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TITLE: Global research priorities for historical ecology to inform conservation

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ABSTRACT

Historical ecology draws on a broad range of information sources and methods to provide insight into ecological and social change, especially over the past ~12,000 years. While its results are often relevant to conservation and restoration, insights from its diverse disciplines, environments, and geographies have frequently remained siloed or underrepresented, restricting their full potential. Here, we synthesize knowledge from the fields of history, anthropology, paleontology, and ecology from scholars and practitioners working in marine, freshwater, and terrestrial environments on six continents and various archipelagoes to identify global research priorities for historical ecology to influence conservation. Specifically, we identify and address questions within four key priority areas: (i) methods and concepts, (ii) knowledge co-production and community engagement, (iii) policy and management, and (iv) climate change impacts. This work highlights the ways that historical ecology has developed and matured in its use of novel information sources, its efforts to move beyond extractive research practices and toward knowledge co-production, and its potential use in addressing management challenges, including climate change. Together, we demonstrate the ways that this field has brought together researchers across disciplines, connected academics to practitioners, and engaged communities to create and apply knowledge of the past to addressing the challenges of our shared future.

INTRODUCTION

Historical ecology is a field of research that addresses how human-environment interactions shape ecological change. This rather recent discipline (at least nominally) emphasizes quantifying environmental change and describing the historical context connecting biophysical and human processes (*1*). Research in historical ecology focuses on the causes and consequences of changes caused by past human actions (*2*), as well as understanding natural variation before and after human intervention (*3*). Although terrestrial ecosystems were initially emphasized (*4*), marine and freshwater ecosystems later increased in prominence. Marine historical ecology has pioneered the development of more informed baselines over timescales relevant for management (*5*) and the documentation of severe impacts to coastal ecosystems due to chronic overexploitation (*6*).

A central feature of historical ecology is employing a diversity of methods and connecting a range of disciplines—especially history, anthropology, paleontology, and ecology. As a result, historical ecology benefits from source materials that span decades to millennia, and frequently focus on changes from the Holocene to 1950 (*3*). Historical ecology overlaps in theme with conservation paleobiology with the latter drawing primarily on fossil and subfossil data and also emphasizing deeper time periods (33). Archaeological and paleontological data provide insights from the fossil record, including bones, teeth, shells and pollen, which can extend from recent to pre-human history (*7*). Historical ecology also has strong overlap with studies of Indigenous and other local knowledge, and in that context often focuses on the relationship people have built and tended with the environment centered on reciprocal processes (*8*). Such local knowledge includes oral histories and community science datasets, which provide observations of ecological change and traditional practices for managing resources (*9-11*). Finally, historical ecology overlaps with environmental history, including a similar focus on archival sources, which can range from texts written in medieval times to paintings, newspapers, tax records, menus, as well as records from early natural historians and ecologists who documented their collections systematically (*12*). Now a highly transdisciplinary field, historical ecology research programs frequently integrate qualitative and quantitative data (*13-17*) and include academic researchers and conservation practitioners.

Applications from historical ecology are relevant to conservation and restoration at the species, ecosystem, and landscape scales. Knowledge of multidecadal, centennial or millennial processes can significantly modify conservation policies based on sub-decadal observations. Reference points, such as species recovery goals and other ecological restoration targets, that are informed by longer-term records can help to avoid the shifting baselines syndrome (*5*), or the gradual erosion of knowledge about the potential for ecosystem productivity or resilience. Knowledge of past faunal and floral abundances and ecosystem resilience has been used to understand natural solutions and develop well-informed conservation plans (*6, 18-20*). As a result, historical ecology provides critical long-term context for the current global environmental challenges (*21, 22*) and responding initiatives like the United Nations Decade on Ecosystem Restoration (*23*).

Since early landmark analyses two decades ago (*4-6*), historical ecology has become a well-recognized field of research that integrates knowledge across disciplines, environments, and geographies. Over this time, multiple initiatives have endeavored to apply historical ecology to conservation, which requires both cross-disciplinary work and engagement with non-academic stakeholders. An increasing focus on diversity, equity, and inclusion, representation, and de-colonization has also encouraged researchers to evaluate past methods and interpretations. For historical ecology, this has meant reconciling extractive research practices with the need for co-production of knowledge and grappling with diverse views on historical change and management derived from Indigenous and other local knowledge-holders.

Given these developments, there is a need to bring diverse perspectives together to evaluate the state of historical ecology, establish future priorities, and build effective conservation strategies in light of climate change and other anthropogenic perturbations. In this study we review historical ecology as it applies to conservation. We gathered leading world experts to identify and define the top priorities that will help shape future progress in the field. What have we learned? What persistent problems remain? Where are emerging opportunities? As our objective is to integrate a range of voices, we prioritized expert representation from diverse demographics, quantitative and qualitative perspectives, and alternative forms of knowledge and worldviews.

METHODS

We followed the form and process of a series of conservation-themed reviews focused on megafauna conservation (*24-26*). Specifically, a steering committee (KV, LM, TR, RHT, and AT) established the scope of the study and created an initial list of international experts from terrestrial and marine ecology, history, archaeology, anthropology, and paleoecology. We then invited coauthors over email to join the project, using chain referral or snowballing (*27, 28*) to gather input on potential additional contributors, with a particular focus on increasing diverse participation .

Next, we employed a structured Delphi process (*29*) to prioritize and select content topics for the review. For the latter, each coauthor submitted up to 4 questions they considered essential to applying the discipline of historical ecology to conservation. We grouped 93 such submissions into four category themes. The steering committee excluded questions that were too narrow in scope or not directly related to historical ecology and merged remaining related submissions into 26 questions. Coauthor voting ranked and focused this list, with questions and category themes further merged by the steering committee where topics overlapped. Coauthors self-selected questions they might answer, with the steering committee then assigning two co-authors to each question. Contributors subsequently jointly drafted a response that aimed to summarize the scholarly advances to date, articulate remaining unresolved issues, and identify potential frontiers for future study. All responses were then made available to the full co-author list for comment and review.

To document a baseline of scholarly activity, we queried three academic search databases for historical ecology publications over time. To accommodate for differences in indexing methodology, open-access, search algorithms, disciplinary focus, and literary sources (*30*) we queried three independent databases: Google Scholar (scholar.google.com/), Scopus (www.scopus.com/), and CORE (core.ac.uk/). From 1970 through 2022, we tabulated the number of annual publications containing either of the exact phrases ‘historical ecology’ and ‘historical ecological,’ separated by the Boolean operator ‘OR’. We report the raw values from each search engine and perform summary statistics on their ensemble average. Due to the broadly defined, interdisciplinary nature of historical ecology, this search is imperfect and does not capture all publications that may be considered to fall within the discipline.

As observation and cultural norms are framed and legitimized by historical contexts and social settings (*31, 32*), throughout the process of this project we prioritized the representation of historically underrepresented communities—diverse voices and demographics, qualitative perspectives, and Indigenous knowledge. We particularly sought contributions from women, early career scholars, and researchers from the Global South. To monitor our progress, we distributed a survey (available in Appendix I) to all project coauthors and report the results from all respondents (n = 37).

A third-party repository at GitHub (bit.ly/477TePD) provides the data and scripts used in this study. All survey data were anonymized to remove any personally identifying information, and all visualizations were made in the R computing environment (*33*).

RESULTS

We defined eighteen questions as essential research priorities for the continued application of historical ecology to conservation, which were split into four subject groups: (i) methods and concepts, (ii) knowledge co-production and community engagement, (iii) policy and management, and (iv) climate change (see Table 1). Question responses aim to summarize the current state of knowledge, emerging opportunities, and recommendations for future progress. Many of the questions that emerged from our analysis focus on issues of colonialism and Indigenous knowledge. These topics are vital for improving historical ecology in the future, but we recognize that not all areas of the world followed the same trajectories as regions with significant settler colonial histories. However, colonialism and associated extractive enterprises permeate all regions of the globe and as such these issues may have broad applicability to the field of historical ecology.

