Journal of the History of Biology
https://doi.org/10.1007/s10739-023-09704-0

ORIGINAL RESEARCH

The Yale Geochronometric Laboratory and the Rewriting of Global Environmental History

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Accepted: 17 January 2023

Abstract

Beginning in the nineteenth century, scientists speculated that the Pleistocene megafauna—species such as the giant ground sloth, wooly mammoth, and saber-tooth cat—perished because of rapid climate change accompanying the end of the most recent Ice Age. In the 1950s, a small network of ecologists challenged this view in collaboration with archeologists who used the new tool of radiocarbon dating. The Pleistocene overkill hypothesis imagined human hunting, not climate change, to be the primary cause of megafaunal extinction. This article situates the Pleistocene overkill hypothesis in a broader history of the emergence of historical ecology as a distinct sub-discipline of paleoecology. Tracing the work of the Yale Geochronometric Laboratory and an interdisciplinary research network that included Paul Sears, Richard Foster Flint, Edward Deevey, Kathryn Clisby, and Paul S. Martin, it reveals how both the methods and the meaning of studying fossil pollen shifted between the 1910s and 1960s. First used as a tool for fossil fuel extraction, fossil pollen became a means of envisioning climatic history, and ultimately, a means of reimagining global ecological history. First through pollen stratigraphy and then through radiocarbon dating, ecologists reconstructed past biotic communities and rethought the role of humans in these communities. By the 1980s, the discipline of historical ecology would reshape physical environments through the practice of ecological restoration.

Keywords History of ecology · Paleoecology · Pleistocene · Extinction · Overkill hypothesis · Carbon dating · Restoration ecology

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Introduction

In summer of 2007, seven Bolson tortoises hatched at Ted Turner's Ladder Ranch, near Truth or Consequences, New Mexico.[1] The birth of these leathery ones might have gone unnoticed, if not for the publication of a controversial article in *Nature*, 2 years prior. In that article, eleven ecologists called for the re-introduction to North America of Pleistocene megafauna: large land animals that disappeared roughly 13,000 years ago, including cheetahs, camels, and Bolson tortoises, 50-kg reptiles once found across the Chihuahuan desert and now critically endangered (Donlan et al. 2005).[2] Supporting the *Pleistocene overkill hypothesis* – the idea that as humans migrated to the Americas, Australia, and the islands of the Pacific, they rapidly hunted large animals to extinction – the article's authors argued that humans bore at least partial responsibility for the extinctions, and therefore should be held responsible for mitigating them. They maintained that the ecological functions once performed by extinct megafauna could be restored by introducing African cheetahs, Asian elephants, and other 'proxy species' to the American West. Plans to restore the Bolson Tortoise were already underway in New Mexico, the authors explained, and in their opinion, (re)introducing proxy species on a small scale would bring ecological and cultural benefits with few costs.

Not everyone agreed with them. In the week after the article was published, the authors received hundreds of angry letters, including one that stated: "you are a f*S#ing moron if you release killers in our homeland;" and another: "just a note to let you know that those of us who actually work for a living think you are a colossal asshat" (Donlan and Greene 2009, p. 298). There were also formal rebuttals. Some ecologists contended that the intentional introduction of large species to North America could lead to ecological catastrophes like disease transmission or food web collapse. Others argued that it was impossible to restore the ecological conditions of the Pleistocene, or even to approximate them, as climate change had irreversibly altered the world (e.g. Rubenstein et al. 2006; Ricciardi and Simberloff 2009).

In a very public way, the 2005 'Pleistocene re-wilding' article threw into question the use of historical baselines in ecological restoration. Its authors argued that while American conservationists routinely used the arrival of European colonizers in 1492 as a restoration benchmark, the arrival of the first people from Eurasia roughly 13,000 years ago constituted a less arbitrary baseline (Donlan et al. 2005). The paper came out at a moment when a handful of ecologists were challenging the use of historical baselines in restoration. The challengers claimed that recent climate change has made it impractical or impossible to restore ecological communities to a past state. Already, some species are no longer found where they used to be; shifts in temperature and rainfall patterns have led their ranges to shift poleward or to higher elevations (Parmesan and Yohe 2003). Such geographical shifts challenge place-based

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[1] New Mexico Wilderness Alliance, "Pleistocene Rewilding: Endangered Tortoises Land in New Mexico," January 8, 2007, https://rewilding.org/pleistocene-rewilding-endangered-tortoises-land-in-new-mexico/ Accessed 23 February 2023.

[2] The article was covered by the Associated Press, *USA Today*, the *New York Times*, *The Economist,* National Public Radio, the British Broadcast Service, ABC's Good Morning America, and elsewhere.

species conservation and could result in the 'uncanny scenario,' as one journalist recently put it, in which Joshua Trees only survive outside of Joshua Tree National Park (Kiefer 2018). Embracing this idea, proponents of novel ecosystems argued that restoration projects should aim to achieve specific ecosystem functions rather than to return to a historical configuration of species (Choi 2004; Williams and Jackson 2007; Hobbs et al. 2009). And so, twenty-first century biologists are confronted with quite the tangled question: should ecological restoration look backward or forward? Should it reconstruct the past or anticipate the future?

2005 was not the first year that the Pleistocene overkill hypothesis had sparked generative and highly public debate among biologists. Whereas recent debates concern the management of non-human nature, debates in the 1960s, when paleoecologists first promoted the overkill hypothesis, concerned *human* nature. Amid war in Vietnam, racialized fears of urban violence, and state violence against civil rights protesters, some biologists advanced a vision of humanity based on the tropes of man the hunter/killer and woman the gatherer/mother (Carthy and Ebling 1964; Milam 2012). Anthropological and archeological accounts naturalized violence as a structuring force in the development of social and political relations. During the same period, environmentalists were beginning to critique a postwar culture of mass consumption (Cohen 2003; Black 2012). The Pleistocene overkill hypothesis naturalized violent overconsumption: it projected overconsumption deep into the past and framed it as an innate human behavior rather than a political choice. The hypothesis depended upon the increasingly popular idea that humans were, *as a species,* naturally selfish over-consumers. It blamed environmental degradation on every human equally, rather than blaming it on specific powerful individuals, irresponsible governments, or destructive corporations.

This article traces the origins of the Pleistocene overkill hypothesis to the 1950s atomic work of the Yale Geochronometric Laboratory, a multi-disciplinary network whose members and collaborators included Paul Bigelow Sears, Edward Deevey, Kathryn Clisby, and Paul S. Martin (one of the eleven authors of the 2005 Pleistocene re-wilding article). The new technique of radiocarbon dating brought together anthropologists and adherents of the relatively new discipline of ecology, opening up new questions for both fields and radically reorganizing the timeline of global environmental history – and human history. Yale Geochronometric Laboratory scientists working with radiocarbon dating placed the arrival of humans to North America and the Pleistocene extinctions on the same timeline for the first time. This temporal reorganization depended on a shift in how ecologists analyzed fossil pollen. Prior to the 1950s, ecologists studied fossil pollen with the primary goal of reconstructing climatic history. They used pollen as a proxy for climate, interpreting the presence or absence of certain plant species in the fossil record to mean that conditions were cold or warm, dry or wet. Climate was their object of study. Paul Martin and his collaborators interpreted fossil pollen toward a related but different end: reconstructing past ecological communities, the group of interacting plant and animal species. Into the 1960s, a small network of paleoecologists would envision a deep history of species migrations and co-existences. Historical ecology, as it is now called, coalesced as a small but influential sub-discipline of paleoecology. Today its theories determine which species are introduced and nurtured, and which species are killed, at tens of thousands of restoration sites around the world, sites that use colonial baselines as well as Oostvaardersplassen, a Pleistocene rewilding park in the Netherlands, and Ted Turner's private ranch in the United States (Swetnam et al. 1999; BenDor et al. 2015; Martin 2022).

Studying Fossil Pollen as a Climate Proxy

The history of paleoecology is entwined with the history of energy production. First used to identify coal deposits, fossil pollen would later be made available for study through uranium mining, as we will see. German scientists first identified fossil pollen embedded in coal with compound microscopes in the 1830s, and by the 1880s fossil pollen was used to identify coal-bearing rocks. During World War I, concern about energy supplies provided European scientists an impetus to study pollen in peat, a soil-like sediment consisting of partially decayed plant matter that collects in acidic bogs, fens, mires, and moors. Finding itself without coal and oil resources, Sweden began to evaluate peat as a potential energy source, and the Swedish geologist Lennart von Post developed a method of extracting fossil pollen from peat while working for the Swedish Geological Survey during the war (Manten 1966; Erdtman 1967; Nordlund 2007, 2014). Peat bogs are often found in depressions carved by retreating glaciers, and von Post thought to use the fossil pollen found in peat to determine the relative age of these depressions. Mixing peat samples with a strong base to separate pollen grains from other material, and then staining the pollen with safranin or gentian violet, von Post and his collaborators worked to classify myriad pollen forms under a microscope. They found a layer of spruce pollen in most of the bogs that they sampled, and they suggested that this 'spruce boundary' had been laid down at the same time across sites, and thus could be used to correlate the age of the bogs with one another. This was a method of relative dating, by which scientists could determine which bog of a set was the oldest, rather than a method of absolute dating, whereby scientists could determine how old an individual bog was (von Post 1916). Early pollen analysts used relative dating to understand the formation of bogs and other landscape features.

Interest in post-glacial climatic history rose in the formerly glaciated landscapes of Scandinavia (Charenko 2022). By 1916, von Post described his methods as a means of reconstructing past climate in addition to physical landscape change (Nordlund 2014). Von Post's methods for ’pollen stratigraphy’ remained obscure until the early 1920s, when the doctoral dissertation of one of his students, Otto Gunnar Erdtman, was published (in German) and rapidly circulated among botanists in Europe and the United States (Erdtman 1921). Among those who read Erdtman's dissertation was American botanist Paul Bigelow Sears. Crucially, Sears was trained both in pollen morphology and plant succession theory, a body of work central to the emergence of ecology as a discipline distinct from botany or zoology.[3] Sears,

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[3] On the history of ecology between 1890 and World War II, see Moore (1920), Worster (1987, chapters 10–11), Egerton (1977), Tobey (1981), Cittadino (1990), Croker (1991), Nicolson (1996), Kohler (2002), and Kingsland (2005, chapters 1–5).

along with a handful of European contemporaries, would employ fossil stratigraphy to visualize the climatic past of formerly glaciated sites.

