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Examining Impacts of Climate Change on Cultural Resource Management in Pennsylvania

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Abstract

As damage from weather and climate events increase due to global climate change, preservation of archeological sites and material is increasingly threatened. This thesis seeks to examine if and how cultural resource management in Pennsylvania has adapted to threats posed by anthropogenic climate change. Through research into climate data and Cultural Resource Management plans, as well as conversations with professionals, I examine the primary climate threats in the state of Pennsylvania as well as if and how practices have changed to prevent them. The use of predictive models areas with high risk to have shown to prevent damage to sites before it occurs. As low risk area, such models have not been applied to Pennsylvania. Predictive models allow for preventative mitigation, and can be used to protect both natural and cultural resources, but require collaboration between natural and cultural resource agencies and databases in order to succeed. In general, a disconnect exists between cultural and natural resource agencies in Pennsylvania, creating a gap that needs to be addressed before predictive and preventative action can be fully affective in the state. Significant data exists that could be used to mitigate climate damage to natural and cultural resources, but such steps have not been taken to create long-term management plans.

Introduction

As climate change has become an increasingly undeniable presence in our modern world, archaeology has an increasingly valuable role in climate research. The long view of history that serves as the basis for archaeological research includes past interactions between humans and the environment in both stable and unstable periods. This field of study is essential, as it provides climate scientists with a backdrop of how societies have succeeded or failed in times of environmental distress. Sharing information about past climate events with a wide range of the public is also part of current discussions of archaeology and climate (Kaufman et al. 2018). In several cautionary examples of destructive human/environment interaction, Kaufman et al. (2018) argues that archaeologists have a civic responsibility to share relevant climate relationships with the public, as they have a unique perspective on human-environmental interactions in the past. This concept of a responsibility to educate the public is also a key tenant of the Society for American Archaeology's ethical standards (SAA 2018). A less prominent portion of the conversation between archaeologists and climate scientists is how archaeological resources themselves are affected by destructive climate events. Despite the importance of interdisciplinary research and public education, this particular discussion is of essential significance to archaeologists. Research sites exposed to unusually strong or damaging climate events lose their potential evidence, preventing any interdisciplinary discussions from taking place. As artifacts, features, and the context surrounding them are lost to floods, erosion, and other increasingly common events, any potential information is lost as well. Without clear, defined research about how climate change affects archaeology as a practice, other conversations about the benefit of archaeological research will eventually be futile. This conversation is ongoing, yet not comprehensive enough to fit the severity of potential loss.

Clear evidence exists within the state of Pennsylvania for growing threats induced by anthropogenic climate change. This spring, the Pennsylvania Department of Environmental Protection published a report in partnership with the Environment and Natural Resource Institute examining climate change on a state scale. Figures 1 and 2 show the projected temperature and precipitation increases in Pennsylvania and surrounding states between the years 2000 and 2041 (Shortle et al. 2015).

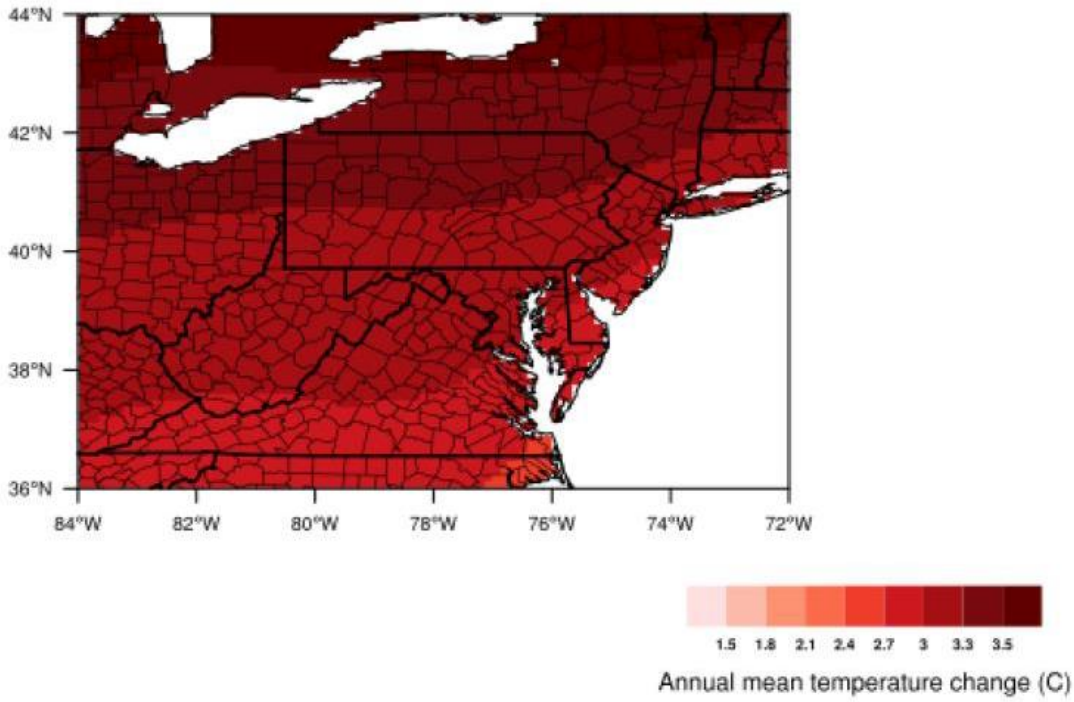

Fig. 1. Map and data from the Pennsylvania Department of Environmental Resources (Shortle et al. 2015). Colors correspond to the projected rise in temperature between the years 2000 and 2041, with darker colors representing larger increases.

