ON THE NATURE OF THINGS: ESSAYS
New Ideas and Directions in Botany

Toward principles of historical ecology[1]

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Rising temperatures and sea levels, biological homogenization and biodiversity loss, habitat fragmentation, and other environmental changes are dramatically reshaping landscapes across the globe. In this context, understanding the patterns, drivers, and consequences of these changes has become one of the central challenges facing environmental scientists and managers today. Yet to do so requires a long-term perspective on environmental systems that predates many of the accelerated anthropogenic impacts of the recent past. How, then, can we understand these changes in the context of decade- and century-scale ecosystem trajectories and human history? What was the structure, function, and dynamics of ecosystems like before these changes? And how have people shaped these systems over time? These questions are the domain of historical ecology.

Historical ecology is the study of nature over time, often (though not necessarily) with a focus on human–environment interactions and the causes and consequences of changes caused by human actions in the recent past (Crumley, 2003; Rhemtulla and Mladenoff, 2007). The field includes both researchers who wish to document ecological patterns and dynamics in the recent past using historical methods, as well as those interested in *historicizing* ecology—that is, understanding the relationships between nature and human culture over time (cf. Szabo [2014] for a detailed treatment). It draws on a broad range of qualitative and quantitative sources that vary in temporal and spatial coverage, require creative and thoughtful methods to synthesize and interpret, and are often integrated in ways that cross traditional disciplinary boundaries (Fig. 1). Data include traditional archival sources such as written documents, maps, oral histories, land surveys, landscape views and photography, along with biological and physical data such as sediment and pollen records, tree rings, species lists, and habitat relationships (Swetnam et al., 1999; Egan and Howell, 2001; Vellend et al., 2013). While relying on data from the past, historical ecology is an inherently future-oriented discipline given its emphasis on temporal dynamics and change trajectories (Higgs et al., 2014). It provides vivid narratives of past landscapes and change that are of interest to specialists and nonspecialists alike (e.g., Sanderson, 2009; Grossinger, 2012).

Historical ecology is part of a long tradition of understanding relationships between humans and environmental change and shares strong topical and methodological affinities with paleoecology, environmental history, and historical geography. It is similar to "temporal ecology" (sensu Wolkovich et al., 2014), though temporal ecology relies more on time series data, rather than integrating a broad array of data types within their historical context. Historical ecology has much in common with landscape and restoration ecology, ecological subfields that emphasize spatial patterns and processes, human–environment interactions, and temporal dynamism.

As a field, historical ecology largely operates at the intersection of ecology, history, anthropology, and geography, using tools and techniques from all four disciplines to help people conceive of what populations, communities, ecosystems, and landscapes existed in the past and how they have changed over time (Szabó, 2014). It also relies heavily on the history of science, since interpretation of often fragmentary, qualitative, and idiosyncratic historical data requires an understanding of the historical, scientific, and cultural contexts in which past records and scientific data were produced (Raby, 2015). Studies cast a broad net of topics of interest, from traditional ecological questions such as documenting population abundance and community composition, habitat distribution, and ecological processes and functions, to geographic questions such as changes in geophysical patterns and processes

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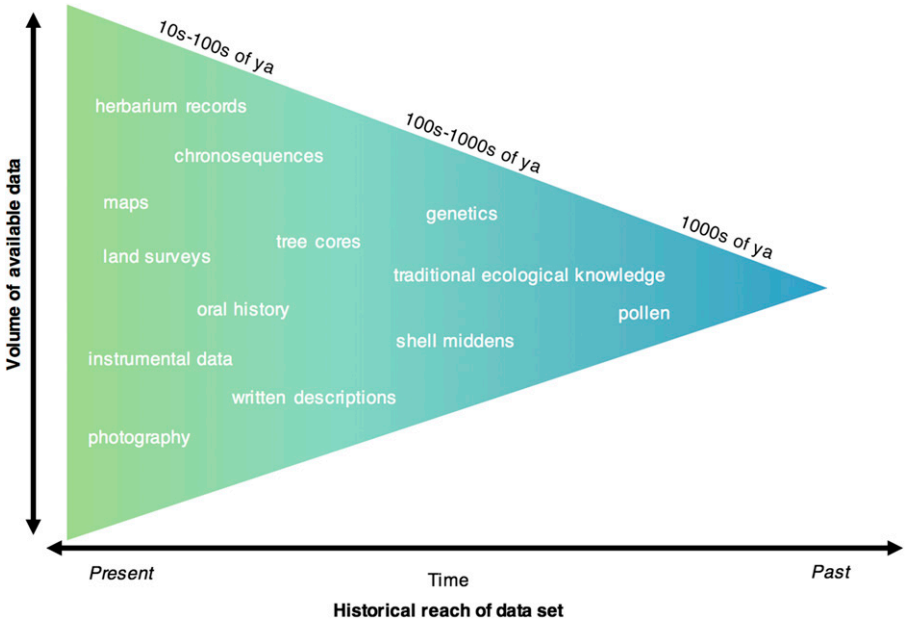