As an undergraduate at the University of Nebraska, Paul B. Sears studied pollen cell physiology under the instruction of renowned botanist Charles Bessey. In 1915, Sears began a Ph.D. program at the University of Chicago, where he learned about the emerging discipline of ecology while continuing his work on pollen physiology (Disinger 2009; Cittadino 2017). After serving in the Army from 1917 to 1919, Sears worked briefly as a botany instructor at Ohio State University. While there, a friend suggested that he read ecologist Henry Gleason's recent article, "Vegetational History of the Midwest." Observing that small patches of prairie plants were common across the Midwest, Gleason hypothesized that in the past, the prairie had been continuous. In his words, these patches were 'relic colonies' that indicated that the Midwest had been warmer and dryer in the past. Gleason argued that relic colonies were the best available archive of climatic change in the Great Plains, unlike in Europe, where written records preserved 'trustworthy accounts' of past vegetation.[4] Up until this point, ecologists had primarily employed succession theory to predict the future. From bare soil, they held, a plant community would progress through predictable stages – grassland, say, and then shrubland, and finally forest, the so-called climax community (e.g. Clements 1909, 1916; Cowles 1911). Gleason argued that "with equal accuracy" ecologists could use succession theory to "look back and deduce the past of the vegetation" (Gleason 1953, p. 37).[5] Living plants became a climate archive.

Sears read Erdtman's dissertation around the same time that he encountered Gleason's writings. Through the juxtaposition of the two authors' work, Sears decided to study the climatic history of the Midwest (Sears 1930a, b). His training in both pollen morphology and succession theory positioned him for such work. The first bog that Sears sampled was in his hometown of Bucyrus, Ohio. In the peat from Bucyrus Bog he found pollen from fir, spruce, cattail, hemlock, oak, elm, and other genera. Graphing the relative number of pollen grains from four genera by depth, he hypothesized that since the last ice age, the climate of Ohio had progressed from cold-wet to cool-dry to cool-moist to warm-moist. This progression seemed to correspond with a glacial retreat hypothesis recently put forth by Yale geologist Richard Foster Flint suggesting an alternation of retreats and re-advances, rather than a continuous retreat, which would cause a cycling of moist and dry periods.[6] "Great shifts in climate do not occur smoothly," Sears went on to write in *The Literary Digest* in 1934; "They may rather be likened to

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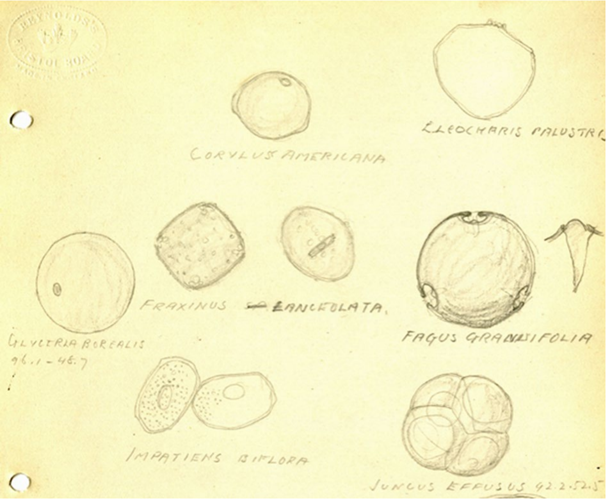
[4] Sears's notes on Gleason (1922) can be found in box 5, folder 2, MS 445, Paul Bigelow Sears Collection, The University of Arizona Special Collections, Tucson, Arizona [hereafter Sears Papers]. Gleason elaborated on the relationship between migration and succession in Gleason (1917).

[5] Among historians of biology, Gleason is best known for rejecting Clements's 'superorganism' theory. See Barbour (1995). Around the same time, E. Lucy Braun came to the same conclusion: succession theory was not only a tool to predict the future, but also a tool to envision the past. E. Lucy Braun to Frederic Clements, October 23, 1929, subseries 1, box 12, folder 1-3, 1929 to 1935, Annette and E. Lucy Braun Papers, MS 1064, Cincinnati History Library & Archives, Cincinnati, Ohio.

[6] Sears mentioned this connection in notes for a lecture he delivered before the Mexican Society of Natural History, June 3, 1955, box 3 folder 27, Sears Papers.

the progress of a drunken man, staggering from side to side as he goes forward along the path."[7]



Sketches of pollen grains from Sears's notebook, c. 1925. Box 6, folder 79, Paul Bigelow Sears Collection, Special Collections at the University of Arizona Libraries, Tucson, Arizona.

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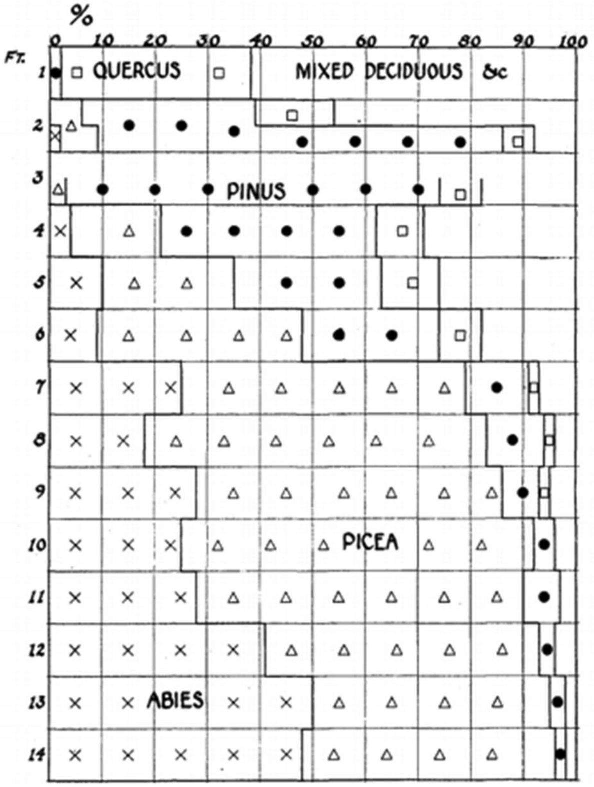
[7] Paul Sears, "Climate in Northern Hemisphere Since Ice Ages," *Literary Digest*, January 6, 1934, clipping in box 5, folder 6, Sears Papers.



A figure from Paul B. Sears, "A Record of Post-Glacial Climate in Northern Ohio," *The Ohio Journal of Science* 30 (1930): 205–217. The diagram shows that in the deepest and therefore oldest samples, *Abies* (fir) and *Picea* (spruce) dominated the landscape, whereas more recently, *Quercus* (oak) and mixed deciduous species deposited pollen. Sears interpreted this to mean that the climate of Ohio had shifted from cold/wet to warm/moist.

Take Nature's Secrets From 'Grave'

Photograph of Paul Sears, right, and two others from Josephine Robertson, "Reads Future in Pollen of Past," The Cleveland Plain Dealer, c. 1935. Clipping in Box 5, Folder 6, Paul Bigelow Sears Collection, Special Collections at the University of Arizona Libraries, Tucson, Arizona.

As a lecturer at the University of Nebraska, Sears set out to refine the von Post method and to construct an identification key for North American pollen (Sears 1930b). In an interview for the *Arkansas Gazette*, he explained his fieldwork process. First, he located a peat bog. Standing on the mat of floating *Sphagnum* (peat moss), he pushed a large hollow rod into the moss and removed cylindrical sections until he hit the bottom of the deposit. He then wrapped these sections in butter parchment. Back at the laboratory, he took samples from every six inches of this core. He extracted the pollen grains from the muck by shaking the sample with hydrochloric acid and mineral oil. He then mounted the grains on slides and identified them under a microscope.[8] Using the changing proportions of pollen grains, Sears visualized how the plant community had changed over time, and from that he inferred how the climate had changed.[9]

Sears's work and that of other early paleoecologists might have remained obscure, if not for the environmental and economic devastation of what is now called the American Dust Bowl. The Dust Bowl rapidly reshaped great swaths of the American landscape and made questions about climate change significant to millions.[10] By

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[8] Clipping in Paul B. Sears to Johnny Erp, May 25, 1934, box 1, folder 6, Sears Papers.

[9] Paul B. Sears to Johnny Erp, May 18, 1934, box 1, folder 6, Sears Papers.

[10] In emphasizing the importance of the Dust Bowl to paleoecology, I am in agreement with Melissa Charenko's recent article, "Reconstructing Climate: Paleoecology and the Limits of Prediction during

1938, Sears had collected peat samples or been sent samples from eighteen states. Many of these samples were sent by employees of the U.S. Forest Service and the new Soil Conservation Service.[11] During this period, Sears and his collaborators increasingly framed pollen stratigraphy as a tool for environmental management. "The future weather and possible fate of the Midwest's dust bowl can be foretold by a 'pollen grain calendar,'" an Associated Press reporter wrote in 1937. Pollen deposits might "contain the answer to the dust bowl's future," Sears explained to the reporter.[12] Pollen deposits would reveal the climatic cycles of the past, Sears reasoned, and therefore how those cycles would play out in the future.

Worldwide economic depression amplified interest in cyclical phenomena across disciplines, including ecology. At a 1931 conference, American naturalist Aldo Leopold and British zoologist Charles Elton – along with business leaders, climatologists, and even the captain of an ice-breaking ship – discussed structural similarities among recent droughts in the Midwest, the Hudson Bay Company's catch record of arctic foxes, the market value of bowhead whales, and the virulence of influenza. They maintained that if cyclic phenomena could be characterized and explained, then booms and crashes, whether biological or economic, could be managed by scientists. "The mechanisms of nature," Leopold wrote in an essay later that year, "like any other engine, can be driven, if we know which levers to pull."[13]

Leopold was not alone in his view that if such cycles could be characterized, they could be predicted and planned for, and that if the mechanisms of these alleged cycles were identified, they could be controlled. This was a common view among ecologists, economists, and meteorologists at the time, who sought to naturalize booms and busts rather than ascribe them to political or economic decisions. Scientists of various disciplines asked whether drought at such a scale had been anomalous, cyclical, or frequent in that history, and ecologists weighed in on these questions, working to reposition themselves as experts on the past using a variety of methods, including pollen stratigraphy, tree ring analysis, and plant succession theory (Charenko 2020). Increasingly, palynologists in Europe and North America collaborated to describe glacial cycles of the last Ice Age. Plants – whether live specimens, in the case of succession theory, or fossilized, in the case of fossil pollen – became proxies for climatic conditions.

Footnote 10 (Continued)

the 1930s Dust Bowl." Charenko (2020) argues that Frederic Clements's and Paul B. Sears's "distinct notions of climate emerged from the particular way each reconstructed past climates" (p. 93). While Clements analyzed tree rings and argued for regularity to climatic change, by the 1940s, Sears rejected the cyclical nature of climate. See also Christophe Masutti (2006).

[11] The logbook with the codes for Sears's peat collections is in box 6, folder 82, Sears Papers.

[12] "Sears Reads Dust History in Peat Bogs: Pollen Grain May Give Clue to Dust Bowl's Fate," *Associated Press,* March 17, 1937, clipping in box 5, folder 6, Sears Papers.

[13] Aldo Leopold, "Science Attacks the Game Cycle," *Outdoor America* (1931), p. 25, Box 1, Series 9/25/10-6, Leopold Papers. Leopold's notes from the conference can be found in Box 5, Folder 2, Series 9/25/10-2, Aldo Leopold Papers, University of Wisconsin-Madison Libraries, Madison, Wisconsin [hereafter Leopold Papers]. See also Elton (1933). On Elton and population ecology more generally, see Kingsland (1985), Crowcroft (1991), Anker (2001), Erickson (2010), Bocking (2012), and Jones (2017).

