Climate Change Impacts on Archaeological Sites of the Middle Atlantic Uplands (U.S.)
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Introduction

The risks of climate change for archaeological sites lie in the alteration and recombination of the environmental forces to which sites have always been subjected. Archaeologists, who rely on long-term environmental reconstructions, are in the position of considering conditions for which we have no analog in human history. Temperature trajectories may lead to a complete decoupling of past, present and future conditions (Monahan and Fisichelli 2014).

Climate change-associated discoveries and losses of archaeological information are well-reported for coastal and tidal regions. For upland settings, current research on such impacts is largely focused on high elevation glacial features or high mountain landscapes burned over by catastrophic wildfires. However, lower elevation uplands and their cultural resources are seeing a wide range of impacts that, while not as dramatic as the emergence of perishable materials from under tons of melting ice are nonetheless significant.

This paper focuses on the uplands of the Middle Atlantic (Figure 1), where public lands and CRM archaeology have provided useful overviews of site types and locational patterning -- information critical to planning for the accelerated changes that are coming (Wall 2018). More expository than analytical, the work is organized around four questions:
1. How are the Middle Atlantic uplands vulnerable to climate change?
2. What is the current state of climate change impacts in the Middle Atlantic uplands and what settings are most vulnerable?
3. How are climate change-associated impacts damaging archaeological sites?
4. How do we manage upland archaeological resources for climate change impacts?

Figure 1. Middle Atlantic Region, with Emphasis on Uplands (after Polsky et al, 2000).

**Uplands Characteristics.** The Middle Atlantic Uplands vary from Piedmont in the east to the steeper Ridge and Valley, and the Appalachian Plateau in the west. Considered low elevation compared to other upland regions of the globe, elevations range from 800 to 4,800 feet above
sea level. The region is underlain with a mix of igneous and sandstone ridges with mostly shale and limestone valleys, resulting in a wide range of forest communities and unique habitats.

Topographic and geologic variability are coupled with weather system influences that include Lake Effect snows, hurricanes, and other large continental and polar systems, as well as local factors such as orographic lifting and rain shadows (Butler et al, 2015). Transects running east-west across the region generally reflect the influences of elevation and physiography, while the Appalachian Mountains provide the opportunity to study different latitudes along a north-south transect (Figure 2).

Figure 2. Transect from Washington, D. C. (east) to Pittsburg (west) along the C & O Towpath and Great Allegheny Passage, showing changes in elevation across the upland Middle Atlantic (gaptrail.org).

A common uplands feature is complexity of topography. Mountain ranges have an impact on local and regional precipitation—rainfall tends to be higher on the windward side of ranges while drier conditions are found on the leeward side from the “rain shadow” effect. The Blue Ridge tends to see precipitation at a level similar to the Appalachian Plateau, while between them, the Valley and Ridge is drier. Related characteristics include rapid and systematic changes in climate parameters, in particular temperature and precipitation, over
very short distances (Becker and Bugmann, 1997); greatly enhanced direct runoff and erosion; and systematic variation of environmental factors, such as differences in soil types. While climate change is often shown as the gradual warming of global temperature, it is the localized effects of more energy in the atmosphere—such as heavy rains, droughts, and intense winds—that are a more immediate threat to archaeological sites.

Uplands also represent unique areas for the detection of climatic change and the assessment of climate-related impacts. As climate zones shift with elevation over relatively short horizontal distances, so do vegetation and hydrology (Whiteman 2000). As a consequence, mountains exhibit high biodiversity, often with sharp transitions in vegetation sequences. The archaeological record of the Middle Atlantic reflects diverse human responses to such variation (Nash 2009).

**Uplands Vulnerability: Current State of Climate Change Impacts in the Uplands**

**Rainfall.** There is fairly high certainty that the enhanced hydrologic cycle associated with climate change will continue to bring about an increase in heavy precipitation events, a decline in snow cover, and an eventual decrease in soil frost. The region from Washington, DC, to Maine has experienced a greater increase in extreme precipitation than any other region in the United States (Karl et al. 2009). Between 1895 and 2012, temperatures in the Northeast increased by almost 2°F (Figure 3), and between 1958 and 2012, the Northeast saw more than a 70% increase in the amount of precipitation falling in heavy storms (USCGRP 2018). According to multiple Federal agencies, the overall regional climate in the Middle Atlantic uplands has become warmer and wetter over the past half-century (Figure 4). While Middle Atlantic
Figure 3. U.S. Average Temperature Change, 1900-2010 (USGCRP 2017).

