Putting Predictive Models Underwater, Challenges New Perspectives and Potential of GIS Based Predictive Models in Submerged Areas

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Abstract. Large areas of the North Sea region have been submerged since the end of the last Ice Age. GIS can be used to reconstruct the submerged landscape and thus aid in the understanding of the landscape before inundation. Predictive models can greatly aid the search for Stone Age sites by eliminating areas where sites are unlikely to be found or have survived. However, there are considerable challenges to overcome before the full potential of GIS can be achieved. Available map and site data along with post-submergence disturbance and uncertain sea level estimates are evaluated. New perspectives on how to meet these challenges are presented as well as experiences with GIS in the actual diving operations.

1. Introduction

The archaeological potential of submerged landscapes in North West Europe has been the focus of research by several archaeologists during the last 20 years (Flemming 1983; Bjerck 1995; Coles 1998; Flemming 2002; Dix et al. 2003). The scope of their research has mostly been focused on regional scales and generally been hypothetical in nature. The prospect of actually conducting fieldwork offshore is not an easy undertaking as the logistical and economical challenges require resources which are rarely, if ever, available to most archaeologists. Flemming (2002) approaches the problem by cooperating with the oil industry and utilizing their data from activities in interesting areas. Dix et al.'s (2003) work is funded by the Aggregate-Levy, and so focuses on the possibilities of cooperating with the marine aggregate extractors.

Our work at the University of Newcastle Upon Tyne has followed a different approach. The Early postglacial coastline in North East England is close to the current shore, which brings it within range of ordinary scuba diving and can easily be reached with boats utilized by any recreational diving club. This favourable combination of factors have made it possible to research and access the submerged landscape within the economical limits of ordinary archaeologists. Currently the work is very much in its early stages, but after the first year we have already gained valuable experience, which we will summarize in this article.

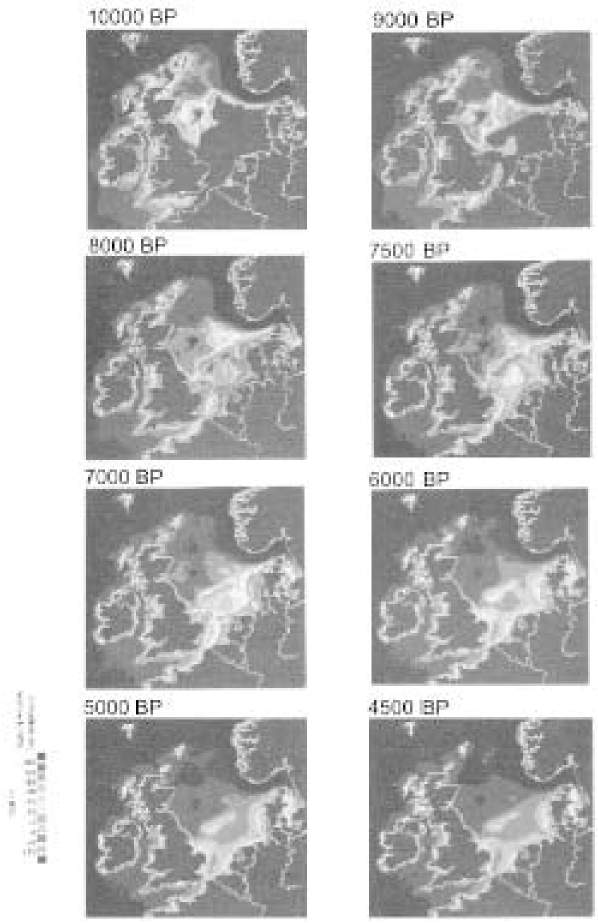

Fig. 1. Example of sea level changes in North West Europe during the Holocene (After Shennan et al. 2000 in ; Dix et al. 2003).

2. The Past and Present North Sea

The landscape of the North Sea basin has changed considerably through the last 10 000 years. Figure 1 illustrates the large area that was dry land at various times in the past. Mesolithic hunter-gatherers undoubtedly had a quite different view of the geography in the North Sea region than we do with the contemporary prehistoric coastline inundated by the sea in almost every part of North West Continental Europe. However, the North West coast of Sweden and the entire Norwegian coastline is still emerging as a result of isostatic uplift after the last Ice Age. A very large number of sites have been discovered along the entire Norwegian coast. Norwegian archaeologists have been using a simple intuitive predictive model based on natural harbours, shelter and good drainage of the ground to prospect for sites for over a century (personal comment by H. Bjerck). Even taking account of the obvious bias towards the coast (where the majority of fieldwork has been done as a result of industrial development), there are no doubts in a major focus of human activity during the Mesolithic at the coast. The earliest known settlement in Norway is considered to have been a coastal variant of the Ahrensburg culture due to the similarities of the lithic technology used in Norway and further South (Prøsch-Danielsen and Høgestøl 1995:123).