Radiocarbon Dating and the Yale Geochronometric Laboratory

Edward Deevey became interested in the climatic history of New England while an undergraduate in Yale's Botany Department in the early 1930s. He suspected that the same techniques Paul Sears was using to analyze peat cores from Midwestern bogs could be used to analyze fossilized pollen in the mud of Northeastern lakes. Although Deevey was unable to find an advisor in his own department, his idea sparked the interest of G. Evelyn Hutchinson, a polymath who, like Paul Sears, had found his way to ecology through cell physiology. Deevey began by analyzing pollen in lake sediments collected by Hutchinson on the Yale North India Expedition of 1932, and then pollen in mud cores from New England lakes.[14]

In 1938, at the age of 23, Deevey received a Ph.D. for his work on the pollen stratigraphy of five southern Connecticut lakes. From his analyses he concluded that after the last glaciers retreated, the New England landscape had been dominated first by spruce and fir, then by birch, then by pine, suggesting a gradual warming and drying.[15] That year, he began corresponding with Sears. At first, they discussed two controversies in their new field: the debate as to whether oak was actually a good indicator of dry conditions or whether the genus could also be found in moist conditions, and the debate around the terminology of mud. What, Deevey asked, was Sears's opinion on terms like "sludge," "ooze," and "slime"?[16] Encouraged by Deevey's success at extracting countable and diagrammable quantities of pollen from lake sediments, Sears began to make plans to collect samples from the arid West. World War II would stall those plans, but it would also provide palynologists with a new method of dating that was to transform their discipline: radiocarbon dating. The discipline's rapid shift from relative dating (through pollen stratigraphy) to absolute dating (through radiocarbon dating) transformed research networks, bringing together palynologists, ecologists, physicists, and anthropologists, and changing the types of questions asked in each field. These transdisciplinary collaborations resulted in new scientific understandings of global environmental history.

Researchers at Berkeley working on photosynthesis in the late 1930s first observed that a radioactive isotope of carbon, carbon-14, was created continuously through collisions of neutrons from cosmic rays with nitrogen in the upper atmosphere (Creager 2013). In 1946, Willard Libby, a Manhattan Project chemist at the University of Chicago, proposed that the carbon in living matter might include carbon-14 as well as non-radioactive carbon. He hypothesized that carbon-14 was a trace element in atmospheric carbon dioxide and that plants should be assimilating the isotope into their tissues. An animal that consumed plants would receive a continuous, if very small, supply of carbon-14 throughout its life, but when it eventually died, it would cease to take in new carbon of any kind. If scientists could determine

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[14] Letters between Deevey and Hutchinson can be found in box 11, folder 194, series I, G. Evelyn Hutchinson Papers, Manuscripts and Archives, Yale Sterling Memorial Library, New Haven, Connecticut [hereafter GEH Papers].

[15] See also series I, box 11, folder 194, GEH Papers.

[16] Edward S. Deevey to Paul B. Sears, October 31, 1939, box 1, folder 5, Sears Papers; Edward S. Deevey to Paul B. Sears, April 9, 1937, box 1, folder 5, Sears Papers.

the rate of decay of carbon-14, they should be able to determine the time elapsed since the death of an organism.[17]

As Kern (2020) details, archeologists were quick to realize the potential of carbon-14 to date human artifacts. The Society for American Archaeology and the American Anthropological Association formed a Radiocarbon Dates Committee in early 1948, which was supported by the Wenner-Gren Foundation. The committee sought to supply Libby's laboratory with samples whose age could be approximated with a high degree of confidence by archeologists. This project was a collaboration between archeologists with well-formed international networks and the rapidly expanding world of atomic chemistry. The rise of carbon dating was part of a broader postwar effort by the Atomic Energy Commission to develop peacetime applications of nuclear technologies, including the production of radioisotopes for illuminating metabolic pathways and genetic transmission (Creager 2013).

Nuclear technologies would also fundamentally reshape ecological fieldwork, and they played a central role in the emergence of the concepts of bioaccumulation and the ecosystem (Martin 2022). It is a lesser-known fact that ecologists, including Edward Deevey and G. Evelyn Hutchinson, were also among Willard Libby's first collaborators. After working for the U.S. Navy (with civilian status) during the war, Deevey accepted a lecturing position at Yale. In 1949, he attended a meeting at Chicago's Institute for Nuclear Studies, where he met Libby there he agreed to supply Libby's lab with peat samples from the Eastern United States. A few months later, at the Ecological Society of America's annual meeting, Deevey described his and Hutchinson's plans to apply Libby's radiocarbon dating methods to peat samples from the Eastern United States.[18] Soon thereafter, Libby wrote to Hutchinson, warning him that the technology of radiocarbon dating was "about as difficult as an appendectomy, or baking a really good cake."[19]

Despite Libby's joking warning, Deevey, Hutchinson, and Richard Foster Flint established the Yale University Geochronometric Laboratory in 1951 with funding from the Office of Naval Research and the Rockefeller Foundation. Flint had been an early member of the Radiocarbon Dates Committee (Kern 2020). In collaboration with Libby's laboratory, the Yale Geochronometric Laboratory worked to tackle the methodological problems of sampling biological materials for carbon-14, of which there were many (Flint and Deevey 1951; Deevey et al. 1959). Few archival traces of

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[17] Series I, box 11, folder 194, GEH Papers. "The Philosophers' Stone," *TIME*, August 15, 1955. On carbon dating see Libby (1946), Anderson et al. (1947), Arnold and Libby (1949), Libby (1955), and Libby (1972).

[18] Willard Libby to G. Evelyn Hutchinson, as cited in Deevey (1984). Hutchinson describes this meeting in "Report of the Ad Hoc Committee on Ecology of the Yale Biology Department," c. 1966, box 50, folder 50, series 2, GEH Papers. See also Deevey (1949), "Program of the New York Meeting" (1949) and Deevey (1952).

[19] Libby as quoted in Hutchinison, "Report of the Ad Hoc Committee on Ecology of the Yale Biology Department," c. 1966, Box 50, Folder 50, Series II, GEHP. See also Edward Smith Deevey, Jr., "Biogeography of the Pleistocene. Part 1. Europe and North America," *Bulletin of the Geological Society of America* 60 (1949): 1315-1416; "Program of the New York Meeting with Abstracts of Papers, Thirty-Fourth Annual Meeting of the Ecological Society of America," *Bulletin of the Ecological Society of America* 30 (1949): 45-72; Edward Smith Deevey, Jr., "Radiocarbon Dating," *Scientific American* 186 (1952): 24-28.

the Yale Geochronometric Laboratory remain. In a retrospective published in 1984, Deevey gave a personal account of the rise of radiocarbon dating, which he acknowledged came from his “leaky, selective memory” rather than historical research (Deevey 1984, p. 1). Deevey first set up the Geochronometric Laboratory at 77 Prospect Street in New Haven “in the basement of a disused fraternity house,” and assured the Yale administration that it would not be a new department or research institute – “units for which the dean and president had reciprocal, well-grounded distaste.” The Laboratory was overseen by an interdepartmental advisory board that included Flint (Geology), Hutchinson (Zoology), Wendell Bennett (Anthropology), George Kubler (History of Art), C.G. Montgomery (Physics), and Henry Thomas (Chemistry). What the Laboratory’s research was about “was clear to the Board, but difficult to describe to others” (Deevey 1984, p. 3, 4). In its early years, it focused on dating late Pleistocene samples of interest to geologists and archeologists and on trying to chart atmospheric carbon-14 concentrations over time. Hutchinson worked with collaborators, including Neils Bohr, Harold Urey, and G.N. Lewis, to explain the puzzling carbon-14 fluctuations they measured in tree-rings: did they result from the sunspot cycle? The oxidation of soil? The rise of industrial burning of fossil fuels? Deevey introduced radiocarbon dating to a wider audience with a 1952 *Scientific American* article. He emphasized that carbon-14 measurement was not only useful for dating human historical events, but would also shed light on “the chemical history of lakes, the atmosphere and the oceans” (Deevey 1952, p. 28).

At first enthusiasm for radiocarbon dating was mixed. A 1952 newspaper article extolled the ’atomic calendar’ that would enable scientists to tell the age of objects dating as far back as 20,000 years. But at a meeting to discuss the establishment of a National Advisory Committee on radiocarbon dating that same year, one researcher claimed that “interest in radiocarbon is declining so rapidly that [scientists] should do nothing but express sympathy.”[20] The trouble was calibration: researchers were arriving at wildly different dates for the same samples.

Nevertheless, in 1954 the Geochronometric Laboratory was able to secure stable funding from the National Science Foundation (NSF), which had been established by Congress 4 years prior. In his proposal to the NSF, Deevey asserted that the Geochronometric Laboratory would succeed because of Yale’s flourishing school of “Pleistocene studies.”[21] Besides Deevey and Flint, Paul B. Sears had accepted a professorship at Yale in 1950.[22] Deevey argued in the proposal that understanding the

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[20] Hutchinson probably learned about radiocarbon dating at the National Academy of Sciences in 1946 or 1947, as he was connected to a group who discussed ’cosmochemistry.’ Edward Deevey attended a meeting of archaeologists and radiochemists in 1952 on the refinement of radiocarbon dating; see Deevey (1951). Deevey’s notes from “Conference on Radiocarbon Dating: Meeting of Society for American Archaeology at Columbus, Ohio on May 3, 1952,” can be found in box 11, folder 194, series 1, GEH Papers.

[21] “Proposal for an Interdisciplinary Program of Study of the Past Million Years,” 1954, box 58, folder 51, series 2, GEH Papers.

[22] Sears became chairman of the Conservation Program at Yale University in the 1950s. Prior to that he had taught botany at the University of Oklahoma and Oberlin College. He authored, among other works, *Deserts on the March* (Norman: University of Oklahoma Press, 1935), *This Is Our World* (Norman: University of Oklahoma Press, 1937), *Life and Environment* (New York: Teachers College, Columbia University, 1939), and *Charles Darwin: The Naturalist as a Cultural Force* (New York: Scribners, 1950).

climatic past was the key to predicting the future. “Only when we know something of the past,” he wrote, “can we venture any predictions.”[23]

By 1955, in addition to the laboratories at Yale and Chicago, five other radiocarbon dating laboratories were in operation in the United States and Canada, along with eleven in operation or near completion in Europe and one in New Zealand. At conferences in Denmark and England in 1954, 1955, and 1956, Geochronometric Laboratory members discussed the establishment of internationally uniform protocols for calculating and reporting radiocarbon results, as well as methods for dealing with fallout contamination from nuclear weapons detonated by the United States, the USSR, and the United Kingdom (Grootes and van der Plicht 2021).