Figure 4. Percent Increases in Amount of Precipitation Falling in Very Heavy Events, 1958-2012, by U.S. Region (USGCRP 2017).
flooding is historically associated with hurricanes and nor’easters, in recent years, flooding is associated with large convective systems that resulted in record-setting precipitation throughout the region (USGCRP 2017).

The higher velocity of water from heavy cloudbursts over high-gradient topography causes bank undercutting and slumping along first- and second-order streams (Butler et al 2015). Both the predicted frequent and violent storms or soaking weather patterns entrenched for weeks or months can cause significant erosion. Narrow valleys and steep slopes of higher order streams in upland areas cause rain events to have more energy for scouring out soils than might occur in flatter downstream settings. In the lowest elevation uplands, flooding occurs more rapidly and frequently than in the past due to soil saturation and forest loss from development (Butler et al 2015).

**Debris Flows.** In temperate areas, projected shifts in the regions exposed to seasonal freeze-thaw cycles could affect subsoil instability, ground heave and subsidence, not to mention more dramatic mass wasting (Monahan and Fisichelli 2014). Due to their slope gradients, uplands are vulnerable to landslides, rock slides, slumping, and debris flows. Despite their varying underlying geology, debris flows have occurred throughout the Blue Ridge, Valley and Ridge, and Appalachian Plateau provinces (Figure 5), usually triggered on steeper slopes by major storm events such as hurricanes (USGS 2008). In 2012, James Madison University geologists Matt Heller and Scott Eaton investigated the 'loading' rate of debris flow chutes (1st order streams) in the Virginia Blue Ridge (Page County) and found that 97% are filled, awaiting intense, long-duration rainfall to slide (Witt and Heller 2012). While there might be millennia
between recurrences in particular areas, in the southern Middle Atlantic, some form of mass wasting recurs every 15 years.

**Winds.** The Middle Atlantic region has seen intense, straight line wind, or “derecho” events such as the June 2012 wind that resulted in significant power outages and other damage and categorized as one of NOAA’s “billion dollar weather events” (NOAA 2019). There is not enough historic data on wind storms to draw any conclusions regarding changes in their frequency or intensity due to climate change. While winds associated with rain events are more likely to damage the region, in early March 2018 and 2019, high winds associated with cold fronts generated gusts of between 50 and 70 MPH across the Middle Atlantic (Halverson...
2018). In situations like these, wind, plus saturated ground from extreme seasonal precipitation, results in tree throws that open landscapes to erosion and damage archaeological sites (Figure 6) (Vidos 2013).

![Figure 6. Appalachian Trail, Shenandoah National Park South District, March 2019.](image)

**Drought.** The National Climate Assessment (USGCRP 2017) predicts with high confidence that higher temperatures are expected to result in increased evapotranspiration, reducing soil surface moisture. Williams et al (2017) analyzed data from 1895 through the severe southeastern drought of 2016 and point to potential for more such events in the future in the far southern Middle Atlantic. Other research by USFS, using data through 2013, showed no signs that drought conditions are increasing in the Central Appalachians (Butler et al 2015).
USFS also points to analysis showing that the droughts that do impact the region are generally growing shorter in duration and severity.

**Wildfires.** Prior-year precipitation in the uplands (and the Eastern US in general) has a strong correlation to the potential for wildfire (USGCRP 2017). The drier Valley and Ridge is also home to large stretches of public lands—primarily National Forests. Pine and oak forests situated on steep slopes can provide an abundant fuel load. The scale of these public tracts results in vast remote areas where fires may burn both intensely and uninterrupted, a pattern seen in the southern Middle Atlantic (Figure 7). Suppression of natural fire regimes has, over time, created forests that see much less ground fire than in the past, making them overdue for intense burns (Laffon et al 2017).

![Figure 7. Locations (yellow dots) of fires greater than 500 acres, Middle Atlantic, 1984-2014 (Lafon et al 2017).](image-url)
In such situations, stressors may reinforce each other. For instance: dead trees may increase the fuel load for wildfires; dry periods may increase the potential for wildfire spread and intensity; and more people living near upland forest areas may increase the chances of anthropogenic wildfire ignition. Human presence has been shown to statistically overshadow the influence of climate on wildfire, so as growth and development moves closer to large forest tracts, we should expect to see increased risk for wildfire (Syphard et al 2017). Indeed, this appears to be the case, based on data from the Monitoring Trends in Burn Severity Program: wildfire is increasing in parts of the Middle Atlantic, and fires are getting larger (Figure 8).