In our review of historical ecology research, the Google Scholar, Scopus, and CORE search platforms identified an average 17,374 publications containing 'historical ecology' OR 'historical ecological' from 1970-2022. From 1970-1989, there is comparatively minor activity, averaging 25 or fewer publications annually (Figure 1). The period from 1990-2016 shows a rapid annual rate of increase (r = 0.114), followed by flat production (r = 0.001) thereafter. Though beyond the scope of the present study, the reasons for the recent production plateau may reflect the diversification of terminology into more specialized topics and phrases (e.g., *7*). The 2017-2022 trend however does not match the increasing research production in the environmental sciences (*34*) over a similar period, and is unlikely related to the decline in research production resulting from the COVID-19 pandemic (*35*) whose impact began in late 2020. Further bibliometric or scientometric research in this area is warranted.

Our author group represents 6 continents, 12 primary languages, diverse career stages and institutional sectors including academic, non-profit, government, and museum (Figure 2). Despite this broad representation, many of this study's contributors self-identify as mid-career academic ecologists working in the USA or Canada, who are white and primarily speak English. While contributions across disciplines, geographic regions, ethnicities, and languages is more diverse, significant progress and opportunity remains to achieve greater representation, inclusion and equity.

METHODS AND CONCEPTS

Q1 What do qualitative and quantitative approaches contribute to understanding long-term change?

Both quantitative and qualitative methods are essential to understanding long-term change. Qualitative approaches can be used to describe human knowledge, perceptions, and decisions, while quantitative data can identify ecological patterns and processes (*36*). For example qualitative ethnographic and quantitative archaeological data on turtle consumption in Polynesia reveal distinct cultural patterns that contributed to different rates of decline over millennia (*37*). Likewise, combining qualitative archival sources and quantitative DNA analysis have documented ancient introductions of non-native species, revealing long-term human influence on biodiversity (*38, 39*).

Working across disciplines can produce new methods that bring analytical weight and narrative power to our understanding of long-term ecosystem change. For example, in the Florida Keys, historical newspapers and photographs were used to quantify an order of magnitude decline in the size of recreational fish caught over 50 years (*40, 41*), while a range of archival sources were synthesized to describe the cultural and political forces motivating this overfishing (*42*). In Baja California, Mexico, fishers' intergenerational knowledge, archival records, and archaeological data were incorporated to show long-term population trends from ~12,000 years ago to the 1960s for green turtles (*Chelonia mydas*), demonstrating sustainability until they became fungible or commercial goods (*43, 44*).

Qualitative observations can be converted to semi-quantitative metrics including rankings of ecosystem state based on qualitative rules (*14*) and binary measures such as presence-absence or dominance versus non-dominance of taxa (*13*). Such methods have facilitated global analyses of ecosystem change over millennia and across ecosystems (*14, 17*). Similarly, the use of archival data in ecological models reveals patterns and consequences of population extinctions (*45*), past food web dynamics and trophic structures (*16*), and historical habitat distributions that challenged established ideas on the distribution of tree species (*46*). In this effort researchers must understand and employ best practices from specific techniques, fields, and subdisciplines. For example, a critical examination (and sometimes reformulation or transformation) of historical sources to be used under ecological analytical frameworks is necessary, and researchers endeavoring to use local ecological knowledge should be aware of ethical and cultural considerations inherent in these approaches (*1, 47, 48*).

Q2 How do historical data help understand long-term ecological change?

Historical ecology has commonly focused on local changes in individual taxa or communities over past decades, centuries and millennia driven by human activities (e.g., exploitation, habitat alteration, pollution, invasive species) and sometimes natural environmental fluctuations (*3, 49*). From the scale of species to landscapes, historical ecology is important for documenting past occurrences, abundance, distributions, demographics, habitat usage, and species interactions. For example, spy satellite data (*50, 51*), historical maps (*52, 53*), and aerial photography (*54*) can be used to reconstruct ecosystem structure and species habitat use at regional to global scales extending centuries in the past. Natural archives (*55, 56*) can be used to quantify ecosystem productivity, community structure and population sizes at millennial time scales via a large number of organic and inorganic proxies, such as pollen, bio-elements, stable isotopes, and ancient DNA (*57, 58*).

When using historical information to understand ecological change several challenges persist. Ecosystem variation over decadal to millennial scales is high (*59*) and available historical sources may miss the full range of variation in ecosystems (*60*). Discriminating the effects of biophysical variability and anthropogenic activity remains difficult even if the range of variation is known (*8, 61*). Finally, when used in isolation, individual historical data sources can be difficult to validate, leading to errors in interpretation (*62*). Several solutions exist. For example, integrating historical species records, modern observations and modelling approaches allows for long-term range and population dynamic reconstructions. Developing more accurate tools, as specific biomarkers may lead to unambiguous conclusions on human-driven vs. environmentally driven change. More precise age models for natural archives would shed light on the past at finer timescales, avoiding large dating-induced bias (*63, 64*).

Q3 How can diverse data types that span a range of time scales be meaningfully integrated?

In integrating diverse data, historical ecology researchers confront issues of scale, resolution, and data format. These can be addressed by standardizing metrics of interest (*65*). For example, oral history, archival, and fossil/subfossil data have been integrated to reconstruct timelines of ecological change, relative abundance of key taxa, and fisheries catch over thousands of years (*17, 44, 66*). In doing so, calibration across diverse datasets has been achieved by assessing the correlation between metrics. For instance, the accumulation of shark dermal denticles preserved in marine sediments and underwater surveys of shark abundance (*67*) and information from oral history and commercial fisheries records (*68*).

Several technological and methodological advances are accelerating the integration of data types across timescales. Increases in instrumentation and artificial intelligence capabilities are increasing the capacity to analyze ancient and environmental DNA, isotopic, elemental, and histologic data that can be collected in the same manner across varying data types (*69*). High-precision chronologies from natural archives are available via radiometric dating, providing similar temporal resolution across historical and modern data (*70*).

There are several approaches that would improve the capacity to integrate diverse data to understand long-term change. Using historical data to validate hindcasting based on modern data can help to understand ecological dynamics, such as if past impacts of climate change on species distributions were similar to those observed today (*71*). Improved data integration may also arise from collaborating across disciplines to create standardized methods and deriving conversion factors for ecological metrics (*72*) by designing studies that allow for statistical comparisons of historical and modern data.

Q4 How can historical ecology leverage quantitative methods, big data, and machine learning?

The large-scale acquisition, storage, and analysis of ecological and related information has propelled conservation science into a new era (*73*). Researchers and institutions are responding by embracing the latest technology and methods in cloud storage and computing, artificial intelligence, automated systems, 'omics, and community science (*74*). Similar initiatives might increase the efficiency and productivity of historical ecology research programs, where the extraction and curation of historical data streams is often manual and logistically intensive. For decades the humanities have focused on digitizing, processing, and publishing relevant historical texts, images, and cultural ephemera (*75, 76*), and further linking those efforts to the goals of historical ecology would be fruitful. When standardized and attributed with metadata, open-access clearinghouses of historical data may further advance the field in the mold of more established (*77, 78*) and growing disciplines (*79, 80*). Techniques to advance automation and robotics in 'omics methods (*81, 82*) will also improve the efficiency of data acquisition and analysis across a range of historical ecology topic areas.

