Monitoring the impact of coastal erosion on archaeological sites: the Cyprus Ancient Shoreline Project

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Coastal erosion of archaeological sites has long been a problem for archaeologists seeking to understand maritime interactions in the past. A new model, using ArcGIS to collate various sources of data relating to processes of erosion over time along the south coast of Cyprus, is showcased here, with the hope that it can be expanded and adapted for use elsewhere in prioritising sites according to rates of destruction.

Introduction

Coastal sites have long been a significant focus of archaeological research, particularly in the Mediterranean, a region that is well suited to the study of maritime connectivity, trade and interaction (Knapp & Demesticha 2017). The generally benign Mediterranean Sea regime (modest tides and wave action) has facilitated the establishment and endurance of many coastal sites throughout history, but has also contributed to their incremental exposure and erosion. Despite recent theoretical and methodological advances in coastal archaeology, ongoing erosion remains a serious predicament for both the preservation and interpretation of coastal sites. Coastal erosion often leads to an irreparable loss of information used in the identification of maritime structures and activities. The Mediterranean, then, is a hotspot of both opportunity and concern.

In light of the time and financial constraints of a large-scale systematic recording of the coastline (Agapiou *et al.* 2017), the Cyprus Ancient Shoreline Project (CASP) developed a classification scheme that will augment strategic planning for sustainable monitoring of continuously exposed archaeological features (Figure 1). The project focuses on the island of Cyprus and its role in the international trade networks of the Eastern Mediterranean since the second millennium BC, a subject that has received considerable attention. This preliminary analysis examines a 20km-long stretch of the south-central coast of Cyprus, extending from Cape Dolos to Cape Kiti (Figure 2).

Coastal erosion and cultural heritage in south-central Cyprus

South-central Cyprus is experiencing the highest rates of coastal erosion on the island. Although archaeological sites in this region have received increased attention thanks to systematic surveys (Manning *et al.* 1994; Manning *et al.* 2000; Georgiou 2013; Andreou

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*Figure 1. Examples of eroding archaeological features from Cyprus recorded by the Cyprus Ancient Shoreline Project. Top: wall (1m preserved height, 1.2m width, 5.5m of maximum exposed length), containing stratified Late Bronze and Early Iron Age pottery found at Tochni-*Lakkia*, a site with evidence for large-scale storage and possibly also pottery production; bottom left: the remains (base) of a stone-filled pit found at Tochni-*Lakkia*; bottom right: rescue-excavated tomb exposed at Maroni-Tsaroukkas, a Late Bronze Age site with significant evidence for international interaction (imported artefacts, anchors, boat models), as well as monumental architecture (photographs by the author and Sturt Manning).*

& Sewell 2015; Demesticha 2015), the impact of coastal erosion has only recently been investigated from a cultural heritage perspective (Agapiou *et al.* 2017; Andreou *et al.* 2017). Since 2014, the CASP has compiled historical (medieval maps), archaeological (terrestrial and underwater survey) and geographical (aerial photographs) information to reconstruct historical coastlines in this region digitally, and to map sites that are under threat. More recently, this dataset was examined to classify the severity of coastal erosion, and to highlight the areas that require more frequent recording.

Erosion classification and archaeological risk assessment

To classify the severity of coastal erosion in segments of 20m, CASP used the Digital Shoreline Analysis System (DSAS), a toolbar for ArcGIS that allows a detailed analysis of diachronic changes in the coastline (Thieler *et al.* 2009; Radosavljevic *et al.* 2016; O'Rourke 2017). The classification process compares the location of digitised historical shorelines (Andreou *et al.* 2017) through the generation of perpendicular transects with customisable lengths and intermittent distances, every 20m, between the transects (Figure 3). This