The Norwegian coast with it's fjords and large number of islands is quite different from the sheltered, shallow waters of the Danish East coast, but the amount of human activity on the coast of both areas throughout the Mesolithic is far more numerous than the inland activity (Bjerck 1995; Fischer 1995; Fischer 1997) nonetheless taking on a nature suitable to the local environment.

An intriguing question arises from the Scandinavian research; how much of the Mesolithic is actually missing from the records in the other countries along the North Sea? Exploring the possibility of using the Scandinavian search methods in North East England is a major goal for the project described in this article.

3. Potential of GIS in Submerged Areas

3.1 Understanding the Landscape

Mesolithic hunter-gatherers were undoubtedly very much aware of their environment. The landscape harboured various resources such as game, fish, raw materials like flint etc. The ability to find and exploit these resources was clearly crucial to survival. The social or symbolic aspects of landscape would probably have been important though we can only guess about their use.

The use of GIS aids the understanding of submerged areas, as these landscapes are generally not accessible and even for divers, hard to visualize as they might have been thousands of years ago. A terrestrial landscape with perpetual fog might be a useful analogy. The GIS can effectively 'lift this fog' and if it is possible to evaluate the later effects of erosion and sedimentation, the prehistoric landscape will literally emerge and add considerably to our understanding of the prehistoric one. Figure 2 provides a good example of how GIS can aid in the understanding of a landscape. The island of Hitra in Norway contains over a hundred sites, mostly dating from the Mesolithic. Most of them are found in sheltered areas with a natural harbour. Figure 2 is a terrain model with raised sea levels, but it instantly reveals good harbours and fishing grounds. Combined with a predictive model and bathymetric data of sufficient quality, a similar image of the English coast with potential sites outlined, would be possible. The results of erosion and sedimentation since submergence would of course also have to be taken into consideration.

3.2 Focusing Search

Terrestrial predictive modelling generally predicts sites based on environmental qualities such as distance to water, good camp sites etc (Maschner 1996; Spikins 1999; Woodman 2000). The models focus the search. The ability to search small areas covering a few hundred square meters is far more effective than searching the entire landscape. This ability is much more important in the search for submerged sites than terrestrial sites, due to greater practical difficulties and resulting cost.

4. Challenges

4.1 Map Data

A GIS is only as good as the information put into it. In this case the available bathymetric data created several difficulties. The UK Bathymetric office provided us with their most detailed

