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Archaeoecology: Using archaeological data to study ecosystems of the human past

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Archaeoecology is a newly emerging field that uses tools from ecology combined with data from the archaeological record. This new field provides a bridge between paleoecology, which generally focuses on periods before major human impacts, and modern ecology.

How can archaeology deepen our understanding of past ecosystems?

What if archaeology could partner with ecology and paleoecology to give us a better depth of understanding of anthropogenic change? The reconstruction of past ecology allows us to understand changes in the biosphere, to look at long-term ecological fluctuations, paleoclimates, extinctions, speciations, and habitat changes, which are all germane to challenges facing planet Earth today. This is embraced in paleoecological studies which study the ecology of Earth long before *Homo sapiens* spread across the planet (Rull 2010); yet, there is a wealth of data on how societies interacted with ecosystems in the past, encompassing the extinction of Pleistocene megafauna and continuing throughout the Holocene. Archaeology has long examined the ways that humans impact environments, and how environments impact societies in the past, with these studies falling under the umbrella of environmental archaeology. But, these studies have often neglected to incorporate ecological modeling on archaeological timescales, and have primarily focused on the abiotic environment. With improvements in computational technology, advancements in ecological modeling, and the digitization of archaeological records, it is now possible to gain a more comprehensive understanding of entire ecosystems from the archaeological past.

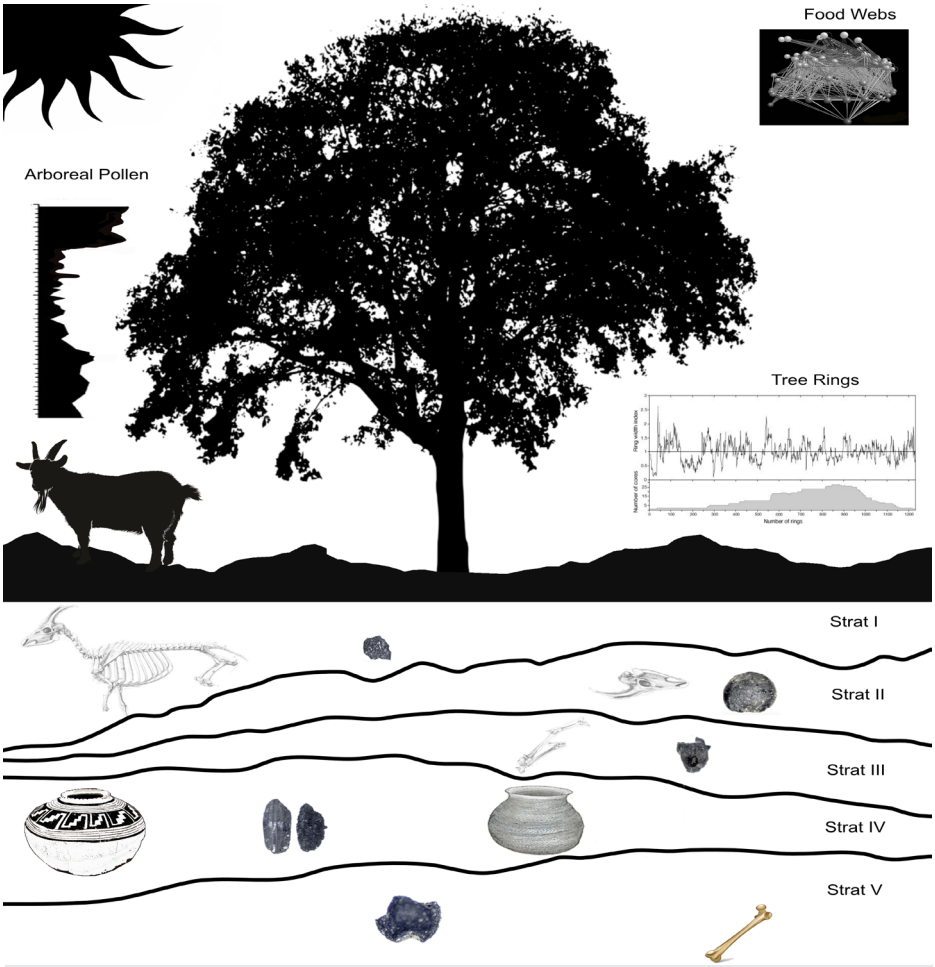

Figure 1: Visual description of the ways that archaeology and ecology can bring data together to create a better understanding of the human place in ecosystems. Here we see the archaeological deposition below a modern ecosystem. We can use the archaeological deposits, such as pollen and bones, to understand what the past ecosystem was and how it relates to a modern ecosystem. In this figure we show how classical environmental archaeology (palynology, dendrochronology, pottery analysis, zooarchaeology) can be combined with modern ecological data (e.g. juxtaposing zooarchaeology of caprid to a modern goat) and computer-aided techniques (like food web modeling). Taken together, the modern ecosystem plus the archaeological ecosystem can enable a deeper understanding of ecological trends. Modified from Crabtree and Dunne (2022).

