

## Addressing the problem of disappearing cultural landscapes in archaeological research using multi-scalar survey

Dylan S. Davis , Katherine E. Seeber & Matthew C. Sanger

To cite this article: Dylan S. Davis , Katherine E. Seeber & Matthew C. Sanger (2020): Addressing the problem of disappearing cultural landscapes in archaeological research using multi-scalar survey, The Journal of Island and Coastal Archaeology

To link to this article: <https://doi.org/10.1080/15564894.2020.1803457>



Published online: 27 Aug 2020.



Submit your article to this journal [↗](#)



View related articles [↗](#)



View Crossmark data [↗](#)



## Addressing the problem of disappearing cultural landscapes in archaeological research using multi-scalar survey

Dylan S. Davis<sup>a</sup> , Katherine E. Seeber<sup>b</sup> , and Matthew C. Sanger<sup>c</sup> 

<sup>a</sup>Department of Anthropology, The Pennsylvania State University, University Park, Pennsylvania, USA;

<sup>b</sup>Department of Anthropology, Binghamton University, Binghamton, New York, USA; <sup>c</sup>National Museum of the American-Indian, Washington, DC, USA

### ABSTRACT

Climate change and anthropogenic activities are actively destroying the archaeological record. The dramatic disappearance of archaeological landscapes becomes particularly problematic when they are also unrecorded. Hidden from view and eroding, these disappearing landscapes likely hold answers to important anthropological questions. As such, disappearing landscapes present a major challenge for twenty-first century archaeology. Left unchecked, this phenomenon will increase the severity of bias in our knowledge of the past. In this paper we use a case study from Pinckney Island in the American Southeast to illustrate how the problem of hidden and disappearing landscapes can be addressed through multi-scalar surveys. Specifically, by combining aerial LiDAR, pedestrian survey, and micro-artifact approaches, the identification of hidden and disappearing cultural materials (including permanent settlements and ephemeral artifact scatters) can be alleviated.

### ARTICLE HISTORY

Received 29 March 2019



Accepted 27 July 2020

### KEYWORDS

Climate change; cultural heritage; multi-scale analysis; hidden landscapes; disappearing landscapes; South Carolina

Recent studies illustrate (e.g., Evans et al. 2013; Freeland et al. 2016; Masini et al. 2018; Quintus et al. 2015) that there is a “hidden” archaeological record (*sensu* Bintliff, Howard, and Snodgrass 1999). When destructive forces act upon hidden cultural deposits, this material becomes the “disappeared”, whereby parts of the archaeological record are damaged, limiting our capability to learn new information. Climate change is resulting in greater risks to the preservation of archaeological materials, especially in coastal and island regions where sea levels and erosion rates are rising (Erlandson 2008, 2012; Reeder, Rick, and Erlandson 2012; Reimann et al. 2018).

Coastal and island environments are critically important for understanding human adaptive cycles and resilience in response to external pressures (see Bradtmöller et al. 2017; Douglass and Cooper 2020; Louwagie et al. 2006; Thompson and Turck 2009; Turck and Thompson 2016; Walker et al. 2004), and the field of historical ecology, in particular, has long addressed human adaptations to environmental perturbation in marine contexts (e.g., Aswani 2019; Balée 2006; Braje and Rick 2013; Brooks 1985; Crumley 1994; Drew 2005; Erlandson et al. 2005; Fitzpatrick and Keegan 2007; Kirch and Hunt 1997; Swetnam, Allen, and Betancourt 1999; Kittinger et al. 2015). The study

**CONTACT** Dylan S. Davis  [dsd40@psu.edu](mailto:dsd40@psu.edu)  Department of Anthropology, The Pennsylvania State University, University Park, PA 16802, USA.

of coastal archaeological sites, specifically, can improve our understanding of how humans respond to environmental changes with a deep-time perspective, and this information can then be applied to contemporary situations (Douglass et al. 2019; Douglass and Cooper 2020; Kittinger et al. 2015; also see Davis 2019b; Kelly 2016).

In this article, we discuss disappearing landscapes, which result in the permanent loss of cultural materials. Using a case study from Pinckney Island in the American Southeast—whose coastal heritage is increasingly at risk of disappearing (Anderson et al. 2017)—we demonstrate how multi-scalar surveys utilizing aerial and ground-based approaches provide one solution for studying disappearing materials.

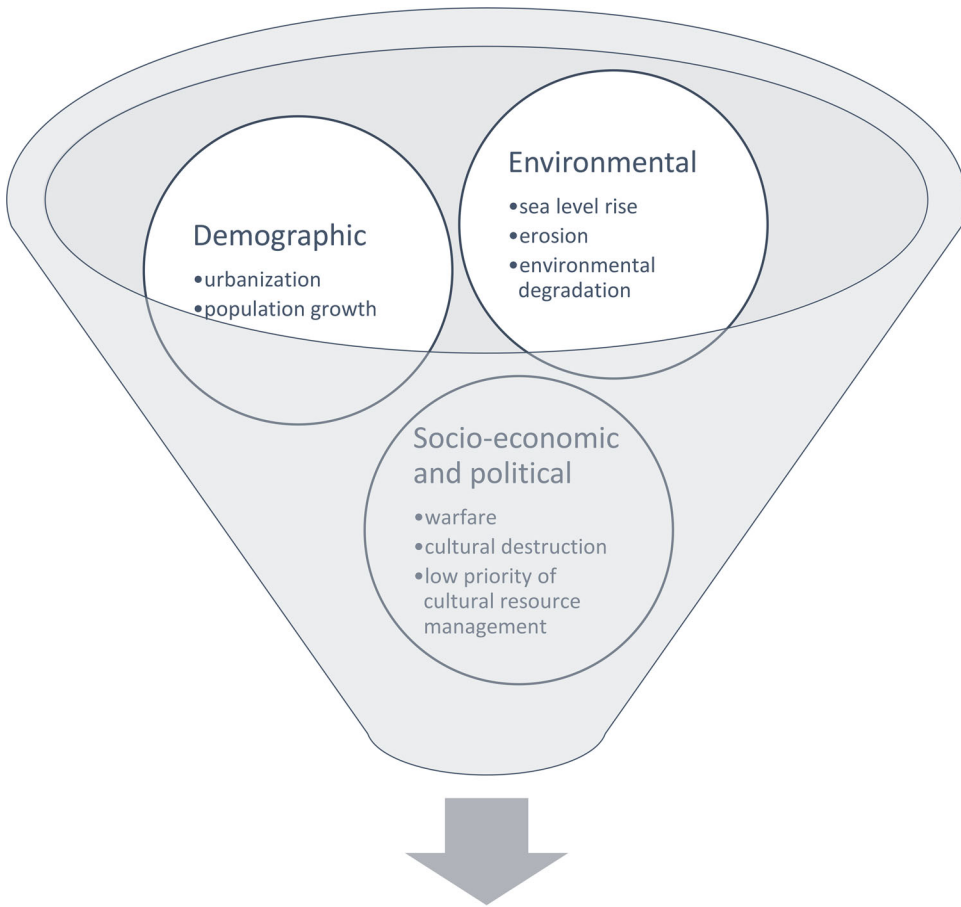
## The disappearing landscape

In 1999, Bintliff and colleagues coined the term “hidden landscape” to describe parts of the archaeological record that have avoided investigation. Hidden landscapes result from visibility issues, limits on survey locations, and the differential experience of field archaeologists, among other factors (Bintliff, Howard, and Snodgrass 1999; Hawkins, Stewart, and Banning 2003; Schiffer, Sullivan, and Klinger 1978; Schon 2002) and bias our understanding of the archaeological record. Equal to—and arguably more problematic—are *disappearing landscapes*; parts of the archaeological record that are actively being damaged (Figure 1). When hidden and disappearing components overlap, unstudied cultural materials risk permanent erasure.

