Valuing Michigan's Coastal Dunes: GIS Information and Economic Data to Support Management Partnerships

MICHIGAN ENVIRONMENTAL COUNCIL

HEART OF THE LAKES

WMEAC

NOAA

DEPARTMENT OF NATURAL RESOURCES · MICHIGAN · DNR

OGL MICHIGAN OFFICE OF THE GREAT LAKES

“This first comprehensive map of Michigan’s coastal dunes indicates that the geographical character of this landscape is far more complex than previously thought. As a result, it provides leaders, planners and local decision-makers their first opportunity to envision and manage the dune landscape in its true form, rather than as we assumed it to be.”

— Dr. Alan F. Arbogast, geographer and mapping project lead, chair of the Department of Geography, Environment and Spatial Sciences, Michigan State University

“Our online survey of users of coastal dunes provides information that can help planners and decision makers understand visitor activities in different areas, including their primary activity. Survey results also provide useful information about visitor spending, social and cultural values associated with coastal dunes, and priorities for the protection and stewardship of dunes.”

— Dr. Robert Richardson, ecological economist and survey project lead, Associate Professor, Department of Community Sustainability, Michigan State University

“Michigan has an opportunity to leverage our unique Great Lakes outdoor experience—so beautifully epitomized in our coastline crowned with the largest collection of freshwater coastal sand dunes in the world—to attract more businesses, recruit more talented workers and support our transition to a more sustainable, place-based economy. The new information we’ve collected through this project provides coastal communities the best maps, data and social insights they need to better promote and steward these amazing landscapes by protecting and celebrating the places and natural assets that make Michigan such a desirable place to live and do business.”

— Brad Garmon, project lead, Director of Conservation and Emerging Issues, Michigan Environmental Council

Valuing Michigan's Coastal Dunes: GIS Information and Economic Data to Support Management Partnerships

By

Alan F. Arbogast, Michigan State University
Brad Garmon, Michigan Environmental Council
Elaine Sterrett Isely, West Michigan Environmental Action Council
Jonathan Jarosz, Heart of the Lakes
Alek Kreiger, Ducks Unlimited
Sarah Nicholls, Michigan State University
Clayton Queen, Michigan State University
Robert B. Richardson, Michigan State University

Michigan Environmental Council

August 29, 2018

Support

Financial assistance for this project was provided, in part, by the Michigan Coastal Zone Management Program, Office of the Great Lakes, Michigan Department of Natural Resources (MDNR), under the National Coastal Zone Management Program, through a grant from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

The statements, findings, conclusions, and recommendations in this report are those of the authors and do not necessarily reflect the views of the Michigan Department of Natural Resources or the National Oceanic and Atmospheric Administration.

Project Management

Michigan Environmental Council (MEC), a 501(c)3 non-profit organization created in 1980, functioned as project coordinator and fiscal agent for this effort. However, the project is first and foremost a partnership of academic experts willing to bring their specific knowledge of coastal sand dunes, tourism or environmental economics to bear on the issue, and non-governmental organizations and stakeholders from across Michigan who care deeply about the future of Michigan's dunes. MEC developed this project to bring the science of natural assets—both physical and social—more fully into the ongoing conversation about how best to manage the coastal sand dune system. As an organization, MEC is committed to advancing the state of scientific knowledge about dunes and supporting the State of Michigan and local communities as they work to protect, preserve, restore, and enhance the world's premier freshwater coastal dune system while also providing access and public enjoyment.

While conducting this original research, MEC developed two individual Quality Assurance Project Plans (QAPP) to guide each portion of the project, and served as QAPP manager for both. MEC also met with the researchers, stakeholders and other interested parties periodically to review and refine research methodologies, manage timelines and expectations, and to develop plans for the final work products. MEC hopes and believes the relationships and collaborations formed or strengthened through the course of this and other related dunes-focused projects will have a lasting impact by improving scientific knowledge and bringing it to bear on governmental and societal decisions about dunes.

Acknowledgements

MEC appreciates and would like to thank the academic experts who contributed to this project, leveraging their scientific/technical expertise in support of the project while also making substantial in-kind contributions to the project through discounted hourly rates and/or significant *pro bono* work on the project. They also presented the project and preliminary findings at more than a dozen community and organizational meetings across the state, from dune communities in the northwest to Midtown Detroit in the southeast.

We are also grateful and extend our sincere thanks to the collaborators, contributors, and community leaders, event participants and hosts who provided inspiration, information and connections throughout this project. It would be impossible to name them all, but the authors want to particularly acknowledge the following: Karen Boase and Ronda Wuycheck (Coastal

Management Program, Office of the Great Lakes, Michigan Department of Natural Resources); Robb MacLeod (Ducks Unlimited); Sara Woodruff (designer and marketing guru); Marci Hamilton (Southwest Michigan Planning Commission); Kathy Evans (West Michigan Shoreline Regional Development Commission); John Paskus (Michigan Natural Features Inventory); Janet Schrader (Chikaming Township); Charles Davis (Preserve the Dunes); Marci Cisneros (Grand Haven CVB); Elizabeth Brockwell-Tillman (Gillette Sand Dune Visitor Center at P.J. Hoffmaster State Park); Lisa Brush (Stewardship Network); Kristin Phillips (Chief of Marketing and Outreach, Michigan DNR); Dustin Isenhoff (Michigan DNR), Christina Pastoria (OGL), Patrick Doran (The Nature Conservancy) and Shaun Howard (The Nature Conservancy's Eastern Lake Michigan Project Manager and coordinator of the Michigan Dune Alliance partnership); Lori Booth, Gus Gates and Pete Stauffer (The Surfrider Foundation); Kate Lederle (Michigan Department of Environmental Quality); Caiden Pietrowski, Donielle Routt, Kristine Tyler, Bryan Lambert and everyone at Run Muskegon; Ryan Goloversic and Jake Mitchell (MACkites); David Swan and Saugatuck Dunes Coastal Alliance (Saugatuck); Julia Chambers and A Few Friends of the Environment of the World (Ludington); Jonathan Knobel (CC Filson and Co., Midtown Detroit); Steve DeBrabander; and Nicholas Occhipinti.

Table of Contents

Support ii
Project Management ii
Acknowledgements ii

Executive Summary 1

Introduction 6

Part 1: Creating a GIS Layer of Michigan's Coastal Sand Dunes 10
Background 10
Methods 13
Mapping 13
Field Verification 17
Results 18

Part 2: Conceptualizing the Uses and Values of Michigan's Coastal Dunes 23
Introduction 23
Background 24
Methods 26
Survey Design and Administration 27
Results 30
Characteristics of Respondents 31
Dunes Trips in the Past 12 Months 36
Dunes Locations Visited 37
Dunes Activities 40
Month of Visits 41
Recreation Activities for Most Visited Locations 42
Most Recent Trip and Trip Expenditures 50
Other Activities 52
Social and Cultural Values of Dunes 53
Trust for Protection and Stewardship of Coastal Dunes 56
Open-Ended Comments 57

Part 3: Outreach and Engagement 60
Background 60
Approach 61
Leadership Engagement 61
Marketing and Branding 62
Freshwater Dune Summit 62
Social Media 63
Presentations and Events 63
Email Campaign 64
Business Outreach 64

Outcomes 66

Conclusions 67
Lessons Learned..... 68
Opportunities..... 70

References 74

Appendices
A: Locations Visited
B: Word Clouds
C: Open-ended Comments
D: Survey Questionnaire
E: Freshwater Dune Summit Program
F: Dune Survey Outreach Efforts

Executive Summary

In late 2016, the Michigan Coastal Zone Management Program, through NOAA and the Michigan Office of the Great Lakes, funded the Michigan Environmental Council (MEC) project, "*Valuing Michigan's Coastal Dunes: GIS Information and Economic Data to Support Management Partnerships.*" The results described here represent an exciting new chapter in the history of Michigan's understanding and management of a true global treasure—the largest collection of freshwater coastal sand dunes found anywhere in the world.

The project is part of an ongoing effort to advance the collective awareness and understanding of this resource. The first effort, also funded by the Coastal Management Program, began in 2014 with the project "*Bringing the Latest Science to the Management of Michigan's Coastal Dunes,*" which compiled a wealth of existing information about the history of dune management in the state, and focused heavily on improving our understanding of the ecological aspects of the coastal dunes. Results of that project can be found in a series of written reports housed online at https://environmentalcouncil.org/discover-post/valuing-michigans-coastal-dunes-with-gis-economics/.

The new project, which kicked off in late 2016, emerged directly from that earlier work. A new project team was assembled including: academic experts Alan F. Arbogast, Sarah Nicholls, and Robert B. Richardson (Michigan State University); community partners Elaine Sterrett Isely (West Michigan Environmental Action Council), Jonathan Jarosz (Heart of the Lakes) and Alek Kreiger (Ducks Unlimited); and an engaged set of dune stakeholders from other organizations and the general public. This team focused on delivering three specific products that improve our understanding of and ability to manage coastal dunes in Michigan:

1. A clearer definition and a comprehensive digital GIS map of coastal dunes.

This is the most detailed, comprehensive map of Michigan's coastal dunes thus far developed in a digital GIS environment, and includes a total of 93,249 hectares (230,423 acres) of coastal dunes. Several dunes on the northeast side of the Lower Peninsula, along Lake Huron, which have been noted by local users but not mapped in other surveys, are acknowledged in this map.

As described in more detail in Part 1, this new map more accurately establishes the full geomorphic extent of Michigan's coastal sand dunes. The digital map layer complements and adds great value to other dune research and projects and local planning efforts. It also fills a critical gap that has previously inhibited constructive discussion about the state of Michigan's overall coastal dunes system. We view it as a powerful new tool to support and enable future research, geographic analysis and community engagement that can be used in conjunction with other new information collected through this project and others to advance the overall level of knowledge of coastal dunes.

Once reviewed and approved by the Michigan Department of Natural Resources (DNR), this map will be freely available to the public as a downloadable map package at: https://environmentalcouncil.org/. In the future we hope to incorporate it into the Dunes GIS created by Calvin College, and promote its availability to state agencies, local

planning departments, researchers and the public. The updated maps enable a variety of new analyses and comparisons to better assess the condition of the overall dunes systems.

As an example of the analysis enabled by the new maps, we compared available digital maps of state-designated "critical dunes" to the new maps of total sand dunes, and found that 32 percent of Michigan's total coastal sand dunes (approximately 74,000 of the total 230,423 acres that were mapped) are currently designated as "critical dunes" by the state of Michigan under state statute. This includes both public and private lands, as discussed in more detail in Part 1.

We can also map the amount and location of the coastal sand dunes currently in public ownership or owned by conservation or land trust organizations, and compare it to the acreage of dunes that are privately owned. Doing so reveals that 125,939 acres (54.7 percent of the 230,423 acres of total coastal sand dunes) are in public ownership (federal, state or local) or controlled by a local land conservancy or other conservation-based ownership (as identified by the Conservation and Recreational Lands [CARL] database managed by Ducks Unlimited).[1] This kind of analysis is useful information for local decision makers when they are considering future conservation and preservation efforts and to support coastal management.

2. A fuller picture of the true social, cultural and economic importance of the dunes, with specific data about how people interact with and value the resource.

Using an innovative online survey approach modeled on earlier studies completed by the Surfrider Foundation, the #HowYouDune Coastal Sand Dune survey deployed during 2017 allowed participants to locate precisely where in Michigan's coastal dune landscapes they visited, log the type of activity they engaged in during these visits, and answer a series of social and economic questions about the trip expenditures and social values they attribute to the coastal sand dunes.

Based on content and questions developed by Michigan State University environmental economist, Dr. Robert Richardson, with support from Dr. Sarah Nicholls and the other members of the project team, the #HowYouDune Coastal Dune Survey was built and deployed by Ducks Unlimited (DU) GIS experts Robb MacLeod and Alek Kreiger. The survey tool combined traditional survey questions with new spatial data collection tools and captured the responses of 3,610 individuals who collectively mapped 7,065 dune sites visited.

Of total survey participants, 3,189 (88.3 percent) reported having visited coastal dune areas in the past 12 months, reporting a total of 21,452 trips to the dune areas—an average of 6.7 visits per person. The average group size for a visit to Michigan's coastal dune areas was 3.4 persons, and they spent an average of $391.75 per trip (or $133.15 per person per trip). More than half of

[1] Note that for some types of properties, the location is withheld from the public in the CARL dataset. Most of these withheld properties represent conservation easements held by a land trust/land conservancy for which the location is not disclosed to protect sensitive plant or animal species. For this analysis, 403 acres of privately owned golf courses, country clubs, or hunt clubs were removed from the protected status, along with a 1,204 acre campground area owned by a private Tawas Beach Club, and a 366 acre designated utility corridor owned by American Electric Power, for a total of 1,973 acres removed from the first run analysis.

dune visitors also reported purchasing meals at a restaurant (63.4%) and buying groceries (52.8%) during their dune visit. Nearly a quarter of respondents (22.7%) visited a winery or brewery.

In terms of the intrinsic values associated with coastal sand dunes, 96.2 percent of respondents rated scenic beauty as *extremely important* or *very important*, and 92.5 percent rated protection for future generations as *extremely important* or *very important*. More than four-fifths indicated that protection of a unique ecosystem (82.6 percent) and outdoor recreation (82.6 percent) were *extremely important* or *very important*. More than four-fifths (81 percent) rated access to coastal dunes in Michigan as *extremely important* or *very important* to the quality of life for them and their households. Fewer than 1 percent rated access to coastal dunes as "not at all important."

The most visited dune area based on our survey was Sleeping Bear Dunes National Lakeshore, followed by Silver Lake State Park, Ludington State Park, Warren Dunes State Park, and Holland State Park. (The popularity of State Parks, it should be noted, may be in part due to the heavy reliance on the Michigan DNR's email lists for dissemination of the survey.)

Beach-going and scenic enjoyment were identified as the top primary reasons for visiting coastal dune areas in Michigan (20.1 percent and 19.7 percent of respondents, respectively), followed by modern camping (14.2 percent), hiking (12.3 percent), and rustic camping (7.4 percent). In terms of all activities undertaken in coastal dunes, beach-going ranked highest (66.5 percent) in popularity, followed by scenic enjoyment (54.1 percent), hiking (46.9 percent), and dune-climbing (37.7 percent).

More than three-quarters of respondents (77.6 percent) indicated that they trust state government with the protection and stewardship of coastal dunes in Michigan. More than two-thirds of respondents identified non-governmental organizations (67.5 percent) as institutions to be trusted with the protection and stewardship of coastal dunes, and more than half identified local government (53.1 percent) as trusted stewards of coastal dunes.

More results of the survey are collected in this report, and in the future this information will be repackaged for use by local communities to support their planning efforts. Continued efforts will be made to share the findings of this report with other agencies, organizations and the public.

3. More engaged dune stakeholders empowered with connections and tools to support future science-based efforts, improve management decisions and engage policy discussions.

Connecting with dune stakeholders—including recreation users, tourism professionals, business leaders, and local planners—was a critical aspect of the research and a boost to the overall project as well. It not only helped improve our research outcomes, it also helped develop and mature a powerful new set of tools and approaches for disseminating this and future dune science information.

Following a model developed by the Surfrider Foundation and Point 97, the #HowYouDune survey participants were recruited using a strategy frontloaded with intensive engagement of

dune user groups and local partners, and through ongoing support of state and local organizations and recreation retailers/outfitters. In addition, we hosted a dunes summit early in the project to generate interest, to help us identify ambassadors who could support more outreach and a wider survey reach, and to recruit volunteers who would participate in early testing of the online survey prior to launch.

Survey promotion was undertaken with a variety of marketing and awareness strategies and tools, including earned media stories about events like our Freshwater Dune Summit, traditional email and direct mail outreach, social media (Facebook, Twitter, Instagram, etc.), and with postcards placed in outdoor retail establishments, eateries, and related service providers. Through presentations to stakeholder groups and interviews with businesses located near coastal dunes, we continued to generate awareness of the survey and interest in dunes. We created a range of print and electronic educational materials to spread the word about the project, and developed a stronger network of dunes stakeholders. The most valuable of these was with the Michigan Department of Natural Resources, who hold and utilize a huge database of outdoor recreationalists and park visitors. Recognizing that they lacked detailed information about dune users, they shared the #HowYouDune survey request with their extensive email database and through social media, significantly improving the reach of the survey.

The survey was also promoted by project team members, advisors and partners, local government, and non-governmental partners through community meetings and arranging presentations before and during the survey process, to share preliminary research results. By partnering with these trusted voices from the outset, we achieved a higher than expected rate of participation in the opt-in survey, and opened up future avenues of dune outreach, engagement and information sharing. It also opened up lines of communication between dunes experts and dunes stakeholders that we believe will yield positive outcomes well into the future.

Going forward, the wealth of new data, maps and tools that were created and collected during the course of the project will be shared in a variety of ways in the months and years ahead. For example, we plan to create attractive infographics that summarize key findings in visually compelling ways, and add these to the growing collection of coastal dune information and knowledge housed at https://environmentalcouncil.org/discover-post/valuing-michigans-coastal-dunes-with-gis-economics/. We will also share these materials and links to the website and full report through social media and email methods, and by tapping the relationships built during the course of the project—including with the many thousands of survey respondents who provided us with email addresses to stay informed about the project—to promote the project results.

Plans are also being developed now to ensure the GIS map set is incorporated into other online shoreline mapping tools, such as the Shoreline Viewer pilot project under development at Michigan Technological University, that are intended to help local communities plan future development in the dynamic coastal environment. We have also presented the #HowYouDune Survey results with the Beachtowns group of Lake Michigan visitor's bureau, and will repackage the results in the form of simple infographics and products that can more easily be used by local community leaders like these. Finally, we identified a number of future modifications, follow up tasks and lessons learned to consider for future work, described at the conclusion of this report.

Taken as a package, we believe the results of this project are immediately useful for state and local communities interested in improving dunes management, and in better understanding how this unique asset can be both protected and leveraged for community benefits and for the enjoyment of future generations.

Introduction

Michigan is home to the largest body of freshwater coastal sand dunes in the world. Early assessments of the coastal dunes in Michigan described the eastern shore of Lake Michigan as "hills of wind-blown sand almost continuously fringing the border of the lake" (Cowles, 1899, p.98). Michigan's world-class coastal dunes are in reality found along Lakes Michigan and Superior, but also on Lake Huron. In Michigan, the dunes are typically comprised of beautiful, soft, evenly sorted wind-blown glacial sand and are revealed in surface features as diverse as towering dunes perched atop hundreds of feet of glacial fill, open foredunes, forested backdunes, inter-dunal wetlands and sandy beaches.

They occur in a variety of land uses, ownerships and management regimes, including local, county and state parks, national lakeshores (comparable to National Parks), private land serving as commercial and residential use, and land conservancies. The dunes have long provided a variety of sometimes competing economic uses and values. Their beauty and rich diversity of plant and wildlife attract residents and millions of visitors to Michigan shorelines to visit, live and work. In doing so, they challenge the state to weigh enjoyment of the dunes against the need to protect them and to live in greater harmony with their dynamic, ever-changing nature.

Although the dunes are heavily utilized in the contexts of recreation, residential and commercial development, tourism, biodiversity, and industry, the exact extent of the location and spatial distribution of the dunes has not fully been articulated, limiting our ability to bring "the most comprehensive, accurate, and reliable information" to bear (Michigan Sand Dune Protection and Management Act, as amended by Public Act 297 of 2012).[2]

A comprehensive inventory of Michigan's coastal dunes has long been desired. Coastal sand dunes in Michigan occur in a variety of land uses, including local, county and state parks, national lakeshores, private land, and land conservancies. For example, a comprehensive 1987 University of Michigan Master's student thesis project suggested that "Michigan's dunes should be comprehensively inventoried and analyzed" by creating a "map of the entire system of dune system" that would, among other things, "document existing land uses in the dunes" (Beede VI-2). It also suggested that the state needed to "design and/or develop a comprehensive dune system map, including geological, ecological, administrative, and other features" (Beede VI-4).

A full and comprehensive map of Michigan's coastal sand dunes has been unavailable due to two key factors: 1) limitations in data quality, and 2) prior mapping efforts were conducted for specific purposes and therefor focused on subsets of the dunes. Previous maps of the dunes have been completed in the past; however, the complex nature of this diverse landscape with its variety of land features and natural cover means that a simple GIS map that both defines and maps this feature did not exist prior to this project.

In an earlier 2015 MEC-led research project, "Bringing the Latest Science to the Management of Michigan's Coastal Dunes," researchers from Calvin College concluded, "There is no available

[2] For a more complete review of the history of coastal sand dune management, please see the 2015 MEC-led research project, "Bringing the Latest Science to the Management of Michigan's Coastal Dunes," available online at https://environmentalcouncil.org/discover-post/valuing-michigans-coastal-dunes-with-gis-economics/

dune GIS layer to identify all of the dunes in Michigan. Without such a layer, fundamental questions about the dunes can only be estimated or answered locally. Furthermore, appropriate stewardship questions cannot be fully answered without knowing the cumulative extent and other characteristics of dunes in Michigan."

With this data gap in mind, there was strong agreement among our collected team of researchers and experts that the creation of a comprehensive GIS data layer showing Michigan's coastal sand dunes was a priority research need. Consultation with previous advisory groups and researchers indicated that Dr. Alan Arbogast, chair of the Department of Geography, Environment and Spatial Sciences at Michigan State University, was the ideal candidate to generate such a GIS layer, based on extensive work in Michigan dunes, including advancing our understanding of their age and structure, geomorphic processes of development and evolution, and geographic extent.

Similarly, researchers have also noted that social and economic values of coastal dunes are not well documented, inhibiting implementation of management that would ensure "compatible economic development and multiple human uses of the critical dunes" (Michigan Sand Dune Protection and Management Act, as amended by Public Act 297 of 2012). Little is actually known about the social and economic values of coastal ecosystem services, particularly Michigan's coastal sand dune landscapes. There have been repeated calls for more and better studies that estimate the value of the full range of ecosystem services of coastal sand dunes. Such estimates of economic and social values are important because policy makers must often make choices between alternative uses of natural resources in all sorts of landscapes, such as coastal dunes.

From an economic perspective, efficient policy decisions require information about the total economic value associated with each policy alternative or land use. Policy makers often rely on the economic values revealed in markets to inform decisions. However, many of the values of natural resources such as dune ecosystem services are not reflected in economic markets because they cannot be easily assessed using conventional measures, such as a property value assessment or another price set by a market. Thus, they are frequently overlooked and undervalued in public policy.

While many of the ecological values of coastal dunes may be seen as intrinsic and "inestimable," human uses of dunes generate social and economic benefits that can be measured or estimated using a variety of techniques. Communication of these kinds of social and economic benefits to policy makers can help improve the information upon which dune management decisions are based. Social values need to be understood and communicated to and by a broader and more actively engaged dune constituency if the state intends to preserve values associated with dune systems over the long term. To that end, our current project set out to apply social science in the task of identifying the specific social, cultural and economic importance of the dunes, including the relative importance of recreation and tourism in dune landscapes.

Economists have a variety of techniques to estimate the so-called "non-market" values of goods and services, such as ecosystem services, and in some cases, non-market benefits can account for a major share of the total economic value of a resource. Therefore, to ensure efficient policy

decisions about dune management, it is important to use state-of-the-art techniques to estimate the economic benefits of ecosystem services from dune landscapes.

The dunes clearly play a prominent role in the state's tourism campaigns and its large outdoor recreation economy. Michigan's Sleeping Bear Dunes National Lakeshore was voted the "Most Beautiful Place in America" by an ABC News/Good Morning America poll in 2011. Based on information from the Outdoor Industry Association, the state's residents spend $26.6 billion each year on consumer goods related to the outdoor recreation economy, putting the state in a league with better known outdoor recreation destinations such as Colorado and Oregon.[3] Sixty-three percent of Michigan residents participate in outdoor recreation activities each year compared to a national average of 48 percent. In general, Michigan residents are more likely to participate in kayaking and camping than the average American. Overall, the outdoor recreation economy supports 232,000 direct jobs in Michigan, $7.5 billion in wages and salaries, and generates $2.1 billion in state and local tax revenue each year, and it's clear that the Great Lakes coastal dunes are a major part of this economy.

There are, however, no specific valuation studies for Michigan's coastal sand dunes. In 2006-2007 researchers from the Annis Water Resources Institute at Grand Valley State University (GVSU), in cooperation with the West Michigan Strategic Alliance, conducted an economic valuation of ecosystem services associated with green infrastructure in West Michigan. The resulting "INtegrated Valuation of Ecosystem Services Tool" (INVEST) developed by GVSU concluded that "Great Lakes Sand Dunes and Beaches" were one of the highest valued components (on a per acre basis) in terms of ecosystems services and associated values.[4] While comprising less than one percent of the overall landscape within the specific seven-county study area (4,762 acres), sand dunes and beaches were estimated to provide the region the second highest total economic value of ecosystem services and associated values, estimated at $138,820,172 per year. Private sand dunes and beaches provided a specific "aesthetic and amenity-based recreation" value estimated at $19,437 per acre per year, while the same value of public sand dunes and beaches was estimated at $62,171 per acre per year.

The study makes it clear, however, that there are currently "no studies valuing Great Lakes sand dunes and beaches" specifically, and that the project's estimated ecosystems values for sand dunes and beaches relied on data from the U.S. East Coast (INVEST, 2007).

It is important to emphasize that many factors influence decisions related to protecting and managing coastal dunes. Economic values certainly should not be the only consideration in decisions impacting their management. However, information on the economic benefits of dunes can help decision makers make informed tradeoffs between various uses, such as conservation, development, or recreation. In addition, policy makers have expressed interest in obtaining

[3] https://outdoorindustry.org/state/michigan/.

