Journal of Archaeological Science 38 (2011) 345–351

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Integrating human dimensions of Arctic palaeoenvironmental science: SEAD – the strategic environmental archaeology database

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A R T I C L E I N F O

Article history:
Received 25 November 2009
Accepted 9 September 2010

Keywords:
Environmental change
Climate change
Environmental archaeology
Multi-proxy database
Research infrastructure
Palaeoecology
Multidisciplinary
E-science
Arctic

A B S T R A C T

Environmental change has a human dimension, and has had so for at least the last 10 000 years. The prehistoric impact of people on the Arctic landscape has occasionally left visible traces, such as house and field structures. More often than not, however, the only evidence available is at the microscopic or geochemical level, such as fossil insect and seed assemblages or changes in the physical and chemical properties of soils and sediments. These records are the subject of SEAD, a multidisciplinary database and software project currently underway at Umeå University, Sweden, which aims to create an online database and set of tools for investigating these traces, as part of an international research infrastructure for palaeoecology and environmental archaeology.

1. Introduction

Environmental archaeology and palaeoecology collectively encompass a number of sciences looking at the evidence for past environmental change, be it ‘natural’ or human induced. The subject matter comprises a massive range of temporal and spatial scales, from the impact of sunspot activity on vegetation (e.g. Blaauw et al., 2004), to the evidence for individual activities such as the cleaning of fleeces (Buckland and Perry, 1989). The evidence for these events, patterns and activities may be found by investigating past changes in proxy indicators. These are the preserved remains of biological organisms or chemical and physical traces left behind after the changes have occurred. In the absence of humans, these relationships may have been direct, such as the range of temperatures in which a species can survive, or indirect, such as the arrival of insect species which feed upon a particular plant which is favoured by forest fires. Similarly, more anthropogenic relationships may also have been direct, such as the presence of grain pest insect species in relationship to the spatial distribution of grain cultivation and particularly storage (Buckland, 1981), or indirect, such as changes in plant species composition due to changes in hydrology caused by human activities in wetlands (e.g. Vasari and Väänänen, 1986). By examining archaeological samples, peat and lake sediments, or spatial and stratigraphic variation in the chemical and physical properties of soils and sediments, we can read these environmental archives and interpret the complex signals in terms of human activities, environmental change and climate change over time. To some extent, we can also gain valuable insights into high resolution weather aspects such as seasonality and hydrology, factors which are often more fundamental to human survival than long term fluctuations in climate (cf. Gräslund, 2007; Hoffert and Covey, 1992; Ojala and Alenius, 2005).

Whilst it is often useful to think in separate terms of natural processes and human impact (customarily background and anomalous signals), the two are intimately linked. Despite political and commercial claims to the contrary, humans cannot exist without cognizance of changes in environment and climate, and have often been forced to adapt to these through technological

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0305-4403/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jas.2010.09.011

Fig. 1. Site V53c in Austmannadal, SW Greenland, a Norse farm abandoned 650 years ago and yet its hayfield is still evident in the landscape. Photo: Paul Buckland, 1982.

innovation or relocation (in the northern Scandinavian context, see most recently Gräslund, 2007). Likewise, wherever humans are, they interact with their local environment at varying scales, and these interactions may in turn have regional or even global impacts, such as the current global warming, which is perhaps the culmination of a process which began with initial forest clearance in the mid-Holocene (Ruddiman, 2003, 2005; Vavrus et al., 2008).

The empirical evidence for these changes represents a massive amount of data, for which there is currently no consolidated, publicly accessible database. Whilst there are several databases covering individual aspects of this (e.g. BugsCEP: Buckland and Buckland, 2006; EPD, 2009), the Strategic Environmental Archaeology Database Project (SEAD; http://www.sead.se), currently underway at the Environmental Archaeology Lab, in collaboration with HUMlab, at Umeå University, will provide a centralised, publicly accessible resource for the storage, extraction, analysis and visualisation of data on past climate and environmental change, including both the human dimension and natural events. SEAD will form part of an international research infrastructure network for environmental archaeology and Quaternary palaeoecology and collaborate closely with the US led Neotoma multi-proxy database project (Neotoma, 2009). This will help us to understand better past natural and human induced changes in the environment and climate, and human responses to these, and thus, (whilst appreciating Hegel's aphorism that what we learn from history is that we never learn from history) to predict, and perhaps cope with future change scenarios. The project is initially concentrating on the available, often unpublished environmental archaeology data from Sweden, later extending to other countries around the Arctic fringe and beyond.