Recently, we proposed the formal definition of the field of archaeoecology (Crabtree and Dunne 2022). Archaeoecology explicitly integrates questions, data, and approaches from archaeology and ecology, highlighting how archaeological data can be a partner for paleoecological and modern ecological studies. This type of research is not new (Revelles 2021). There are instances in the literature going back decades that address aspects of how humans interact with other species and ecosystems in deep time, and there are increasing calls for integration and synthesis that support interdisciplinary research on these types of questions (e.g. Haldon et al. 2018).

What is archaeoecology?

What is new in this approach is the coalescence of approaches, topics, and prior and future studies under the name archaeoecology, much as paleoecology emerged at the intersection of paleontology and ecology in the first half of the 20th century. By blending contemporary ecological modeling methodologies with archaeological data, we can enhance our knowledge of the trajectory of human-ecosystem interactions across the past 60 kyr. Archaeoecology, then, can be partnered with modern studies of anthropogenic change. By understanding the ways that people in the past manipulated and changed ecosystems, by examining the full connection of these ecosystems, and by modeling these changes, we can better understand the human place in ecosystems worldwide. Archaeoecology, we believe, will enhance the transfer of knowledge and methods across adjacent disciplines and support novel lines of research. Moreover, archaeoecology will provide new ways to investigate old questions, and can provide pathways for education, development, and collaboration at the intersection of ecology, paleoecology, and archaeology. Most importantly, by defining a field of archaeoecology, we recognize how the study of Homo sapiens in ecosystems in the past can aid us in understanding the human place in ecosystems today, and into the future.

Archaeologists have been studying ecosystems for as long as the field has been formally defined, though often only as one external aspect of past society. For example, Clark defined the field of "ecological archaeology" in the 1930s with the Fenland research project, aiming to understand the surrounding environment of the sites where he worked (Smith 1997). In the 1970s, environmental archaeology was formally