Coastal regions are particularly vulnerable to urban development, which has been driving heritage destruction for over a century (Al-Houdalieh and Sauders 2009; Byram 2009; Ceci 1984; Cleere et al. 1984; Randall 2014; Rowland and Ulm 2012), because of the economic appeal of coastal property. Environmental forces also take a toll on cultural heritage. Erosion and inundation of coastal sites caused by sea level rise are a constant threat to the coastal archaeological record (Erlandson 2008, 2012; Fitzpatrick, Kappers, and Kaye 2006; Hilton et al. 2018; Hollesen et al. 2018; Marzeion and Levermann 2014; Reeder, Rick, and Erlandson 2012; Reimann et al. 2018; Westley et al. 2011). Thousands of archaeological sites around the world are below sea level (Bailey, Harff, and Sakellariou 2017; Faught and Gusick 2011; Flemming 1983) and this number will continue to rise with sustained sea level increases.

## The hidden and the disappearing

The major difference between hidden and disappearing landscapes is scale (Figure 2). Hidden components are obscured and are harder to recognize than other more pronounced objects (Bintliff 2000; Bintliff, Howard, and Snodgrass 1999), but are ultimately still identifiable. In contrast, disappearing landscapes consist of actively damaged known and hidden components of the record. Thus, disappearing landscapes themselves can be broken into two types: known and disappearing (KAD) and hidden and disappearing (HAD). In HAD landscapes, obscurity compounded by active erosion often prevents identification because materials are at a much smaller (possibly even microscopic) scale. Such facets may not retain any structural properties, which archaeologists often look for as evidence of human occupation.

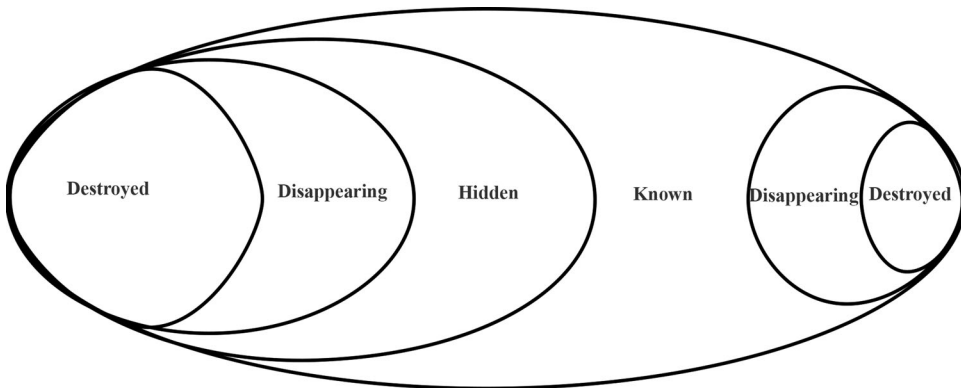


## Disappearing Landscapes

**Figure 1.** Variables culminating in a disappearing archaeological landscape.

As such, the major change brought by disappearing landscapes is a shift in investigative scale. Viewing this problem through the lens of scalar change also provides potential solutions. One longstanding limitation of archaeology is that researchers tend to associate specific types of assemblages with equally particular kinds of deposits. For example, the term “site” ultimately favors high-density (large-scale) deposits over low-density (small-scale) deposits (Dunnell and Dancey 1983), thereby biasing our understanding of spatial distributions of human activity. However, due to depositional processes, HAD components often lack macro-scale structures that are usually associated with a “site” typology. Thinking about the concept of disappearing landscapes requires the modeling of such processes to refine expectations of what sites will look like post-deposition (see for example Magnini and Bettineschi 2019), and subsequently identify methods that can capture these cultural expressions.

One solution to this problem lies in multiscale analyses. When thinking about archaeological landscapes, especially relating to settlement distributions, we must consider



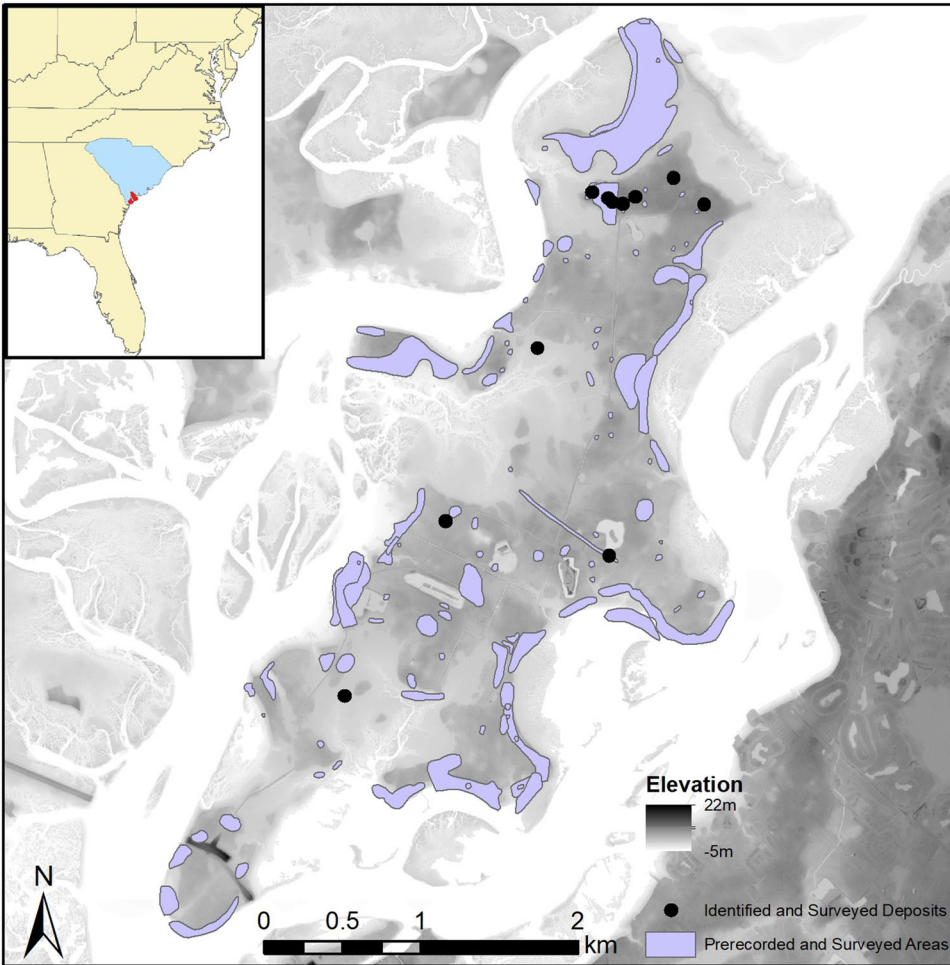
**Figure 2.** Diagram demonstrating known and disappearing (KAD) and hidden and disappearing (HAD) components of the archaeological record. We have the total archaeological record, demonstrated by the largest, all-encompassing ellipse. Then we have the known portion of the record, and those known sections that are disappearing (KAD) or already destroyed. On the other side we have the hidden record, which also has components that are disappearing (HAD) and already destroyed.

both the visible and hidden archaeological records, which in some instances are subtle or microscopic traces that are easily overlooked using traditional survey methods. Thus, the specific problem posed by HAD landscapes requires an intensive process to result in identification, including a combined strategy of aerial, ground, subsurface, and/or microscopic sampling. Below we describe our efforts to record these site types in South Carolina in the Southeastern United States.