With new data come new analytical opportunities. Artificial intelligence and machine learning methods, for example, provide informed and insightful analysis across a range of disciplines. In ecology, these approaches have been used in genetics, climate, and biotelemetry, often by incorporating autonomous sensor networks into research workflows (*73*). Applying machine learning to qualitative data such as text (e.g., natural language processing and large language models) is rapidly advancing (*83*) with significant potential for conservation (*84*). Such approaches might complement traditional historical ecology methods, where expert-trained datasets and advanced algorithms work together to automate learning from historical texts (*85*) in multiple languages. Beyond removing barriers to historical data, adopting big data and artificial intelligence in historical ecology may help reduce geographic bias (See Q5) (*86*), while increasing access and cultural representation (see Figure 2, Q8-9). Collectively, these outcomes will advance a core goal of historical ecology—to increase knowledge for conservation practitioners across contexts and solutions.

Q5 How does bias affect the distribution of knowledge in historical ecology?

The availability of historical ecology data is affected by biases across space, taxonomy, and time. Most fundamentally, historical ecology has, like other Western scientific endeavors, been affected by colonial power structures, which results in biases in knowledge (*87*). For example, colonial administrations destroyed historical sources, while also producing documents that can help understand the historical ecology of many colonized regions. In using such sources, researchers must document and consider those biases (*47*). Additionally, there are socio-economic and geographic biases in knowledge production (*87, 88*) (*89*). For example, 90% of historical ecology studies derive from North America and Europe (*2*). Furthermore, biological and cultural objects held in museums or private collections, trapped behind paywalls, or written in languages not spoken by local communities, present significant barriers to equitable access (*90*).

These cultural biases result in an unequal distribution of records relevant for historical ecology, such as an overrepresentation of studies on environmental change and biodiversity in the global north and human population centers (*91, 92*), with large data gaps in the biodiversity-rich tropics (*34, 93, 94*). Cultural biases for charismatic species drive taxonomic biases regardless of time and location (*34, 95*), while available data are also region and taxon-specific and accompanied by taphonomic biases (*96*). Temporal biases emerge from technological advancement, accessibility, research interests, and socioeconomic factors changing over time (*97*), and the tendency to collect historical sources and ecological data based on convenience, such as adjacent to research centers (*98*) perpetuates global biases despite the growth of community science records in recent decades (*9, 91, 95*). Biased ecological data distort our understanding of biodiversity gradients, species distributions, and predictions of their responses to human-driven change (*92, 95, 99*). Solutions include addressing sources of cultural bias and amplifying and broadening knowledge systems from developing countries, marginalized communities, and Indigenous and other local knowledge co-production (See Q6, Q8-9).

Knowledge Co-production and Community Engagement

Q6 What are best practices for knowledge co-production and community engagement for historical ecology?

Despite historical ecology's transdisciplinary nature, information sharing remains restricted by factors including the disciplinary siloing of knowledge (*100*), competition among researchers, and the privileging of specific knowledges and holders (see Q5) (*101*). Platforms for open-source data sharing (See Q4) and guidelines for ethical best practice (*102, 103*) facilitate information sharing to meet global conservation challenges. Likewise, knowledge may be better shared through audio-visual tools such as infographics, videos, and the classroom, and relevant materials should be communicated in locally-spoken languages (*104, 105*).

While improved communication training and the implementation of wider dissemination strategies can enhance information sharing in historical ecology, they often remain unidirectional as they may host data 'from' researchers 'for' others to use. Instead, more fundamental changes needed to ensure equitable representation of historically marginalized histories, voices, and knowledge systems. For example, 'community peer review' is a mechanism which supports research and knowledge co-production led by community groups. Community peer review includes steps to ensure that research outputs (papers, data etc.) are accurate and consistent with community standards for data sharing (*106*). This process helps to guard against parachute science or tokenism, where knowledge is extracted and misapplied without consent (*107*). Appreciating the deep entrenchment of local knowledge (*108*) and recognition of oral traditions and knowledge systems (*109*) is essential in this process. Likewise, ethical engagement and community self-determination must be the foundation for collaboration (*105, 110, 111*).

Emerging models of information sharing could also be more broadly incorporated into historical ecology. For example, collaborative Research Learning Networks (RLN) promote more inclusive models of knowledge co-production and information sharing (*112*) and are emerging as alternatives to traditional institutional and academic networks. RLNs, such as the current UN Ocean Decade (*113*), promote formal working groups with wide representation that aim to collectively build a comprehensive and accessible knowledge base while fostering collaboration and inclusivity (*114*). Blending RLNs with enhanced media and information literacy could further facilitate knowledge co-production and sharing, empower individuals and communities, and more effectively navigate complex environmental issues (*114*).

Q7 How can natural history museums expand the relevance of historical ecology?

Although rarely nominally referenced, natural history museums have long featured some of the most prominent tenants of historical ecology in their research. These include museum collections, exhibits, research, and educational outreach on climate and ecosystem change, evolution and biodiversity loss, and the dynamics of human-environment relationships. Such themes are often presented across multiple time scales represented by paleontological, archaeological, and historical natural history collections. Recently, however, the history and societal relevance of natural history museums as collection repositories and bastions of public education have been critiqued (*115, 116*). Natural history museums' long-professed interpretive neutrality when exhibiting natural and cultural history is now increasingly recognized as problematic and perhaps a disingenuous representation of the featured ecosystems and people (*117, 118*). Rather, 'museum activism,' has emerged as the way of the future for relevant natural history museum practice and exhibits. This approach centers purposeful community engagement and co-production in research, exhibits, public education, and solutions to pressing societal challenges (*119-122*).

It is within this spirit that natural history museums are well positioned to expand historical ecology from the status quo which is more of an underlying academic framework. Beyond increasing access and diagnostic research on collections (see Q4), this transformation may move to more publicly recognized, community accessible, and applied science focused on understanding how the past can help address Anthropocene challenges (*123*). Doing so may help communicate how linked ecological and cultural histories have together shaped socioecological systems through time (see Figure 3). This work requires unpacking colonial structures through consultation and collaboration with the communities whose histories, legacy environments, and continuing biocultural heritage are represented in collections and exhibits. Engagement with local biological and cultural heritage stakeholders is essential. Natural history museums are often the public face of historical ecology and bear responsibility for shaping and demonstrating its societal, scientific, and conservation relevance. At the same time, these principles also apply to local education centers and in classroom settings, in particular in areas of the world where natural history museums lack access.

Q8 How can historical ecology encourage community participation in cultural heritage preservation?

Historical ecology increasingly recognizes the pivotal role that communities play in the framing and prioritization of research questions, data collation, and conservation efforts, including the preservation of cultural heritage (*124-126*). Historical ecology's focus on place and potential for powerful imagery can act as a catalyst to break down barriers to community participation (*127*). Hurdles to equitable partnerships between communities and researchers remain, however (*128*). This may require a respect for and appreciation of differing perspectives by the researcher (*125*), as well as, expertise in inclusive community engagement techniques, such as participatory or consensus-based techniques (*129*). Such relationship building requires significant time and resources from the beginning of research and extends beyond typical project timelines (*130, 131*).

Cultural heritage is both tangible (e.g., cultural landscapes) and intangible (e.g., traditions) and intertwined with people's interactions with local environments (*132, 133*). Historical ecology research can help identify cultural heritage, its significance to communities in time, and provide tested frameworks for best practices in community engagement (*127, 134*). Leveraging community knowledge via historical ecology research applying community-based approaches can empower communities to protect cultural heritage by engaging with drivers of heritage decline (*135, 136*), reconnecting with and redefining their heritage (*127*), reframing dominant discourses (*137, 138*), and generating information for consensus-driven policy and practice (*8, 137*). Heritage can also evolve, and in these cases understanding the past helps communities to reframe their priorities and build future visions that facilitates community adaptation and transformation in the face of heritage loss (*139, 140*).

