Hidden in plain sight: Spatial patterns in Late Woodland shell midden archaeological sites across Virginia's Eastern Shore

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Abstract

Shell middens are archaeological deposits that form when people eat large amounts of oysters and other shellfish. For the Native American communities that lived on the lower Delmarva Peninsula during the Late Woodland period, shell middens were often gathering places for ceremonial feasts. In a highly diverse estuarine seascape, understanding the particular environmental characteristics of midden locations can inform what these community experiences may have been like, and how these social activities may articulate with Native conceptions of landscape, space, and spirituality. Using the theoretical framework of landscape archaeology and site data maintained by the Virginia Department of Historic Resources, I mapped Late Woodland shell middens and applied the exact test of goodness of fit to their distribution across categories of three variables: hydrologic soil group, land cover, and nearest water body. Results show a significant tendency toward sites with grass, scrub, shrub, marsh, and well-draining soils. Results are insignificant for midden distribution amongst water features. This suggests that the experience of open spaces with proximity to water may be more relevant to site interpretation than proximity to resource assemblages. Shell middens are unique, visible, and culturally meaningful markers on today's landscape. Informing the public about these sites would spread awareness about the continued Native presence on the Shore, and may motivate residents to conserve undeveloped shorelines that will play a key role in buffering the coast from increasingly frequent storm events and sea level rise.

Introduction

I. Project description, questions, and goals

This project explores and contextualizes the many shell-bearing archaeological sites created by Native communities during the Late Woodland (ca. 1000-1600 C.E.) period on Virginia's Eastern Shore. I begin by defining my research questions and goals, identifying my theoretical framework within the scheme of landscape archaeology, describing the environment of the Eastern Shore and the diverse array of estuarine "microenvironments" (i.e. places with unique characteristics) found across the landscape, and synthesizing the archaeology and ethnohistory of the study area and the region. I use this information to interpret my results regarding shell midden distribution amongst categories of environmental variables.

The specific goals of my research are a) to explore the pattern of known Late Woodland shell midden sites on the Eastern Shore of Virginia, b) to identify the geological, hydrological, and ecological context of those sites, c) to explore the relationship between the presence of shell midden sites and existing environmental conditions, and d) to characterize shell middens as cultural places in the socio-natural landscape.

My research focuses on two major questions: a) What are Late Woodland shell midden sites on the Eastern Shore like, and how might this have featured in individuals' experiences of different microenvironments in the estuarine seascape? b) Do shell midden sites on the Eastern Shore follow any overt spatial pattern with regard to arrangement or environmental context?

Although many shell middens are scattered across the landscape of the Eastern Shore, they are no longer central places of community memory. Most residents of the peninsula do not know that these places exist, are undereducated about the indigenous culture whose history surrounds them, and are unaware that many Native people remain their neighbors, living and working alongside others.

Marquardt (1994) has noted the untapped potential that archaeology and cultural heritage can play in mobilizing communities to conserve and restore their local environments. A sense of connection to a place that one calls *home* is something that all of us, in the past and in the present, have in common. Tidewater Virginia's coastal resources, archaeological and otherwise, are among those most threatened by continuously accelerating land development, sea level rise, erosion, and storm frequency across the country, in terms of both physical magnitude and social and economic vulnerability (Stafford & Abramowitz, 2017). Northampton County in particular has been ranked the highest out of all counties on the Atlantic coast for combined socioeconomic and geophysical risk of future coastal erosion (Boruff, Emrich, & Cutter, 2005). Despite globalization, the residents of the Delmarva Peninsula have retained strong ties to a local economy that is heavily invested in coastal resources. Without efforts to bolster resilience to climate effects, particularly via protection of salt marshes and other natural buffer areas, Delmarva communities will likely undergo fragmentation, emotional and economic hardship, and displacement during the process of losing their homes.

As climate change progresses, over 13,000 archaeological sites in the region will be lost with a 1m rise in sea level (Anderson et al., 2017), rendering southeastern coastal archaeology increasingly important. This is true not only in terms of documenting known and unknown sites prior to destruction, but perhaps more importantly in providing an educational and organizational locus for community engagement with the landscape's socially charged past and present. Because of their history as places of coalescence and community strength, shell middens are contextually well-situated to serve as focal points in this effort. Shell middens tend to be located in nearshore areas where conservation is most important for creating and protecting storm buffer zones (Lowery, 2003). According to a study conducted for Anne Arundel County, Maryland, shell middens are the archaeological site type most threatened by sea level rise, with 76% of middens there facing destruction (Rick et al., 2014). Threatened sites occur on both private and public properties, and different strategies are needed to address this division (Wright, 2015). Furthermore, it is local residents more than any other group who play the biggest role in site destruction or stewardship through their land use decisions, long after cultural resource professionals have identified or excavated a site (Wright, 2015). Residents that are made aware of the history under their feet are more likely to protect and restore the sites as well as the ecosystems that house them; the integrity of these ecosystems will play a key role in coastal resilience. An exploration of Eastern Shore shell middens as historically and socio-ecologically potent places may boost this awareness and may encourage citizen action.

II. Landscape archaeology, mosaic microenvironments, and theoretical framework

Landscape archaeology is a broad term that refers to archaeological techniques and approaches seeking to contextualize past human existence within an inhabited, continuous area, whether that area is geographically large or small. “Landscape” refers not only to what we think of as the natural world, but instead to the socio-natural world holistically (Anschuetz, Wilshusen, & Scheik, 2001; Gallivan, 2016). The socio-natural world includes the built or modified environment; the geological, ecological, and hydrological environment; the sensory experiences, memories, and meanings attached to specific places; and the relationships amongst actors inhabiting those places (Thompson, 2014; Herlich, 2016; Anschuetz, Wilshusen, & Scheik, 2001). Actors inhabiting the landscape may include humans, plants, animals, spirits, landforms, ancestors, and deities (Thompson, 2014; Moore & Thompson, 2012). The socio-natural landscape is a dynamic setting that is continuously reworked both spatially and temporally, and the connection that people have to certain places is both reinforced and recreated through periodic actions (Herlich, 2016). The cultural topography that is embedded in the landscape is created in this way through the process of *placemaking*, "whereby locations are named, constructed, and instilled with significance" (Gallivan, 2016, p. 6). This way of thinking about the human experience draws heavily on perspectivism, cognitive archaeology, historical ecology, cultural performativity, and recent efforts to include spatiality in cultural studies (Anschuetz, Wilshusen, & Scheik, 2001; Gallivan, 2016).

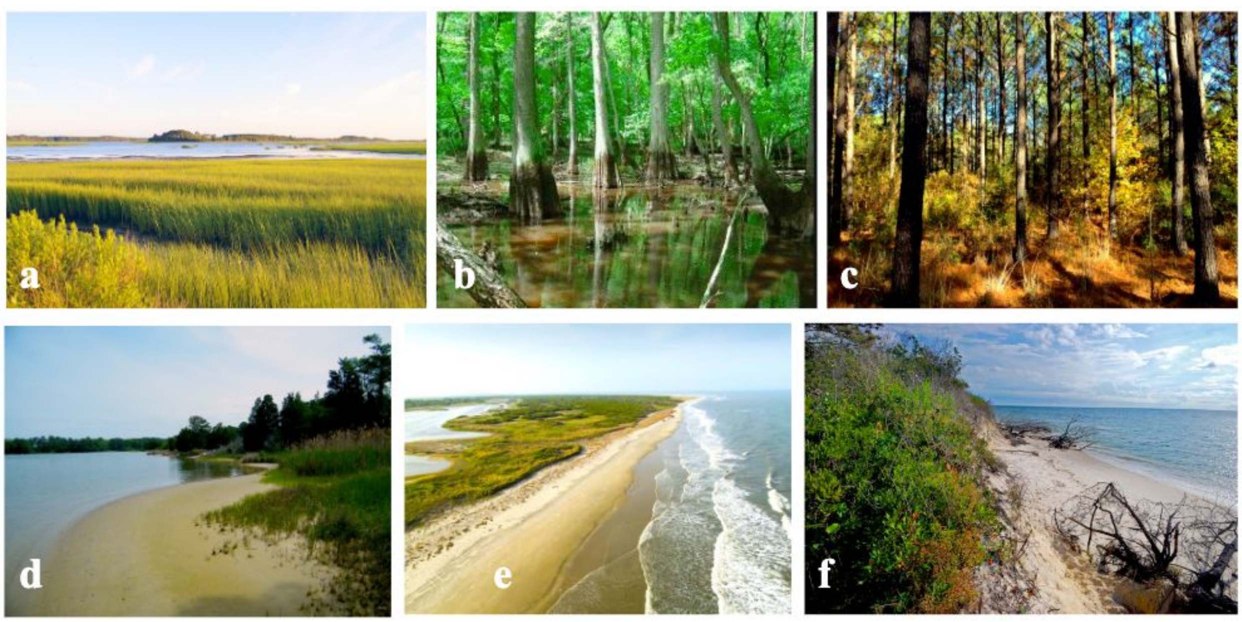
Landscape archaeology has its roots in the discipline of cultural ecology, pioneered in the 1950s by Julian Steward (Sutton & Anderson, 2013). Followed by a series of intermediary disciplines, cultural ecology focused on the relationship between humans and the environment, with these components treated as alternatingly active or passive, but usually discrete and disconnected, mechanisms of cultural change (Sutton & Anderson, 2013). This framework was quickly applied to many North American indigenous groups; scholars often relied on evolutionary models that placed Native groups in a simple-to-complex trajectory (or vice versa), an academic narrative that is damaging in many cases (Sutton & Anderson, 2013; Herlich, 2016). Settlement patterns, estuarine productivity, and adaptation to the environment during the Holocene were the primary points of discussion (Gallivan, 2011).

The northern and middle portions of the Delmarva Peninsula were the subject of studies by Custer (1984, 1988, 1989) and Gelburd (1988) that examined the correlation between subsistence, settlement patterns, and environmental variables. These studies developed and tested models of indigenous settlement that were intended for use in site prediction and future site identification. While these models are practically useful, they interpretively simplify the decisions made by past communities and individuals in site selection, the ways that sites of different uses and settings were experienced, and the conceptual maps that people lived by. In recent years the focus has shifted to landscape management and alteration; these academic choices help us bring Native decision-making to the interpretation of archaeological data, and give a more active note to the term “adaptation” (Sutton & Anderson, 2013; Herlich, 2016; Thompson & Turck, 2009).

Several topics that fall under the umbrella of landscape approaches include Ingold’s (1993) “taskscape”, Moore and Thompson’s (2012) discussion of persistent places, Gallivan’s (2016) discussion of placemaking, and Nieves’s (2015) discussion of movement and mobility. These perspectives all seek to interpret past actions and activities within a landscape layered with meaning. Ingold’s (1993) taskscape is, as paraphrased by Herlich (2016), “a view of the world as it is formed by interwoven tasks or activities… [it] combines abstract or intangible elements of how people connect with space and time with concrete activities and physical evidence in the study of hunter-gatherers” (p. 8, 9). It is this connection between sense of place, experiences, and the spatial pattern of activities that I will use in my analysis of Late Woodland period sites on Virginia’s Eastern Shore.

The dynamics of estuarine environments are such that a wide range of diverse “microenvironments” are present on the landscape (Day et. al., 2013). On the Eastern Shore, one does not have to travel very far to encounter many different places, each with its own unique sights, smells, and sounds created by varying abiotic and biotic combinations. The estuarine land- and seascape is a mosaic pattern generated by known and unknown geological, hydrological, and ecological processes (Weins, 1995). Environmental subzones include, to name a few, open beaches and grass-covered dunes along the Atlantic Ocean, low-lying salt marshes that become fragrant with sulfur and boisterous with crabs at low tide, interior swamps and forests where pine needles and acorns crunch underfoot, protected inlets with calm water and wading birds, and patches of mudflats, shoals, and vast seagrass beds interspersed with deep underwater channels (Figure 1).