[4] Associated values included in the GVSU study are benefits to people derived from ecosystem services. Examples would include property value, scenic beauty, tourism, improved mental health, genetic resources, timber, firewood, lumber, hiking, hunting, camping, wildlife viewing, stormwater management, and air and water purification. For more information see: https://www.gvsu.edu/wri/invest

information about the economic benefits of dunes, and of the economic impacts of dune landscapes.

The objective of this study was to generate information about the uses and values of coastal sand dunes in Michigan to advance understanding about their social and economic importance, and to support improved awareness and better foundations for management partnerships.

Part 1: Creating a GIS Layer of Michigan's Coastal Sand Dunes

Background

The first statewide mapping of coastal dunes was conducted by Kelley et al. (1962), in association with increasing interest in dune tourism, when the Michigan Department of Conservation commissioned a map (Figure 1). This map included dunes throughout the state (including interior dunes) and was primarily based on U.S. Department of Agriculture county soil surveys, which associates landforms and soil parent materials (e.g., dune sand, glacial outwash).

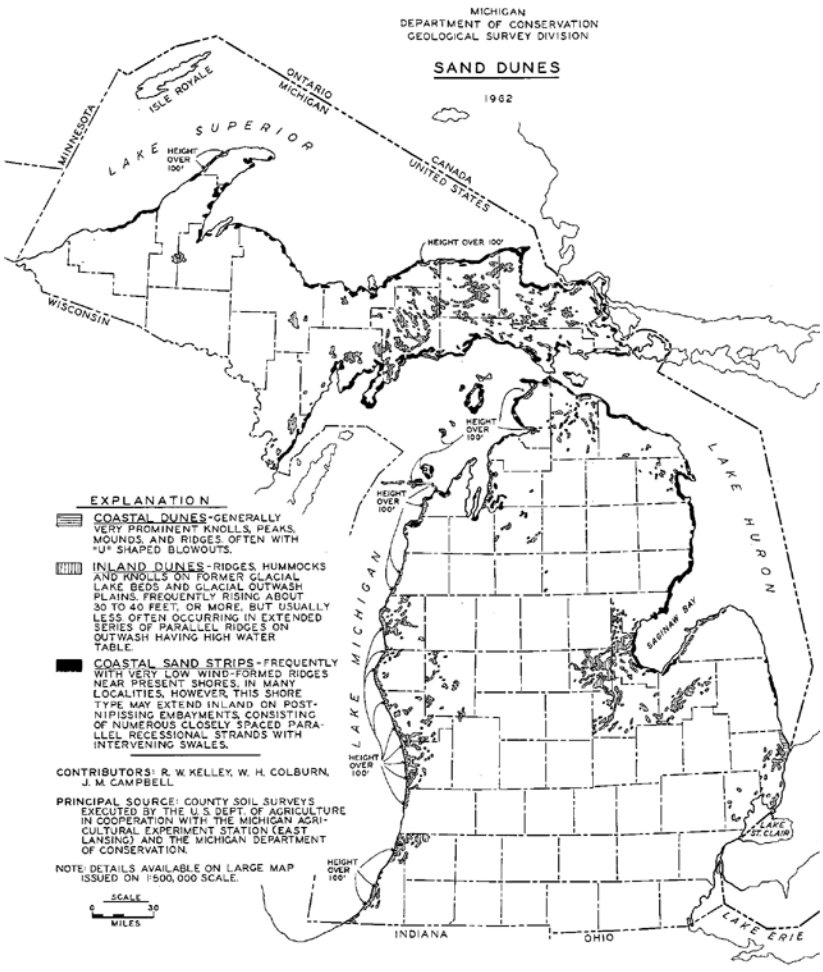

Figure 1. Dune map created by Kelley, Colburn, and Campbell (1962) for the Michigan Department of Conservation. This map shows dunes throughout the state and is largely based on soil surveys.

The next effort to map Michigan's coastal dunes occurred in 1979 in accordance with the creation of Michigan's Sand Dune Protection and Management Act (Dune Act). That law was

primarily focused on the regulation of sand dune mining within a sand dune area "designated by the department that includes those geomorphic features composed primarily of sand, whether windblown or of other origin and that lies within 2 miles of the ordinary high-water mark on a Great Lake."

The Michigan Department of Natural Resources (DNR) staff at that time defined a "designated sand dune area" as "a land mass which exhibits the physiographic features of a dune-type ecosystem." They used several existing studies to assist their identification of designated sand dune areas, such as Kelley's 1962 DNR study, a 1975 Great Lakes Basin Framework Study that identified "high sand dunes" and "low sand dunes," and Soil Conservation Service information on shoreline areas that were identified as "sand dune types" or "sand dune associated soil types" and areas adjoining dunes. The sand dune areas were legally described in 40-acre parcel sections, providing a rough estimate of 275,000 acres of total coastal dunes in Michigan.

The State of Michigan also hired William Buckler of the Remote Sensing Project at Michigan State University to create a coastal dune classification system and to map dunes within designated dune areas (e.g., Figure 2a). Buckler (1979) termed the largest dunes in this map "barrier dunes," because they provided a physical barrier to the interaction of lakeshore environments and activities with those inland. Buckler worked under the legal mandate that his barrier dunes would be "the first landward sand dune formation along the shoreline of a Great Lake or a sand dune formation designated by the Michigan DNR" (Buckler, 1979).

Buckler used the following criteria, based on language in the Dune Act, in his mapping exercise:

a) the dunes are relatively permanent features;
b) the inland boundary is the landward boundary line at the most landward base of the barrier dune which displays the greatest relative relief within a designated sand dune area;
c) the shoreward boundary is the most shoreward base of the barrier dune that is not temporary;
d) the boundary shall be easily recognizable and delineated on aerial photographs;
e) the dunes will impede the interaction between the lakes and inland activities (Public Act 222 of 1976).

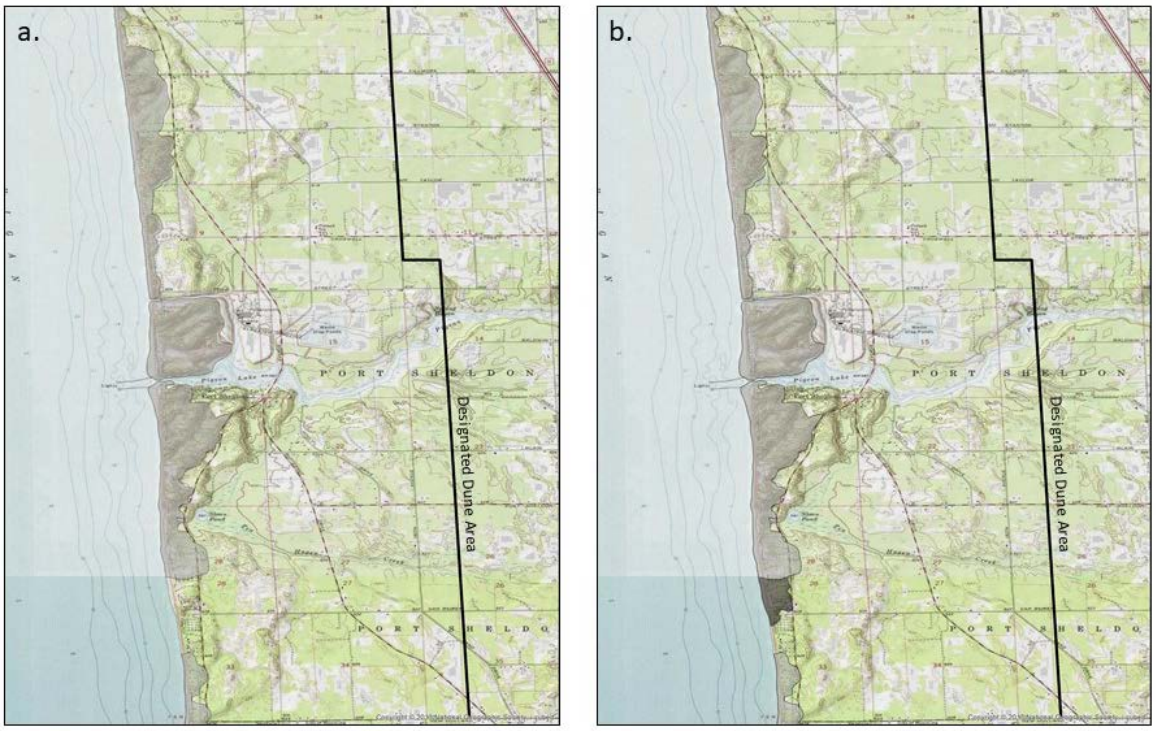

Figure 2. Regulatory dune map units along a coastal reach in Ottawa County before (a) and after (b) the Critical Dune statute was passed in 1989. a) Spatial distribution of barrier dunes (light gray) within the "designated dune area" (black boundary line) in this portion of the coast. b) Additional "critical dunes" (dark grey) were included in 1989 based on the presence of an exemplary dune-associated plant community.

In 1989, the state's sand dune protection law was revised, and expanded upon Buckler's classification and mapping effort by creating the *Atlas of Critical Dunes* (e.g., Figure 2b) which added areas to Buckler's map that met all of the following criteria: a) dunes composed primarily of dune sand; b) dunes at least 20 feet in height; c) and dunes exhibiting a minimum length of 1.5 miles parallel to the shore. The critical dunes map effort also added areas supporting exemplary dune-associated plant communities as designated by the Michigan Natural Features Inventory.

Based on these characteristic, the state's regulated dunes encompassed approximately 70,000 acres of the estimated 275,000 lakeshore dune acreage total. Michigan State University's Center for Remote Sensing later reviewed the *Atlas of Critical Dunes* and other available data, and in 1994 recommended that the state revise the atlas by adding approximately 12,000 acres that were not designated as critical and removing 230 acres that were included. Those changes were reflected in new dune maps produced at MSU; however, the recommendations were not applied to the state's official *Atlas of Critical Dunes*, so the original map is still the basis for regulatory activities of state and local authorities.

In summary, three previous significant efforts have been undertaken to map extensive portions of the coastal dune landscape in Michigan. The first effort, conducted by Kelley et al., (1962), attempted to map all dunes in Michigan regardless of interior or coastal position. Although a

comprehensive effort, it was based primarily on soil surveys, which inherently have high spatial uncertainty. Subsequent efforts to map coastal dunes in 1979 and 1989 were based on regulatory considerations (e.g., height, length along shore, vegetation) associated with Michigan's Sand Dune Protection and Management Act and subsequent statutory revisions. As a result, mapping of coastal dunes was narrowly focused and excluded large areas of wind-blown sand.

Given the high-resolution digital imagery available today, it is now possible to map coastal dunes in a comprehensive way with high resolution. The new map generated for this project delineates the spatial extent, location and relative age (Holocene) of Michigan's coastal sand dunes.

The resulting map provides a more comprehensive view of the spatial distribution and relative age of coastal dunes within Michigan, and offers local land managers information in a digital GIS environment appropriate for use as an underlying "map layer" for other social science research, regional planning efforts and educational purposes.

Methods

Mapping

Sand dunes are distinctive landforms because they can be identified based on diagnostic morphological characteristics such as form (e.g., parabolic, linear), steepness of the slip face, and orientation. As a result, it is possible to accurately delineate the spatial distribution of dunes, especially where high-resolution digital imagery is available.

For this project, Dr. Arbogast devised a definition of what constitutes a coastal sand dune unit, based on the most up-to-date and objective understanding of dune geology and geomorphology and current mapping technology. Under his direction, graduate research assistant Clayton Queen then painstakingly gathered and analyzed sophisticated remotely sensed data, compared air photos, topographic maps, and soil data, and conducted necessary field verification to create the first complete digital map of the full geomorphic extent of Michigan's coastal dunes.

Mapping for this project[5] was conducted by visual identification of physical dune forms on digital elevation models (DEMs) obtained from the MDNR and U.S. Geological Survey (USGS). Due to data limitations, these DEMs varied in spatial resolution across the state. Some counties have high-resolution (1-meter), LiDAR (Light Detection and Ranging) derived DEMs available (Figure 3a). The rest of the state, however, is covered by the USGS National Elevation Dataset's (NED) 3-D Elevation Project (3DEP) seamless product, with a range of spatial scales available. The product used in the creation of this map has a spatial resolution of 1/3 arc second (Figure 3b). In Michigan, 1/3 arc second equates to roughly 10-meter resolution imagery.

[5] Prior to undertaking the mapping work, the project team developed a Quality Assurance Project Plan (QAPP) for the collection of GIS data, and a NOAA-compliant data sharing plan. The QAPP was finalized and approved by the Michigan Office of the Great Lakes on March 16, 2017.

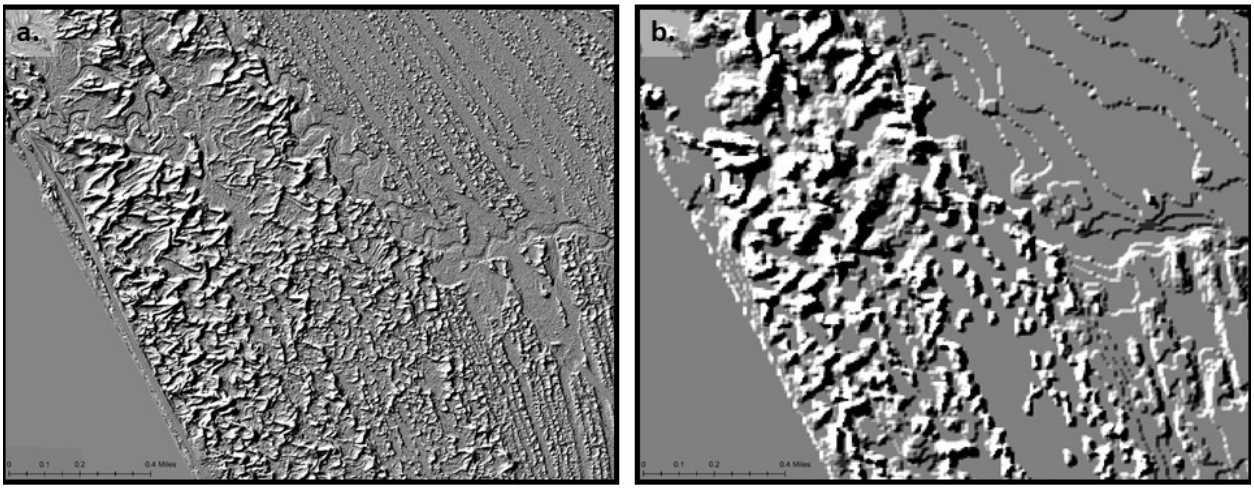

Figure 3. Sand dunes in Mackinaw County, MI as seen on a) a high-resolution DEM with 1-meter spatial resolution and b) a low-resolution DEM with 10-meter spatial resolution. Both DEMs are shown at a scale of 1:10,000.

For this map, dunes were delineated using a process of heads up digitization, or manually tracing a computer mouse over the dune features on a screen. Boundaries were set at the junction between the dunes and adjacent landforms. The width (i.e., from the shore to a point inland) of dune fields was based on an assessment of physical continuity of dunes across space. In other words, if dunes that are more interior were connected to those along the shorezone proper, they were considered mappable landforms in this exercise. On high-resolution DEMs—those that have a 1-meter spatial resolution—dune edges are often easily recognizable (Figure 3a). In contrast, dune edges are less well defined on low-resolution DEMs (Figure 3b), which have 10-meter resolution. The resolution of the underlying data was noted in the attributes of the GIS shapefile.

Three distinct attributes were added to the dune map to account for the differing spatial resolution, spatial uncertainty, and type of dune complex. These three attributes are described below. Spatial resolution refers to the resolution of the base data, the DEMs. Two categories of base data were created: high spatial resolution (LiDAR products) and low spatial resolution (1/3 arc second NED 3DEP products). Spatial uncertainty is an expression of the confidence in the accuracy of the line designating the dune boundary. The degree of uncertainty was determined by deciding on an envelope that can surround the line drawn to express the confidence in the location of that line. For both high- and low-resolution data, a solid line and a dashed line are used as cartographic representations of uncertainty (Table 1).

High-resolution data has a confidence of ~5 meters. Thus, a solid line along the margin of a given dune field represents the location of a boundary with a perceived spatial accuracy of $\pm$ 5 meters (Figure 4b). In contrast, a dashed line marks the boundary of a dune field with a spatial uncertainty of $\pm$5 meters (Figure 4a). In places where dunes were delineated using low resolution data the degree of spatial uncertainty is considerably greater—50 meters for high confidence (Figure 4d) or > 50 meters for low confidence (Figure 4c).

Table 1. Description of the lines used in delineating dunes for high and low resolution DEMs. Column two describes the degree of uncertainty for each of the resolution types. The third column indicates the visual representation of spatial uncertainty.

Resolution	Spatial Uncertainty	Map Symbology	Representative Figure
High	> 5 meters	Dashed Line	Figure 4a
High	< 5 meters	Solid Line	Figure 4b
Low	> 50 meters	Dashed Line	Figure 4c
Low	< 50 meters	Solid Line	Figure 4d

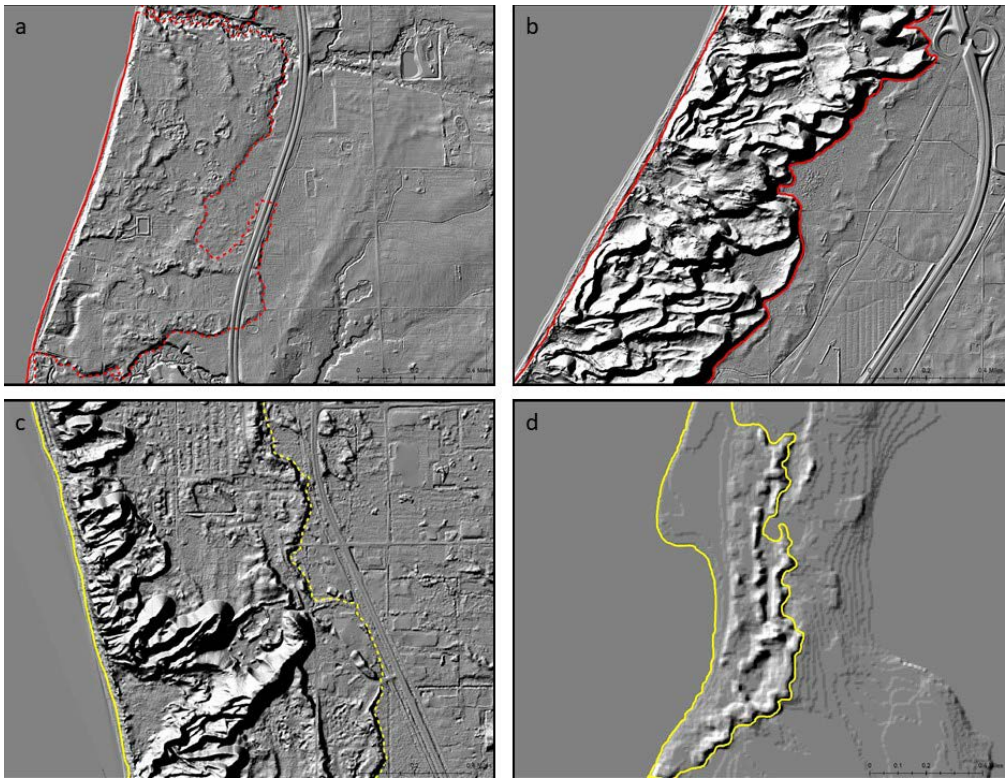

Figure 4. Examples of various resolution DEMs with Holocene dunes delineated at a 1:10,000 scale. a) High resolution DEM with a spatial uncertainty of greater than 5 m represented by a red dashed line. b) High resolution DEM with a definite dune boundary (< 5 m) represented by a red solid line. c) Low resolution DEM (although LiDAR derived) with high spatial uncertainty (> 50 m) represented by a yellow dashed line. d) Low resolution DEM with low spatial uncertainty (~ 50 m) represented by a solid yellow line.

Dune-swale and dune areas are separately designated to express the discontinuity of dune-swale areas. In all cases dune-swale areas are delineated by a dashed line due to the representation of a discontinuous dune zone (Figure 5b). Dune areas may be represented by both solid and dashed lines based on uncertainty.

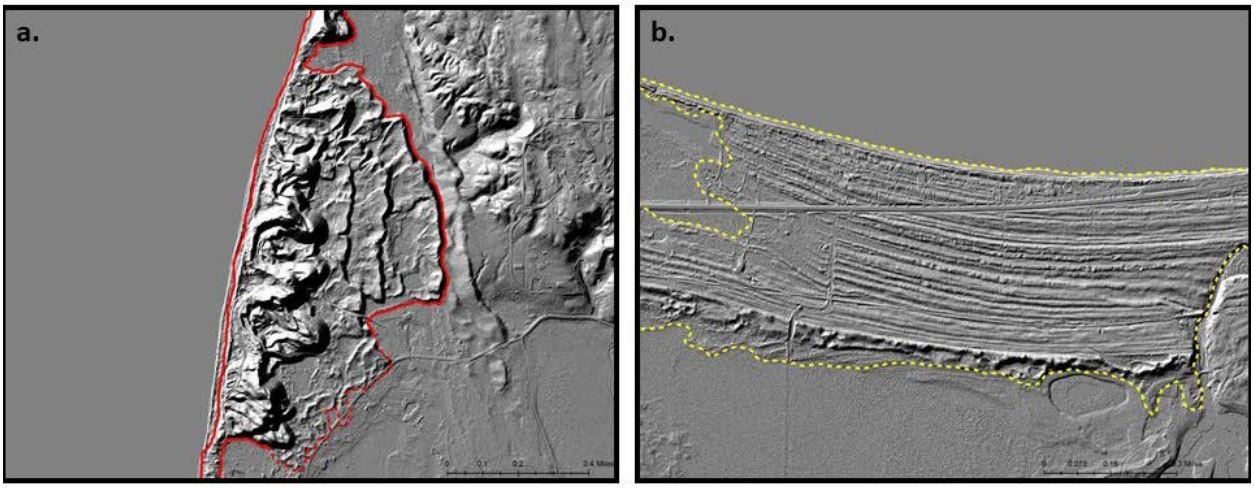

Figure 5. Dunes were classified as either dunes or dune-swale complexes. a) A dune complex in Manistee County. Note the easily observable dune forms. b) Dune-swale complex in Marquette County with a series of alternating dune ridges and swales progressing away from the lake.

In addition to the analysis of LiDAR imagery, mapping decisions were also informed by ancillary data such as USDA SSURGO soils data, aerial photography and satellite imagery, topographic maps, and previously mapped dune sites. Soil data were used to help identify locations where dunes were likely to be found and provide an accurate boundary.

In places where dunes boundaries were poorly defined, or where dune forms were potentially smaller than the resolution of the DEM, aerial photography or satellite imagery were used to provide additional detail. Topographic maps were used rarely in this project, but helped to inform decisions where other data were limited. Previously mapped dunes (i.e., the *Atlas of Critical Dunes*) were helpful in determining where dunes were located. Other data gathered from land descriptions from local land use agencies, land conservancies, DNR, etc., provided information about the location of dune fields. Together, data from all sources allowed for the comprehensive recognition of dune forms and improved map accuracy.

The coastal dunes mapped for this project were assumed to be younger Holocene age (classical "barrier" dunes), as older Pleistocene (ice age dunes on old lake plains) dunes were assumed to be located further inland and disconnected from the younger shoreline dunes. It was also hypothesized that coastal Pleistocene dunes would be oriented in a northwesterly direction, whereas younger (Holocene) dunes would be oriented to the west/southwest. Field verification conducted during this mapping effort served primarily to validate this assumption and to assure researchers that this hypothesis was correct. In the end, all the coastal dunes mapped for this project proved to be Holocene in age.

The resulting effort provides a quality of data and mapping useful for general research, planning and educational purposes, but should not be used as a regulatory or decision-making tool. The coastal dunes GIS layer provides the geographic boundaries of Michigan's Holocene-aged coastal sand dunes, rather than a detailed articulation of features within the overall boundary and

is not intended to provide an ecologically based sub-classification system for dunes, beyond the distinction between dune-swale and dune. Such work has been undertaken in a limited geography by the Michigan Natural Features Inventory and Networks Northwest through their "Increasing Coastal Resiliency in the Northwest Lower Peninsula" project.

Field Verification

Although the protocol described above generally inspired high confidence in map decision-making, certain areas proved difficult to resolve spatially due to the lack of topographic expression in dunes. As mapping progressed, researchers targeted specific locations to test map interpretations in the field. This ground-truthing exercise including 1) testing accuracy of identified coastal dune boundaries, 2) assessing the accuracy of spatial-age relationship between Holocene and Pleistocene coastal dune systems.

In both circumstances, representative sites were chosen during the mapping process to visit in the field. Map accuracy was assessed by field checking to verify the location of boundaries (Figure 6). Such field verification was conducted three times throughout the course of the project, including 1) early October to the Upper Peninsula and northern-lower Michigan, 2) mid-November to south-west Michigan, and 3) late-November to the east coast of Lower Michigan. Each of the excursions consisted of visual identification of dunes at the assessment of mapped boundaries. Field work was conducted by visual inspection of those locations previously identified and notes were taken about the size and boundaries of the dune field in question. These notes were subsequently used to inform map boundaries and to clarify the map in areas where the location of dune boundaries or the specific dune edge was unclear based on the aerial imagery.

Soil characteristics assessed during field visits provided a means to differentiate these map units and verify the accuracy of age classification between Holocene and Pleistocene coastal dune systems. Field observations indicated that "old" soils were not present in any inland dunes examined, which, in turn, indicated that all dunes in the study were Holocene in age.

As a result, verification did not require the collection and dating of sand using Optical Stimulated Luminescence (OSL) dating techniques, though additional OSL dating would be useful for greater understanding of age and dune dynamics. The hypothesis that would be tested in further OSL dating of these eolian sands is that they accumulated during the Nipissing high stand of ancestral Lake Michigan. If this hypothesis was verified, it would make these sands ~5,000 years old and thus similar in age to "backdune" deposits reported in previous studies near Holland. Such results would be significant from a geomorphic perspective because they would demonstrate that eolian sands accumulated farther inland during the early part of the constructional phase that built the modern coastal dune complex than previously recognized. Such inquiries were beyond the scope of this project.