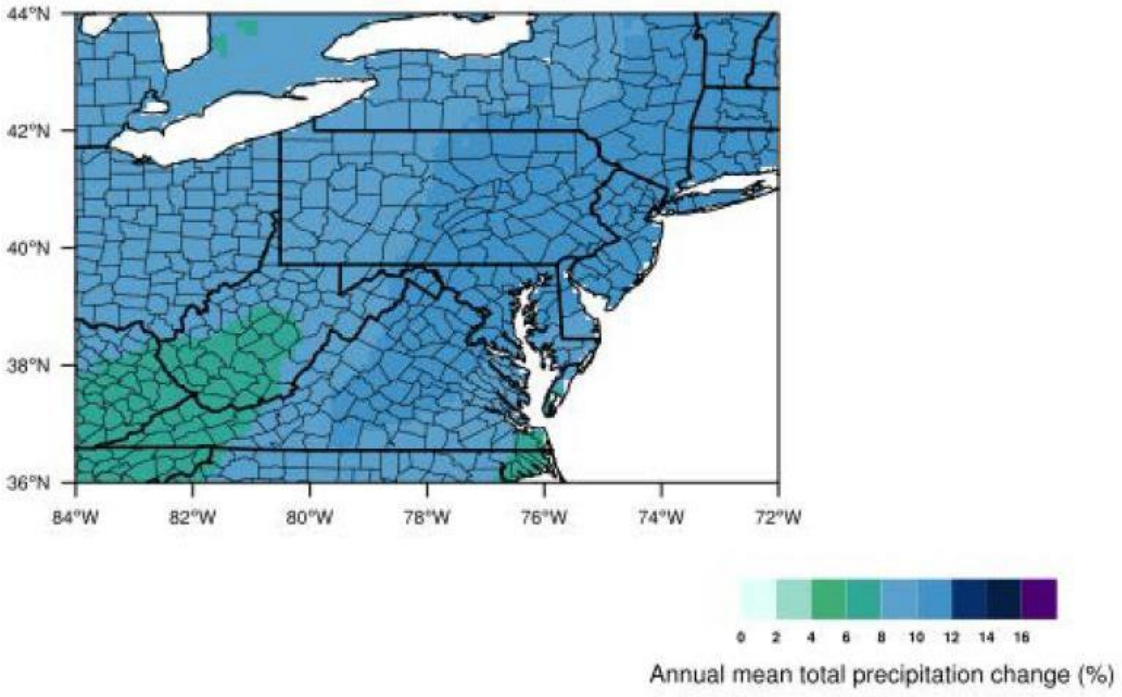

Fig. 2. Map and data from the Pennsylvania Department of Environmental Resources, (Shortle et al. 2015). Colors correspond to the projected increase in precipitation between the years 2000 and 2041, with darker colors representing larger increases.

Mean temperatures and precipitation are both shown to increase, exacerbating the current flood and melt issues seen in the region. This also increases potential damage to known and unknown archaeological sites.

This project seeks to understand how discussions of climate damage have affected Cultural Resource Management (CRM) in the United States. Generally, regions where threats of climate damages are highest have seen the most research, often in the form of predictive models that aim to identify where damage will occur before it does. The use of these models helps to focus conservation efforts on specific vulnerable regions (Heinlen et al. 2018). This thesis discusses these predictive models, and identifies the lack of inclusion of low risk regions in overall discussions of climate damage. My research focuses on Cultural Resource Management in Pennsylvania, as it is at a lower risk for climate threats yet still experiences damage, as well as

increasing temperatures and precipitation (Shortle et al, 2015). There are four main goals guiding this research. First, to understand how climate events are actively damaging cultural resources in the state of Pennsylvania. Cultural Resource Management in the United States in a large and complex topic, due to the diversity of archaeological sites, materials, ecosystems, and weather patterns in the country. Smaller examinations of how individual states have responded to climate are useful in order to understand this national scale. Second, identifying what portions of the state are at the highest risk of climate damage and what main threats are is essential to understanding how CRM professionals have responded. Both this first and second goal were accomplished through research of historical papers and public documents. Third, I seek to identify what specific action has been taken by the CRM professionals within the state of Pennsylvania to mitigate climate damage to archaeological sites and resources. Lastly, as cultural resources are inextricable connected to natural resource management, understanding the relationship of natural and cultural resource professionals in Pennsylvania is key to answering questions of how methods have adapted to climate change. These latter two goals were accomplished mainly through interviews and discussions with CRM professionals in the state and supplemental research.

General information regarding climate change and archaeology in the state is divided along the lines of natural versus cultural resource management. For the context of this paper, the term cultural resources refers to historic and archaeological material, while natural resources refers to naturally occurring landforms, ecology, and waterways. Despite different definitions, these two groups are inextricable connected. Issues of erosion exacerbated by a long history of industrialization and logging is the most prominent example in Pennsylvania – eroding shorelines of lake and rivers damage the natural banks and any cultural material at the same time.

Despite the fact that Pennsylvania is less impacted than other areas of the country, such as coastal states, it is clear that a full examination of the state would provide valuable additions to the conversations revolving around climate change and cultural resource management. Through my research, I found that both natural resource management plans and cultural resource professionals in Pennsylvania are aware and worried of the threat posed by climate change. Despite this, little long-term planning has been done to try and prevent damage before it happens. It is abundantly clear that the effect of climate change on archaeological resources in low risk regions is understood as a threat, but regular management has not changed to reflect this knowledge.

Primary Responses to Climate Threats

One of the main roles of CRM involves the identification, evaluation, and mitigation of threats to historic and pre-historic sites in the United States (Heinlen 2018). In the past, industrialization and urban development have been the major forces threatening archaeological sites (Hudson et al, 2012). While these threats, along with looting, have the potential to be devastating to archaeological resources, there are established methods and laws for CRM within the United States that mitigate them. These issues are still present, but anthropogenic climate threats have become increasingly problematic to CRM practices, as cultural heritage sites experience devastating impacts from increasingly violent storms, droughts, sea level rise, ice melt, and coastal erosion. Climate change is different from previous threats to the archaeological record in both the scale of potential damage and the speed at which it is changing. Unlike looting, development, or decay, it is not selective to any particular environment or region, nor to the size or significance of a site. There are no established guidelines for the best ways to handle

instances of climate damage, as each site will face a different set of threats defined by environmental variables. A main critique of general solutions posed to this threat is that it is impossible to create any single overarching model for the United States, due to the diversity of ecological zones and archaeological sites themselves (Roscoe 2014). In recent literature, archaeologists have developed methods of predictive modeling in an attempt to understand the scope of the challenges posed by climate change at a broad scale (Anderson et al. 2017; Heinlen et al. 2018; Lee 2012; Reeder-Meyers 2015; Reeder-Meyers and McCoy 2019). These predictive methods draw from public data to create models of study areas. Although the general application is the same, the use of unique data from each site creates a model that is specific to the region in question.

Predictive Models in CRM

Similar to archaeology itself, predictive methodologies are primarily interdisciplinary, and can be constructed in a multitude of ways, each of which examines specific questions that incorporate the material record, human society, and the environment. Prediction models occur throughout climate science, typically divided into physical versus human categories that separately examine the effects of a given variable on human resources and on environmental resources (Roscoe 2014). Combined, these are meant to predict the impacts of climate change on the biological world and human society. Archaeologists use prediction models to estimate the potential location of unknow sites by combining data on resource availability, terrain, and known sites (Heinlen et al. 2018). These models characterize aspects of past human behavior most commonly seen in sites of a given ecological zone and combine the data with the most probable location of past human behavior, reducing the amount of labor required to identify sites. This

method can predict both surface and subsurface sites, and can be used over any area of similar cultural history or physiography (Heinlen et al. 2018). Roscoe (2014) suggests that the combination climate and human behavior models can benefit both archaeologists and environmental scientists. Combinations of this type have been used to predict the potential damage to cultural resources in a given area (Reeder-Meyers 2015.)