While a professor at Yale, from 1950 to 1960, Sears worked with the Yale Geochronometric Laboratory to analyze sediment cores from the arid West. Unlike peat samples from the northern United States, he argued, samples from former lakebeds in the West would contain a pollen record that extended earlier than the last glaciation, as that area had not been covered by the glaciers. And so, in 1950, Sears began submitting proposals to funders for the purpose of visiting New Mexico to secure cores.[24] It would prove to be a difficult sell, and Sears variably played up the climate history angle and the archeology angle. To the Carnegie Institution he pitched the project as a study of the “close correlation between climatic history and cultural shifts.” They declined.[25] To the Office of Naval Research he explained that research into past climatic cycles of the earth could improve climatic forecasting, which might be “helpful information in the strategic planning of the Navy in some of the areas of its global responsibilities.”[26] The ONR was not persuaded. The Geological Society he found to be concerned chiefly with “what is known in the trade as ‘hard-rock’ problems,” and not ecological problems.[27] Finally, he secured a few thousand dollars from the Wenner-Gren Foundation for Anthropological Research to study “a stratigraphic scale for human cultural sequences.”[28]

Sears tasked his laboratory assistant, Kathryn Clisby, with the development of methods for extracting pollen from the sediments. Like Sears and Hutchinson, Clisby had found her way to ecology via cell physiology. But unlike Sears, she had no formal training. After high school, Clisby worked as a laboratory assistant analyzing the blood of dogs injected with *E. coli* at Toledo Hospital in Ohio, and then in a laboratory at Oberlin College studying lead poisoning. At Oberlin she audited classes in Botany and Geography.[29] Clisby’s innovations in extracting pollen from silt and clay soils allowed her and Sears to study sediment cores further west than

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[23] “Proposal for an Interdisciplinary Program of Study of the Past Million Years,” 1954, box 58, folder 51, series 2, GEH Papers.

[24] Paul B. Sears to Warren Weaver, May 25, 1950, box 1, folder 23, Sears Papers.

[25] Warren Weaver to Paul B. Sears, May 31, 1950, box 1, folder 23, Sears Papers.

[26] C. C. Furnas to Admiral C. M. Bolster, September 19, 1952, box 1, folder 3, Sears Papers.

[27] John N. Adkins to C. C. Furnas, October 6, 1952, box 1, folder 3, Sears Papers.

[28] Untitled manuscript, n.d., Box 1, folder 7, Sears Papers.

[29] Kathryn Clisby to Paul B. Sears, November 1, 1951, box 6, folder 30, Sears Papers; “Climate Scientist: Wellington Woman Reads Story of Past in Samples of Earth,” newspaper clipping without publication information, box 6, folder 31, Sears Papers.

ever before.[30] Through the 1950s, Clisby and Sears traveled across New Mexico, Arizona, and Mexico to collect sediment cores.

While it is not apparent from Sears' publications, the cooperation of the Atomic Energy Commission (AEC), the successor of the Manhattan Project, was essential to his obtaining sediment samples. The price of hiring a commercial driller to drill deep into hard sediments initially proved prohibitive for Sears and other paleoecologists. Then, in 1952, a geologist working on an AEC uranium reconnaissance project in west-central New Mexico obtained permission to give Sears samples from a 645-foot-deep core.[31] Whereas funding for fossil pollen studies had come from coal prospectors in the early twentieth century, the Atomic Energy Commission now provided pollen workers with physical samples. The only stipulation was that Sears could not refer to AEC activities in his publications. Subsequently, the draft of Sears and Clisby's manuscript, "Two Long Climatic Records," published in *Science* in 1952, was edited by the AEC to read: "Our left-hand profile is based upon a reconnaissance drilling in Valle Grande, a caldera and former lake bed shown in the Jemez Springs and Santa Clara Quadrangles, northern New Mexico"[32] Such censorship obscured the relationship between the AEC and paleoecology, between extractive energy landscapes and experimental ones.

As Sears and Clisby worked on identifying pollen from the New Mexico core, Deevey suggested that their material might contain enough organic material to date with the carbon-14 methods he and Libby were developing.[33] But this effort, too, was complicated by a lack of funding. The AEC would not fund the work, despite Sears's claim that it would "give us a clue as to climatic and physiographic events that can be associated with the concentration of radioactive material."[34] The NSF declined their study, too, which Sears had pitched as the history of how the weathering of high-elevation rocks carries uranium into lakebeds.[35] Finally, in 1955, the Magnolia Petroleum Company agreed to fund the project in the hopes that their methods might help locate oil deposits.[36]

The results of Sears and Clisby's pollen stratigraphy, together with radiocarbon dates, appeared in *Science* in 1956 (Clisby and Sears 1956). A passage from an early draft, cut from the published version, illuminates their motivations, which were not always quite what they had expressed in the many iterations of their grant proposals: "A clear understanding of climatic fluctuations during the past century is basic to intelligent land use. Whether such long time records as are now being studied will

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[30] Clisby's methods for studying "non-calcareous silts and clays" in box 6, folder 1, Sears Papers.

[31] Copy of Chas V. Theis to L. G. Mohr, August 9, 1950, box 1, folder 21, Sears Papers.

[32] Clyde S. Conover to Paul B. Sears, June 10, 1952, box 1, folder 4, Sears Papers; Paul B. Sears and Kathryn H. Clisby, "Two Long Climatic Records," *Science* 116 (1952): 176-178.

[33] Paul B. Sears to the Committee in Charge, Geochronometric Laboratory, May 14, 1952, box 2, folder 8, Sears Papers.

[34] Paul B. Sears to Atomic Energy Commission, March 24, 1954, box 2, folder 1, Sears Papers.

[35] D. L. Anderson, "Appendix: Report on Exploratory Investigations on Radioactivity of Core Samples," 1953, box 6, folder 4, Sears Papers.

[36] D. H. Clewell to Paul B. Sears, April 28, 1955, box 1, folder 3, Sears Papers. See also Paul B. Sears to W. H. Burke, April 22, 1955, box 2, folder 2, Sears Papers; Paul B. Sears to Kathryn Clisby, July 5, 1955, box 2, folder 4, Sears Papers.

eventually shed light on future trends remains to be seen, but the possibility cannot be ignored."[37] Sears and Clisby used the patronage of the energy industry to pursue their underlying research goal: revealing the climatic past in order to inform the environmental management of the future.

In 1957, the editor of *Science*, Graham DuShane, complained to Deevey that the journal was receiving too many lists of radiocarbon dates and was not an "archive" for any branch of science (Deevey 1984). In response, Deevey, Flint, and Hutchinson decided to found a journal, *Radiocarbon* (called then *Radiocarbon Supplement*), with the support of the National Science Foundation (Deevey 1984; Stuiver 2009). The Yale Lab was thus the birthplace of what would become the primary publication of Quaternary studies. Students, postdocs, and visiting researchers at the Yale lab went on to establish geochronology laboratories at the University of Washington, the University of Arizona, and elsewhere. Paul Martin, who developed the Pleistocene overkill hypothesis, was one such member of the "Yale Mafia," as Minze Stuiver, who worked in the Geochronometric Lab in the 1960s, called them (Stuiver 2009, p. 296).

Reconstructing America's Ecological History

By the second half of the 1950s, radiocarbon dating had become a popular method among palynologists. There were no presentations on radiocarbon dating at the Second National Pollen Conference in December 1953.[38] But at the Third National Pollen Conference, organized by Clisby and Sears and held at Oberlin College in May 1956, almost every presentation discussed radiocarbon dating, with titles like "Postglacial Chronology in the Light of Radiocarbon Dates" and "A Carbon-dated Pollen Profile from Umiat."[39] While Deevey's 1949 paper, "Biogeography of the Pleistocene," relied on the relative time scales of pollen stratigraphy, his 1951 paper, "Radiocarbon Dating of Late-Pleistocene Events," assigned absolute dates to peat, charcoal, and mud samples (Deevey 1949; Flint and Deevey 1951).

For more than 20 years, palynologists had worked to correspond samples from distant sites using stratigraphic positioning. For example, if a spruce horizon was found in a sample from Massachusetts and a sample from New York, the horizons were assumed to have been deposited around the same time. However, there were limitations to such inferences. Geological uplift could move older samples closer to the surface, confounding the stratigraphy. "I'm frankly scared of even guessing at time or past climates in the belt of the volcanoes," geographer Carl O. Sauer wrote to Sears in 1949.[40] Radiocarbon analysis provided another method of dating samples, one dependent on an invisible quality of the sediments. Archaeologist Frederick Johnson wrote in Libby's 1955 reference book on radiocarbon dating that the

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[37] Sears and Clisby, draft manuscript, n.d., box 6, folder 23, Sears Papers.

[38] Box 6, folder 22, Sears Papers.

[39] Final Program for Third National Pollen Conference, Oberlin, May 18-20, 1956, box 6, folder 23, Sears Papers.

[40] Carl Sauer to Paul B. Sears, July 8, 1949, box 1, folder 19, Sears Papers.

new method enabled archeologists, geologists, and ecologists to correlate their disciplines' data because it allowed for "measures made by different laboratories on identical samples," rather than inferences from field sites (Johnson 1955, p. 141). The technique opened up new puzzles in old samples, which ecologists debated heatedly, mostly in private correspondence.[41]

In a significant revision to climatic history, Carbon-14 data led many scientists to believe that the glaciers in North America had retreated much later than scientists of the early twentieth century had believed. In his 1951 paper, "Radio-carbon Dating of Late-Pleistocene Events," Deevey announced that peat, wood, and charcoal samples previously assumed to be from 25,000 years before present proved to date from about 11,000 years before present (Flint and Deevey 1951). These revisions to Pleistocene chronology led to new hypotheses in biogeography, archeology, and ecology, and ultimately to a dramatic reimagining of global environmental history.

By the 1930s, many archeologists and anthropologists believed that humans had first populated North America by crossing the Bering Strait via a land bridge in small groups. But they differed radically in their opinions as to when this had happened. One school of thought believed that humans had come from Asia to North America before the advent of the last glacial period, at least 25,000 years before the present. Another vocal group placed the migration far more recently, speculating that humans reached Mexico only around 2500 years before present (Boas 1929; Antevs 1935; Howard 1936). With radiocarbon dating of artifacts and human remains in the 1950s, archeologists rather quickly converged on the idea that humans had arrived in North America around 11,000 years before present (Haynes 1964; Haynes 1967).

Paul S. Martin's controversial and consequential Pleistocene overkill hypothesis emerged from this temporal reordering. A zoologist by training, Martin had studied the contemporary biogeography of amphibians and reptiles in the forests of Tamaulipas, Mexico, while pursuing his doctorate at the University of Michigan (Martin 1958b). As a postdoctoral researcher at the Yale Geochronometric Laboratory in 1955, Martin attempted to unite the recent findings in Pleistocene archeology and ecology generated by 'methods of isotope dating' (Martin 1958a). Deevey taught him the methods of palynology and radiocarbon dating. The archives do not contain clues as to how Martin found his way to the Yale Geochronometric Laboratory. In *Twilight of the Mammoths*, published many years later in 2005, Martin implied that he chose to pursue laboratory research instead of intense field work after a bout of polio. He wrote:

> Had I not suffered a handicap from a bout with polio in 1950, I might never have turned my attention to peat, rich fossil pollen, being studied by botanists in the postglacial lakes around Ann Arbor. Then, in 1955, I learned from ecologist Ed Deevey at Yale University how to extract, identify, and count fossil pollen. From these counts one could learn what happened to plants after the glaciers melted away.