### Recording HAD landscapes using multiscalar analysis in the American Southeast

Eastern North America contains a vast archaeological record, a dominant component of which are mounded constructions (Anderson 2012; Marquardt 2010; Russo 2006; Sanger and Ogden 2018). While mounds have long been the focus of archaeological investigation (Ford and Willey 1941; Moore 1894; Squier and Davis 1848), many such features remain hidden (Davis, Lipo, and Sanger 2019a, Davis, Sanger, and Lipo 2019b; Johnson and Ouimet 2014; Witharana, Ouimet, and Johnson 2018). Mounds have provided insight into demographic change, human-environmental interaction, social organization, and site formation in this region (Anderson 2012; Brennan 1977; Claassen 1986; Davis et al. 2020; Lightfoot and Cerrato 1989; Peacock and Rafferty 2013; Peacock, Rafferty, and Hogue 2005; Reitz 1988; Sanger et al. 2019; Thompson et al. 2016). However, the coastline of eastern North America, with its gently sloping bathymetry and extensive watersheds that lead to the ocean, is at high-risk of becoming a disappeared landscape, as sea levels continue to rise (Anderson et al. 2017; NOAA (National Oceanic and Atmospheric Administration) 2015; also see Mississippi River Delta Archaeological Mitigation (MRDAM) Consortium [<https://userweb.ucs.louisiana.edu/~mar4160/mrdam.htm>]).

Pinckney Island (Figure 3), located in Beaufort County, South Carolina, provides an excellent opportunity to evaluate the utility of multiscalar survey for uncovering HAD landscapes. The area has been extensively surveyed and over 100 archaeological sites have been recorded (Charles 1984; Kanaski 1997; Trinkley 1981). However, sea level rise



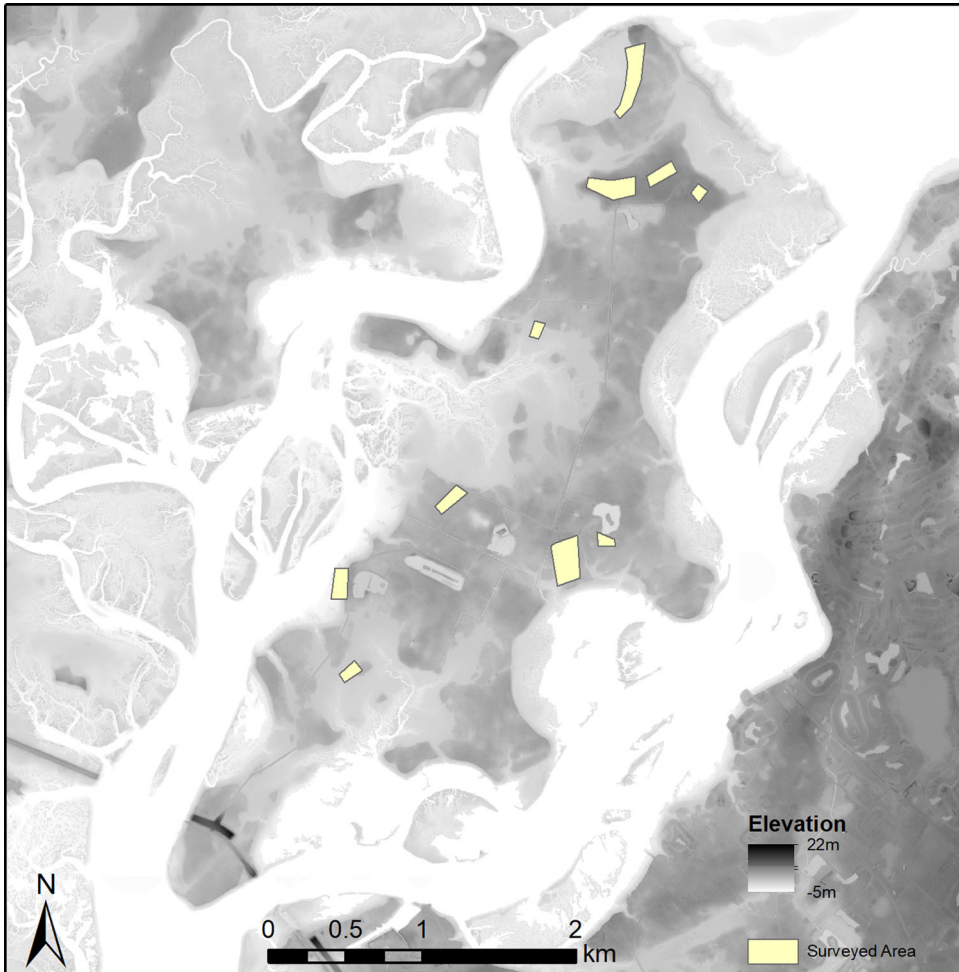
**Figure 3.** Locations of cultural deposits identified during surveys and previously identified sites on Pinckney Island, SC. Many visited locations contained a mounded feature detected by LiDAR, while others contain artifact scatters located while on the ground. Most locations contained both types of deposits. Locations of previously surveyed/identified areas acquired through the South Carolina State Archaeological Database (accessed May 2018).

and erosion continue to impact the archaeological record in this area (Kanaski 1997). The effects of depositional forces are noticeable while surveying the coasts of Pinckney Island, as midden deposits are actively eroding and weathering. As such, we can assess the degree to which traditional surveys identify archaeological deposits and the improvements that can be offered by multiscale strategies.

### **Methods**

As part of a larger project involving the use of automated remote sensing methods, Davis, Lipo, and Sanger (2019a, Davis, Sanger, and Lipo 2019b) conducted a LiDAR (light detection and ranging) survey to locate mound deposits and associated cultural materials in Beaufort, South Carolina. LiDAR data are produced by a sensor that emits electromagnetic





**Figure 4.** Locations of ground surveys conducted during October of 2017. Several of these areas revisited previously surveyed locations (see [Figure 3](#)), while others had not been previously investigated.

energy (i.e., light) and records the return times of each light pulse to calculate distance. By measuring the return times of multiple light pulses simultaneously, LiDAR data can capture ground surfaces, even in densely vegetated localities (Jensen 2007). While often prohibitively expensive, LiDAR is freely available for most of the Eastern U.S. coastline from the National Oceanic and Atmospheric Administration (NOAA).

