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Creating Connections through Predictive Modeling and Cultural Resources Research

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This paper synthesizes research via two internship collaborations, focusing on predictive modeling of archeological site practices in two regions of the National Park Service (NPS). Lindsey Cochran's two internships were sponsored by National Center for Preservation Technology and Training (NCPTT), Natchitoches (LA) in 2015, and the George Melendez Wright Young Leaders in Climate Change program (YLCC) in Washington, DC, in 2016. Specifically, this paper highlights the intersection of these two internships while detailing the multi-spatial, multi-temporal, and multi-cultural connections the authors made through these two predictive modeling projects for the NPS.

As archeologists, we use material records of the past to interpret human history and link it to the present day using known site locational data and environmental factors. These diverse lines of evidence converge through our analysis, allowing us to better understand the environmental and cultural constraints that conditioned past human lives. Federal properties require that the managers create and maintain an inventory of resources within site boundaries; cultural resources use the Archaeological Sites Management Information System (ASMIS). The authors' participation in both programs was predicated on the implication of legacy and ASMIS archeological data into computer-based predictive modeling systems to model archaeological site type, location, and surrounding environment.

Our first project models known sites and probable locations of multi-temporal archaeological sites. The project incorporates the entire 3.6 million acres of Death Valley National

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Park (DVNP) into an ecological niche modeling approach. The second project analyzes the impact of rising sea levels on archeological sites, both above and below ground, in five national parks on the eastern seaboard. Both projects involve spatial predictive modeling using GIS, previously collected data, and statistical analyses to model past human behavior, and will provide management recommendations to parks.

Archeological site monitoring at Death Valley National Park

The initial premise and objective of the DVNP project was to develop a series of models as proof of concept for the applicability of ecological niche modeling to archaeological research. Our goal was to create these maps as tools for more effectively managing cultural resources, and to assist NPS resource managers in identifying ways to protect, preserve, and educate the public about archeological resources within DVNP boundaries. Using a database of various time periods and potentially significant environmental variables, we "mapped" the statistical outcome of the combination of such datasets. Outcomes of these tests will assist in determining the future trajectory of both "real-life" and digital cultural resource management of sites in the park. Output models are then shared with NPS archeologists to ultimately integrate them with improved maps of geomorphological and environmental characteristics of the park.

Archeological research has established that humans settle within identifiable spatial relationships relative to their environment. If humans from any time period settle in patterns constrained by their environment, then it is possible to create relational models to determine where unidentified habitation settlements may be located (Ruiz et al. 2014). Cochran and Britt combined grid-based geographic information systems (GIS) with statistical modeling to create three products to address these goals: create a series of maps that show the relative probability of locating unidentified sites, assess the accuracy of the location of current cultural resources used to "train" the model; and generate raw statistical outputs that can be exported and used in statistical software (like "R") for further analysis.

To create these predictive models, influenced by statistical patterning, Cochran and Britt collected data from over 2,600 known sites, assembled GIS layers that included landscape characteristics and other environmental data, assimilated geomorphological data, and developed models using a maximum entropy-based niche modeling approach called MaxEnt (Elith et al. 2011; Peterson 2006). This technique combines GIS imagery files, such as digital elevation model (DEM) and LiDAR (remote sensing) data, site file and type data, and other environmental variables. A series of statistics, chosen by the user, are then integrated into the maximum entropy model to run the final output.

We first identified a set of landscape features most likely to impact human habitation. These included: elevation, slope, aspect, water availability in soils, depth to water, depth to restrictive sediment layer, soil texture, geology, distance from intermittent and perennial streams, distance to playas, distance to ponds, distance to springs, and distance to faults (Ruiz et al. 2014). Then, a series of site types, identified through the ASMIS database, were classified as being prehistoric or historic, and then the functional uses of the site were further defined based on information recorded within ASMIS. As for the model, the better the contrast, the better we can define the location of undiscovered sites. Workflow involves the integration of raw site locational data, environmental data, MaxEnt input, and the final output niche model product (Figure 1).

As with all statistics, no matter the breadth or complexity of the program, the results and model output are often solely contingent upon the quality of data input. We identified the primary sources of statistical bias from within the DVNP dataset through the output data in MaxEnt, and subsequently either eliminated the skewed data or used post-hoc statistical methods to analyze and subsequently minimize the impact of outlying data.

However, the archeological data present in the Death Valley database is biased in multiple and often unknown ways. Some sites are entered into the ASMIS database due to casual observations, others were part of specific undertakings, and for some sites the associated research design was not recorded or well defined. Some sites were recorded as early as the 1930s—these, of course, are not exactly up to geodata standards now. In addition, and for a variety of reasons, location data are not required in ASMIS. To bypass error inherent with inconsistent surveying techniques, we used a single northing/easting coordinate for each site location, rather than calculating the approximate area of each site. The tendency to collect site information differentially near roads or other easily accessible points also impacts the types of landscape features associated with sites in the model.