FIGURE 1 Historical ecology draws on a broad range of archival and biophysical sources that provide windows into the nature of past ecosystems and landscapes. A wide array of material is available for recent decades; artifacts, traditional ecological knowledge, and natural archives such as pollen cores shed light on earlier eras. ya = years ago.

(e.g., groundwater dynamics, stream morphology) and socioecological questions such as understanding traditional landscape management and setting goals and objectives for ecological restoration. As a result, historical ecology research is highly interdisciplinary and not restricted to a subfield of ecological science; rather, practitioners are spread across the humanities, social sciences, and natural sciences.

While this interdisciplinarity is a source of strength, it has also complicated the consolidation of historical ecology into a unified field. Historical ecology has developed rapidly over the past two decades, especially with the adoption of geographic information systems, widespread digitization of historical documents and maps, and increased concern about the state of future landscapes. Yet unlike other related fields, historical ecology has no degree programs, no conference for its practitioners, and no journals dedicated to its study and advancement. Efforts to bring together scholars of historical ecology have largely occurred to date through topical conferences (e.g., Oceans Past) and at special sessions at conferences for other fields (e.g., at the American Association of Geographers, the American Society for Environmental History, International Association for Landscape Ecology, or the Ecological Society of America); similarly, historical ecological research is currently published in a broad variety of ecological, geographic, historical, and anthropological journals. While this certainly reflects the applicability of historical ecology to a wide range of disciplines, it may also limit potential advancements in the field that could be facilitated by dedicated venues.

More importantly, perhaps, to date there has been no attempt at defining principles or a theory of historical ecology, despite the rapidly growing quantity of research in the field. We contend that the time is right to develop a unified framework for understanding temporal change in complex social–environmental systems. Here we provide background on the value of historical ecology and outline initial principles of historical ecology, with a view toward consolidating existing approaches.

WHAT DOES HISTORICAL ECOLOGY CONTRIBUTE TO THE STUDY OF ECOLOGY?

Historical ecology can provide novel insights across a uniquely broad range of ecological scales, from population to landscape. At the population level, historical ecology can address questions about long-term changes to population size, density, distribution, and structure. For example, 19th century fishing logs from the Scotian Shelf suggested biomass of Atlantic cod (*Gadus morhua*) was two orders of magnitude greater than fisheries scientists observed it to be in the 20th century, which changed views of the potential productivity of this system (Rosenberg et al., 2005). At the community level, historical ecology can address questions of how past changes in species dominance have contributed to observed changes in community stability. For example, in Caribbean coral reefs, a phase shift to algal-dominated systems was observed in the 1980s, with the proximate cause diagnosed as a disease in the most abundant herbivore, the spiny sea urchin (*Diadema antillarum*). However, historical analyses revealed that overfishing over centuries reduced the abundance of other herbivores, facilitating the rapid transition (McClenachan et al., 2015).

At the ecosystem level, historical ecology can provide insight into long-term changes in resource-use patterns that can affect nutrient availability and ecosystem processes. For example, indigenous peoples of the Pacific Northwest have been harvesting shellfish for millennia, resulting in the movement of significant amounts of marine-derived nutrients into the nearby terrestrial ecosystem and creating legacies of enhanced forest productivity that persist today (Trant et al., 2016). At the landscape level, historical ecology can assess change and persistence in habitat type extent and distribution over time and link observed patterns to geophysical characteristics. For example, an analysis of land cover change along a large California river documented a formerly heterogeneous mosaic of riparian vegetation communities (including willow–cottonwood forested wetlands and xeric scrublands) linked to local variations in dry-season surface flow, then this analysis was used to identify priority locations with suitable conditions for riparian restoration (Beller et al., 2016).