To record hidden and disappearing landscapes on Pinckney Island, we undertook two phases of survey. The first phase was the automated analysis of LiDAR datasets to identify mound features (see Davis, Lipo, and Sanger 2019a, Davis, Sanger, and Lipo 2019b for a detailed discussion). We analyzed freely available LiDAR data from NOAA with a spatial resolution of 1.2 m using object-based image analysis (OBIA). OBIA is a form of machine learning where features are identified based on spectral and morphological information (Davis 2019a). Mounds, in this case, were identified on the basis of elevation change, morphological properties, and textural differences with the surrounding landscape (Davis, Lipo, and Sanger 2019a).



**Figure 5.** A previously unrecorded mound feature identified on Pinckney Island, according to the South Carolina state archaeological database (accessed May of 2018). (A) the mound as seen in LiDAR data; (B) the mound as seen on the ground during survey. It is clear that identifying the mound is difficult due to vegetation and limited ground visibility, but with the aid of LiDAR, the feature can be located. Shell material and historic tabby and glass were found throughout this area. Photo (B) taken by Dylan Davis.





**Figure 6.** Previously unrecorded mound (indicated by the red arrow) located in the marshes of Pinckney Island. Site could only be accessed during low tide. Photo taken by the author.

The automated LiDAR survey aided in identifying the largest scales of human activity (i.e., mounds). However, because the LiDAR used cannot easily identify smaller scales of activity around mound structures, ground-based pedestrian survey was needed to:

- (1) confirm the archaeological nature of these identified structures; and
- (2) locate smaller deposits of artifacts (i.e., ceramics, lithics, etc.) that would signify extended human use.

Following the identification of mound features on Pinckney Island, targeted ground surveys were conducted at areas containing detected mounds and their adjacent areas. In total, ground surveys covered approximately 0.25 km<sup>2</sup> (Figure 4). While some of these locations contained previously investigated areas, our goal was to survey outside of previously studied localities (Figure 3). We recorded all materials identified but left them *in situ* so as not to further damage these deposits. Together, the LiDAR and ground surveys provided two scales of analysis (regional and local) of the landscape.

## Results

Many of the mounded features identified in LiDAR were extremely subtle, and without prior knowledge of the presence of these objects, the vegetation would have obscured them from view (Figure 5). In fact, several locations surveyed had evaded detection by decades of previous investigation according to the South Carolina Archaeological Site Files. Other deposits were located in marshland where conducting systematic ground survey is difficult (Figure 6). At each confirmed archaeological deposit identified in LiDAR, smaller artifacts were usually located nearby. Such materials ranged from ceramics and glass to marine shells and tabby (a building material made by burning oyster shells) (Table 1).

**Table 1.** Materials identified by LiDAR and ground survey on Pinckney Island in October, 2017.

Feature ID	Material identified in LiDAR	Size of LiDAR detection	Material identified during ground survey
2	Anthropogenic mound	20m x 16m	Marine shell
16	Anthropogenic mound	17m x 13m	Ceramic, marine shell, historic bottles, tabby
19	Natural topographic rise	15m x 15m	Marine shell
20	House clearing	15m x 15m	Historic house structure, marine shells
22	Refuse pit	5m x 5m	Historic roadway, fence posts, modern refuse
26	Natural topographic rise	15m x 7m	Faunal remains
28	Anthropogenic mound	15m x 15m	Glass, ceramic, marine shell
29	Midden	20m x 20m	Marine shell fragments, ceramics, tabby, corded tree
31	Midden	15m x 15m	Marine shell fragments, ceramics, tabby

This list contains only those areas that contained anthropogenic materials, as other locations were investigated that yielded no artifacts. Even in locations where LiDAR misidentified a feature, cultural materials were still sometimes recovered nearby.

Ground-testing of deposits identified in LiDAR revealed five previously unrecorded archaeological deposits, dozens of recorded features on Pinckney Island (see Davis, Lipo, and Sanger 2019a), as well as cultural deposits consisting of shell and ceramics that did not fit within any currently included site boundaries (Figure 3). Overall, semi-automated LiDAR analysis identified 80 features within Pinckney Island and the true positive detection rate during ground-survey and evaluating the state archaeological site files was 75%. However, the LiDAR data had too few data points (4 per m<sup>2</sup>) to identify objects smaller than a few meters in diameter, leaving many artifact scatters undetectable. Ground survey was able to identify nearby artifacts to these larger mound constructions, helping to map the extent of human activity in these areas (Table 1).

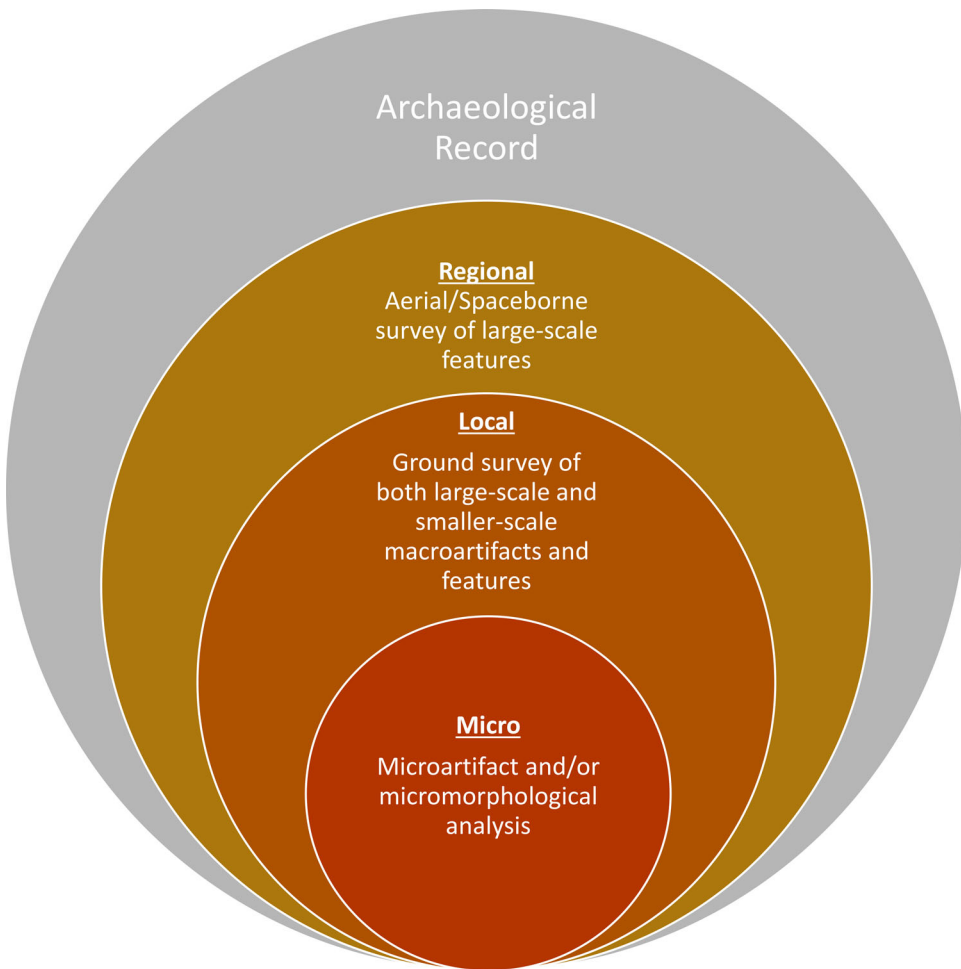
Our case study indicates that landscape-scale remote sensing data, in conjunction with smaller-scale ground-survey, allows for the identification of:

- (1) previously unrecorded archaeological features;
- (2) hidden components of the landscape at risk of disappearing; and
- (3) smaller scales of cultural activity (evidenced by shell debris, ceramic sherds, lithics, glass, and metal) that represent the disappearing cultural landscape of Pinckney Island.