The ideal MaxEnt model will show spatial variation between high and low probability areas for habitation, but the variation between those places will be stark and easy-to-identify (Jaynes 1957). Eight models were run with a cumulative output (rather than a logistic re-

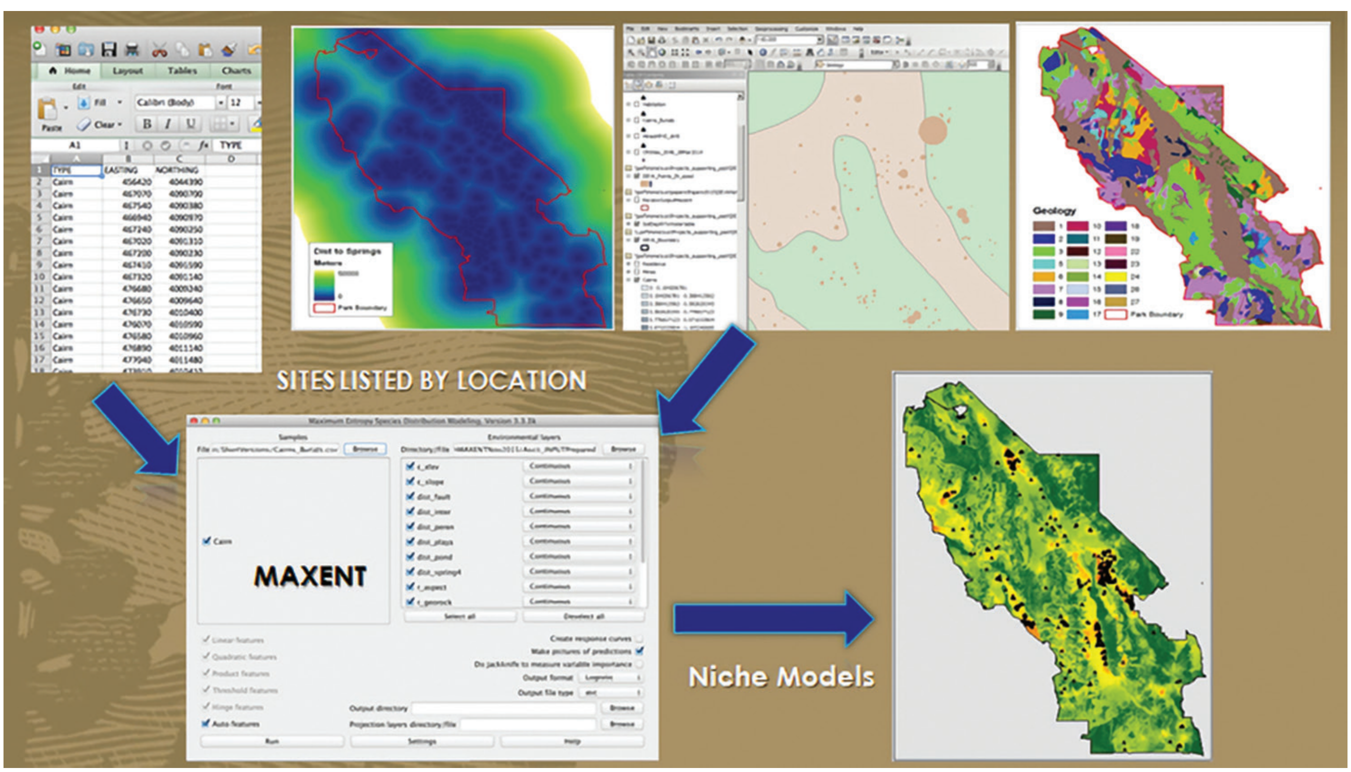

Figure 1. Modeling approach for DVNP.

gressive output) to emphasize variation between high and low probability areas after separating values for testing versus training of the model. Additionally, running the replicated MaxEnt string as a bootstrapped sample positively influenced the logistic regression variable measure of importance. Finally we used post-hoc jackknife testing to estimate the bias of each variable, essentially identifying the most and least influential environmental variables relative to the total inputs (Elith et al. 2011).