Figure 1: Examples of unique microenvironments in the estuarine seascape. a) Tidal salt marsh interspersed with mud flats, shoals, and channels (Qiu, 2014); b) interior wetlands with mixed deciduous forest and cypress swamps (Photo by Dan Murphy; Reshetiloff, 2010); c) xeric pine-oak forest (Virginia Tech Media Relations, 2018); d) protected inlets with calm water, fringing marsh, and surrounding woodlands (Blue Heron Realty Co., 2019); e) barrier islands along the Atlantic shoreline (The Nature Conservancy, 2019); d) sand dunes and bluffs topped with shrubby vegetation along the Chesapeake shoreline (Virginia Tourism Corporation, 2016).



While many microenvironments in the seascape, particularly the subtidal ones, are not archaeologically accessible, it remains a likely truth that those microenvironments featured prominently in Native settlement patterns and site selection (Lowery, 2001). Different activities on the Delmarva Peninsula were correlated with different types of places, and these activities can be inferred by examining the archaeological record (Gelburd, 1988).

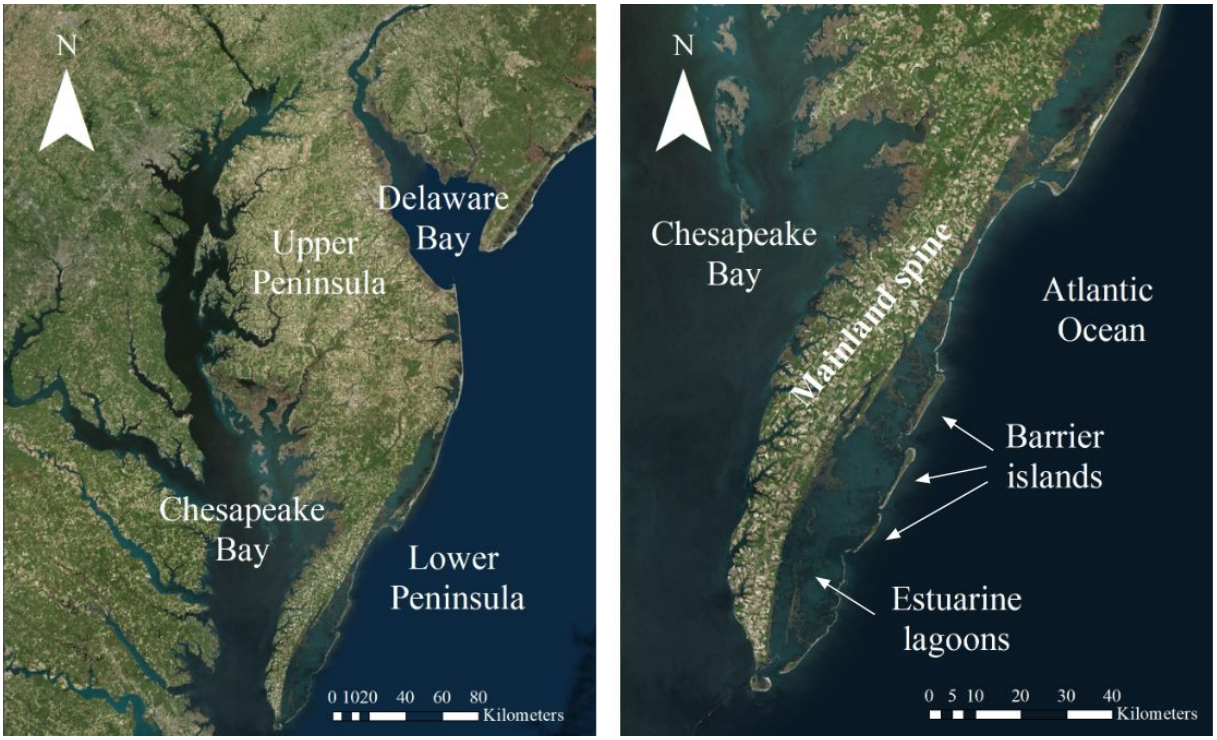
One especially interesting activity undertaken by Late Woodland people was shellfish gathering and consumption on large scales. When people discard the shells of oysters, clams, scallops, and/or crabs during a large feasting event or in smaller, repeated events at the same place, a shell midden is formed (Wittkofski, 1988; Herlich, 2016). Shell middens mark the sites of daily or periodic experiences, and oftentimes events of ceremonial, ritual, or political significance (Herlich, 2016). The resulting shell piles were visual markers on the landscape that reaffirmed the meanings and memories associated with those locations (Herlich, 2016). Identifying the locations and environmental context of shell middens on Virginia's Eastern Shore would give us a better picture of where Late Woodland social gatherings and community events took place, and what those experiences may have been like in terms of the surrounding geological, ecological, and hydrological landscape.

III. Study area and environmental setting

The Delmarva Peninsula is a landform on the Eastern Seaboard of North America, separating the Chesapeake Bay from the Atlantic Ocean. It became isolated from the adjacent Eastern Seaboard when the ancestral Susquehanna paleochannel drowned during glacial melting between 13,000 and 10,000 years ago, forming the Chesapeake Bay estuary and its assemblage of unique micro-environments (Lowery, 2001). The resulting peninsula is surrounded by the waters of the Chesapeake Bay to the west, the Delaware Bay to the northeast, and the Atlantic Ocean to the east. Today it known colloquially as the Eastern Shore of Virginia, Maryland, and

Delaware. The area has been occupied by many indigenous groups for at least 10,000 (possibly 12,000) years, and is still inhabited indigenous people today (Wittkofski, 1988, Busby, 2010).

Figure 2: Satellite images of the study area. The upper and lower Delmarva Peninsula are distinct in width and location along the Chesapeake Bay. The lower peninsula is characterized by a mainland spine, a fringing coastal plain, and barrier islands that protect estuarine bar-built lagoons. (Satellite imagery basemap: ESRI, 2018).



The Peninsula can be divided into lower and upper portions, with the Eastern Shores of Maryland and Delaware occupying the upper portion and the Eastern Shore of Virginia occupying the lower, southernmost portion (Figure 2). The upper peninsula is significantly wider than the lower peninsula. Different terrain and hydrological regimes result in notable differences between the the upper and lower sections (Rountree & Davidson, 1997); in this way, the state line occurs along a natural geographic transition zone, and is less arbitrary than many U.S. state borders.

The upper peninsula, or the Eastern Shore of Maryland and Delaware, is characterized by pronounced uplands in excess of 50 feet above sea level, with discrete drainage zones and true rivers that are tributaries to the Chesapeake Bay, including the Pocomoke, Wicomico, Nanticoke, Choptank, Chester, and Sassafras Rivers (Rountree & Davidson, 1997). The uplands are fringed by low-elevation coastal areas. I refer to these as “true” rivers because they carry enough freshwater discharge that the saltwater at the river mouths is not able to penetrate the headwaters of the rivers. Instead, these rivers are characterized by a gradient from freshwater to saltwater as one moves from the head toward the outlet. The gradient in salinity and the gradient in the shape and form of the riverbed (rocky conditions in headwaters, sandy or silty conditions with channels and shoals near the outlet) combine to produce a range of varied ecological zones (Rountree & Davidson, 1997).

In the interior uplands of the upper peninsula, narrow freshwater and fresh-brackish marshes line the rivers and create structural habitat for freshwater and diadromous fish, crustaceans, and mollusks, all of which were eaten by Native people (Custer, 1984). Also found growing on these riverbanks are a variety of edible roots and tubers, which were a starchy dietary staple (Rountree & Davidson, 1997). Although the forests of the upper peninsula are today dominated by pine, most of these forests are the result of secondary succession following the abandonment of 17th and 18th century agricultural fields (Rountree & Davidson, 1997). Before the forests were cleared for tobacco and other cash crop cultivation, they were dominated by oak, with a gradient of oak-hickory, oak-gum, and oak-pine patches as one moved from the high elevation uplands to the coast (Rountree & Davidson, 1997). These and other hardwood trees produced a large amount of acorns, nuts, and seeds that were significant to Native diets. These resources were also a food source for deer and wild turkeys, the primary types of game hunted on the peninsula (Rountree & Davidson, 1997).

This study focuses on the lower peninsula. The lower peninsula is ~120 km (75 mi) long, and ranges between ~2-23 km (1-14 mi) wide (Wittkofski, 1988; Rountree & Davidson, 1997). It is currently divided into Northampton and Accomack Counties. Because it is so narrow, this area lacks pronounced uplands, but possesses a mainland "spine" that runs the length of the landform from north to south and ranges between 25 and 50 feet above sea level. The rest of the lower peninsula, including its barrier islands and marshes, is less than 25 feet above sea level, and is typically only a few feet or less above sea level. Runoff from the mainland is drained by tidal creeks (classified as sub-estuaries) into the Chesapeake on one side, and into the tidal lagoons that are protected from the Atlantic Ocean by a series of morphologically unstable, mobile barrier islands on the other side. In contrast to the rivers of the upper peninsula, the creeks do not drain a large enough area to maintain a strong current and therefore a freshwater-saltwater gradient (Lowery, 2001). In the upper peninsula, the water column is circulated (i.e., mixed) by the movement of freshwater from the headwaters to the outlet; in the lower peninsula, the water column is circulated instead by tidal movement and wind (Lowery, 2001). In terms of salinity, the offshore and tributary waters of the Chesapeake are seasonally mesohaline (15-18 ppt) and polyhaline (18-30 ppt), while the waters on the ocean side are polyhaline and euhaline (>30 ppt) (Lowery, 2001). The geological formations of the lower peninsula are comprised of sands and some gravel (Lowery, 2001). The region experiences mild winters and humid, hot summers, with frequent storms in the fall, winter, and spring (Lowery, 2001). Proximity to major water bodies is important in regulating seasonal temperatures (Rountree & Davidson, 1997).

Within the lower peninsula, the northern and southern counties share most soil types, with the exception of three soil types that can be found only in the northern half and are associated with salt marshes (Lowery, 2001). Along the Chesapeake Bay, the northern portion (i.e. Accomack County) is more structurally diverse than the southern portion, particularly because this is where the most extensive salt marshes are found (Lowery, 2001). The marshes are tidally inundated, and are punctuated with small hummocks, ridges, and hills that form dry elevated islands (Lowery, 2001). The salt and brackish marshes along the Bay side of the southern lower peninsula are smaller and occur along the tidal creeks. In this area the Chesapeake shoreline itself is lined with bluffs that are topped by reworked sand dunes (Wittkofski, 1988). Because the water inundating the marshes is salty, the starchy tubers found in the upper peninsula cannot grow here, but the marsh remained a source of diverse estuarine food for foragers, and ready access to marsh was valued by Native communities (Rountree & Davidson, 1997). Resources found in or near the marshes, tidal creeks, and waters of the Chesapeake Bay included a variety of fish species, waterfowl, shorebirds, crabs, periwinkle snails, American oysters, hard clams, knobbed whelks, channeled whelks, and Atlantic ribbed mussels; mammals such as foxes, raccoons, and weasels were attracted to these areas as well (Wittkofski, 1988; Lowery, 2001).

The lower peninsula is characterized by sandier, more xeric conditions, and mixed deciduous hardwood forest patches are not as prevalent as in the upper peninsula (Lowery, 2001). Instead, forests are now dominated by pine, but would have been dominated in the past by drought-tolerant oak, with some pine mixed in (Rountree & Davidson, 1997). This information is based on observations of forest succession in the region, in which sandy, xeric, Mid-Atlantic coastal forests have an oak-pine composition when mature, but become dominated by pine during secondary succession following fire or agricultural clearing (Rountree & Davidson, 1997). Scattered across the mainland spine are shallow, broad, basin-like features commonly called Delmarva Bays or Carolina Bays (Fenstermacher, Rabenhorst, Lang, McCarty, & Needelman, 2014). These features are not visible from the ground, but can be identified in LiDAR elevation data as elliptically shaped pockets with a relief ranging from .5 to 2 m across several or more miles (Fenstermacher, Rabenhorst, Lang, McCarty, & Needelman, 2014). Because they collect water, these areas may form freshwater swamps occupied by Bald Cypress and other vegetative species. About 60% of the Delmarva Bays have been at least partially drained and converted to agricultural fields or used for other purposes (Fenstermacher, Rabenhorst, Lang, McCarty, & Needelman, 2014). Since colonization, agriculture has been the primary land use on the peninsula (Lowery, 2001).