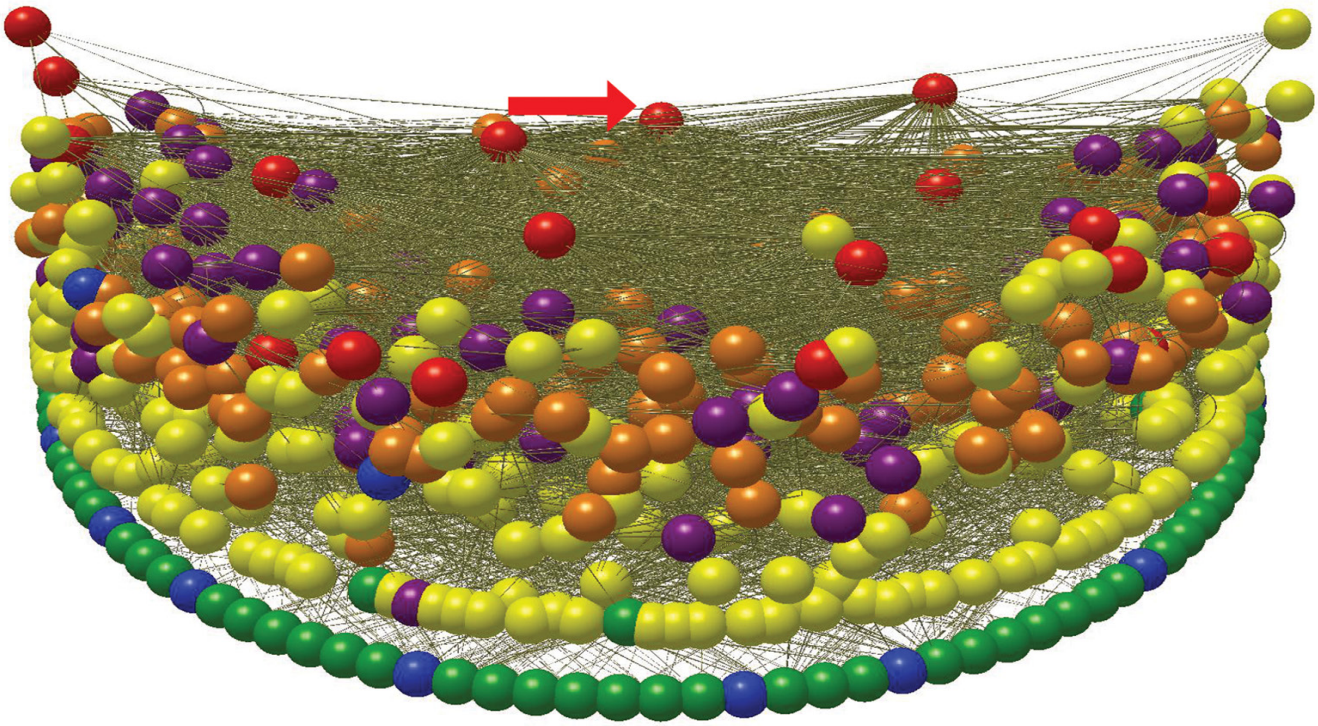

Figure 2: Full nearshore food web for the Sanak Aleut people, indicated with the red arrow. Sphere color indicates the type of taxon: green = algae; blue = miscellaneous (e.g. detritus, protozoa, bacteria, biofilm, lichen, seagrass); yellow = invertebrates; orange = fishes; red = mammals; purple = birds. The trophic level of the organism is indicated by how high they are, vertically, in the graph. Lines are feeding links. This was the first archaeoecological study to integrate humans into a full food web and shows the power of combining archaeological and ecological data. Modified from Dunne et al. (2016).

defined as an archaeological subfield leading to more work within the area of studying past environments (O'Connor 2019). Environmental archaeology typically includes studies of the abiotic environmental context reconstructed via geoarchaeological methods, and cataloguing extant plants and animals via zooarchaeology and archaeobotany. The addition of methods reconstructing things such as past temperature (d'Alpoim Guedes and Bocinsky 2018) or rainfall (Bocinsky and Kohler 2014) via computational modeling, have widened the scope of environmental archaeology. A similar widening of the scope of work via ecological modeling approaches has recently emerged by moving beyond presence/absence accounts of zooarchaeological and archaeobotanical remains, to interactions among taxa in the past (Crabtree et al. 2017). These studies do not typically encompass an understanding of full ecosystems of the past, presenting an opportunity.

Archaeoecology, thus, provides the opportunity to move beyond environmental reconstructions of the abiotic context, building past ecosystems via computational models from the data that archaeologists have been curating for decades (Fig. 1). To do this, archaeoecology integrates the increasingly detailed empirical record of archaeological traces, zooarchaeological and archaeobotanical remains, environmental data, and information on extant species and ecosystems, and makes use of methodological advances in areas such as statistical analysis, computational modeling, information theory, and network analysis (Crabtree and Dunne 2022). In this way, this field is novel, as it explicitly uses ecological approaches to model not only the human place in an ecosystem, but the full connectivity of the past ecosystem's components.

An example of archaeoecology in practice

One example of a published archaeoecological study is the work led by Dunne et al. (2016) examining the Sanak Island food web. For this study, researchers created full food webs for the intertidal and marine systems of the Sanak Islands, linking these food webs with data from archaeological excavations studying the Aleut fisher/hunter/foragers, as can be seen in Figure 2. This study showed the human place in the ecosystem – how humans were highly generalist feeders – and used simulations to show how humans were poised to create cascading impacts on the food web, but did not. This work is one way of showing how the blending of archaeological data with ecological models can lead to greater insights in coupled human-natural systems.

Archaeology as evidence of past ecological interactions

Using new methodological approaches with already collated data provides avenues for many practitioners going forward with this area of study, and enables new ways to work with archival data. As more archaeological sites are analyzed, digitized, and recorded, archaeoecologists can compare similarities and differences across societies, deepening our understanding of the human relationship with ecosystems through space and time (e.g. Freeman et al. 2018). Furthermore, archaeoecology can serve as a valuable connection between paleoecological and ecological studies, using our knowledge of past events at various timescales and critical moments in Earth's history, to enhance and transform our understanding of existing and future ecosystems.

Archaeological records can serve as evidence of past experiments in sustainability, allowing for a better understanding of modern challenges such as the predicted wave of extinctions and community restructurings likely to be caused by climate change. By examining when and where human actions have positively impacted ecosystems, negatively impacted them, or had no effect, scientists and policy makers can be better equipped to make recommendations for ecosystem resilience in the face of massive change. As a result, archaeoecology can play a crucial role in addressing the challenges of the Anthropocene.

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