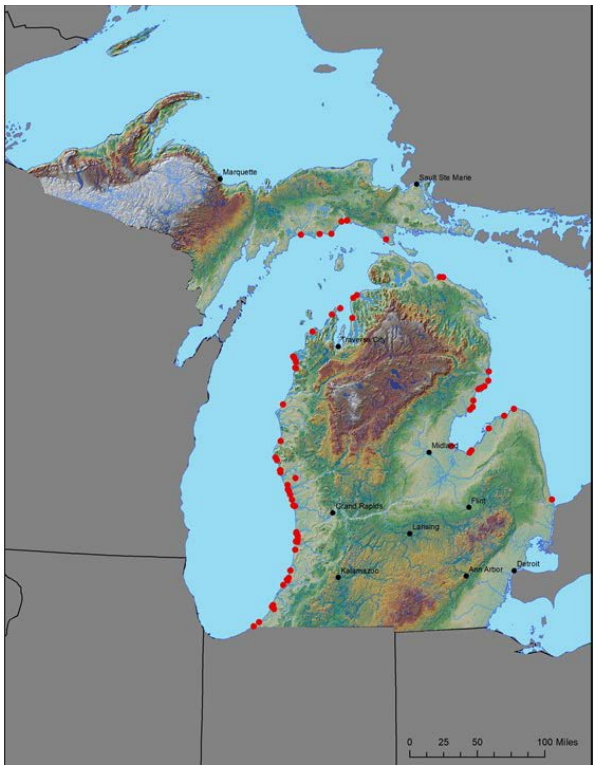

Figure 6. Map of sites (red dots) where field checking was conducted to verify map accuracy and Holocene age dune classification.

Results

This study has created the most detailed, comprehensive map of Michigan's coastal dunes thus far (Figure 7). As a result of this work, a total of 93,249 hectares (230,423 acres) of coastal dunes was mapped. All the coastal dunes mapped for this project are younger Holocene age. These dunes are predominantly found on the east coast of Lake Michigan (the west coast of Lower Michigan). Dune-swale complexes are most common on the east side of the state and in embayments in northern Lower Michigan and the Upper Peninsula. Significant dune fields are also located along the north- and south-eastern coastlines of the Upper Peninsula. Smaller dunes on Lake Huron that have long been recognized by local residents are also captured by this mapping effort.

Along with a final report, the digital map package will be made available at https://environmentalcouncil.org/discover-post/valuing-michigans-coastal-dunes-with-gis-economics/. This digital data, accessible through a GIS program environment, provides a much-needed asset for natural resource management. Given its digital nature, it can be easily updated in areas where high-resolution DEMs become available in the future.

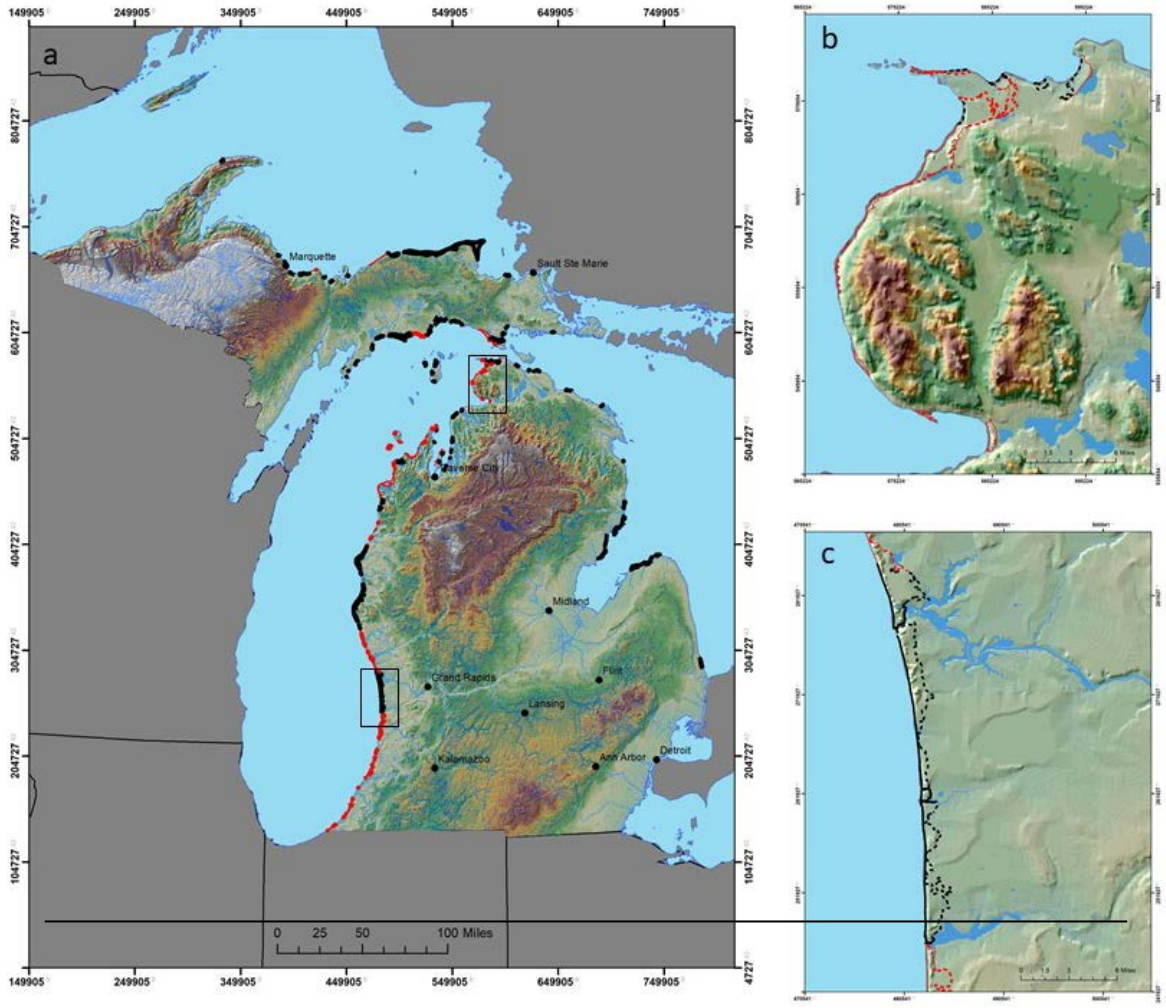

Figure 7. a) Comprehensive final map of Michigan's coastal sand dunes. All mapped dunes are Holocene aged. Coastal reaches mapped in red are areas where high-resolution DEMs are currently available, whereas those in black reflect use of low-resolution imagery. b) Example of mapped dunes in Emmet County. c) Example of mapped dunes in Ottawa County.

Although an earlier effort to comprehensively map coastal dune landforms was conducted in the early 1960s, it was based on county soil surveys, which are sometimes inaccurate and have low spatial resolution. Subsequent mapping exercises were conducted in specific association with Michigan's Dune Act (and subsequent modifications) and were thus narrowly focused.

This project was not limited by such constraints, and was also armed with the most accurate and modern digital imagery currently available. As a result, it is an important contribution to the evolving science about coastal dunes in Michigan. As an example of the analysis enabled by the new maps, we compared available digital maps of state-designated "critical dunes" to the new maps of total sand dunes, and found that 32 percent of Michigan's total coastal sand dunes (approximately 74,000 of the total 230,423 acres that were mapped) are currently designated as "critical dunes" by the state of Michigan under state statute. A simple comparison of the coastal

dunes mapped and used for regulation under the Critical Dunes Act against the new map illustrates the differences (Figure 8).

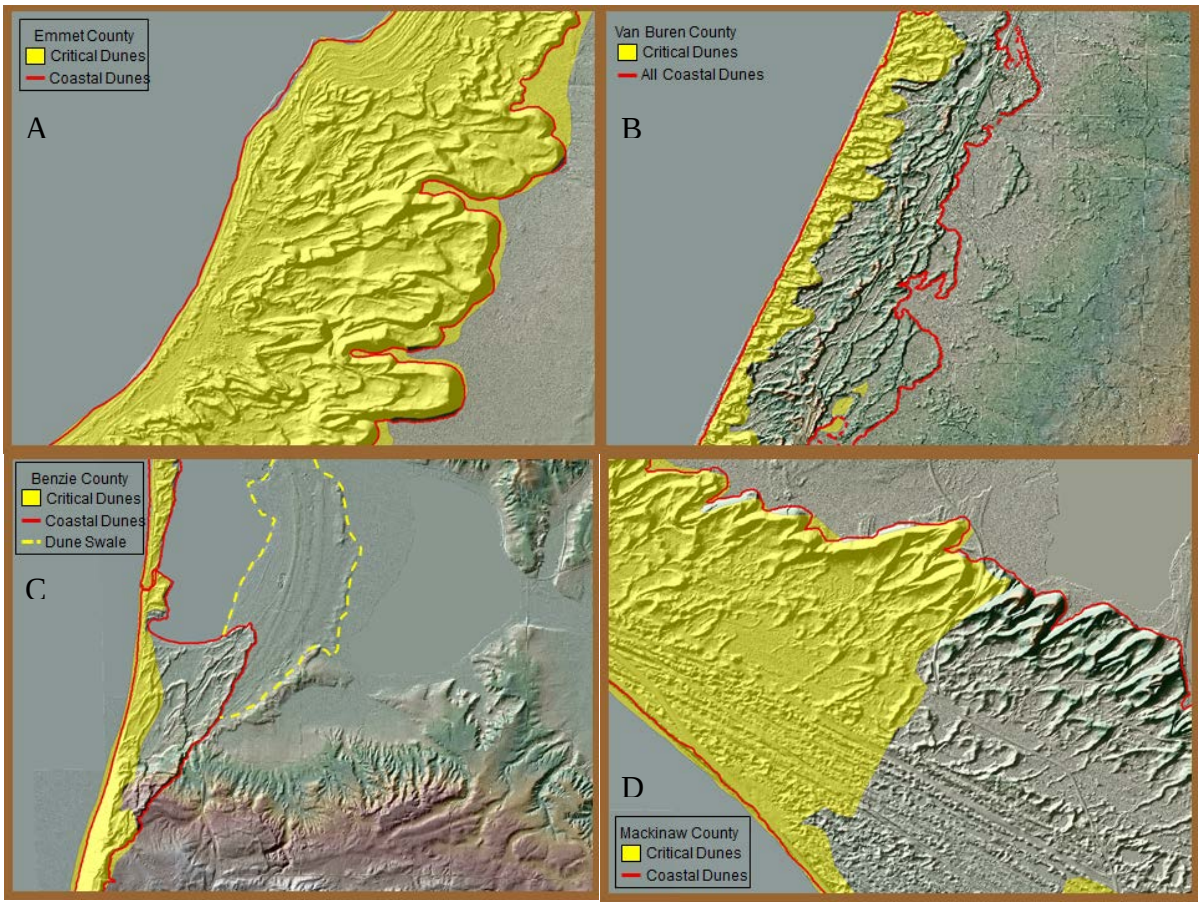

Figure 8. Comparisons of "Critical Dunes" contained in the state's current "Critical Dune Atlas (in yellow) against "Coastal Dunes" mapped using techniques described in this project (red line). Maps shown are comparisons for A) Emmet County, B) Van Buren County, C) Benzie County (with new dune-swale complex mapped with dotted yellow line; and D) Mackinaw County.

We can also make comparisons related to the amount of Michigan's coastal dunes in other categories, such as "protected lands." As an example, an overlay analysis was conducted comparing the newly mapped coastal dunes against properties designated by the U.S. Geological Survey's Gap Analysis Program (GAP) as part of the "Protected Areas Database of the United States" (PAD-US) database.[6] Ducks Unlimited conducted the overlay analysis using their 2013 Conservation and Recreational Lands (CARL) database, which includes the PADUS-US GAP status properties.[7] See Figure 9 below.

[6] "The Protected Areas Database of the United States (PAD-US) is the official inventory of public parks and other protected open space. With more than 3 billion acres in 150,000 holdings, the spatial data in PAD-US represents public lands held in trust by thousands of national, State and regional/local governments, as well as non-profit conservation organizations." Online at https://pubs.usgs.gov/fs/2013/3086/.

[7] "For some types of properties, the location is withheld from the public in the CARL dataset. Most of these withheld properties represent conservation easements held by a land trust/land conservancy for which the location is not disclosed to protect sensitive plant or animal species. For this analysis, 403 acres of privately owned golf courses, country clubs, or hunt clubs were removed

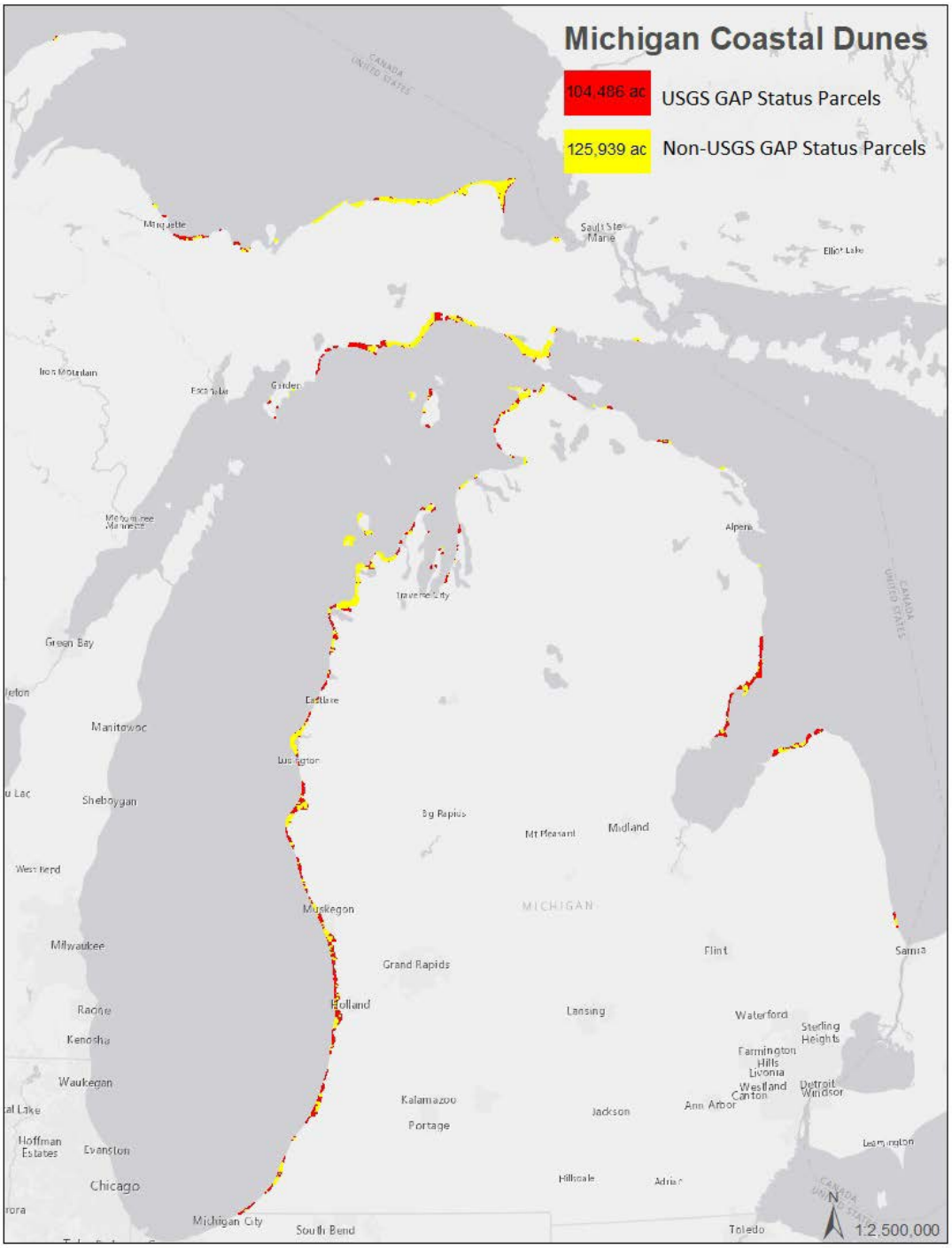

Figure 9. Coastal dunes in "protected status" (GAP) as delineated by the USGS PAD-US, in the Conservation and Recreational Lands (CARL) database managed by Ducks Unlimited. Overlay analysis conducted by Alek Kreiger, Ducks Unlimited, based on the Michigan coastal sand dune maps created by Dr. Alan Arbogast and Clayton Queen, MSU.

from the protected status, along with a 1,204 acre campground area owned by a private Tawas Beach Club, and a 366 acre designated utility corridor owned by American Electric Power, for a total of 1,973 acres removed from the first run analysis.

The results show that 125,939 acres (54.7 percent of the 230,423 acres of total coastal sand dunes) are in public ownership (federal, state or local), controlled by a local land conservancy or in similar “protected” status as defined by the USGS PAD-US process. This kind of analysis is useful information for local decision makers when they are considering future conservation and preservation efforts and to support coastal management.

Part 2: Conceptualizing the Uses and Values of Michigan's Coastal Dunes

Introduction

Survey results from an earlier project, "Bringing the Latest Science to the Management of Michigan's Coastal Dunes," revealed that local government officials in jurisdictions with state-designated critical dunes were interested in obtaining information about the economic impact of recreation and tourism in coastal dune landscapes. They felt this information would help them address challenges associated with coastal dune management and make better decisions. The project team consequently identified this as a research gap that could have implications for management of coastal dunes.

Coastal sand dunes provide an array of important benefits that are supported by coastal geomorphic processes and location-specific ecosystems, including direct and indirect economic benefits to humans. For example, dunes that are relatively undeveloped provide a natural laboratory for scientific research, they provide coastal protection and erosion control, and they serve as a storehouse for biological diversity. In addition, coastal sand dunes provide attractive landscapes for recreation and tourism activities; they have cultural heritage value; and they also generate economic impacts that support local communities. Coastal sand dune ecosystems are ecologically and geomorphically important, but their specific values and uses are understudied, poorly understood, and underappreciated (Everard et al., 2010; Barbier et al., 2011).

Scientists refer broadly to these kinds of benefits as "ecosystem services," which are usually interpreted to imply the contributions of nature to a variety of ''goods and services." Simply put, ecosystem services are the benefits people obtain from ecosystems, and in economics, the term ''ecosystem services'' would normally be classified under three different categories:

1. ''goods'' (e.g., products obtained from ecosystems, such as resource harvests, water, and genetic material),
2. ''services'' (e.g., recreational and tourism benefits, or certain ecological regulatory and habitat functions, such as water purification, erosion control, climate regulation, and habitat provision), and
3. cultural benefits (e.g., often intangible, benefits of gathering places, inspired art, spiritual renewal, heritage values).

Broadly speaking, these are considered to be ecosystem services, and many of them have social and economic values which generate benefits that support local communities. This is true across many natural landscapes—from mountains to deserts and boreal forests—and it is also true of the ecosystem services provided by coastal dunes. Some of the ecosystem services of coastal sand dunes have been identified and measured, including coastal protection, erosion control, carbon sequestration, nutrient cycling, recreation, and other cultural services (Read, 1989; Everard et al., 2010).

Many of the ecosystem services provided by coastal sand dunes in Michigan are valuable in part because of their uniqueness and global importance. Based on our new comprehensive mapping project, there are 230,423 acres of coastal sand dunes in Michigan, which is the greatest amount of land area in freshwater coastal dunes in the world. These dunes support an array of threatened and endangered animal and plant species, several of which are dependent on the movement of windblown sand for long-term survival, and they support numerous habitats, including open sand dunes, interdunal ponds, and temperate forests. In addition, coastal sand dunes in Michigan provide areas for a variety of recreation activities that attract millions of visitors each year.

Many of the ecosystem services provided by sand beaches and dunes are threatened by human use, development, invasive species, and climate change (Brown and McLachlan 2002; Zarnetske et al. 2010). In particular, the removal or disruption of sand and vegetation coupled with increased storm intensity threaten critical services provided by coastal dune ecosystems, specifically those of coastal protection and coastal freshwater catchment (Barbier et al., 2011). Coastal sand dunes serve multiple environmental and socioeconomic functions that often have competing interests, such as recreation, biodiversity conservation, development, sand mining, freshwater catchment, and coastal protection.

The scientific literature describes how coastal ecosystems in general are dynamic and rapidly transforming due to numerous forces, such as sand movement, fishing pressure, fluctuations in water levels, climate change, and land use change. Other forces, including urban development, population growth, road construction, and intensive pressures from motorized recreation threaten the biological diversity and integrity of coastal dune ecosystems in some regions. This implies that coastal ecosystem services—including the ecosystem services of coastal dunes in Michigan—are also changing, along with the economic values of these ecosystem services. Coastal sand dunes provide a range of ecosystem services, including provisioning and regulating services. This study focuses on cultural ecosystem services such as the benefits of outdoor recreation.

In this study, we used an innovative, online platform to conduct a survey to obtain spatial data about the locations people visit in coastal sand dunes, information about the activities in which visitors participate, visitor spending data, and responses to questions about the relative importance of numerous social and cultural values of dunes. Findings from the #HowYouDune Michigan Coastal Sand Dune Survey were used to characterize the uses and values of coastal sand dunes, and the results are expected to inform coastal zone management and support environmental partnerships. The project also necessitated, and benefited from, the recruitment of a stakeholder community which has the potential to help improve information dissemination and the facilitation of partnerships to promote awareness of coastal dunes knowledge in Michigan.

Background

While numerous studies have been conducted on the ecosystem service value of functional green infrastructure like green roofs and rain gardens, generally little is known about the social and economic values of coastal ecosystem services, particularly these coastal sand dune landscapes (Everard et al., 2010). There have been repeated calls for increased and improved studies that estimate the value of the ecosystem services of coastal sand dunes. Such estimates of economic

and social values are important because policy makers must often make choices between alternative uses of natural resources in all sorts of landscapes, such as coastal dunes.

From an economic perspective, efficient policy decisions require information about the total economic value associated with each policy alternative or land use. Policy makers often rely on the economic values revealed in markets to inform policy decisions. However, many of the values of natural resources such as dune ecosystem services are not reflected in economic markets because they cannot be easily assessed using conventional measures, such as a property value assessment or another price set by a market. Thus they are frequently overlooked and undervalued in public policy.

While many of the ecological values of coastal dunes may be seen as intrinsic and "inestimable," human uses of dunes generate social and economic benefits that can be measured or estimated using a variety of techniques. In turn, communication of these social and economic benefits to policy makers can help improve the information upon which dune management decisions are based. Economists have a variety of techniques to estimate the so-called "non-market" values of goods and services, such as ecosystem services, and in some cases, non-market benefits can account for a major share of the total economic value of a resource. Therefore, in order to ensure efficient policy decisions about dune management, it is important to use state-of-the-art techniques to estimate the economic benefits of ecosystem services from dune landscapes.

Many factors influence decisions related to protecting and managing coastal dunes. Economic values certainly should not be the only consideration in decisions impacting their management. However, information on the economic benefits of dunes can help decision makers make informed tradeoffs between various uses, such as conservation, development, or recreation. In addition, policy makers have expressed interest in obtaining information about the economic benefits of dunes, and of the economic impacts of dune landscapes. The objective of this study was to generate information about the uses and values of coastal sand dunes in Michigan to advance understanding about their social and economic importance, and to support environmental management partnerships.

There have been previous studies of recreation visitor uses and economic impacts of visitation related to several state parks in Michigan that feature coastal sand dunes. The MDNR has developed General Management Plans for numerous state parks that include coastal sand dunes, including some of the most visited areas reported by respondents to this survey (DNR, 2017). Public and stakeholder input is an integral part of the park general management planning process, and feedback is solicited through online surveys, stakeholder meetings, and public open houses/meetings. Similar to this study, these online surveys are a form of self-selected sampling, and as such, the input may not reflect the total population of visitors to state parks; nevertheless, it is a convenient and useful way to gather input from interested stakeholders regarding their uses and valuation of the resources of state parks.

A visitor study conducted at Sleeping Bear Dunes National Lakeshore involved the distribution of questionnaires to visitors at eleven different locations in 2009 (Holmes et al., 2010). The study involved brief interviews with a systematic, random sample of visitor groups that arrived at selected locations in Sleeping Bear Dunes National Lakeshore during July 12-21, 2009. A total

of 1,158 questionnaires were distributed to visitor groups, and 696 questionnaires were returned by mail, resulting in a 60.1 percent response rate. Approximately 47 percent of visitors were visiting the park for the first time, and 25 percent had visited six or more times. For 56 percent of visitor groups, visiting Sleeping Bear Dunes National Lakeshore was the primary reason for visiting the area. The average group expenditure in the park and the surrounding area (within a one-hour drive) was $702, with a median expenditure of $300. The average total expenditure per person was $199. Visitors were asked about their perceived importance of protecting several resources and attributes, and 96 percent of respondents rated clean water as "extremely important" or "very important." Respondents also rated protection of clean air (95 percent), scenic views (95 percent), and sand dunes (94 percent) as "extremely important" or "very important."

Methods

The #HowYouDune Michigan Coastal Sand Dune Survey study differs from other studies of the uses and values of coastal sand dunes in Michigan in several ways. Studies that collect data using questionnaires that are distributed in parks, or interviews conducted with visitors in parks typically involve random sampling of visitors in order to minimize sampling bias and to ensure that each member of the population has an equal and known chance of being selected.