**MTBS.gov Data on Fires Larger than 500 acres**

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>New Jersey</td>
<td>19 (Pinelands)</td>
<td>19 (Pinelands)</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Delaware</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Maryland</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>Virginia</td>
<td>28</td>
<td>67</td>
</tr>
</tbody>
</table>

**MTBS.gov Data on Acres Burned by Wildfires > 500 acres, Virginia**

Figure 8. Fires larger than 500 acres, by Middle Atlantic state, 1984-2014; Virginia data for same time frame (MTBS 2019).
III. Impacts on Upland Archaeological Sites

Common pre-contact site locations of the upland Middle Atlantic coincide with topographic settings in danger of the greatest impact from climate change: ridge tops and hilltops, saddles, benches, fans and toe slopes, and terraces (Chiarulli 2001; Barber et al 2003; Nash 2009). Given that Middle and Late Archaic period foragers, particularly, tended to focus on such settings, the potential loss of information on seasonality and mobility is concerning. In the higher elevation settings of the Middle Atlantic, the limited nature of Holocene deposition places occupation levels high in the stratigraphic column and, thus, vulnerable to erosion, deflation, mixing, and overall loss of integrity (Hayes 2018). A recent mitigation project in Shenandoah National Park provides an example of the impacts of extreme climate-related events on a fragile, multicomponent archaeological site with occupations extending from the Early Archaic through the Late Woodland periods (Nash and Kain 2018). The overall landform consists primarily of colluvial deposits associated with a debris fan that was subsequently incised by a minor, first-order drainage (Hayes 2018). Located on the toe slope of an alluvial fan, sites 44MA01050 and 44MA0205 were recently subjected to extreme precipitation (77.8” in 2018), and extreme winds (80 MPH gusts). Since initial formation, the landform has been subjected to a variety of extensive weathering, erosion and disturbance processes that likely have resulted in net deflation over time. The deflation of surface sediments (primarily surface fines such as silt and clay fractions) through processes such as sheet wash has resulted in a concentration of weather-resistant artifacts and natural rocks within deflated near-surface contexts. As evidenced in excavation units and profiles, these near-surface contexts (soil horizons O/A thru E/Bt) have undergone various physical disturbances (primarily attributable to
tree roots, frost heave, burrowing, etc.) that likely account for the lack of easily discernable (vertical) cultural stratigraphy. An example is the recovery of an Albemarle Incised sherd adjacent to a Clovis base in a .15’ thick Bt1 horizon (Figure 9). The impact of modern sheet wash on 44MA0150 was seen in the loss of .2’ of soil from large portions of the site during the two years between initial testing and mitigation, attributable to extreme rainfall (Figure 10).

Figure 9. 44MA0150, N1060 E1015, Level 5. Albemarle (Late Woodland) ceramic (left) and Clovis (PaleoIndian) projectile point base (right).

Figure 10. Profile of excavation units, 44MA0150, showing soil surface in 2016 (red dashed line) and 2018 (L-1).
The National Park Service has evaluated all its holdings along 30 climate change-related dimensions and found that two upland Middle Atlantic facilities are in immediate danger from extreme warm and wet conditions: Chesapeake & Ohio Canal National Historical Park in Washington DC, Maryland, and West Virginia, and the Delaware Water Gap National Recreation Area in New Jersey and Pennsylvania (Monahan and Fisichelli 2014). Delaware Water Gap has approximately 500 documented pre-contact archeological sites, of which more than 100 are considered NRHP-eligible. Three-quarters of these are found in the Middle Delaware River floodplain. Well-known to Middle Atlantic archaeologists, this complex of sites is one of the best preserved in the northern Middle Atlantic, making it a high-value research area (NPS 2014). One hopes that it will be of high value to resource managers.

Accelerated erosion of rock shelters has already been witnessed on sites composed largely of erodible sandstone that are more frequently being inundated with water. Artifacts and other cultural materials located in these shelters have been transported by water to nearby creeks (Butler et al 2015). Increased moisture levels and damage from freeze/thaw cycles and subsequent erosion have resulted in roof collapse within these rock shelters, as well. Projected increases in rapid freeze-thaw events will exacerbate these effects.