The interpretations of the models are preliminary, as they were developed as a starting point to facilitate NPS site identification and stewardship. The need to determine the reliability of the surveys and to develop a more nuanced metric for the site occurrence (or lack thereof) is an important area of future work (Ruiz et al. 2014). Current research seeks to identify at what scale this model no longer predicts site locations. In summary, Cochran and Britt find the ecological niche approach to development of cultural resource site models for DVNP was found to be informative, but not definitive. The results of these models can then be interpreted more completely, and used to develop maps that reflect management goals and plans, with the understanding that these models can be adjusted to focus on the changing priorities and requirements for sustainable site management.

Modeling effects of coastal climate change

The YLCC-sponsored internship focused on the potential to use existing archeological site data, as stored in the ASMIS for a new purpose: to understand the degree to which selected sites are vulnerable to the effects of climate change, such as increased erosion and sea level rise. ASMIS is a web-based application that allows users to access and enter data into NPS's official site inventory database, which stores basic site data as well as information on site condition, known threats and disturbances, site management efforts, and more. This system includes site location data, but as illustrated in the Death Valley project, their reliability and precision vary depending on the age of the record. While ASMIS has been in development for several decades, it incorporates some much older records, with observations dating, in a few cases, as far back as the nineteenth century.

NPS staff sought to understand the degree to which the data stored in ASMIS could be brought to bear on the problem of climate change adaptation for cultural resources, by isolating threats and disturbances for select coastal sites in five parks in the southeastern United States, and bringing those data into a GIS. Threatened coastal areas and the five sites used in this study included Cape Canaveral National Shoreline, Cumberland Island National Seashore, Timucuan Ecological & Historic Preserve, Cape Lookout National Shoreline, and Colonial National Park (Figure 2).

The primary goal of this project was to determine the applicability and accuracy of ASMIS data in addressing the impacts of climate change on archeological resources. If ASMIS data sources contain consistent information about the location, condition, and natural disturbances to sites within a national park, then it is possible to predict the effect of climate change on those cultural resources. A secondary goal of this project is to assess the quality and applicability of ASMIS data to understand short-term but accelerated climate change at archeological sites within national parks.

Cochran queried ASMIS to determine the degree to which records revealed that archeological sites were impacted by climate change, using criteria identified by Rockman and