2. Why begin with the Arctic?

Arctic environments are particularly sensitive to both human impact and climate change (ACIA, 2004). These ecosystems generally have low biodiversity, with many species lying at the limits of their tolerance or unique to high arctic habitats (cf. Makarova et al., 2008), having relatively slow development and recovery rates (Woodin and Marquiss, 1997). The effects of past landscape management activities often persist for hundreds or even thousands of years (Buckland and Edwards, 1984). In the areas of Norse settlement in south-west Greenland, farms abandoned half a century ago are still evident in the landscape, even where grazing of the infield is now restricted to a few reindeer (Fig. 1). The impact of manuring may be evident in the isotopic composition of the vegetation (Commisso and Nelson, 2007), with field systems remaining visible in vegetation structures, and buried soil surfaces clearly visible in shallow core samples. Whilst such past impacts may be less evident in forested taiga, rather than tundra landscapes (e.g. Segerström, 1990), it is an important attribute of any conservation strategy that each unique trajectory to the present vegetation is understood in as much detail as possible before management decisions are made. The unfortunate history of natural fire suppression provides a particularly salutary example (Morrison, 1993).

The basic Lyellian principle that the present is the key to the past underlies all attempts to reconstruct Quaternary environments, although it has to be recognised that periods of rapid climate transition and occasional historical accident may produce assemblages which lack any direct modern analogue. The southward movement of the Arctic fringe during periods of intense cold may also allow mixing of arctic and alpine elements, as for example in the Lateglacial insect assemblages from Church Stretton (Osborne, 1972) and Messingham (Buckland, 1982) in England. With knowledge of present distributions and ecology, it has been possible to reconstruct glacial and periglacial conditions from sediments deposited when the ice margins extended southwards into northern central Europe and the United Kingdom, some 15–70 000 years ago, as well as the intervening warmer periods (e.g. Coope, 1995a,b, 2002). Insect species have been found in these deposits which have present day distributions in Siberia (e.g. Angus, 1973), Tibet (e.g. Coope, 1973), and northern Scandinavia (e.g. Coope, 2002; Coope et al., 1980), as well as other indications of arctic desert (Briant et al., 2004). Beetles (Coleoptera) were the first proxy data source which indicated the rapidity of changes at the end of the last Ice Age (Ashworth, 1973; Coope and Brophy, 1972; Osborne, 1972), long before similar evidence emerged from the Greenland ice cores (Alley, 2000), and they have subsequently been widely