## Discussion

The case study illustrates how disappearing archaeological landscapes can be recorded using multiple scales of analysis. While LiDAR (regional-scale) methods successfully identified new and prerecorded mounded architectural structures, surface scatters where larger deposits used to be were likewise identified on the ground nearby aerially detected features (local-scale). This includes several large middens which, because of coastal erosion, did not produce an elevation profile great enough for the LiDAR to detect. Using these case studies as a framework, we can think about the ideal research strategy for studying HAD landscapes as a multi-tier process of continuously decreasing scale (Figure 7).

Remote sensing provides the ability to systematically evaluate large-scales ( $X > 1$  m), helping to identify dominant cultural materials. However, for subtle traces of cultural material, these large-scale approaches must be supplemented with ground-based studies of materials (exceptions include Chiabrando et al. 2018; Herrmann et al. 2018; Orengo



**Figure 7.** An illustration of how the study of HAD landscapes can be improved. Each subsequent method fills in gaps of the previous, and thus they are not overlapping circles, but plugs to an otherwise empty space in our knowledge of the past.

and Garcia-Molsosa 2019). Recently, archaeologists used kayak surveys to extend coastal investigation along Eastern North America, recording many HAD archaeological sites (Reeder-Myers and Rick 2019). For those disappearing components of the record, which consist of small ( $1\text{ m} > X > 2\text{ mm}^1$ ) to-microscale ( $X < 2\text{ mm}$ ) traces, only through systematic sampling of survey locations can we hope to identify these deposits.

While our study stopped at macro-artifacts, much could be gained from micro-artifact analysis. For example, a study in Kentucky emphasized that micro-artifacts tend to occur in higher densities and present more reliable evidence of buried surfaces than macro-artifact scatters (Johnson, Pritchard, and Poplin 2016; Schiffer 1987). Johnson, Pritchard, and Poplin (2016) demonstrate how the use of micro-artifacts can be used to both include and exclude sites from the National Register of Historic Places (NRHP) in the United States. Specifically, they show how micro-artifacts help to affirm site integrity and spatial organization, identify lithic processing strategies, and even provide insight into gendered activities (Johnson, Pritchard, and Poplin 2016:48).

Using microscale approaches, we can think of disappearing landscapes as a *permanent change in scale of the archaeological record*, whereby we move from dominant landscape features to subtler (sometimes microscopic) scale features. Thus, in a “perfect” study of an archaeological landscape, all three levels of investigation (regional, local, and micro) will be present to alleviate extant biases at other scales. In our study on Pinckney Island, only two of these scales were utilized (regional and local). The inclusion of micro-analysis would help to determine important site characteristics (e.g., locating living surfaces [Shahack-Gross 2011], intentional manipulation of environmental surroundings [Friesem et al. 2016], etc.), and is important for preserving the cultural history of at-risk areas like coastal South Carolina. Microscale methods make it possible to restructure our expectations of cultural remnants toward identifying ephemeral or otherwise degraded sites, where only slight traces remain (see Friesem et al. 2016).

## Conclusions

We demonstrate how the problem of HAD landscapes can be alleviated using multiscale research designs. Researchers should also take other steps to address the issues posed by the disappearance of the archaeological record. Increased collaboration between researchers and local communities, for example, is critical. Collaborations with local communities can provide new sources of funding (Simpson and Williams 2008) and information (including the locations of unrecorded cultural sites) which are vital for improving scholarly knowledge of the past (e.g., Colwell 2016; Guilfoyle and Hogg 2015; Gallivan and Moretti-Langholtz 2007). Such abilities are essential in the race to document disappearing cultural landscapes.

Ultimately, climate change is increasing risks to the preservation of archaeological material, especially in coastal and island regions. Over a decade ago, Jon Erlandson (2008, 169) wrote:

Island and coastal archaeologists cannot afford to stand idle as the long and diverse history of maritime cultures around the world is lost to sea level rise and accelerating erosion ... We need a concerted, collaborative, and global effort to bring the problem to the attention of resource managers, government leaders, and the general public ... In coastal regions around the world, we need to accelerate our own efforts to inventory, investigate, and interpret the history of endangered coastal sites before it is lost forever.

Since then, climate-change related threats have only grown (see IPCC 2018). Nonetheless, coastal archaeologists have also been improving the techniques they use for recording the archaeological record at landscape scales using remote sensing technologies (e.g., Davis 2019a; Davis, Sanger, and Lipo 2019b; Freeland et al. 2016). Documenting and studying these at-risk sites thus becomes one of the fundamental challenges for archaeologists in the twenty-first century.

## Acknowledgements

We want to thank Scott M. Fitzpatrick and the anonymous referees who provided invaluable feedback on earlier drafts of this manuscript. We also thank the staff of Pinckney Island, especially Richard Karnaski, for allowing us access and providing background information.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Note

1. 2 mm is the threshold for microartifacts according to Dunnell and Stein (1989).

## Funding

Funding for surveys in South Carolina was supported through National Geographic Grant Reward Number HJ-107R-17 and Binghamton University. DSD was supported by the National Aeronautics and Space Administration under Grant No. NNX15AK06H issued through the PA Space Grant Consortium.

## ORCID

Dylan S. Davis  <http://orcid.org/0000-0002-5783-3578>

Katherine E. Seeber  <http://orcid.org/0000-0002-3869-3725>

Matthew C. Sanger  <http://orcid.org/0000-0002-0553-8809>

## References

- Al-Houdalieh, S. H., and R. Sauders. 2009. Building destruction: The consequences of rising urbanization on cultural heritage in the Ramallah province. *International Journal of Cultural Property* 16 (1):1–23. doi:10.1017/S0940739109090043
- Anderson, D. G. 2012. Monumentality in eastern North America during the Mississippian period. In *Early New World monumentality*, ed. R. L. Burger and R. M. Rosenwig, 78–108. Gainesville: University Press of Florida.
- Anderson, D. G., T. G. Bissett, S. J. Yerka, J. J. Wells, E. C. Kansa, S. W. Kansa, K. N. Myers, R. C. DeMuth, and D. A. White. 2017. Sea-level rise and archaeological site destruction: An example from the southeastern United States using DINAA (Digital Index of North American Archaeology). *Plos One* 12 (11):e0188142. doi:10.1371/journal.pone.0188142
- Aswani, S. 2019. Perspectives in Coastal Human Ecology (CHE) for marine conservation. *Biological Conservation* 236:223–35. doi:10.1016/j.biocon.2019.05.047
- Bailey, G. N., J. Harff, and D. Sakellariou (Eds.). 2017. *Under the sea: Archaeology and palaeolandscapes of the continental shelf*, Coastal Research Library. Cham: Springer International Publishing. doi:10.1007/978-3-319-53160-1.
- Balée, W. 2006. The research program of historical ecology. *Annual Review of Anthropology* 35 (1):75–89. doi:10.1146/annurev.anthro.35.081705.123231
- Bintliff, J. L. 2000. The concepts of ‘site’ and ‘off site’ archaeology in surface artefact survey. In *Non-destructive techniques applied to landscape archaeology*, ed. M. Pasquinucci and F. Trement, 200–15. Oxford: Oxbow Books.
- Bintliff, J., P. Howard, and A. Snodgrass. 1999. The hidden landscape of prehistoric Greece. *Journal of Mediterranean Archaeology* 12 (2):139–68. doi:10.1558/jmea.v12i2.139
- Bradt Möller, M. S. Grimm, and J. Riel-Salvatore. 2017. Resilience theory in archaeological practice – An annotated review. *Quaternary International* 446:3–16. doi:10.1016/j.quaint.2016.10.002.
- Braje, T. J., and T. C. Rick. 2013. From forest fires to fisheries management: Anthropology, conservation biology, and historical ecology. *Evolutionary Anthropology: Issues, News, and Reviews* 22 (6):303–11. doi:10.1002/evan.21379