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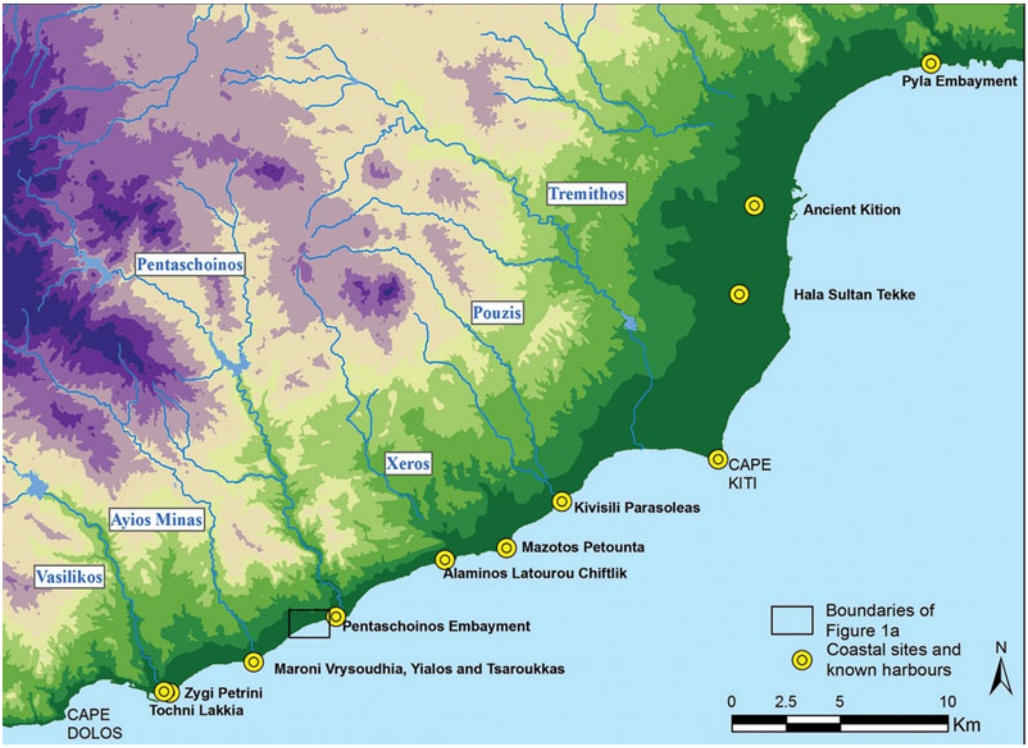

Figure 2. Late Bronze Age to Late Roman coastal sites along the south-central coast of the island (produced on ArcGIS by the author using a basemap with permission from the DLS).

comparison concludes with a table that quantifies the net shoreline movement along each transect (Figure 4).

The results of this classification process highlight the locations that have experienced higher rates of erosion (indicated with red and orange) since the 1960s, and which, accordingly, require more frequent archaeological recording. This classification is stored in a relational database along with photographs, illustrations, historical and cartographical references, aerial photographs and quantifiable photogrammetric models (Figure 5). The combination of these data forms the core information for coastal archaeological risk assessment, which in turn can inform strategies for coastal monitoring by directing endeavours to the most vulnerable areas.

Conclusion

The results of this project enable the assessment of erosion risk on known sites and thus help to prioritise the monitoring of the most endangered areas. They can also provide information for the recovery of otherwise unknown sites. While the use of the Digital Shoreline Analysis System highlights areas that are more vulnerable to coastal erosion, it also demonstrates the large number of locales that have potentially lost visible evidence of past maritime interactions. Future research will focus on the

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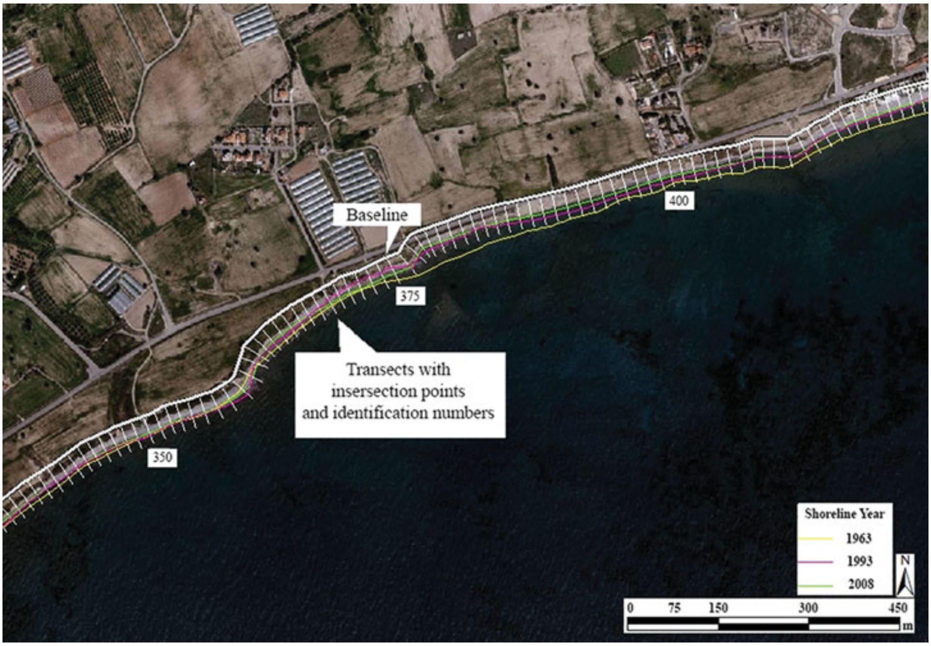

Figure 3. The components of the Digital Shoreline Analysis System function in ArcGIS (produced on ArcGIS by the author with an aerial photograph used with permission from the DLS). The shorelines of 1963 (yellow), 1993 (pink) and 2008 (green) are superimposed on a 2014 aerial photograph (provided by and used with permission from the DLS). A white baseline parallel to the shoreline and a series of white transects perpendicular to the shoreline were produced on the Digital Shoreline Analysis System (ArcGIS) and subsequently used to measure the historical changes in the location of the coastline.