Many of these models rely on LiDAR (Light Detection and Ranging) mapping, a high cost/high reward method of surveying large areas with varying levels of accessibility. The most difficult regions to physically survey, such as dense forests, are often neglected by both avocational and professional archaeological surveys, thus creating gaps in databases that include these regions (Bristow and Therien 2015). Despite financial concerns, LiDAR is the only technology available that can fill this gap, as it provides detailed imagery of remote and densely wooded areas that cannot be easily accessed otherwise (Johnson and Ouimet 2014). Once collected, LiDAR data can be made available to a wide range of researchers and public audiences, and has be used to create valuable data collections such as the Digital Index of North American Archaeology (DINAA). This technology has incredible potential, as it allows archaeologists to gain a basic understanding of a site before it is even visited, and has been increasingly accessible as more LiDAR surveys are conducted. In person surveys and sampling of regions for archaeological potential takes time, energy, and money that is often in short supply. The majority of predictive models rely on collections such as DINAA to combine contemporary climate data and information on past human land use (Heinlen et al. 2018). By modeling the potential for human activity in a landscape, archaeologists can streamline the process of locating sites, which facilitates preservation. Predictive methodologies take advantage of digital technologies to both preserve the physical remains of the archaeological record as well

as cataloguing information for future use. Using vulnerability models, archaeologists can also attempt to understand how climate events and trends may affect sites and research practices.

Threats and Regions Identified by Predictive Methods

Currently, the development of combination archaeology and climate models is a response to extreme weather events such as Hurricane Harvey in 2017 (Heinlen 2018). These models aim to determine the threat level of individual sites within a given region, as well as categorize sites by potential value to determine which should be prioritized. Value measures are determined by economic, social, cultural, and educational factors, while threats are determined by the specific location of the study (Heinlen 2018). For the purpose of an initial review, this project considers wildland fire, snow and ice melt, and coastal erosion as the three primary threats to cultural resources that have been recently exacerbated by climate change. High-risk regions are those where these threats are the most prominent; for example, the southeastern seacoast is a high-risk region for flooding and erosion because the low-lying areas around the coast are easily inundated, either temporarily or permanently. Colorado and Alaska are high-risk regions for melt due to the density of artifacts preserved by glaciers and ice patches (Reckin 2017). The highest risk region of the United States for wildland fire is California by a large margin, due to the high density of fire susceptible species, history of fire suppression, and general arid climate (Thompson et al. 2011). After California, the southern region of the United States is the most at risk, due to both unattainable areas and high densities of structures (Thompson et al. 2011). The south as defined by Thompson et al. 2011 begins at the east coast, and stretches to mid Texas and the northernmost border of Virginia. Predictive models exist for all three of these threats, some

developed specifically to examine the relationship between archaeology and environmental damage and other focused on general risk management.

Coastal Erosion

Anthropogenic climate change has caused an unprecedented rate of coastal erosion in the past decade, with a similar if not more aggressive trend of further damage predicted for the future. Sandra Fatorić and Erin Seekamp (2017, 2018) have published a series of articles addressing the effects of coastal erosion on historic buildings in the Southeastern coast of the United States. Generally, they focus on the construction of new analytical frameworks as a form of predictive methodology rather than vulnerability models. Fatorić and Seekamp (2018) use "historical significance" and "use potentials" as value measures for historic coastal buildings, and reference the National Registrar of Historic Places as an existing method of categorizing sites. They stress the necessity for an interdisciplinary approach within analytical frameworks, and emphasize "transparency" as a key feature (Fatoric and Seekamp 2017, 2018). At a broader scale, Anderson et al. (2017) utilizes DINAA to create a quantitative analytical method for determining threats to coastal sites in the Southeastern United States.

Reeder-Meyers (2015) proposes a model designed to address coastal site vulnerability in the most efficient way possible. The prime variable used in the example are site position (distance from shoreline and elevation), degree of vulnerability of nearest seashore, and modern land use at the site. Recent increases in coastal climate events have created scenarios that test the validity of existing vulnerability models and analytical frameworks. Four years after the initial publication of their model, Reeder-Meyers and McCoy (2019) reference the first author's earlier work as well as the model proposed by Anderson (2017) to examine aftermath of Hurricane

Harvey, aiming to determine the accuracy of predictions for coastal regions of Texas and Louisiana. One of the key driving forces behind this work is the acknowledgement that in the past 10 years, major hurricanes (categories 3-5) have become regular occurrences in the United States, when previously they were one of the rarest weather events. Using the Reeder-Myers (2015) model, it was predicted that 95 of the 259 coastal archaeological sites (about 36 percent) in the study area would be severely affected by sea-level rise. Reeder-Myers and McCoy (2019) critique the 2015 model, as it is based only on gradual coastal change and does not consider events at the level of Hurricane Harvey.

Fire

While fires in California have been dominating the news cycle for the past several years, droughts brought on by anthropogenic climate change invoke the threat of fire in every region of the United States. The Bugaboo Fire of 2007 occurred in southern Georgia, as well as areas of southern Alabama and northern Florida, and was devastating to forests, residential communities, and archaeological sites (Timmons et al. 2012). Along with climate change, suppression of forest fires throughout the twentieth century caused the buildup of flammable underbrush, increasing the heat, intensity, and durations of wildfires that occur in fire suppressed areas. The US Forest Service and NPS are currently working to undo the damage done by a century of fire suppression, and in the past few decades have come to realize the benefit fire has on maintaining ecosystems throughout the United States. Additionally, researchers throughout the country have been analyzing indigenous land management practices, including prescribed burns, through environmental and landscape archaeology. When exacerbated, fires are dangerous and destructive to both human and "natural" environments. Despite this, they are essential

components of many ecosystems, and have historically been managed by human societies in sustainable and effective ways. The relationship of archaeological sites to fire shares a similar dichotomy. Fire is undoubtably destructive. It destroys any organic material remaining at or near a surface level, posing a large problem in arid areas where wood and cloth artifacts may preserve. In forested regions, stumps cause burns to affect subsurface material more than a meter down (Oster et al. 2012). Post-colonial era structures, most commonly made of or incorporating wooden building materials, are at the highest risk. At high enough intensities, fire causes stone structures to crack, dismantling the stability of archaeologic features.

Predictive modeling exists within fire management, used to estimate the intensity and heat of a burn in a given area, as well as to estimate potential damage to known archaeological sites (Ryan and Koerner 2012). Cultural resource management in the FS and NPS work closely with fire crews to mitigate fire damages to archaeological sites. Researchers use prescribed burns to determine the effectiveness of various predictive models as well as fire treatments. Treatments include removal of duff, dead and down, and strategically cutting of trees to drive fires away from sensitive cultural sites and to mitigate damage at sites that do experience burning (Ryan and Koerner 2012). Following these experiments, archaeologists accompany survey crews to determine the amount of damage on known sites and to record any previously unknown sits newly exposed by fire (Flanigan et al. 2018). The level of preservation at burned sites and new sites are both included in datasets for the creation of future predictive models. These models are improved upon after each prescribed burn, yet unscheduled wildfires still cause unpredictable damage to regions that have not yet been the site of fire treatments.

