Applications of GIS and Remote Sensing in Coastal Archaeology

Overview

The process of archaeology involves the scientific examination of physical remains from the past in an effort to better understand our human culture. In order to achieve this end, archaeological context – the precise relationships between physical remains (artifacts, ground features, landscapes, etc.) and the locations and environments where they are found – is paramount. Context is arguably even more important than the actual remains themselves, so when context is lost before being accurately recorded, potentially vital archaeological information is lost as well. Archaeological excavation by its nature is a destructive process, so accurate spatial recording and non-destructive remote sensing technologies help guard against squandering this precious resource. Archaeology in all its forms is fundamentally a study of the relationship between space and time, and coastal archaeology (both underwater and onshore) is no different. The accurate collection and interpretation of spatial data relates directly to how the past is perceived, identified, and communicated to others.

Over the past several decades, Geographic Information Systems (GIS) and various methods of digital remote sensing have become increasingly important tools for archaeologists (some would say they are indispensable). While research methods and excavation strategies may differ considerably between sub-disciplines and individual projects, GIS and remote sensing have become standard practices throughout the field. With concerns over global climate change, increased coastal erosion, and sea level rise, many archaeologists have begun to focus on better ways of understanding the associated effects these conditions have on coastal sites. In some cases archaeologists, geologists, GIS professionals, and others have joined forces to document these pressures, assess the damage and potential repercussions, and help mitigate the harm wherever possible. With this in mind, several professional papers relating to the subjects of geo-archaeology and shoreline change are included in this case study review.

In 2007, a multi-disciplinary group of researchers from the Georgia Southern University Applied Coastal Research Laboratory, Georgia Department of Natural Resources, and Skidaway Institute of Oceanography teamed up to assess the problems of coastal erosion and sea level rise, and help identify and prioritize over sixty threatened archaeological sites for potential mitigation (Robinson, et. al., 2010). Over a three year period, they used geo-referenced historic maps, coast surveys, aerial and satellite imagery, LiDAR information, and large amounts of shoreline data collected via survey-grade GPS survey and Phase I archaeological site assessments to develop a comprehensive ESRI-based GIS. The project also relied on the statistical mapping software package AMBUR (Analyzing Moving Boundaries Using R) developed by the Georgia Southern team, which examines and interprets historical shoreline change using spatio-temporal “transect-casting” techniques (Jackson, et. al., 2012). From examinations of remaining Late Archaic Native American villages through digital reconstructions of colonial merchant wharf sites to submerged twentieth century shipwreck mapping, their productive efforts were extensive in scope.

Shortly after the Georgia project was underway, a team from Southern Methodist University, the National Museum of Natural History, and University of Oregon released the results of a similar study using spatial and statistical methods to create a Cultural Resource Vulnerability Index which measured the threats of sea level rise and urban expansion on archaeological sites in the Santa Barbara Channel region of California (Reeder, et. al., 2012). In both the Georgia and California case studies, the data and subsequent analyses revealed actively expanding threats to coastal archaeology sites requiring considerable mitigation and modifications to relevant standards and coastal plans.
In 2010, the combination of ArcGIS, AMBUR, and conventional archaeological field methods was again used to assess shoreline change and site formation processes affecting coastal sites in Georgia (McCabe and Jackson, 2012). In this case, the remains of two wooden shipwrecks appeared at separate eroding beach areas on Jekyll and Cabretta Islands. Shoreline “hindcasting” analyses, spatial interpretations, onsite examinations, and lab analysis determined accurate date ranges for both sites. However, GIS interpretation of the geomorphic cycles of the relevant shorelines was able to confirm the suspected identity of the Jekyll Island shipwreck by establishing that the beachline in 2010 was the same as that of 1852: the year of the initial wrecking event. This innovative approach to archaeological dating would not have been possible without spatio-temporal analyses via GIS.