Vegetative communities correspond to zones defined by drainage type (Table 1). Common tree species include Black Cherry (*Prunus serotina*), Prickly Pear Cactus (*Opuntia compressa*), Oaks (*Quercus* spp., including Live Oak, *Q. virginiana*), Pines (*Pinus taeda, P. serotina, P. virginiana*), American Holly (*Ilex opaca*), and Red Cedar (*Juniperus virginiana*) (Lowery, 2001). A variety of shrubs and grasses, especially cordgrass (*Spartina alterniflora*) and other salt tolerant species, are equally important components of the vegetative landscape.

Table 1: Vegetative communities and drainage zones.

Major drainage zones for the peninsula are characterized by different plant communities. (Adapted from Custer and Mellin, 1991, in Lowery, 2001, p. 28.)

Interior Well Drained Zone	**Poorly Drained Zone**	**Major Drainage Zone**	**Coastal Zone**
Oak-pine-hickory forest with mixed mesophytic communities	Bogs and swamps with deciduous gallery forest	Deciduous gallery forests (oak-chestnut) with extensive fringing salt marshes	Extensive salt marshes, oak-pine woodland with some scrubby xeric vegetation, high productivity

Estuaries have been shown to foster extremely high levels of biological productivity compared to other biomes (Day, Yáñez-Arancibia, Kemp, & Crump, 2013). Part of the mechanism behind this is the spatial, structural, and chemical variation that defines the dynamic estuarine environment. Variation creates a long and diverse list of microenvironments, each with a different assemblage of resources and species. People have long been one of the key occupants of estuarine ecosystems, and utilized each of the microenvironments available to them in different ways. Archaeological and sociocultural research is often spent understanding how the indigenous people of Tidewater Virginia procured food and other resources from environmental subzones across the estuarine seascape. Much less time has been spent understanding Native culture in terms of how places were/are conceptualized, and where a range of activity types, and their cultural underpinnings, took place.

IV. Archaeology, ethnohistory, and current status of the indigenous people of the Delmarva Peninsula

The cultural histories of Native people occupying the Eastern Shore and the general Middle Atlantic region have been reconstructed using archaeological patterns, historical accounts, and ethnographic data and comparisons. It is important to understand that each of these types of information has its own unique sources of bias that alter how we interpret archaeological data today, and that archaeology in many ways remains entangled with colonialism. In light of these concerns, enough work has been done in the Tidewater region that scholars are confident in their knowledge of how Native daily life, political relationships, and cultural geographies looked, at least in the centuries leading up to C.E. 1600.

Table 2: Cultural chronology of the Middle Atlantic region.

Dates are approximate and vary by interpretation. (Adapted from Dent, 1995, p. 9, with beginning date of Paleoindian period modified to reflect current knowledge; Lowery, 2001).

Temporal Period or Subperiod	**Range (Approximate Years B.P.)**
Paleoindian	12,000 - 10,000
Archaic	10,000 - 3,000
● Early Archaic	● 10,000 - 8,000
● Middle Archaic	● 8,000 - 5,000
● Late Archaic	● 5,000 - 3,000
Woodland	3,000 - 400
● Early Woodland	● 3,000 - 2,300
● Middle Woodland	● 2,300 - 1,000
● Late Woodland	● 1,000 - 400 (C.E. 1,000 - 1607)
"Historical;" increasingly controlled by European presence	412 - 0 (C.E. 1607 - Present)

Virginia's cultural history begins in the Paleoindian period (approximately 12,000 - 10,000 B.P.; Table 2), when people arrived in the region and lived fully mobile lifestyles in a significantly colder and drier climate, following large game and practicing traditions that would eventually transform into Eastern Woodland culture (Dent, 1995). As the climate became warmer and wetter and as the Chesapeake estuary formed, people became less mobile and coalesced into larger groups. The population expanded. People began to experiment with the region's first ceramic technologies and then its first small-scale agricultural practices. By the end of the Early Woodland period (Table 2), the diverse estuarine environment of the Eastern Shore had stabilized and looked much like it does today (Busby, 2010). In this context, without evidence of intensive agricultural practices, people of the Delmarva began to show material evidence of living in a stratified society, with elaborate mortuary ceremonialism and multi-nodal trade networks for luxury goods, particularly in the upper peninsula; these assemblages are known as the Delmarva Adena and Webb complex (Custer, 1984). Much of what we know about these Early Woodland upper peninsula groups is derived from intensive excavations of burials that took place before protection of indigenous burial sites by law. Recent excavations in the lower peninsula suggest a possible presence of the Meadowood complex during the Early Woodland period (Lowery, Rick, Barber, Wah, & Madden, 2015). The Meadowood cultural phase is usually found in the northeastern Atlantic seaboard and is diagnosed by the Vinette 1 pottery type, thin side-notched Meadowood projectile points, and the manufacture and trade of marine shell ornaments (Lowery, Rick, Barber, Wah, & Madden, 2015). In the Middle Woodland period, people on the Delmarva began to focus their subsistence strategy on estuarine resources, especially shellfish (Busby, 2010). An increase in site density during this period indicates an increase in sedentism, population, or both (Busby, 2010).

In this study, I will focus on the Late Woodland period, by which time Native communities around the Chesapeake Bay resided in permanent or rotating seasonal villages, spoke varieties of the Algonquian language, tended gardens and in some cases fields of corn, beans, and squash, and fished in the Bay, Atlantic Ocean, lagoons, and tidal inlets using lines, nets, and spears, and hand-collection of shellfish (Rountree & Davidson, 1997). People also possessed a detailed knowledge of local animal and plant species' uses and locations, and selected species for particular goals based on known chemical and structural characteristics. Notably, these communities organized themselves within a complex network of political relationships that extended from the Siouan-speaking, mountain-dwelling groups to the west, to the Iroquoian-speaking groups to the north, to the Algonquian- and Siouan-speaking groups to the south (Busby, 2010; Gallivan, 2016). Chief leadership and other social positions were matrilineally inherited, and kinship was/is an important organizing facet of life (Rountree & Davidson, 1997). Most communities practiced agriculture, although this was always in tandem with a hunting and foraging lifestyle and had varying degrees of intensity. Some areas had dispersed hamlets, while others had large centralized villages (Gallivan, 2016).

The archaeological assemblage of Late Woodland settlement on the middle and lower Delmarva Peninsula, first used to refer to the southern portion of Delaware and now extended to include the Eastern Shores of Maryland and Virginia, is referred to as the Slaughter Creek complex (Busby, 2010). This complex includes large permanent or semipermanent basecamps or village sites, Townsend Ware ceramics, triangular stone projectile points, and a unique combination of tool types and faunal remains (Busby, 2010). To the north, a "no-man's land" with a low density of sites has been noted between the Slaughter Creek complex sites and the Minguannan complex of sites in northern Delaware (Custer, 1984; Busby, 2010).

Several scholars have conceptualized the Delmarva peninsula as varying in socio-political "complexity," subsistence practices, and settlement patterns along a gradient from north to south (Busby, 2010; Rountree & Davidson, 1997). The northern groups were interpreted by Custer (1984) to be more complex because of the large secondary ossuary burials found there, and because "the necessary social environments for the development of more complex ranked societies" was not to be found on the lower peninsula (Custer, 1984, in Rountree & Davidson, 1997, p. 27). Now that archaeologists question the need for social hierarchy as a prerequisite for social complexity, these characterizations of the lower peninsula seem misguided or drawn from a simple lack of data. Rountree and Davidson (1997) claim that the sandy, dry conditions of the lower peninsula forced a dependence on horticulture greater than that in the upper peninsula, where wild deciduous nuts, seeds, berries, and freshwater roots and tubers were plentiful. While it is true that agriculture was probably used in the lower peninsula more than in other places in the region (Busby, 2010), and that these environmental differences are striking, this view may undervalue the quantity of food could be obtained from the estuarine systems easily accessible on both sides of the narrow lower peninsula.

Historical accounts identify the Accomac and Accohannock (also spelled Occohannock) peoples as the two dominant groups that occupied Virginia's Eastern Shore at the time of European contact (Rountree & Davidson, 1997). In Algonquian, these place names translate literally to "other side town/place" and "other side river," respectively (Gallivan, 2016, p. xxi). The Nassawaddox were a smaller group that belonged to either the Accomac or the Accohannock; the Accohannock were subject to the Accomac under a Confederation (Rountree & Davidson, 1997). The Accomac inhabited the southernmost area, while the Accohannock inhabited what is now Accomack County. These groups each had chiefs and were a part of the Powhatan paramount chiefdom, which was centered at Werowocomoco across the Chesapeake. In several instances, this alliance was broken or strained by the Accomac, but the relationship lasted at least into the early years of the 17th century (Busby, 2010). The Accomacs and Accohannocks, having direct access to the coast, produced *peake* (also *wampumpeake*; beads produced from clam and whelk shells) as part of their tribute to the Powhatan (Rountree & Davidson, 1997). The two tribes were held only loosely to their expected conduct (e.g. production of tribute, exchange of marriage partners, peaceful intent toward other groups) as tributaries (Busby, 2010).

John Smith counted 40 Accohannock men and and 80 Accomac men (more specifically, "warriors"); assuming a factor of four, this would translate to local populations of about 160-230 people (Busby, 2010). Because John Smith only traveled along the inlets and creeks on the Chesapeake Bay side of the peninsula, it is very possible that he missed a number of villages located inland or on the Atlantic side (Rountree & Davidson, 1997). Given that Smith would not have encountered all of the community members, these numbers are probably underestimates, and the groups may have had a fluid identity that extended to multiple hamlets across the landscape.

Although both archaeological and historical evidence of Native lifeways on the Eastern Shore are an important foundation for my study, these descriptions are often somewhat homogenizing. The nuanced differences that people experienced through their daily routines and practices, individual or community beliefs, and conceptual identities are often not captured in the archaeological or historical record. It should not be assumed that all Eastern Shore Late Woodland societies were the same, or that differences between groups on the Eastern Shore were smaller than the differences between mainland and Eastern Shore groups as a whole. For example, early colonists noticed differences between the James River dialect of Algonquian and the dialect spoken by the Accomac, but these differences were not larger than the differences between the lower and upper Eastern Shore dialects (Rountree & Davidson, 1997).

Several primary groups inhabiting the middle and northern Delmarva peninsula at this time were the Nanticoke, the Lenape, and the Wighcomoco (Pocomoke) (Busby, 2010). The Nanticoke were large in number, inhabited several recorded village sites, were allied to the Piscataway Chiefdom on the present-day Maryland mainland, and had a relatively hostile relationship with the Powhatan (Busby, 2010). Smaller, more transient groups included the Assawoman, the Gingoteague, the Kickotank, and the Assateague. While it may be tempting to view the Eastern Shore chiefdoms as having developed secondarily or in response to the mainland Powhatan Chiefdom, one line of evidence to suggest an independent development of a large tiered chiefdom on the peninsula is the mention in 1660 of a long-ago "emperor" on the Eastern Shore; although the tribe is not mentioned, this leader probably belonged to the Nanticoke (Rountree & Davidson, 1997, p. 29). It is likely that large chiefdoms developed in their own right on the Shore by at least the early 16th century (Rountree & Davidson, 1997).

European encroachment on the peninsula began with the Dutch and Swedish from the north, and the English from the south (Busby, 2010). English occupation began in the 1620s. Native communities knew about the Europeans long before this time, as many groups had encountered various Spanish and English groups in the 16th century, including a group of Spanish Jesuit missionaries that kidnapped an Eastern Shore boy in 1588 (Rountree & Davidson, 1997). It was not until the 1590s that Wahunsenacawh (the proper name of the paramount chief of the Powhatan people) expanded his territory all across Tsenacomacoh (loosely, "the land dwelt upon closely together," now known as Tidewater Virginia; Gallivan, 2016, p. 5), and intended to extend his control to the Eastern Shore. Rather than fight off the Powhatan, the Accomac and Accohannock agreed to become tributaries peacefully (Rountree & Davidson, 1997).

