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PHILIP I. BUCKLAND

Environmental Archaeology, Climate Change and E-Science

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OUR ABILITY TO PREDICT how natural and human systems will respond to future changes is highly dependent on our understanding of how the systems have interacted in the past. To reliably obtain this information, both within and beyond the scope of historical documents, we must rely on a set of methods commonly falling under the umbrella of palaeoecology, or more generally, palaeoenvironmental science. According to the Oxford English Dictionary, this is the, "...branch of ecology that deals with extinct and fossil plants and animals" (OED, 2009). The American Heritage Dictionary of the English Language (2004) is slightly more illustrative with its definition of, "[t]he branch of ecology that deals with the interaction between ancient organisms and their environment". Humans, and their ancestors, are, of course, one group of the ancient organisms, and have perhaps been the greatest influences on the environment over at least the last 8 000 years (Ruddiman, 2003, 2005; Vavrus *et al.* 2008). The area of palaeoecology which generally puts humans, and their past interaction with their surroundings and other species, at the centre of attention, is commonly known as environmental archaeology (e.g. Branch *et al.* 2005; O'Connor & Evans, 2005; Viklund, 2007a).

Palaeoecology cannot function without ecology, as the former requires an understanding of species-Earth interactions from modern and historical observations as a basis for reconstructing past events. In other words, modern ecology provides the frames of reference and calibration data for palaeoecology. Balancing lightly on the edge of circular reasoning, palaeoecology, and more widely, palaeontology, provides the long-term perspective for the fundamental principles of ecology. The relationship between environmental archaeology and archaeology is somewhat more contentious, but it could be said that neither can adequately perform without the other. Without the natural science methods and empirical data from environmental archaeology there is little scope for generating knowledge on the underlying situation and effects of prehistoric human settlements. Archaeology (sans environmental-) provides a set of theories and methodologies for the excavation of sites and the reconstruction of human activities based on their material cultures, which are in essence intimately related to the environments in which they were expressed.

Whether one chooses to separate *the natural* and *the human* is often regarded as a matter of culture or philosophy (e.g. Simmons, 1989, 1993), and something of an academic construct. To some degree it may depend on the time frame in question, and one could argue that prior to 10 000 years ago nature was left to its own devices. Natural processes of vegetation succession, animal migration, sediment and water movement, weather etc. followed natural rules as they coevolved in the interconnected web of life on Earth. Once the early evolution of human societies got underway, exceptions to these rules became more common, as humans put more weight onto the web. These exceptions increased in number and scale as humans expanded and developed more impacting technologies. The past few thousand years have seen a divergence from natural successions with worldwide implications such as widespread landscape management and an enhanced global warming (IPCC, 2007a). There are now very few areas of the planet which could be considered as not having been directly influenced by people at some time in the past. In reality, humans are just a part of this intricate web as are elephants, and the holistic approach is to regard them as such. Creating the dichotomy is a vehicle by which environmental archaeologists can look at what would be expected according to natural processes, or the background signals, and human impacts, or anomalies to these expectations. It allows us to discuss topics such as sustainability, conservation and resilience in terms of the expectations of our social constructs of natural environments with respect to parallels from the ancient past (e.g. Viklund, 2009).

The Environmental Archaeology Laboratory at Umeå University

Since 1975, Umeå University has been host to a unique national resource for environmental archaeology, which has had strategic support from the Swedish Research Council since 1993. The laboratory has its roots in the late 1960's and the Early Norrland project directed by Margareta Biörnstad and Evert Baudou (Engelmark, 2005), the results of which were published for an international audience in the Early Norrland monograph series (see in particular Engelmark, 1976, 1978; Renberg, 1976, 1978; Zackrisson, 1976). These beginnings initiated a long tradition of ecologically orientated archaeological investigations and international collaboration and publication, with over six hundred publications having been produced since the laboratory attained national resource status in 1993. The Environmental Archaeology Laboratory (Miljöarkeologiska laboratoriet, MAL) currently gives Umeå University the competitive advantage of being the only Scandinavian university offering courses, and PhDs, in environmental archaeology. This fact was recently highlighted and commended in the Swedish National Agency for Higher Education's evaluation of teaching in archaeology (HSV, 2009). MAL is also an internationally active consultancy unit, with the rare goal of making all data retrieved through this publically available (see databases, below), and giving students an insight into this post-degree world.