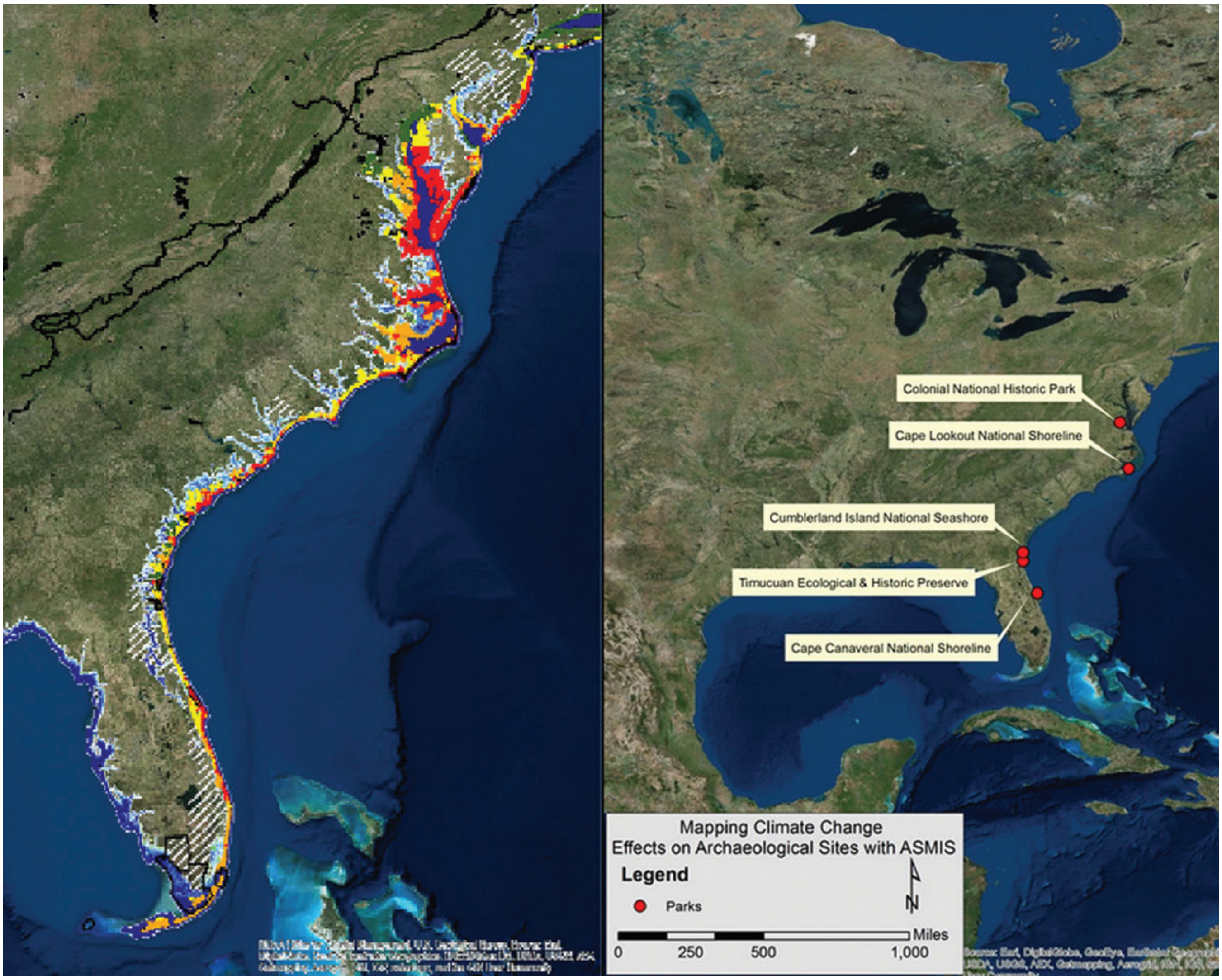

Figure 2. Threatened coastal areas displayed with data from NPS, USGS, and NOAA (left); national parks used in the YLCC study (right).

her colleagues (2016, 20–25). Cochran and Gadsby identified four variables, corresponding to ASMIS data fields, to represent impacts from climate change. These variables include condition of the archeological site, arch site disturbance levels, type of disturbance to the cultural resource, and effect of the disturbance type. Additional map and spatial projection layer sources include United States Geological Survey, Federal Emergency Management Agency, and National Oceanographic and Atmospheric Administration datasets that were corroborated with historical maps to assess the impact of storms dating back to the 1880s. Integrating these data sources, when possible, facilitates accurate estimates of the source and extent of damage to archeological sites from climate-change influenced processes.

In a 2015 assessment of impact of predicted sea level rise in coastal parks, Peek and her colleagues list most assets—such as roads and parking lots, buildings and structures, and historic and cultural resources—within the five national park units are listed as “high exposure" in a recent report (Peek et al. 2015), however, threat assessments listed in ASMIS do not often correspond with this determination. This is likely due to the extended time interval between site recordings, but may also be partially explained by data collector bias regarding what constitutes a threat to a buried archeological site. Decreasing the time interval between surveys, and requiring location information would greatly increase the uses of ASMIS in identifying the impact of climate change on cultural resources.

As an example, the following are summary results from Canaveral National Seashore (CNS). CNS, situated on Florida's Atlantic coast, approximately 100 miles southeast of Jacksonville, and 30 miles west of Orlando, contains 206 archeological sites, 119 of which are determined to have been recently impacted by climate change. Of the known impacts to sites at CNS, two are associated with climate change: erosion–water (n = 93), and erosion–general (n = 26; NPS 2015a). Of the impacted sites, 104 are in good condition, 14 are in fair condition, and 1 is in poor condition (NPS 2015). These results (Figure 3) are somewhat at odds with the 2015 Coastal Assets Report, in which all modern assets in Cape Canaveral National Seashore are listed as being immediately and severely threatened (Peek et al. 2015, 126–128).

What should have been a fairly straightforward mapping exercise was rendered difficult by several factors, including the absence of location data for many of the sites in one park, and the peculiarity of how threat and disturbance and other data are stored in the ASMIS system. Overall, however, the results of this preliminary study suggest that ASMIS data can be useful in managing threats to archeological sites, as predicted by climate change.

Our analysis shows that ASMIS can be part of the tool kit that the NPS uses to manage sites in the face of changing long-term conditions. The use of existing data provides a low-cost planning tool for parks, and illustrates examples of the types of physical changes that sites have undergone over the past several decades. Further, we hope that the results of this study will assist with mitigation or adaptation responses as sea levels continue to rise, and the effect of changing climate on coastal sites intensifies.

Although the research undertaken at NCPTT and NPS-WASO through the YLCC internship were spatially disconnected, they relied on park-wide datasets, and both projects came to similar conclusions about the inherent spatial biases in the datasets. Both projects recommend decreasing on-ground survey intervals at parks to improve monitoring of impacts of common detriments to archeological sites, like receding shorelines and increased strength and frequency of storms.

The DVNP Predictive Modeling Project connected unknown prehistoric and historic cultural resources through a maximum entropy niche-based modeling system using regression-based Bayesian statistics in a GIS framework. The output, however, is created to give park managers and researchers new information about the probable location of archeological sites, and can be used to protect and preserve both known and unknown buried resources. At its core, this project represents a symbiotic relationship between humanities-driven questions and science-based methods.