The old story of the transition from indigenous to European dominance across the landscape does not need retelling here, although several key aspects of this process on the Eastern Shore should be noted. First, the Accomac and Accohannock tribes never went to war with the English; second, there was only one, limited epidemic event of infectious disease in 1607 on the Eastern Shore (Rountree & Davidson, 1997). The idea that violence and disease wiped out the indigenous population in all places is misinformed. Instead, Accomac and Accohannock communities and individuals slowly lost access to central places of cultural activity and resource acquisition, became entangled in the colonial capitalistic economy of the fur trade and swidden agriculture, and endured their identities being systematically erased by colonial and U.S. government policies, many of which persist into the 21st century. Because discrete events did not mark major turning points for the Eastern Shore cultures, the process was gradual and is not often recognized in the typical discourse of Virginian tribal history. This is the case for many Middle Atlantic tribes that chose tactics other than violence to cope with colonialism. For the Monacans of the piedmont, this strategy was intentional avoidance of colonists (Hantman, 2018); for the Accomacs and Accohannocks, the strategy was assimilation and/or migration to the northern peninsula and Maryland mainland, where individuals were absorbed into other tribes (Busby, 2010). In other words, the strategy was to “hide in plain sight” (Accohannock Indian Tribe, Inc., 2017). Beginning in the mid-17th century, the Accomac became known as the Gingaskins and were granted a reservation by the colonial government in

Northampton County; this reservation became known as Indiantown, but was eventually broken up into privately owned parcels in the 19th century (Rountree & Davidson, 1997).

Despite the fragmentation of Native communities, many people retained contact with one another and preserved their cultural heritage. Today, the Accohannock Indian Tribe identifies descendance from the Accohannock people of the Eastern Shore of Virginia and Maryland, under the Accomac Confederation (Accohannock Indian Tribe, Inc., 2017). Since 2017 the Tribe has been recognized by the State of Maryland, but is not recognized by the federal government (Maryland Commission on Indian Affairs, 2017). Although the Accohannock Tribe is centered in Marion, Maryland, many members live and work in the original Eastern Shore homeland and have continued to pass on their clan names (Accohannock Indian Tribe, Inc., 2017). According to the Tribe's oral history, "the Clan Mothers prayed for peace and survival and received a vision to follow Pocahontas, to marry their daughters to the white colonists in order to hide in plain sight, survive and preserve the tribal bloodlines until in the fullness of time the tribe could be reborn" (Accohannock Indian Tribe, Inc., 2017).

V. Shell middens and previous archaeological work on Virginia's Eastern Shore

Shell midden sites are a widespread phenomenon across the region and the globe (Álvarez, Godino, Balbo, & Madella, 2011). The term "shell midden" may refer to any shell bearing site or feature, including monumentally tall mounds, horizontally extensive but low-relief sheet features, small sheet features, or shell-filled pits. These features are found in both archaeological and contemporary deposits, and are associated with a variety of activities and cultural associations (Álvarez, Godino, Balbo, & Madella, 2011). The term "shell midden" is often used indiscriminately, resulting in confusion when determining site use and deciding which data should be collected in order to support various lines of inquiry (Claassen, 1991). Many scholars have developed typologies to define what comprises a shell midden and its variations (Claassen, 1991). These classifications are often based on the ratio of sediment to shell or the density of shell per unit volume of sediment as a quantitative means of standardization (Claassen, 1991).

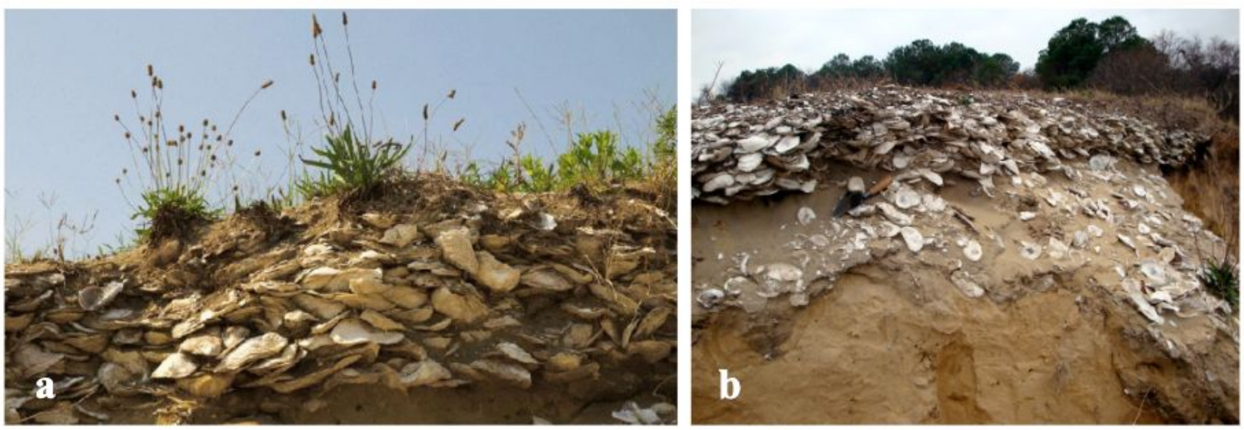
In the discourse of southeastern archaeology, the term shell midden usually refers to the monumental midden-mounds that are so visually pronounced on coastal landscapes of low relief (Thompson & Worth, 2011). Midden mounds may be over 10 meters tall and often have distinct ring or arc shapes, a form that suggests a variety of possible site functions (Thompson & Worth, 2011; Marquardt, 2010). The shells forming these mounds, and most other shell middens globally, were deposited as a result of food consumption (Álvarez, Godino, Balbo, & Madella, 2011), although there is some debate regarding criteria to distinguish southeastern mounds as trash middens (i.e. relatively passively deposited) versus constructed architectural works (Marquardt, 2010). Studies of shell middens are often used to demonstrate the breadth and diversity of coastal hunter-gatherer diets, such as those along the coasts of California and Japan (Álvarez, Godino, Balbo, & Madella, 2011).

Middens may serve other functions later in their occupational history, for example as elevated platforms on which ritual or domestic structures are built; this practice occurred in the southeast U.S. and along the southern coast of Brazil (Marquardt, 2010; Álvarez, Godino, Balbo, & Madella, 2011). The drainage qualities of shell piles make them excellent structures on which to build a house (Claassen, 1991). Burials are common features found within shell middens of the southeast U.S. and Australia (Ceci, 1984). Other activities, such as industrial processing of shellfish for the production of beads, dyes, ceramic temper, or tools, may result in midden formation (Claassen, 1991). Examples of these sites can be found along the coasts of India and the Mediterranean Sea (Álvarez, Godino, Balbo, & Madella, 2011; Claassen, 1991). Even when a midden is confidently identified as a result of shellfish consumption, it is not always clear whether the midden was a) part of a habitation site where shellfish consumption occurred every day, b) a processing site where shells were discarded but the meat was taken elsewhere for consumption, or c) a specialized, single-event site where people gathered only on certain occasions (Ceci, 1984).

Shell middens in the Middle Atlantic region tend to be less monumental than those farther south, but many remain visible on the landscape (Herlich, 2016). In other cases, middens may form shallowly buried strata that are discovered by archaeological survey or the modern tilling of fields for cultivation; this is usually the case on Virginia's Eastern Shore (Virginia Dept. of Historic Resources, 1975, 1989A-D, 1991). Whether or not these sites truly constitute "shell middens" or simply "shell bearing sites" according to various classification schemes (Claassen, 1991), they are recorded as "shell midden" in Virginia Department of Historic Resources (VDHR) site database; investigations are often not detailed enough to make the distinction. On the mainland of Tidewater Virginia, shell middens representing the Late Archaic, Early, Middle, and/or Late Woodland periods have been intensively excavated a) along the York River at the Kiskiack site and Werowocomoco, and b) along the Potomac River at the Gouldman Oyster Shell Midden site, the White Oak Point site, and the Plum Nelly site (Rick, Barber, Lowery, Wah, & Madden, 2015; Herlich, 2016). Many of these excavations have focused on recovering faunal and botanical remains, in which shell middens tend to be rich (Herlich, 2016).

This is true partially because the alkaline conditions created by addition of calcium carbonate to the soil are favorable for the preservation of organic matter (Álvarez, Godino, Balbo, & Madella, 2011), and partially because shell midden sites are usually the result of communal feasting activities during which a wide variety of both cultivated and foraged dishes were consumed (Herlich, 2016). Food remains from off-site feast celebrations and daily meals were likely discarded at these places as well, and shell middens might be associated with core settlement sites, smaller clusters of houses, and gathering and hunting sites (Busby, 2010).

Figure 3: Examples of Eastern Shore shell middens exposed by bluff erosion. a) Photo by Dave Harp (Lutz, 2011); b) photo by Torben Rick (Lavery, 2016). Exposure of the midden stratum by erosion allows for easy site identification along sand dunes, bluffs, and creek beds.



Archaeological testing of shell middens have been supplemented by ethnographic studies of shellfish foraging in various places of the world. Shellfish foraging was systematically documented among the Meriam people of the Eastern Torres Strait Islands by Bird and Bird (2000). The focus for this study was the foraging behavior of children, who have a consistently high level of involvement in marine subsistence activities across the globe (Bird & Bird, 2000). Unlike Algonquians, Meriam people generally encounter shellfish one by one and culled them on the spot (Bird & Bird, 2000). Children learn how to forage from other children, are experimental in their selection and processing methods, and choose a wider variety of species compared to adult foragers (Bird & Bird, 2000).

In Virginia, shellfish harvesting has been commonly marked up to a "starvation avoidance strategy" (Barfield & Barber, 1992, p. 226). While it's true that shellfish were foraged most intensively from fall to early spring and were relied upon as a protein source during lean winter and spring months (Claassen, 1986; Herlich, 2016), it is now recognized that this activity was important for more reasons than subsistence. Among Eastern Woodland people, shellfishing was one of many tasks carried out predominantly by women (Herlich, 2016), although other community members may have participated as well. In the southeastern tankscape, shellfishing was a daily activity that women balanced with other work, including management of cultivated crops, maintenance of fires for smoking fish, shellfish, and game, production of salt in places with salt spring flats, and the harvest and processing of raw materials to make textiles, ceramic vessels, jewelry, and tools (Herlich, 2016; Dumas, 2018).

Oysters were the dominant shellfish collected, and were roasted in fires or boiled in broth with flour, mussels, and other ingredients (Herlich, 2016). Oysters were preserved for long term storage by stringing them and hanging them to dry by smoking (Herlich, 2016). Shells were used as raw material for jewelry, ceramic temper, and tools, including a tool to shave hair (Herlich, 2016). Rick et al. (2016) tested changes in oyster shell size from archaeological deposits around the Chesapeake Bay over time; conclusions suggest that the Native oyster fishery was sustainably harvested over the course of millennia. The fishery was sustainable likely because a) oysters were hand-collected from fringing nearshore reefs instead of from deep-water reefs, maintaining a stable source of larvae to the system, and b) there was a tendency toward collection of medium-sized oysters (Rick et al., 2016).

Shell middens are sometimes associated with village sites (yielding more varied artifact assemblages) or with hunting and foraging sites (yielding less varied artifact assemblages) (Lowery, 2001). Most of the time, archaeological surveys do not categorize associated components because these components cannot be identified from surface observations alone; if artifacts are found on the surface, the site might be classified as "shell midden, artifact scatter" (VDHR, 2019). Qualitative differences have been observed between shell refuse sites on the Eastern Shores of Virginia and Maryland (Lowery, 2001). In Maryland, shell refuse sites tend to be denser in marine refuse and cultural debris than those found in Virginia in similar environmental contexts; this suggests that a cultural process may explain the differences in midden sizes and predictability between the two areas (Lowery, 2001).

Aside from those sites identified by local residents or during construction compliance investigations, archaeological sites on Virginia's Eastern Shore have been identified and recorded during three prominent survey events undertaken by Wittkofski (1988; survey carried out in 1982) and Lowery (2001, 2003). In 1920, Stevens identified 512 acres of the Sassafras sandy loam shelly phase soil type along the Atlantic coast of the peninsula (Wittkofski, 1988). Stevens described these areas as containing "a considerable quantity of shell fragments in both subsurface and subsoil. These are angular in shape, and their presence can only be attributed to bands of Indians hundreds of years ago, who congregated at these places and feasted on clams and oysters, leaving the shells on the shore. They are present in sufficient quantity to impart a rather distinct character to the soil" (Stevens, 1920, in Wittkofski, 1988, p. 78-79). Wittkofski's survey included ground verification of a sample of these locations identified by Stevens; all locations visited were shown to have prehistoric shell middens present (Wittkofski, 1988).