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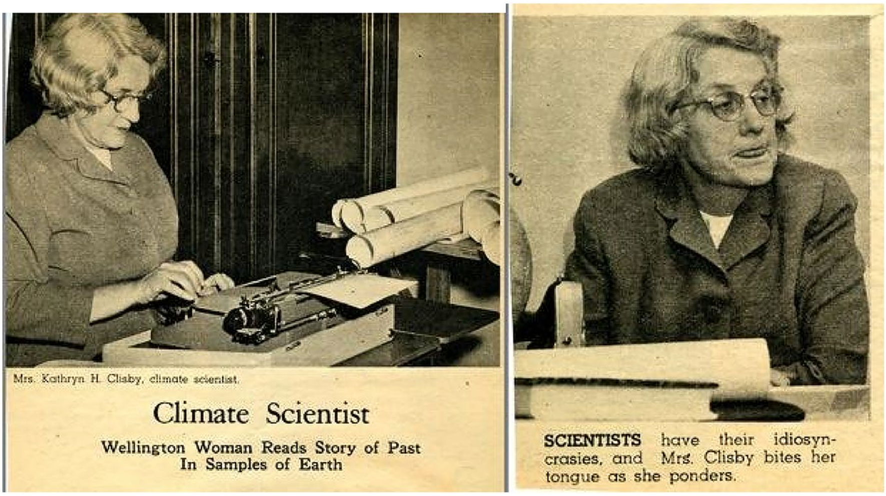
[41] See, for example, Phil C. Orr to Paul B. Sears, June 1, 1955, box 1, folder 16, Sears Papers.



Mrs. Kathryn H. Clisby, climate scientist.

Climate Scientist

Wellington Woman Reads Story of Past
In Samples of Earth

SCIENTISTS have their idiosyncrasies, and Mrs. Clisby bites her tongue as she ponders.

Clipping of a news article on Kathryn Clisby, unknown publication and date. Box 6, Folder 31, Paul Bigelow Sears Collection, Special Collections at the University of Arizona Libraries, Tucson, Arizona.

> For Ed, the biogeography of the Pleistocene (the last ice age, 1.8 million years ago to 10,000 years ago), with all its glacial and interglacial changes in climate, was the key to understanding modern plant and animal distributions. Ed took cores of organic sediment from lake beds and counted samples of the fossil pollen, spores, and copepods (minute aquatic crustaceans) they contained. He could date these remains by Willard F. Libby's then-new radiocarbon method; scientists could now refer to "Libby time" (roughly the last 40,000 years, the period for which radiocarbon dating is most effective). Magically, the fossil pollen record in sediment cored from New England lakes told of the comings and goings of treeless tundra and of spruce, fir, jack pine, and other trees as the climate warmed, the glaciers melted and on occasion readvanced, and eventually the ice-margin boreal vegetation yielded to today's deciduous forest (Martin 2005, 4).

After learning palynology and radiocarbon dating at Yale, Martin took a second postdoctoral position at the Université de Montréal, working on a pollen record of late-glacial climatic change and teaching a seminar on Quaternary biology. One night, by his recollection at any rate, he decided to plot late-Quaternary megafaunal extinctions against those that had taken place earlier in the Cenozoic. He found that at the end of the Quaternary, the large terrestrial mammals of North America disappeared – but not the large marine mammals or the small terrestrial mammals. Newly published radiocarbon dates for some of these fossils suggested that the extinctions had happened quite suddenly.

In *Twilight of the Mammoths*, Martin noted that he was far from the first biologist to be intrigued by the Pleistocene extinctions. Megafaunal extinctions had puzzled naturalists since the discovery of mastodon remains in the late eighteenth century

(Grayson 1984; Cohen 2002). In 1812, French naturalist George Cuvier published a compendium of his work on fossil animals, *Recherches sur les ossemens fossiles de quadrupèdes*, detailing more than forty extinct species, including giant sloths and marine dinosaurs. The sudden disappearance of great numbers of species in the fossil record, Cuvier posited, suggested "the existence of a world previous to ours, destroyed by some kind of catastrophe."[42] As naturalists embraced the idea of extinction, they imagined it to be caused by large-scale geological or climatic catastrophes like volcanic eruptions and floods. Then, in 1848, British naturalist Hugh Strickland and physician A.G. Melville published *The Dodo and Its Kindred*, in which they claimed proof of the "first clearly attested instances of extinction of organic species through human agency."[43] Strickland and Melville speculated that after the Dutch colonized the island in 1644, the dodos were speedily diminished, and that their extinction was further hastened by introduced dogs, cats, and swine, for whom the eggs of the Dodo "would be a dainty treat."[44] By the late 1800s, some naturalists believed it was possible, even inevitable, that American settlers would exterminate the bison and other large game species in their lifetimes. Naturalist and eugenicist William T. Hornaday, for example, wrote in 1889 that "the home of the buffalo was everywhere overrun by the man with a gun."[45] Going forward, debates about whether humans could extinguish an entire species hinged on arguments about technological capability. For Hornaday and his allies, it was the gun that made human-caused extinction plausible. Much of the early debate around the Pleistocene overkill hypothesis concerned whether Clovis points – stone projectile points fashioned in the Pleistocene – were a 'sophisticated' enough technology to kill off an entire species. As of 2021, this debate remains wide open, with many archeologists arguing that the Pleistocene extinctions resulted from a combination of climate change and human action (Surovell et al. 2016; Prates and Perez 2021).

Martin was one of the first people to compare radiocarbon dates of fossils between continents and continental extinctions with those on oceanic islands. Unlike most of his peers, he simultaneously considered both botanical and zoological fossils in order to examine North America's 'biotic history' (Martin and Harrell 1957) – what today we call ecological history.[46] In *Twilight of the Mammoths*, Martin wrote that among early geochronologists, "Nobody bothered to study the extinctions. Somehow the Pleistocene megafauna, big as it was, remained out of sight and out of mind. (Martin 2005, p. 5).

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[42] Translated from Cuvier, "Espèces des éléphans," 1796, in Martin J.S. Rudwick, *Georges Cuvier, Fossil Bones, and Geological Catastrophes* (University of Chicago Press, 1997), 24.

[43] Quoted in Mark Barrow, *Nature's Ghosts*, x.

[44] Quoted in Mark Barrow, *Nature's Ghosts*, 27.

[45] *The Extermination of the American Bison* initially appeared in 1889 as part of the annual report of the U.S. National Museum and was later published separately. William Temple Hornaday, *The Extermination of the American Bison* (Washington, D.C.: Smithsonian Institution Press, 2002).

[46] Sears and Martin had corresponded since at least 1952. See Paul S. Martin to Paul B. Sears, April 28, 1952, box 1, folder 14, Sears Papers. Many felt that Martin overreached with his hypothesis. One student wrote to Sears of Martin's paper, "It is an impressive documentation, but again he wields a sharp axe. In some instances, I don't think he has justification, unless it is just to stir up argument." See Pete J. Gordon Ogden II to Paul B. Sears, December 6, 1958, box 2, folder 16, Sears Papers.

Whereas previous scholars held that the North American megafaunal extinctions were separated from the arrival of humans by as many as tens of thousands of years, Martin suggested that they were nearly (in paleohistorical terms) simultaneous. At a 1957 meeting of the American Association for the Advancement of Science, he argued that radiocarbon data suggested that megafauna had survived multiple interglacial periods only to go extinct at the end of the last glacial period. Martin had spent 2 years collecting radiocarbon dates associated with extinct animals, and thought that the climate change hypothesis failed to account for the narrow chronological range of this extinction: he believed that it had occurred around 11,000 years before present. But this was the same window of time that archeologists had recently proposed for the migration of humans to North America, and Martin posited that humans had caused the extinctions; he argued that newly arrived humans quickly hunted North America's megafauna, including ground sloths, camels, and mastodons, until not one individual of any of these species remained.[47]

In his 1958 paper "Pleistocene Ecology and Biogeography of North America," Martin noted that "students of animal and plant distribution" found themselves "increasingly committed" to archaeological data (Martin 1958a, p. 375). Citing recent work by Braun, Deevey, and Flint, along with studies by archeologists including George Irving Quimby (1958), Hannah Marie Wormington (1957), and José Cruxent and Irving Rouse (1956), he argued that radiocarbon dates from human and non-human artifacts (including fluted points, sloth dung, charred bone, bison horns, and mastodon remains), confirmed that megafaunal extinction was a postglacial event (Martin 1958a).

Martin's hypothesis sparked immediate contention, in part because there were few megafaunal remains that showed signs of having been hunted. Ecologists and archeologists debated whether North American Pleistocene extinctions were caused by human hunting, climatic change, a combination of these factors, or something else entirely (Martin and Wright 1967; Krantz 1970). The debate, as a reviewer for *Scientific American* summarized it, was: "Who done it? Was it our cousins – the agile, tireless, able hunters, masters of the chase, of the stampede over the edge of the ravine, of fire scorching the dry prairie? They had newly come from old Asia to find a huge plain of tame grazers unafraid of man. Or was it merely the last shrinking of the glaciers? Drought and warmth then reduced the enormous areas that must nourish such large beasts, forcing all animal life through a narrow funnel of survival."[48]

Martin would defend the overkill hypothesis throughout his career. The work of Katherine Clisby and Paul Sears in New Mexico convinced Martin that the southwestern United States was a promising place to look for fossil pollen deposits disclosing changes in plant and animal ranges, and in 1957, he took a position at the

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[47] A copy of the paper Martin presented at the AAAS Program on Unsolved Problems in Biology can be found in box 6, folder 53, Sears Papers. See also Burney and Flannery (2005).

[48] R.M. Fano, Review of *Pleistocene Extinctions*, *Scientific American*, vol. 218, May 1968, pp. 157-159, clipping in folder 9, box 16, Paul S. Martin Papers, MS 442, The University of Arizona Special Collections, Tucson, Arizona [hereafter Martin Papers].

University of Arizona's Geochronology Laboratories, where, for the next four decades, he expanded his work on the overkill hypothesis to other continents (Martin 2005). An article in *The Arizona Daily Star* explained that Martin had used "pollen study and the new Carbon 14 carbon dioxide gas counting technique" to demonstrate that humans, not climate, had caused the extinction of the giant ground sloth. Martin's research associate, Dick Shutler, had found fossilized sloth dung in a limestone cave 4,000 feet below the rim of the Grand Canyon. The pollen preserved in the dung suggested that ground sloths ate diverse forms of vegetation, including juniper, sagebrush, and other shrubs. Pleistocene megafauna disappeared "not because they lost their food supply but because they became one," Martin contended in 1959.[49] By the 1970s, Martin and his students were running a major program studying preserved plant and animal remains in ancient dung and packrat middens.