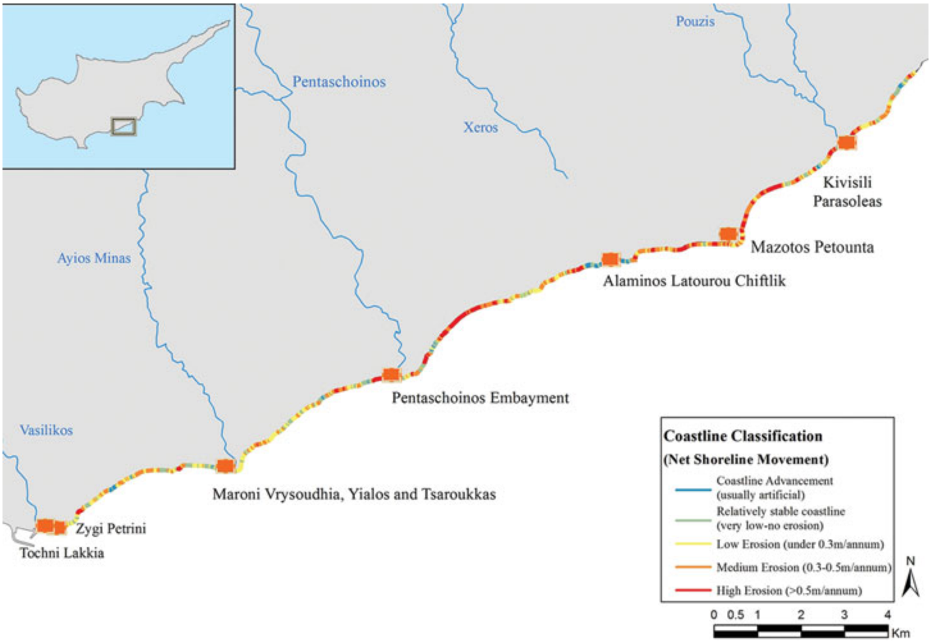

Figure 4. Classification of coastal erosion (high, medium, low) according to the results of the Digital Shoreline Analysis System analysis used to inform future research on maritime archaeology (produced on ArcGIS by the author).

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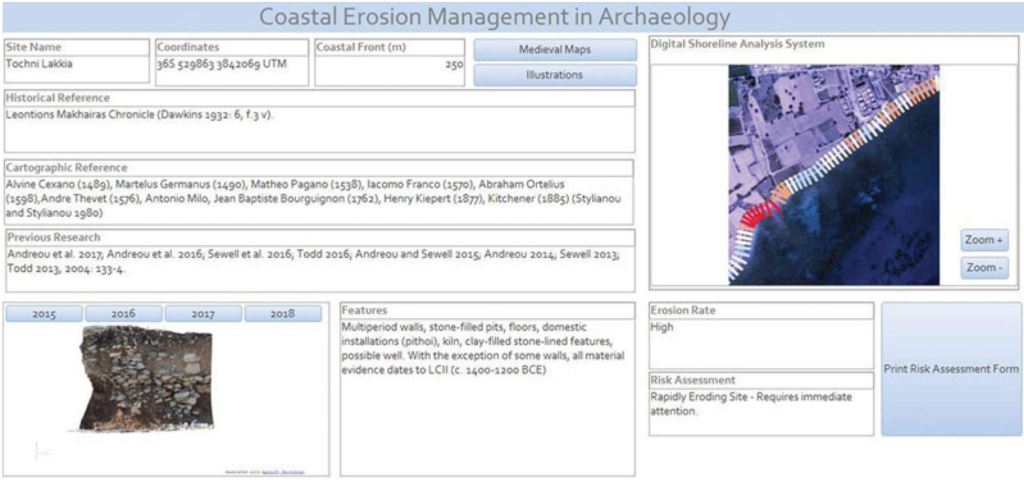

*Figure 5. Example entry (the site of Tochni-*Lakkia*) in the relational database showing information used to develop risk assessments for different coastal sites.*

development of GeoApps—mobile apps that collect, store and analyse georeferenced data—to accommodate crowd-sourced information on the location of eroding features.

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