While Wittkofski's (1988) survey was designed to identify a representative sample of sites across three major environmental zones (including the Chesapeake forelands, the Atlantic forelands, and the upland spine), Lowery's (2001, 2003) surveys were designed to inspect the shorelines of both sides of the peninsula for visible archaeological sites and especially to identify those under threat of erosion. Lowery's (2001, 2003) surveys concluded that environmental processes, rather than cultural processes, play the dominant role in the observable archaeological record along shorelines, especially in cases where individual artifacts have been eroded from their primary context and deposited elsewhere, usually as a result of tidal action and storm energy (Lowery, 2001). Because some areas of the peninsula, particularly the northern and southern interior uplands, were not inspected during these events, there is a reasonable degree of bias to be expected in the locations of currently known sites.

Most shell midden sites on Virginia's Eastern Shore have not been tested for subsurface archaeological data. Exceptions include intensive salvage excavations at the Savage Neck Shell Midden site on the Chesapeake side of the peninsula (Rick, Barber, Lowery, Wah, & Madden, 2015), and a handful of sites that were subject to limited shovel-pit testing. Among the potential Late Woodland middens, these include sites 44NH310, 44NH326, 44NH329, 44NH337, 44AC019, and 44AC417 (VDHR, 1975, 1989A-D, 1991). The most important information gained from shovel-pit testing of these sites has been the starting and ending depths of the midden strata and any diagnostic artifacts found in the midden fill, usually ceramic sherds and occasional stone projectile points (VDHR, 1975, 1989A-D, 1991). The use of diagnostic artifacts is the most common way to date sites to the general time period; accelerated mass spectrometry (AMS) radiocarbon dating is a more reliable but expensive method, and is not usually available for routine site identification and recording.

The Savage Neck Shell Midden site, 44NH478, is by far the best documented shell midden on Virginia's Eastern Shore. The site dates to about 1100 B.C.E. in the Early Woodland period (Rick, Barber, Lowery, Wah, & Madden, 2015). Situated along and partially submerged into the Chesapeake, the midden is surrounded and covered by fine dune sand, and is backed by a wooded terrace with trees, grass, and shrubs (Rick, Barber, Lowery, Wah, & Madden, 2015). At the time of occupation, sea level was 3-4 m lower, and the shoreline was significantly farther away from the site (Rick et. al., 2015); the need for environmental reconstruction, as well as the loss of many sites during the formation of the Chesapeake Bay, makes Archaic and Early Woodland middens more difficult to assess for microenvironmental patterns across regions. The severely eroding nature of the site mobilized archaeologists to conduct intensive excavations in 2011 and 2012 (Rick, Barber, Lowery, Wah, & Madden, 2015). Findings included a lack of structures or storage features, trace amounts of fish and mammal bones, Meadowood stone projectile points, shell-tempered ceramic sherds characteristic of the Early Woodland period, and a variety of shellfish including oysters, clams, and scallops (Rick, Barber, Lowery, Wah, & Madden, 2015). The shellfish assemblage was consistent with the pattern followed across the Chesapeake region, in which Late Archaic and Early Woodland middens are more diverse in both richness and evenness of species, while Middle and Late Woodland middens are dominated by oyster shells (Rick, Barber, Lowery, Wah, & Madden, 2015). A human mandible and long bone were also found on the surface, although no burials were encountered during excavation;

this suggests the midden may have been used as a secondary burial site (Rick, Barber, Lowery, Wah, & Madden, 2015). AMS radiocarbon dating of marine shell, faunal remains, and charcoal from the midden fill confidently establishes the Savage Neck site as the earliest known shell midden on Virginia's Eastern Shore (Rick, Barber, Lowery, Wah, & Madden, 2015).

The Savage Neck site is an example of a midden that has remained intact except for erosional damage by tidal and storm action (Rick, Barber, Lowery, Wah, & Madden, 2015). This is not the case for all sites; indigenous shell deposits have been subject to extreme secondary transformation processes during the historical period, particularly in the 17th and early 19th centuries before the widespread adoption of imported agricultural fertilizers (Ceci, 1984). These secondary transformations have included mining of the midden fill for use as fertilizer or construction material, plowing and cultivation of the midden itself, or illegal looting by individuals in search of indigenous artifacts (Ceci, 1984). Archaeological survey, while usually able to date the midden content in terms of diagnostic artifacts, is often too limited to distinguish between primary and secondary formation processes, and this may lead to misidentification of primary midden site locations (Ceci, 1984).

Numerous concerns in the scope and design of archaeological survey on the Eastern Shore have limiting implications for this project, particularly because the environmental settings of known sites may or may not be representative of all Late Woodland shell middens. However, because a) local knowledge has supplemented systematic survey in site identification and mapping (Wittkofski, 1988; Lowery, 2001, 2003), b) shell middens have not been entirely relocated as a result of environmental or secondary cultural processes, and c) shell middens are more readily and confidently identifiable than village sites or camp sites without extensive excavation, I proceeded with my investigation of known shell midden locations without applying projections of potential site locations to the unsurveyed areas. Another concern is the extent to which estuarine microenvironments have changed over the past 1,000 years B.P. Although rough generalizations have been made to describe past conditions across the peninsula (e.g. Lowery, 2001), changes to the environment within the past 1,000 years are minimal compared to the changes that occurred, for example, between the Late Archaic and Middle Woodland periods. Unlike many Late Archaic through Middle Woodland sites, most Late Woodland sites have not (yet) been inundated as a result of sea level rise (Rick et al., 2014). The Late Woodland period was chosen partially to minimize the error in applying current environmental datasets to archaeological sites experienced in the past.

Methods

I. Data sources

Five primary geospatial datasets were used to contextualize shell middens on the Eastern Shore of Virginia, using the Virginia-Maryland state line and the peninsula's shorelines to delineate the study area. These datasets include site locations, soil type, land cover, elevation, and bodies of water.

The Virginia Cultural Resource Information System (V-CRIS) is a database maintained by the Virginia Department of Historic Resources (VDHR) that houses information on historic and archaeological site locations and attributes (VDHR, 2019). These data are available to the public as an interactive web map at the VDHR archives in Richmond, and are available via a Geographic Information System (GIS) Web Feature Service (WFS) to those who apply for a license (VDHR, 2019). Because the WFS contains restrictions on the number of records that may be queried or exported at once, the web database and the WFS were used together to extract sites of interest. The V-CRIS web database was queried for archaeological sites that a) had a site type classification of "shell midden" (or some combination of "shell midden" and other site types), b) included a Native American cultural affiliation, and c) contained a known or potential Late Woodland component (i.e., contained "Late Woodland" or "prehistoric; unknown" designation). The resulting list of 55 sites was used to manually identify, select, and export site polygons from the V-CRIS WFS layer in ArcMap version 10.6 (ESRI, 2018).

The map of known Late Woodland shell middens was overlaid with datasets describing basic environmental variables. These included a classified raster land cover dataset (Richardson and Shao, 2014)[1], soil type polygons (Natural Resources Conservation Service, 2019), a high-resolution digital elevation model created using Light Detection and Ranging (LiDAR) methods, (Virginia Information Technologies Agency, 2011), and hydrographic area delineations (U.S. Census Bureau, 2017).

II. Data exploration and preparation

Using the Calculate Slope and Zonal Statistics tools (ESRI, 2018), the maximum slope of the ground surface at each shell midden site was measured in order to assess whether middens produce a specific relief signature in the DEM. A kernel density map was created for site polygon centroids in order to visualize the distribution of known sites across the peninsula.

Using manual selection and the Calculate Geometry tool, the shorelines of hydrographic areas were roughly classified into four categories (tidal creek, lagoon, Chesapeake Bay, and

[1] The land cover classification was created over twenty years ago and would not be a reliable source of information for an analysis of ecological phenomena occurring today. Because this analysis concerns archaeological sites, the datedness of the dataset is not a major issue; a land cover dataset describing the current conditions and the 1993 dataset would contain similar error regarding to conditions 1,000 years B.P.

Atlantic Ocean shorelines; see Figure 4c). The measured length represented by each shoreline category was divided by the total shoreline length to yield the approximate percentage represented by each category[2] (Table 5). The Calculate Geometry and Raster Attribute Table tools were used to determine the percentages of the total land area represented by each land cover and soil type categories (Figures 4a, 4b; Tables 3, 4). Excluding open water and areas for which no data are available, the land cover dataset contains 10 total categories, while the soil dataset contains 19 total categories (Tables A-2, A-3; some categories have subcategories). The expected number of middens to be found in each category, assuming a random distribution of middens across the peninsula, was calculated by multiplying $n = 55$ by the proportion of land area (for land cover and soil group) or shoreline (for water feature) represented. The exact test of goodness of fit is most appropriate when each category has an expected frequency ≥ 1 (Cochran, 1954). In order to meet this requirement, land cover and soil type categories were combined to yield a condensed total of 5 and 4 categories, respectively[3] (Figure 4; Tables 3, 4).

Using manual entry and the Zonal Statistics as Table tool, all shell midden sites were classified according to a) the land cover group representing the majority of the area within each site polygon, b) the soil group representing the majority of the area within each site polygon, and c) the nearest water feature (i.e. shoreline category) to the site. Midden occurrence was counted by category for each of these three variables (Figure 4; Tables 3, 4, 5).

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[2] Shoreline percentages are a rough approximation rather than a confident estimate, and for this reason were rounded to the nearest 10%.

[3] Soil type categories were combined to represent generalized hydrologic soil groups. These four groups (A, B, C, and D) are defined based on their drainage potential, with group A soils having the least runoff and group D having the most (Natural Resource Conservation Service, 2007). The soil types in the study area fell into four categories: group A, group B, group A/D, and group B/D. Land cover categories were combined according to a different scheme used by the VCR LTER (1993). Categories were combined according to culturally/experientially relevant, rather than purely ecological, characteristics (Table A-2).

Figure 4: Environmental variables used to categorize shell midden sites. The original 11 land cover categories were re-classified into 5 groups (Table A-2). The original soil types were combined by hydrologic soil group (Table A-3). Shorelines were roughly classified to measure tidal creek, lagoon, bay, and ocean components. (Data Sources: Richardson and Shao, 2014; National Resource Conservation Service, 2019; U.S. Census Bureau, 2017).

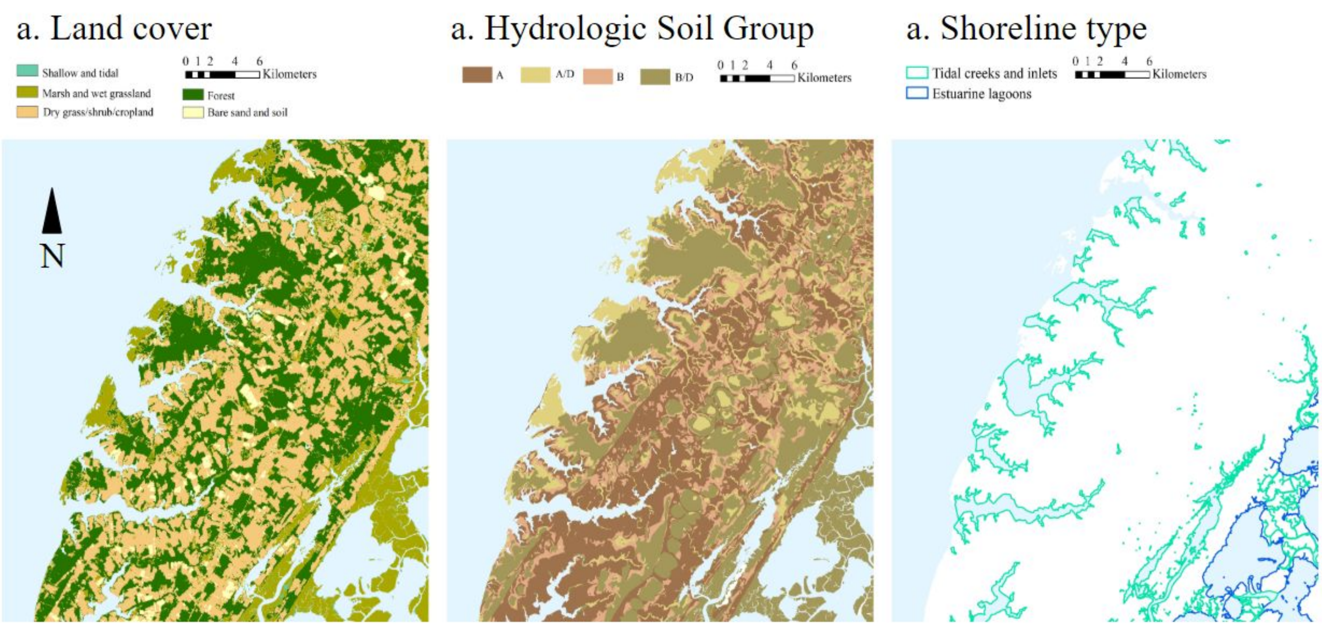


Table 3: Midden frequencies by land cover.