The Pleistocene overkill hypothesis spurred ecologists to see landscapes as emptied by humans. In their 1967 book *Pleistocene Extinctions*, Paul Martin and H. E. Wright argued that the seemingly 'pristine' American West must in fact contain many empty niches, space once shared by elephants, camels, horses, sloths, extinct bison, and four-horned antelope. Perhaps, they suggested, our National Parks, wilderness areas, and wildlands are an illusion on a continent where herbivore herds evolved and thrived for tens of millions of years (Martin and Wright 1967). Hinted at here is the idea that land management should strive to recreate a past before humans. One reviewer noted the implications of the book for "the question of replacing the missing members of local megafaunas."[50] It would be another forty years before scientists would pursue the idea of returning missing megafauna to the North American landscape – Pleistocene re-wilding, as it is now called. The Pleistocene overkill hypothesis imagined the Americas as a space of empty niches and unfulfilled ecological relationships. The idea allowed for the later hypothesis that large-seeded New World plants are "anachronistic" (Janzen and Martin 1982, p. 22) and 'ghosts of evolution' (Barlow 2002), for example, that avocado seeds were once dispersed by giant ground sloths.

For decades, paleoecologists had used fossil pollen to imagine past climates, as a proxy for temperature and precipitation. Martin and his collaborators depended upon the climatic history constructed by these paleoecologists. But their object of study was the species themselves: they sought to understand which species had overlapped in space and time. This was *ecological history*. "The giant tortoise has become a paleoclimatic thermometer in the hands of some American paleontologists," Martin quipped in 1967; "Its remains are regarded as indicating a warm, frost-free climate without a winter freeze-up [...]" (Martin and Guilday 1967, p. 3). Martin and his collaborators were interested in tortoise remains and fossil pollen not only as "thermometers," but as records of past ecological relationships, such as that between prey and predator. A 1959 review paper in *Science* noted that, among paleontologists, "attention to ecological considerations, and their interest in ecology seems to be

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[49] George Wilson, "Giant Sloth Perished with Arrival of Man," *The Arizona Daily Star,* January 15, 1959, clipping in MS 442, folder 1, box 22, Martin Papers.

[50] G. B. Corbet, "Review of *Pleistocene Extinctions: The Search for a Cause*," *Journal of Animal Ecology* (1969), clipping in folder 9, box 16, Martin Papers.

growing" (Ladd 1959, p. 71). One reviewer of Martin's 1963 book, *The Last 10,000 Years*, noted that Martin had "gleaned a refreshing new dimension" of pollen stratigraphy by using it "to recreate the southwestern landscape of the past five thousand to ten thousand years as a function of floristic composition and ecology."[51]

Martin and Deevey, in other words, belonged to a cohort of paleoecologists who began to ask how extinct species interacted with one another. Which species competed with one another? Had a species' population size remained stable, or had it experienced population cycles? Did Pleistocene grazers shape the composition of their plant communities, as contemporary grazers did in the American Midwest and in game parks in Africa? Such questions about America's past were clearly ecological, focusing on the relations among species.

MAN ATE HIM UP?

Scientific time studies of the food eaten by this giant, bear-like sloth showed that the animal managed to survive climate changes thousands of years ago, but probably met his doom when early man showed up on the scene as a hunter.

"Hungry Man, Not Harsh Climate, Killed Sloth," *Tucson Daily Citizen,* January 15, 1959, clipping in folder 1, box 22, Paul Bigelow Sears Collection, Special Collections at the University of Arizona Libraries, Tucson, Arizona.

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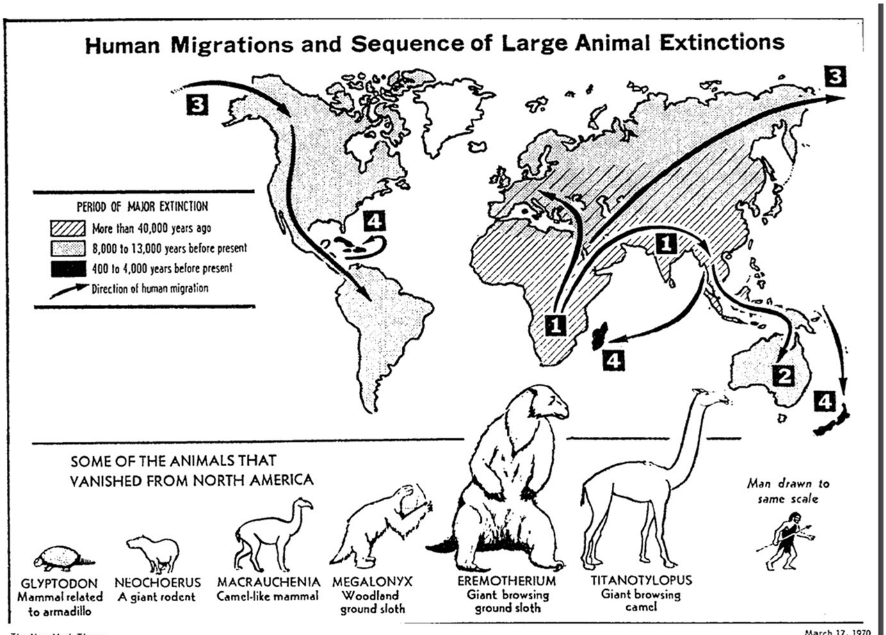
[51] Herman F. Becker, Review of *The Last 1,000 Years*, Garden Journal of the New York Botanical Garden, July-Aug 1964, 160, clipping in Folder 7, Box 16, Martin Papers.



The New York Times March 17, 1970

RISE AND FALL: It is believed that big-game hunting arose in Africa and southern Asia (1), spread through the East Indies to Australia (2), across Bering land bridge to Americas (3) and to such islands as Madagascar, New Zealand and Cuba (4). Evidence that extinction of many large mammals followed this timetable has led to a belief man was responsible. Map and drawings were adapted from "Pleistocene Extinctions," Yale University Press, 1967.

Walter Sullivan, "Scientist Urges Rearing Lost Species' Relatives," *New York Times*, March 17, 1970, p. 24.

In describing the Pleistocene overkill hypothesis, scientists and journalists often compared the Pleistocene extinctions to the extinctions attending European settler colonialism. One reviewer of Martin's book *Pleistocene Extinctions* wrote in 1967: "We can only imagine the [Pleistocene] flesh orgies, festivals, murder-joy fire entrapments, mystery rites of blood, and screams of giant mammals. [...] White colonization brought the next bio-rape."[52] Further, in the 1960s, pollen stratigraphy would become a key method for imagining North America's pre-colonial ecology. In 1963, in one of the earliest of such studies, James Gordon Ogden III compared pollen from surface samples of bogs on Martha's Vineyard with cores from precolonial times. He determined that these plant communities had not changed substantially with European settlement, although pollen from certain European species like *Plantago* and *Artemisia maritima* were, as expected, only present in the modern samples (Ogden 1961). Increasingly, ecologists hypothesized that fossil pollen from oak and hickory might be an indication of Native American fire management, not of periods of relative climatic dryness as earlier palynologists had inferred.[53] William Cronon

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[52] Wolfgang Breed, "Review of *Pleistocene Extinctions,*" *Clear Creek* 2 (1967): 65, clipping in folder 9, box 16, Martin Papers.

[53] See also Day (1953), Lutz (1959), Swain (1973), Ogden (1964), and Russell (1980, 1983).

depended on this literature for his deeply influential comparison of Native American and English settler land management in colonial New England, *Changes in the Land* (Cronon 1983). But since publication of *Changes in the Land*, scientific consensus has shifted: the authors of a recent paleoecological study of New England concluded that "anthropogenic impacts on the landscape before European contact were limited, and fire activity was independent of changes in human populations" (Oswald et al. 2020, p. 241). Environmental historians sometimes use scientific findings in their interpretations, but all scientific findings are historically contingent, contested, and dynamic.

Paleoecologists came to see the inability to distinguish between cultural and climatic events in the pollen record as a problematic constraint of their study material, as Edward Deevey argued in his wonderfully titled 1969 paper, "Coaxing History to Conduct Experiments." Deevey concluded, indeed, that it was impossible to distinguish "a minor climatic change" from "a major or nonlocal interference with vegetation by man" in the pollen record: "Until a few years ago," he wrote, "almost any ecologist would have supposed that pollen stratigraphy […] contained all the data needed to treat the evolution of plant communities. Today, we are not so confident." The extension of the prairie into Minnesota and Wisconsin around 4000 B.C. "now sounds suspiciously like human disturbance." Noting this "annoying mixup between climatic and cultural events," Deevey challenged ecologists to better understand the signatures of human "disturbance" (Deevey 1969, p. 43).

In a playful tone, Deevey admitted that pollen stratigraphers have no way of knowing whether a plant community has been shaped by climatic conditions, human actions, or both. The distinction between human agency and climatic agency is no longer secure. Anthropogenic climate change means that climatic conditions are themselves shaped by human agency. Those who strive to restore pre-human ecological conditions can no longer do so, as climate transmits and transmutes human agency.

Human Nature/Humans Changing Nature

In 1972, the *New York Times* quoted Martin describing the Pleistocene extinction of "innocent" large mammals as the "manifestation of a human desire to kill that, in his view, continues to plague modern society." It continued with Martin's contention that "[p]owerful behavioral reinforcers associated with excitement of the chase and the killing passion have made modern man a superpredator, a species which kills for more than food alone."[54] This was one of the earliest uses of "superpredator," a term that in the 1990s would come to refer to the racialized idea that there are impulsive juvenile criminals who commit violent crimes without remorse.[55]

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[54] Walter Sullivan, "'Overkill' of Animals Laid to Huntsmen in 9000 B.C.," *New York Times*, February 13, 1972, p. 62.

[55] A handful of papers in the 1950s describe predatory fish as superpredators. I have found one use of the term earlier than Martin's and journalists' descriptions of Martin's research: Frank C. Hibben, "Notes

The Pleistocene overkill hypothesis naturalized violent overconsumption. If to waste was an essential human behavior, then it followed that the only way of protecting other species was to sequester them away from humans. It is also in the 1970s that the era of fortress conservation began. In 1970, around two million square kilometers of terrestrial area were under some form of legal protection; today it is around 20 million square kilometers, or about 15 percent of Earth's ice-free land (Leverington et al. 2010).