Changes to coastal environments negatively affecting shoreline and underwater cultural resources are of considerable importance to planners and administrators. Properly managing these resources has long been a challenging responsibility for coastal archaeologists. While satellite imagery analysis is not currently a mainstream remote sensing technique on most underwater archaeology sites, hydrographic surveys, acoustic and magnetic technologies, photogrammetry and ortho-imaging, and spatial analyses via GIS continue to be dependable methods, consequently several professional papers relating to these approaches are also included in this review.

In 2006, the state of Georgia commissioned a project to document shipwrecks in their waters which fall under the jurisdiction of the U.S. Navy (Watts, 2006). The result was a wide-ranging report, extensive GIS, and thorough preservation plan which identified sixty-two historic shipwrecks, numerous navigational improvements, and several intertidal sites from the Revolutionary War through World War II. The report and associated GIS include previous archaeological and historical research layered with geo-referenced side-scan sonar and magnetic representations, bathymetric data, nautical charts, topographic maps, and polygon features representing surveyed areas and locations requiring attention due to cultural or natural hazards. The project was the first of its kind in the state and provided an important reference for coastal researchers and administrators. It also laid a technological groundwork for additional archaeological survey and resource management. Site examples include the colonial period shipwrecks HMS Rose, Defiance, Ceres, and Hope, Civil War wrecks CSS Georgia, Nashville, and Water Witch, the World War I-era USS Montauk, and World War II “Liberty Ship” shipyards in Savannah and Brunswick.

Analyzing, recording, and protecting coastal archaeology sites is a lengthy and involved process requiring expertise, dependable equipment, and often some experimentation. Underwater sites are often the most difficult to assess due to their challenging locations and environments. For the past decade, researchers from the North Carolina Department of Natural and Cultural Resources have been excavating the wreck site of the frigate Queen Anne’s Revenge, the famous flagship of notorious pirate Edward Teach, better known as Blackbeard. Recently they presented the finding of a five year study on efforts to protect the site from natural underwater processes which repeatedly threaten the site, especially during the fall and winter months when coastal storm activity is often the greatest (Bernstein, et. al., 2015). Their goal was to find better ways to reduce the effects of storm surge and bottom scour in order to continue their annual underwater site mapping and artifact recovery activities. After placing a large mound of dredged sediment adjacent to the site designed to mitigate these hazards, they used acoustic remote sensing, GPS (RTK) positioning, and diver elevations to monitor the effects. Accurate GIS layering of the hydrography, bottom elevations, and site features were critical to the evaluation of their experimental efforts.

Underwater sites offer unique opportunities for research and technological testing. Archaeologists recently used the discovery of an ancient Phoenician shipwreck off Malta in the western Mediterranean Sea to study deep-water photogrammetry and three-dimensional modelling methods (Drap, et. al., 2015). They used real-time, post-processed, and theoretical methods to identify archaeological site features and artifacts while at the same time developing innovative photogrammetric techniques with high resolution orthophotos which they used to create extremely accurate 3D visualization models and interpretive site maps. As technology expands so does our ability to creatively solve problems, whether in archaeology or elsewhere.

Archaeological methods have come a long way since humans first began to scientifically and contextually examine their pasts, and as environmental conditions change on earth, humans must adjust accordingly. Spatially understanding the connections of human activity to earth environments, whether terrestrial or underwater,
requires determination and expanding capabilities. The information age we currently live in can often be intimidating, however recent technologies should be seen with a sense awe and power as well. We have never before had more efficient ways to understand ourselves and the world around us, and the futures of exploration and scientific analyses look remarkably bright.

Annotated Bibliography


This paper discusses experimental field and interpretive methods associated with short and long-term preservation tactics at the Queen Anne’s Revenge shipwreck site (31CR314) off Beaufort Inlet, NC. Since its discovery in 1996, researchers have continually sought constructive ways to protect the site from the energetic natural processes which threaten it between their annual field seasons. In 2006, state and federal agencies joined forces to position a large mound of dredge spoil adjacent to the site designed to limit exposure and decrease bottom scour. Spatial and temporal monitoring via hydrographic surveys, underwater remote sensing, and GIS over the five years that followed revealed geomorphic activities which reduced erosion and help protect the remaining cultural artifacts.