Experimental archaeology is the simulation of ancient activities, based on archaeological and ethnographic data, and helps us to understand the implications of the remains found in archaeological excavations (e.g. Linderholm *et al.* 2004). These data give a quantitative base for the interpretation of remains found on archaeological sites and valuable insights into the possibilities for using geochemical prospection methods for locating and delimiting sites. MAL has been actively involved in such experiments from the start, and has recently started a series of informal workshops on ancient techniques for making things such as fire, fabrics and beer. An important aspect in all of this is the constant cycle of data and information between excavation,

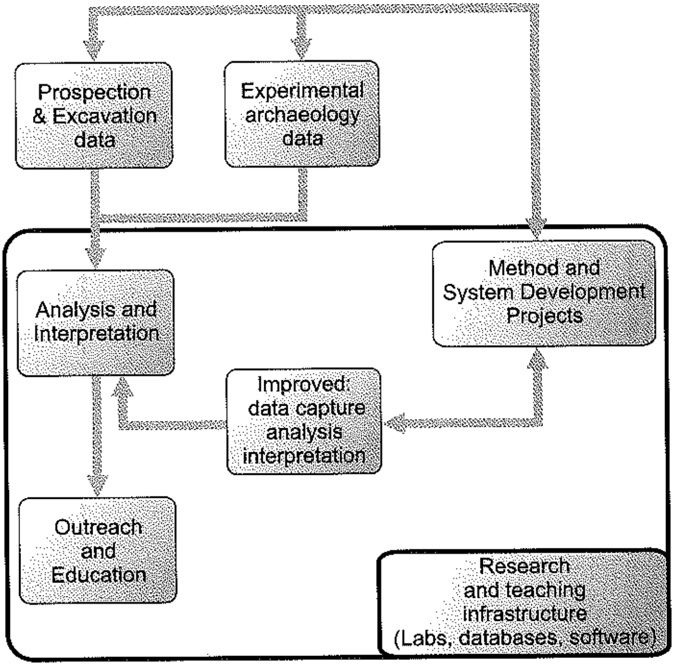

Figure 1. The cycle of experiment, excavation, research, analysis and method development whereby palaeoenvironmental science advances. Research infrastructure is a critical component.

experiments, consultancy work, research and teaching and method and software development (figure 1).

Following the evidence – into the landscapes of the past

By way of an example, imagine that the upper part of figure 2 represents a prehistoric landscape: a wetland with a wooden trackway and a forested backdrop. There is a clear indication of human presence, although without the trackway, it would be hard to tell, and failing maintenance the trackway is destined to be claimed by the bog and the elements. It will, however, most likely leave direct traces in the archaeological record, and the activities around its construction will likewise leave signs in the palaeoenvironmental record. Finding the archaeological remains of something as small as a wooden trackway is something of a rare event, and we are more likely to find indications of human activities that may have been associated with the structure though the use of so-called proxy indicators (a few of which are shown in the lower part of figure 2). The construction and maintenance of the trackway will have required timber, and past forest clearance events can be identified through concurrent changes in the pollen and insect records, among others. The age of these events can then be established through Carbon 14 dating (see e.g. Bell & Walker, 2005, for an explanation of C_{14} dating). The identification of deforestation is not only possible through observing decreases in the abundance or diversity of tree pollen and tree dependent insects, but also through increases in species able to take advantage of the new, more open habitats created by the removal of even small numbers of trees. Open spaces, and the new vegetation growth which they promote, also encourage grazing animals, the past presence of which can be detected through the dung beetle fauna (e.g. Gustavsson, 2009; Olofsson & Lemdahl, 2009). A temporary settlement, used for the duration of the construction activity, could even be visible in sediments in close proximity to the site, although such small scale activities are difficult to resolve (e.g. Hicks, 1993; Kuoppamaa *et al.* 2009).

Trackways are, of course, created for specific purposes and are used to allow access or network communications. Usage phase activities may also leave traces in the fossil record, which can be read with the help of environmental archaeological methods. A settlement, perhaps behind the photographer, would now have easier summer access to the timber and new forest grazing lands across the bog. Trade links may have been formalised with communities beyond the forest and new artefacts, raw materials and foodstuffs could now be imported. Foods and related remains, such as pests of stored products, are a common target for environmental archaeology (e.g. Panagiotakopulu, 2001; Viklund, 2007b) and can often be found in well preserved sediments or carbonised in post holes and other structural remains from settlement sites. Communications also bring ideas, and can thus lead to cultural or subsistence changes which alter the way in which a community interacts with its surroundings. The introduction of agriculture was a series of major such events, and its effects can often be