TOWARD PRINCIPLES OF HISTORICAL ECOLOGY

By casting a wide net across space and time and integrating across disciplines, historical ecology is uniquely situated to provide novel insights into complex system dynamics and change in the Anthropocene. We argue that historical ecology's uniquely integrated approach and ability to provide novel insights across all scales of ecology make it more than a tool to "simply provide

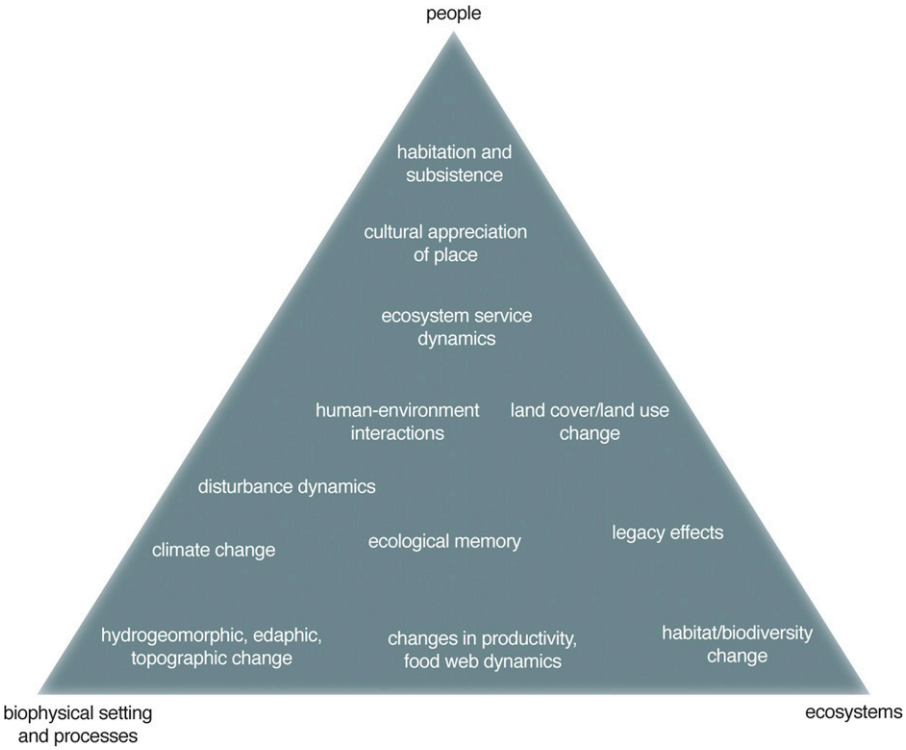

FIGURE 2 Conceptual framework illustrating the scope of historical ecology. Historical ecology encompasses historical ecosystem characteristics (bottom right), biophysical setting and processes (bottom left), and the interaction of humans with their environment (top); time (both past states and change) is implicit across all.

a means of extending the time frame" of ecological research (e.g., Vellend et al., 2013). Instead, shared general concepts and theories unite the discipline as a framework for research, analysis, and application. Looking forward, we identify the need to develop a conceptual framework that clearly defines the topical, spatiotemporal, and methodological scope of historical ecology along with widely accepted principles to standardize methods and sources, unite disparate studies, and maximize the application of findings (Fig. 2). We see a parallel evolution to that of landscape ecology, for which general principles coalesced in the 1990s (Wiens, 1992; Forman, 1995), or that of geographic information science (GIS) over the past two decades as emphasis has shifted from GIS as a "tool" or "system" to a "science" (Goodchild, 2010).

So what might historical ecology principles look like? They might address human–environment interactions and feedbacks, define the scope of "history" in the context of ecological change, delineate the spatial and temporal scale and resolution of historical ecology studies and temporal continuity, address the importance of place, address theories of ecological and landscape transformation and disturbance, and reflect on its application to current and future ecosystems, to name a few. These principles can draw inspiration from existing ecological principles, such as principles of landscape change and scale from landscape ecology (Forman, 1995) or of land-use management (Dale et al., 2000). Principles could range from the extremely simple (e.g., "Ecosystems change through time" or "Humans are important, often dominant, drivers of disturbance") to complex concepts that address historical continuity and ecological memory (e.g., "Ecological landscape patterns at a given time are reflective of landscape and land-use history, setting, and biological interactions").

In developing principles of historical ecology, the challenge will be how to retain the "big tent" flexibility that historical ecology currently offers—that accommodates multiple perspectives, disciplines, and approaches—while articulating and honing a shared conceptual framework. Such principles could provide a backbone for subsequent historical ecology research, education, and application, setting the stage for helping all of us anticipate and manage for ongoing and future environmental change.

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