An altered fire regime could become an increasing source of disturbance if climate shifts encourage more frequent or intense fire behavior. Both fire and firefighting activities can threaten all types of cultural resources (Buenger 2003). The direct effects of fire on archaeological materials result from either energy transported from the burning fuel to the material artifact or from the deposition of combustion byproducts on the site (Ryan 2010).
Thermal effects vary depending on the type of material (e.g., lithics, ceramics, organic remains, metals, etc.), the physical chemistry of the material (e.g., sandstone vs. chert lithics or terracotta pottery vs. porcelain ceramics), the artifact’s provenience with respect to the fuels burned, fire behavior (ground/surface/crown/spotting), and heat transfer (Figure 11). Direct thermal effects include combustion of organic objects and food residues embedded in composite materials. Thermal stress associated with rapid temperature increase can physically damage artifacts, resulting in shattering fracturing, spalling, crazing, cracking, etc., depending on the material type. Second-order or indirect effects include post-fire damage caused by increased weathering, erosion, and redistribution, such as have been documented for the April 2016 Rocky Mount fire in Shenandoah National Park (Figure 12). Accelerated post-fire erosion

<table>
<thead>
<tr>
<th>Cultural Resource</th>
<th>Temperature</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic Materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>350</td>
<td>Organic paint begins to burn off</td>
</tr>
<tr>
<td></td>
<td>400</td>
<td>TL readings altered</td>
</tr>
<tr>
<td></td>
<td>750-870</td>
<td>Spalling, quicklime formation</td>
</tr>
<tr>
<td>Lithic Materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chert</td>
<td>150</td>
<td>Impurities and possible fractures</td>
</tr>
<tr>
<td></td>
<td>121-400</td>
<td>Interior faster changes</td>
</tr>
<tr>
<td></td>
<td>350-400</td>
<td>Distortion, brittleness, explosiveness</td>
</tr>
<tr>
<td></td>
<td>240-800</td>
<td>External surface color change</td>
</tr>
<tr>
<td></td>
<td>600-800</td>
<td>Optical dulling of external surface</td>
</tr>
<tr>
<td>Obsidian</td>
<td>300</td>
<td>Hydration band diffused</td>
</tr>
<tr>
<td></td>
<td>500+</td>
<td>Hydration band not present</td>
</tr>
<tr>
<td></td>
<td>540</td>
<td>Cracking</td>
</tr>
<tr>
<td></td>
<td>760</td>
<td>Vesiculation</td>
</tr>
<tr>
<td></td>
<td>700-800</td>
<td>Melting</td>
</tr>
<tr>
<td>Basalt</td>
<td>300-600</td>
<td>Spalling, Fracturing</td>
</tr>
<tr>
<td></td>
<td>100-800</td>
<td>Weight Loss</td>
</tr>
<tr>
<td>Quartz</td>
<td>&gt;573</td>
<td>Blackening, thermal expansion, crystalline diminishment, pollen</td>
</tr>
<tr>
<td>Ground Stone</td>
<td>360+</td>
<td>Smudging, organic materials present begin to diminish pollen</td>
</tr>
<tr>
<td></td>
<td>800+</td>
<td>Organic material diminished, animal proteins</td>
</tr>
<tr>
<td>Rock Art Resources</td>
<td>High heat</td>
<td>Exfoliation, blackening</td>
</tr>
<tr>
<td>Subsurface Materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Stone</td>
<td>300</td>
<td>Spalling, cracking</td>
</tr>
<tr>
<td></td>
<td>300</td>
<td>Spalling, cracking</td>
</tr>
<tr>
<td></td>
<td>400</td>
<td>Chalking</td>
</tr>
<tr>
<td>Bone</td>
<td>500</td>
<td>Severe chalking</td>
</tr>
<tr>
<td></td>
<td>800</td>
<td>Frothing</td>
</tr>
</tbody>
</table>

Figure 11. Thermal Effects on Lithic Raw Materials (Ryan 2010).
can either wash-away, bury or redistribute archaeological materials. In this instance, a large quartzite quarry site was burned over by a crown fire, with temperatures exceeding 500 degrees C. While quartzite artifacts were damaged directly, the greater threat to the site is the erosion that has occurred post-burn. Third-order effects include the human response to fire, including line construction and chemical damage to surfaces from fire retardants (Figure 13). In

Figure 12. Impacts of Rocky Mount Fire, Shenandoah National Park, on 44RM0225 (Big Run Quarry), April 2016.

the case of wildland fire, unknown sites and artifacts are often discovered due to the removal of vegetation, which raises the question: how much do we really know about the archaeology
of the uplands (Chiarulli et al. 2001)? In Eastern North America, upland archaeology has lagged for a number of reasons, the most damaging of which is the long-held belief that upland sites have limited signatures and are thereby less likely to provide information on cultural processes (Sullivan and Prezzano 2001). Given that the upland forests of the Appalachians are among the most diverse natural communities in the temperate world (Stephenson, Ash, and Stauffer 1993), their heterogeneity provides the setting for a study of change and flexibility as an essential feature of existence, both for pre-contact and historic sites.