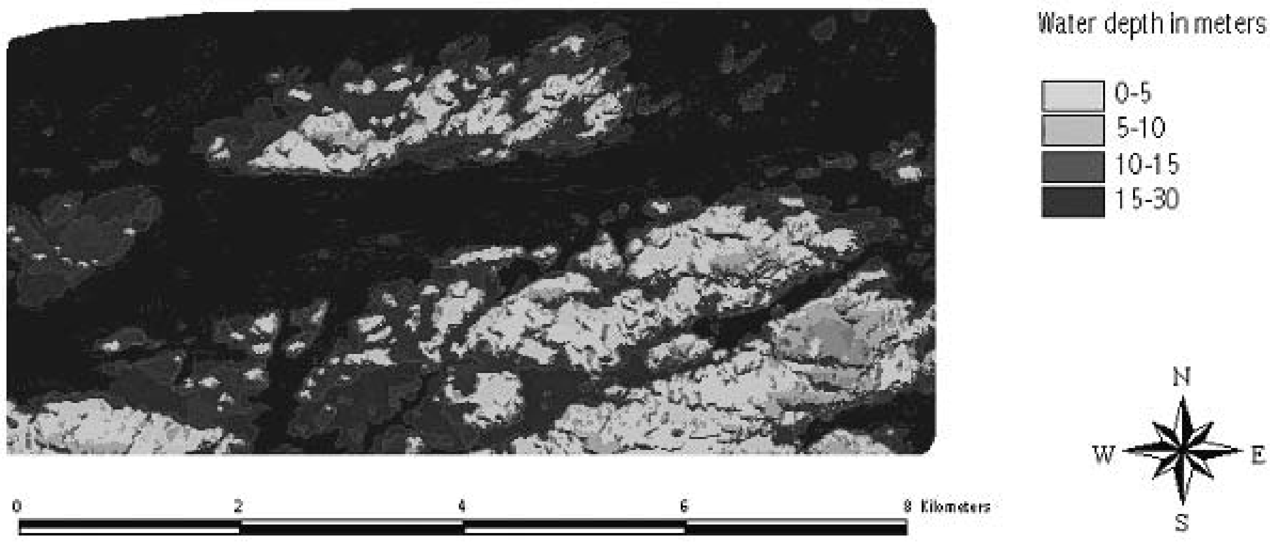

Fig. 2. The island Hitra, Norway with a sea level set 30 metres higher, consistent with estimated sea level at approximately 8500 BP (After Engen 2003).

data, but this resulted in having several hundred thousand points with various distances to each other. The average distance between points seemed about 50 meters. The result is maps with too coarse resolution to display the local terrain features, which would provide shelter according to the Norwegian intuitive model. Even small harbours could be missing.

4.2 Site Data

There are currently two known submerged sites in England, in the Solent (Momber 2000) and at Cullercoats, Northumberland. Further fieldwork is needed at both sites to provide more details of their use and extent. Subsequently the data used in a predictive model are hypothetical, based on intuitive concepts or interpolation of factors such as those utilized in Norwegian and Denmark.

4.3 Post-Submergence Disturbance

Wave action and currents are continuously shifting sediments of all sizes around in coastal areas. A good knowledge of how these forces work is necessary to avoid areas where site survival is unlikely. The impact of transgression and regression on sites is discussed in depth by Dix et al. (2003), while Flemming (2002: 12) summarises topographical features beneficial to survival of archaeological sites.

- Very low beach gradient and offshore gradient so that wave action is attenuated and is constructional in the surf zone.
- Minimum fetch so that wave amplitude is minimum, wavelength is short, and wave action on the seabed is minimum.
- Original deposit to be embedded in peat or packed lagoonal deposits to give resistance and cohesion during marine transgression. Drowned forests and peat are good indicator environments.
- Where deposits are in a cave or rock shelter, roof falls, accumulated debris, concretions, breccia, conglomerate formation, indurated wind-blown sand, all help to secure the archaeological strata.
- Local topography contains indentations, re-entrants, bays, estuaries, beach-bars, lagoons, nearshore islands, or other localised shelter from dominant wind fetch and currents at the time of transgression of the surf zone.

However, these factors need to be quantified to be of use in GIS.

4.4 Sea Level Estimates

Accurately estimating the sea level is critical. An error of just 2–3 metres can result in searching hundreds of metres, even kilometres away from the planned area. The problem is most pronounced in areas with low relief such as the North Sea.

Dix et al. (2003) has produced an excellent review of the making and use of sea level estimates. Going into any depth of this issue is not within the scope of this article, however the main point is that sea level estimates have to be treated with great caution since there are several factors at work. Dix et al. (2003:31) recommend "in areas not suffering from rapid coseismic events, the relative sea level changes for a particular place and time should at least take into account glacio-eustatic change, geoidal fluctuations, local glacio-hydro.isostatic change and local tectonics"

5. New Perspectives

5.1 GIS Data

Currently available bathymetric data is not of sufficient detail to be used to pin point possible sites based on local topography. However, it can provide a general impression of the current submarine landscape. Potential areas can be discovered and the general nature of erosion and sedimentation in the area can be evaluated. The information gathered through this method can be further enhanced by having smaller areas mapped in greater detail using commercial surveyors or even doing the mapping using depth sounders in combination with data logger and GPS. The last option is the most economical and could produce maps with 1 metre accuracy by using differential GPS. An added advantage is that this equipment could be used in a small boat, which can access areas inaccessible to ships. High-resolution data has to be interpreted carefully. Sandbanks can shift due to a single storm and erosion through 10 000 years of waves and currents could easily change the submarine landscape completely. The sea also has tendency to even out depressions in the seabed, as depressions act as sediment traps. A combination of the aforementioned equipment and a sub bottom profiler would be of great value in gathering data and interpreting the current submerged landscape.