Snow and Ice Melt

Stable, perennial ice patches such as those found within the Greater Yellowstone Ecosystem (GYE), area threated by rising global temperatures, in term threatening the inorganic and organic artifacts preserved within them. Arctic archaeology has greatly benefited from these ice patches for decades as they allow researchers to examine organic material that would otherwise be lost entirely. Although there is still little understanding of the stability of ice patches and little ability to predict precisely how climate change will affect them, it is clear that this resource is not one that can be relied on to preserve organic material for much longer. As a result of this, both federally and privately funded archaeology has increased in glacial regions. The increased speed of research has been the primary reaction to inevitable ice melt, but models have begun to appear in this field of archaeology as well. Research into the stability and resilience of ice patches is conducted stretching back to the early Holocene to establish how long the patches have been stable and what degree of warming would cause the dense, inner cores of ice to melt (Lee 2012: Reckin 2017). This research is used as a basis for archaeological study, as these dense inner cores are most likely to contain organic artifacts (Reckin 2017.)

Vulnerability models are prevalent for glaciers and ice patches, as ice melt is a highly recognized issues of global climate change. Rogers et al. (2014) used geomorphology and archaeological site location analysis to create GlaciArch, a database of information about the relationship between archaeology and ice melt in the Pennine Alps along the Swiss/Italian border. The resulting model predicts archaeological potential of areas along glacial margins, breaking down a large, inaccessible region into manageable zones of archaeological interest. This trend is seen in the previous three examples as well – all prediction models seek to reduce large tracks of land, often in remote regions, into quantifiable regions for study. Although Rogers et al. (2014) created a database specifically for use in Europe, the work is referenced by authors

in the United States looking to create a similar system for glacial and ice patch regions in Alaska and the GYE. As ice melt has been a recognized and indisputable effect of climate change for several decades, these models include the understanding that it is not possible to prevent future damages. Snow and ice create a stable environment that has yielded organic artifacts as old as 10,000BP in the GYE, yet once ice has revealed objects, they are subject to rapid decay from the destabilized environment (Lee 2012).

Gaps in Predictive Methodology

In the re-examination of coastal flooding after Harvey, Reeder-Meyers and McCoy (2019) found that distance from the shoreline or any other body of water did not affect the likelihood of flooding. Both Anderson (2017) and Reeder-Meyers (2015) use distance from water as a primary variable in predicting damage, yet in the case of an extreme event this analysis is no longer applicable. In total, Reeder-Meyers and McCoy (2019) included 2,336 sites in their study area, 920 of which were severely flooded after Hurricane Harvey, about 39 percent While this number is similar to the original number predicted by the 2015 model, it included sites greater than 5km from the coastline, which the initial model does not. In total, Reeder-Meyers (2015) failed to predict that 586 of the total 920 damaged sites would have been flooded. The model proposed by Anderson (2017) relied heavily on elevation as the major variable, and while this was generally more reliable than distance, the prediction still failed to identify 535 sites as vulnerably in the event of a large storm such as Harvey (Reeder-Meyers and McCoy 2019). This information shows two faults of predictive methodologies: first that they do not account well enough for major weather events that have become increasingly common, and second that they cannot be tested until after damage has been done. Regions that were considered

safe prior to the increase of storm severity were completely inundated by Hurricane Harvey, resulting in the destruction of numerous unprotected archaeological resources (Reeder-Meyers and McCoy 2019). These models predict researcher ability to prevent damage, but do nothing practical to meet this goal. Reeder-Meyers and McCoy (2019) emphasize strongly that creating models of mega storms is incredibly difficult, but also incredibly necessary for the field of archaeology. This trend of developing models and methods after disaster events is detrimental for both archaeological and natural resources. There is also little research into how storm surge on major rivers affects nearby archaeological resources. As early settlements in the US as well as prehistoric indigenous peoples relied on rivers as sources of water and nutrients, the majority of archaeological sites in the state are concentrated around rivers, with high risks of damage from floods. The repetition of extreme weather events in the past decade has forced archaeologists as well as climate scientists to rewrite their models, as it has become increasingly clear that events such as Hurricane Harvey are now the rule and no longer the exception. This understanding of climate damage inevitability has yet to be put into practice, and must be included in any further models attempting to predict coastline vulnerability and damage.

Models that predict the damage of wildfire rely on the physical survey of land, as the largest contributing factors in severe burns are the type and density of dry vegetation (Thompson et al. 2011). Land surveys for fire management are done only on threatened areas, uncovering threated archaeological resources by accident, and leaving the vast majority of sites unprotected (Flanigan et al. 2018). In low-risk regions, there is even less overlap between surveys of fire potential and cultural resource potential. The US Forest Service classifies known archaeological sites after data taken is taken from prescribed burns, and cannot be applied to uncontrolled wildland fire. As previously mentioned, Timmons et al. reference the Bugaboo Fire of 2007,

which burned over 600,000 acres of National Forest and Wildlife Refuge in Florida and Georgia. Along with ecological and habitat destruction, tractor-plow firelines damaged hundreds of known and unknown cultural sites (Timmons et al. 2012). Surveys following the fire revealed over 100 unknown archaeological sites, both damaged and undamaged, which have since been identified and recorded. Even though this was a relatively high-risk area and monitored for wildland fire, an uncontrolled severe burn damaged hundreds of cultural resource sites. Prescribed burns are rarely performed in low-risk regions, thus increasing the risk in these areas for destruction of resources when wildfires do occur. While the Forest Service (FS) recognizes the inevitability of fire in rural landscapes, there has not yet been methodology developed to fully include cultural resource damage in this conversation.

Climate change induced events such as the Bugaboo Fire have become even more common in the following decade, and the IPCC indicates occurrences and intensities of fire will continue to increase (IPCC 2018). Timmons et al. (2012) recommends the inclusion of a cultural resource expert on every fire management crew in order to identify damaged sites and help in the protection of undamaged resources. NPS and FS lands need to use fire to maintain iconic anthropogenic landscapes, as well as to protect encroaching development for high intensity, high heat fires. In the midst of this, resources focused on protected cultural resources from prescribed and wild burns are slim. Examples in high fire prone areas such as the American southwest have shown highly successful results integrating fire and CRM crews in the same method suggested by Timmons et al. (2012), yet these techniques have not been applied to other areas public lands in the United States.

CRM and Climate Change Mitigation in Pennsylvania

Pennsylvania represents a low risk region of the United States that currently experiences damage to archaeological sites from climate events. As a landlocked state, it is not directly affected by sea level rise. There are no high-altitude regions of the state with glacial or ice patch archaeological sites. Relative high humidity and low temperatures when compared to the west coast diminishes the risk of uncontrolled burns (Thompson et al. 2011). Although climate events have affected the state, Pennsylvania has not experienced damage at the same level as high risk regions, and thus research into vulnerability models for the area have not been conducted. Despite this, the state still in a vulnerable position when it comes to the three threats previously discussed. Roscoe (2012) discusses the tendency of predictive methods to result in vague predictions with a large margin of error. Without specific data for a given area, models fall back on highly general assumptions that are not useful in identifying sites or risks.