The #HowYouDune study incorporated the use of opt-in, or self-selected, sampling, a form of non-probability sampling. The sample used in this study consists of respondents who volunteered to participate in the online survey. As such, the data have not been weighted to reflect the demographic composition of the total population of visitors to coastal dune areas in Michigan. Because the sample is based on those who self-selected for participation (rather than a probability sample) no estimates of sampling error can be calculated.

All sample surveys and polls may be subject to multiple sources of error, including, but not limited to, sampling error, coverage error, and measurement error. There is no systematic way to collect a traditional probability sample of the population of visitors to coastal dune areas using online surveys.

However, collecting survey data using the opt-in sampling approach has several advantages, including convenience and lower costs associated with recruiting a large sample size. The opt-in sampling also provides a participatory approach to survey data collection, and a vehicle for catalyzing a group of dunes stakeholders. The online platform used in this study was integrated with maps that asked respondents to drop "pins" indicating the places they visited, which also allows for the collection of spatial data on "hotspots," or sites that are commonly visited by users. The approach also allows for the capture of responses about the personal and social importance of coastal sand dunes from both respondents who had visited coastal dune areas, and those who had not.

Given these parameters, the project team developed an innovative approach to collecting data for the #HowYouDune socioeconomic study[8] of the values of coastal dunes, based on a method that has been used by The Surfrider Foundation, an organization dedicated to the protection and conservation of coastal ecosystems (Surfrider Foundation, 2015). Surfrider conducted a number of coastal recreation studies in ocean environments that have engaged recreational users and the general public in collecting data on a variety of recreational uses, including surfing, kayaking, diving, beach-going, and even wildlife viewing.

The project team consulted with staff members at Surfrider, and adapted their approach for the #HowYouDune survey, using a web-based survey to collect data from respondents on recreational use patterns, trip expenditures, and demographic information by users of coastal dune landscapes. Like Surfrider, our survey also included questions about the social and cultural values associated with the resource, in order to characterize the relative contribution of dune ecosystems to quality of life, and to identify those attributes of coastal dunes that are of greatest importance to recreational users.

The Surfrider effort also relied on substantial early outreach and engagement as a part of their survey recruitment, an approach we adapted to our project in order to support our outreach and stakeholder engagement goals. This is visible in activities like our "Freshwater Dune Summit," held in Muskegon, Michigan on May 7-8, 2017 (see Appendix D). The Summit, explained in more detail in Part 3, was the #HowYouDune survey kick-off. The Summit also provided participants an overview of the #HowYouDune Michigan Coastal Sand Dune Survey, promotional materials to spread the word about the survey, and an opportunity to sign up to act as "testers" for the survey's early beta versions.

Survey Design and Administration

The survey was based on the Surfrider Foundation approach, with some significant alterations and additions based on technology, timing and to reflect the Great Lakes location. The project team designed the online valuation survey approach by modeling it on previous work done by Point 97 for The Surfrider Foundation's "Coastal & Ocean Recreation Studies" series.[9] The team felt that Surfrider's approach was innovative and worth emulating because it used an online survey tool that integrated spatial data; employed direct survey recruitment and outreach early in the survey process to improve response rates; and used real-time monitoring of results to monitor and make adjustments in survey recruitment efforts. For Surfrider's Mid-Atlantic project, almost 1,500 respondents completed surveys, providing more than 20,000 data points on their specific recreation experiences, which provided an early baseline target (later exceeded) for our #HowYouDune survey response. Finally, Surfrider's data was subsequently made available to public agencies working on plans for improving ocean management in the region, providing a good example of the potential application and usefulness of our own survey data.

[8] Prior to undertaking the survey work, the project team developed a Quality Assurance Project Plan (QAPP) for the collection of social and economic data. This QAPP was finalized and approved by the Michigan Office of the Great Lakes on May 4, 2017.

[9] See http://www.surfrider.org/pages/coastal-recreation-studies.

While the Surfrider/Point 97 team typically employed a random sample survey in addition to the opt-in online survey (in which survey respondents choose to participate and are recruited based on their likely interest in participating), our project design team necessarily chose to only utilize the opt-in online survey methodology due to cost considerations. Surfider also worked with Point 97, a technology firm, to develop their own proprietary software to deliver their online survey and its associated mapping component; our project team instead solicited proposals from in-state GIS providers to build our survey.

The research team for the dunes project ultimately opted to utilize the expertise of Alek Kreiger, GIS Specialist with Ducks Unlimited, to pilot a new, out-of-the-box survey and mapping application called Survey123, which was newly available through Esri, a leading national GIS software provider. While this approach allowed us to reduce costs and work directly with a valuable local partner, it also became clear that the Survey123 application was so new that we would essentially become beta-testers for the system. This meant Kreiger spent a great deal of time working directly with Esri to identify and resolve various bugs and glitches in the new application as they were identified, and also forced the project team to accept some limitations and usability challenges inherent in the new application's mapping tool.

In the end, the survey map was successful and allowed survey respondents to take the survey via desktop/laptop computers, tablets, and mobile smartphones. The survey included questions about the locations of visits to coastal dunes in the previous 12 months and about the recreation activities of visitors. In addition to the mapping component, there were questions about spending on visits and trips to dune areas, and a series of questions pertaining to the social and cultural importance of dunes was also included.

The online survey was integrated with maps that allow respondents to drop "pins" indicating the places they visited and the locations of the activities in which they participated. To navigate the mapping portion of the survey, respondents could search for a specific location or navigate the map themselves (zoom in/out and pan and then drop activity markers to indicate the location they visited and associate specific recreational activities with that location. A map of coastal dune areas was defined as local jurisdictions with designated critical dunes with an additional "coastal dune area" boundary overlay for the dunes that showed every local jurisdiction (e.g., townships) with any state-designated Critical Dunes. This buffer was added to account for differences between this older map and our newer one that was being developed simultaneously, and to capture offshore activities adjacent to dunes, such as swimming and boating.

The Survey123 software allowed respondents to toggle between aerial imagery and a street map for basemaps to locate the specific areas of trips to the dunes and the recreational activities undertaken during those trips. Aerial imagery with a resolution of 30 cm was available through DigitalGlobe and made available through Esri. A more familiar street-based basemap, available at a scale of 1:4,000 and also available through Esri, served as the default map view. The map viewer opened to a default scale of 1:24,000. To keep the map interface simple, the mapping tool did not prevent pins from being dropped outside of the dunes boundary, resulting in a few errant points being mapped despite clearly not being in a coastal dune, likely the result of user challenges in utilizing the map tool.

A pre-test of a draft survey questionnaire and mapping tool was conducted with selected partners and stakeholders who were familiar with sand dunes, management challenges, and conservation issues. After some revision, a shorter and simpler questionnaire was integrated into the design of the website that provided access to the survey. Given the complexity of the survey delivery instrument, a panel of attendees of the Freshwater Dune Summit was also recruited to participate in a pilot test of the online survey before the survey was launched to the wider public. Survey improvements were made throughout the process in an effort to balance the desire for a broad range of data and the need to keep the survey short enough that a large number of participants would be willing and able to complete it in an acceptable amount of time.

After extensive testing and revision, the public survey was launched on Memorial Day weekend, May 29, 2017 and remained open to respondents through October 15, 2017. The outreach portion of the project is explained in more detail in Part 3, but survey respondents were recruited to participate in the survey through several outreach efforts, including messaging from MEC and contracted partner organizations, Heart of the Lakes and the West Michigan Environmental Action Council (WMEAC). Invitations to participate in the online survey were distributed widely to additional organizations likely to have members or followers who might be interested in the topic and willing to complete the online survey. Postcards were made accessible in tourism offices, and notification was delivered through e-mail messages from Travel Michigan and Michigan Office of the Great Lakes, email-based communications from the Michigan Department of Natural Resources, and announcements via several social media platforms, including Facebook posts and events, Twitter, and Instagram, all using the hashtag #HowYouDune.

This approach to collecting survey data had several benefits. For example, the project team used the survey as a tool or vehicle to identify a broad dune stakeholder community, and to engage these constituencies or groups in discussions about the science and management of Michigan's natural assets. This approach also enabled the team to take real-time assessments of survey response rates, and to adjust outreach and recruitment strategies based on the locations and characteristics of respondents. For example, the Michigan DNR was recruited several weeks into the survey when it became clear that outreach efforts were not yielding adequate response rates. DNR's email lists were much larger and more broadly representative than any of the non-governmental organization partners, and their efforts yielded a large increase in survey responses.

Similarly, an additional two-week social media campaign was launched when it was noted that survey respondents were predominantly white/Caucasian, despite the fact that coastal dunes are present in several minority communities along the coastline. An additional two-week survey period was added at the end of the survey in October in conjunction with a targeted social media push to the largely minority communities of Benton Harbor, Muskegon, Muskegon Heights and Covert, in an attempt to increase participation among minority respondents, and to test our ability to reach these underrepresented populations using social media tools. While not effective in garnering additional minority responses (a fact determined by reviewing the survey responses during the two-week social media campaign targeting minority communities), this aspect of the project highlights both the team's ability to modify the online survey approach in mid-stream,

and the need to improve overall outreach mechanisms and strategies to more effectively engage underrepresented minority communities.

During the entire survey period, 3,610 responses were received, and 7,065 sites were mapped using the spatial tool. Survey data were analyzed using Microsoft Excel (data analysis and spreadsheet tool) and Stata (statistical analysis software).

Results

The objective of this study was to generate information about the uses and values of coastal sand dunes in Michigan to advance understanding about their social and economic importance, and to support environmental management partnerships. In general, participants in the online survey responded with enthusiasm about their fondness for coastal sand dunes in Michigan, their satisfaction with recent visits to coastal dune areas, and their support for the protection of coastal dunes.

The results include information about the characteristics of respondents, the number of trips taken in the past 12 months, locations visited, recreation activities, months of visits, and social and cultural values associated with coastal sand dunes in Michigan.

During the survey period, 3,610 responses were received, and 7,065 sites were mapped using the spatial tool. Most participants in the online survey were from Michigan, but nearly 23 percent of respondents were from other states or from Canada. Respondents from Michigan included residents who live near coastal dune areas (approximately 28 percent of respondents) as well as individuals who traveled long distances from their homes in other parts of the State (approximately 49 percent of respondents). Most respondents were white, married, employed, and well-educated.

Of the 3,610 responses to the online survey, 3,189 participants (88.3 percent) reported having visited coastal dune areas in the past 12 months. Respondents reported having taken an average of 6.7 trips to coastal dune areas in the past 12 months, and they reported having visited an average of 2.2 locations. The most visited dune area was Sleeping Bear Dunes National Lakeshore, followed by Silver Lake State Park, Ludington State Park, Warren Dunes State Park, and Holland State Park.

The most popular recreation activities reported by survey respondents included beach-going (20.1 percent), scenic enjoyment (19.7 percent), modern camping (14.2 percent), hiking (12.3 percent), and rustic camping (7.4 percent). More than three-quarters (76 percent) of visits occurred in the months of June, July, and August. Approximately one-third of respondents (33.6 percent) indicated that someone in their household was a member of a conservation organization.

When asked about their most recent trip to coastal dune areas in Michigan, respondents reported an average group size of 3.4 persons, and they reported having spent an average of $391.75 on their trip, which implied an average spending of $133.15 per person per trip. On their most recent trip to coastal dune areas, more than 70 percent of respondents purchased fuel (71.2 percent), and more than half of respondents purchased meals at a restaurant (63.4 percent) and/or

purchased groceries (52.8 percent). Nearly a quarter of respondents (22.7 percent) visited a winery or brewery.

Respondents were also asked to rate the importance of a series of social and cultural values that are associated with coastal sand dune areas in Michigan on a 5-point scale (1 = "not at all important, 5 = "extremely important"). Scenic beauty and protection for future generations were rated as especially important values of coastal dunes; 96.2 percent of respondents rated scenic beauty as *extremely important* or *very important*, and 92.5 percent of respondents rated protection for future generations as *extremely important* or *very important*. More than four-fifths of respondents indicated that protection of a unique ecosystem (82.6 percent) and outdoor recreation (82.6 percent) were *extremely important* or *very important*.

When asked about trust for the protection and stewardship of coastal dunes in Michigan, more than three-quarters of respondents (77.6 percent) indicated that they trust state government, and more than two-thirds of respondents identified non-governmental organizations (67.5 percent) as institutions to be trusted with the protection and stewardship of coastal dunes. More than half of respondents identified local government (53.1 percent) as trusted stewards of coastal dunes.

A total of 731 individuals (more than 20 percent of total respondents) provided open-ended comments related to their visit or their attitudes about coastal sand dunes. The vast majority of respondents expressed their enthusiastic support for the protection of coastal dune areas, while others expressed concern about litter, sand mining, and drilling in protected areas. Some comments highlighted the need for greater awareness of coastal sand dune ecosystems and a broader understanding of the processes that contribute to the formation, development, and geomorphological change in coastal dune areas.

Finally, respondents were also asked if they were willing to be contacted with additional information related to the protection of coastal sand dunes in Michigan and other topics related to this project. More than half of respondents (57.5 percent) responded to indicate they were willing to be contacted, and they responded with their email addresses. These responses will contribute to the objective of the study to catalyze a dunes stakeholder community and to foster new partnerships to promote awareness of coastal dunes in Michigan.

Characteristics of Respondents

Over three-quarters of the respondents were from Michigan (approximately 77 percent), with an additional 12.3 percent from adjacent or nearby states (IL, IN, OH, WI, and MN. See Table 2). Fewer than 1 percent of respondents were from Canada. Respondents from Michigan included residents who live near coastal dune areas (approximately 28 percent of respondents) as well as individuals who traveled long distances from their homes in southeast Michigan, mid-Michigan, or other parts of the state (approximately 49 percent of respondents).

Table 2. Home state of respondents (n=3,610)

Home state	**Percentage**
Michigan	77.2%
Illinois	4.6%
Indiana	3.3%
Ohio	2.7%
Wisconsin	1.2%
Minnesota	0.5%
Florida	0.4%
Missouri	0.4%
Kentucky	0.4%
New York	0.3%
Pennsylvania	0.2%
Other states	2.2%
Canada	0.6%
No response	6.0%

The majority of respondents were white (84.5 percent), with relatively few respondents representing other races or ethnicities. Approximately 5.5 percent of respondents indicated that they preferred not to answer the question about race or ethnicity, and nearly 5 percent of respondents provided no response (see Table 3).

Table 3. Race or ethnic group of respondents (n=3,610)

Race or ethnic group	Percentage
White	84.5%
Hispanic/Latino	1.2%
Non-Hispanic/Latino	0.8%
Native American	0.8%
Asian	0.6%
Black/African-American	0.5%
Other	1.3%
I prefer not to answer	5.5%
No response	4.8%

According to the US Census 2012-2016 American Community Survey 5-Year Estimates, residents of Michigan were 78.9 percent white, 13.9 percent black, 4.8 percent Hispanic/Latino, 2.8 percent Asian and <1 percent Native American (United States Census Bureau, 2016).

Approximately 32.4 percent of respondents were 45 years old or younger, while 63 percent were older than 45 years old (nearly 5 percent of respondents did not answer the question about age). The average age of respondents was 50.6 years old, while the median age was 53 years old (see Table 4).

Table 4. Age of respondents (n=3,610)

Respondent age groups	Percentage
Age—18-25 years old	4.8%
Age—26-35 years old	10.9%
Age—36-45 years old	16.7%
Age—46-55 years old	22.3%
Age—56-65 years old	27.0%
Age—more than 65 years old	13.6%
No response	4.7%

According to the US Census 2012-2016 American Community Survey 5-Year Estimates, the median age in Michigan is 39.5 years (United States Census Bureau, 2016).

Approximately 48 percent of respondents were female, and nearly 44 percent were male (8.1 percent of respondents indicated “Other” or “I prefer not to say”) (see Table 5).

Table 5. Gender of respondents (n=3,610)

Gender	**Percentage**
Female	48.0%
Male	43.9%
Other	1.6%
I prefer not to say	6.5%

Most respondents were married (70.7 percent), while 8.3 percent were never married, and 6.7 percent were divorced or separated (8.6 percent of respondents did not answer the question about marital status) (see Table 6).

Table 6. Marital status of respondents (n=3,610)

Marital Status	**Percentage**
Married	70.7%
Never married	8.3%
Divorced/separated	6.7%
Unmarried domestic partnership	4.4%
Widowed	1.3%
No response	8.6%

More than half of respondents indicated that they held full-time employment (56.7 percent), while nearly 23 percent were retired, and nearly 9 percent were employed part-time (7.8 percent of respondents did not answer the question about employment status) (see Table 7).

Table 7. Employment status (n=3,610)

Employment status	Percentage
Employed full-time	52.3%
Retired	20.9%
Employed part-time	8.2%
Self-employed	6.7%
Unemployed	2.7%
Student	1.4%
No response	7.8%

Respondents were relatively well-educated, as nearly all respondents completed high school, and more than 65 percent held a Bachelor's degree or higher (nearly 7.0 percent of respondents did not answer the question about education level) (see Table 8).

Table 8. Education level of respondents (n=3,610)

Education level	Percentage
Some high school, not completed	0.4%
High school	7.0%
Some college, not completed	25.0%
Bachelor's Degree	36.3%
Higher Degree	24.4%
No response	6.9%

According to the US Census 2012-2016 American Community Survey 5-Year Estimates, 89.9 percent of Michiganders have graduated high school or some higher level of education (United States Census Bureau, 2016).

Nearly 16 percent of respondents reported annual household income of less than $50,000 per year, while nearly 34 percent of respondents reported annual household income between $50,000 and $99,000 per year. Nearly 27 percent of respondents reported annual household income of $100,000 or more per year. More than 8 percent of respondents indicated that they preferred not to provide their annual household income (15.6% of respondents did not answer the question about annual household income) (see Table 9). Income data were reported in ranges, and the median response was $75,000 - $99,000 per year.

Table 9. Annual household income of respondents (n=3,610)

Annual household income	Percentage
Less than $50,000 per year	15.8%
$50,000 - $74,000 per year	17.1%
$75,000 - $99,000 per year	16.5%
$100,000 - $149,000 per year	18.2%
$150,000 - $200,000 per year	5.1%
$200,000 or more per year	3.4%
I prefer not to say	8.3%
No response	15.6%

The median response was annual household income of $100,000 - $149,000 per year. According to the US Census 2012-2016 American Community Survey 5-Year Estimates, Michigan's median household income was $50,803, and mean household income was $68,928 (United States Census Bureau, 2016). Therefore, respondents to the coastal dune survey represented higher-income households, relative to the income of U.S. households.

The survey asked respondents if anyone in their household was a member of a conservation or outdoor organization. Nearly one-third of respondents (31.9 percent) indicated that someone in their household was a member of such an organization, and about 63 percent indicated no membership in such an organization. Approximately 5.3 percent of respondents provided no response (n=3,610).

Dunes Trips in the Past 12 Months

Over 88 percent of the 3,610 respondents had visited a coastal sand dune area in Michigan for recreation in the past 12 months. The survey data included responses representing a range of visits, from one visit to daily visits over the past 12 months. These 3,189 visitors made a total of 21,452 trips to these dune areas, an average of 6.7 visits per person over the past year. Respondents reported having visited a total of 7,119 locations in coastal dunes in the past 12 months, or an average of 2.2 locations in coastal dune areas. Table 10 provides an overview of trip characteristics of visitors to coastal sand dune areas in Michigan during the past 12 months. The median reflects the middle value when ranked in order.

Table 10. Trip characteristics by visitors to coastal sand dune areas in Michigan (n=3,189)

Trip characteristics	Mean	Median	Total
Number of visits to dunes in last 12 months (minimum = 1, maximum = 365)	6.7	3.0	21,452
Number of locations visited (minimum = 1, maximum = 26)	2.2	2.0	7,119

Dunes Locations Visited

The 3,189 respondents who had visited a coastal sand dune area in Michigan for recreation in the past 12 months were then asked a series of six questions about each of the different location(s) they had visited. These questions pertained to dune location, frequency of visit, activities engaged in, and month of visit, and they generated 7,066 distinct responses.

The most visited dune area was Sleeping Bear Dunes National Lakeshore, followed by Silver Lake State Park, Ludington State Park, Warren Dunes State Park, and Holland State Park. Figure 10 includes a bar graph depicting the ten most visited coastal dune locations. A list of all visits to all locations is provided in Appendix A.

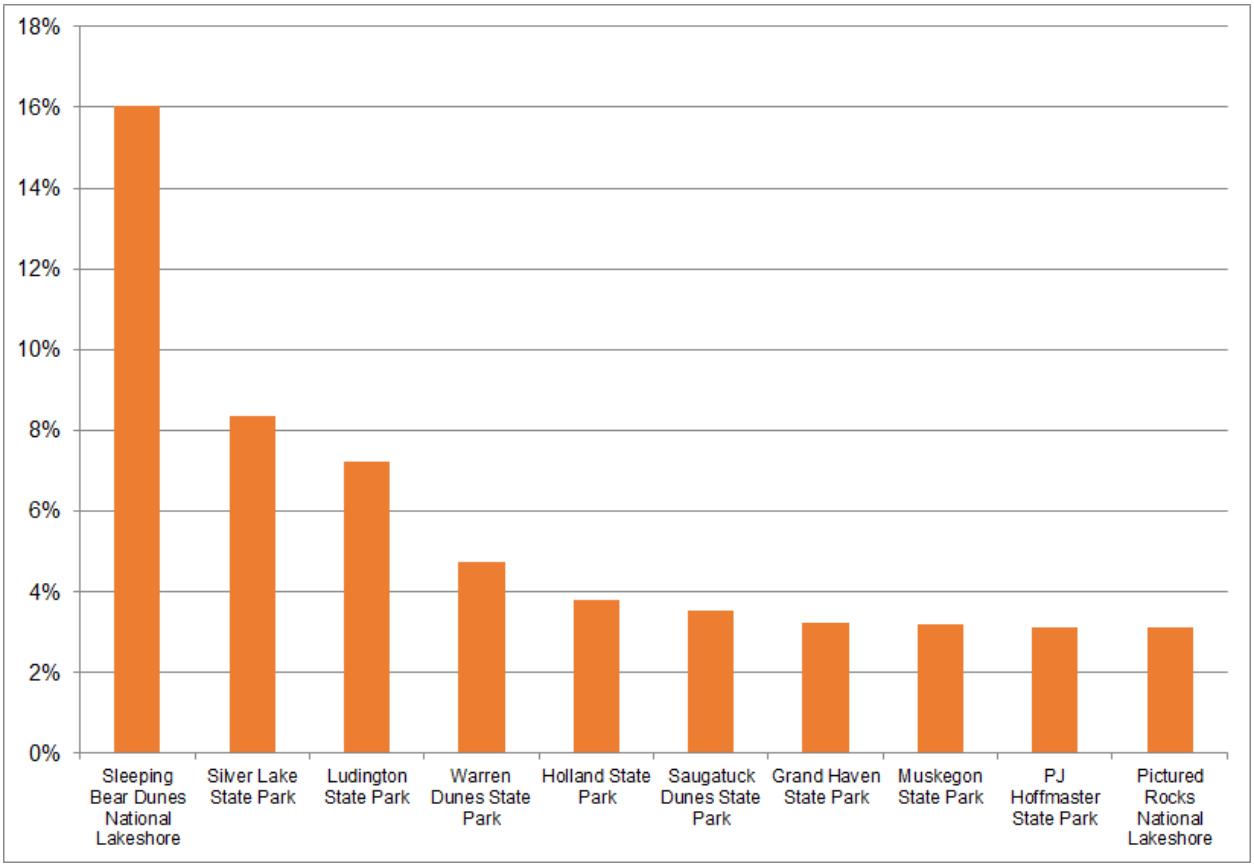

Figure 10. Ten most visited dune locations (n=7,059).

The mapping feature of the online survey allowed for the creation of heat maps depicting recreation "hotspots," or dune locations that were reported as having the greatest number of visitors. A heat map of dune locations visited in the Lower Peninsula of Michigan is presented in Figure 11. A heat map of dune locations visited in the Upper Peninsula of Michigan is presented in Figure 12.