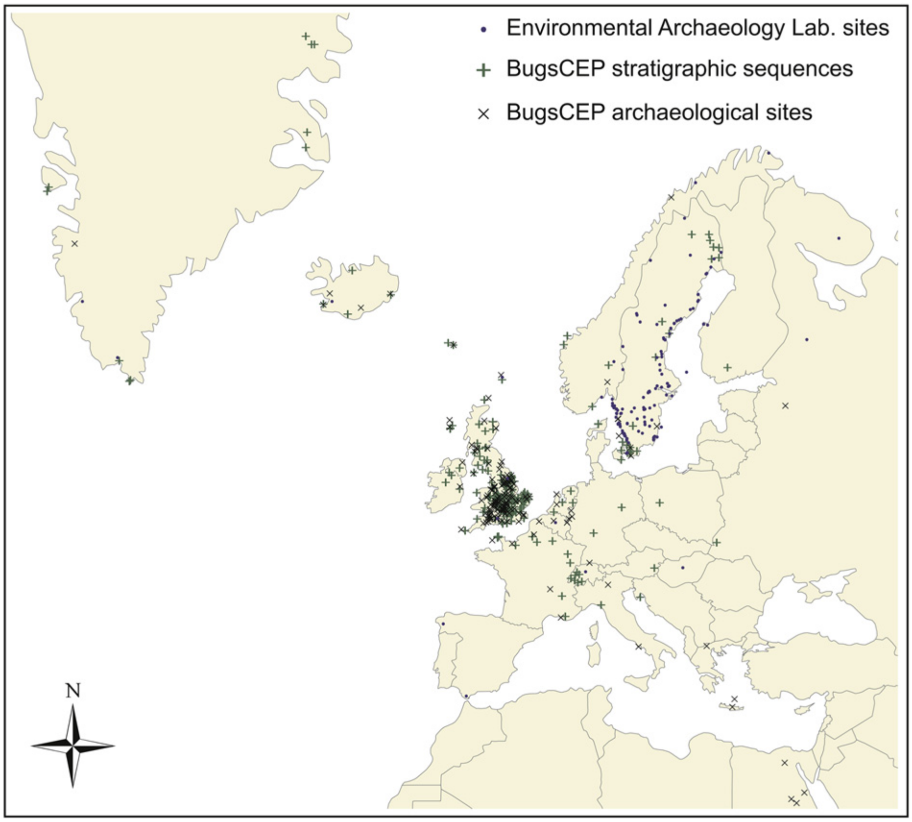

Fig. 2. The geographical distribution of sites from which data is currently included in the SEAD database, including the contents of the Bugs Coleopteran Ecology Package (BugsCEP) database.

used to undertake large scale geographical temperature reconstructions (e.g. Coope and Lemdahl, 1995; Coope et al., 1998). Similar studies have also been undertaken using chironomids (Brooks and Birks, 2000), and pollen records provide reconstructions of past vegetational changes in the Arctic (e.g. Bigelow et al., 2003). In terms of the application of database sources, Davis et al. (2003) used data from the European Pollen Database (EPD, 2009) to reconstruct Holocene temperature changes. Buckland (2007) used the BugsCEP database to experiment with general north-western European environmental and climate change reconstructions for the last 20 000 years.

Occasionally the several lines of evidence have been integrated into a more holoptic picture, for example at Kråkanes in Norway (Birks et al., 2000), but there are far more cases where the lines of evidence remain discrete, or sites where only one element of the biota or other evidence has been examined. A further problem concerns the longer timescale. There are few continuous palaeoenvironmental records which extend the Holocene and Lateglacial record back through the last glacial period into the previous interglacial. In terms of its use of both pollen and coleopteran evidence, La Grande Pile a peat bog in the French Vosges, remains a unique record in northern Europe of some 140 000 years of climate and environmental change (de Beaulieu and Reille, 1992; Ponel, 1995; Ponel et al., 2003), although there are much longer pollen sequences further south (cf. Tzedakis et al., 2006). This means that any reconstruction, which seeks to address the more extended timescale, especially over large geographical areas, must rely upon aggregating data from a number of sites. This task is also essential if spatial and temporal variation at the species, habitat and human activity levels is to be considered. The only effective and reproducible manner of undertaking these tasks is through the use of large scale multi-proxy databases, where archaeological and environmental data are integrated.

Hominin ability to cope with extreme environments is critical in understanding evolutionary and cultural change and has been much discussed in the context of the interplay between *Homo sapiens* and *Homo neanderthalensis* (cf. Mellars, 2004; Tzedakis et al., 2007). Human adaptations to the Arctic involved major biological and cultural adaptation, seen perhaps at its most extreme in the Independence I (= Sarqqaq *partim*) and II (= Dorset I) hunters of the far north of Greenland (Grønnow and Jensen, 2003; Jensen, 2006). Although there are dates from the Russian Arctic (Pavlov et al., 2001) and the Finnish cave site of Susiluola (Schultz, 2002), which suggest that hominins had reached the edge of the Arctic before the last glaciation (for Swedish evidence, see also Heimdahl, 2006), detail of changing environment and rapid climate change during the postglacial colonisation of northern Scandinavia requires further elaboration (Englemark and Buckland, 2005). In evolutionary terms, these events were extremely rapid, and the Arctic provides the opportunity to trace the speed of environmental and cultural response to past climate change over the last 13, 000 years. These events in human biogeography are impossible to understand fully without detailed knowledge of the contemporary environments, and thus factors influencing the availability of resources and other conditions for survival. A large quantity of these data is contained in unpublished Swedish grey literature, and it is the aim of the SEAD project to make them publicly available.