The Pleistocene overkill hypothesis was controversial at its inception, and it remains so today (Koch and Barnosky 2006; Sandom et al. 2014). Critics of the overkill hypothesis note that there is little archeological evidence for direct association between people and megafauna – few kill sites have been found, and only five of the 37 genera (mammoths, mastodons, gomphotheres, camels, horses) are present at those sites (Meltzer 2015). Instead, these critics argue that the extinctions were caused by climatic change. The Late Quaternary Extinction coincided with the most recent glacial-interglacial transition, leading some scientists to conclude that as climate changed, the habitat suitable for megafauna disappeared or became too fragmented to support viable populations (e.g. Guthrie 2003; Wroe and Field 2006). In *Red Earth, White Lies*, Vine Deloria, Jr., argued that the Pleistocene overkill hypothesis blames Native Americans and their ancestors for the extinctions without convincing evidence. He asks why Paleo-Indian hunters would not have targeted smaller animals, which would have been easier to kill, and concludes that the theory "is a good way to support continued despoilation of the environment by suggesting that at *no* time were human beings careful of the lands upon which they lived" (Deloria 1995, p. 97). A recent study found that ecologists are more likely than archaeologists to state that humans caused the Late Quaternary extinctions; archeologists typically cite overkill as only one of a combination of causal mechanisms (Nagoka et al. 2018).

And yet despite this lack of consensus, the Pleistocene overkill hypothesis has deeply influenced both the discipline of ecology and the popular imagination, and it has shaped ecological restoration projects in North America and Europe. In the Netherlands, for example, 'de-domesticated' horses and cattle have been introduced to the Oostvaardersplassen. The goal is to recreate the ecological conditions that existed at the end of the Pleistocene, when these species' now-extinct ancestors, Aurochs and Tarpans, would have grazed the land (Marris 2011; Svenning et al. 2016). The Pleistocene has become a new temporal baseline for ecological restoration. Martin would later reflect:

> […] ignorance of the late-Pleistocene extinctions warps our view of what 'state of nature' we should be trying to conserve or restore. In North America, the modern extinction-pruned large-mammal fauna, those animals at 'home on the range' since European settlement, are not a normal evolution-

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Footnote 55 (Continued)

and Comment: The Mountain Lion and Ecology," *Ecology* 20 : 584 (1939), "No one will deny that man, as the superpredator, has become an ecological factor himself. Few killing factors are as important a predator as the rifle.".

> ary assemblage. The fossil record thus suggests, for instance, that we reconsider the impact of wild equids in the New World. Because horses evolved here, flourished for tens of millions of years, and vanished around 13,000 years ago, their arrival with the Spanish in the 1500s was a restoration, not an alien invasion. In evaluating the ecological impacts of wild horses and burros, we need to be aware not just of their presence in the last half millennium, but of the coevolution of equids with the land for tens of millions of years before a relatively brief 10,000-year interruption (Martin 2005, 56).

De-extinction, Pleistocene re-wilding, and other contemporary ecological restoration proposals are evidence of how our imagined relationship to nature and the wild continues to evolve in tandem with our new economic, climatic, ecological, and technological realities. The debate over the use of historical baselines in restoration is often framed as a question of *what is to be done*. For example, when restoring a site in North Carolina, should ecologists plant *Quercus stellata* [post oak], a species predicted to do well under changed climatic conditions (Fisichelli et al. 2014)? Or *Pinus palustris* [longleaf pine], which was prevalent prior to European colonization? Or *Pinus banksiana* [jack pine], abundant 21,000 years before present (Taylor et al. 2011)? But implicit in the question of restoration baselines is the question of *who is responsible*, and relatedly, *what is to be undone*. Although it is rarely if ever acknowledged, with the 1492 baseline, restorationists attempt to remediate the ecological damage wrought by European colonists and/or their descendants. With a Pleistocene baseline, they attempt to recreate a pre-human world. Responsibility is imagined to be shared equally among all people, and human violence against other species is projected into the deep past. The politics of these two baselines are sharply different.

In this sense, restoration baselines are a microcosm of the big questions at play in today's Anthropocene debates. In recent years, both the sciences and the humanities have taken up the question of whether the Earth system has entered the Anthropocene, a new geological epoch defined by human activity at such a scale that it constitutes a global geological force (Crutzen 2002). Historians and historical ecologists alike are invested in identifying a period of historical rupture to mark a dramatic, human-caused decrease in wildness. Proposals included – along with the Pleistocene extinctions – the rise of agriculture, the rise of European colonialism, the Industrial Revolution, and the detonation of hundreds of atomic weapons (Lewis and Maslin 2015). In the context of defining and imagining the Anthropocene, Historians and paleoecologists find themselves asking the same question: How far into the past should we imagine that humans had the capacity to destroy worlds?

Funding Funding was provided by National Science Foundation (Grant Number 1329750) and Social Science Research Council.

Declarations

Conflict of interest I do not have any conflict of interest to declare.

References

Anderson, E. C., Willard Frank Libby, S. Weinhouse, et al. 1947. Radiocarbon from cosmic radiation. *Science* 72: 931–936.

Anker, Peter. 2001. *Imperial ecology: Environmental order in the British Empire, 1895–1945*. Cambridge: Harvard University Press.

Antevs, Ernst. 1935. The spread of aboriginal man to North America. *Geographical Review* 25: 302–309.

Arnold, J. R. and Willard Frank Libby. 1949. Age determinations by radiocarbon content: Checks with samples of known age. *Science* 110: 678–680.

Barbour, Michael G. 1995. Ecological fragmentation in the fifties. In *Uncommon ground: Rethinking the human place in nature*, ed. William Cronon, 233–255. New York: W.W. Norton & Co.

Barlow, Connie. 2002. *The ghosts of evolution: Nonsensical fruit, missing partners, and other ecological anachronisms*. New York: Basic Books.

Barrow, Mark. 2009. *Nature's ghosts: Confronting extinction from the age of Jefferson to the age of ecology*. Chicago: University of Chicago Press.

BenDor, Todd, T. William Lester, Avery Livengood, Adam Davis, and Logan Yonavjak. 2015. Estimating the size and impact of the ecological restoration economy. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0128339.

Black, Brian. 2012. Oil for living: Petroleum and American conspicuous consumption. *Journal of American History* 99: 40–50.

Boas, Franz. 1929. Migrations of asiatic races and cultures to North America. *The Scientific Monthly* 28: 110–117.

Bocking, Stephen. 2012. Nature on the home front: British ecologists' advocacy for science and conservation. *Environment and History* 18: 261–281.

Burney, David A. and Timothy F. Flannery. 2005. Fifty millennia of catastrophic extinctions after human contact. *Trends in Ecology & Evolution* 20: 395–401.

Carthy, J. D. and F. J. Ebling (eds.). 1964. *The natural history of aggression*. New York: Academic Press.

Charenko, Melissa. 2020. Reconstructing climate: Paleoecology and the limits of prediction during the 1930s dust bowl. *Historical Studies in the Natural Sciences* 50: 90–128.

Charenko, Melissa. 2022. Blowing in the wind: Pollen's mobility as a challenge to measuring climate by proxy, 1916–1939. *Journal of the History of Biology* 55: 465–493. https://doi.org/10.1007/s10739-022-09677-6.

Choi, Young D. 2004. Theories for ecological restoration in changing environment: Toward 'futuristic' restoration. *Ecological Research* 19: 75–81.

Cittadino, Eugene. 1990. *Nature as the laboratory: Darwinian plant ecology in the German empire, 1880–1900*. New York: Cambridge University Press.

Cittadino, Gene. 2017. Paul Sears: Cautious 'subversive' ecologist. *Human Ecology Review* 23: 29–38.

Clements, Frederick E. 1909. Plant formations and forest types. *Proceedings of the Society of American Foresters* 4: 50–63.

Clements, Frederic E. 1916. *Plant succession: An analysis of the development of vegetation*. Washington, D.C.: Carnegie Institution.

Clisby, Kathryn H. and Paul B. Sears. 1956. San Augustin plains—Pleistocene climatic changes. *Science* 124: 537–539.

Cohen, Claudine. 2002. *The fate of the mammoth: Fossils, myth, and history*. Chicago: University of Chicago Press, p. 2002.

Cohen, Lizabeth. 2003. *A consumers' republic: The politics of mass consumption in postwar America*. New York: Vintage Books.

Cowles, Henry C. 1911. The causes of vegetative cycles. *Botanical Gazette* 51: 161–183.

Creager, Angela H. 2013. *Life atomic: A history of radioisotopes in science and medicine*. Chicago: University of Chicago Press.

Croker, Robert W. 1991. *Pioneer ecologist: The life and work of Victor Ernest Shelford, 1877–1968*. Washington: Smithsonian Institution Press.

Cronon, William. 1983. *Changes in the land: Indians, colonists, and the ecology of New England*. New York: Hill and Wang.

Crowcroft, Peter. 1991. *Elton's ecologists: A history of the bureau of animal population*. Chicago: University of Chicago Press.

Crutzen, Paul J. 2002. Geology of mankind. *Nature* 415: 23–32.

Cruzent, J. M. and I. Rouse. 1956. A lithic industry of Paleo-Indian type in Venezuela. *American Antiquity* 22: 172–179.

Day, G. M. 1953. The Indian as an ecological factor in the Northeastern Forest. *Ecology* 34: 329–346.

Deevey, Jr. Edward S. 1949. Biogeography of the Pleistocene, part 1: Europe and North America. *Bulletin of the Geological Society of America* 60: 1315–1416.

Deevey, Jr. Edward S. 1951. A brief discussion of the relation of some radiocarbon dates to the pollen chronology. *Memoirs of the Society for American Archaeology* 8: 56–58.

Deevey, Jr. Edward S. 1952. Radiocarbon dating. *Scientific American* 186: 24–28.

Deevey, Jr. Edward S. 1984. Zero BP plus 34: 25 years of radiocarbon. *Radiocarbon* 26: 1–6.

Deevey, Jr, S. Edward, J. Gralenski and V. Hoffren. 1959. Yale natural radiocarbon measurements IV. *American Journal of Science Radiocarbon Supplement* 1: 144–172.

Deevey, Jr. Edward S. 1969. Coaxing history to conduct experiments. *BioScience* 19: 40–43.

Deloria, Jr. Vine. 1995. *Red earth, white lies: Native Americans and the myth of scientific fact*. New York: Scribner.

Disinger, John F. 2009. Paul B. Sears: The role of ecology in conservation. *Ohio Journal of Science* 109: 88–90.

Donlan, C. Josh and Harry W. Greene. 2009. NLIMBY: No lions in my backyard. In *Restoration and history: The search for a usable environmental past*, ed. Marcus Hall. New York: Routledge.

Donlan, Josh, et al. 2005. Re-wilding North America. *Nature* 436: 913–914.

Edgerton, Frank N. 1977. *History of American ecology*. New York: Arno Press.

Elton, Charles S. 1933. *Matamek conference on biological cycles: Abstract of papers and discussion*. Labrador: Matamek Factory.

Erdtman, G. 1967. Glimpses of palynology, 1916–1966. *Review of Paleobotany and Palynology* 1: 23–29.

Erdtman, O. 1921. *Pollenanalytische Untersuchungen von torfmooren und marinen Sedimenten in Südwest-Schweden*. Stockholms Högskola.