Q9 What are equitable approaches to knowledge co-production with Indigenous communities?

Indigenous and other local knowledge are valuable for generating more holistic understandings of ecosystems and the human/environment relationship through time, which is central to historical ecology (*94*). Combining Indigenous and scientific knowledges as complementary approaches (*141-144*) is referred to as 'two-eyed seeing' (*145*); this methodology values and amplifies the intellectual tool-box Indigenous peoples carry and draw from daily activities and across generations when engaging in socio-cultural and ecosystem-based activities [see also 'braiding knowledge' (*146*)]. Central to this methodology is ensuring that the research benefits all (*145*) and does not exploit Indigenous people.

A persistent challenge facing conservation practitioners is how to work with Indigenous and other local knowledge respectfully and ethically throughout the processes of conservation. Two related models for partnership with Indigenous and other local communities include the equitable exchange and boundary spanners (*147, 148*). The equitable exchange focuses on 'currencies' within different communities and proposes a framework for defining these currencies prior to formal partnerships with the goal of equal and self-defined benefit. The success of many mainstream-community partnerships is frequently dependent on a boundary spanner—a person or small team that is fluent in both community protocol and mainstream science. Future progress may also be found in the Indigenous 'land back' and 'water back' movements (*149-151*). These efforts are rooted in Indigenous peoples' sovereignty over their traditional territories and focus on the use of local ecological knowledge to support Indigenous conservation methods (*152*).

Equitable approaches to knowledge co-production also integrate ethical data management and acknowledge Indigenous authority over intellectual property rights. Methodologies that ensure data sovereignty and protect intellectual property rights are essential to knowledge sharing and co-production relationships. Strategies within this realm include community-controlled information databases such as Mukurtu (https://mukurtu.org), protocols for Indigenous intellectual property use and memoranda of agreements (*153-155*).

POLICY AND MANAGEMENT

Q10 In what specific policy and decision-making contexts is historical ecology most relevant?

Historical ecology is relevant for policy and decision-making involving the management of species, populations, and ecosystems. Historical research has helped resolve the biogeography of priority species (*38*), justify source populations for species reintroductions (*156*) and challenge modern ideas of 'natural' ecosystem states (*46, 157*). One such case involves the 'American' Atlantic sturgeon (*Acipenser oxyrinchus*) and European sturgeon (*A. sturio*). These species diverged at least 15 million years ago (Ludwig et al. 2002), and it was thought that American Atlantic sturgeon did not exist in European waters. However, historical research documented that humans extirpated Atlantic sturgeon from European waters in the 1600s (*158*), which supported enhancing Baltic sturgeon populations with the more abundant Atlantic sturgeon instead of the critically endangered European sturgeon (*156*).

Historical ecology can help communities converge on shared goals for restoration (see Q8). In South Australia for example, a multidisciplinary network of scientists, practitioners and managers was successful in reaching out to a diversity of stakeholders to communicate the past (and potential future) social, ecological, and economic significance of oyster (*Ostrea angasi*) reefs. This helped to build political support for the establishment of a large-scale restoration initiative and a nationwide 'reef building' agenda (*159*). Pooled data from explorer histories, fisheries catch, archaeological records, and sediment cores contributed to a critically endangered listing of Australian oyster reefs on the IUCN Red List of Ecosystems (*160*). Here, historical ecology motivated and legitimized government intervention, including customizing restoration for the current environment and paired social benefits (*161*).

Finally, historical approaches are necessary to historicize and critique ideas like management itself, as Western scientific management exists within a specific set of cultural frameworks and biases. For example, in southwestern Ethiopia, fire plays a crucial role in the conservation of African savannas and as a tool for nomadic pastoralists to create pastures. The establishment of a national park in 1980 led to a fire ban for local communities, particularly the Mursi people (*162*), as high frequency fires were thought to cause bush encroachment and reduced grass availability for wild ungulates. However, a combination of paleoecological indicators (*163*), Mursi oral histories (*162, 164*), and current-day plant ecology revealed that bush encroachment was related to fire suppression policies (*163*). By adding more voices to the field of historical ecology, it will become more complex, more meaningful, and allow more people to join a respectful community of practice.

Q11 How do we select baselines dates for use in conservation?

Baselines are ubiquitously though often implicitly used in conservation endeavors (*165*). Such reference points from the past simultaneously provide targets to guide management actions and thresholds for assessing recovery progress or status (*166*). Poorly-chosen baselines—whether due to unacknowledged assumptions, cultural biases, or shifting baselines—can have negative consequences, such as the premature removal of protections [e.g., Yellowstone wolves, (*167*)] and misleading assessments of population trends [e.g., furbearer hunts, (*168*), also see Q13, Q17].

Why are baselines selected, and by whom? The IUCN Green Status of Species (*169*), a recovery assessment, identifies species-relevant baselines between 1500 and 1950, recognizing that human impacts occurred outside of that period, but asserting that earlier baselines are too removed from the present (*170*). Policy baselines are often set later, within the past 50 years (*171*). Choice of baselines is also vulnerable to cultural biases that render them value laden. The initial objective of US National Parks, for example, was that "the biotic associations within each park be maintained, or where necessary recreated, as nearly as possible in the condition that prevailed when the area was first visited by the white man" (*172*). Recognizing the biases inherent in this objective, it has since been updated to "to steward NPS resources for continuous change that is not yet fully understood, in order to preserve ecological integrity and cultural and historical authenticity..."

Another consideration is whether reference periods are selected *a priori* or emerge from a synthesis of historical data. *A priori* baselines include inflection points in humanity's relationship with the environment and each other, as occurred during the climatic shifts and megafaunal extinctions of the Late Pleistocene/Holocene transition (~11,000 years ago and earlier), the onset of European colonization and the widespread dislocation of Indigenous communities (ca. 1500), in the Industrial Revolution (beginning ca. 1750) and the Great Acceleration (ca. 1950) (*173*). However, not all species were affected equally by these shifts in human activity, so synthesis of species-specific historical data may be necessary to choose a meaningful baseline. It is also important to remember that not all conservation goals are backward-looking. In some cases, historical baselines are put aside or used as a menu of options when helping species, communities, and ecosystems adapt to a changing world. (*96, 174, 175*).

Q12 How can conservation baselines consider complex linkages between people and nature?

Deriving ecological baselines helps contextualize change and establish conservation goals but can only do so with knowledge of how diverse human societies interacted with and profoundly transformed many ecosystems. Historical ecologists have described human agency in landscape formation, even in seemingly pristine forests, where intermediate disturbances of people sometimes enhanced the biodiversity in landscapes (*19, 176-182*). People developed complex socio-ecological arrangements all over the world, many of which have been disrupted over past centuries by growth centered capitalist (*183*) and modernizing forces—including state-sponsored conservation, which is often based on the human-nature dichotomy (See also Q10) (*184, 185*). Many protected areas overlap lands where Indigenous peoples and local communities historically lived (*186*). Therefore using 'pristine environments' as benchmarks for conservation baselines, while untenable as it is often embedded within colonial discourses (*44*), causes normative, scientific and practical problems (*187*). When discussing ecosystem restoration, we should not overlook the ecological roles of people in ecosystem function (*188*). Conservation can in fact become more effective by reinforcing the role, capacity, and rights of Indigenous peoples and local communities (*189*).