3. Palaeoenvironmental database systems

While there are a number of existing database systems for the storage, retrieval, and in some cases mapping, of multiple

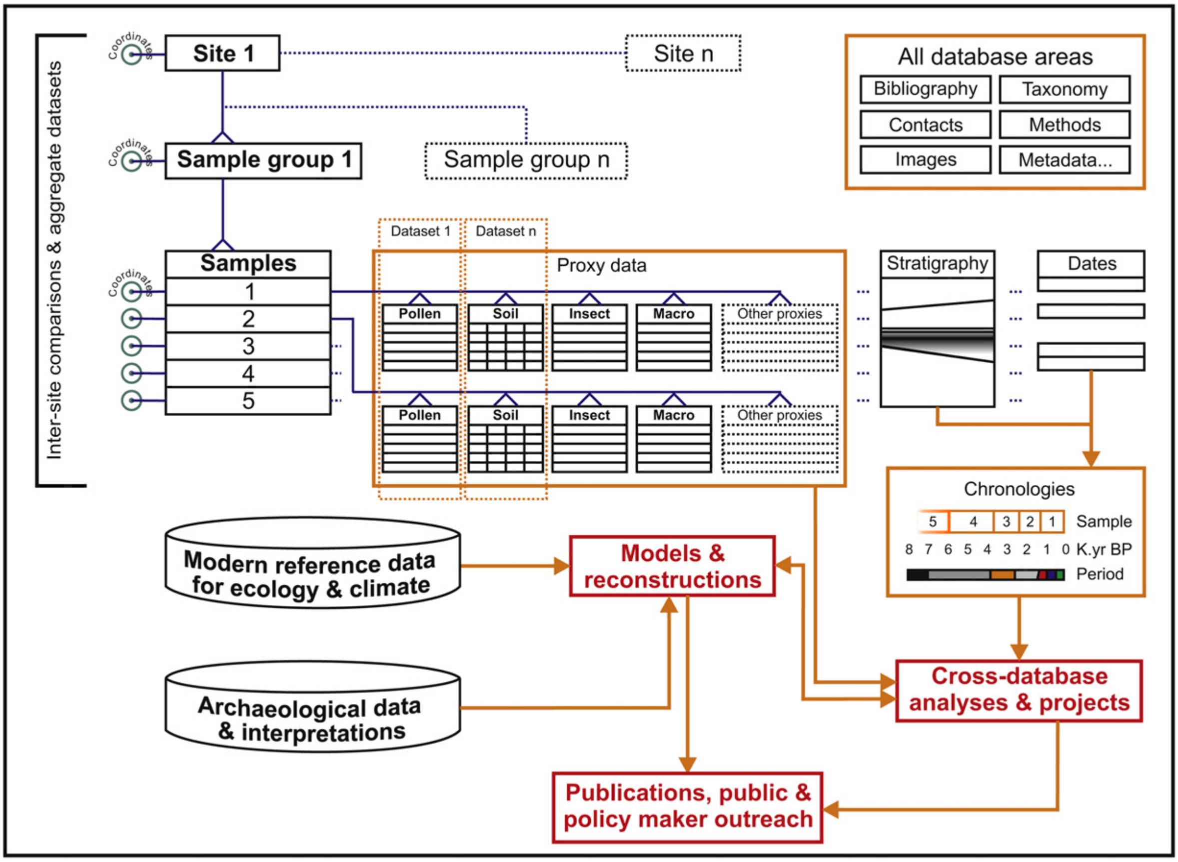

Fig. 3. Research orientated representation of the SEAD database structure. Datasets represent a single proxy type from a single group of samples, essentially equivalent to the traditional spreadsheet of species/variables vs samples. Geographical positioning of sites, samples and sample groups in combination with externally constructed chronologies allow the cross-correlation of SEAD data with external datasets.