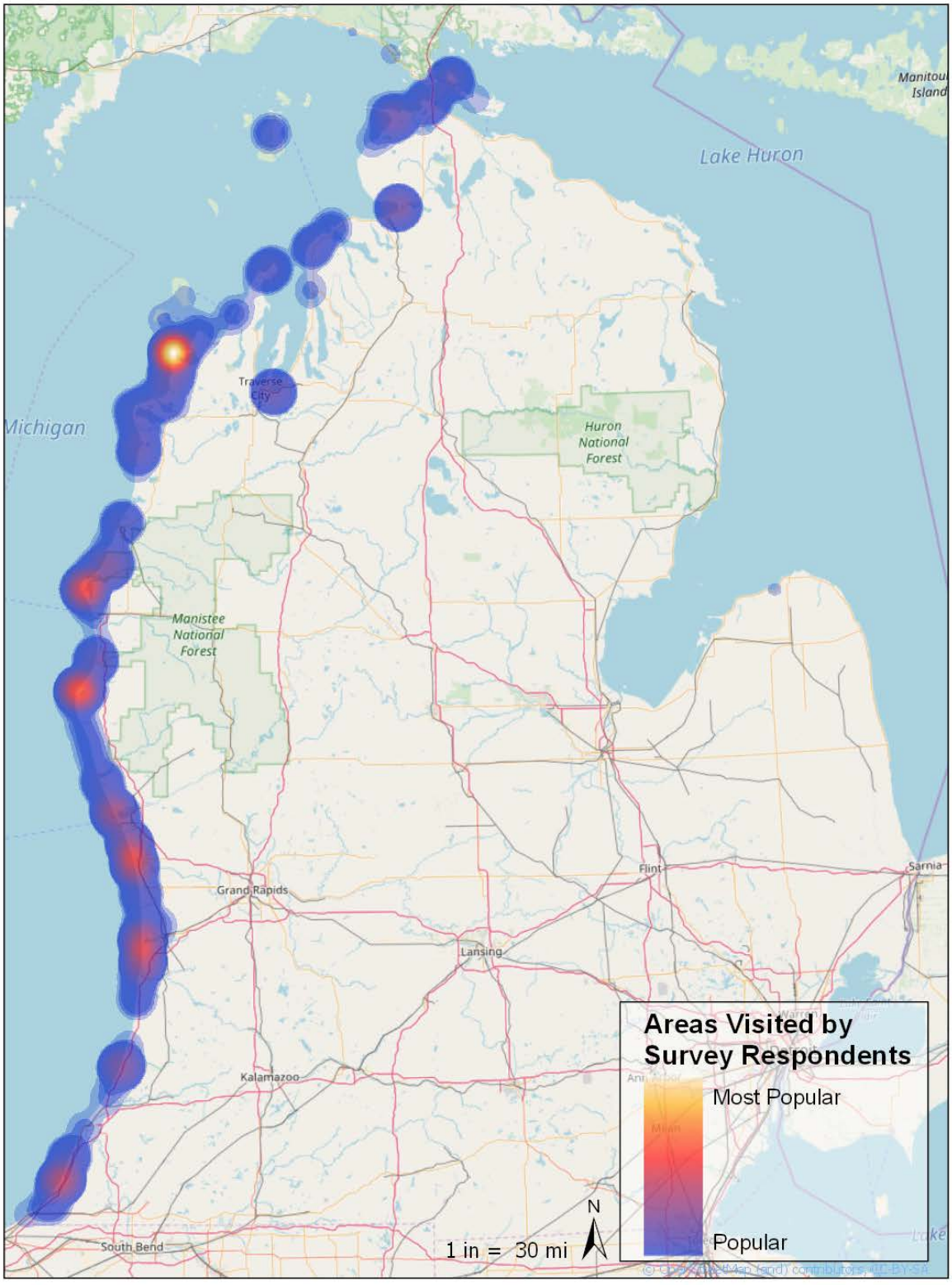

Figure 11. Heat map of dune locations visited in the Lower Peninsula of Michigan.

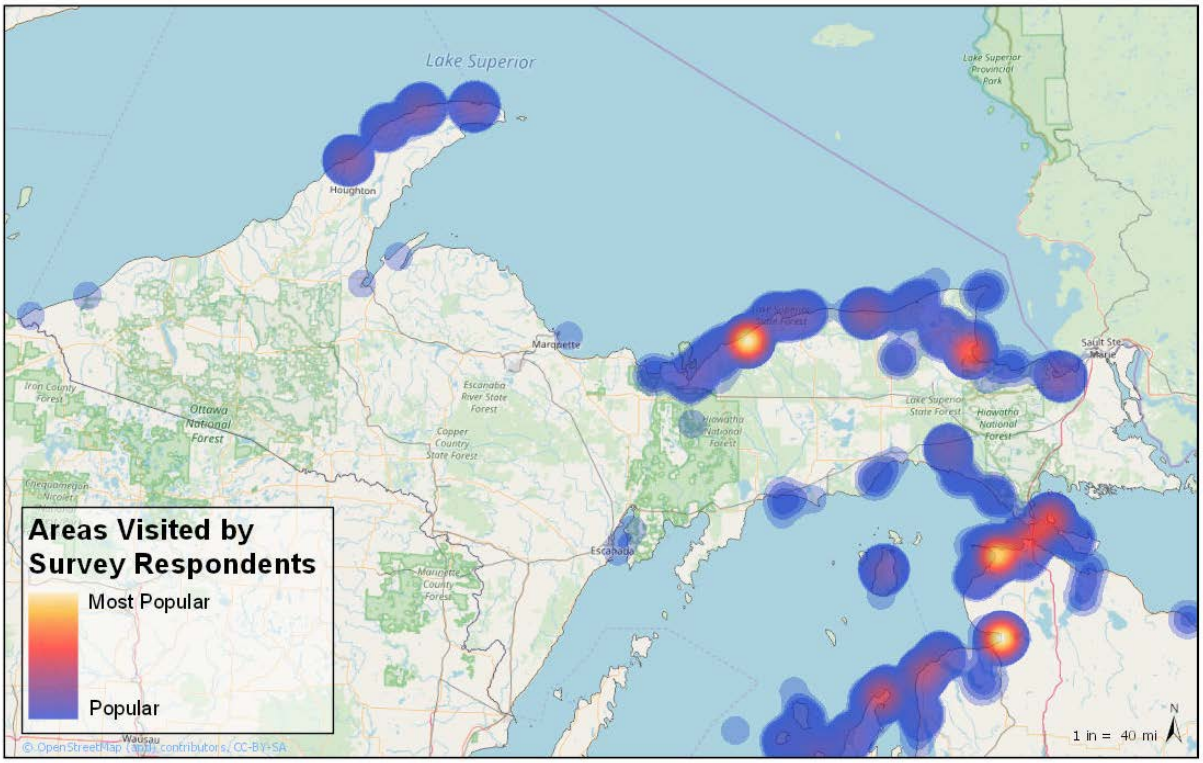

Figure 12. Heat map of dune locations visited in the Upper Peninsula of Michigan.

Dunes Activities

For each coastal dune location visited, respondents were asked to specify the activity that was the *primary reason* for visiting the location, as well as *all activities* in which the respondents participated for each visit. The five most popular activities in coastal dunes are depicted in Figure 13. The activities of beach-going (20.1 percent) and scenic enjoyment (19.7 percent) were identified as the top *primary reasons* for visiting coastal dune areas in Michigan (n=7,062).

The percentage of responses to questions about *primary activity* and *all activities* in coastal dune areas in Michigan are presented in Figure 14. In terms of *all activities*, beach-going ranked highest (66.5 percent), followed by scenic enjoyment (54.1 percent), hiking (46.9 percent), and dune-climbing (37.7 percent).

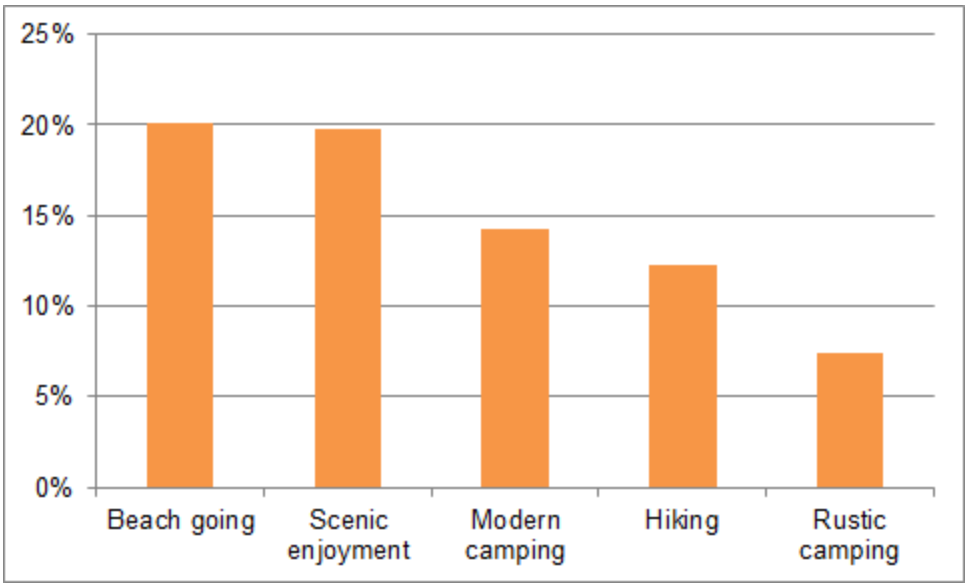

Figure 13. Five most popular dunes activities, based on primary activity.

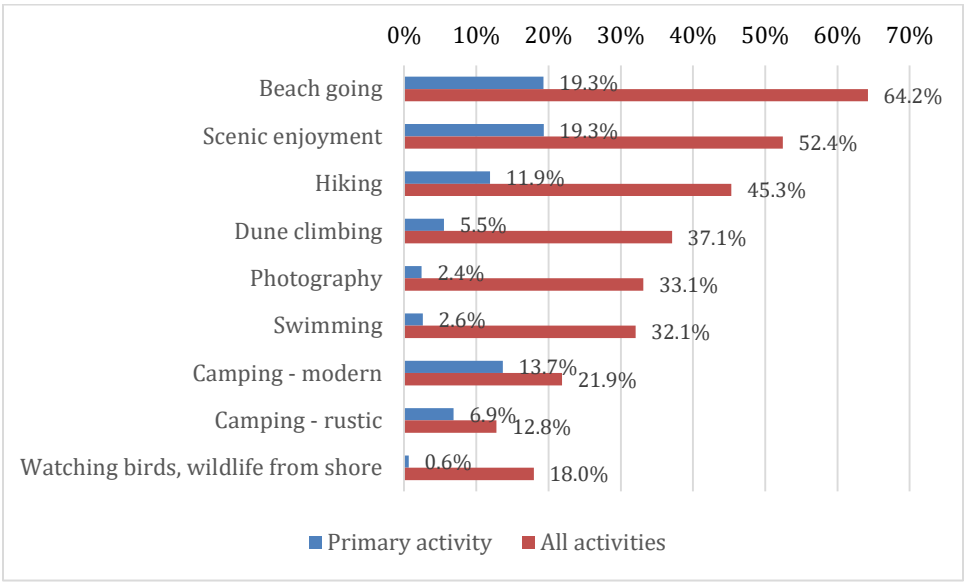

Figure 14. Activities in dune locations - primary and all (n = 7,059).

Month of Visits

Respondents were asked to provide the month of their visit to dune locations for each location visited (see Table 11). More than three-quarters (76 percent) of visits occurred in the months of June, July, and August.

Table 11. Month of visit (n = 7,059)

Month	Percentage of Visits
January	0.2
February	0.7
March	0.6
April	1.8
May	7.1
June	15.3
July	31.8
August	28.9
September	10.4
October	2.7
November	0.3
December	0.2

Recreation Activities for Most Visited Locations

Respondents provided information about recreation activities in all dunes locations visited. Recreation activities for the five most visited locations are provided here. Sleeping Bear Dunes National Lakeshore was the most visited dune area among survey respondents, accounting for 16.0 percent of all trips. Respondents who visited the site reported an average 2.2 trips during the past 12 months. The site was most commonly visited in August (34 percent), July (30 percent), and June (14 percent). The percentage of responses to questions about primary activity and all activities in Sleeping Bear Dunes National Lakeshore are presented in Figures 15 and 16.

Scenic enjoyment was ranked highest as the primary activity (32.9 percent, followed by dune climbing (19.4 percent), hiking (12.1 percent), and beach going (9.5 percent). In terms of all activities, dune climbing ranked highest (66.8 percent), followed by scenic enjoyment (64.8 percent), hiking (58.7 percent), and beach going (57.4 percent). (Note that percentages for all activities do not total to 100 percent because of multiple activities reported.)

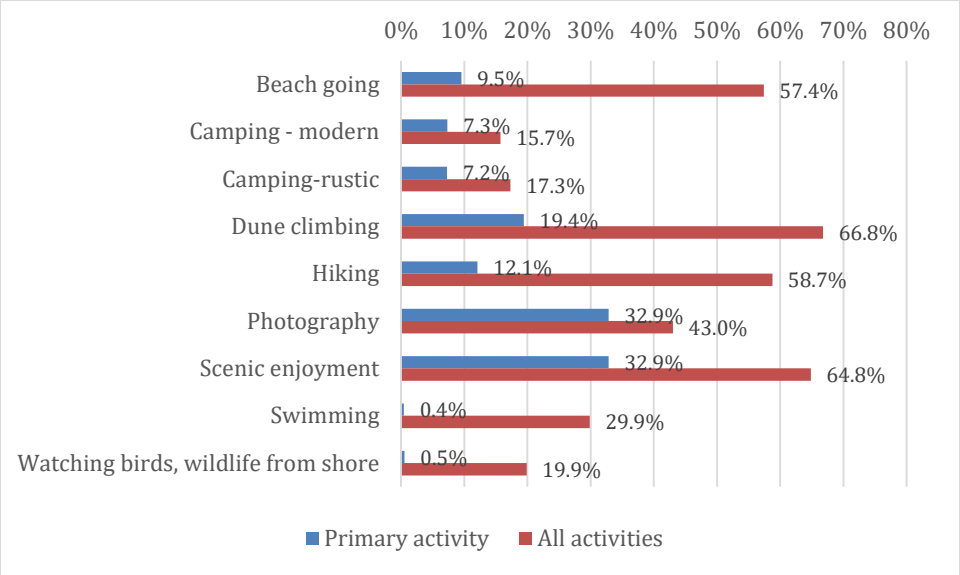

Figure 15. Activities in Sleeping Bear Dunes National Lakeshore - primary and all (n = 1,132).

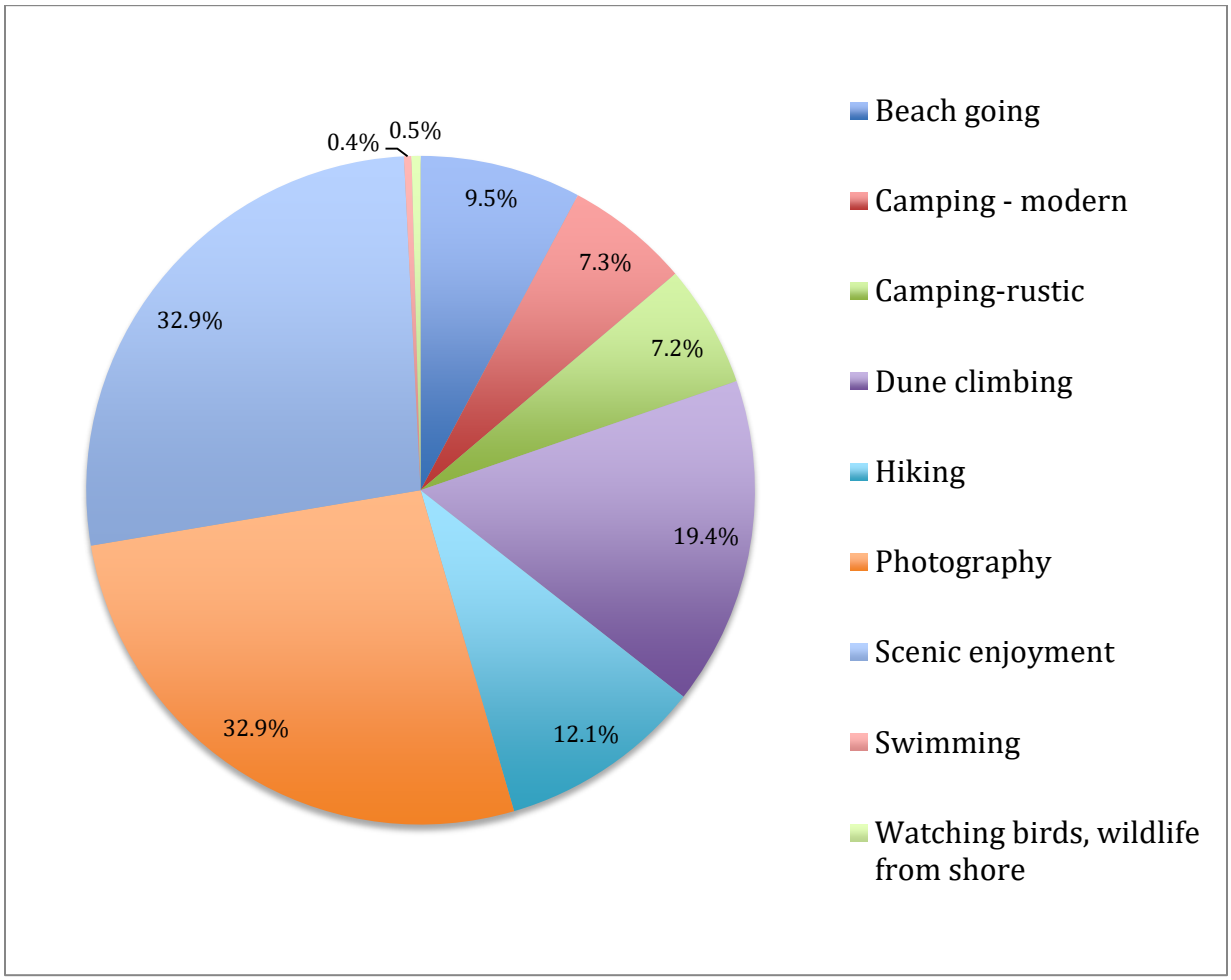

Figure 16. Primary activities in Sleeping Bear Dunes National Lakeshore (n = 1,132).

A heat map of dune locations visited in Sleeping Bear Dunes National Lakeshore and the surrounding area is presented in Figure 17.

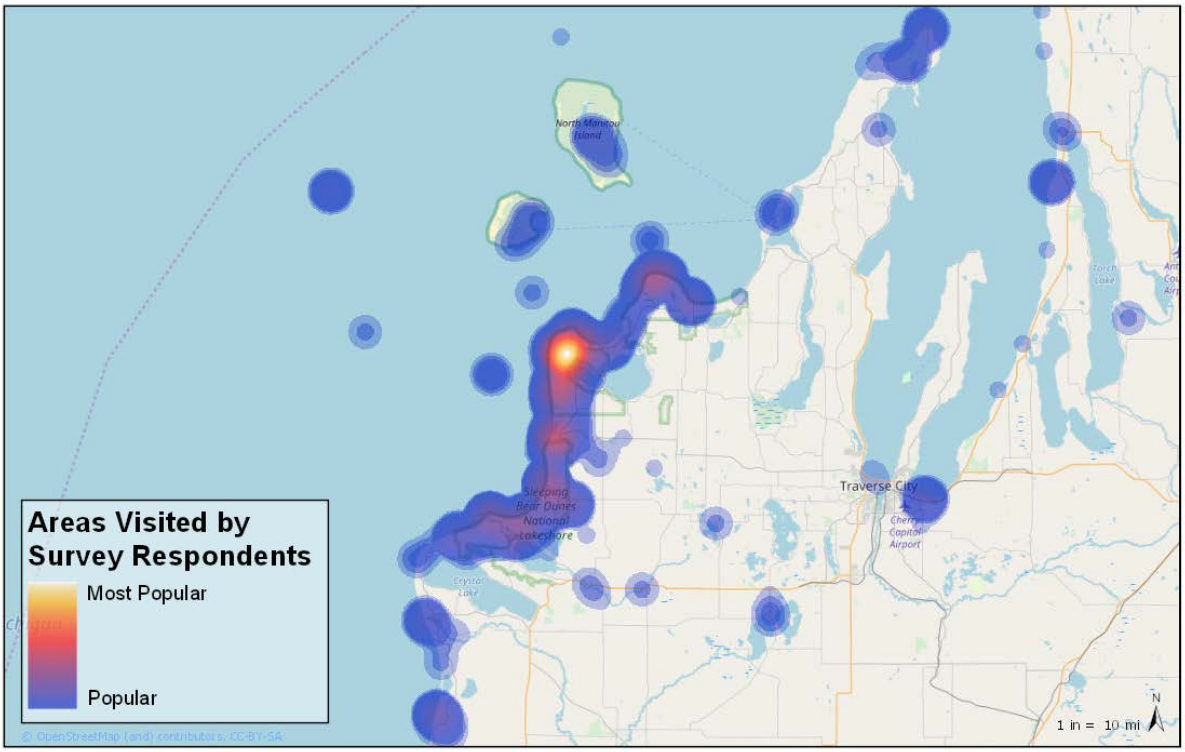

Figure 17. Heat map of locations visited in Sleeping Bear Dunes National Lakeshore and the surrounding area.

Silver Lake State Park was the second most visited dune area among survey respondents, accounting for 8.3 percent of all trips. Respondents who visited the site reported an average 4.4 trips during the past 12 months. The site was most commonly visited in July (37 percent), August (26 percent), and June (19 percent). The percentage of responses to questions about primary activity and all activities in Silver Lake State Park are presented in Figure 18.

Using an off-road vehicle was ranked highest as the primary activity (47.4 percent), followed by modern camping (14.1 percent), dune climbing (11.2 percent), scenic enjoyment (10.2 percent), and beach going (7.0). In terms of all activities, beach going ranked highest (63.6 percent), followed by using an off-road vehicle (63.4 percent), dune climbing (62.6 percent), and scenic enjoyment (40.1 percent). (Note that percentages for all activities do not total to 100 percent because of multiple activities reported.)

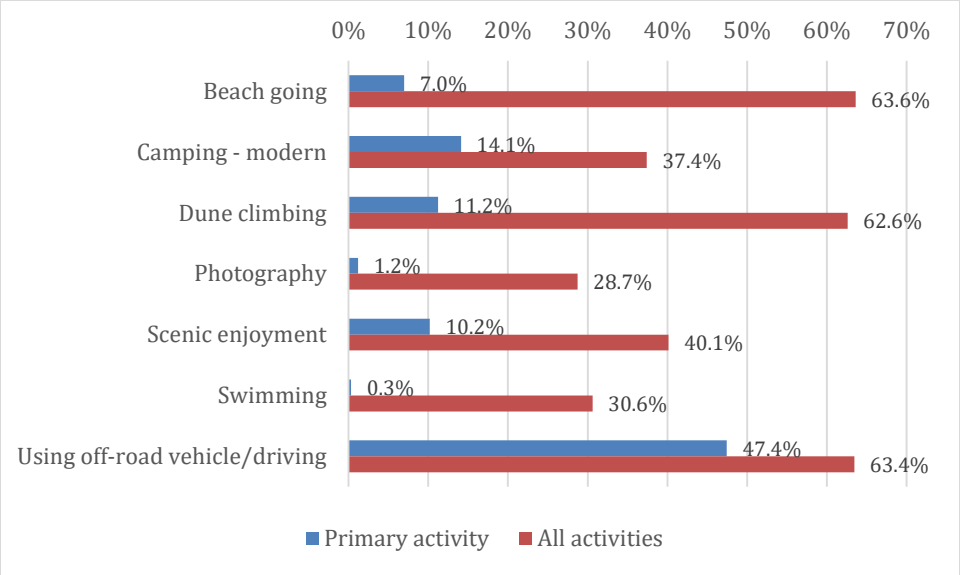

Figure 18. Activities in Silver Lake State Park - primary and all (n = 588).

A heat map of locations visited in Silver Lake State Park is presented in Figure 19.

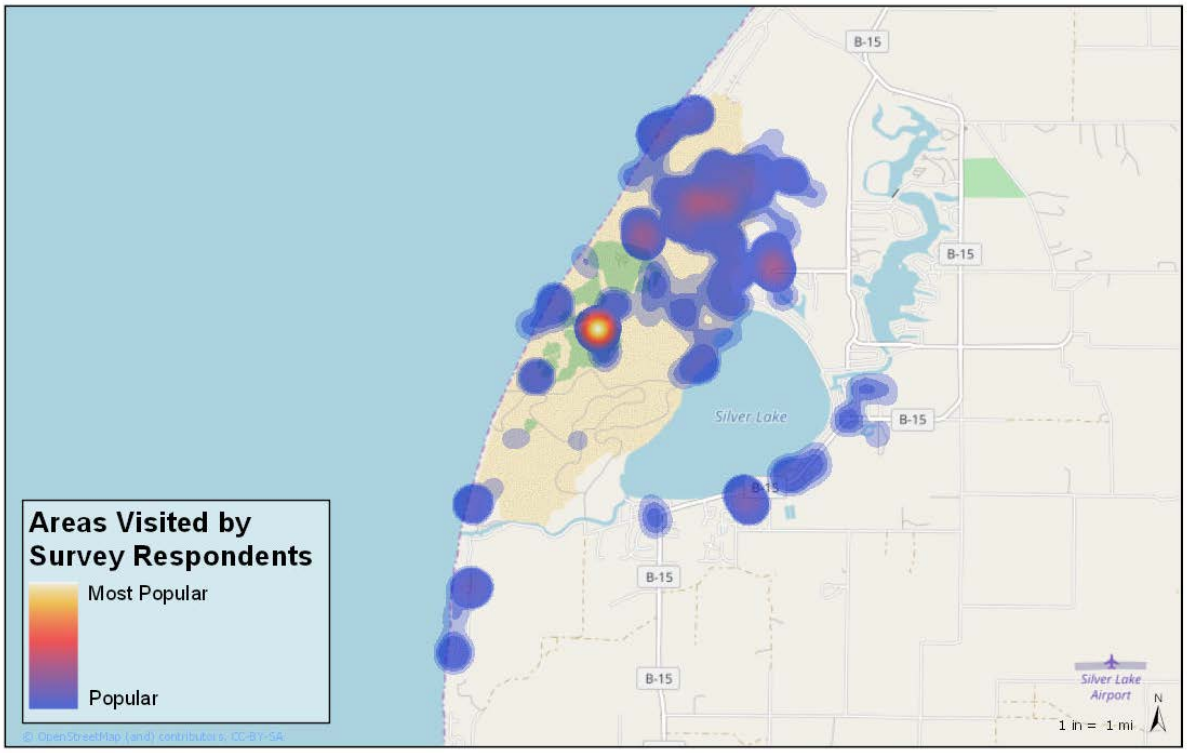

Figure 19. Heat map of locations visited in Silver Lake State Park.

Ludington State Park was the third most visited dune area among survey respondents, accounting for 7.35 percent of all trips. Respondents who visited the site reported an average 2.9 trips during

the past 12 months. The site was most commonly visited in July (33 percent), August (25 percent), and June (16 percent). The percentage of responses to questions about primary activity and all activities in Ludington State Park are presented in Figure 20.

Modern camping was ranked highest as the primary activity (29.1 percent), followed by beach going (19.8 percent), hiking (15.8 percent), and scenic enjoyment (10.6 percent). In terms of all activities, beach going ranked highest (75.7 percent), followed by hiking (62.8 percent), scenic enjoyment (60.9 percent), dune climbing (44.1 percent) and swimming (43.7 percent). (Note that percentages for all activities do not total to 100 percent because of multiple activities reported.)