Baselines are socially constructed and thus influenced by political agendas, economic realities, preconceived ideas, and socio-cultural 'understandings' of human impacts on nature (*187*). Therefore, to share more appropriate baselines and collaborate with local peoples in a dynamic world, knowing the past, as well as ongoing, human-landscape interactions, even if imperfect, will be an indispensable guide (*165*). Future work in historical ecology that focuses on the complex material and cultural linkages between people and nature will help scholars, decision-makers, and community members articulate and attain support for ambitious conservation goals that seek to repair and conserve nature while respecting local knowledge and traditions and promoting environmental justice.

Q13 How did past Indigenous management result in outcomes that provide insight today?

For millennia, Indigenous peoples throughout the world have directly and indirectly shaped ecosystem dynamics resulting in a continuum of outcomes from enhancement to degradation. Habitat modification by Indigenous peoples includes structural changes, such as building stone walls in the intertidal, as well as changes in ecological processes like fire and propagating and hunting species (*190-192*). Bringing together historical ecology and Indigenous knowledge offers insight into the scale and scope of past management and stewardship activities. Importantly, these insights can empower Indigenous communities, guide place-based restoration, and help identify conservation priorities.

For example, in forest islands of the Llanos de Moxos, in the Bolivian Amazon, shellfish gatherers visiting seasonally flooded grasslands for more than 10,000 years, have built-up middens on higher ground, which transformed into islands supporting trees and other dense vegetation (*193*). These constructed soils provided nutrient inputs to support intensive traditional agricultural production starting around 5,000 years ago to present day (*194*). In the Western Desert of Australia, the Indigenous practice of deploying hunting fires buffer against larger scale and, increasingly climate driven, wildfire and creates more diverse landscape mosaics (*195, 196*), increasing food and shelter for common wallaroo (*Osphranter robustus*) (*197*) and monitor lizards (*Varanus* spp.) (*198*), which are critically important food for Indigenous peoples (*199*). On North America's Pacific Coast, the construction of clam gardens by coastal Indigenous peoples increased the available niche space for clams and secured a reliable food source for people (*200-202*). Clam gardens have had persistent indirect effects on soft sediment marine communities (*203*) and increased nearby forest productivity around village sites where clam shells and other materials were deposited after being consumed (*204*). Clam garden restoration is occurring today in many Indigenous territories (*205*). While most commonly studied in settler colonial regions, similar lessons emerge from research in other parts of the world. For example, coppice management in pre-modern Europe maintained higher plant diversity in lowland forests than that found in unmanaged closed forests (*206*).

Solutions gleaned from Indigenous stewardship and historical ecology include strategies that increase productivity and crop yields through the addition of soil amendments, enhance habitat conditions for culturally important foods through use of fire, and set conservation and restoration targets (*16, 37, 124, 207*). While all of these practices are critical for Indigenous food security and food sovereignty, they may also shed light on contemporary conservation and restoration strategies more broadly.

Q14 What unique challenges and opportunities exist for historical ecology in data-poor or colonized countries?

Knowledge on the dynamics of populations and ecosystems on centennial and millennial scales has recently increased in low- and middle-income countries in the Global South. The unique challenges that these countries face in making historical ecology part of their scientific repertoire are that most of them were subjected to European colonial expansion, which led to the abrupt imposition of new elites and their languages and the silencing of the original surviving inhabitants (*208*). As a result, much of the knowledge of colonized societies, including those with written records [e.g., the Maya, whose books were burned (*209*)] was lost. Thus, while the time horizon that historical ecologists choose to work on tends to depend on the ecosystem they study and on the study's goals and outcomes, those working in countries that were colonized will also have to overcome the damage of the linguistic and cultural rupture that colonialism caused. Additional challenges include the maintenance of archives, and colonial science which results in knowledge being controlled by outsiders.

Certain countries in the Global South face challenges such as political instability and limited funds, coupled with debatable priority areas for fund allocation that may perceive disciplines related to historical ecology as less strategically aligned with economic development. For example, Brazil, despite being a biodiversity hotspot, has experienced substantial cuts in research and disciplines within the social and humanities realms. This issue is not exclusive to Global South countries but increasing populism and political polarization have a more pronounced impact on low-income and less literate nations than countries in the Global North (*210*). This underscores the importance of engaging with local communities, private sectors, institutions such as museums (see Q7), and the general public to enhance the visibility of historical ecology, advocate for its application and promotion in education at both undergraduate and postgraduate levels.

While there are many challenges, historical ecology also presents unique opportunities. Ecological knowledge in most post-colonial countries is limited by the short duration of instrumental records. In this context, archeological and paleoenvironmental sources are vital, as they can provide quantitative evidence of ecological status for pre-instrumental periods (see Q4). For example, such sources can help estimate pre-colonial richness and ultimately provide strong arguments for the protection and conservation of ecosystems.

CLIMATE CHANGE

Q15 How can historical data help distinguish between anthropogenic and biophysical ecosystem drivers?

Linking historical changes to underlying biophysical drivers at the millennial and basin scale has long been of interest (*4*), but progress has been limited, partly because of the mismatch of temporal and spatial scales and the resolution of available data (*2, 65, 211-214*). With increasing coverage of historical, archaeological and paleoecological data plus advances in modeling for hindcasting and mapping, integrating various data sources can help discern between drivers of change and inform future projections (*215, 216*). For example, in the Northwest Atlantic, future climate change might shift ecosystems towards conditions last seen >5,000 years ago, with warmer waters, red tides and other algal blooms being much more prevalent than in recent centuries (*214*). Similarly, synthesizing global paleoecological records during the past 21,000 years illustrates future warming will cause major changes to terrestrial ecosystem composition and biodiversity (*217*).

To better resolve long-term (centuries to millennia or more) changes it is critical to analyse additional historical records from terrestrial and aquatic, inshore and offshore sources (e.g., marine sediments, mollusk shells, corals, animal bones and teeth, phytoliths, and also see Q2, Q4) for a more complete spatiotemporal coverage of environmental drivers of change (*214, 217-219*). Comparing these to more human-driven ecological changes, often documented in historical and archaeological sources, will help address foundational questions about natural versus cultural ecosystem changes in the past, present, and future. For instance, integration of different environmental proxies (pollen from lake sediments, dendrochronology, historical maps, etc.) document the drivers of changing vegetation composition in the Mediterranean over the past millennium, with implications for understanding future vegetation change in an uncertain climate (*220*).

Q16 How can knowledge of ecological responses to past warming inform conservation in the face of future climate change?

The structure and composition of ecological communities are, to a large extent, driven by climate at millennial and global scales (*221-224*). Understanding the complex dynamics between oceans and air is essential to provide robust predictions of future ocean and climate conditions and historical environmental data are central to resolving these models (*22, 215, 225*). On land, records of past environmental and ecological dynamics reveal the thermal fragility of high mountain flora that are likely to be driven extinct along with their endemic fauna as temperatures rise (*226*). In contrast, lowland tropical forests may be able to tolerate rising temperatures, but only if rainfall persists (*227*) demonstrating the importance of modeling precipitation patterns as well as temperature to inform conservation. With enough spatial resolution, prior records are well suited to help resolve several key questions facing conservation, including the long-term threat of extinction debt (*228*) and the ability (or lack of) communities to persist under changing climates (*229, 230*).

Due to its inherent extended chronology, historical ecology is uniquely situated to evaluate past responses and adaptations to major weather events and climate variability. In addition to applications for ecosystem and resource management, this knowledge is useful for building more just and equitable conservation and restoration efforts in the face of future climate change (*231*). A more accurate and fair depiction of peoples' past environmental interactions and responses to climate change cuts through our assumptions and biases of peoples' knowledge, capabilities, success, and failures when mitigating socio-ecological risks from changing weather patterns, sea level, and climate variability (*232*). For example, people have been shown to exploit the expansion of fire prone landscapes under changing climates (*192*). Mid-Holocene terracing and terraforming of the intertidal across the Pacific Northwest was a highly localized but broadly applied practice for dealing with sea level changes while increasing food production (*233*). Pastoralism has been highly variable and adaptive over space and time, despite (incorrect) assumptions about its heterogeneous practice and regional impacts (e.g., overgrazing) (*234*). These, and similar historical-ecological studies (*235, 236*) form part of our collective knowledge of peoples' ecological responses that can inform conservation in a changing climate.