archaeological site and find data (e.g. FMIS, 2009; ADS, 2009), there are no existing systems which provide researchers with online access to raw multi-proxy environmental archaeology or palaeoecology data in connection with these. Furthermore, there are few database supported systems which offer built in tools for the analysis and visualisation of multiple multi-proxy datasets, forcing the user to rely on exporting datasets to external software tools for these tasks. With respect to single proxy, that is to say individual biological proxy groups, there are a number of systems currently available, including the European and other regional pollen databases (EPD, 2009), FAUNMAP (1994), the North American Plant Macrofossil Database (Jackson et al., 1997), the North American Packrat Midden Database (Strickland et al., 2001; USGS/NOAA, 2006), as well as a large number of other datasets available through individual project websites or portals such as the World Data Centre for Palaeoclimatology (NOAA, 2009) and the PAGES paleo data resources website (PAGES, 2008). The Bugs Coleopteran Ecology Package (BugsCEP: http://www.bugscep.com; Buckland and Buckland, 2006; Buckland, 2007) is one such system, covering both fossil insect data and modern ecological and climate reference data. BugsCEP is one the few systems which integrates tools for the interrogation and visualisation of its data into the software/database package, thus providing users with immediate access to both the data of interest and the apparatus for performing a number of invaluable analyses (Buckland, 2007). By simple virtue of the members of the SEAD development team, BugsCEP is an immediate ancestor to SEAD. The Bugs database will be ingested into SEAD and form one of its two initial master datasets, the other being the Umeå Environmental Archaeology Laboratory's collected analysis results and associated metadata from over 25 years of work as Sweden's national resource for environmental archaeology (Fig. 2).

4. The SEAD project

In 2007, the Swedish Research Council identified a significant need for improving the availability of publicly accessible databases for archaeological data, as part of a national appraisal of data resources and needs in the humanities (Strangert, 2007). The SEAD project attempts not only to fill part of this demand, but also to bridge a number of gaps between the humanities and natural sciences in terms of access to, and tools for the analysis of, data concerning past changes in climate and environment, and especially human components in these. By the latter we mean the evidence for impacts that past societies may have had on their local and regional environments, as well as the potential influence climate and environmental change may have had on various aspects of subsistence, daily life and interaction between groups. The ongoing discussion of relationships between Viking and Saami (most recently, see Zachrisson, 2006) provides one example wherein the database will collate the necessary environmental background.

Creating a database and associated set of software tools on this scale is no simple process, and the project was fortunate enough to receive a Swedish Research Council planning grant prior to the construction grant. This enabled a comprehensive survey of the Laboratory's data, both analogue and digital, analysis and interpretation pathways, and the visualisation and interfacing needs of