This recently released journal article discusses deep-water photogrammetry and three-dimensional modelling methods at the ancient Xelendi Phoenician shipwreck site off of Gozo Island in the Maltese archipelago in the western Mediterranean Sea. Researchers from several distinct disciplines (archaeology, ocean engineering, computer science, etc.) examined real-time, post-processed, and theoretical methods in order to identify in situ archaeological artifacts, develop an innovative photogrammetric process, and create accurate 3D models and interpretive site maps. Emphasis was placed on building information systems based on cultural and technological considerations (spatial orientations, taxonomy, cognitive and procedural improvements, etc.) using both existing and experimental methods and collecting survey information in formal technological frameworks.


This journal article uses a Jekyll Island, Georgia case study to explain the creation and use of the AMBUR (Analyzing Moving Boundaries Using R) software package, which examines and interprets historical shoreline change using “transect-casting” techniques. This method better quantifies distances and rates of change in otherwise difficult subject areas, including oceanfronts, sounds, inlets, and backbarrier islands. It uses compatible geospatial formats to provide statistical measurements and estimate shorelines, and can be customized to perform additional functions capable of analyzing the movement of nearly any geographic boundary. It can also provide graphics, tables, and feature classes to quickly identify erosional hotspots and other areas of dynamic shift.


This conference paper describes several archaeological sites located in dynamic coastal environments and how the study of associated shoreline movements/migrations provided important data related to geo-archaeology and archeological dating. High levels of erosion and accretion can mask or destroy coastal sites, and windows for study are often extremely limited. Researchers used a recently developed statistical mapping tool called AMBUR
(Analyzing Moving Boundaries Using R) in conjunction with more conventional archaeological methods to targeted comparable archaeological sites in Georgia waters. This innovative approach examined geomorphic cycles and created detailed conceptual models that allowed researchers to determine how particular shorelines and bottom formations may have appeared at specific points in time, thus helping to date the endangered archaeological sites in question.


This journal article discusses threats to coastal archaeological sites from the conditions of sea level rise, population expansion, and rapid urban development in Santa Barbara Channel region of California. Researchers analyzed and quantified these threats using spatial and statistical methods and by combining gathered data into a Cultural Resource Vulnerability Index. Emphasis is placed on relevant statistical values, archaeological context and importance, continuing research, and onsite mitigation efforts. Examples include applicable coastal heritage sites and elements of industrial and residential sprawl which affect them. Environmental factors and site loss also played significant roles in their evaluations and results. The report is opened ended with recommendation for improvements and suggestions for future reporting and index adjustments.


This journal article examines a three year collaborative effort to identify endangered archaeological sites in coastal Georgia where coastal erosion processes are an active threat. Researchers from the Skidaway Institute of Oceanography, Georgia Southern University Applied Coastal Research Lab, and Georgia Department of Natural Resources developed a Geographic Information System (GIS) using geo-referenced historic maps, charts, coast surveys, aerial and satellite imagery, and field generated data to assess moving shorelines and identify and prioritize threatened areas for possible mitigation. Robinson, et. al. narrowed the list from hundreds of potential sites then established specific boundaries, evaluated conditions on the ground, and provided relevant recommendations for coastal managers. The study was one of the first of its kind and served as a springboard to increased awareness on the subject.


This professional report explains the developmental process of a Geographic Information System (GIS) in which archaeologists identified sixty-two shipwrecks in Georgia state waters falling under the jurisdiction of the U.S. Navy. Watts included shipwrecks and shoreline sites associated with the Revolutionary War, Federal Period, War of 1812, antebellum and the Civil War, through the two World Wars, and also discussed submerged cultural resource legislation, site protection and enforcement, and the relevant importance of the National Register of Historic Places. It also includes important summaries of maritime history, navigational improvements, and naval activities along the Georgia coast. These correlated efforts not only afford informational, spatial, and temporal interpretive layers enabling increased resource management and protection, but also laid a technological foundation for additional historical research and archaeological survey of Georgia shipwrecks and other cultural maritime sites.