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Wind and wave modelling for the evaluation of the maritime accessibility and protection afforded by ancient harbours

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ABSTRACT

Ancient harbour sites are known for the protection and shelter they afford ships and boats, and their degree of maritime accessibility. This paper presents a methodological approach for the evaluation of the natural affordances of Bronze Age and Iron Age harbours located in central and southern Phoenicia, on the coast of modern-day Lebanon. It looks at two particular factors that characterize a harbour location: its afforded maritime accessibility and afforded protection. The methodology builds on an enhanced framework of analysis that includes modelling of wind speed and direction along the Levantine basin, and of wave heights for harbour sites. A review of the maritime developments and activities during the Bronze Age and Iron Age, and of the maritime environment of the eastern Mediterranean, suggests that localized and enhanced frameworks of studies are substantial in order to bypass general observations and trends. Through the modelling of winds, regional differences in mean wind speed and direction are distinguished. These shed insight into the sailing potential along the Levantine basin, particularly on the Lebanese coast. Moreover, in accord with the topography of harbour sites, the wind models highlight their maritime accessibility: direction of sailing from and to each site, and their protection from predominant winds. Congruently, the modelling of wave heights for harbour sites reveals the level of protection they afford ships and boats from the maritime environment.

1. Introduction: maritime spaces, harbours, and affordances

Maritime spaces are endowed with a set of natural characteristics acting upon and beneath the water surface. Together with land, these spaces blend seamlessly fostering a home for the movement of winds, of water, of ships, and of people. Movement through maritime spaces is a function of a complex system of interaction between humans, the environment, and humans' perception of the environment. This paper evaluates the significance of maritime spaces and landscapes, specifically ancient harbours, through an analysis of their affordances which could have prompted the development of maritime practices and the appropriation of these spaces.

Maritime landscapes are studied through a variety of lenses. They can be perceived as liminal spaces or territorial (Van De Noort, 2003; Hviding, 1996). Congruently, the significance of human engagement with these spaces has been recognized and appreciated through the attributions of seascapes (Cooney, 2004; Cosgrove, 1998), topocentricity, and multivalency (Gibbs, 2005; MedAtlas Group, 2004; Westerdahl, 1994; Bender, 1992). Maritime spaces however are not present in isolation or within demarcations, in fact land and sea seamlessly merge shaping waterfronts and shores marked by human activities. The importance of these coastlines and their imbued heritage, is well paramount in maritime cultural landscape studies (Westerdahl, 1986, 1989, 1992). They form a substantial heritage record, a place of archaeological signature (e.g., Fischer, 1995; Wickler, 1999; Indruszewski, 2002; Breen and Lane, 2003; Pollard, 2008a, 2008b), and specialization (Hunter, 1994; Parker, 1995, 2001). Yet, though our knowledge of maritime spaces is growing, much of their potential and affordances remain concealed. Through reconstructing, testing, and analysing, experimentally or digitally, we can reach a step closer to lived maritime spaces.

Digitally testing and modelling maritime environments, enable us to understand factors that influenced maritime activities in the past. Geographical Information Systems (GIS) are of a great advantage to archaeologists for a number of reasons as it provides methods to visualize and analyse data. Its use is very much recognized in archaeology (Bevan and Lake, 2013; Conolly and Lake, 2006; Wheatley and Gillings, 2002). GIS and modelling approaches for archaeological maritime spaces have a long history of application (e.g. Knappett et al., 2008; Indruszewski and Barton, 2008, Leidwanger, 2013; Harpster, 2013; Törnqvist, 2014; Scheidel, 2014), yet perhaps not as recurrent and developed as for terrestrial landscapes. One of the reasons for that is the accentuated complexity when dealing with the maritime environment given that too many factors intertwine, e.g. winds, currents, waves, coastal topography, combined with ships, and men-made installations. Nonetheless, this is made easier nowadays with the availability of large data-sets, integrative approaches, as well as advances in oceanographic sciences and applications (e.g. Challenor et al., 2006; Seibt et al., 2013). Prehistoric seafaring for instance has a long history of computer simulation modelling (e.g. Levinson et al., 1973; Callaghan, 2003; Davies and Bickler, 2013) that relies on integrating agent-based,

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GIS, statistical modelling, and high resolution datasets. The work presented in this paper makes use of the availability of data, and tools, in order to evaluate two factors that influence the localities of ancient harbour sites and their afforded accessibility, on the Levantine coast of modern day Lebanon: winds and waves. The main focus of this paper is maritime landscapes, specifically anchorages and harbours, and their imbued characteristics. Wind speed and direction dictate to a degree sailing routes and harbours' accessibility, yet they are more than often investigated on large scales either temporally or geographically, i.e. seasons and regions, in archaeological studies. As for wave heights, they determine the degree of protection that harbours afforded. An analysis of wave heights for not only a single harbour but several harbours on one coastline, offers a framework within which we can compare and highlight differences in the level of protection of harbour sites.

The location of harbours is of critical importance since it must afford boats and ships a sheltered haven from environmental conditions, i.e. bad weather, and a safe location to approach and embark from. The study of ancient harbours is a well-established strand in maritime archaeology (Morhange, 2014; Marriner, 2009; Carayon, 2008; Raban, 1995; Blue, 1995; Blackmann, 1982; Flemming, 1980; Frost, 1972; Polyani, 1963; Savile, 1941). So far it has relied on a multitude of sources and methods for the identification and understanding of harbours: textual, archaeological and geoarchaeological, environmental, coastal investigations, topographic analysis, and so on. Early investigations in the Levant were initiated by pioneer archaeologists who established the basis of harbour studies (Frost, 1971, 1972, 1973, 1995; Poidebard, 1939; Poidebard and Lauffray, 1951). The state of research of harbour studies as summarized in the early 1980s (Blackmann, 1982) has grown ever since from its initial phase in bypassing difficulties and targeting site specific complexities.