Added to the inability of models to adjust for increasingly severe storms and unpredictable burns, this gap represents a serious issue for CRM professionals attempting to protect resources in low risk regions such as Pennsylvania. Areas that are not considered high risk are rarely included in vulnerability models, as there are no precedents of severe damage to imitate research into future damage. Although predictive modeling has been overall beneficial, these significant gaps affect current understandings of the relationship between archaeological resources and climate damage. The tendency to begin modeling only after an event has occurred also contributes to a lack of work in low risk regions, as they are less likely to have experienced extremely damaging events in the past. Cultural heritage across the country will be affected by anthropogenic induced climate change, and a lack of focus on low-risk regions will result in neglect and eventually loss. High-risk regions have been the center of conversations involving climate change due to the transparency and history of extreme threats, but they are far from the

only regions at risk. Research into areas such as Pennsylvania is essential for preserving cultural resources before they are severely threatened and damaged by climate events.

Methods

My research focuses specifically on examples of Cultural Resource Management within public lands of Pennsylvania. A significant portion of the research was document based, focusing on the examination of public legislation pertaining to archaeology and climate change in the state as well as contemporary management plans. Initially, I planned to personally interview a wide range of CRM professionals employed by the state in order to understand current issues in archaeology that were not published in documents. The closure of public and private institutions in the spring of 2020, including Dickinson College, due to COVID-19 significantly delayed this project and altered the way interviews were conducted. I spoke with five professionals within the state through emailed conversations and Zoom meetings. These conversations focused on three specific regions in Pennsylvania; the Lake Erie shoreline, north and western forests, and the south-central valley region (figure 3).

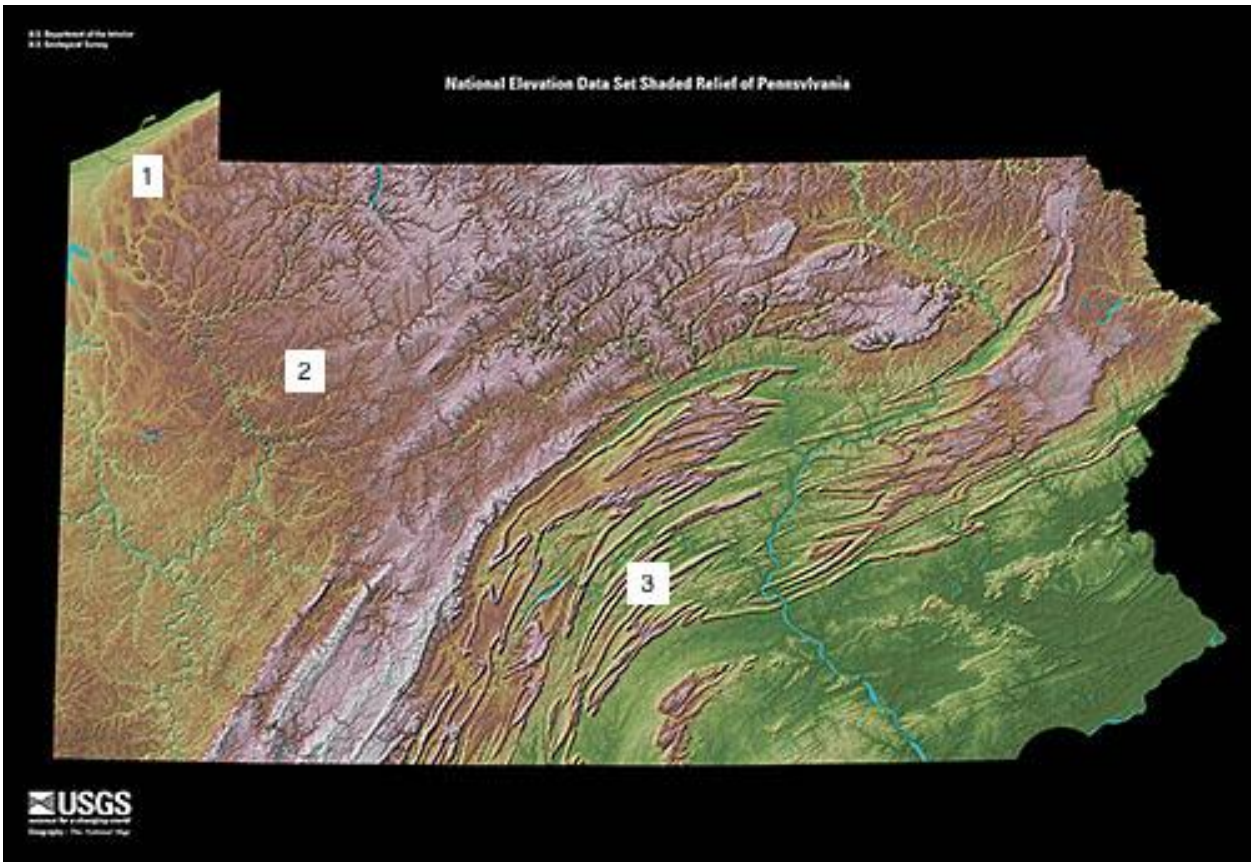

Fig. 3. A map of the state of Pennsylvania, showing basic topography and rivers, as well as the regions primarily discussed in this paper: Lake Erie shoreline (1), northwestern forested region (2) and the south-central valley region (3). Base map from United States Geological Survey.

A greater focus was placed on the least densely populated areas of the state, which contain more public lands. These were also the areas with which my correspondents were the most familiar. Initially, I reached out to several individuals working within CRM in Pennsylvania with a short description of my project, and four questions, presented below.

- What are the major threats to cultural resources in Pennsylvania? Are they climate based? Do they differ significantly from major threats identified in literature on climate and archaeology?
- What archaeological and/or heritage sites in Pennsylvania are determined to be at the highest risk? What factors create this determination? What, if any, special protections are given towards these sites?
- What are the current projects being undertaken by public cultural resource management agencies in Pennsylvania (DCNR, PATC, Heritage PA, etc.…)? How are they being informed by climate science? What projects are being prioritized? Why factors have caused prioritized projects to be singled out?

- National Historic Preservation Act (amended 1992) and Pennsylvania State Historic Codes were developed prior to contemporary understandings of the severity of climate change. How do laws such as these restrict what sites can be analyzed and/or protected? Do these laws help in adjusting conservation and management practices?

From these four initial points, each correspondent elaborated with information within their area of expertise. Initially, I intended to speak with at least one member of each key organization that is responsible for cultural heritage resources in Pennsylvania. I was unable to speak with a current employee of the Department of Conversation and Natural Resources, although one respondent was a former consultant. Three respondents were current or former employees of the Pennsylvania Department of Transportation (PennDOT), one a current professor of historic archaeology and CRM in Pennsylvania, and one a current employee of the State Historic Preservation Office (SHPO).