Erickson, Paul. 2010. Knowing nature through markets: Trade, populations, and the history of ecology. *Science as Culture* 19: 529–551.

Fisichelli, Nicholas, Scott Abella, Matthew Peters and Frank Krist. 2014. Climate, trees, pests, and weeds: Change, uncertainty, and biotic stressors in Eastern U.S. National Park forests. *Forest Ecology and Management* 327: 31–39.

Flint, Richard Foster and Edward S. Deevey. 1951. Radiocarbon dating of late-Pleistocene events. *American Journal of Science* 249: 257–300.

Gleason, Henry. 1917. The structure and development of the plant association. *Bulletin of the Torrey Club* 44: 463–481.

Gleason, Henry. 1922. The vegetational history of the middle west. *Annals of the Association of American Geographers* 12: 39–85.

Gleason, Henry. 1953. Letter. *Bulletin of the Ecological Society of America* 34: 37.

Grayson, D. K. 1984. Nineteenth-century explanations of Pleistocene extinctions: A review and analysis. In *Quaternary extinctions: A prehistoric revolution*, eds. Paul S. Martin and R.D. Klein, 5–39. Tucson: University of Arizona Press.

Grootes, Pieter and Hans van der Plicht. 2021. Hessel de Vries: Radiocarbon pioneer from Groningen. *Radiocarbon* 64: 419–433.

Guthrie, R. D. 2003. Rapid body size decline in Alaskan Pleistocene horses before extinction. *Nature* 426: 169–171.

Haynes Jr., C. V. 1964. Fluted projectile points: Their age and dispersion. *Science* 145: 1408–1413.

Haynes Jr., C. V. 1967. Carbon-14 dates and early man in the new world. In *Pleistocene extinctions: The search for a cause,* ed. Paul S. Martin and H. E. Wright, 267–286. New Haven: Yale University Press.

Hobbs, R. J., E. S. Higgs and J. A. Harris. 2009. Novel ecosystems: Implications for conservation and restoration. *Trends in Ecology and Evolution* 24: 599–605.

Howard, Edgar B. 1936. An outline of the problem of man's antiquity in North America. *American Anthropologist* 38: 394–413.

Janzen, Daniel and Paul S. Martin. 1982. Neotropical anachronisms: The fruits the gomphotheres ate. *Science* 215: 19–27.

Johnson, Frederick. 1955. Reflections upon the significance of radiocarbon AATE. In *Radiocarbon dating*, 2nd edn., ed. Willard F. Libby, 141–162. Chicago: University of Chicago Press.

Jones, Susan D. 2017. Population cycles, disease, and networks of ecological knowledge. *Journal of the History of Biology* 50: 357–391.

Kern, Emily M. 2020. Archaeology enters the ‘atomic age:’ A short history of radiocarbon, 1946–1960. *British Society for the History of Science* 53: 207–227.

Kiefer, Philip. 2018. Iconic Joshua trees may disappear—but scientists are fighting back. *National Geographic*, October 15, 2018.

Kingsland, Sharon E. 1985. *Modeling nature: Episodes in the history of population ecology*. Chicago: University of Chicago Press.

Kingsland, Sharon E. 2005. *The evolution of American ecology, 1890–2000*. Baltimore: Johns Hopkins University Press.

Koch, Paul L. and Anthony D. Barnosky. 2006. Late Quaternary extinctions: State of the debate. *Annual Review of Ecology, Evolution, and Systematics* 37: 215–250.

Kohler, Robert E. 2002. *Landscapes and labscapes: Exploring the lab-field border in biology*. Chicago: University of Chicago Press.

Krantz, Grover S. 1970. Human activities and megafaunal extinctions. *American Scientist* 58: 164–170.

Ladd, Harry S. 1959. Ecology, paleontology, and stratigraphy. *Science* 129: 69–78.

Leverington, Fiona, et al. 2010. *Management effectiveness evaluation in protected areas—a global study*. Queensland: University of Queensland Press.

Lewis, Simon L. and Mark A. Maslin 2015. Defining the Anthropocene. *Nature* 519: 171–180.

Libby, Willard Frank. 1946. Atmospheric helium three and radiocarbon from cosmic radiation. *Physical Review* 69: 671–672.

Libby, Willard Frank. 1955. *Radiocarbon dating*. Chicago: University of Chicago Press.

Libby, Willard Frank. 1972. *Radiocarbon dating, memories, and hopes*. Washington, D.C.: National Science Foundation.

Lutz, H. J. 1959. Aboriginal man and white man as causes of fires in the boreal forest. *Yale University School of Forestry Bulletin* 65.

Manten, A. 1966. Half a century of modern palynology. *Earth Science Review* 2: 277–316.

Marris, Emma. 2011. *Rambunctious garden: Saving nature in a post-wild world*. New York: Bloomsbury.

Martin, Laura. 2022. *Wild by design: The rise of ecological restoration*. Cambridge: Harvard University Press.

Martin, Paul S. 1958a. Pleistocene ecology and biogeography of North America. In *Zoogeography,* ed. C. L. Hubbs. Washington, D.C.: American Association for the Advancement of Science.

Martin, Paul S. 1958b. *A biogeography of reptiles and amphibians in the Gómez Farias Region, Tamaulipas, Mexico*. Ann Arbor: Museum of Zoology, University of Michigan.

Martin, Paul S. 2005. *Twilight of the mammoths: Ice age extinctions and the rewilding of America*. Berkeley: University of California Press.

Martin, Paul S. and Byron E. Harrell 1957. The Pleistocene history of temperate biotas in Mexico and Eastern United States. *Ecology* 38: 468–480.

Martin, Paul S. and J. E. Guilday. 1967. Bestiary for Pleistocene biologists. In *Pleistocene extinctions: The search for a cause,* ed. Paul S. Martin and H. E. Wright. New Haven: Yale University Press.

Masutti, Christope. 2006. Frederic Clements, climatology, and conservation in the 1930s. *Historical Studies in the Physical and Biological Sciences* 37: 27–48.

Meltzer, David J. 2015. Pleistocene overkill and North American mammalian extinctions. *Annual Review of Anthropology* 44: 33–53.

Milam, Erika. 2012. Making males aggressive and females coy: Gender across the animal-human boundary. *Signs* 37: 935–959.

Moore, Barrington. 1920. The scope of ecology. *Ecology* 1: 3–5.

Nagaoka, Lisa, Torben Rick, and Steve Wolverton. 2018. The overkill model and its impact on environmental research. *Ecology and Evolution* 8: 9683–9696.

Nicolson, Malcolm. 1996. Humboldtian plant geography after Humboldt: The link to ecology. *British Journal for the History of Science* 29: 289–310.

Nordlund, Christer. 2007. Between science and industry: On the establishment, organisation and practices of the Swedish geological survey in the nineteenth century. *Earth Sciences History* 26: 127–149.

Nordlund, Christer. 2014. Peat bogs as geological archives: Lennart Von Post et al., and the development of quantitative pollen snalysis during World War I. *Earth Sciences History* 33: 187–200.

Ogden III, J. G. 1961. Forest history of Martha’s vineyard, Massachusetts. *American Midland Naturalist* 66: 417–430.

Ogden III, J. G. 1964. Pleistocene pollen records from eastern North America. *Botanical Review* 31: 481–504.

Oswald, W. Wyatt, et al. 2020. Conservation implications of limited native American impacts in pre-contact New England. *Nature Sustainability* 3: 241–246.

Parmesan, Camille and Gary Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421: 37–42.

Prates, Luciano and S. Ivan Perez. 2021. Late Pleistocene South American megafaunal extinctions associated with rise of fishtail points and human population. *Nature Communications* 12: 2175.

Quimby, G. I. 1958. Fluted points and geochronology of the Lake Michigan Basin. *American Antiquity* 23: 247–254.

Ricciardi, Anthony and Daniel Simberloff. 2009. Assisted colonization is not a viable conservation strategy. *Trends in Ecology & Evolution* 24: 248–253.

Rubenstein, Dustin R., Daniel I. Rubenstein, Paul W. Sherman and Thomas A. Gavin. 2006. Pleistocene park: Does re-wilding North America represent sound conservation for the 21st Century? *Biological Conservation* 132: 232–238.

Russell, Emily. 1980. Vegetational change in northern New Jersey from precolonization to the present: A palynological interpretation. *Bulletin of the Torrey Botanical Club* 107: 432–446.

Russell, Emily W. B. 1983. Indian-set fires in the forests of the northeastern United States. *Ecology* 64: 78–88.

Sandom, Christopher, Søren Faurby, Brody Sandel and Jens-Christian Svenning. 2014. Global late Quaternary megafauna extinctions linked to humans, not climate change. *Proceedings of the Royal Society B*. https://doi.org/10.1098/rspb.2013.3254.

Sears, Paul B. 1930a. A record of post-glacial climate in northern Ohio. *The Ohio Journal of Science* 30: 205–217.

Sears, Paul B. 1930b. Common fossil pollen of the Erie Basin. *Botanical Gazette* 89: 95–106.

Stuiver, Minze. 2009. A random walk through time. *Radiocarbon* 51: 291–300.

Surovell, T. A, et al. 2016. Test of Martin’s overkill hypothesis using radiocarbon dates on extinct megafauna. *PNAS* 113: 886–891.

Svenning, Jens-Christian, et al. 2016. Science for a wilder Anthropocene: Synthesis and future directions for trophic rewilding research. *PNAS* 113: 898–906.

Swain, A. M. 1973. A history of fire and vegetation in northeastern Michigan as recorded in lake sediments. *Quaternary Research* 3: 383–396.

Swetnam, Thomas, Craig Allen and Julio Betancourt. 1999. Applied historical ecology: Using the past to manage for the future. *Ecological Applications* 9: 1189–1206.

Taylor, Barbara E., Fredrick Rich, Mark Brooks, Andrew Ivester and Christopher Clement. 2011. Late Pleistocene and Holocene vegetation changes in the sandhills. *Fort Jackson, South Carolina, Southeastern Geology* 48: 147–163.

Tobey, Ronald C. 1981. *Saving the prairies: The life cycle of the founding school of American plant ecology, 1895–1955*. Berkeley: University of California Press.

von Post, Lennart. 1916. Einige sudschwedischen Quellmoore. *Bulletin of the Geological Institute of the University of Uppsala* 15: 219–278.

Williams, J. W. and S. T. Jackson. 2007. Novel climates, no-analog communities, and ecological surprises. *Frontiers in Ecology and the Environment* 5: 475–482.

Wormington, H. M. 1957. *Ancient man in North America*, 4th ed. Denver: Denver Museum of Natural History.

Worster, Donald. 1987. The vulnerable earth: Toward a planetary history. *Environmental Review* 11: 87–103.

Wroe, S. and J. Field. 2006. A review of the evidence for a human role in the extinction of Australian megafauna and an alternative interpretation. *Quaternary Science Reviews* 25: 2692–2703.