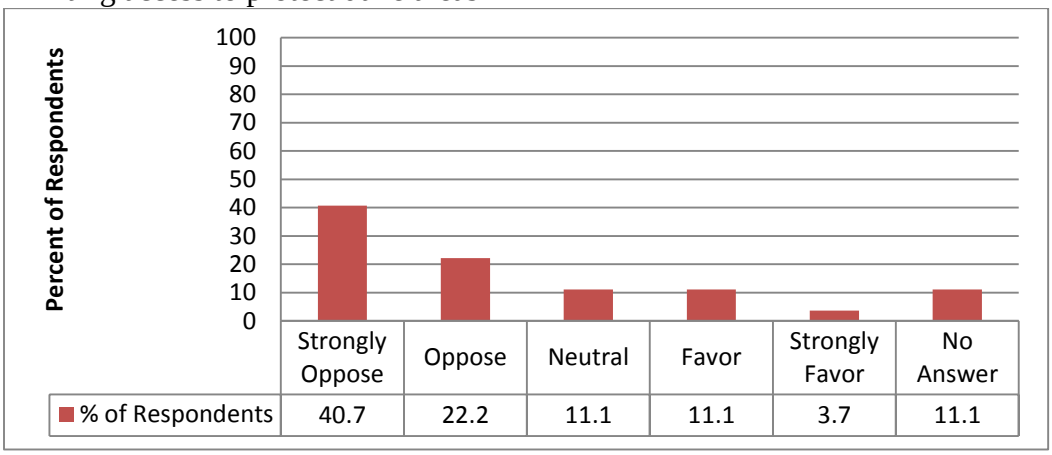


Building a boardwalk to protect dune surface

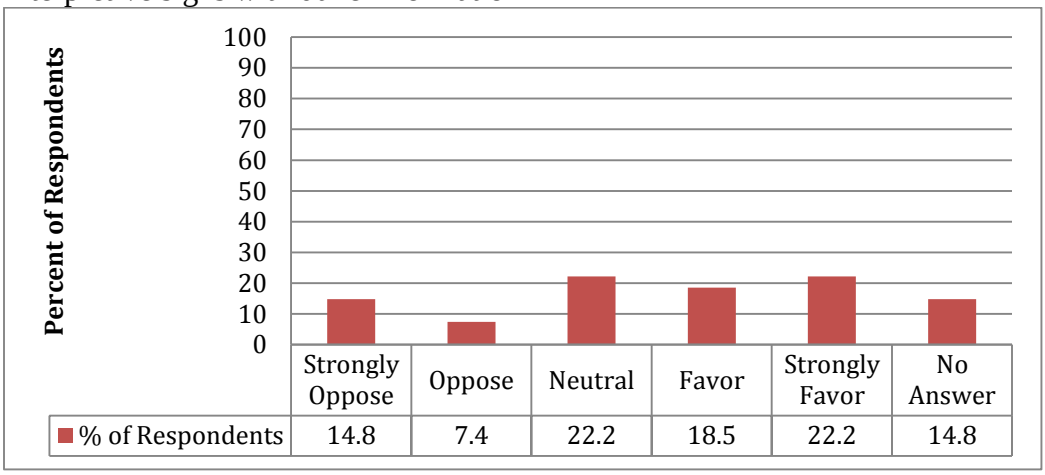


E-3 (continued). Resident responses to the question "What is your opinion of these dune management and interpretation activities?"

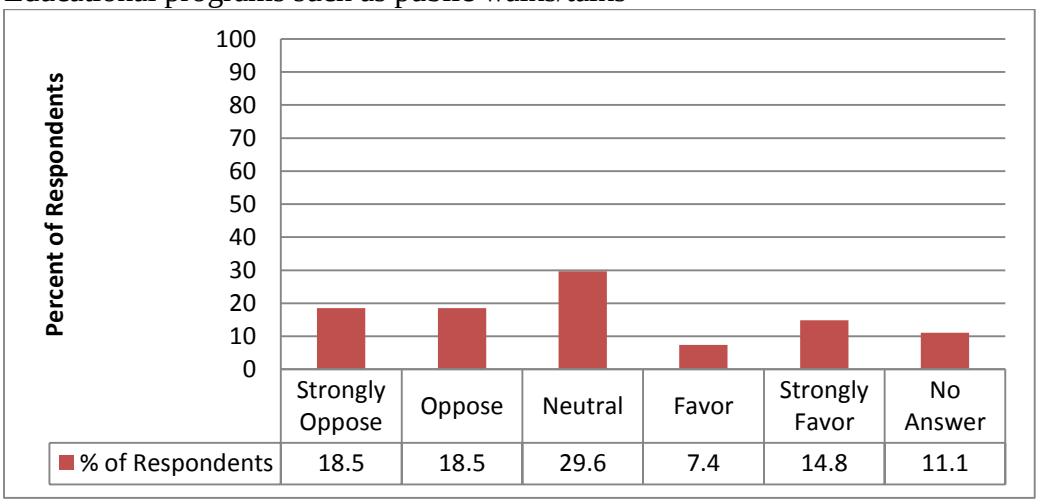
Limiting access to protect dune areas



Interpretive signs with dune information

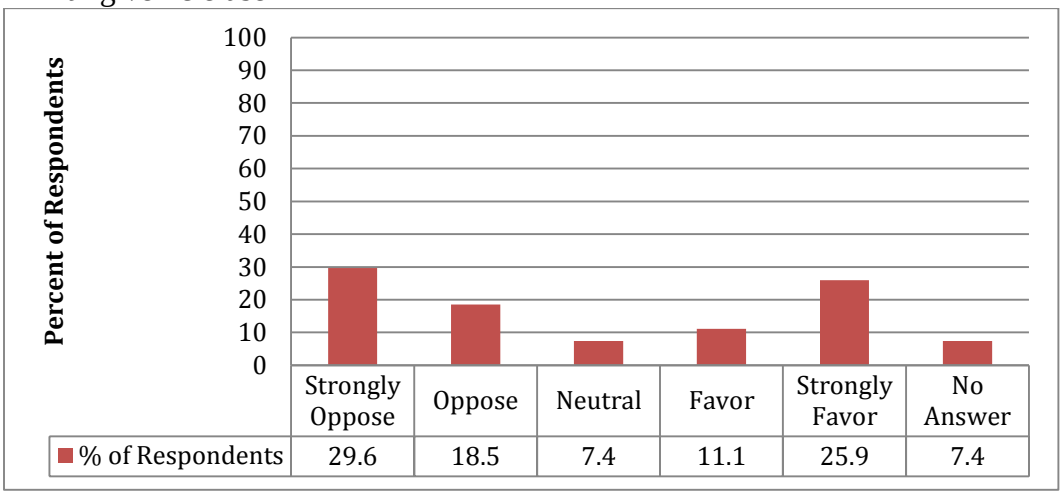


Educational programs such as public walks/talks



E-3 (continued). Resident responses to the question "What is your opinion of these dune management and interpretation activities?"

Limiting vehicle use



Banning vehicle use