- Brennan, L. A. 1977. The midden is the message. *Archaeology of Eastern North America* 5: 122–37.
- Brooks, D. R. 1985. Historical ecology: A new approach to studying the evolution of ecological associations. *Annals of the Missouri Botanical Garden* 72 (4):660–80. doi:10.2307/2399219
- Byram, S. 2009. Shell mounds and shell roads: The destruction of Oregon coast middens for early road surfacing. *Current Archaeological Happenings in Oregon* 34 (1):6–14.
- Ceci, L. 1984. Shell midden deposits as coastal resources. *World Archaeology* 16 (1):62–74. doi:10.1080/00438243.1984.9979916
- Charles, F. N. 1984. Archaeology at Last End Point: The testing and evaluation of three shell midden sites (38BU66, 38BU166; and 38BU167) at the Pinckney Island National Wildlife Refuge. Southwind Archaeological Enterprises, Tallahassee, FL.
- Chiabrando, F., F. D’Andria, G. Sammartano, and A. Spanò. 2018. UAV photogrammetry for archaeological site survey. 3D models at the Hierapolis in Phrygia (Turkey). *Virtual Archaeology Review* 9 (18):28. doi:10.4995/var.2018.5958
- Claassen, C. 1986. Shellfishing seasons in the prehistoric Southeastern United States. *American Antiquity* 51 (1):21–37. doi:10.2307/280391
- Cleere, H., F. Audouze, C. Renfrew, N. Schlanger, A. Sherratt, T. Taylor, and W. Ashmore, eds. 1984. *Approaches to the archaeological heritage*. Cambridge: Cambridge University Press.
- Colwell, C. 2016. Collaborative archaeologies and descendant communities. *Annual Review of Anthropology* 45 (1):113–27. doi:10.1146/annurev-anthro-102215-095937
- Crumley, C. L., ed. 1994. *Historical ecology: Cultural knowledge and changing landscapes*. Santa Fe: SAR Press.
- Davis, D. S. 2019a. Object-based image analysis: A review of developments and future directions of automated feature detection in landscape archaeology. *Archaeological Prospection* 26 (2): 155–63. doi:10.1002/arp.1730
- Davis, D. S. 2019b. Studying human responses to environmental change: Trends and trajectories of archaeological research. *Environmental Archaeology*. doi:10.1080/14614103.2019.1639338
- Davis, D. S., R. J. DiNapoli, M. C. Sanger, and C. P. Lipo. 2020. The integration of LiDAR and legacy datasets provides improved explanations for the spatial patterning of shell rings in the American Southeast. *Advances in Archaeological Practice*. In Press. doi:10.1017/aap.2020.18
- Davis, D. S., C. P. Lipo, and M. C. Sanger. 2019a. A comparison of automated object extraction methods for mound and shell-ring identification in coastal South Carolina. *Journal of Archaeological Science: Reports* 23:166–77. doi:10.1016/j.jasrep.2018.10.035
- Davis, D. S., M. C. Sanger, and C. P. Lipo. 2019b. Automated mound detection using LiDAR and object-based image analysis in Beaufort County, SC. *Southeastern Archaeology* 38 (1):23–37. doi:10.1080/0734578X.2018.1482186
- Douglass, K., and J. Cooper. 2020. Archaeology, environmental justice, and climate change on islands of the Caribbean and southwestern Indian Ocean. *Proceedings of the National Academy of Sciences* 117 (15):8254–62. doi:10.1073/pnas.1914211117.
- Douglass, K., J. Walz, E. Quintana-Morales, R. Marcus, G. Myers, and J. Pollini. 2019. Historical perspectives on contemporary human-environment dynamics in Southeast Africa. *Conservation Biology* 33 (2):260–74. doi:10.1111/cobi.13244
- Drew, J. A. 2005. Use of traditional ecological knowledge in marine conservation. *Conservation Biology* 19 (4):1286–93. doi:10.1111/j.1523-1739.2005.00158.x
- Dunnell, R. C., and W. S. Dancey. 1983. The siteless survey: A regional scale data collection strategy. *Advances in Archaeological Method and Theory* 6:267–87. doi:10.1016/B978-0-12-003106-1.50012-2.
- Dunnell, R. C., and J. K. Stein. 1989. Theoretical issues in the interpretation of microartifacts. *Geoarchaeology* 4 (1):31–41. doi:10.1002/gea.3340040103
- Erlandson, J. M. 2008. Racing a rising tide: Global warming, rising seas, and the erosion of human history. *The Journal of Island and Coastal Archaeology* 3 (2):167–9. doi:10.1080/15564890802436766
- Erlandson, J. M. 2012. As the world warms: Rising seas, coastal archaeology, and the erosion of maritime history. *Journal of Coastal Conservation* 16 (2):137–42. doi:10.1007/s11852-010-0104-5