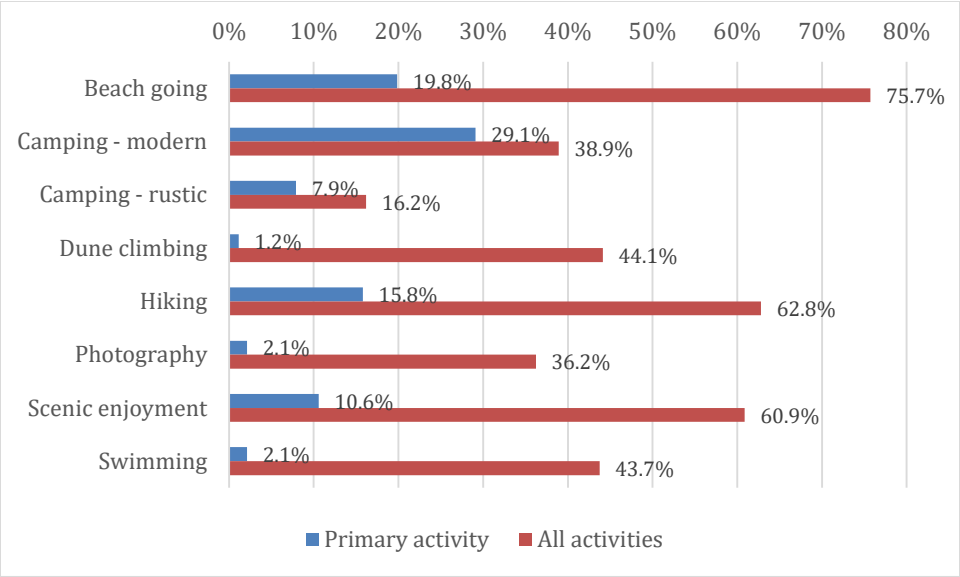

Figure 20. Activities in Ludington State Park - primary and all (n = 519).

A heat map of locations visited in Ludington State Park is presented in Figure 21.

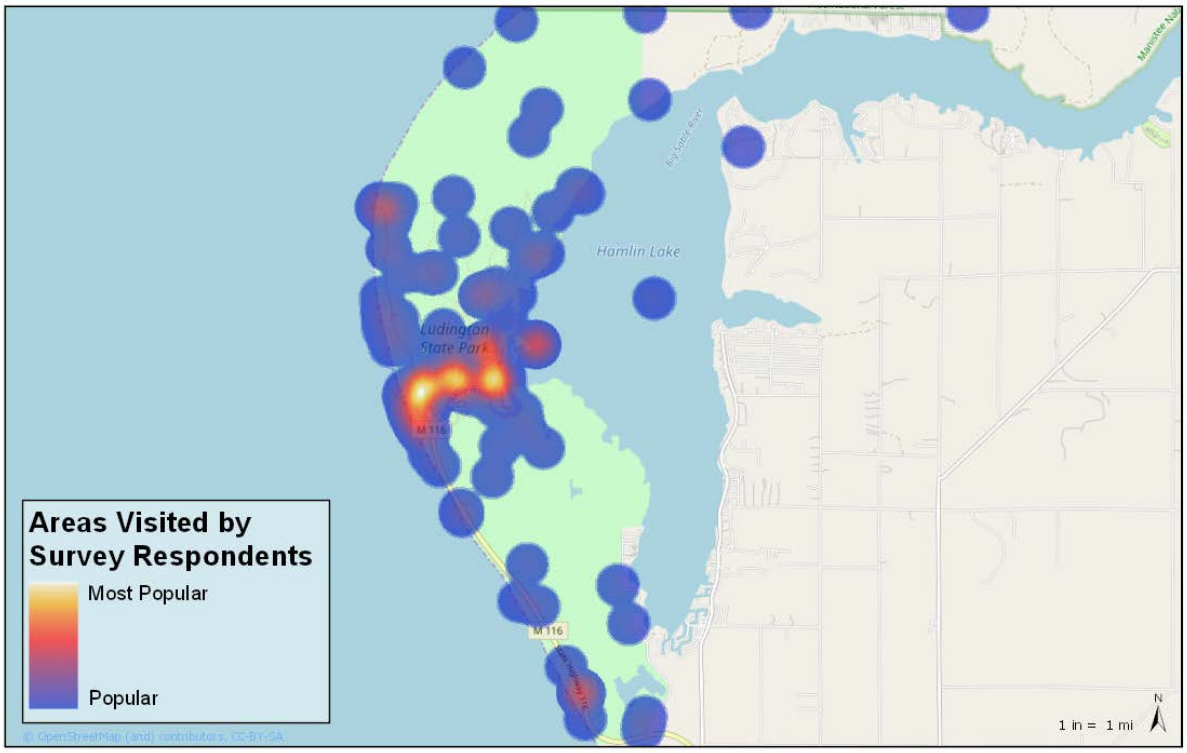

Figure 21. Heat map of locations visited in Ludington State Park.

Warren Dunes State Park was the fourth most visited dune area among survey respondents, accounting for 4.7% of all trips. Respondents who visited the site reported an average 2.5 trips during the past 12 months. The site was most commonly visited in July (33 percent), August (27 percent), and June (18 percent). The percentage of responses to questions about primary activity and all activities in Warren Dunes State Park are presented in Figure 22.

Beach going was ranked highest as the primary activity (32.3 percent), followed by nodern camping (20.7 percent), rustic camping (13.5 percent), and dune climbing (9.6 percent). In terms of all activities, beach going ranked highest (87.7 percent), followed by dune climbing (67.4 percent), swimming (51.8 percent), hiking (48.2 percent) and scenic enjoyment (47.0 percent). (Note that percentages for all activities do not total to 100 percent because of multiple activities reported.)

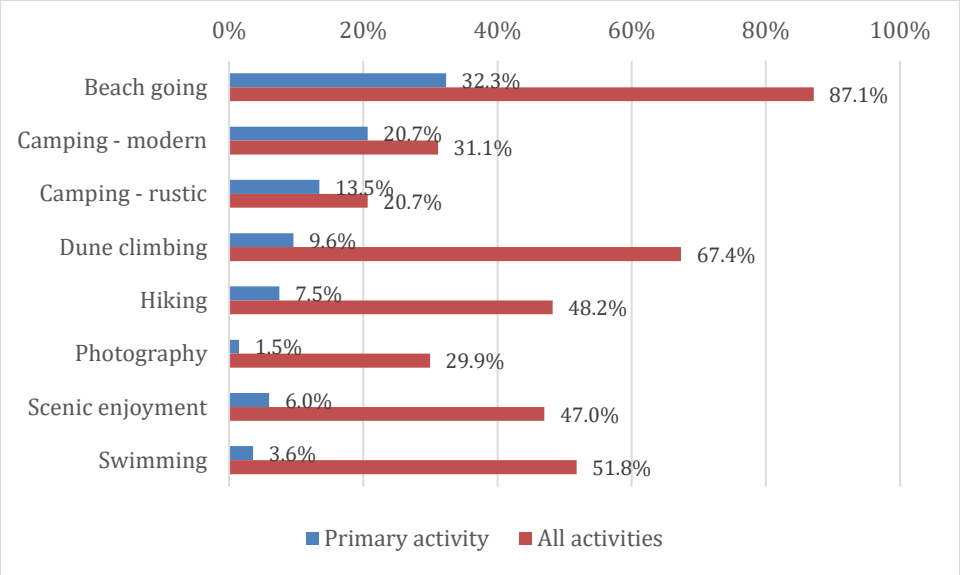

Figure 22. Activities in Warren Dunes State Park - primary and all (n = 334).

A heat map of locations visited in Warren Dunes State Park is presented in Figure 23.

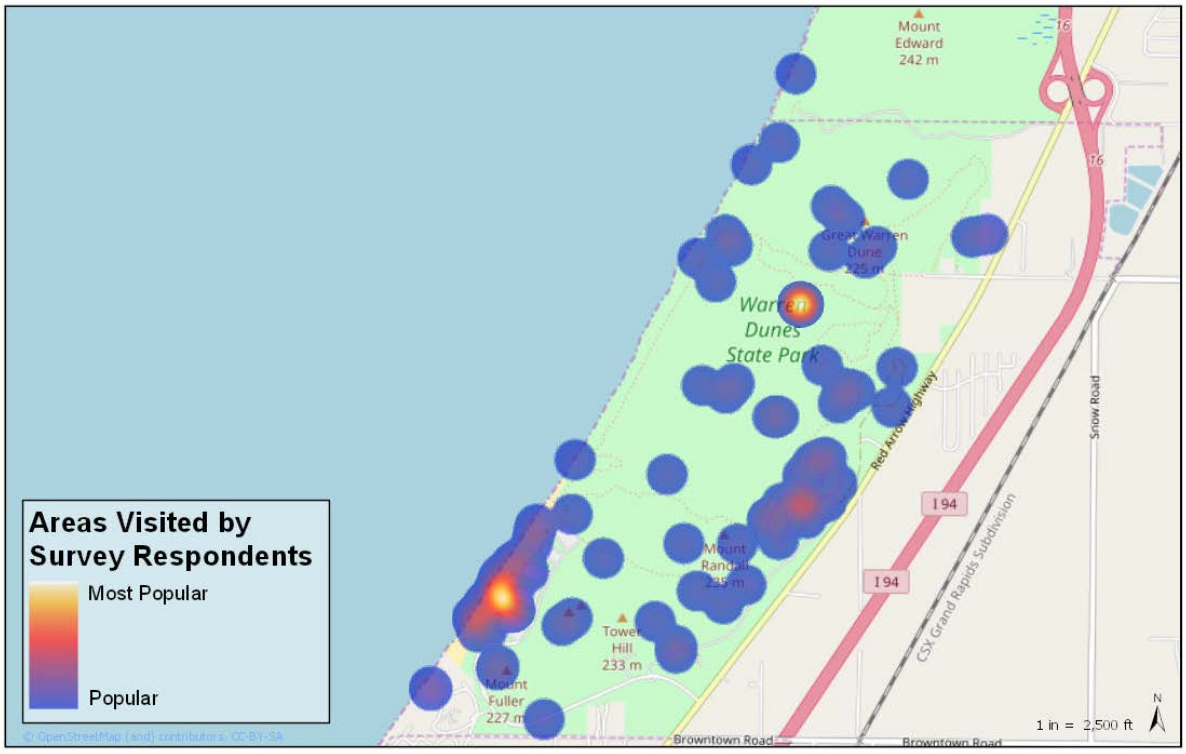

Figure 23. Heat map of locations visited in Warren Dunes State Park.

Holland State Park was the fifth most visited dune area among survey respondents, accounting for 3.8 percent of all trips. Respondents who visited the site reported an average 4.2 trips during

the past 12 months. The site was most commonly visited in July (32 percent), August (31 percent), and June (17 percent). The percentage of responses to questions about primary activity and all activities in Holland State Park are presented in Figure 24.

Beach going was ranked highest as the primary activity (37.1 percent), followed by modern camping (18.0 percent), and scenic enjoyment (16.5 percent). In terms of all activities, beach going ranked highest (85.8 percent), followed by scenic enjoyment (50.6 percent), swimming (37.8 percent), and hiking (30.0 percent). (Note that percentages for all activities do not total to 100 percent because of multiple activities reported.)

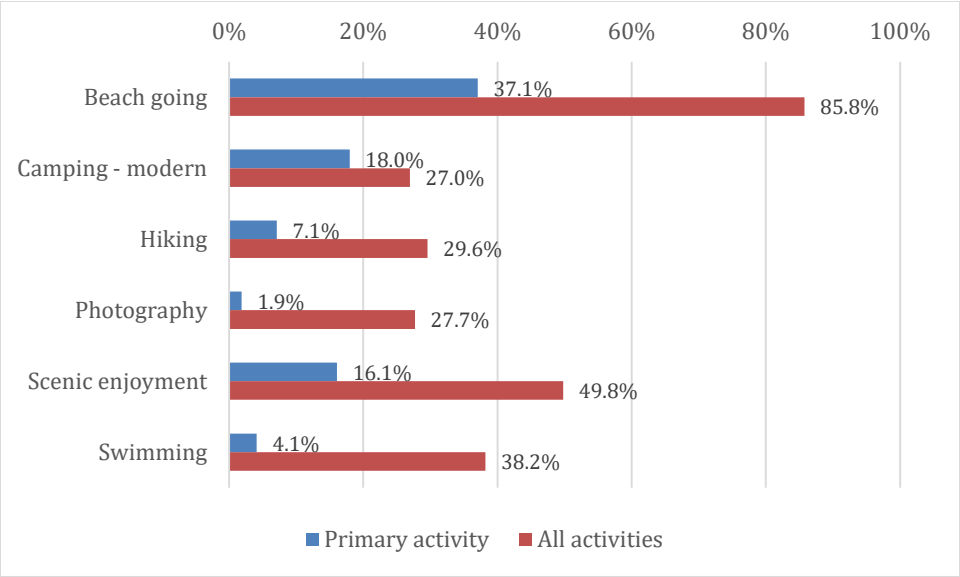

Figure 24. Activities in Holland State Park - primary and all (n = 267).

A heat map of locations visited in Holland State Park is presented in Figure 25.

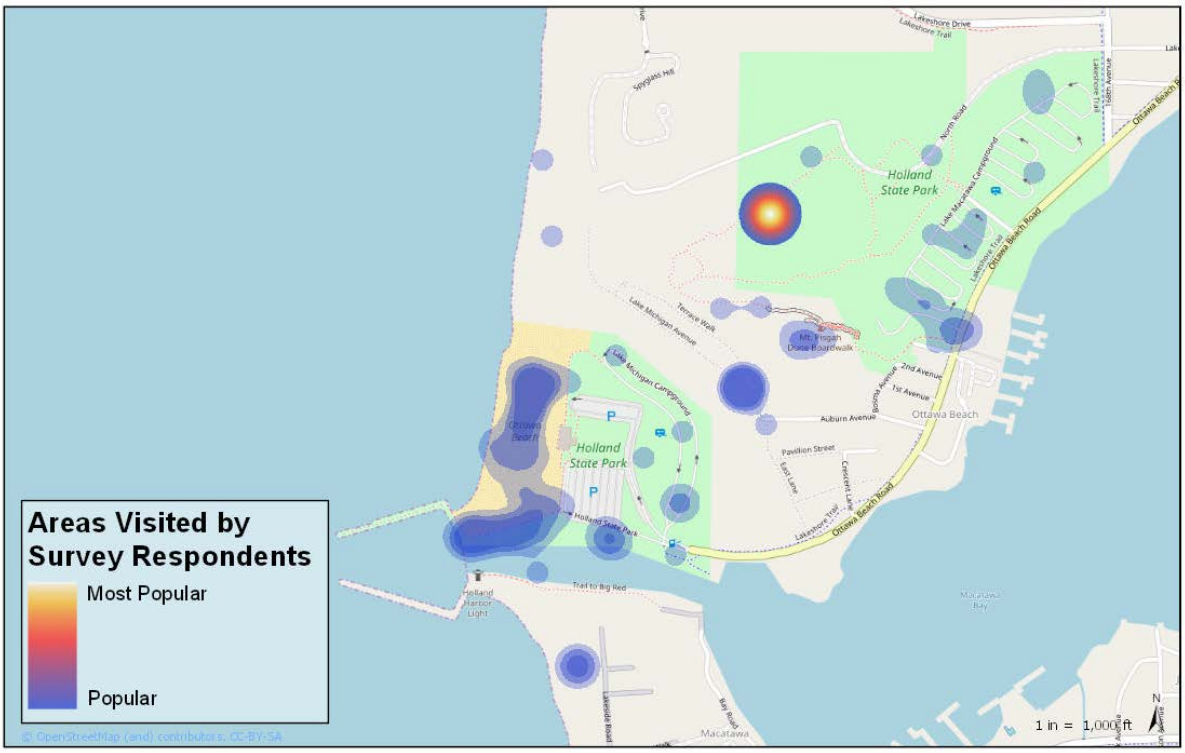

Figure 25. Heat map of locations visited in Holland State Park.

Most Recent Trip and Trip Expenditures

The 3,189 respondents who had visited a coastal sand dune area in Michigan for recreation in the past 12 months were asked to consider their most recent trip. The survey data included responses representing a range of visits and group sizes, from solo visitors to large groups, and a range of spending per trip, from no expenditures to thousands of dollars per trip for some groups. Visits by large groups tend to skew the average number of people per group, so both mean and median values are provided, where the mean represents the average response, and the median represents the middle response when responses are ranked. Trip characteristics of the most recent trip to coastal sand dune areas in Michigan are presented in Table 12. The average group size was 3.4 persons, while the median group size was 2.0. Respondents reported having spent an average of $391.75 per trip, with median spending of $200.00 per trip. Average spending per person was $133.15, with median spending of $66.67 per person.

Table 12. Trip characteristics of most recent trip to coastal sand dune areas in Michigan (n=3,189)

Trip characteristics	**Mean**	**Median**
Number of people in group (minimum = 1, maximum = 68)	3.4	2.0
Spending per trip on trip-related expenditures (minimum = 0, maximum = $10,000)	$391.75	$200.00
Spending per person	$133.15	$66.67

Trip characteristics of the most recent trip were calculated by region and are presented in Table 13. The Southwest region (n=651) includes visits to coastal dune areas along Lake Michigan from Berrien County to Ottawa County. The Central West region (n=1,192) includes visits to coastal dunes areas along Lake Michigan from Muskegon County to Manistee County. The Northwest region (1,039) includes visits to coastal dune areas along Lake Michigan from Benzie County to Emmet County. The Northeast region (n=56) includes visits to coastal dune areas along Lake Huron and Mackinac Island. The Upper Peninsula region (n=197) includes coastal dune areas along Lake Michigan and Lake Superior. Some responses included locations that could not be identified. Average group size and average spending per trip were greatest in the Central West region.

Table 13. Trip characteristics of most recent trip to coastal sand dune areas in Michigan, by region

Trip characteristics	**Mean**	**Median**
Number of people in group		
Southwest	3.3	2.0
Central West	3.7	3.0
Northwest	3.2	2.0
Northeast	2.7	2.0
Upper Peninsula	3.1	2.0
Spending per trip on trip-related expenditures		
Southwest	$270.77	$100.00
Central West	$429.23	$250.00
Northwest	$415.75	$200.00
Northeast	$494.49	$376.00
Upper Peninsula	$481.39	$363.00
Spending per person		
Southwest	$91.55	$30.00
Central West	$132.79	$75.00
Northwest	$145.90	$75.00
Northeast	$200.87	$133.33
Upper Peninsula	$192.34	$129.00

Trip characteristics of the most recent trip were also calculated for the five most visited coastal dune areas among respondents and are presented in Table 14. Average group size and average spending were greatest among visits to Silver Lake State Park.

Table 14. Trip characteristics of most recent trip to the five most visited coastal sand dune areas among respondents

Trip characteristics	**Mean**	**Median**
Number of people in group		
Sleeping Bear Dunes National Lakeshore	3.3	2.0
Silver Lake State Park	4.0	3.0
Ludington State Park	3.4	3.0
Warren Dunes State Park	3.5	3.0
Holland State Park	3.2	2.0
Spending per trip on trip-related expenditures		
Sleeping Bear Dunes National Lakeshore	$428.73	$200.00
Silver Lake State Park	$551.15	$350.00
Ludington State Park	$442.54	$300.00
Warren Dunes State Park	$256.10	$100.00
Holland State Park	$318.37	$140.00
Spending per person		
Sleeping Bear Dunes National Lakeshore	$150.06	$75.00
Silver Lake State Park	$158.23	$100.00
Ludington State Park	$143.49	$100.00
Warren Dunes State Park	$86.06	$35.40
Holland State Park	$106.83	$50.00

Other Activities

Respondents were asked if they participated in other activities during their most recent trip to coastal dune locations in Michigan. An overview of other activities is provided in Figure 26.

More than 70 percent of respondents purchased fuel (71.2 percent), and more than half of respondents purchased meals at a restaurant (63.4 percent) and purchased groceries (52.8 percent). Nearly a quarter of respondents (22.7 percent) visited a winery or brewery. These responses reflect regional expenditures by visitors during their most recent trip to coastal dunes in Michigan.

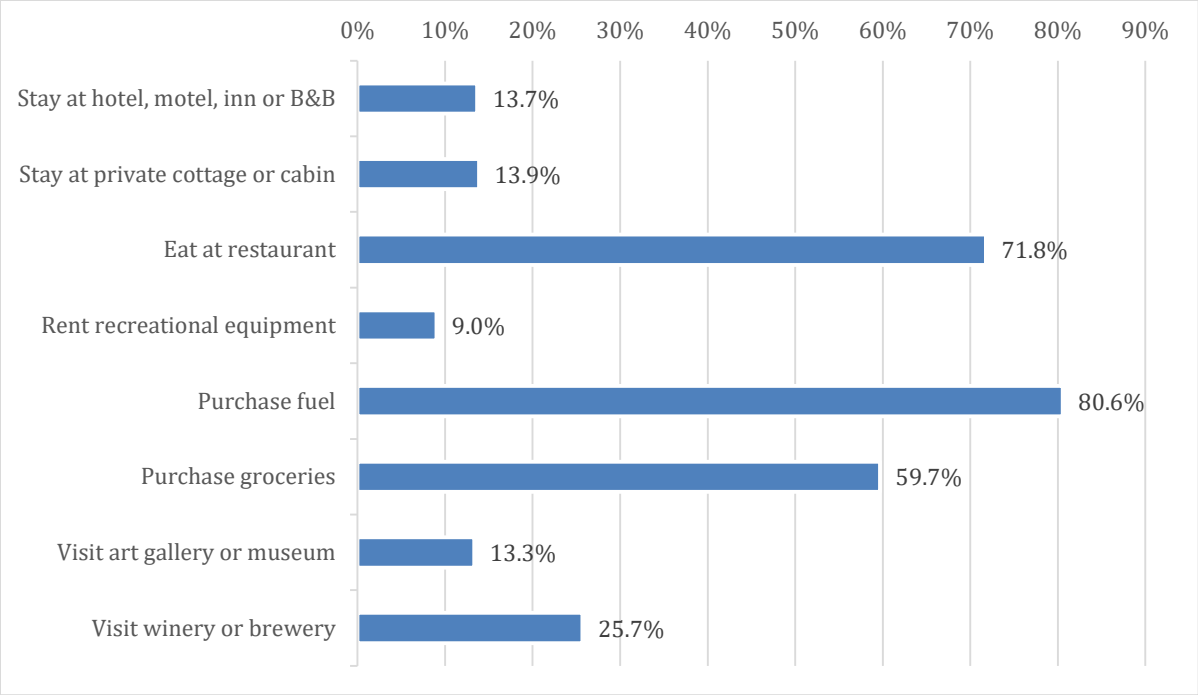

Figure 26. Other activities during trip (n = 3,188).

Social and Cultural Values of Dunes

Respondents were asked to rate the importance of a series of social and cultural values that may be associated with coastal sand dune areas. Ratings on the perceived importance of a series of aesthetic, ecological, education, recreation and economic values were generally high, with all mean scores exceeding 3.0 on a 5-point scale (Responses: 1 = "not at all important, 5 = "extremely important"). The results are presented in Figure 27.

Protection for future generations and scenic beauty were rated as especially important values of coastal dunes; more than 60 percent of respondents rated these values as *extremely important*, and the mean score equaled 4.6 in each case. More than four-fifths of respondents rated protection of a unique ecosystem (82.6 percent) and outdoor recreation (82.6 percent) as *extremely important* or *very important*. More than half of respondents (53.8 percent) rated the importance of protection of a unique ecosystem as *extremely important*, and the mean score was 4.32.

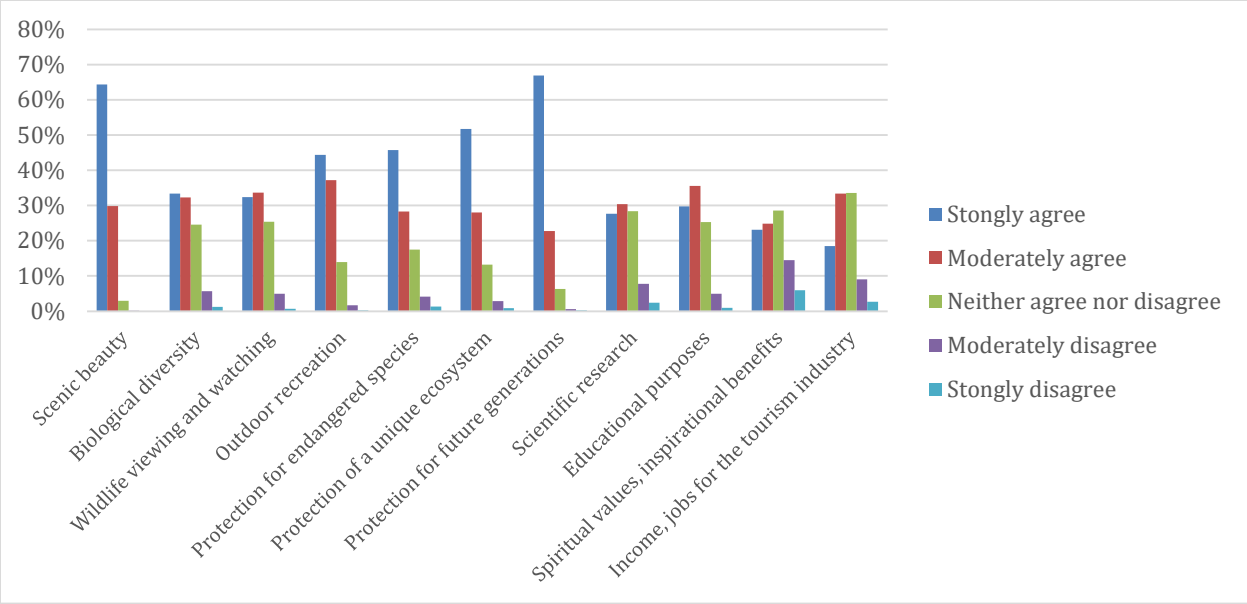

Figure 27. Importance of cultural values of dunes (n=3,610).