Results

Land and Cultural Resource Management in Pennsylvania

Two agencies handle the majority of public land in Pennsylvania, the Department of Conservation and Natural Resources (DCNR) and PennDOT. Although neither are specifically focused on archaeology, maintenance of this public land includes the preservation and protection of cultural and heritage resources on that land. The Pennsylvania Historical and Museum Commission (PHMC) is the main agency responsible for the collection and maintenance of state heritage resources. The State Historic Preservation Office (SHPO) is a component of PHMC the protects cultural sites, and works closely with PennDOT on sites identified through regular survey. Archaeologists within these divisions both manage resources and educate the public about resource protection and history through outreach programs and museums. In publications,

PHMC recognized that archaeology is an essential yet underfunded aspect of the agency, and mentions climate threats as a key concern for archaeological resources (PHMC 2018). It is clear from both through both publications and conversations with informants that climate threats to cultural resources are managed as they occur. There is no overarching legislation or planning for climate-based conservation issues, despite the acknowledgement of the threat.

PennDOT records and protects sites in accordance with Section 106 of the National Historic Preservation Act (NHPA). This law requires that prior to any construction or development project receiving federal funds, "the effect of the undertaking on any district, site, building, structure, or object that is included in or eligible for inclusion in the National Register," must be officially reviewed (NHPA 106, 1966). As this applies to all transportation project, Cultural Resource Management is a key program within PennDOT, equal to the other main branches of the agency including road construction and bridge conservation. The CRM programs within PennDOT includes management of historic structure as well as archaeological sites, and works to protect sites of the best of their ability while also maintaining transportation systems throughout the state. In most cases, this involves surveying land for potential cultural significance before development, and sometimes conducting short term excavation projects. In most cases of excavation, artifacts and features are thoroughly recorded before the site is refilled and a project is developed. Rarely, sites qualify to be included for the National Registrar of Historic Places, in which case the project will be halted or revised to avoid the site entirely. Cultural resource professionals at PennDOT work explicitly with environmental resource managers, but the primary goal of the department is to improve transportation and development in the state, preserving cultural heritage and archaeology within the guidelines of the State

Historic Preservation Office (SHPO) and the National Historic Preservation Act, specifically Section 106.

The DCNR maintains, manages, and protects state parks and forest lands within PA, ultimately responsible for over 2 million acres of land (DCNR 2020). Within the organization, separate bureaus manage state parks, forestry, recreation and conservation, geological survey, and facilities and design. Numerous archaeological and cultural resources fall under several of these categories, yet very few of these resources are specifically addressed by the DCNR. Historic structures such as the Ironmaster's Mansion in Pine Grove Furnace State Park or the various iron furnaces throughout state fall under recreation and conservation, as they are popular attractions for visitors interested in history. At the Camp Michaux site in Michaux State Forest, trees planted in the 1930s by the Civilian Conservation Corps technically fall under forestry, but are still an important example of the cultural heritage of the region. The Bureau for Geological Survey handles the creation of databases and maps, an essential resource for archeologists regarding both known and unknown sites. In addition, metarhyolite quarries used by indigenous communities in Pennsylvania long before contact also fall under geological survey, even though they have been a point of archaeological interest for over a hundred years (Sargent et al. 2016). This diversity of resources in the south-central region is echoed throughout the state. Despite this, DCNR does not contain a division or staff dedicated to archaeological research and protection. Instead, a heritage areas program called Heritage PA maintains historic sites and shares information with the public. Management regarding the preservation of natural resources and cultural resources almost always completely separate. Climate threats that effect natural resources are the same that effect cultural ones, yet conservation plans such as the DCNR's Climate Change Adaption and Mitigation Plan (2018) and the 2015 document of "Planning for

the Future" of climate change do not contain a single reference to cultural resources. Heritage PA's most recent plan for heritage management spanned from 2015-2020, and does not mention climate change once.

General Responses

In initial correspondence with the five professionals involved in my study, the overwhelming response was that Cultural Resource Management in Pennsylvania desperately needs to address the realities of climate threats. Joe Baker, an archaeologist retired from PHMC, PennDOT, and the DCNR, strongly emphasized that all three institutions need to increase research. All five of the responses indicated that increased research into specific climate effects on Pennsylvania's cultural resources was necessary for future preservation. All five also identified erosion as the state's most pressing issue. Dr. Benjamin Ford, a professor at Indiana University of Pennsylvania, spoke specifically of shoreline erosion in the Lake Erie region. Two of the PennDOT correspondents also focused on the western half of the state, emphasizing the historic deforestation behind current soil loss.

All five also identified this facet of climate change in Pennsylvania that I had not previously considered – the direct connection between the state and the history of the fossil fuel industry that is currently causing the majority of anthropogenic climate change. Pennsylvania saw tremendous growth in the Industrial Revolution of the 19th century, largely due to new lumber, coal, and oil industries (Black 1999). Both past and current land uses have considerable effects on cultural resources, and in the case of Pennsylvania many of the cultural and historic resources threatened were once the source of land damage.

As a response to questions about current legislation changes or management plans that would aid in protecting archaeological sites, the general consensus among my respondents was the action is not taken unless it is explicitly needed. One PennDOT archaeologist referenced the gaps of federal and state historic codes. Despite limited resources and funding, the state still appropriately surveys all development projects that require review under Section 106, thus protecting anything of significance encountered. Private developers, including contemporary oil and gas companies, only require state issued permits, which are subject to a less thorough review.

Discussion

Erosion and Ice Melt

Of the three examples discussed earlier, erosion was the most prevalent within the state of Pennsylvania, and will be focused on the most in the discussion below. In the context of Pennsylvania, ice melt directly effects erosion, especially in the Lake Erie region and along major riverways such as the Delaware and Susquehanna. Shoreline erosion has been steadily increasing, despite the efforts of state and federal conservation agencies to add sand to the shore and reduce the problem (Comoss 2002). Warming contributes to this erosion through the melting of ice and snow, which increases the water table of the lake. Shorelines continuously buffeted by increasingly larger ways wear down, and any archaeological resources along the shore are removed for their contexts and washed away. Dr. Ford emphasized the issue of shoreline erosion, especially when in the context to underwater sites. The stable environment several meters under the water's surface protects artifacts and sites, yet waves reducing the shoreline wash artifacts out of the original context.

The archaeologists who informed this study focused specifically on forests across the state that were clear cut in order to facilitate the growing lumbar and iron industries in the 19th century. Although reforestation efforts have been ongoing, there are still few old growth forests in the state. Angela Jaillet-Wentling, a current archaeologist at PennDOT, specifically referenced the steeper valley topography of southwestern Pennsylvania as a major source of erosion, as there is little to no dense vegetation on the banks. Given that precipitation in the state increased by an average of 10 percent between 2015 and 2020, this issue of shoreline and valley erosion will increase (Shortle et al. 2020). Erosion of alluvial deposits that effects archaeology both removes artifacts from their original location and buries sites completely. In both cases, context for the sites and artifacts is lost. As storms are exacerbated by climate change, this issue will inevitably get worse.