- Erlandson, J. M., T. C. Rick, J. A. Estes, M. H. Graham, T. J. Braje, and R. L. Vellanoweth. 2005. Sea otters, shellfish, and humans: 10,000 years of ecological interaction on San Miguel Island, California. In *Proceedings of the Sixth California Islands Symposium*, 58–69. Arcata, CA: Institute for Wildlife Studies.
- Evans, D. H., R. J. Fletcher, C. Pottier, J.-B. Chevance, D. Soutif, B. S. Tan, S. Im, D. Ea, T. Tin, S. Kim, et al. 2013. Uncovering archaeological landscapes at Angkor using LiDAR. *Proceedings of the National Academy of Sciences of the United States of America* 110 (31):12595–600. doi: [10.1073/pnas.1306539110](https://doi.org/10.1073/pnas.1306539110)
- Faught, M. K., and A. E. Gusick. 2011. Submerged prehistory in the Americas. In *Submerged prehistory: The underwater archaeology of ancient sites and landscapes*, ed. J. Benjamin, C. Bonsall, C. Pickard, and A. Fischer, 145–57. Oxford: Oxbow Books.
- Fitzpatrick, S. M., M. Kappers, and Q. Kaye. 2006. Coastal erosion and site destruction on Carriacou, West Indies. *Journal of Field Archaeology* 31 (3):251–62. doi:[10.1179/009346906791071954](https://doi.org/10.1179/009346906791071954)
- Fitzpatrick, S. M., and W. F. Keegan. 2007. Human impacts and adaptations in the Caribbean Islands: An historical ecology approach. *Earth and Environmental Science Transactions of the Royal Society of Edinburgh* 98 (1):29–45. doi:[10.1017/S1755691007000096](https://doi.org/10.1017/S1755691007000096)
- Flemming, N. C. 1983. Survival of submerged Lithic and Bronze Age artifact sites: A review of case histories. In *Quaternary coastlines and marine archaeology: Towards the prehistory of land bridges and continental shelves*, ed. P. M. Masters and N. C. Flemming, 135–74. London: Academic Press.
- Ford, J. A., and G. R. Willey. 1941. An interpretation of the prehistory of the eastern United States. *American Anthropologist* 43 (3):325–63. doi:[10.1525/aa.1941.43.3.02a00010](https://doi.org/10.1525/aa.1941.43.3.02a00010)
- Freeland, T., B. Heung, D. V. Burley, G. Clark, and A. Knudby. 2016. Automated feature extraction for prospection and analysis of monumental earthworks from aerial LiDAR in the Kingdom of Tonga. *Journal of Archaeological Science* 69:64–74. doi:[10.1016/j.jas.2016.04.011](https://doi.org/10.1016/j.jas.2016.04.011)
- Friesem, D. E., N. Lavi, M. Madella, P. Ajithprasad, and C. French. 2016. Site formation processes and hunter-gatherers use of space in a tropical environment: A geo-ethnoarchaeological approach from South India. *Plos ONE* 11 (10):e0164185. doi:[10.1371/journal.pone.0164185](https://doi.org/10.1371/journal.pone.0164185)
- Gallivan, M. D., and D. Moretti-Langholtz. 2007. Civic engagement at Werowocomoco: Reasserting native narratives from a Powhatan place of power. In *Archaeology as a tool of civic engagement*, ed. B. J. Little and P. A. Shackel, 47–66. New York: Alta Mira Press.
- Guilfoyle, D. R., and E. A. Hogg. 2015. Towards an evaluation-based framework of collaborative archaeology. *Advances in Archaeological Practice* 3 (2):107–23. doi:[10.7183/2326-3768.3.2.107](https://doi.org/10.7183/2326-3768.3.2.107)
- Hawkins, A. L., S. T. Stewart, and E. B. Banning. 2003. Interobserver bias in enumerated data from archaeological survey. *Journal of Archaeological Science* 30 (11):1503–12. [https://doi.org/10.1016/S0305-4403\(03\)00051-7](https://doi.org/10.1016/S0305-4403(03)00051-7)
- Herrmann, J. T., B. Glissmann, P. Sconzo, and P. Pfälzner. 2018. Unmanned aerial vehicle (UAV) survey with commercial-grade instruments: A case study from the Eastern Habur Archaeological Survey, Iraq. *Journal of Field Archaeology* 43 (4):269–83. doi:[10.1080/00934690.2018.1465808](https://doi.org/10.1080/00934690.2018.1465808)
- Hilton, M., R. Walter, K. Greig, and T. Konlechner. 2018. Burial, erosion, and transformation of archaeological landscapes: Case studies from southern New Zealand (Aotearoa). *Progress in Physical Geography: Earth and Environment* 42 (5):607–27. doi:[10.1177/0309133318795844](https://doi.org/10.1177/0309133318795844)
- Hollesen, J., M. Callanan, T. Dawson, R. Fenger-Nielsen, T. M. Friesen, A. M. Jensen, A. Markham, V. V. Martens, V. V. Pitulko, and M. Rockman. 2018. Climate change and the deteriorating archaeological and environmental archives of the arctic. *Antiquity* 92 (363):573–86. doi:[10.15184/aqy.2018.8](https://doi.org/10.15184/aqy.2018.8)
- IPCC. 2018. Global warming of 1.5°C: An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. SR15. Incheon, Republic of Korea: Intergovernmental Panel on Climate Change. <https://www.ipcc.ch/report/sr15/>.

- Jensen, John R. 2007. *Remote sensing of the environment: An earth resource perspective*. 2nd ed. Upper Saddle River, NJ: Pearson Prentice Hall.
- Johnson, K. M., and W. B. Ouimet. 2014. Rediscovering the lost archaeological landscape of southern New England using airborne light detection and ranging (LiDAR). *Journal of Archaeological Science* 43:9–20. doi:10.1016/j.jas.2013.12.004.
- Johnson, P. S., J. C. Pritchard, and E. C. Poplin. 2016. In much smaller things forgotten: A case for microartifact analysis in cultural resource management. *Southeastern Archaeology* 35 (1): 38–50. doi:10.1080/0734578X.2015.1120589
- Kanaski, R. S. 1997. Archaeological assessment and survey of proposed pond expansions. Boardwalk, and erosion control at shell point, Pinckney Island National Wildlife Refuge. Fish and Wildlife Services, Beaufort County, SC.
- Kelly, R. L. 2016. *The fifth beginning: What six million years of human history can tell us about our future*. Oakland: University of California Press.
- Kirch, Patrick V., and Terry L. Hunt, eds. 1997. *Historical ecology in the Pacific Islands: Prehistoric environmental and landscape change*. New Haven: Yale University Press.
- Kittinger, J. N., L. McClenachan, K. B. Gedan, and L. K. Blight, eds. 2015. *Marine historical ecology in conservation: Applying the past to manage for the future*. Berkeley: University of California Press.
- Lightfoot, K. G., and R. M. Cerrato. 1989. Regional patterns of clam harvesting along the Atlantic Coast of North America. *Archaeology of Eastern North America* 17:31–46.
- Louwagie, G. C. M. Stevenson, and R. Langohr. 2006. The impact of moderate to marginal land suitability on prehistoric agricultural production and models of adaptive strategies for Easter Island (Rapa Nui, Chile). *Journal of Anthropological Archaeology* 25 (3):290–317. doi:10.1016/j.jaa.2005.11.008.
- Marquardt, W. H. 2010. Shell mounds in the Southeast: Middens, monuments, temple mounds, rings, or works? *American Antiquity* 75 (3):551–70. doi:10.7183/0002-7316.75.3.551
- Marzeion, B., and A. Levermann. 2014. Loss of cultural world heritage and currently inhabited places to sea-level rise. *Environmental Research Letters* 9 (3):034001. doi:10.1088/1748-9326/9/3/034001
- Masini, N., F. Gizzi, M. Biscione, V. Fundone, M. Sedile, M. Sileo, A. Pecci, B. Lacovara, and R. Lasaponara. 2018. Medieval archaeology under the canopy with LiDAR. The (re)discovery of a medieval fortified settlement in southern Italy. *Remote Sensing* 10 (10):1598. doi:10.3390/rs10101598
- Moore, C. B. 1894. Certain sand mounds of the St. John's River, Florida, Part I. *Journal of Academy of Natural Sciences of Philadelphia* 10 (1):1–103.
- NOAA (National Oceanic and Atmospheric Administration). 2015. Sea level rise adaptation report Beaufort County, South Carolina. SCSGC-T-15-02. [http://www.scseagrant.org/pdf\\_files/Beaufort-Co-SLR-Adaptation-Report-Digital.pdf](http://www.scseagrant.org/pdf_files/Beaufort-Co-SLR-Adaptation-Report-Digital.pdf).
- Orengo, H. A., and A. Garcia-Molsosa. 2019. A brave new world for archaeological survey: Automated machine learning-based potsherd detection using high-resolution drone imagery. *Journal of Archaeological Science* 112:105013. doi:10.1016/j.jas.2019.105013
- Peacock, E., and J. Rafferty. 2013. The bet-hedging model as an explanatory framework for the evolution of mound building in the southeastern United States. In *Beyond barrows: Current research on the structuration and perception of the prehistoric landscape through monuments*, ed. D. R. Fontijn, A. Louwen, S. Vaart, and K. Wentink, 253–79. Leiden: Sidestone Press.
- Peacock, E., J. Rafferty, and S. H. Hogue. 2005. Land snails, artifacts and faunal remains: Understanding site formation processes at prehistoric/protohistoric sites in the Southeastern United States. In *Archaeomalacology: Molluscs in former environments of human behavior*, ed. D. Bar-Yosef, 6–17. Oxford: Oxbow Books.
- Quintus, S., J. T. Clark, S. S. Day, and D. P. Schwert. 2015. Investigating regional patterning in archaeological remains by pairing extensive survey with a LiDAR dataset: The case of the Manu'a Group, American Samoa. *Journal of Archaeological Science: Reports* 2:677–87. doi:10.1016/j.jasrep.2014.11.010