Ancient harbours, anchorages, boat-launching sites, and major trading ports are all sites located at the interface between land and water. They fall under a comprehensive term, a 'landing site' (Ilves, 2012). These sites are principally characterized by their geographical setting (creek, estuary, bay), their aspect or degree of confinement (open/closed), and their exposure to maritime conditions, i.e. degree of shelter (Morton, 2001; Blue, 1995; Mcgrail, 1983). These characteristics define the quality and suitability of the natural environment for mooring purposes, and protection for ships and boats. Congruently the environment of harbours is also characterized by the nature of its sea bottom (rocky or sandy). Thence, it is evident that a landing site is first and foremost distinguished by a set a features that makes it appropriate for watercraft activities. Although this is not entirely conclusive given that humans adapt to and change their environment, and what seems to be impractical becomes practical for socio/economic and political reasons. There is however, on a gradient scale, inherent affordances of landing sites.

The affordances of a harbour site are those elements of a place, its topography, geomorphology, and its maritime conditions, that differentiate it from other coastal sites in the eyes of the perceiver that can be a seafarer, a fisherman, or a community with maritime interests (McGrail, 1983: 34). On this basis, this paper addresses the natural affordances of ancient harbour sites by looking at their maritime setting, and analyse differences between harbour sites in an attempt to evaluate their roles and functioning environment. This allows for a shift from large scale interpretations to localized ones in terms of the afforded maritime accessibility and protection of harbour sites. Hence this paper falls into the local character of the Mediterranean that Horden and Purcell (2000) and Beresford (2013) correctly emphasized in their works. Two dynamics were selected for an analysis of the maritime accessibility and protection afforded by ancient harbours, winds speed and direction, and wave heights. The natural affordances of ancient harbours however, are not only reflected through these two processes, several other variables play an equally significant role such as the nature of the sea-bottom, the geomorphology of sites, terrestrial accessibility, and visibility. Nonetheless, this paper presents a baseline that can be modified in future works and improved upon with the inclusion of more characteristics of interest.

The analysis of winds throughout the seasons along the Levantine coast allows for an understanding of sailing directions and routes from and to each harbour site. Although predominant winds are recognized and known for the eastern Mediterranean (Davis, 2001; Blue, 1995), regional differences are hard to pick up without a study that can highlight localized patterns. Moreover, an analysis of wave action reveals whether or not harbour sites afford protection for ships and boats, at anchor. The Levantine coast is known to afford only few natural harbours and places that can shelter boats and ships (Frost, 1995; Raban, 1995: 141–145). Nonetheless this is a generalized view that does not consider local variations in the topography and the impact of waves upon the coast. Observations need to be amended in order to consider small scale changes in variables which to an extent are key in understanding the functioning environment of harbours. Indeed, winds and wave patterns are not the sole components of harbour sites characteristics, but they are important in terms of their physical setting.

Wind directions and speed are usually incorporated when modelling maritime networks and routes such as in the Orbis project (Scheidel, 2014). Moreover, Leidwanger (2013) uses wind data to create a cost surface for ancient Mediterranean seafaring and assesses the time of travel in respect to the sailing performance of vessels. Additionally, the works of Indruszewski and Barton (2008), and Knappett et al. (2008), incorporate wind observations for an analysis of maritime routes and connections. Wind modelling in this paper however, focuses mostly on harbour sites in order to reconstruct their environment. Common methods of looking at the mean wind speed and direction in respect to harbour sites is by following the predominant and known wind patterns of the area at large, based only on cardinal directions. Modelling winds within a GIS platform has many advantages. It accounts for all the potential directions (from 0 to 360°), and generates interpolated wind patterns at specific locations rather than assuming that global Mediterranean wind speed and directions apply to all local regions.

The modelling of wave heights for harbour sites, on the other hand, is extremely important in evaluating the maritime setting and the natural predisposition of harbour sites for protection and shelter. It is usually undertaken on a site basis (e.g. Marriner, 2009), yet rarely used as a tool for comparing different harbour settings and evaluating its implication on harbour roles.

Although computational modelling is much advantageous, it is nevertheless limited by the available data, its precision and accuracy. Moreover, the spatial extent, resolution, and data generation methods must be taken into account. However, this does not eradicate the significance of this approach as a method for visualizing and representing the available data in ways that it would elucidate local patterns otherwise indiscernible. Yet, it is important to recognize and work within the restraints of the data, while being transparent about the implications of the models.

Twenty Bronze Age and Iron Age harbour sites (Table 1) located within central and southern Phoenicia – coinciding with modern-day Lebanon – (Fig. 1), were subject to an analysis of their maritime accessibility and protection. The harbour sites are in between 5 to 40 km apart along the coastline. They were chosen based on their material cultural, textual, and potential evidence of having functioned as an ancient harbour or anchorage site during the time period in focus (following criteria elaborated by Carayon, 2008).

2. Modelling methods for winds and waves

2.1. Mean wind speed and wind directions

The main sources of wind and wave data available for users are visual observations from ships, data measured from buoys or platforms, data measured remotely on high altitude satellites, and meteorological and