Q17 How can management reference historical climate conditions, given that there may be multiple baselines?

As world temperatures continue to rise and affect ecosystems, multiple baselines may be beneficial and practical. Historical reference conditions, at least regionally, can be selected from records of past analogues of current climatic trends, such as the Last Interglacial (~110,000 years ago), the mid-Holocene Climatic Optimum (~8000-4500 calendar years before present [cal. BP]) and the late Holocene Medieval

Climate Anomaly (MCA, ~1300–650 cal. BP) (*237, 238*). Quantitative data derived from these records can be used to characterise ecosystem functions at that time and socio-environmental responses to climate change, providing much needed insights within the context of current warming trends, now and in the future (*238, 239*). Paired with recent written records of species and habitat occurrences and their use (e.g., fisheries records), these data can build an effective target for ecological conservation (*240*).

More studies on the ecological contexts of human adaptations to past warm climates are, however, necessary, and close collaborations of historical ecologists and conservationists are vital for establishing reliable baselines. Further, few studies have used data on specific past environments for projecting into the future (*241*), and while lists of taxonomic abundances are described for past environments, it is not always straightforward how they would translate into baselines (See Q11) considering that these have shifted through time (*242*).

Q18 How may historical knowledge be relevant for future ecosystem states that have no precedent?

Historical knowledge has significant value for guiding ecosystem restoration, resource management, and conservation under unprecedented or novel future conditions (*243*). Historical knowledge in many forms (*243*) can illustrate past variability to explain ecological legacies, contextualize unprecedented change, and provide a set of possible expectations for and responses to unpredictable climatic and ecological conditions (*134, 244, 245*).

For example, catastrophic marine heat waves threaten many fisheries, and North Pacific fisheries managers have called for the integration of a historical perspective into management strategies (*246, 247*). Historical data suggest there have been significant climate-driven periods of change in the Pacific herring, cod, and salmon fisheries over millennia (*248*). Both managers and archaeologists (*247, 248*) have drawn on these data to develop a series of guiding questions that apply historical data to present fishery management: what were past conditions like under different climate regimes? How did broad-scale climate changes affect biophysical, biological, and social dynamics in the marine environment? Can the answers to these questions provide a range of possible responses to changing climate conditions in increasingly warm periods, and be used to frame a range of possible responses?

These questions underscore that increasing ecological novelty does not necessarily mean a separation from historically continuous functions and composition (*249, 250*). Even in cases where thresholds produce novel ecosystems or alternative stable states, there is much to be learned from careful study of historical data (*251*). With a rise in unprecedented ecosystem conditions, ecologists of all kinds will benefit from historical knowledge that yields insights into the pathways of change or analogs offering clues for managing new conditions.

4. DISCUSSION and CONCLUSIONS

During the past few decades, historical ecology has grown from an approach used by just a few scholars primarily studying terrestrial forests, to a large community of researchers and practitioners working around the world on a wide variety of terrestrial and aquatic organisms and ecosystems (*1-3*). Synthesis of publications focused on historical ecology demonstrates a dramatic increase in research during the past twenty years (Figure 1). A variety of initiatives, training opportunities, and networks such as the Conservation Paleobiology Network and Oceans Past will help carry forward historical ecology and its application to conservation. Given this increase in research and growing list of collaborative networks, our group of historical ecologists from around the world, worked to chart a course for the future of historical ecology by developing research priorities centered around key issues and questions. Four key research priorities emerged: (i) Methods and Concepts, (ii) Knowledge Co-production and Community Engagement, (iii) Policy and Management, and (iv) Climate Change, covering everything from machine learning and open access data, to diversifying perspectives, Indigenous knowledge, integrating disparate datasets and information, and the place of museums, social media, and other forms of engagement in broader education and research efforts. Here we discuss each of these priority areas and their value to historical ecology, conservation biology, and science more generally.

From history to paleoecology and archaeology, historical ecologists aim to understand natural climatic and anthropogenic environmental change, drawing on a wide range of different datasets and intellectual frameworks (*2*). Consequently, historical ecology is inherently interdisciplinary and requires collaboration that breaks down traditional intellectual silos. This is a key perspective that emerged in our five research questions focused on methods and concepts (priority i). Advancements in historical ecology demonstrate that both collaboration among scholars from diverse fields and the transdisciplinary expansion of individual scientists' interests and skills are important to effectively integrate quantitative and qualitative approaches (*7, 13, 36-38, 71*). While progress has been made, progress for better integration of datasets across spatiotemporal scales and drivers remains. At the same time, there is a need to move beyond data to take a critical view of baselines, considering the ways in which these are socially constructed, and the power dynamics embedded in the selection and implementation of baselines (*59, 60, 168, 188, 220*). Historical ecology must continue to embrace its interdisciplinary nature and seek partnerships across disciplines, including natural science, social science, and the humanities when developing and interrogating baselines and other aspects of research.

One of the most significant aspects of our research is the need for engaging diverse communities, the co-production of knowledge and research, and diversifying perspectives (priority ii). This includes expanding training opportunities that promote diversity in scholarship and practice, enchaining funding opportunities for projects that emphasize under-represented groups and co-production, and democratizing knowledge through equitable open-access publication and dissemination. Our work here emphasizes the critical need for greater equity and engagement in historical ecology, which will ultimately, enhance, expand, and improve research. While historical ecology is in many ways a leader of this type of research, there are still many areas for improvement, particularly to help make research less extractive and dominated by Western scientific interests and knowledge systems and towards one that appreciates diverse knowledge systems and is done with, for, and by Indigenous and other local communities (*106, 107*). Such a transdisciplinary approach to historical ecology, based on knowledge co-production, fosters a holistic understanding of ecosystems and their dynamics, benefiting both scientific research and communities (*101, 112, 252*), and should be broadly incorporated in professional training, funding, and publication priorities. Continued recognition that people are not separate from ecosystems, not all human activities are negative, and people can be nested within ecosystems to promote long-term sustainability is important for better integrating distinct perspectives and knowledge systems to educate conservation practitioners, researchers, and the broader public. Knowledge co-production also seeks to break down traditional intellectual silos—a key goal of historical ecology—and one with significant opportunities for training, mentoring, and education. Finally, a more inclusive and equitable research framework offers a bridge between environmental justice, restoration, and ecological conservation with historical ecology poised to lead in these efforts (*253*).

Historical ecology research priorities identified here also include the need for collaboration between academic researchers and practitioners (priority iii). Curating data from the past that are relevant to conservation today demands collaboration with those implementing management actions (*254*). Collaboration among researchers and practitioners overlaps with the previous research priorities by demonstrating another step in taking historical ecology from an academic pursuit to one focused on action and application to solving conservation and other environmental challenges (*255*). Four questions identified in this priority emphasize the value of historical context as an integral part of the management decision process. Still, this is an area in urgent need of attention, especially investigations into how resource managers view findings from historical ecology and their application to decisions. Conservation efforts and application of historical ecological insights also draws from integrating diverse perspectives from different scientific communities and Indigenous communities into management decisions and priorities (*176, 256*).