The original ten land cover categories represented in the data were combined in order to yield five condensed categories (Table A-2. Land cover at each midden was identified as the category representing the largest area within each site polygon, and middens were counted by category. Observed counts are also reported as relative frequencies, i.e. the percent out of 55 total middens. Expected frequencies reflect the percentage of total peninsula area represented by each category. Expected counts were estimated from expected frequencies.

Category: Land cover type	Observed count	Expected count	Observed frequency (%)	Expected frequency (%)
Shallow water, tidal flats and bars	2	3	3.64	5.14
Marsh and wet grassland	16	12	29.09	22.05
Cropland, grassland, and shrub/scrub	25	18	45.45	32.81
Forest (including evergreen and mixed deciduous)	10	20	18.18	36.77
Bare sand/soil	2	2	3.64	3.24

Table 4: Midden frequencies by water feature.

Middens were categorized by identifying the nearest water feature to each site polygon. Middens were counted by category. Observed counts are also reported as relative frequencies, i.e. percent out of 55 total middens. Expected frequencies represent the approximate percentage of total peninsula shoreline bordered by each water body; because the precision of this process was low, these values were rounded to the nearest 10%. Expected counts were estimated from expected frequencies.

Category: Water feature	Observed count	Expected count	Observed frequency (%)	Expected frequency (%)
Tidal creek	30	33	54.55	60
Coastal lagoons	19	16	34.55	30
Chesapeake Bay	4	3	7.27	5
Atlantic Ocean	2	3	3.64	5

Table 5: Midden frequencies by hydrologic soil group.

Middens were categorized by identifying the specific soil type (Table A-3) and hydrologic group occupying the greatest area within each site polygon. Middens were counted by soil group category. Observed counts are also reported as relative frequencies, i.e. the percent out of 55 total middens. Expected frequencies reflect the percentage of total peninsula area represented by each category. Expected counts were estimated from expected frequencies.

Category: Hydrologic soil group	Soil types included	Observed count	Expected count	Observed frequency (%)	Expected frequency (%)
A	AsE, AtD, BhB, BkA, BoA, FhB, FmD, FrB, MoB, MoD, SeA, UpD, BeB[4]	37	19	67.27	34.94
A/D	AhA, AmA, CaA, DrA, McA, PoA	3	6	5.45	10.56
B	MuA	6	9	10.91	15.85
B/D	ChA, MaA, NmA	9	21	16.36	38.66

[4] While soil type BeB (beaches) is not explicitly included in hydrologic group A (National Resource Conservation Service, 2019), it was included in group A for this analysis because this group traditionally includes sand.

III. Exact multinomial tests of goodness of fit

Three goodness of fit tests were conducted, one for each environmental variable. Tests were conducted using the XNomial package in R (Engels, 2015A-B, R Core Team, 2019). The exact multinomial test of goodness of fit considers *n* observations (*n* = 55 shell midden sites), each of which falls under one of *k* types (for example, land cover categories) (Engels, 2015B). Each type is associated with an expected probability that the observation might fall under that category. The assumptions and hypotheses of the test are the following (Engels, 2015B; McDonald, 2014; Cochran, 1954):

A. Each observation is independent[5]

B. The same set of hypothesized probabilities is true for each observation

C. Each category has an expected observation count ≥ 1[6]

H_0: There is no difference between observed midden distribution amongst categories and how middens might be distributed according to random chance (i.e., midden occurrence aligns with the proportions of area represented by each category on the landscape).

H_a: The observed site distribution amongst categories deviates significantly from that which may be expected from random chance.

If one were to calculate all of the possible outcomes of how 55 shell middens may be distributed amongst the categories of a particular environmental variable, what is the probability that shell midden contexts would deviate from their expected distribution, assuming that the null hypothesis is correct? The test generates all of these possible outcomes and calculates this

[5] This assumption is violated as a result of spatial autocorrelation and the biases of past archaeological surveys in the study area; because of this violation, the analysis proceeded with caution.
[6] This assumption is not always used, but was used as an assumption here because it strengthens the credibility of the test results (Cochran, 1954).

probability exactly; this is what sets the exact test apart from the chi-square test of goodness of fit, which uses a pre-existing distribution to calculate the p-value (Engels, 2015). In this way the exact test is preferable to the chi-square test when the sample size is small (McDonald, 2014). The exact test may use one of several p-value options to evaluate the result (Engels, 2015). These include a) the simple probability of the outcome occurring under conditions of a true null hypothesis, and b) the ratio of that probability to the probability of the hypothesis occurring under conditions of a true alternate hypothesis; this is referred to as the likelihood ratio (LLR) (Engels, 2015B). The likelihood ratio is preferable to the outcome probability because it captures the relative nature of the test, in which outcomes are compared to one another (Engels, 2015B).

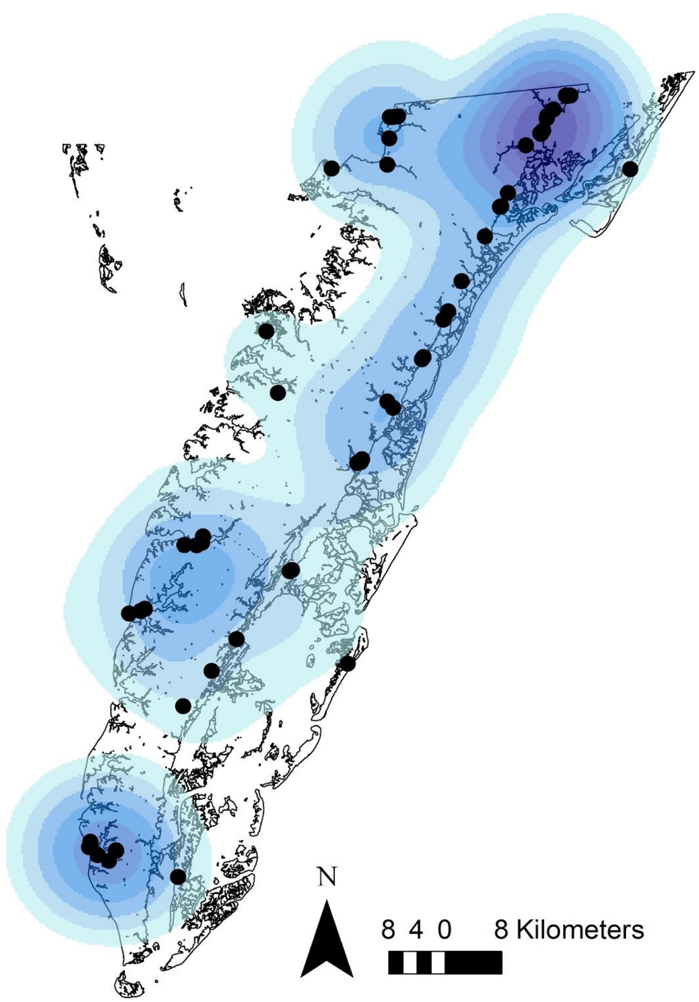
If the null hypothesis is rejected, this would support the existing evidence that shell midden locations are the result of cultural processes that are non-random with respect to each environmental variable, and that midden locations are indicative of meaningful patterns in how indigenous people used space. While the basic premise that cultural processes are non-random should come as no surprise, testing the particular distribution that shell midden sites take on may help identify the factors that contributed to how these places were chosen and experienced by Late Woodland people.

Results

I. Kernel density mapping

The 55 known or potential Late Woodland sites are distributed in an uneven fashion across the peninsula; several prominent trends can be noted by mapping these sites. Shell middens are clearly found along the edges of the peninsula, near shorelines, as opposed to the upland spine that runs along the center (Figure 5). On the Chesapeake side, middens appear to be clustered around major tidal creek systems, while on the Atlantic side, middens appear more dispersed or linearly arranged. Only two known or potential Late Woodland shell middens lie on barrier islands that protect the coastal lagoons from the Atlantic Ocean, including Chincoteague Island and Hog Island; most shell middens are located on the mainland. The midden cluster with the highest density of sites is located along the tidal creeks and coastal lagoons of the northwestern shoreline, along Chincoteague Bay (Figure 5).

Figure 5: Kernel density map of known and possible Late Woodland shell midden sites. Highest site density occurs along the shoreline and tidal creeks adjacent to Chincoteague Bay. (Data source: VDHR, 2019).



II. Site relief characterization

The maximum slope values of each shell midden follow a random distribution with no clear center beyond ~10 degrees (Figure 6). Shell middens do not appear to produce a reliable signature in terms of relief on the ground surface; for this reason this method was not pursued further for remotely identifying potential undocumented midden sites. Future efforts may include the development of a kernel to identify such locations, although other datasets than elevation may prove more fruitful for this technique, since Eastern Shore middens are shown to have relatively low relief with a wide range of variation in maximum relief (Figures 6, 7).

Figure 6: Shell midden maximum slope values. (n=55) The histogram of maximum slope values shows that most middens are not completely flat, but are relatively low in relief.