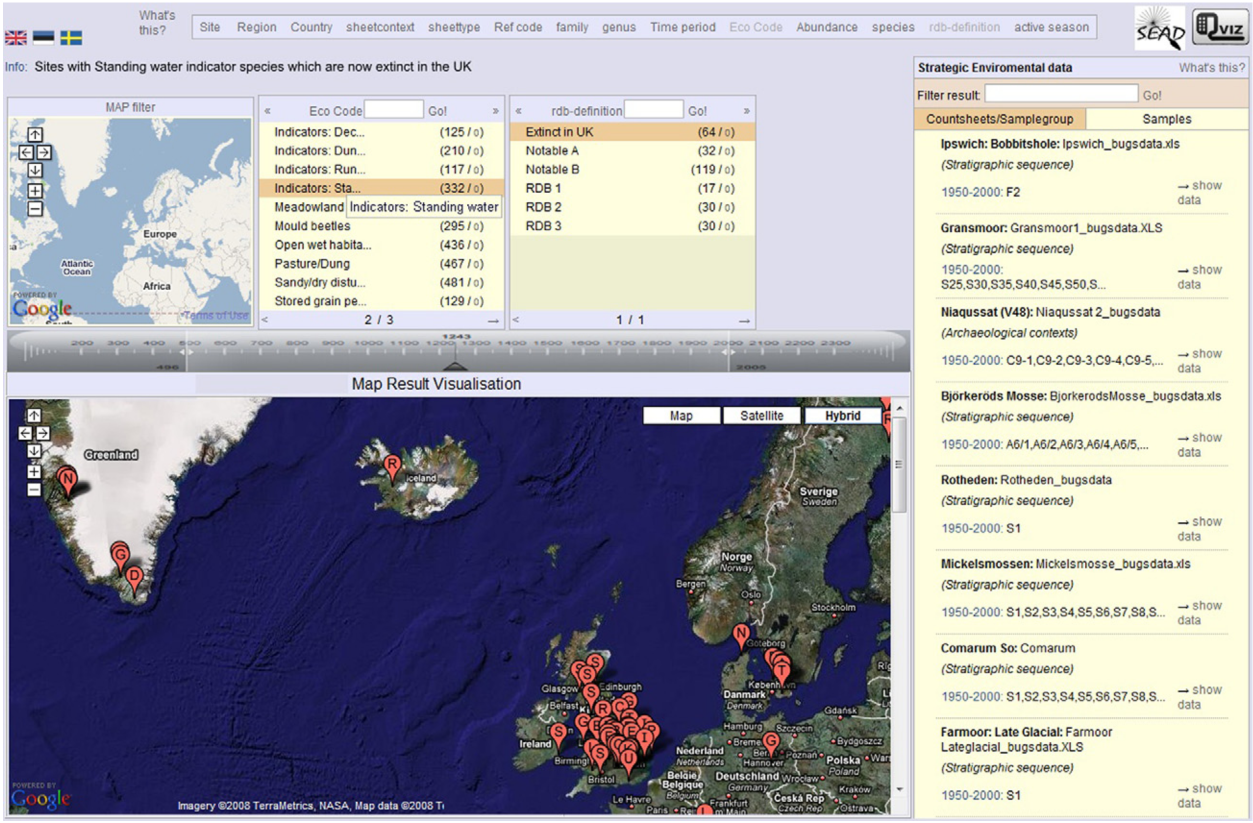

Fig. 4. Screenshot of a prototype of the online SEAD mapping interface adapted from the QVIS archive integration project. Filter boxes (facets) are brought forth or removed by clicking on their titles at the top of the screen. The facets allow a logical data mining progression from left to right, the results of which are shown by points on the map and a list of sites and samples on the right. The time bar in the centre of the screen displays the extent of the dating evidence for the sites. This particular screen shows the location of fossil sites for beetle species specific to standing water environments, but which are now considered to be extinct in the UK.

potential users from internal and external research groups (Buckland et al., 2006). The project also draws from the collective experience of over 20 years of developmental history from the Bugs database project (Buckland, 2000, 2007; Buckland and Buckland, 2002, 2006; Buckland et al., 1997, 2004; Sadler et al., 1992), which provided numerous lessons on what to do, and not to do, in terms of relevant database structure and interface design. It also provides a very large initial test dataset with which to kick-start the development of SEAD (see http://www.bugscep.com/help/help_databaseoverview.html for a summary of the scope of BugsCEP). In terms of its database structure, SEAD borrows certain aspects from the Neotoma database (Neotoma, 2009). In particular, the handling of chronologies and datasets (Fig. 3), which will help ensure the integration of SEAD into an international framework.

The SEAD project comes at a time when a number of national and international funding bodies are investing in international research infrastructures (Borgman, 2008), and large databases form an important part of this. The majority of projects funded by the Swedish Research Council's DISC (Database Infrastructure Research Committee: http://www.disc.vr.se/) funding stream are of medical or demographic substance (approx. 35 of 49 projects funded in 2007–08), and only five concern environmental or climate data (Source: Swedish Research Council online project database, VR, 2009). There are, however, a number of multidisciplinary, palaeoenvironmental database projects currently underway internationally, including the European Pollen Database (EPD, 2009) and Neotoma (2009), with which the SEAD project is collaborating, in addition to numerous national and regional environmental archaeology databases. The latter include: The Archaeobotanical Computer Database – ABCD (2009), The Dutch Relational Archaeobotanical Database – RADAR (Haaster and Brinkkemper, 1995), The Irish Archaeological wood and charcoal database – WODAN (2009), to mention but a few.

It is intended that inter-project cooperation will lead to a greater collective utilisation of database storage and application, and that community based, cross-platform tools will be developed to enhance the potential investigative power of the palaeoenvironmental sciences. The development of new tools for database linking, custom application programmer interfaces (API's) for developing new tools, and the establishment of international networks for research led development and data stewardship will help achieve these objectives.