5.2 Sea Levels

The low relief of the seabed along the English coast is a considerable problem when attempting to reconstruct the landscape. The distance between the 8 and 10 metres contours is hundreds of meters near Newcastle Upon Tyne. The result is a large area of uncertainty, which greatly increases the search area. Any errors in sea level estimates further complicates the search. The best approach to this problem is probably to use available sea level estimates such as Shennan and Horton (2002) as an initial guide. The next step would be to take core samples of the seabed in the area and/or dive and dig a trench to produce a profile of the seabed, thereby producing our own history of developments in the area since it's submergence. Organic material might even be discovered and provide C14 dating.

5.3 Evaluating Post-Submergence Disturbance

Post-submergence disturbance is the result of a combination of factors such as wave exposure, currents and sedimentation. These factors interact and their internal relationship will vary, depending on local conditions such as topography and distance to sediment sources such as rivers. In addition, marine forces change the topography over time, so the situation in any given location is likely to have changed since the transgression. Modelling these factors accurately may not be feasible however high accuracy might not be necessary for the purpose of estimating the possibility of survival of archaeological sites in a given area.

Relative estimates like "high, medium and low" potential might be good enough for our purpose. Indeed that might be the best we can hope for at this time as so few submerged sites have been excavated and provided information on the conditions which led to their survival.

The Danish sites might be an example, but they only represent very sheltered areas. Many Norwegian coastal sites from the Middle Mesolithic were transgressed during the Holocene (Tapes) transgression between 9000BP and 6700–4500BP, but some still survived under beach sediments (Bang Andersen 1995). These sites survived both transgression and regression and being on dry land today, could readily be excavated. The local topography could probably explain why they survived and be used to extract criteria for survival in similar conditions.

Fetch and thereby wave exposure has been measured and modelled in GIS by Ekebom et al (2002) This method can readily be used by archaeologists and will provide an idea of potential waves. Combined with sea level information and possible landscape at the given time, it should be possible to acquire a reasonable estimate of wave action in the past.

5.4 Diving Operations

Maximum knowledge of the potential site and its surroundings is necessary to ensure maximum effectiveness of the diving and thereby reduce cost. This can be achieved by filtering potential sites from areas of low potential through consultations with local knowledge. This approach has proven to be invaluable in our fieldwork. Modern day features like currents are not always easy to evaluate in GIS. Currents have proved a problem in our fieldwork in the Farne Islands (North East England) as the tide is channelled through the islands and create very strong currents several places. Some areas are only accessible for an hour each day, as dives have to be conducted on slack tide. The presence of artefacts in such placs is entirely dependent on local topography providing cover. However, the diving conditions need to be known in detail before bringing the divers out. GIS can provide substantial help in evaluating local conditions, but is still no replacement for local knowledge.

Accurate navigation under water is a serious problem when conducting underwater prospecting for prehistoric sites. Mapping the searched areas as well as relocating minor clusters of artefacts becomes difficult, as the diver need to avoid frequent surfacing due to the increased danger of suffering decompression illness. The underwater visibility in the Farne Islands varied between 5 to 15 metres during our fieldwork and we operated down to 20 metres depth. A diver will usually navigate using compass bearings and time to estimate position and distance. Relocating a small site during poor visibility is very difficult. However, we found a very satisfactory solution. An ordinary handheld GPS was placed in a watertight bag, which was fastened on small float. A diver would tow the float along using a reel. By simply keeping the line to the float tight, the float would be almost overhead of the diver. Even without a differential GPS, we were able to get a position with between 3–5 metres of accuracy. Relocating sites was then simply a matter of swimming on the surface to the position and descending to the location. This method makes the diver vastly more effective when combined with a predictive model as no time is wasted searching for the interesting area.

6. Conclusion

Scandinavian research indicates major human activity in coastal areas during the Mesolithic. Despite similarities between the early Mesolithic in Scandinavia and Britain, this aspect is generally missing from the research in Britain due to inundation of former coastal areas. GIS has great potential for arresting this situation by focusing search and improves situational awareness during desktop analysis as well as diving. However, better bathymetric data and understanding of post submergence processes and their modelling in GIS, is required to search effectively for sites and evaluate their potential for survival before conducting fieldwork. Research is currently in its early stages, but shows great potential.

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