Another significant feature of Pennsylvania's landscape are major riverways. Heavy management of these rivers, including dam construction and occasional dredging, has decreased the erosion of banks, in many ways preventing riverside sites from being washed away. As these dams are controlled by the US Army Corps of Engineers, the archaeological sites in the area are monitored more regularly than in other rural areas of the state. Smaller rivers that are not controlled by dams receive considerably less monitoring for cultural resources, although many are actively monitored by natural resource protection professionals (DCNR 2018). These smaller rivers have potential to erode their banks and damage archaeological resources, as they are subject to less investigation than the larger, controlled riverbanks. Figure 4 is taken from the 2018 Climate Change Adaption and Mitigation Plan published by the DCNR, and demonstrates the level of severe flooding that occurs after heavy rains.

Fig. 4. Image of Swatara Creek by DCNR 2018.

The state park pictured above falls under the jurisdiction of the DCNR, and is located north of Harrisburg in the central area of the state. Flooding at this scale has the potential to strip topsoil and deposit sediment in new areas. In personal communication, Joe Baker spoke specifically to this issue – that sites can be both relocated and buried in the same flooding event, causing immense damage to resources and preventing further research.

Fire

The individuals I spoke with did not comment of the potential for fire to harm archaeological resources in Pennsylvania. Currently, the risk of fire in most areas of the state is low but persistent (Thompson et al. 2011). The majority of fires in Pennsylvania are started by people, either burning debris or campfires (DCNR 2018). Limited research into the effect of fire on archaeological sites means there is no precedent for if burns do effect cultural resources. A large percentage of designated protected sites and landmarks are historic structures, which are

the most susceptible to fire damage. Fire management is an important aspect of DCNR, as it does pose significant risk to natural resources when uncontrolled, but seems to be poorly incorporated into discussion of cultural resources (Thompson et al. 2011). Despite the relatively low potential for dangerous burns, this lack of integration creates unnecessary risk, as if a fire did occur there would be little or no communication between agencies of the state trying to protect natural and cultural resources. As temperatures increase across the United States, the threat of fire in Pennsylvania will increase as well, and the management systems within the state will be unprepared to protect archaeological resources threated by wildland fires.

Industrial History and Urbanization of Pennsylvania

The historical legacy of industrialization in Pennsylvania was a consistent point of emphasis for archaeologists working with PennDOT and the PHMC. Coal, oil and timber industries have strong roots in Pennsylvania and are considered important points of cultural heritage, yet these industries in their current forms are the primary contributors to destructive climate change. Industrialization and climate change are part of the state's heritage just as much as they are currently threatening cultural resources. In this discussion, the issue of erosion was again the most present. Jaillet-Wentling refers directly to the history of clear-cutting forests for western Pennsylvania's lumbar industry as the cause of today's erosion. There is a clear connection between the historic fossil fuel industry and current climate threats to PA. Jaillet-Wentling also addressed a factor of the current fossil fuel industry in Pennsylvania – the fact that private developers have less regulation than federal projects. Even if current development is a more immediate threat to cultural resources than climate, the connection between development and future damage is clear.

Multiple correspondents also reference the fact that the majority of funding for cultural resource preservation and management is funneled into sites that represent the states industrial past. The following image (*figure 5*) is a demonstration of the twelve heritage regions identified and preserved by Heritage PA.

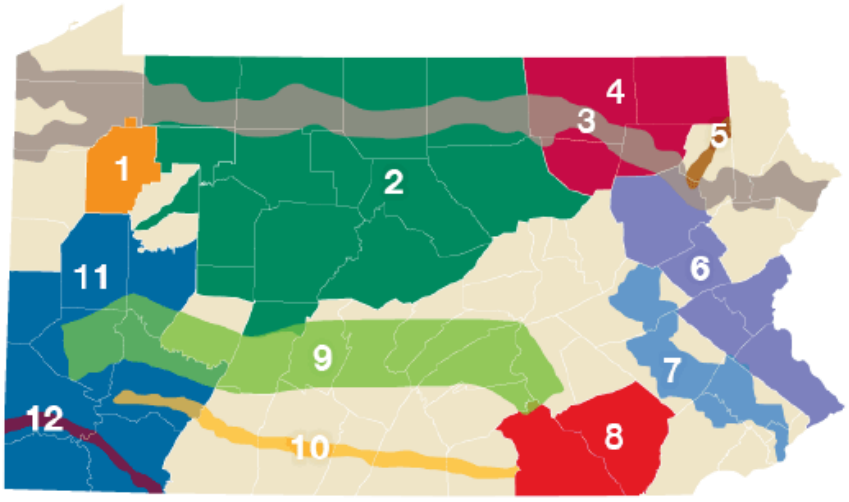

Fig. 5. Heritage regions as defined by Heritage PA, 2020.

Names of Pennsylvania's Heritage Regions

1	Oil Region National Heritage Area
2	Lumber Heritage Region
3	PA Route 6 Heritage Corridor
4	Endless Mountains Heritage Region
5	Lackawanna Heritage Valley
6	Delaware & Lehigh National Heritage Corridor
7	Schuylkill River Greenways National Heritage Area
8	Susquehanna National Heritage Area
9	Allegheny Ridge Heritage Area
10	Lincoln Highway Heritage Corridor
11	Rivers of Steel National Heritage Area
12	National Road Heritage Corridor

Table 1: Names of heritage regions corresponding to Figure 5 (Heritage PA, 2020).

Of the twelve, areas 1-3, 5, and 10-12 directly celebrate and preserve the state's industrial past of logging, oil, coal, steel production, and highway development. The remaining four focus on natural spaces, three on rivers and one on mountains. The seven heritage regions that

celebrate Pennsylvania's industrial past can be directly connected to climate change today, as well as to the erosion and flooding that threatens natural and cultural resources. In many cases, these sites themselves are threatened by the climate damage they once caused. Region 2, the Lumbar Heritage Region, is the largest of the spaces designated historic by Heritage PA. This same region was also identified by correspondents as one that often experiences heavy erosion, which can be directly linked to the historic deforestation.

Another factor contributing to erosion damage is the increase of impermeable surfaces associated with urbanization. Baker addressed this point when asked about current threats – indicating that flood and melt issues will increase along with new developments, even if they do not directly affect cultural resources. Ford addressed the issue of increasing urbanization through discussing movement of people affected by climate change. As high-risk regions become dangerous, people migrate into low risk regions, increasing urbanization (Brown 2008). As Pennsylvania is relatively safe from severe storm damage, it is conceivable that increasing threats in coastal areas will lead to an increase in population and development. In terms of Pennsylvania's cultural resources, this will directly cause an increase of impermeable surfaces and therefore erosion, which will damage both known and unknown sites. There is a clear cycle of historic industrialization leading to climate damage in Pennsylvania, as well as signs that this will continue into the future.