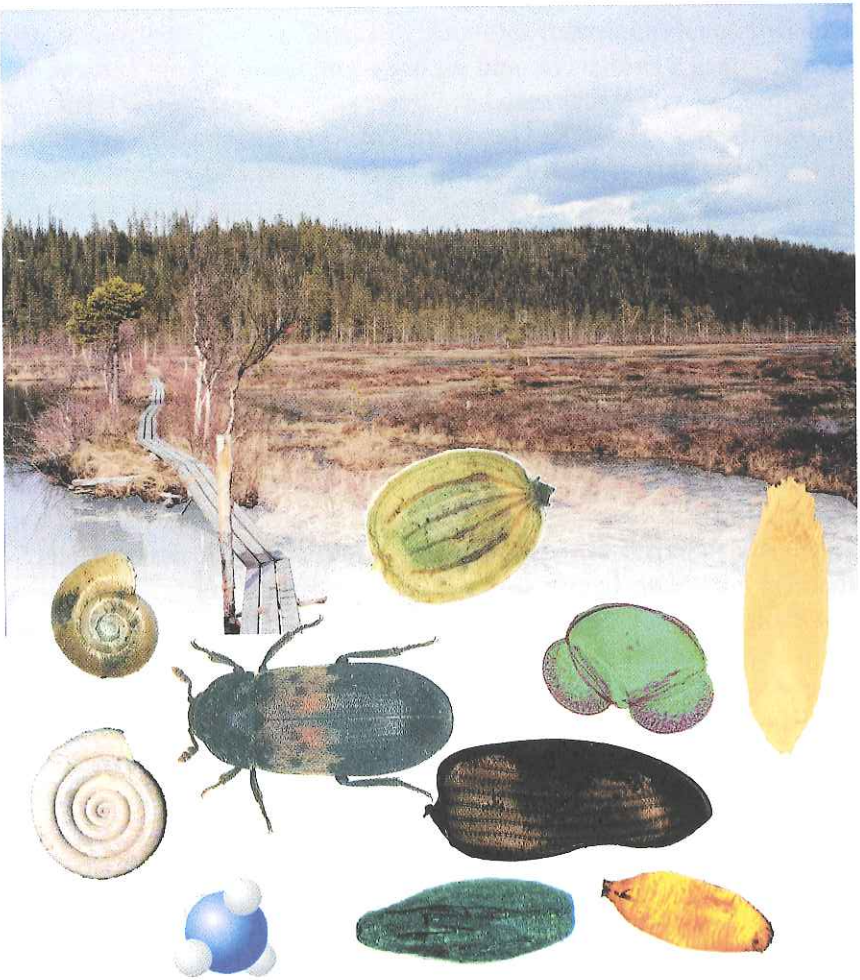

Figure 2. Upper part: A hypothetical prehistoric landscape, with a trackway leading over a wetland to a forest. Lower part: Examples of proxy indicators used in Environmental Archaeology: snails, insects, seeds, pollen and phosphates.

detected through a range of methods from the identification of cereal pollen in lake cores (e.g. Edwards *et al.* 2005) and soil profiles (e.g. Hannon *et al.* 2008) to the spatial delineation of field systems and activity areas through soil chemistry (e.g. Linderholm, 2007).

The persistence of human impacts in the landscape may be regarded as a function of the scale of the impact in combination with the resilience of the ecosystems effected (see e.g. Folke 2006; Goudie, 2005). That is to say, the ability of an ecosystem to return to something resembling the pre-impact state, once impacts have ceased, influences the subsequent visibility of the impacted area. Arctic and other high latitude ecosystems operate under slow nutrient cycling conditions, and thus recover more slowly than tropical ecosystems where biological turnover is more rapid (c.f. Stark, 2007). As a result, the location of medieval fields can still be clearly seen in the Western Settlement area of Greenland 500 years after abandonment (Buckland & Edwards, 1984). The situation with indigenous shifting cultivators in tropical forests may, however, be more complex, and what may look like little long term damage could in fact be the result of thousands of years of traditional, sustainable, land management (Berkes, 1999). All systems have their limits, however, and a clear-felled tropical rainforest may take just as long to recover as a cutover Scandinavian peat bog: hundreds to thousands of years. The interaction of people with their environment is a complex web of feedbacks, inter-species and inter-system relationships which must be studied holistically if we are to better understand the past and present and predict the future. One of the problems facing conservation or landscape restoration is that we can never go back to the past, only create something new which is a reasonable approximate, hopefully constrained by evidence from the palaeoecological record. The archaeological and palaeoenvironmental records, however, once removed, are gone forever. It is therefore imperative that they be properly investigated prior to destruction.