5. Integrating human dimensions of palaeoecology and environmental archaeology

The SEAD project integrates human dimensions at two levels. Firstly, the core design and development stages of the project are being undertaken as a collaborative venture between the Environmental Archaeology Lab (MAL) and the Humanities Computing Lab (HUMlab) at Umeå University. In working with HUMlab, SEAD has access to a full-scale digital humanities infrastructure, associated research groups and competence in innovative digital tool making and interaction design (Svensson, 2009). This collaboration is working in particular towards the efficient use of multi-purpose, online data exploration tools through their application in multiple projects, such as the Facetted Browser system developed within the QVIZ project (http://www.qviz.eu/; Palm, 2008). This system, which was initially developed for exploring historical archive metadata, has now been adapted to work with the Bugs insect dataset (Fig. 4) and will be further adapted to work with the significantly more complex SEAD database structure. This work also ties in with several ongoing European collaborative efforts and initiatives and shows how research infrastructure can be both a common, expanding platform and cater for project specific adaptations. The focus on creating interpretative tools in SEAD is well in line with current developments in the field of digital humanities (cf. Drucker and Nowovskie, 2004). The Environmental Archaeology Lab is itself also a multidisciplinary organization, applying methods from the natural sciences to questions of archaeology and palaeoecology. The resultant combined force, in addition to a variety of external advisors, is a project group with an unusually broad spectrum of skills which can benefit different aspects of the development cycle.

The second human dimension, so to speak, is that encompassing human activities, past societies and human interaction with the environment. Whilst natural processes are undoubtedly the most powerful elements in environmental and climate change, it is no longer valid to dismiss the importance of human impact on both the Holocene and contemporary scales (IPCC, 2007a; Ruddiman, 2003, 2005). Simultaneously, we are becoming more aware of our vulnerability to natural forces, in that climatic and environmental change is now not only affecting the sustainability of our current lifestyles, but even influencing global politics at heretofore unrivalled levels (IPCC, 2007b). It would be perhaps foolish to think that past societies were any less open to the impact of these forces, although it must be remembered that influencing factors should never be considered in isolation. The potential impacts of past, present or future climate change and greenhouse warming, for example, must be considered in the context of demographics, human activity, habitat availability and inter-species associations. For many species of plant and animal climatic amelioration alone is not enough to lead to an expansion of their geographical distribution: suitable habitats or host environments must also be available (Lomolino et al., 2006). Humans are not only responsible for massive habitat destruction, but also excellent creators of artificial habitat, as the history of mosquito-borne diseases testifies (Spielman and d'Antonio, 2002; Reiter, 2001). These actions can have profound effects on local biodiversity, especially where they constitute habitat modification in the quest for resources and food (cf. Ruddiman, 2005). Consequently, archaeological and palaeoecological data should be vital components in any model of climate and environmental change if we are to use them to predict future conditions, including possible factors which could influence health, quality of life and the sustainability of resources.

In common with a number of similar palaeoecology databases, SEAD aims to bridge the human–nature divide and provide a transparent interface to data on both natural and human influenced environmental change, and a number of the tools necessary to evaluate these with respect to their components and interrelationships. From this base, we can then move forwards to more detailed and accurate large scale studies of how past cultures have interacted with, manipulated and been influenced by their environments, and thus gain a better understanding of the long term consequences of land management practices and demographic changes.

6. Conclusions

There is a clear and important need for improving access to high quality palaeoecological data, particularly in connection with archaeological investigations, in order to improve our collective abilities to understand past changes in human activities, environments and climates. Projects such as SEAD, EPD, Neotoma and BugsCEP are critical elements in establishing freely accessible international research infrastructures for multidisciplinary environmental science. The collaborative engagement of multiple trans-disciplinary research groups in the design stage of such projects is a clear advantage in terms of inspiring what would be considered "outside the box" solutions to problems from within traditional disciplinary boundaries. It is also essential that the different groups creating either similar, or complementary, systems interact with each other and work together towards efficient solutions for problems outside of the scope of any single research group.

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