Statistical tests were conducted on responses to questions about cultural values between those respondents who had visited a coastal dune area in the past 12 months and those who had not visited. The t-test is a parametric test of differences in mean values that assumes that responses are normally distributed. The Mann-Whitney test is a non-parametric test of the differences in median values that makes no assumption about the distribution of responses between the two groups. A p-value of 0.05 or less indicates that there is a significant difference between the responses of the two groups at a 5 percent level of statistical significance, which is a standard benchmark in statistical analysis. The results of both tests are provided in Table 15.

Under both tests, there is a significant difference in responses between the two groups only for the importance of “Scenic beauty”; respondents who did not visit a coastal dune area in the past 12 months ranked the importance of scenic beauty lower (mean = 4.3683) than those who did visit a coastal dune area (mean = 4.6281). For the other cultural values of coastal sand dunes, there was no statistical difference among responses from those who visited a coastal dune area and those who did not.

Table 15. Statistical tests of differences in responses between visitors and non-visitors.

Cultural values	**t-test**	**Mann-Whitney test**
Scenic beauty	t = -8.2666, p = 0.000	z = -5.771, p = 0.000
Biological diversity	t = 0.1088, p = 0.9133	z = 1.126, p = 0.2600
Wildlife viewing and watching	t = 0.4991, p = 0.6177	z = 1.507, p = 0.1318
Outdoor recreation	t = -0.3509, p = 0.7257	z = 1.507, p = 0.1318
Protection for endangered species	t = -0.3209, p = 0.7483	z = 0.544, p = 0.5866
Protection of a unique ecosystem	t = -1.1191, p = 0.2632	z = -0.227, p = 0.8206
Protection for future generations	t = -0.8436, p = 0.3989	z = 0.026, p = 0.9796
Scientific research	t = -1.2501, p = 0.2114	z = -0.723, p = 0.4697
Educational purposes	t = -1.6653, p = 0.0959	z = -0.829, p = 0.4072
Spiritual values or inspirational benefits	t = -1.8104, p = 0.0703	z = -1.635, p = 0.1020
Income and jobs for the tourism industry	t = -1.7310, p = 0.0835	z = -1.493, p = 0.1354

Respondents were also asked about the importance of *access* to coastal dunes to their households and their quality of life (How important is access to coastal dunes in Michigan to the quality of life for you and your household? Responses: 1 = “not at all important, 5 = “extremely important”). Responses are summarized in Figure 28.

Nearly three-fourths of respondents (72.3 percent) rated access to coastal dunes in Michigan as *extremely important* or *very important* to the quality of life for them and their households (n = 3,225, mean score = 4.21). Fewer than 1 percent rated access to coastal dunes as “not at all important.” Those who had not visited a coastal dune area in the past 12 months rated dune access as significantly less important (mean = 3.66) than those who had visited (mean = 4.28) (t = -11.57, p = 0.000). (A p-value of 0.05 or less indicates that there is a significant difference between the responses of the two groups at a 5 percent level of statistical significance.)

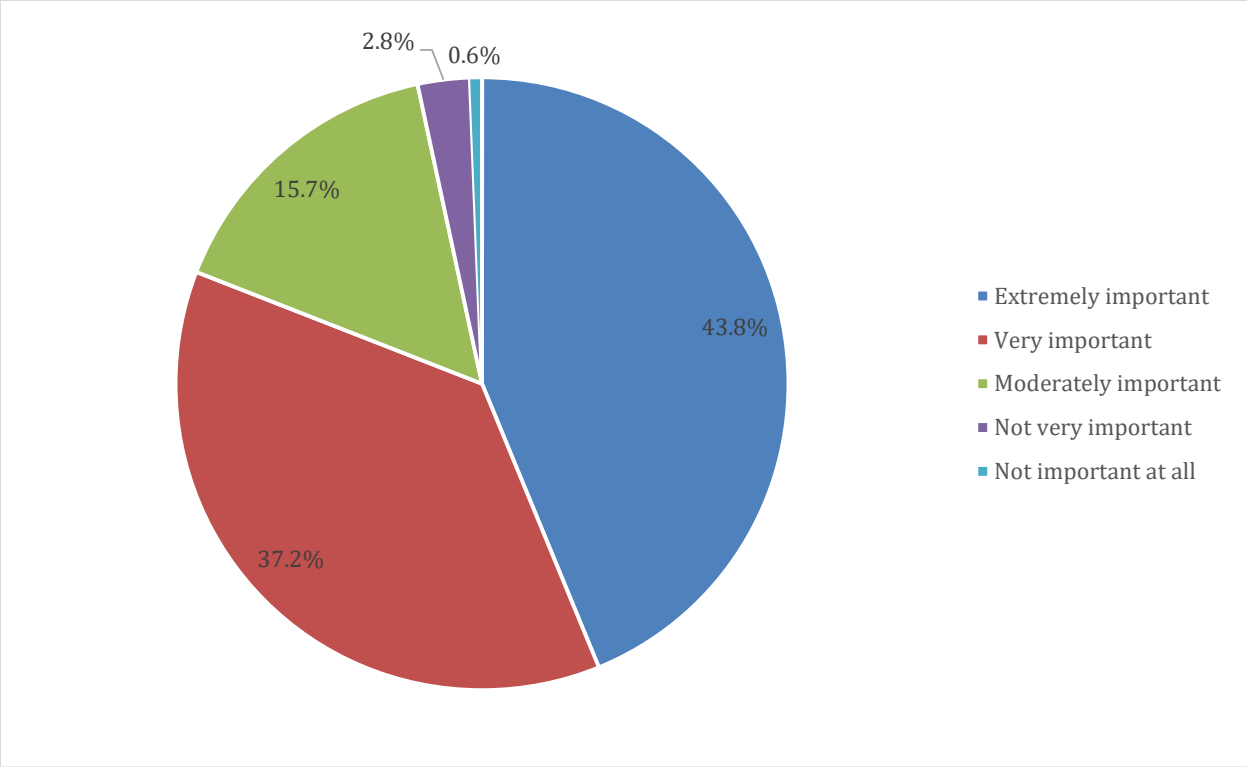

Figure 28. Importance of access to coastal dunes (n=3,226).

Trust for Protection and Stewardship of Coastal Dunes

Respondents were asked about their trust in institutions for the protection and stewardship of coastal dunes (Who do you trust with the protection and stewardship of coastal dunes in Michigan?). Responses to this question are presented in Figure 29.

Respondents were invited to select all options that apply, so the totals do not sum to 100 percent. More than three-quarters of respondents (77.6 percent) indicated that they trust state government with the protection and stewardship of coastal dunes in Michigan. More than two-thirds of respondents identified non-governmental organizations (67.5 percent) as institutions to be trusted with the protection and stewardship of coastal dunes, and more than half identified local government (53.1 percent) as trusted stewards of coastal dunes.

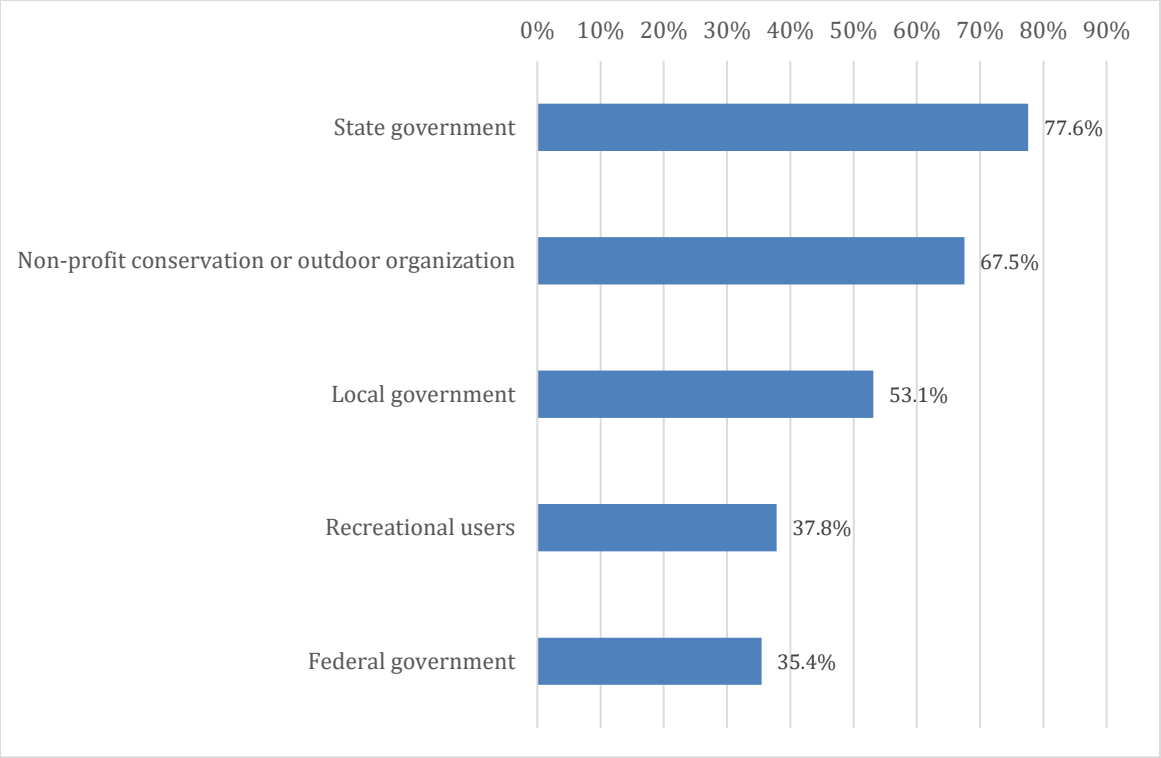

Figure 29. Trusted stewards of coastal dunes (n=3,452).

Respondents were also asked if they were willing to be contacted with additional information related to the protection of coastal sand dunes in Michigan and other topics related to this project (May we follow up with you with additional information or questions related to this project?). More than half of respondents (57.5 percent) indicated they were willing to be contacted, and they responded with their email addresses. This widespread willingness of survey respondents to be contacted with additional information will contribute to the objective of the study to catalyze a dunes stakeholder community and to foster new partnerships to promote awareness of coastal dunes in Michigan.

Open-Ended Comments

Finally, respondents were also invited to provide open-ended comments related to coastal sand dune areas in Michigan ("If you have any additional comments related to the management of coastal sand dune areas in Michigan or the activities you enjoy while visiting these areas, please provide them in the space below."). A total of 720 individuals (approximately 20 percent of total respondents) provided open-ended comments related to their visit or their attitudes about coastal sand dunes. Numerous respondents expressed their support for the protection of coastal dune areas, while others expressed concern about litter, sand mining, and some comments reflected a lack of awareness about coastal sand dune ecosystems.

One respondent from southeast Michigan responded, "The dunes and the lakefront of Lake Michigan is the most beautiful thing in our state. Something that I remember from a kid that never went away. Someday I would like to be lucky enough to live closer to it." Another

respondent from southeast Michigan commented, “Please do whatever you are able to do and what is needed to preserve this natural beauty for future generations.” Other comments from respondents from southeast Michigan included, “Thanks for keeping Michigan’s vital dune ecosystems beautiful for us and for future generations!” and “Preserve our dunes—they are so unique and valuable!” A respondent from west Michigan commented, “I think that the dunes are so very important to Michigan!” Other responses from residents of west Michigan included, “Coastal dunes are Michigan’s greatest natural treasure and must be protected to the greatest extent possible,” and “It is an awesome experience every time I visit the coastal dunes and realize how beautiful they are and how important it is to preserve these wonders of Michigan.”

Several tourists who visited coastal sand dunes responded with comments about the importance of dunes for their family vacations. One respondent from Indiana commented, “My family loves Michigan and the dunes we will be there every chance we get.” A respondent from southeast Michigan responded to say, “My family and I visit the coastal dunes every summer. It is one of our favorite places to go on vacation and the dunes are beautiful.” A resident of Georgia responded, “This is my favorite spot in the world. Please do not allow them to be commercialized or destroyed.” A visitor from Ohio commented, “This is our 4th year in a row going to the dunes because everyone in our family can enjoy it.” A resident of Iowa commented, “We grew up in Michigan and every year return for vacation. We always go to Sleeping Bear and the dunes on Lake Superior.”

Several respondents reported visiting coastal sand dunes in Michigan regularly. A resident of southeast Michigan responded to say, “Visiting the coastal dunes of Michigan is my favorite way to recharge my life. I have been visiting various dunes every year for 20+ years. Every time, it’s a different experience.” Another southeast Michigan resident commented, “We have camped every year since 1976 in the Sleeping Bear Dunes area.” A resident of mid-Michigan responded, “Michigan dune areas rival the most beautiful spots in the world. They are one of the main reasons me and my family remain in Michigan.”

Some respondents indicated that coastal sand dunes are an important reason for living in Michigan. For example, one resident responded, “Lake Michigan’s sand dunes will keep us residents of this region even though other states have much to offer.” Another resident responded, “These areas are the greatest asset to living here in Northern Michigan. Their protection and accessibility are extremely important to our quality of life and is greatly appreciated!”

Numerous respondents commented with support for the protection of coastal sand dunes in Michigan. One resident of west Michigan responded to say, “I think the State of Michigan is doing a wonderful job at protecting our coastal dunes!” More than a dozen respondents commented simply to say, “Keep up the good work!”

Other respondents expressed concern about development in coastal sand dune areas. A resident of southeast Michigan responded, “Do not develop these areas. Keep them as scenic, educational places for generations to come,” while a resident of west Michigan commented, “Dunes need to be preserved, not turned in to more housing!” Other comments included, “Protect it as a natural environment with little to no development,” and “No more development please.”

Several respondents expressed concern about sand mining, including a resident of west Michigan who commented, “I am concerned about the continuing sand mining that is depleting our dunes.” Other comments included, “Ban sand mining of dunes,” and “Stop the sand mining!”

Some comments reflected a lack of awareness about coastal sand dune ecosystems, particularly the dynamic nature of dunes, and the role of dune grasses in erosion control. Comments in this regard included, “Everything was better before they planted all the useless dune grass,” “The invasive grass has taken over the beach. We used to have several feet of beautiful white sand to enjoy!” “Please remove beach grass within 200 feet of Lake Michigan,” and “Please do whatever you can to eliminate dune grass and return the beaches back to the expansive sandy areas they once were.” Meanwhile, other comments expressed support of dune grasses, including “We need to plant more dune grass to prevent erosion.” These comments highlight the need for greater awareness of coastal sand dune ecosystems and a broader understanding of the processes that contribute to the formation, development, and geomorphological change in coastal dune areas.

Appendix B includes two word clouds, or graphical images representing the frequency of words used in the open-ended comments. Appendix C includes the full list of open-ended comments (unedited) provided by survey respondents related to coastal sand dune areas in Michigan.

A copy of the survey questionnaire is provided in Appendix D.

Part 3: Outreach and Engagement

Background

Opportunities for Michigan to better leverage its economic opportunities as a natural resource-based "amenity" state are increasingly being recognized and promoted. For example, the state's highly successful "Pure Michigan" marketing campaign has elevated the state's profile as a national and international destination. The Great Lakes coastline and the state's high-profile coastal sand dune features have played a prominent role in this marketing campaign from the earliest stages.

Michigan's coastal dune communities continue to garner increased recognition, frequently appearing on national "best of" lists, including "America's Best Little Beach Town" (Saugatuck, *MSNBC*)" and "21 Best Beaches in the World" (Traverse City, *National Geographic*) and "21 Best Beachside Bars in America" (Muskegon, *Thrillist*). But these communities often seem unable to fully leverage these assets to support improved economic outcomes, and these accolades do not appear to directly inform overall approaches to coastal dune management or local planning efforts.

Amenity-based talent development initiatives and "placemaking" concepts are slowly being embraced, based on the recognition that the state's natural assets also hold potential to attract and retain young professionals and high-value retirees; to recruit and grow outdoor adventure industries; and to inspire active enjoyment, concern and protection of everything the Great Lake State has to offer. As mobile talented workers are increasingly making decisions about where to move based on quality of life and outdoor recreation amenities, the visibility of Michigan's natural assets on a national stage have the potential to play a vital role in developing and realizing a more robust and diversified economy.

However, as noted in the previous sections of this report, specific data and information about the social and economic value of coastal sand dunes have thus far not been available. This has limited the ability of outdoor businesses, dune stakeholders and community members to effectively engage in dune management decision-making and planning. While tourism groups are effectively organized in some Michigan dune regions, emerging low-impact users like paddle boarders and fat bike enthusiasts have yet to speak with a unified voice in public dialogue about the future of dune landscapes and other natural assets. Tourism communities, planning agencies and economic developers generally have not found effective ways to engage these dune enthusiasts on a long-term basis. The tourism industry itself has yet to fully position its successes as integral parts of place-based, quality of life initiatives focused on talent attraction and retention.

Thus, in addition to providing valuable data, the survey work outlined in the previous section was also designed to pilot new tools—with a special focus on social media and events—to engage, convene, and assist stakeholders in finding useful social and economic information about coastal dunes, and ensure they have the tools and awareness to be part of the ongoing conversation about coastal dune management.

Approach

As highlighted by comments received on the #HowYouDune survey, ensuring an informed and science-driven management approach to the coastal dunes requires a better understanding of the myriad social and economic benefits of dunes, and also better communication of this knowledge.

With these communications and information-sharing needs in mind, and in support of the research program described in the previous sections of this report, an extensive outreach effort to connect to dune stakeholders, community members and businesses was conducted as part of this overall project. The goals were to:

- Raise awareness of Michigan's coastal dunes, and improve the response rate for the #HowYouDune Michigan Coastal Dune survey.
- Develop a more knowledgeable network of dune stakeholders, including outdoor businesses and outdoor enthusiasts who are often underrepresented in natural resource policy discussions; and
- Build partnerships with community leaders, civic organizations, visitors bureaus, regional tourism councils, and chambers of commerce who might not be aware of the various ways that outdoor recreation benefits Michigan's economy.

Using this approach, the project would ideally inform and improve future conversations about coastal dune policy and management at the state and local levels by inspiring a deeper and broader public understanding of the critical role that the coastal dunes can play in Michigan's future prosperity and quality of life.

To support survey recruitment and build capacity for sharing project results, the team sought to engage professionals, conservation voices, recreational users, and local tourism, planning and economic development leaders throughout the project. The goal of this stakeholder engagement was to learn about and improve the level of knowledge of the dune resource among the general public, to begin to identify shared values among dune stakeholders, and to lay the foundation for future efforts to disseminate relevant scientific information and research in order to support the development of shared visions and goals related to the use and management of coastal dunes.

As part of that effort, the project team developed the survey approach described in Part 2, using an opt-in sampling approach that necessitated substantial outreach to recruit and engage survey participants directly. Unlike a random sample survey, the opt-in survey required a long and sustained outreach program and a variety of tools, partnerships and strategies to ensure that participants were made aware of the survey. For this project, a wide variety of tools were developed and deployed before and during the survey period. These outreach efforts, while challenging and time consuming, also provided the project team with contacts and relationships that will provide benefits beyond the length of the project itself.

Leadership Engagement

As discussed in Part 2, the project team consulted with a variety of representatives from key sectors who advised the design of the #HowYouDune survey, and who were willing to engage their respective communities to increase survey response rates. These partners and leaders—

many of who were also part of the Freshwater Dune Summit described below and found in Appendix E—helped the project team host community forums to share dune science information, and identified and developed other opportunities for dune supporters to learn more about the dunes, express their views, and get involved in ongoing dune management discussions and planning efforts. From small non-profits to local businesses, and statewide organizations and agencies, we believe the engagement of these leaders throughout the process ensured a much stronger survey and better response rates, while also building the base of contacts and supporters willing to help share research findings with the wider public.

Marketing and Branding

To spread the word about the project and encourage people to take the survey, the team worked to get stories placed in online newsletters (such as the Office of the Great Lakes' Coastal Notes, the newsletter of Preserve the Dunes, blog posts by the West Michigan Environmental Action Council (WMEAC), and other similar print and online outlets.

Using the #HowYouDune hashtag, designer Sara Woodruff worked with Heart of the Lakes and MEC to create professional marketing materials that were available online, and then printed in hard copy form as needed, including posters (11"x17") and postcards (4.25"x5.5"). The eye-catching materials directed people to the Freshwater Dune Summit and eventually to the online survey itself. Hundreds of these materials were distributed by partners to various venues across the state where dune stakeholders might likely see them. For a sample of these materials, and a partial list of locations where marketing materials were shared, see Appendix F.

Freshwater Dune Summit

MEC and partners hosted the "Freshwater Dunes Summit" in May 2017, bringing together leading dune researchers, policymakers, land conservancies and MEC member groups, outdoor recreation enthusiasts and industry leaders, and other stakeholders for two days of fun, education and community building. Serving as both a policy summit and a social gathering, this event was co-produced with Heart of the Lakes as part of the annual spring gathering, with extensive outreach and event support from WMEAC.

Including speakers, nearly 100 people attended the event, which featured prominent speakers, panel discussions with experts, educational sessions highlighting our research, and a dunes recreational component organized in partnership with recreational groups, such as the Run Muskegon running group. Presentations by dunes ecologists, social scientists, and conservation professionals highlighted the ecological, social, and economic importance of coastal sand dunes in Michigan, and also included opportunities for participants to take part in dune-based recreation activities, such as trail running and a kayak trip through the dunes, as well as a social time for participants to get together and share dune experiences.

The summit nurtured a feeling of camaraderie and shared purpose among participants; fostered a reevaluation of Michigan's outdoor assets as drivers of economic activity and talent attraction; and served as a kick off for advancing goals and objectives for future collaboration. The full list of Freshwater Dune Summit speakers, their biographies and an agenda can be found in the event program, reprinted in Appendix E.

Social Media

Social media was used to promote events throughout this period, including the creation of Facebook events, targeted posting and paid "boosts" of dunes survey posts, and Twitter announcements. Sample posts were developed for Facebook, Twitter, Instagram, etc. along with graphics designed to use on these platforms, and provided to our project partners, who were critical to helping spread the word using social media. Many individuals, groups, organizations, and business used these tools, including the Michigan Mountain Biking Association, MParks (Michigan Recreation and Parks Association), Michigan Hiking and Backpacking Facebook Group, Run Muskegon Facebook Group, Southwest Michigan Planning Commission, Heart of the Lakes, WMEAC, Preserve the Dunes, and many more.

The social media outreach also sparked lots of interesting discussion among dunes stakeholders. Examples including comments such as:

> I've never been unimpressed with any stretch of dunes. I cannot comment enough on the beauty and the immense differentiation in the dune shoreline. I mean: look at Pierce Stocking, then go look at Silver Lake, then go the Grand Haven, Holland, so on: the beauty is endless and each beautiful in a different way. I am grateful I have seen them and will never tire or pass up a chance to travel back to Pure Michigan to spend some time immersed in the dunes. For instance: I have a glass cutting board that was special made with a photo of a glorious sunset in ludington state park: No one can comprehend until the[y have the] experience.
>
> Dunes all over the Lake Michigan coastline are priceless. They draw thousands of visitors to MI from all over the world. Let's protect them. I'll be at the Silver Lake Dunes in a day, been hearing how gorgeous they are!

For additional examples of social media posts and activity related to promotion of the #HowYouDune Michigan Coastal Dune Survey, see Appendix F.

Presentations and Events

Direct interaction and engagement with people in communities was also a priority of the project. Project leaders and partners were asked to help arrange and sometimes deliver presentations to dune communities in support of the survey and to expand the reach of the project, and in total 20 individual presentations and events were held during 2017. Sites were typically coastal dune communities, such as several presentations to civic groups including the Rotary Clubs in Holland and Grand Haven. The team also left the coastline for an event held in Midtown Detroit, partnering with a high-end outdoor clothing and equipment store, Filson, in order to connect with a younger outdoor demographic. For many of these events, Brad Garmon, Jonathan Jarosz, or Elaine Sterrett Isely would present on the dune survey, Dr. Arbogast would provide an informative science-based presentation, and Dr. Richardson offered explanations of the dune survey. Sometimes only part of the team was available, and other times all three parts of the project were presented. Whether speaking singly or in a group, the information and presenters were consistently well received.[10]

[10] Two versions of these presentations can be found online:
The Stewardship Network (context and background): https://www.stewardshipnetwork.org/june-2017-most-beautiful-place-america-sand-dunes-outdoor-recreation-future-conservation.

One of the highlights of this effort was a presentation and discussion with the drivers of Mac Woods Dunes Rides, a long-standing business that takes tens of thousands of visitors onto leased public dunes at Silver Lake State Park. The presentation was during the staff's annual season kick-off breakfast, and Dr. Arbogast provided new information for the drivers—many of whom are schoolteachers—to share with their dune visitors, and engaged them in our survey effort.

For a list of sample presentations and events hosted during the project, see Appendix F.

Email Campaign

Many local organizations and state agencies shared the survey through their email lists. In addition to the state's Travel Michigan program, local convention and visitors bureaus were excellent partners in this project through the support of Dr. Sarah Nicholls, who works with the local CVBs regularly. Many of these groups were made aware of the survey and shared it either through email or through their social media outlets.

The Michigan DNR became perhaps the most important email marketing outlet, sharing the survey with their extensive lists of more than 700,000, and also through their DNR bulletin email distribution list, in addition to social media notifications. As seen in Figure 30 below, the DNR's email blast was tracked, and their reach was extensive. There was a notable increase in survey responses following this notification.