Databasing the past, for the sake of the future

Archaeology is fundamentally an empirical science. Physical remains are excavated, sampled, analysed and counted, through laborious hours of laboratory work. The interpretation of these counts and the construction of theories, models and reconstructions based on them account for the sum of our knowledge of prehistory, data which also underpin our understanding of how the Earth is likely to behave in the future. The amount of raw data that this represents is (to misquote the late Douglas Adams, 1979) mind bogglingly big. The BugsCEP database (Buckland & Buckland, 2006), which holds the raw data for almost all European published finds of Quaternary fossil insects, contains alone over 110 000 fossil record entries representing over 400 000 individual, once living, insects. It is estimated that the raw data produced by the Environmental Archaeology Laboratory would add over 2 000 000 objects to this from the archaeobotanical, pollen and geochemical records (Buckland *et al.* 2006). The BugsCEP data are also supported by over 260 000 records of bibliographically referenced data which describe the modern habitat and distribution of the insect species. These modern reference and calibration data allow the system to provide quantitative climate reconstructions (using the MCR – Mutual Climatic Range method of Atkinson et al. 1986) and graphical habitat reconstructions (Buckland, 2007). In addition to its use in archaeology, the system has been used in innumerable studies ranging from environmental agency evaluations of UK forest structure and conservation issues (e.g. Buckland, 2005; see also Whitehouse & Smith 2009), systematic reviews of insect mobility (Brouwers & Newton, 2009) and floodplain ecology (Davis *et al.* 2007), to the palaeobiogeography of beetles in Japan (Shiyake, 2009). It was also used in constructing the authoritative list of UK beetle species (Buckland, 2008).

A toolbox for reconstructing past landscapes and human activities

SEAD will combine the aforementioned databases and the continuation of the project will ensure the digitalisation and online availability of the data contained therein (figure 3). SEAD will also make all the raw data available online as part of a database and GIS (Geographical Information Systems) enabled toolbox for palaeoecological and environmental archaeological research and teaching. This toolbox will give researchers increased power to be able not only to find, but also interrogate and analyse data on past environmental and climate change along side that from environmental archaeological investigations. There is a clear market for this kind of data, especially with user friendly tools to utilise it. As the reality of the effects of

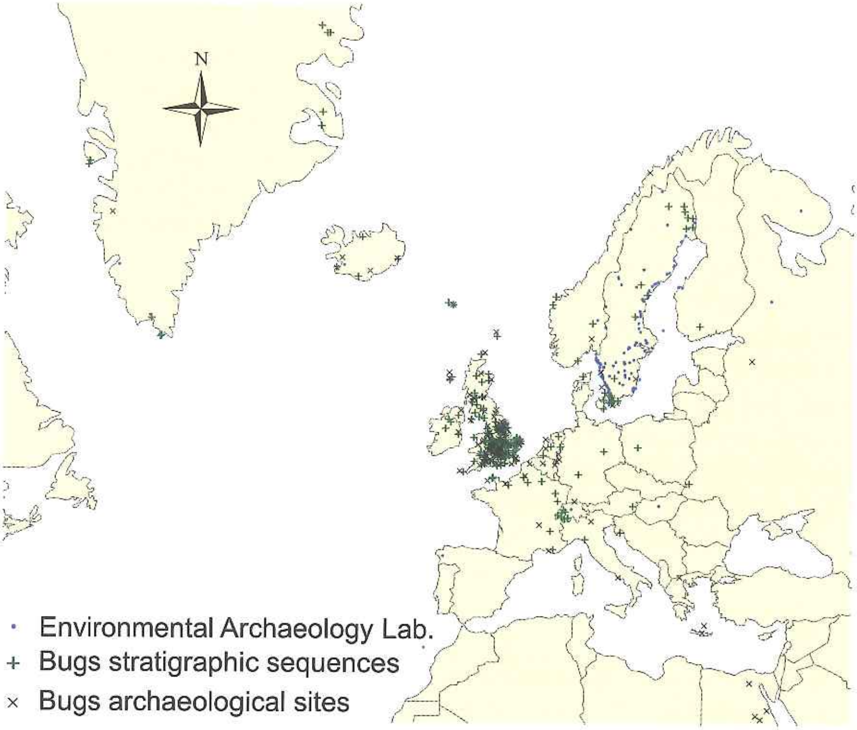

Figure 3. Map of sites currently included in the BugsCEP database along with those in the Environmental Archaeology Laboratory (MAL) archives. These sites, in addition to some MAL and Bugs sites not yet mapped, will constitute the initial fossil data contents of SEAD.

ongoing and impending climate change and environmental degradation hit home over the coming years, the potential user base will only increase, as others understand that the past is the key to understanding both the present and the future (e.g. IPCC, 2007a & b).