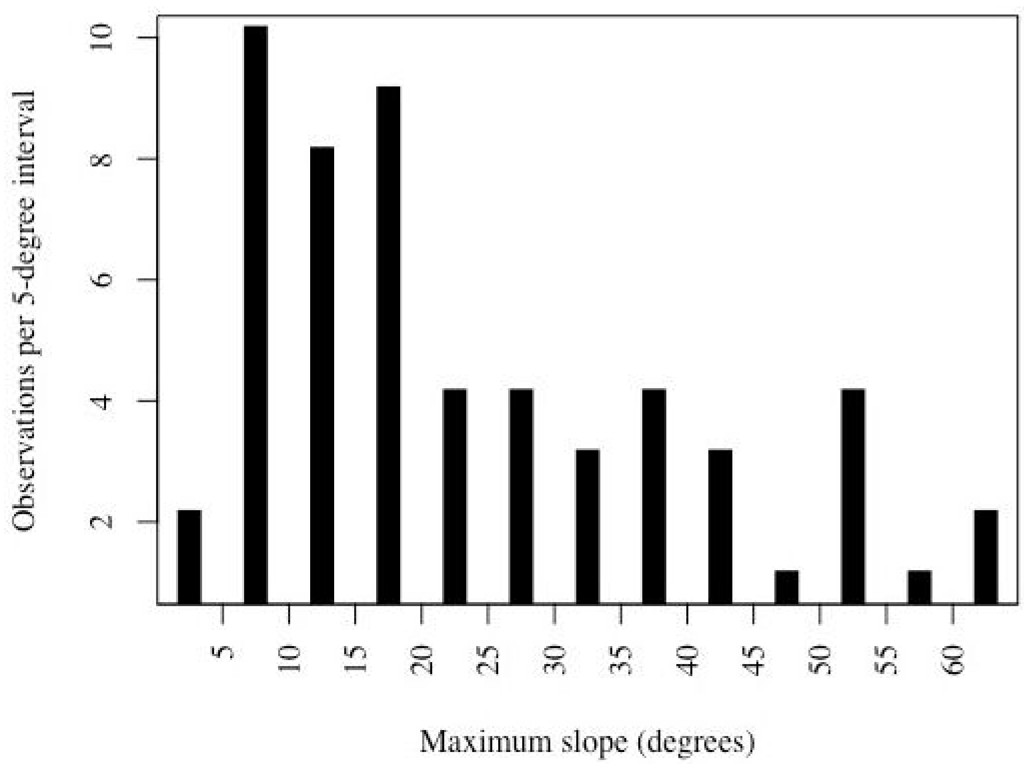
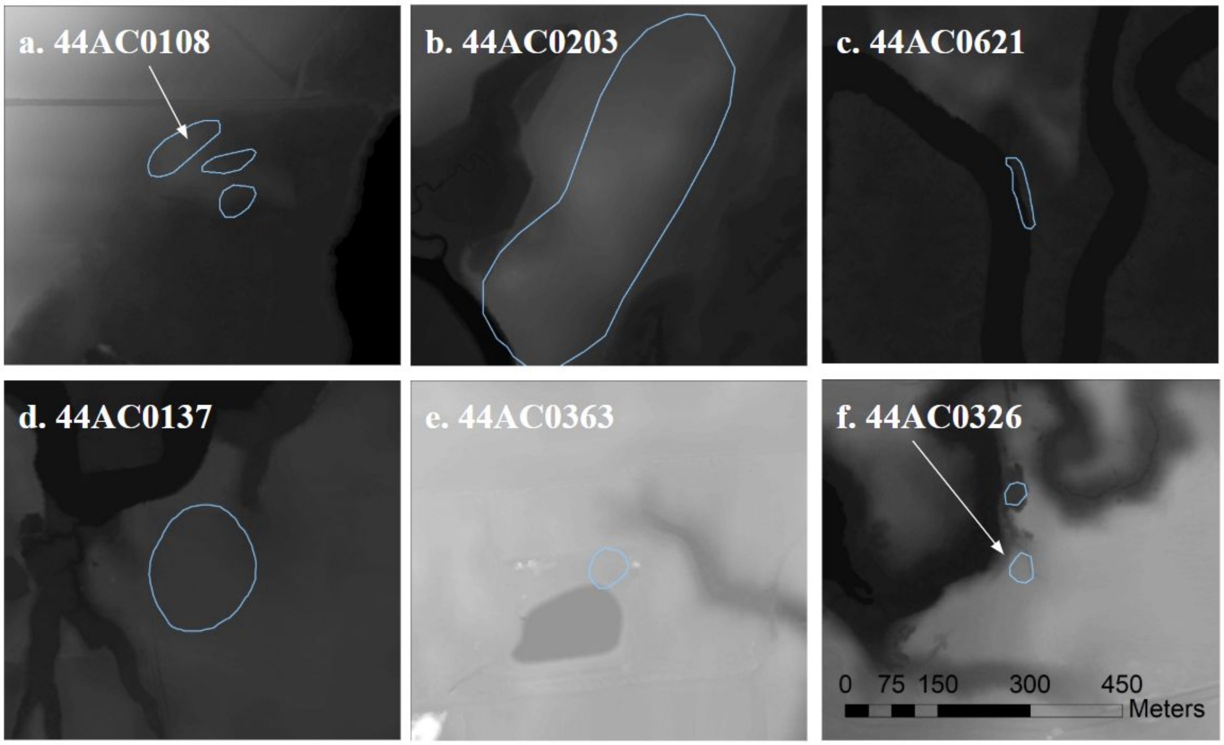


Figure 7: Six randomly selected shell midden site polygons shown with ground elevation data. Although several sites show high degrees of relief, many shell midden sites are not from the DEM alone. Map scale applies to all images. (Virginia Information Technologies Agency, 2011; VDHR, 2019)



III. Goodness of fit tests

The goodness of fit tests yielded p-values <0.05 for the environmental variables of land cover and soil group (Table 6). For these variables, the null hypothesis was rejected, and there is evidence that micro-ecological conditions (on the scale of tens of meters) played a role in selection of shellfish processing, consumption, and/or feasting locations over the last 1000 years. The test for water features resulted in a high p-value, and the null hypothesis was not rejected (Table 6); this is evidence that communities had no strong preference for or avoidance of certain water bodies over others for shellfish feasting or processing activities. These results should be interpreted cautiously, since past surveys have targeted the shorelines rather than the interior of the peninsula, since agriculture has altered land cover since the Late Woodland period, and since this analysis did not take into account the intrinsic covariation of the variables tested. In addition, α is by nature an arbitrary value, and in cases such as the land cover results for which the p-value is very close to 0.05 (Table 6), the distinction between rejecting and failing to reject the null hypothesis becomes less useful. In light of these limitations, the most confident goodness of fit test result is the insignificance of differing water bodies or shoreline types (and their unique resource assemblages) to the occurrence of shell middens, while proximity to any given water body appears to be a dominant factor in site choice (Figure 5). In other words, the experiences associated with proximity to the water itself may have been more important for site choice than the availability of particular resource assemblages found in the water nearby.

Table 6: Goodness of fit test results.

The exact multinomial test of goodness of fit was conducted using the XNomial package in R (Engels, 2015A-B). The LLR p-value was used to assess the test result at α = 0.05.

Variable tested	**P-value (LLR)**	**Null hypothesis rejected?**
Land cover	0.046	Yes
Water feature	0.712	No
Soil group	1.87×10^{-5}	Yes

Discussion

The correlation between well-draining soils and archaeological sites in the Mid-Atlantic is well known by cultural resource management professionals (D. Dutton, personal communication, March 1, 2019). It makes practical sense to construct a village on a spot that will not retain standing water. The same pattern is shown to be true for shell midden sites on the Eastern Shore, and supports the idea that middens were places where people spent significant amounts of time. While well-draining locations were chosen (whether over the course of moments or centuries) as spots to construct villages, hamlets, camps, or social gathering spaces (e.g. shell middens), this doesn't mean that poorly drained places lacked activities of cultural significance. For example, historical accounts describe a "ritual in the swamps" undertaken in 1742 by the Nanticoke, to the north of the Accohannock (Rountree & Davidson, 1997; Busby, 2010). The event's purpose was to "make a new leader." This involved gathering men, women, and children from multiple Eastern Shore groups together, organizing a hunting party to retrieve deer skins, and consuming a "liquor," probably the "blank drink," brewed by a medic or shaman (Busby, 2010). This ritual or set of rituals coincided with the planning of the uprising against the English in coordination with the French, the Shawnee, and the Seneca Indians, an effort that was suppressed by the colonists; to this end the gathering also included war dances and the stockpiling of munitions and arrows (Busby, 2010).

Rountree (1998) has asserted that researchers must reach beyond English colonial documents and utilize ethnographic analogy if they are to truly understand Accomac and Accohannock lifeways. Colonial officials did not gather information about Algonquian people out of scientific inquiry or curiosity. Instead, they essentially surveilled Native cultures for information that might pose threats or offer advantages to the colonial project. With this interest in mind, Englishmen focused on recording and reporting Algonquian politics, wars, and religious practices. Gender norms likely prevented in-depth interviews and observations of Native women as well. In this way, women, the people responsible for foraging and transporting most of the shellfish that make up midden sites, operated farther below the colonial radar than others.

Because different resources were distributed widely across the landscape, women had a busy traveling schedule and had ready access to canoes and paddles (Rountree, 1998). The skeletons of women that were interred at protohistoric sites in Virginia are often more robust than men's, showing clearly that women carried out physically strenuous tasks on a daily basis (Rountree, 1998). Women's labor (agriculture, canoe travel, shellfishing, root digging, flour pounding, digging and transporting clay, and building houses) did not align with the typical Western interpretation of Algonquian women as domestically oriented. Since women were responsible for building new houses, it's likely that they were the ones to decide where those houses went (Rountree, 1998). Locations of ceremonial activity may have been guided by men, who managed the ceremonial sphere and occupied the roles of shamans and medics (Rountree & Davidson, 1997).

Eastern Shore shell middens are associated with grassy, marshy, and/or scrub-shrub covered areas, characterized by openness and visibility rather than dense forest. Coastal meadows with similar characteristics can be found in British Columbia and are discussed by Deur, Turner, Dick, Sewid-Smith, and Recalma-Clutesi (2013). These places were the sites of extensive estuarine gardens where women and others cultivated edible roots. The gardens were maintained by weeding, soil modification and aeration, and transplanting roots within and between plots. Plots were situated in relation to distant mountain peaks; using multiple peaks, one can navigate to a plot or identify the name of a plot. Because the coastal meadows were among the few open, broad sites requiring less effort to clear, they were in demand by Anglo-Canadians and became sites of intense displacement and fragmentation of indigenous communities.

Today, efforts by members of the Kwakwaka'wakw Nation to reclaim or reoccupy estuarine meadows are ironically blocked by conservationists and government policies in order to preserve them as natural areas (Deur, Turner, Dick, Sewid-Smith, & Recalma-Clutesi, 2013). These policies "preserve" something that never existed, because the meadows have been fundamentally *un*natural (i.e., occupied and altered) for at least several centuries prior to Anglo-Canadian arrival. In this way misguided visions of pristine nature continue to perpetuate the exclusion of indigenous voices from resource stewardship practice. Despite these challenges, clan members continue to cultivate roots on small scales and hold recurring root feasts at Kingcome Village.

One obvious reason why coastal meadows were valued by Native and European communities alike was access to waterways. Rivers, creeks, and other water bodies have long been used globally as a means of labor-efficient transportation. In the Chumash and other societies of the northwestern Pacific coast, large, sturdy vessels were used to hunt whales and other marine life on the open ocean; participation in these hunting trips is a male rite of passage (Arnold, 1995). Canoe owners charged fees for transporting people, and canoes were used to haul large amounts of goods to potlatch ceremonies; the announcement of feasts, marriage proposals, and potlatch ceremonies to other communities was dependent on canoe travel (Arnold, 1995). These practices are interpreted to show the significance of water transportation to the development of social hierarchy in and amongst these communities (Arnold, 1995).

Anglo-Americans often use waterways as boundaries; for Late Woodland people, waterways were connective rather than divisive, and villages often spanned both sides of a stream or tidal creek (Rountree & Davidson, 1997). Most shell middens on the Eastern Shore are located along tidal creeks (Table 5); because the creeks have convoluted shorelines that penetrate inland, they represent the greatest percentage of total shoreline on the peninsula. Shell middens do not show a distribution that deviates significantly from that expected based on shoreline length estimates; the high number of middens associated with tidal creeks is likely an effect of proportional shoreline length, rather than cultural preference. This suggests that Late Woodland people did not select gathering locations based on locations of particular resource assemblages; instead, accessibility and spiritual ideas associated with water were probably more important factors.

Indigenous southeastern mapmakers used circles to represent communities across the landscape, with the mapmaker always located in the center (Gallivan, 2016); the most famous example of this is probably Powhatan's Mantle, a well preserved deerskin dating to the early seventeenth century. The mantle shows the Powhatan surrounded by 34 tributary towns, represented as circles of embroidered *Marginella* shell beads (Gallivan, 2016). The Kickotank chief drew circles in the sand to explain the locations of other Native groups to English colonists (Busby, 2010). Other historical accounts give examples of circles featuring prominently in ceremonial rites, dances, and the mainland Algonquian creation story, which tells of a Great Hare creating a circular world containing land, water, fish, and a deer god (Gallivan, 2016). The Hare created four more gods occupying the four winds (the cardinal directions; Busby, 2010), and these hunted and consumed the deer. The Lenape creation myth tells how a great tortoise created land by lifting its back out of the waters that covered Earth; in this story, water and earth are two prominent elements mediated by the deity (Busby, 2010). The world is distinguished into levels, including the upper sky world, the middle world (earth), and the underwater world (Busby, 2010).

Place names are usually relational in nature and use the orientation of land and water together to describe a place, pointing to “the salience of a waterborne frame of reference that viewed places from the perspective of a canoe moving through the Chesapeake estuary” (Gallivan, 2016, p. 55). Many Algonquian place names end in “locating” suffixes, including “-omoco” (a “bounded enclosure or encircled place”) and “-anient” (“on a path or trail”) (Gallivan, 2016, p. 53).