![Diagram of Fire Impacts to Cultural Resources](Ryan2010)

An example of our lack of understanding of upland archaeology is seen in the site records of the State of Virginia, maintained by the Virginia Department of Resources in the Virginia Cultural Resources System (V-CRIS) geodatabase. Archaeologists are prompted to
complete an on-line site survey form that contains a variety of locational and cultural information fields. Currently, V-CRIS contains entries for 12,620 upland archaeological sites. The “Site/Component Category,” which identifies whether the occupation is “Domestic,” “Industry,” “Religion,” “Subsistence,” etc., includes the category of “Indeterminate” for those sites whose artifact signatures are not conclusive for site function identification. Of the 1,097 Indeterminate sites recorded for Virginia, 40% (n=429) are in the uplands, and given the low priority of such settings for research or further consideration through regulatory processes, the likelihood of these sites seeing additional work is low.

The issue of low priority becomes more pronounced with the identification of site types. Two categories – “artifact scatter” and “lithic scatter” are included in V-CRIS to capture sites with small, diffuse artifact signatures. Of the 4,033 scatters recorded for Virginia, 67% (n=2,690) are in upland counties (Table 1). The impacts of climate change, especially erosion, on these small sites may remove an entire class of information, despite the fact that they comprise much of the archaeological record in the Eastern Woodlands (McDougal and Funk 2006). These small sites present a challenge to conventional settlement modeling and are often considered too ephemeral to offer meaningful information concerning cultural change and settlement activities (Barber 2001). In themselves, they may not provide a great deal of information—few diagnostics or features, low artifact density, and small in area. These are the kinds of sites usually deemed ‘insignificant’ and cleared during the Section 106 review process (Wandsnider and Camilli 1992; Chiarulli et al 2001). However, if treated in an additive fashion, the patterning of such sites can provide important insight into long-term cultural change,
including transformations in social organization, regional interactions, and shifts in resource use.

<table>
<thead>
<tr>
<th>Physiographic Province</th>
<th>Artifact Scatter (#)</th>
<th>Lithic Scatter (#)</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piedmont</td>
<td>484</td>
<td>1605</td>
<td>2089</td>
</tr>
<tr>
<td>Blue Ridge</td>
<td>24</td>
<td>89</td>
<td>113</td>
</tr>
<tr>
<td>Ridge and Valley</td>
<td>118</td>
<td>344</td>
<td>462</td>
</tr>
<tr>
<td>Appalachian Plateau</td>
<td>0</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>626 (47% of State Total)</strong></td>
<td><strong>2064 (76% of State Total)</strong></td>
<td><strong>2690 (67% of State Total)</strong></td>
</tr>
</tbody>
</table>

Table 1. Virginia Upland “Scatter” Sites, by Upland Physiographic Province (V-CRIS 2019)

**IV. Conclusion: Managing Upland Archaeological Sites for Climate Change Impacts**

Sustained archaeological and historic research in the Appalachian system and its associated lower-elevation uplands demonstrate a remarkable variety of human adaptations across thousands of years, some of which emphasize the fluidity of social organization and others the long-term persistence of cultural traditions (Nash 2009). Yet, the window for investigation may be closing. Middle Atlantic upland archaeological sites are already experiencing the impacts of climate change, which is ongoing and can be documented without having to project an additional 50 or 100 years. Importantly, future changes in temperature and precipitation will likely push portions of the region beyond the limits of its historic range of variability (Monahan and Fisichelli 2014). In addition to the climate-related impacts will be pressure from development as “climate migrants” move from the coast to the interior. Managing cultural resources will become more challenging as a result.
Fortunately, there are those among us who are planning for climate change impacts (Rockman et al 2016) and providing guidance for prioritizing archaeological sites. There is no question that documenting upland archaeological sites is critical to the effort, and upland-focused archaeologists need to identify understudied regions and site types, particularly those vulnerable to impacts, and encourage their study. Given the presence of large tracts of public lands in the Middle Atlantic uplands, regulatory studies have been on-going for fifty years, yet much of the data remains in the gray literature. Conferences such as Upland Archaeology in the East, co-sponsored by the U.S. Forest Service and various universities, are indispensable to information sharing. In the field, archaeologists who take on this work must develop interdisciplinary teams that include geomorphologists and fire specialists. We need to become more involved in planning efforts, working with fire crews to identify high probability areas that require protection. Most importantly, we must adopt triage-based methodologies that allow us to enter an impacted area and recover the information that remains.

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