A primary aim of the SEAD project is to provide tools for the quantitative reconstruction of prehistoric environments, with their human components. Some of these are already available in BugsCEP, which can draw bar graphs showing the prominence of different habitats for a set of samples (see Buckland, 2007 for examples). With time, and through collaboration with colleagues in the fields of environmental informatics, visualisation and humanities computing (primarily at Penn State College, USA and HUMlab, Umeå), the aim is to be able to produce more visually accessible, lifelike reconstructions. In addition to being scientifically useful, these would be more illustrative and appealing to students, scientists from other fields, policy makers and the general public. Such outreach is vitally important for projecting the openness of science, for recruiting students and staff, and for maintaining public and political visibility of the field. To many, the current Pro Vice Chancellor of Umeå University included (Bergenheim, 2009), photorealistic reconstructions are what springs to mind in this context (c.f. figure 2. upper part). This is a long term goal, but the intermediate stages must be strategically designed to have clear research and outreach applications, relating the raw data to the visualisation transparently as part of a common, database coupled, framework which allows international, inter-site comparisons and intercomparability of reconstructions.

So what is E-Science?

There are numerous definitions of e-science, a term having originated from the UK government in 1999 and having spread internationally (Hey & Trefethen, 2005). Perhaps the most useful definition here is large scale research which requires international cooperation over the internet and through large, community based databases and comprehensive digital (analysis and visualisation) tools. These databases and tools are research orientated systems which facilitate studies which are beyond the scope of any single research group. Other definitions emphasise grid or high power computing for handling immense amounts of data, or specific technologies for enabling large scale online collaboration. There is often an over-emphasis on the technology side of things, and as a (non-IT) scientist one often gets the feeling of technology looking for applications which have yet to be found, as was the case in the early days of research level GIS. GIS worked out extremely well, as a set of research empowering tools, but there have been many failures with this approach, where the focus on developing IT (Information Technology) systems has taken priority over the real research and data needs of the scientists. In the long run, research led development, especially when it has working outreach and teaching components, is often more successful in terms of the science produced, and has lead to several well established database systems in palaeoecology such as Bugs (Sadler *et al.*, 1994; Buckland & Buckland, 2006), FaunMap (FAUNMAP, 1994) and the EPD (EPD, 2009). Such projects, at least initially, are characteristically less ambitious, partly due to the limited nature of the funding available for such development projects and partly due to simple, yet large scale, primary goals. The main struggles with this approach are, however, the large workload required initially and subsequently to engage other researcher groups; funding initial and continued high quality data entry; and ensuring continuation and maintenance funding to ensure user support and keep up with advances in ICT (Information and Communication Technologies). The latter being something that few funding agencies, internationally, seem to be able to supply reliably.

Conclusions

Palaeoenvironmental reconstruction is often equated with retrodiction – "The explanation or interpretation of past actions or events inferred from the laws that are assumed to have governed them" (OED, 2009). The same methods can be used to help predict the implications of future scenarios by turning them around and playing "What if?" games. For example, what happens to the ranges and diversity of forest pest insects if winter temperatures increase by three degrees? What would happen to hayfield biodiversity if pre-industrial cultivation methods were reintroduced? What then, would be the implications for organic farming strategies and sustainable development policies? Environmental archaeology and palaeoecology have thus implications and relevance far beyond what would traditionally be regarded as the somewhat fuzzy boundaries of the disciplines themselves.

The Environmental Archaeology Laboratory at Umeå has played a significant part in the research and development of subjects where knowledge of past environmental change, and human interaction with the landscape, are important. Through the continuation of work at the laboratory and other related departments, and with the help of international research infrastructure projects such as SEAD, Umeå will continue be a lead player in fields that are critical to working towards sustainable human societies alongside rich, diverse and changing landscapes.

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Philip I. Buckland erhöll Kungl. Skytteanska Samfundets pris till en yngre forskare vid Umeå universitet 2009.

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