In most ranked Middle Atlantic societies, eastness is associated with life, while westness is associated with death; deities are believed to reside in the west, and the soul travels to the west following death (Busby, 2010). The individual expressions of this belief system vary from society to society, especially with regard to temple and burial axis orientation (Busby, 2010). While the souls of chiefs and priests also traveled to the west after death, it was believed that these individuals would eventually be reborn in the east; for this reason these individuals and their material wealth were placed, before or after the bones were naturally defleshed, in above-ground structures called quiankeson houses (sometimes referred to as charnel houses) (Busby, 2010). While these structures and the remains they contained are not easily identifiable in the archaeological record, there is evidence that quiankeson structures associated with the Nanticoke town of Chincone tended to be placed to the east of the town, toward the interior of the peninsula (Busby, 2010).

Quiankeson site locations were intentionally chosen because of their status as thresholds to the spiritual world, places physically endowed with Manitou, the animating force that may be accessed differentially across the landscape (Busby, 2010). Manitou can be considered a presence that heightens the ease of communication between the animated, i.e. spiritual, and tangible worlds. Dreaming or receiving visions from manitouwak, the spirits or lesser deities that inhabit certain places endowed with Manitou, was a means of communication with the animated realm (Creese, 2011). Young men on the Eastern Shore completed a rite of passage in which, after fasting, they were driven by the community into the interior forest in order to obtain visions (Busby, 2010). Certain places were more conductive to these visions (Busby, 2010). If the boy was particularly successful in receiving visions from spirits, he could become a candidate for training as a shaman or priest, since manitouwak held the secrets critical to these roles, especially regarding medicine (Creese, 2011).

For the Algonquian societies of the far north, the places most saturated with Manitou were those where the distinct levels of the world (underground, underwater, earth, and sky) intersected (Creese, 2011). In these places, manitouwak reside in steep cliff faces and rocks, onto which symbolic narratives were carved. A picture of these sacred locations is painted by Rajnovich (1994, p. 35, in Creese, 2011, p. 10):

> The Algonkian universe was layered with Sky, Earth, Underwater and Underground being distinct worlds connected in places such as deep lakes, whirlpools, caves and crevices where a man or manitou [i.e., a priest who has died and transformed into a spiritual entity] could travel from one realm to another. The places where these realms meet, such as the base of a lakeside cliff where sky, earth and water and underground touch, was the 'home of the manitous'.

While there are no cliffs, caves, or whirlpools to be found on Virginia's Eastern Shore, places where land and water intersect are abundant. In the north, manitouwak also resided in the banks of rivers running through broad, open prairies (Creese, 2011). Busby (2010, p. 419) uses the endowment of the landscape with Manitou to distinguish between the symbolic and mundane landscape on the Eastern Shore:

> Supra-village sacred locations embodied the qualities of the other worlds-- high spots, and low, marshy areas and areas close to the water. Here the three realms of the cosmos converged. The concept of 'thresholds' has been applied to such places where humans and other-than-humans communicated and crossed between the different worlds through physical, spiritual, and social transformations… These places served as spatial correlates of Manitou where it mediated the connections between different levels of experiences, between the different worlds.

These places of particularly high or low ground where water was enmeshed with land seem to have served the purpose of social gathering, whether for feasting in the open clearings along the shorelines and marshes, or for leadership initiation rituals amidst interior freshwater swamps. On the lower Shore, shell middens tend to be located on open grassy or shrub-covered sites, along shorelines, with views of both water and land, sometimes semi-encircled by the forest behind. Despite analytical limitations, applying northeastern Algonquian notions of manitou provides insight into shell middens as socially and spiritually important places for Late Woodland Eastern Shore communities.

While some shell middens remain visible on the ground surface today, many are buried below other strata and do not show a consistent pattern in the maximum degree of relief as calculated from elevation data (Figure 7). However, other possible methods for identifying shell-bearing sites remotely remain to be explored. Cook-Patton, Weller, Rick, and Parker (2014) showed conclusively that 100-1000 year old shell middens on the Chesapeake Bay significantly alter soil nutrient conditions, which then affects the vegetative communities found growing on these sites. Specifically, the elevated nutrient conditions created by the release of calcium ions results in greater vegetative cover, a shift from woody species to herbaceous and grass species, and a higher species richness (Cook-Patton, Weller, Rick, & Parker, 2014). These characteristics may be used to refine or correct the recorded boundaries of known sites, which were often delineated based on limited survey methods, and have been prone to systematic error as they were repeatedly retraced without georeferencing into each successive database maintained by VHDR (D. Dutton, personal communication, March 1, 2019). If ground survey of vegetative communities around these sites is not available, there is a possibility that multispectral and multitemporal Landsat Thematic Mapper (TM) satellite imagery could be used to identify plant community composition remotely; this method has been developed specifically for the forested wetlands for the southeastern United States (Townsend & Walsh, 2001).

Because relatively less work has been devoted to the Eastern Shore compared to mainland Virginia, there are many questions that remain to be tested. If future intensive excavations on the Shore incorporate shell midden sites, the selected sites should meet the following criteria. Currently eroding and vulnerable sites should be given first preference, since many of these sites will soon be lost to the effects of climate change. The selection should include middens on both sides of the peninsula and along shorelines facing both east and west, enabling comparisons to be made that potentially relate to the directional cosmology of Late Woodland people. Excavations should involve the Accohannock Indian Tribe and the public in some way, as part of the continuous effort to decolonialize archaeological practice (Gallivan, Moretti-Langholtz, & Woodard, 2011). Local policymakers should be informed of the opportunities these places represent for public education, environmental advocacy, and providing an additional motivation to conserve wetlands and forested storm buffer zones.

Conclusion

The spatial heterogeneity found across the Shore plays a well-known role in supporting high levels productivity and ecological diversity. Thinking about coastal hunter-gatherer societies typically relies on the relationship between this ecological diversity and resource availability. For example, Arnold (1995, p. 735) discusses the role of ecotone convergence in the emergence of social hierarchy in the Pacific northwest:

> This means that quantitatively more habitat is available to exploit across a given area, which permits efficient exploitation of a wide range of resources by logistically organized collectors (Binford, 1980). Such convergence of habitat areas begins with the land-sea interface and its range of both terrestrial and aquatic products within short distances of coastal residential bases. These include pelagic, kelp bed, sandy and rocky intertidal, estuary, riparian, grassland, and other resource zones.

While its true that the resource assemblages available to a given culture have important influences on that culture, focusing on this facet of Native lifeways alone is somewhat dehumanizing and may even lead to incorrect interpretations of site location and purpose, especially when socially and spiritually significant activities took place on those sites. The embodiment of places with Manitou is not based on how dense the nearby oyster beds are or how many waterfowl prowl through the marsh, but instead on a nuanced set of cosmic beliefs. These beliefs led people to choose and return back to certain places over others, where their activities performatively reaffirmed the meanings and memories associated with those landscapes. The goodness of fit tests, especially that for the variable of nearest water body, support the interpretation that the experience of water itself was a more important factor in site location than the immediate availability of particular resource assemblages. Shell middens represent a unique opportunity to improve the visibility of Virginia's indigenous culture, and encourage land conservation in a way that allows Native reclamation of symbolic places.

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Appendix A

Table A-1: Shell midden sites and characteristics.

See Tables A-3 and A-4 for land cover type and soil type keys.

FID	Land Cover Type	Water Feature	Soil Type	FID	Land Cover Type	Water Feature	Soil Type
44AC296	5	Lagoon	BkA	**44AC205**	5	Lagoon	MuA
44AC122	5	Lagoon	BkA	**44AC109**	5	Lagoon	MaA
44AC133	5	Tidal creek	BkA	**44AC108**	5	Lagoon	MaA
44AC115	5	Tidal creek	BkA	**44AC558**	3	Tidal creek	ChA
44AC137	11	Tidal creek	BkA	**44AC620**	3	Tidal creek	McA
44AC034	4	Tidal creek	UpD	**44AC621**	7	Tidal creek	AmA
44AC081	5	Lagoon	BoA	**44AC623**	3	Tidal creek	McA
44AC110	5	Lagoon	MaA	**44AC628**	3	Tidal creek	McA
44AC044	3	Lagoon	MoD	**44AC642**	4	Chesapeake	AmA
44AC118	4	Lagoon	MaA	**44NH337**	3	Tidal creek	BoA
44AC015	5	Lagoon	BoA	**44NH075**	3	Tidal creek	BkA
44AC036	3	Lagoon	ChA	**44NH235**	3	Lagoon	ChA
44AC080	11	Lagoon	MuA	**44NH056**	8	Atlantic	FrB
44AC302	4	Tidal creek	BkA	**44NH326**	7	Tidal creek	MoD
44AC203	5	Tidal creek	BkA	**44NH310**	5	Tidal creek	MoD
44AC075	5	Lagoon	BoA	**44NH053**	7	Lagoon	MuA
44AC037	8	Tidal creek	MaA	**44NH0167**	5	Chesapeake	BoA
44AC143	4	Tidal creek	BkA	**44NH194**	4	Tidal creek	BkA
44AC173	5	Tidal creek	BhB	**44NH329**	7	Tidal creek	MoD
44AC165	5	Tidal creek	MoD	**44NH044**	2	Tidal creek	ChA
44AC042	5	Lagoon	BkA	**44NH368**	7	Tidal creek	BoA
44AC014	2	Chesapeake	McA	**44NH048**	5	Tidal creek	BoA
44AC206	5	Lagoon	BkA	**44NH058**	5	Tidal creek	BoA
44AC008	3	Lagoon	BeB	**44NH047**	5	Tidal creek	BoA
44AC019	5	Tidal creek	MoB	**44NH363**	5	Tidal creek	BoA
44AC299	5	Lagoon	BkA	**44NH134**	7	Tidal creek	BkA
44AC135	5	Tidal creek	BoA	**44NH362**	8	Chesapeake	BoA
44AC417	7	Atlantic	FrB				

Table A-2: Original and recombined land cover type categories.

Original land cover categories were re-combined in order to meet assumptions for the exact test of goodness of fit. Categories were combined according to experiential, rather than purely ecological, characteristics. (Richardson & Shao, 2014)

Land cover type	**Land cover type code**	**Recombined category code**	**Expected frequency (%)**	**Observed frequency (%)**
Shallow water, tidal flats and bars, wet sand, exposed shoals and mud flats	2 / 10	1	5.14	3.64
Salt marsh	3	2	15.56	18.18
Brackish, freshwater marsh, wet grassland, irrigated cropland	4	2	6.50	10.91
Grassland, cropland, lawns, some reed marsh	5	3	30.12	45.45
Shrub/scrub marsh, shrub-cedar thicket (transition zone)	6	3	2.69	0.00
Evergreen forest (pine and red cedar)	7	4	15.30	12.73
Mixed forest (pine-hardwood, Myrica shrub)	8	4	19.61	5.45
Deciduous forest (hardwood)	9	4	1.86	0.00
Bare sand and soil (beaches, shell, tilled cropland)	11	5	3.24	3.64

Table A-3: Individual and grouped soil types.

Individual soil types are grouped according to drainage capacity (Natural Resource Conservation Service, 2007, 2019).

Soil type	Soil type code	Hydrologic group	Expected frequency (%)	Observed frequency (%)
Arapahoe mucky loam	AhA	A/D	1.94	0.00
Arapahoe-Melfa complex	AmA	A/D	1.07	3.64
Assateague sand, Assateague fine sand	AsE, AtD	A	0.46	0.00
Beaches	BeB	A	1.10	1.82
Bojac loamy sand, Bojac sandy loam, Bojac fine sandy loam	BhB, BkA, BoA	A	27.78	49.09
Camocca fine sand	CaA	A/D	1.26	0.00
Chincoteague silt loam	ChA	B/D	18.59	7.27
Dragston fine sandy loam	DrA	A/D	3.83	0.00
Fisherman fine sand	FhB	A	0.58	0.00
Fisherman-Assateague complex	FmD	A	0.32	0.00
Fisherman-Camocca complex	FrB	A	1.45	3.64
Magotha fine sandy loam	MaA	B/D	0.94	9.09
Melfa-Hobucken complex	McA	A/D	5.58	7.27
Molena loamy sand	MoB, MoD	A	3.76	10.91
Munden sandy loam	MuA	B	10.56	5.45
Nimmo sandy loam	NmA	B/D	18.04	0.00
Polawana mucky sandy loam	PoA	A/D	2.16	0.00
Seabrook loamy sand	SeA	A	0.10	0.00
Udorthent and Udipsamment soils	UpD	A	0.49	1.82