- Randall, A. R. 2014. LiDAR-aided reconnaissance and reconstruction of lost landscapes: An example of freshwater shell mounds (ca. 7500–500 cal b.p.) in northeastern Florida. *Journal of Field Archaeology* 39 (2):162–79. doi:10.1179/0093469014Z.00000000080
- Reeder, L. A., T. C. Rick, and J. M. Erlandson. 2012. Our disappearing past: A GIS analysis of the vulnerability of coastal archaeological resources in California's Santa Barbara Channel region. *Journal of Coastal Conservation* 16 (2):187–97. doi:10.1007/s11852-010-0131-2
- Reeder-Myers, L. A., and T. C. Rick. 2019. Kayak surveys in estuarine environments: Addressing sea-level rise and climate change. *Antiquity* 93 (370):1040–51. doi:10.15184/aqy.2019.91
- Reimann, L., A. T. Vafeidis, S. Brown, J. Hinkel, and R. S. J. Tol. 2018. Mediterranean UNESCO World Heritage at risk from coastal flooding and erosion due to sea-level rise. *Nature Communications* 9 (1):1–11. doi:10.1038/s41467-018-06645-9
- Reitz, E. J. 1988. Evidence for coastal adaptations in Georgia and South Carolina. *Archaeology of Eastern North America* 16:137–58.
- Rowland, M. J., and S. Ulm. 2012. Key issues in the conservation of the Australian coastal archaeological record: Natural and human impacts. *Journal of Coastal Conservation* 16 (2):159–71. doi:10.1007/s11852-010-0112-5
- Russo, M. 2006. Archaic shell rings of the Southeast U.S.: National Historic Landmarks Historic Context. Southeast Archeological Center, United States National Park Service, Tallahassee, FL. <http://www.npshistory.com/publications/nhl/theme-studies/archaic-shell-rings.pdf>.
- Sanger, M. C., and Q.-M. Ogden. 2018. Determining the use of late archaic shell rings using lithic data: 'Ceremonial villages' and the importance of stone. *Southeastern Archaeology* 37 (3): 232–52. doi:10.1080/0734578X.2017.1398995
- Sanger, M. C., I. R. Quitmyer, C. E. Colaninno, N. Cannarozzi, and D. L. Ruhl. 2019. Multiple-proxy seasonality indicators: An integrative approach to assess shell midden formations from Late Archaic Shell Rings in the Coastal Southeast North America. *The Journal of Island and Coastal Archaeology* In Press:1–31. doi:10.1080/15564894.2019.1614116
- Schiffer, M. B. 1987. *Formation processes of the archaeological record*. Albuquerque: University of New Mexico Press.
- Schiffer, M. B., A. P. Sullivan, and T. C. Klinger. 1978. The design of archaeological surveys. *World Archaeology* 10 (1):1–28. doi:10.1080/00438243.1978.9979712
- Schon, R. 2002. Seeding the landscape: Experimental contributions to regional survey methodology. PhD diss., Bryn Mawr College.
- Shahack-Gross, R. 2011. Household archaeology in Israel: Looking into the microscopic record. In *Household archaeology in ancient Israel and beyond*, ed. A. Yasur-Landau, J. R. Ebeling, and L. B. Mazow, 27–35. Boston, MA: Brill.
- Simpson, F., and H. Williams. 2008. Evaluating community archaeology in the UK. *Public Archaeology* 7 (2):69–90. doi:10.1179/175355308X329955
- Squier, E. G., and E. H. Davis. 1848. *Ancient monuments of the Mississippi Valley: Comprising the results of extensive original surveys and explorations*. Vol. 1. Washington, DC: Smithsonian Institution.
- Swetnam, T. W., C. D. Allen, and J. L. Betancourt. 1999. Applied historical ecology: Using the past to manage for the future. *Ecological Applications* 9 (4):1189–206. doi:10.1890/1051-0761(1999)009[1189:AHEUTP]2.0.CO;2
- Thompson, V. D., W. H. Marquardt, A. Cherkinsky, A. D. R. Thompson, K. J. Walker, L. A. Newsom, and M. Savarese. 2016. From shell midden to midden-mound: The geoarchaeology of Mound Key, an anthropogenic island in Southwest Florida, USA. *Plos ONE* 11 (4):e0154611. doi:10.1371/journal.pone.0154611
- Thompson, V. D., and J. A. Turck. 2009. Adaptive cycles of coastal hunter-gatherers. *American Antiquity* 74 (2):255–78. doi:10.1017/S0002731600048599
- Trinkley, M. B. 1981. Studies of three Woodland Period sites in Beaufort County, South Carolina. Columbia, SC: Department of Highways and Public Transportation.
- Turck, J. A., and V. D. Thompson. 2016. Revisiting the resilience of Late Archaic hunter-gatherers along the Georgia Coast. *Journal of Anthropological Archaeology* 43:39–55. doi:10.1016/j.jaa.2016.05.006

- Walker, B., C. S. Holling, S. R. Carpenter, and A. Kinzig. 2004. Resilience, adaptability and transformability in social-ecological systems. *Ecology and Society* 9 (2):5. <http://www.ecologyandsociety.org/vol9/iss2/art5/>. doi:10.5751/ES-00650-090205
- Westley, K., T. Bell, M. A. P. Renouf, and L. Tarasov. 2011. Impact assessment of current and future sea-level change on coastal archaeological resources—Illustrated examples from northern Newfoundland. *The Journal of Island and Coastal Archaeology* 6 (3):351–74. doi:10.1080/15564894.2010.520076
- Witharana, C., W. B. Ouimet, and K. M. Johnson. 2018. Using LiDAR and GEOBIA for automated extraction of eighteenth–late nineteenth century relict charcoal hearths in southern New England. *GIScience and Remote Sensing* 55 (2):183–204. doi:10.1080/15481603.2018.1431356