Shoreline assessments of the Eastern Seaboard employed a larger-scale focus than the DVNP project by temporally connecting known archeological sites to modern endan-

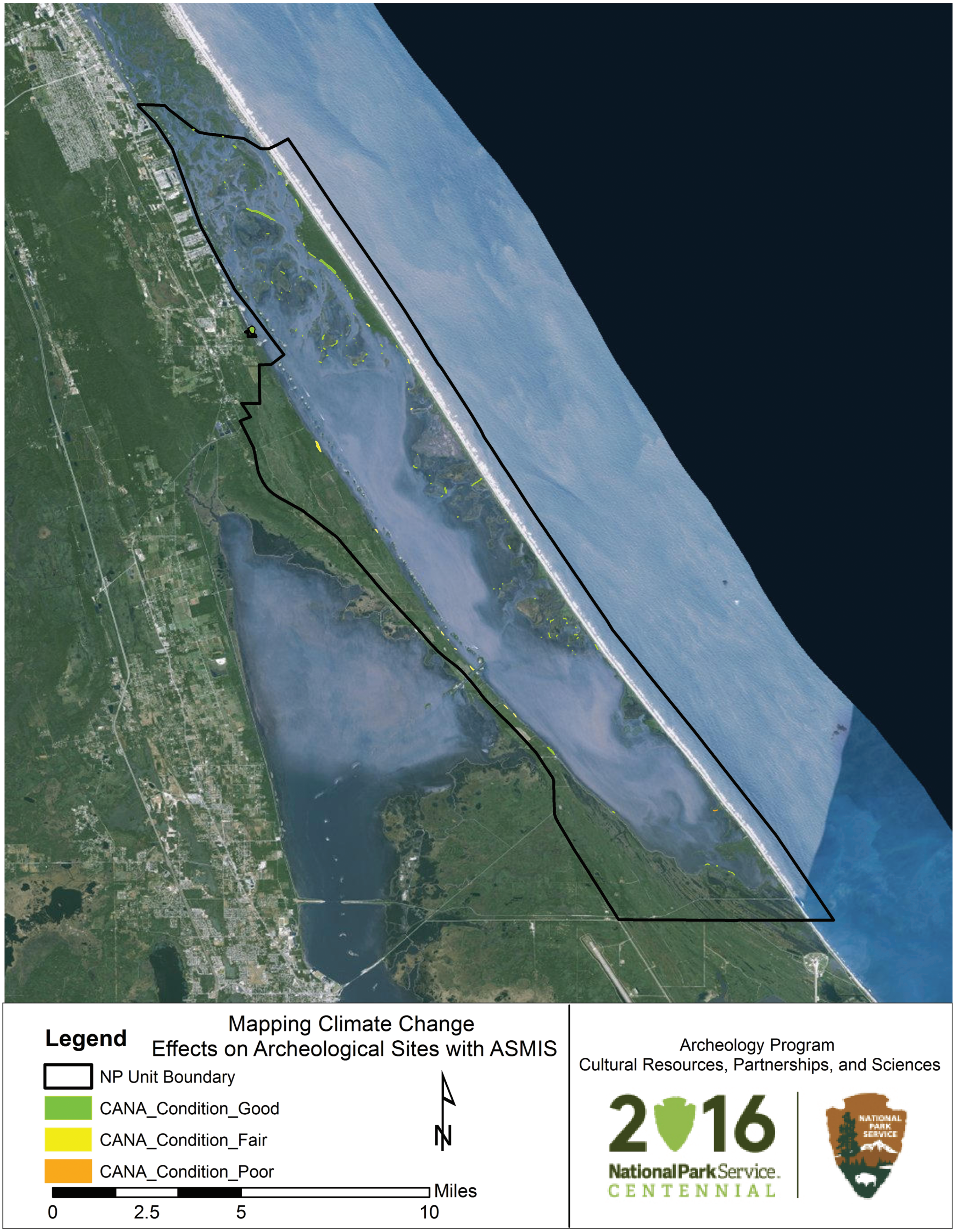

Figure 3. Canaveral National Seashore condition of impacted archeological sites.

germent and destruction. These models necessarily are built on multidisciplinary ideas, data, methods, and analytical techniques, encouraging increased communication and collaboration between many networks both internal and external to the NPS. These broad research trajectories created connections today that built on multidisciplinary data through federally funded research groups using previously collected multi-temporal and multi-spatial data to help managers understand broad scale mechanisms of past, modern, and future change.

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