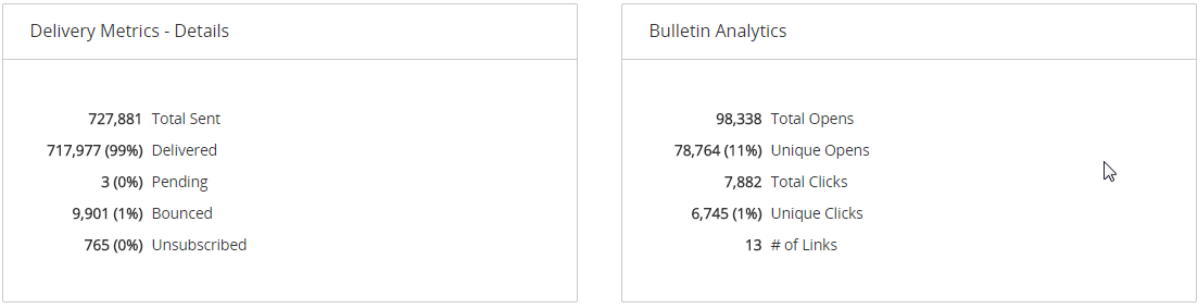

Figure 30. Metrics from the Michigan DNR's email outreach for the #HowYouDune Michigan Coastal Dune Survey. The emails were sent on Sept. 7, 2017, and the statistics were logged the following day, Sept. 8, 2017.

Business Outreach

The team also worked to recruit businesses located near coastal dunes to support survey promotion, either by allowing the distribution of marketing materials, putting a dune survey poster in their shop window or utilizing their online social media reach to help promote the survey. Business outreach during the course of the dunes project included contact with dozens of retail stores, and other eateries, breweries and rental outlets. A sample of the kinds of businesses that were recruited can be found in Appendix F.

Presentation by Dr. Arbogast at Tip of the Mitt Watershed Council on his dune research and project contributions (detail and science): https://www.youtube.com/watch?v=ilgyYAJ_2uQ.

In addition, the team often took these opportunities to learn more about the ways these business leaders understand and value the dunes as part of their business or as part of the quality of life of themselves or their employees. Similar work done by Headwaters Economics to document the influence of protected landscapes on businesses in Western states noted that leading business professionals understood and valued protected public lands in terms of business location and talent attraction.

During the outreach, several informal interviews were completed, and short videos were shot at the "Dunes Day in Detroit with Filson" event, and with three local dune-related businesses (Mac Woods Dune Rides in Mears/Silver Lake; The Sandbox in Silver Lake; Moxie Wild outfitters based out of Grand Haven). These interviews provided useful insights into how local businesses understand the dunes as economic drivers, and the videos will eventually be edited and posted online to help promote the project. Samples of the imagery and content developed during these interviews can be found in Appendix F.

Finally, as part of our efforts to engage and understand the economic and social value of dunes, Elaine Sterrett Isely from WMEAC spoke to a slightly different group of dunes-related business people—four landscape artists and an art gallery director who create and feature paintings of Great Lakes sand dunes in West Michigan: Anne Corlett of Saugatuck, Ed Duff of Birmingham (MI), Steve Mottram from the Water Street Gallery in Douglas, Joan Richmond from Traverse City, and Brian Smith from Paw Paw.

Some of these artists were drawn to the dunes by connections from their childhood memories and experiences. Others were inspired to focus on Michigan's coastal landscapes during their travels. All of these painters are plein air artists, which means that they work outside of their studios—experiencing the light, walking out into the landscape, and painting what they see in a constantly changing environment.

These locations include many West Michigan coastal dune sites—Ludington, Sleeping Bear Dunes, Southwest Michigan, and Saugatuck, to name a few. These artists paint in these locations because they love digging their feet in the sand and translating the sights and sounds of the dunes onto the canvas. But they also do it because of the demand. The art galleries that represent these artists are in summer tourist resort towns. The summer and second home tourists are big buyers of shoreline and dunes paintings. The dunes are important economic drivers in this context. Tourists come for a visit and want to take part of Michigan home with them.

Local art galleries explain that landscape shows are among the biggest events of the year. They host "paint out" *plein air* events, where artists are sent out to paint local scenes to be sold later that day. Some of the local land conservancies have even hosted similar events to create wall calendars to sell as fundraisers. The coastal dunes play a big part in the imagery for those events, and they bring in the artists, who stay to work and paint. As Joan Richmond says, "The dunes keep calling you back. They're so fascinating and they continue to change." The West Michigan coast, they explain, changes constantly. It can be calm and peaceful, and suddenly turn dark and stormy. And in the dunes, it's not just the shadow and light changes, but the shape—the geography—also changes. It's this dynamism that keeps these artists coming back. As Ed Duff put it, "I'm drawn to the drama of it."

All of these artists commented on the uniqueness of the dunes landscape and the inspiration they pull from their unique connection to the water. They suggest that the Michigan dunes have a mountainous feel that makes it seem like you're in a different, more isolated place, and that the dunes in some ways are timeless and can help connect viewers to the past. For them, the coastal landscape has a vastness, a sense of depth and scale that is unexpected, reminding us of how small we really are compared to our environment. For examples of the art produced in Michigan dunes, see Appendix F.

Outcomes

Through an extensive outreach and engagement campaign, the project team raised awareness of the #HowYouDuneSurvey and increased survey responses; shared the latest scientific understanding of dune features and improved dune literacy among the public; identified and activated leaders from Michigan local businesses as potential spokespeople on dunes issues; developed more functional networks of recreational users who are underrepresented in natural resource discussions; and formed new relationships with convention and visitors bureaus, regional tourism councils, and chambers of commerce.

In addition, more than half of the #HowYouDune survey respondents (57.5 percent) indicated they were willing to be contacted, and they responded with their email addresses. Many hundreds of them also voluntarily submitted photographs of their visits to the dunes, and gave the project team permission to use these photos as part of the project. This widespread willingness of survey respondents to share their imagery and to be contacted with additional information will contribute to the objective of the study to further catalyze a dunes stakeholder community and to foster new partnerships to promote awareness of coastal dunes in Michigan.

Conclusions

Michigan is a state with abundant outdoor recreation assets and natural resources, including one of the largest publicly owned forests in the eastern half of the United State (more than 4 million acres of state-owned public forests and another 4 million acres of National Forests) and many more privately owned forests tracts accessible for hunting, fishing and trapping. We have more miles of freshwater coastline than any other state in the U.S., and the Great Lakes host the largest collection of freshwater sand dunes in the world. While making up a relatively tiny slice of the state's overall landscape, the coastal sand dunes of these shores provide a rich and often undervalued range of recreational, ecological, cultural and economic value to the state and its coastal communities.

This is the second MEC-led dune research project undertaken so far, and collectively they share two deeply interconnected imperatives that MEC and our project partners have identified for promoting sound coastal dunes management:

- Advancing our scientific knowledge of how our coastal dunes were formed, developed over time, and respond to influences ranging from interactions with human beings to changes in lake levels and climate. In other words, sound decision-making requires us to understand how dunes work as a fundamentally dynamic landscape.
- Increasing public awareness of that science—with numerous public presentations and stakeholder meetings—and cultivating a community of stakeholders who understand how we can maximize our enjoyment of the dunes while minimizing the extent to which we undermine their natural processes and dynamic nature. Sound decision-making also depends on citizens carrying science forward into state and local venues where hundreds of discreet decisions will determine our dunes' fate.

Reflecting these intersecting tracks, by working with academic experts, community partners and an engaged set of dunes stakeholders, the project team has therefore delivered information that improves our understanding of coastal dunes, and greatly improved our ability to manage this resource with a more robust understanding and picture of the role coastal dunes play for the people of Michigan and beyond. This project has both:

- **Deployed cutting-edge GIS spatial imaging data/tools to produce a comprehensive new delineation of Michigan's coastal sand dunes.** This is the most detailed and comprehensive map of Michigan's coastal dunes thus far developed in a digital GIS environment. By defining and mapping the full geomorphic extent of Michigan's coastal dune areas in a digital environment, while also reaffirming the processes and Holocene age of these dynamic natural features, the project fills a critical hole that currently inhibits constructive discussion about the state of Michigan's overall coastal dune system, and creates a powerful tool to support and enable future research, geographic analysis and community engagement in support of wise management of the dunes.

- **Applied innovative online survey techniques to measure and assess how residents and visitors value and use these truly world-class scenic and recreational landscapes.** While it certainly should not be the only consideration in decisions impacting their management, information on the social and economic value of dunes can help decision

makers make informed tradeoffs between various uses, such as conservation, development, or recreation. The project provides a fuller—though still incomplete—picture of the social, cultural and economic importance of the dunes, with specific data about how people interact with and value the resource. In the future this information can be repackaged for use by local communities to support their planning efforts and to better celebrate, promote and educate people and communities about our coastal dune assets. The project identifies and characterizes in great detail the popularity of certain uses of dunes for scenic enjoyment or recreation, and helps articulate clearly the underlying values that people associate with Michigan's coastal dunes. By using this information to guide planning and land use decisions about coastal dune landscapes, communities and decision-makers can be more responsive—and ultimately more successful—in managing this dynamic landscape for the greatest good of the largest number of people, plants and habitats.

And finally, a more engaged set of dunes stakeholders and more connections and tools were developed to support future science-based efforts and improved management decisions and policy discussions. Connecting with dunes stakeholders—including recreation users, tourism professionals, business leaders, and local planners—was a critical aspect of the research and a boost to the overall project as well. It not only helped improve our research outcomes, it also helped develop and mature a powerful new set of tools and approaches for disseminating this and future dune science information.

This new collection of quantitative dune information, novel approaches to information gathering, and qualitative stories and insights opens new territory in the conversation about the kinds of information that can and should be brought to bear in decisions about the future of Michigan's coastal dunes. Moreover, by engaging in communities, sharing new information as it was being developed, and connecting with dunes stakeholders across the state, the team built a solid foundation of relationships and tools that can now be shared with local leaders, or analyzed in greater detail to learn more about certain sub-geographies, to better understand the wide range of uses and benefits of dunes and ensure that these various values can be met on the limited landscape of coastal dunes that remains.

Notably, the online valuation survey tool itself piloted a new approach that could easily be expanded, improved and adapted to help other agencies and organizations better gauge the public's values around natural assets.

Lessons Learned

Along the way, the project team also faced some challenges and learned several lessons that can be useful learning tools for future work along these lines. These include:

1. **Trade-offs are inevitable when selecting a survey method.** Rather than using a random sample method, in which each member of the overall population has an equal and known chance of being selected, due to financial limitations, the #HowYouDune study necessarily relied on an opt-in sampling method, a form of non-probability sampling consisting of respondents who volunteer to participate. As such, the data cannot be extrapolated or serve as a direct input to economic impact modeling tools, such as IMPLAN, since they do not reflect

the demographic composition of the total population of visitors to coastal dune areas in Michigan. While not ideal, our chosen opt-in sampling approach had several advantages, including convenience and lower costs associated with recruiting a large sample size. The opt-in sampling also provides a participatory approach to survey data collection, and a vehicle for engaging directly with a broader group of dunes stakeholders. With more resources, an additional random sample survey should ideally be deployed in conjunction with the opt-in approach to allow for greater analytical capability.

2. **Integrating survey questions with GIS presents technical hurdles.** The Surfrider Foundation recreational use studies that inspired our proposal relied on a technical consultant to build a custom survey tool that combined the mapping component (the ability of respondents to drop pins relating to survey questions). That company (Point 97) has since gone out of business, and our team did not have the technical programming expertise necessary to build the custom survey tool that we envisioned for this project, specifically, one that would integrate a geospatial mapping component. We solicited proposals and selected Alek Kreiger, GIS Specialist with Ducks Unlimited, as our contractor to build our survey tool. He used a new, out-of-the-box survey application called Survey123, newly available through Esri (a leading national GIS software provider) to create the #HowYouDune survey for us.

   While this approach allowed us to reduce costs and work directly with a valuable local partner, it also became clear that the Survey123 survey application was so new that we would essentially become beta-testers for the system. Kreiger spent a great deal of time working directly with Esri to identify and resolve various bugs and glitches in the new application as they were identified, and those inherent limitations also forced the project team to accept some reduced functionality and usability. Frustrations with the system were noted in some of the open-ended comments, and could potentially have reduced the number of completed surveys. In the end, the survey map was successful in allowing 3,610 respondents to take the survey via desktop/laptop computers, tablets, and mobile smartphones, and to map more than 7,000 sites they visited. Given that our initial goal was 1,000 completed surveys, we think this is a success.

   However, the interface was not as clean or as seamless as we would have liked, and some survey respondents complained the mapping portion of the survey was complicated and/or time consuming. Thus, the maps are useful for "heat map" analysis of general activity by area, but some of the very local data points are likely entered in error (e.g., in water) and the team lacked the resources necessary to manually clean the data, leading to some stray or odd data points. As technology continues to improve, surveys like this one, with spatial information linked to traditional user responses, will likely become better, as well as easier and more affordable to deploy.

3. **Achieving diversity in survey responses requires new approaches.** One of the benefits of the opt-in online survey is that it allowed the team to periodically review data and refine our outreach strategy based on the demographics of the respondents. Thus, it was noted toward the end of the survey period that survey respondents were predominantly white/Caucasian, despite the fact that coastal dunes are present in several minority communities along the Michigan coastline. While a problematic lack of racial diversity is notable in many venues of

outdoor recreation (National Park visitation, for example), the team hoped to increase survey participation among minority respondents, and also to test our ability to reach these underrepresented populations using social media tools.

An additional two-week survey period was thus added in October, in conjunction with a targeted social media push to the largely minority communities of Benton Harbor, Muskegon, Muskegon Heights and Covert. While ultimately not effective in garnering additional minority responses (a fact determined by reviewing the survey responses during the two-week social media campaign targeting minority communities), this aspect of the project proved the team's ability to modify the online survey approach in mid-stream in response to results—a key benefit of the online survey approach -- but also highlights a larger need to improve overall outreach mechanisms and strategies to more effectively engage underrepresented minority communities in projects focused on natural resources and coastal recreation.

4. **Connecting with younger recreational users is difficult.** One of the underlying goals of the #HowYouDune survey was to connect with younger users of dunes, particularly the 25-34 year old, highly educated workforce, whose satisfaction and willingness to locate in the state is increasingly important to the future economic success of Michigan. However, despite our efforts to connect with this group through social media and events at outdoor retailers, only 34 percent of the dune survey respondents were 45 years old or younger, while 66 percent were over 45. The average age of respondents was 50.6 years old, while the median age was 53 years old. Again, this is likely due to the heavy reliance on the DNR's email lists. Future work should review recruitment and engagement strategies to better connect with this age group. For example, based on surveys of users to Nordhouse Dunes Wilderness areas, the area attracts a significantly younger cohort than our survey, with 40.7 percent of Nordhouse dunes visitors aged 20-40, and only 24.8 percent over the age of 50. Targeted work and partnerships with locations that are more popular with younger audiences might yield more insights into this importance demographic.

Opportunities

The team identified additional information gaps and opportunities for future work that could be undertaken to build on the new knowledge generated, and to advance the cause of dune science and overall natural resource management and decision-making going forward.

1. **Updating the dunes map as high-resolution data becomes available.** At present, high-resolution (1m) LiDAR imagery is available for select coastal counties, though new high-resolution data is being collected and should become available within a few years. Given its digital nature, the dunes map created for this project should be updated when high-resolution DEMs become available in the near future for areas currently mapped with lower resolution products. This will require funds and time from a skilled GIS technician, though the technique used for this project is replicable and repeatable.

2. **Translating passion into informed citizen engagement in coastal dune decision-making and conservation planning**. While love and general appreciation and enthusiasm for coastal sand dunes came through clearly in the survey results, the open-ended comments collected

through the survey often reflected respondents' lack of awareness about coastal sand dune ecosystems, particularly the varying types of dune landscapes implicated in the survey (which encompass sandy beaches, forested back dunes, wetlands and other geomorphic expressions of coastal windblown sand), the dynamic and ever-changing nature of dunes, and the role of dune grasses and other vegetation. We would like to a more robust effort to inform residents and visitors about dunes, and gather information about what would motivate them to become engaged in wise management and decision-making in the coastal dunes context.

3. **Undertaking research to better understand how human uses and interactions have shaped the dunes over time**. The recent research project has improved our understanding of how dunes develop and change, in both ecological and geological terms. However, our knowledge of the specific ways human behavior has impacted these natural dune processes—since intense uses like mining and residential/commercial development emerged last century—is less advanced and scientifically tested. Clearly, they provide a host of services to the state and region and have for many decades. But we think specific research to understand how those human activities may change dune development or evolution would be a vital addition to the dune literature and continue to provide leaders, decision-makers and dune users with information to make better decisions about their management and use.

4. **Doing additional age classification of coastal sand dunes.** Soil characteristics assessed during field visits for this project verified the accuracy of age classification between Holocene and Pleistocene coastal dune systems. Field observations indicated that "old" soils were not present in any inland dunes examined, which, in turn, indicated that all dunes in the study were Holocene in age. As a result, verification did not require the collection and dating of sand using Optical Stimulated Luminescence (OSL) dating techniques; however, additional OSL dating would be useful and should be collected and analyzed when possible. The hypothesis that would be tested in further OSL dating of these eolian sands is that they accumulated during the Nipissing high stand of ancestral Lake Michigan. If this hypothesis was verified, it would make these sands ~5,000 years old and thus similar in age to "backdune" deposits reported in previous studies near Holland. Such results would be significant from a geomorphic perspective because they would demonstrate that eolian sands accumulated farther inland during the early part of the constructional phase that built the modern coastal dune complex than previously recognized. Such inquiries were beyond the scope of this project, but would be very valuable contributions to our understanding of Michigan dunes.

5. **Investing in random sample surveys to allow additional economic modeling.** As mentioned in the lessons learned section, our dune survey data could potentially generate more specific economic impact estimates if it were augmented with random sample surveys of Michigan residents, park visitors, etc. We are currently reviewing other existing data sets, such as DNR park visitation data, point surveys at state parks, and federal studies of visitors to Nordhouse Dunes, to see if any can be used to extend our data and make it useful for running more sophisticated statistical models and analyses that provide more comprehensive economic impact information.

6. **Avoiding heavy reliance on self-selected email lists for future survey work.** The popularity of state parks reflected in our survey may be in part due to the project's reliance on the Michigan DNR's massive email lists to recruit participants. Comprised primarily of individuals who have registered as state park campers, or have opted to receive emails from the DNR, this list was the largest single outreach tool for dissemination of the #HowYouDune survey. While the lists might provide a reliable sample of Michigan's general public, it is more likely it reflects a bias toward the interest and demographics of the lists. These same lists are also relied on heavily by the DNR for park planning efforts, such as the development of park general management plans. A project to analyze the extent to which these lists accurately capture the sentiments of the general population or the population of outdoor recreationists could be undertaken and would likely prove useful in making a future survey more broadly representative of the general population with more robust datasets for statistical analysis.

7. **Undertaking targeted efforts to improve outreach and engagement of minority communities in recreation and natural resources decision-making.** As noted in the lessons learned section, the majority of #HowYouDune survey respondents were white (87 percent), with relatively few respondents representing other races or ethnicities. Additional social media pushes to large minority dune communities failed to impact these statistics. Going forward, a project focused on reaching out to minority communities and finding better avenues and ambassadors to communicate with them about recreation and values would yield positive outcomes. Research suggests this is not an issue unique to dune landscapes, but is more widespread, impacting National Park visitation, employment in natural resource management careers, and the recreation industry as a whole. Minority communities enjoy the outdoors, but it is clear that current models of taking input on recreational interests are failing to capture this reality. Additional effort should be made to improve in this area.

8. **Continuing to improve outreach and engagement of young talent.** As noted previously, one of the underlying goals of the #HowYouDune survey was to connect with younger users of dunes, particularly the 25-34 year old, highly educated workforce, whose satisfaction and willingness to locate in the state is increasingly important to the future economic success of Michigan. However, only approximately 34 percent of the dune survey respondents were 45 years old or younger, while 66 percent were over 45. The average age of respondents was 50.6 years old, while the median age was 53 years old. Future work should review recruitment and engagement strategies to better connect with younger age groups. For example, based on surveys of users to Nordhouse Dunes Wilderness areas, the area attracts a significantly younger cohort than our survey, with 40.7 percent of Nordhouse Dunes visitors aged 20-40, and only 24.8 percent over the age of 50. (USDA Forest Service Visitor Use Report).

In the end, Michigan decisions makers at the state and local level need better access to spatial, economic and social data to support our understanding and assessment of the value of Michigan's rare coastal dunes. Many factors influence decisions related to protecting and managing the natural resources of coastal dune ecosystems. While economic and overall social values should not be the only considerations in decisions impacting natural resources

management, such information can help decision makers make informed tradeoffs between various uses, such as conservation, development, or recreation.

Together with the new map of Michigan dunes, this project provides information that can be applied locally to help communities begin to integrate social data and spatial knowledge into local planning efforts and to shape larger regional economic development, tourism and talent-attraction strategies, and in the long run, benefit not only the dunes, but also the people and communities who appreciate and depend on them.

References

Atlas of Critical Dunes, 1989. Michigan Department of Environmental Quality. Available for individual townships online at http://www.michigan.gov/deq/0,1607,7-135-3311_4114_4236-70207--,00.html. Accessed May 27, 2015.

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. *Ecological Monographs* 81(2): 169-193.

Beede, Susan, et al., 1987. "Michigan Sand Dune Management Project." Submitted in partial fulfillment of the Master's degree requirements at the University of Michigan School of Natural Resources. University of Michigan. 509 p.

Brown, A. C., and A. McLachlan. 2002. Sandy shore ecosystems and the threats facing them: some predictions for the year 2025. *Environmental Conservation* 29:62–77.

Buckler, W. R., 1979. Dune type inventory and barrier dune classification study of Michigan's Lake Michigan Shore. Michigan Geologic Survey Report of Investigation 23.

Cowles, H. C. (1899). The Ecological Relations of the Vegetation on the Sand Dunes of Lake Michigan. Part I.-Geographical Relations of the Dune Floras. *Botanical Gazette* 27(2), 95-117.

DNR (Michigan Department of Natural Resources). (2017). Park Management Plans (various). Lansing, MI: Department of Natural Resources. Available at: https://www.michigan.gov/dnr/managing-resources/prd/parks/mgt-plans

Everard, M., Jones, L., and Watts, B. (2010). Have we neglected the societal importance of sand dunes? An ecosystem services perspective. *Aquatic Conservation: Marine and Freshwater Ecosystems* 20(4): 476-487.

Hutchinson, Michael J. (1996). Land Use Regulations as a Means to Protect Fragile Environmental Areas: An Analysis of Michigan's Sand Dune Protection and Management Act, 13. *T. M. Cooley Law Review* 177.

Holmes, N. C., Papadogiannaki, E., Eury, D., & Hollenhorst, S. J. (2010). Sleeping Bear Dunes National Lakeshore Visitor Study. National Park Service, Park Studies Unit, Visitor Services Project, Report 216. Moscow, ID: University of Idaho. Available at: https://wpcdn.web.wsu.edu/wp-wpsites/uploads/sites/3019/docs/216_SLBE_rept.pdf

INVEST: Integrated Valuation of Ecosystem Services Tool. Annis Water Resources Institute, Grand Valley State University, in cooperation with the West Michigan Strategic Alliance, 2007. Available at: https://www.gvsu.edu/wri/invest/.

Lusch, David P., et al., 1996. Final Report: Evaluation of Critical Dune Atlas Designated Under Part 353 Sand Dune Protection and Management of the Natural Resources and Environmental Protection Act 1994 PA 451. Center for Remote Sensing, Michigan State University. 14 p. not including maps and appendices.

Kelley, R. W. (1962) Michigan's Sand Dunes: A Geologic Sketch. Michigan Department of Conservation.

Part 353, Sand Dunes Protection and Management (Critical Dunes), Michigan Natural Resources and Environmental Protection Act, Public Act 451 of 1994.

Public Act No. 297 of 2012, Michigan Legislature (Critical Dunes, revised). Approved by the Governor August 7, 2012. Lansing, MI: State of Michigan. Available at: http://www.legislature.mi.gov/.

Read, D. J. (1989). Mycorrhizas and nutrient cycling in sand dune ecosystems. *Proceedings of the Royal Society of Edinburgh, Section B: Biological Sciences* 96, 89-110.

Sand Dunes Protection and Management. (1994). Sand Dunes Protection and Management: Part 353 of the Natural Resources and Environmental Protection Act, PA 451 of 1994. Lansing, MI: State of Michigan. Available at: http://www.legislature.mi.gov/.

Surfrider Foundation. (2015). Coastal recreation studies. San Clemente, CA: Surfrider Foundation. Available at: http://www.surfrider.org/pages/coastal-recreation-studies.

United States Census Bureau. (2016). 2012-2016 American Community Survey 5-Year Estimates. Available at: https://www.census.gov/programs-surveys/acs/.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database. Available online at https://sdmdataaccess.sc.egov.usda.gov.

USDA Forest Service Visitor Use Report, FY 2012. Huron Manistee National Forest, Region 9 National Visitor Use Monitoring Program, United States Department of Agriculture, Forest Service.

USGS (United States Geological Survey). (2017). The National Map, 3DEP products and services: The National Map, 3D Elevation Program Web page at https://www.usgs.gov/3d-elevation-program

USGS (United States Geological Survey). (2017). Minerals Information: Silica - Statistics and Information. Available at: https://minerals.usgs.gov/minerals/pubs/commodity/silica/.

Zarnetske, P. L., Seabloom, E. W., & Hacker, S. D. (2010). Non-target effects of invasive species management: beachgrass, birds, and bulldozers in coastal dunes. *Ecosphere* 1(5): 1-20.