Climate change is a central issue of the 21st century, evidenced by 2023 being the hottest year on record, with a wide variety of climate related perturbations, including massive fires in Canada and the Pacific, and extreme heat in American deserts and elsewhere, and marine heatwaves globally (*257-259*). Priority iv emphasizes historical ecology's contribution to climate change, discussed in four questions. One of the opportunities and challenges in this area is integrating long-term records of climate change that are generally on a global scale, with historical ecological data that are often more locally focused (*214, 220*). Similarly, the integration of distinct data sets focused on past climate such as fossil and marine sediment records provide opportunities to compare past climatic change and ecological responses, both with and without people, to help forecast future change (*211, 213*). Although we increasingly live in a no analog world, historical ecological records still offer an unparalleled source of information on the relationships between climate change, anthropogenic processes, and the responses of ecosystems and organisms (*243*).

The four research priorities discussed here demonstrate tremendous opportunity and growth for historical ecology. These priorities are all synergistic, illustrating the need to increase collaboration and expand historical ecology's field of inquiry, community of scholars and practice, and heighten inclusion and co-production of knowledge. These expanding frameworks will undoubtedly drive novel insights and breakthroughs and enhance the application of historical perspectives to contemporary and environmental issues, all while emphasizing the links between social justice and environmental conservation. Even though we are living on a rapidly changing planet, we believe that now more than ever historical perspectives are central to helping better prepare for and navigate environmental uncertainty.

As we conducted our research, a commission of scholars is poised to mark the onset of a new geological epoch, the Anthropocene, or Age of Humans, that recognizes the profound influence of people on our planet (*260*). After considerable debate, the Anthropocene appears to be set to begin around 75 years ago (~CE 1950), signified by the global appearance of radionucleotides in Global Boundary Stratotype Sections and Points from thermonuclear weapons tests (*261, 262*). With an Anthropocene that began less than a century ago, historical perspectives from the preceding 12,000 years of the Holocene and earlier, will be crucial for understanding both how we arrived at present day conditions and illuminate the path ahead.

SUPPLEMENTARY MATERIALS

Includes Appendix 1 which is the complete survey of 14 self-identification questions presented to the study's 39 authors.

DATA AND MATERIALS AVAILABILITY

All data needed to evaluate the conclusions in the paper are present in the paper, the Supplementary Materials, and the linked repositories. Data and source code used in this study are available in the open-access third-party repository at GitHub (bit.ly/477TePD).

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AUTHOR CONTRIBUTIONS

KV and LM conceived the project and with TR, RT, and AT designed and edited the study. KV curated the data, wrote the code, and generated the figures with input from ML. LM, TR, and KV wrote the paper with significant contributions from all authors. All authors reviewed the manuscript.

COMPETING INTERESTS

The authors declare that they have no competing interests.

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ETHICS STATEMENT

Our study did not require human or nonhuman animal subjects.

i. Methods and Concepts
Q1. What do qualitative and quantitative approaches contribute to understanding long-term change?
Q2. How do historical data help understand long-term ecological change?
Q3. How can diverse data types that span a range of time scales be meaningfully integrated?
Q4. How can historical ecology leverage quantitative methods, big data, and machine learning?
Q5. How does bias affect the distribution of knowledge in historical ecology?

ii. Knowledge Coproduction and Community Engagement
Q6. What are best practices for knowledge co-production and community engagement for historical ecology?
Q7. How can natural history museums expand the relevance of historical ecology?
Q8. How can historical ecology encourage community participation in cultural heritage preservation?
Q9. What are equitable approaches to knowledge co-production with Indigenous communities?

iii. Policy and Management
Q10. In what specific policy and decision-making contexts is historical ecology most relevant?
Q11. How do we select baselines dates for use in conservation?
Q12. How can conservation baselines consider complex linkages between people and nature?
Q13. How did past Indigenous management result in outcomes providing insight today?
Q14. What unique challenges and opportunities exist for historical ecology in data-poor or colonized countries?

iv. Climate Change
Q15. How can historical data help distinguish between anthropogenic and biophysical ecosystem drivers?
Q16. How can knowledge of ecological responses to past warming inform conservation in the face of future climate change?
Q17. How can management reference historical climate conditions, given that there may be multiple baselines?
Q18. How may historical knowledge be relevant for future ecosystem states that have no precedent?

Table 1. Global research priorities for historical ecology to inform conservation. The final list of 18 questions grouped into four categories addressed in this review.

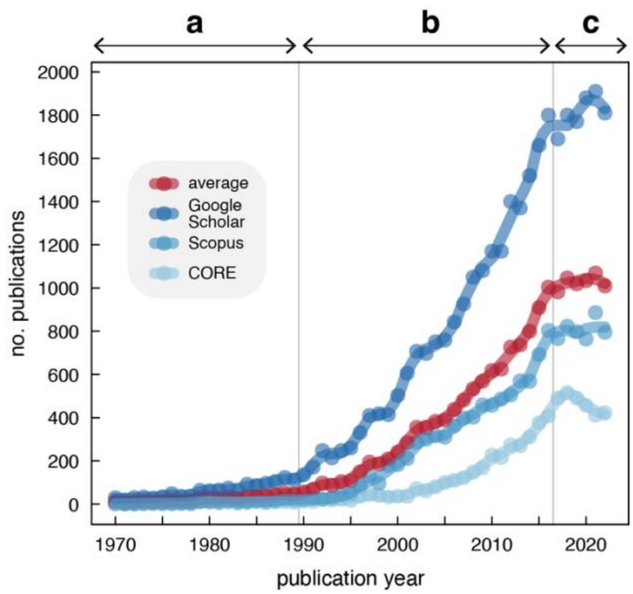

Figure 1. Annual changes in historical ecology research publications from 1970-2022. A query for the whole phrases ‘historical ecology’ OR ‘historical ecological’ from the Google Scholar, Scopus, and CORE databases returned an ensemble average of 17,374 publications during the 52-year record. These sources indicate slow growth in scholarly production from (a) 1970-1989, (b) a sharp rise from 1990-2016 (annual increase 11.4%), followed by (c) relatively flat production from 2017-2022 (0.1%). The most recent pattern (c) does not appear to reflect either broad research production trends or impacts from the COVID-19 pandemic (see text).