Cultural and Natural Resource Collaboration

As mentioned in the results section, research into the DCNR showed little explicit collaboration between cultural and natural resource management in Pennsylvania. Until recently, DCNR did not employ archaeologists of any kind, instead relying on Heritage PA and PHMC to

protect and manage cultural resources within state forests. Dr. Ford suggests that the lack of clear communication between natural and cultural resource managements stems from a dearth of concrete data connecting the damage of climate on archaeological resources. Connections between climate events and natural resources are well established and well research, even in relatively low impact states such as Pennsylvania (DCNR 2018). Collecting data requires specific research, which is not conducted in Pennsylvania until after events occur.

Each of the professionals I spoke to emphasized that erosion is the most pressing climate issue within the state of Pennsylvania. A key aspect to this threat is that it destroys sites by washing them out of context and burying them as landforms grow. Survey and sampling can only identify a small number of these sites, and even less after they have been flooded and buried. Sites that vanish before they are found cannot be counted and included in assessments of damage, thus decreasing the amount of data available to measure the scope of the problem. leading to a lack of direct engagement between cultural resource professionals and natural resource conservation professionals.

The separation between cultural and natural resource management is clearest in the documents published by DCNR and Heritage PA regarding future management plans. Despite the fact that climate threats are a clear and pressing issues for DCNR, there are no publicly available documents or management plans that integrate cultural and natural resource protection for the agency. Comprehensive work has been done identifying climate threats to cultural resources (Shortle et al. 2015; 2020). Just like CRM professionals, natural resource management identifies flooding and erosion as the highest threat to resource preservation, yet still a disconnect exists.

In the examples of predictive modeling discussed previously, each model was created through a combination of data pulled from natural and cultural resource archives. Although flawed, predictive modeling is the only way in which CRM is working to prevent damage before it happens, rather than fixing what has already occurred. When asked about predictive modeling in Pennsylvania, my correspondents had no information of efforts to integrate cultural resources into predictive models. While a lack of funding and research could explain this gap, some element is also due in part to the lack of collaboration between natural and cultural resource management. This disjunction of agencies is problematic, as it limits preventative action to protect cultural resources. PennDOT and PHMC identify the strong relationship between natural and cultural resources. Not only are both resources severely impacted by climate, a key aspect of Pennsylvania's cultural heritage is industrialization that directly impacted many current climate issues. In order to fully understand the threats to cultural resources in the state of Pennsylvania, natural and cultural resource management must be involved in joint conversations and research.

Public Education of Cultural Heritage and Climate

The last point I addressed through my conversations was the level of public outreach within state cultural resource management. All of the agencies included in this project have public outreach components, meant to educate and encourage community members in cultural and natural resource conservation. Public GIS Story Maps, websites that rely on GIS data to share information in an interactive and engaging way, serve to keep the public informed of resource protection and are generally successful online. These exist both for natural resources, such as the climate resources page developed by the Department of Environmental Protection (https://www.depgis.state.pa.us/ClimateChange/index.html), and cultural sites, such as the public

GIS database accessible through PHMC. Created through a partnership with PennDOT, the database has information on over 150,000 sites in the state, both archaeological and historic, and allows the public access to state research without the need to visit public archives (PHMC 2020). Other regions of the US, both high and low risk, have developed more explicit methods of including the public in cultural resource protection.

In 2016, the Florida Public Archaeology Network (FPAN) began the Heritage Monitoring Scouts (HMS) program. The aim of HMS was to use public volunteers to monitor historic cemeteries, historic structures, and archaeological sites throughout the state, specifically near the coastline. Over 200 individuals volunteered in the first year of the program, and the numbers have grown in successive years. Between 2017 and 2018, the HMS program monitored 418 new sites that would not have been included in archaeological records without the program ("Annual Report 2017-2018"). This inclusion of volunteers gives community members a personal look at the preservation process, and encourages the public to protect heritage resources. In a separate region of the county, The Appalachian Trail Corridor is managed entirely by volunteer groups. (Bristow and Therian 2015). Technically owned by the National Parks Service, surveys intended to find and record the location of archaeological sites are completely run by volunteer groups (Bristow and Therian 2015). Heinlen et al. (2018) encouraged the use of volunteer groups to aid in cultural resource preservation, as community investment in local resources increases their protection, which can be vital when official agencies have minimal operating budgets. Two of my conversations emphasized this point as well, addressing that public involvement and education can be low cost ways of identifying and protecting cultural resources. Public concern over community resources serves as a method of cultural resource protection, and can even facilitate additional research. Cultural resources can also serve as a method to teach about the

impacts of climate change and carbon emissions, showing the public more tangible evidence through the combination of natural and cultural resource management.

Conclusions

This project began based on an unresearched assumption that climate change is actively affecting archaeology practice, just as it affects so many other significant aspects of contemporary society. This topic is immensely complex, and investigation into the precise relationship between archaeology and climate damage requires understandings of specific cultural and historic contexts, archaeological sites, and the contemporary organizations that manage them. One aspect of the conversation that has been overlooked in literature thus far is future effects of climate on areas that are currently considered low risk. When climate is examined on a national scale, these highly effected areas are the only ones that stand out, but they are far from the only ones damaged. On the scale of a single state such as Pennsylvania, it is clear that cultural resources in each region of the US are being lost to climate damage. Regions that currently experience lower levels of risk will become increasingly susceptible as anthropogenic induced change accelerates, and it is in the best interest of CRM organizations to recognize and act on this threat before it fully manifests. CRM professionals in Pennsylvania are aware of this, yet specific management plans have not been developed, potentially due to the assumption that Pennsylvania is at a low risk of climate damage. A tendency to research only after problems have begun to manifest has prevented Pennsylvania from close examination. The designation as low risk is not synonymous with safe, and there are a multitude of ways climate threats will affect the archaeological and cultural resources in Pennsylvania.

Despite the fact that Pennsylvania and other low risk areas do not receive the national and international attention of areas that experience greater threats, there is still a considerable amount of data and research within the state. PHMC has an enormous database of cultural resource information, available both to professional resources and to interested members of the public through the Cultural Resources GIS inventory (PHMC 2020). Considerable climate research also exists within Pennsylvania. Reports and management plans published by the DCNR and the state Department of Environmental Protection show considerable research into rising temperatures, floodplains, runoff, and storm surge, as well as how each of these have or will affect natural resources in the state (Pennsylvania DCNR 2018, Shortle et al. 2020). Cross comparing these two sets of data would be an important first step in integrating low risk regions into the conversation of cultural resource management and climate change.

It is vital that low risk regions are a part of the conversation, especially in regard to public lands, as the inevitability of climate damage is not restricted to seacoasts or glacial regions. As low-risk regions have been excluded from discussions of vulnerability modeling and preparation for severe events, there is no way to accurately evaluate the potential for damage to the many archaeological and historic sites located in areas such as Pennsylvania. Without understanding the full scope of the problem, cultural resources in Pennsylvania will be damaged and lost as a result of anthropogenic climate change.

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