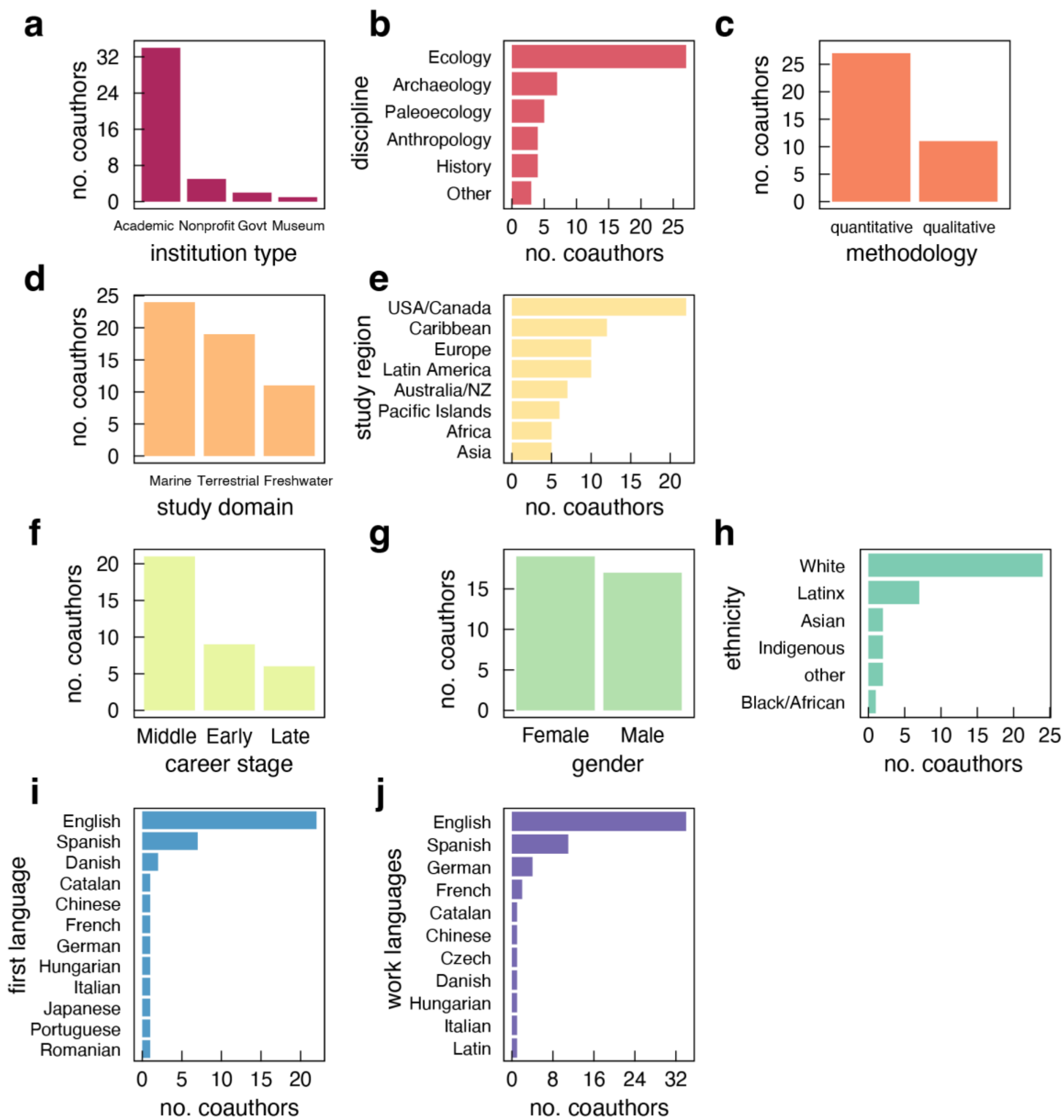

Figure 2. Self-reported perspectives from the contributing authors of this study. Authors responses to survey questions on (a-c) professional affiliation and approach, (d-e) geographic domain, (f-h) demographics, and (i-j) language use. Despite significant representation beyond these categories, most authors of this study are white, English-speaking, quantitative marine ecologists who conduct research in the USA or Canada at universities.

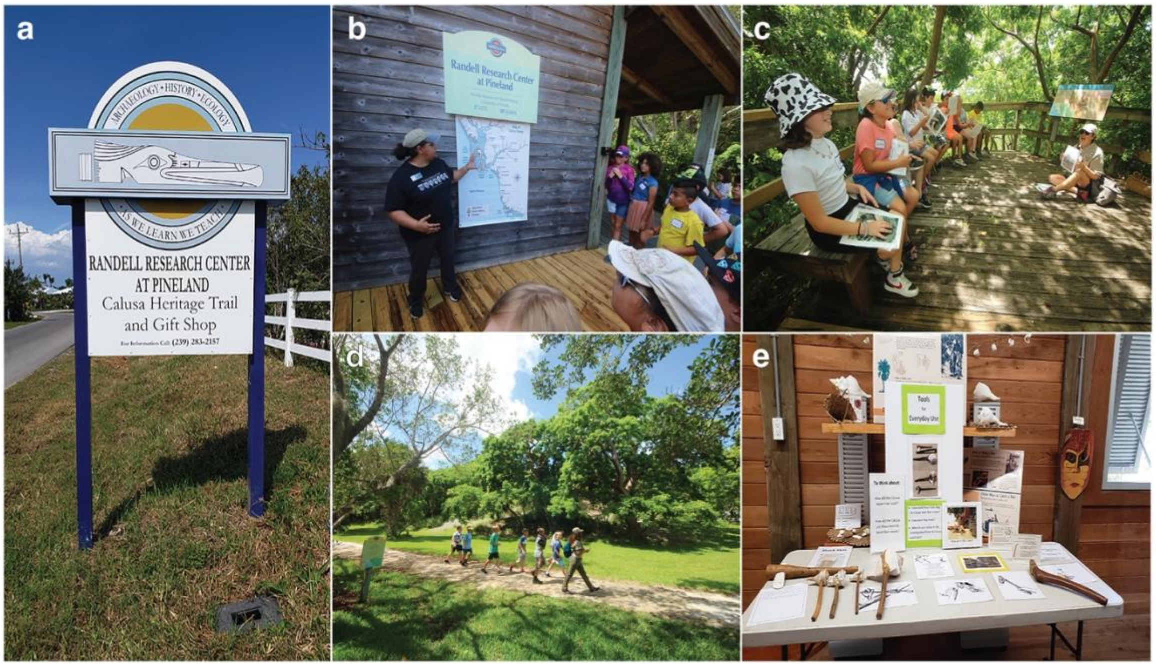

Figure 3. The Florida Museum of Natural History's Randell Research Center and Calusa Heritage Trail. Located at the Pineland Site Complex on Pine Island, Florida, the museum center is explicitly dedicated to the research, preservation, and public education about the archaeology and historical ecology of the Calusa and Pine Island Sound estuary. (a) Welcome sign clearly naming archaeology, history, and ecology as the cornerstones of the center and trail. (b) Center operations manager and (c-d) museum educators leading Title I School fourth-grade educational programs across preserved Calusa shell mounds, middens, and canals. (e) Classroom display with replica artifacts for public education about estuarine historical ecology and 2,000 years of fishing. Photos provided by Annisa Karim and Charles O' Connor and used with permission.

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ONLINE SUPPLMENTAL MATERIAL

For the manuscript "Global research priorities for historical ecology to inform conservation"

By the authors Loren McClenachan, Torben Rick, Ruth H. Thurstan, Andrew Trant, *et al*.

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APPENDIX I

Full survey of identity questions presented to study authors.

The below 14 questions were distributed to all 39 study co-authors using the Google Forms platform. Data from 37 respondents (2 did not respond) appear in Figure 2 of the main text. See Methods for more details.

1. Please write your full name.

2. What is your preferred email for correspondence?

3. Provide your full institutional affiliation as you would like it in the published paper. If you have more than 1, please list all.

4. What is your professional sector? (check all that apply)
    a. Academic
    b. Nonprofit
    c. Government
    d. Museum
    e. Other

5. What is the discipline with which you most affiliate? (check all that apply)
    a. Anthropology
    b. Archaeology
    c. Ecology
    d. History
    e. Paleoecology
    f. Other

6. What is the scholarly approach you use most? (check all that apply)
    a. qualitative / non-quantitative
    b. quantitative

7. Which system/s do you work? (check all that apply)
    a. Marine

b. Terrestrial
c. Freshwater

8. In which region/s do you work? (check all that apply)
    a. Africa
    b. Asia
    c. Australia or New Zealand
    d. Caribbean
    e. Europe
    f. Latin America
    g. Pacific Islands
    h. USA or Canada

9. What is your working definition of historical ecology?

10. What is your career stage? (A suggestion: late career = you've had your PhD ≥ 24 years, mid-career = you've had your PhD ≥ 8 years)
    a. Early
    b. Mid
    c. Late

11. What is your gender?
    a. Female
    b. Male
    c. Non-binary
    d. Other

12. What is your ethnic self-identification (check all that apply)?
    a. Asian
    b. Black / African
    c. Indigenous
    d. Latinx
    e. Middle Eastern North African
    f. Pacific Islander
    g. White / Caucasian
    h. Other

13. What was your first language?

14. What language/s do you use frequently in professional settings? (list all that apply)